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Novotny et al.

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[54] **LIGHT DIFFUSING-NONDIFFUSING WINDOW**

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Jan. 22, 1970	Germany	P 20 02 853.9

[52] **U.S. Cl.** **350/319**, 350/312
[51] **Int. Cl.** **G02b 5/24**
[58] **Field of Search** 350/179, 312, 319

[56] **References Cited**

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Assistant Examiner—Toby H. Kusmer
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[57] **ABSTRACT**

A window-like arrangement comprises two panes with a cavity between them. Liquid can be caused to flow into the cavity between the two panes in order to come into contact with an element having an irregular surface which, in the absence of the liquid diffuses light, and when the liquid is disposed between the panes, owing to agreement between the refractive indices of the element and the liquid, the diffusing action ceases.

18 Claims, 7 Drawing Figures

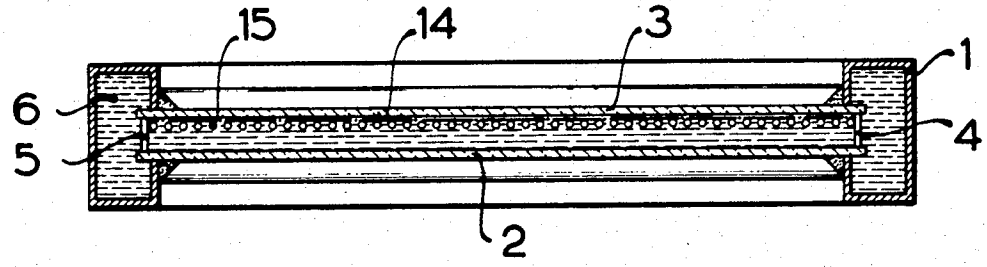

FIG.1

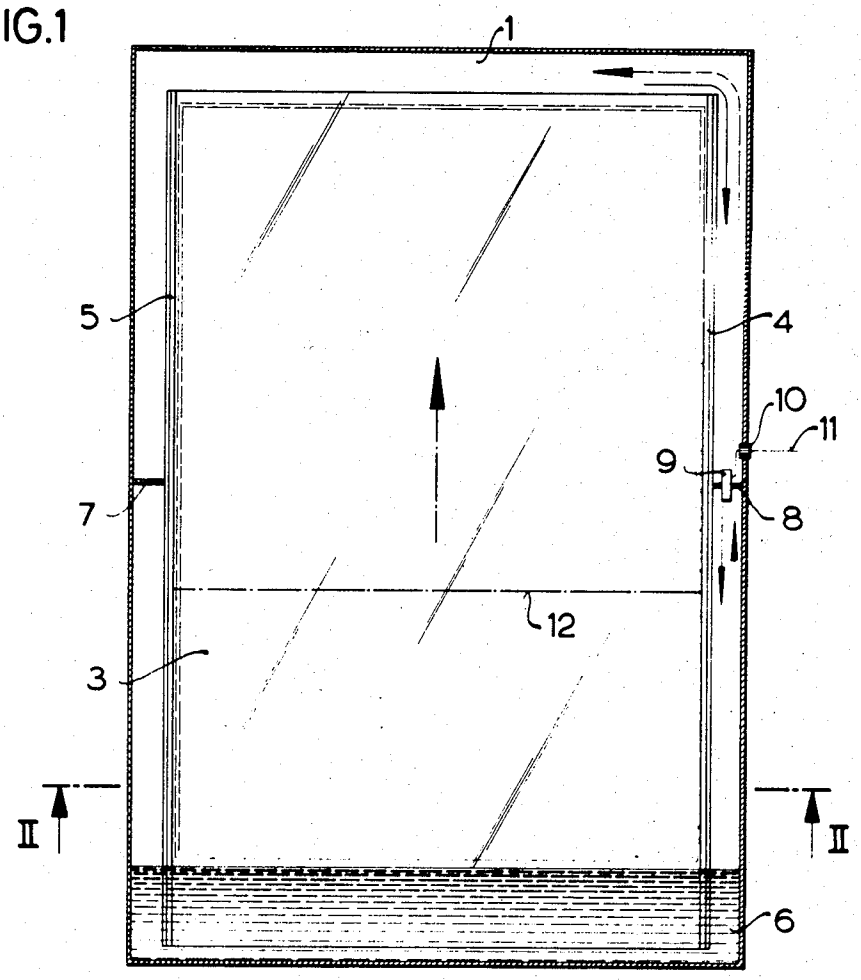

FIG.2

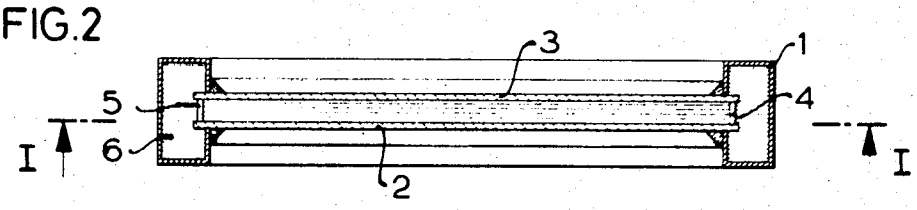

FIG.3

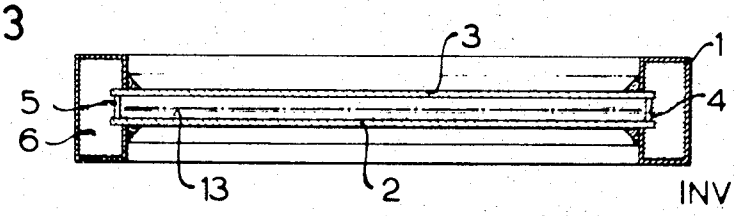

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FIG. 4

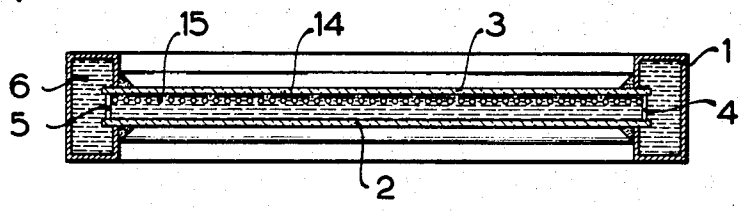


FIG. 5

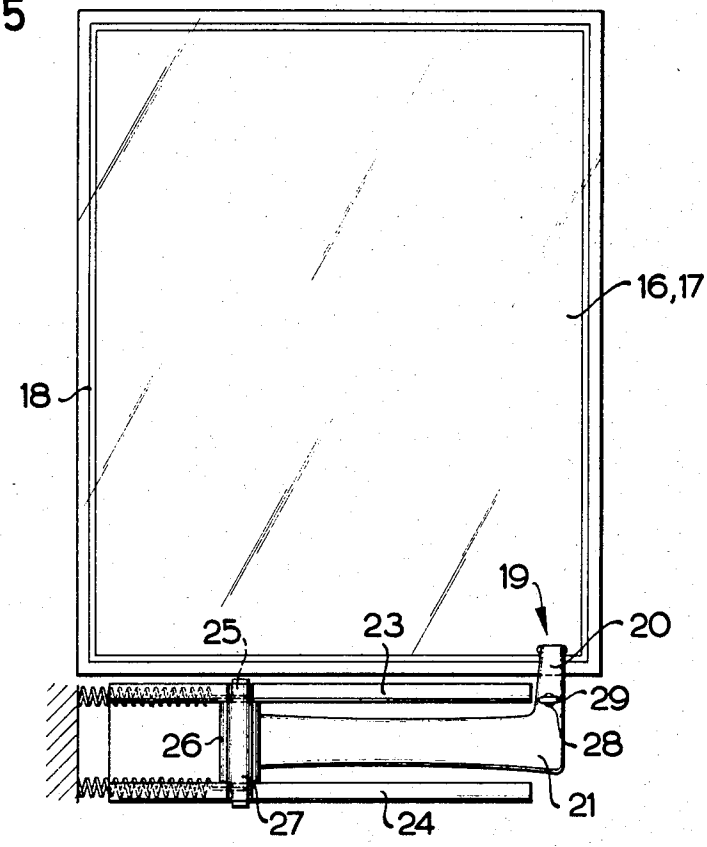


FIG. 6

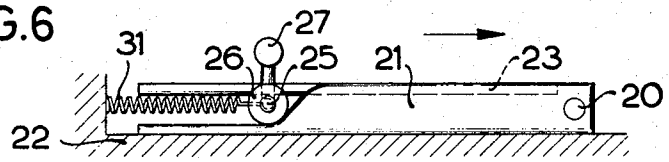
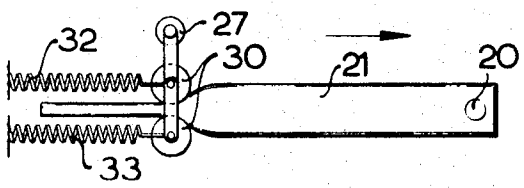


FIG. 7



LIGHT DIFFUSING-NONDIFFUSING WINDOW

The present invention is concerned with window-like or screening arrangements for openings in buildings or the like, and more particularly to such arrangements comprising two substantially plane-parallel spaced panes of transparent material and a pump or the like for introducing liquid between the panes in order to influence the transparency of the arrangement, and a container for supplying the liquid and tanking up the liquid again when it is removed from the space between the panes.

In the case of a previously proposed sealing device, more particularly intended for darkening aircraft cabins, colored liquid was to be passed through a duct system to a window support frame into the space between the two panes of an individual window, see U.S. Pat. No. 2,439,553.

In accordance with a still further prior proposal the space between the two window panes was to be filled with colored liquid supplied from one of a number of colored liquid containers via a valve manifold and a vacuum pump, see U.S. Pat. No. 3,368,862.

In the case of both previously proposed devices use was thus made of a colored liquid which absorbs the light to a greater or lesser extent in order to reduce the transparency of the window structure or completely darken the window.

One aim of the present invention is that of decreasing the transparency, that is to say the possibility of viewing objects through the window structure, while not bringing about any substantial reduction in the quantity of light passing through the window structure.

For the purpose of achieving this aim, the surface of at least one of the panes adjacent to the space between the panes has an unevenness which reduces its transparency and the liquid which is placed in this space has a refractive index which approximately corresponds to that of the pane material. In accordance with a further development of the invention the unevenness of the pane is replaced by a woven, knitted, braided, felted or like fabric of threads or filaments of transparent material, which is mounted in the space between the panes. The liquid has in this case a refractive index which is at least approximately the same as the refractive index of the transparent material.

It is also possible to embody the unevenness of woven, knitted, felted or like material of filaments or threads, which are transparent, or of a material or in an arrangement so that parts of the liquid, after emptying, adhere in the form of fine droplets to the fabric, the refractive index of the liquid being approximately the same as that of the fabric or the like. In accordance with a further embodiment of the invention the liquid can be water-clear so that upon emptying of the interior space between the panes, the window will have a diffusing action, which is brought about by the unevenness in the one pane or by the woven, knitted, felted or like fabric mounted between the panes.

The liquid can, in accordance with a further embodiment of the invention, also comprise a colored component or itself can be colored so that the diffusing arrangement does not only become transparent when the liquid is pumped into it, but also filters out particular colors from the light spectrum. In accordance with a further development of the invention, the system provides, in the space between the panes and the pump, at least two liquids which are not mutually miscible, of which at least one has a refractive index which is at least approximately equal to that of the pane provided with the unevenness or the transparent material mounted in the arrangement. It is also possible to construct the arrangement in such a manner that this system comprises the space between the two panes and the pump or the like completely filled with the liquids so that a completely air or gas-free system is produced, something which represents an improvement having regard to wetting problems and problems connected with the vaporization of the liquids in the gas or air-filled space otherwise present.

Naturally, at least one of the liquids can be colored or be milky, that is to say diffusing.

The material mounted in the arrangement can be a woven fabric or felt of organic, or also inorganic threads or filaments. It can be a woven fabric or felt of mixed organic and/or inorganic threads or fibers if only the refractive index of the materials used is at least approximately the same for each material so that by arranging this mounted material in a liquid with a correspondingly matching refractive index the poor transparency, or even opaqueness of the woven fabric or felt can be overcome.

Use can advantageously be made of a glass fiber fabric or felt.

If use is made of an arrangement in which parts of the liquid adhere in the form of fine droplets to the fabric or the like after the space between the panes is emptied of fluid, it is convenient to use a fabric or the like which is comparatively coarse in mesh and is, for example, directly stuck on one of the panes. The liquid particles adhering to it refract the light so strongly that a pane with this arrangement on it is practically completely lacking in transparency. This lack of transparency can be overcome by causing the liquid to rise in the space between the two panes to absorb the adhering droplets and restore the optical homogeneity owing to the identity of its refractive index with that of the fabric or the like.

Instead of sticking the fabric or the like in position on the glass pane, it is possible to arrange the fabric immediately adjacent to and in front of the glass pane.

In accordance with a further embodiment of the device of the present invention, there is the feature that one of the panes is made reflecting on its side remote from the space between the panes. In this case all the previously mentioned features as regards the liquid used and the arrangement of the unevenness, or the replacement of this unevenness by stretched fabric or the like can be used. In this case the mirror is more or less darkened and becomes visible when the liquid is pumped into the the space between the panes.

In particular the panes can form a double pane arranged in a window frame.

The arrangement for conveying the liquid can, in a conventional manner, be in the form of a conventional pump, for example a piston pump or a gear pump, which conveys the liquid into a supply container and removes it from the container. It is also possible to use a simple air pump, which can place the liquid container under pressure so that the liquid can pass into the space between the panes through suitable openings in the

frame surrounding the panes, and can leave the space between the panes when the pump is switched off to eliminate the air pressure in the liquid container.

The screening or window structure in accordance with the invention can be used with particular advantage to darken a window. In this case the panes are arranged in a window frame, as is the case with conventional double pane windows, which are joined together with the help of a lead connecting piece. This window frame is preferably a hollow frame which forms a storage or supply container for the liquid in its lower part. The lower edge of each pane extends into this supply container formed by the lower part of the hollow frame. The frame is then divided into two halves, and a pump is mounted in one half. This pump conveys air out of the other frame half into the supply container for the liquid so that the liquid level between the panes gradually rises. Displaced air is drawn off by the pump at the top of the frame through suitable openings or holes. Thus, the system used is closed, and by the incorporation of a simple pump it can be darkened or changed over into the light passing condition. More particularly, for the use of the device in accordance with the invention as a double pane which can be darkened there are the following health and security requirements to be made as regards the liquid used.

1. The liquid should be insensitive to thermal changes. For normal mid-European living conditions its freezing point must be about −25°C while its boiling point should be considerably above 100°C. For normal conditions the vapor pressure-temperature curve must have low values below 100°C so that the vapor pressure of the liquid in the closed system is as low as possible. Furthermore, the liquid should not decomposed on heating.
2. The liquid should not be affected by light radiation and in particular by ultra-violet radiation, and should be capable of at least being stabilized.
3. The liquid should be substantially free of odor so that traces of liquid escaping from the system will not have undesired effects in the surroundings.
4. Furthermore, the liquid should not be subject to any objections on health grounds so that, for example, if a window pane breaks there should be no direct danger of asphyxiation by inhalation of the vapors of the liquid.
5. The liquid should conveniently be capable of being mixed with other similar liquids so that the refractive index can be adjusted precisely.
6. The liquid should have a very low viscosity so that it can rapidly pass from the space between the panes to the storage container without making the space between the panes excessively large. If the spacing between the panes is not suitably chosen having regard to the viscosity of the liquid, it may be that the liquid will not completely run out of the space and islands of liquid will remain between the panes.
7. The liquid must completely wet the pane surfaces. Its surface tension should be as low as possible.
8. The liquid should not form any stable foam.
9. The liquid should not react with the material of which the panes are made, and should not decompose owing to a catalytic action with the material from which the panes are made.
10. The liquid should not be inflammable or at least be of low inflamability. More particularly, in the case of use in public buildings the liquid should be able to serve as a fire extinguishing liquid.

In tests it has been found that the above-mentioned requirements are best fulfilled by halogenated aliphatic and halogenated cyclic hydrocarbons and cyclic amines.

Since the arrangement, or device in accordance with the present invention also makes possible a completely closed system, liquid vapors cause trouble in the environment when there are leaks in the system. Such leaks can be avoided by the adoption of measures which are familiar to those in the art.

The following table indicates a few liquids and gives an indication of their value in accordance with the above-mentioned conditions.

Dimethyl-aniline, which has a brownish shade, can be used as a colored liquid and approximately corresponds to dibenzylamine in its behavior.

TABLE

Liquid	1*2*3 4 5 6 7 8 9 10	suitability
Ethyl abietate	+−+++−−−+−	slight
Acetonitrile	−++−−++++−	slight
Allyl isothiocyanate	+−−−+−−++−	slight
Chlorobenzene	+−+ ++++++−	in some cases
Tetrachloro-ethylene	++++++++++	good
1,1,2,2,-Tetra-bromopropane	++++++++++	good
1-Chloro-naphthalene	++++++++++	good
Dibenzylamine	+++++−++++	good

*see paragraphs 1 to 10 above.

A double pane comprises, for example, two glass panes mounted in a liquid-tight frame. One of the glass panes is highly ribbed and therefore practically non-transparent. The refractive index N_D of the glass is 1.52.

The intermediate space between the glass panes is filled with the mixture of tetrachlorethylene and 1,1,2,2-tetrabromopropane with a volumetric ratio of 100:7.45. After the space between the double panes is filled the glass ribs disappear completely and a perfect transparency is achieved. If the liquid is pumped out of the intermediate space the device becomes non-transparent again.

A simple device with which it is possible to fill the intermediate space between the panes or empty the space in accordance with the invention is characterized in that the space between the panes is connected by a flexible tube to a rolling device with one handle which is adapted to squeeze the tube to displace the liquid into the intermediate space between the panes.

In accordance with one embodiment of the present invention, the arrangement is so constructed that the tube is attached on a plate or the like with guide rails running parallel to it. The guide rollers fit under the ends of a shaft which carries a roller. The shaft has a handle adapted to displace the rollers in the longitudinal direction of the flexible tube, squeezing it together or releasing it upon rolling in one direction or the other.

A pair of rollers can also be mounted on opposite sides of the flexible tube being capable of being moved along the tube, squeezing it as they move. A handle is

operatively affixed to the rollers as a means to impart motion to them.

In accordance with a further development of the invention, the roller or the pair of rollers can be automatically moved back into their starting position.

Advantageously, a check valve which can be overridden can be provided in the duct leading to the space between the panes. In this manner it is not absolutely necessary for the pressing action of the rollers on the flexible tube to provide an absolutely liquid-tight sealing action because the flow of the liquid out of the space between the panes is checked by the check valve. If the check valve is overridden and the rollers have been moved back into their starting position, the liquid runs out of the space between the planes automatically and the arrangement ceases to be transparent.

A valve also offers the advantage that it is possible to hold the level of the liquid in the space between the panes in a positive manner and, if it is required, to control the rate of discharge flow.

The accompanying drawings show embodiments, by way of example of the present invention.

FIG. 1 is a diagrammatic view of the arrangement in accordance with the invention, the front wall of the frame being removed.

FIG. 2 is a section on the line II—II of FIG. 1.

FIG. 3 is a view similar to FIG. 2 through a modified embodiment of the invention.

FIG. 4 is a section similar to FIG. 2 through a further modified embodiment of the invention.

FIG. 5 is a front view of an arrangement in accordance with the invention with a filling and emptying means.

FIG. 6 is a side view of a part of the arrangement in accordance with FIG. 5.

FIG. 7 is a side view of another embodiment of the filling and emptying device.

As can be seen, FIG. 1 shows a frame 2 constructed in the form of a box frame and having a hollow channel extending around the periphery thereof, which is also clearly indicated by FIG. 2. The frame is glazed with glass panes 2 and 3, which are connected along the lateral edges by means of connecting pieces 4, 5. At the bottom of the frame this pair of panes extends into the storage container for the liquid 6 which is formed by part of the frame. The frame has partitions 7, 8 dividing it up into two spaces. In the case of the embodiment shown in FIG. 1, a diagrammatically indicated pump 9 is mounted in the partition 8 and is connected by a cable 11 to a supply of electricity (not-shown). A liquid and gas-tight plug 10 is used to seal around the cable where it extends through the frame.

If pump 9 pumps the liquid 6 in the direction of the arrows in full lines, air in the upper frame part is passed into the lower frame part and displaces the liquid 6 at this position into the space between the panes 2 and 3, which is in open communication with the channel, so that a liquid level 12 indicated in broken lines slowly rises upwards. If the pump operates in the opposite direction, the air moves in the direction of the arrow shown in broken lines, and the liquid level 12 indicated in the broken lines again drops. Since one of the panes 2 or 3, or possibly both is provided on its inner side with grooves, or another form of unevenness, which makes it non-transparent, or translucent when there is no liquid between the panes 2 and 3 the arrangement will be non-transparent owing to this unevenness. When the liquid level as shown in the broken line rises, the panes will become transparent owing to the approximately identical value of the refractive indices of the liquid and the pane material which causes the diffusion or dispersion of the rays of light to cease.

In the case of the embodiment shown in FIG. 3 there is a fabric 13 such as a woven fabric, knitted fabric, felted fabric, braided fabric or the like, disposed between the panes 2 and 3. This fabric consists of threads, filaments or fibers of transparent material, but the refraction of the light on the fibers or filaments makes the arrangement at least partially, non-transparent.

This transparent material has a refractive index which is the same as that of the liquid 6 in the frame 1. When the liquid 6 is pumped upward in the space between the panes by the pump 9, as is the case with the embodiment in accordance with FIG. 1, so that the liquid level 12 rises, the arrangement begins to be transparent starting at the bottom, with the effect that the operation corresponds approximately to the raising of a curtain. Naturally another liquid can be arranged between the panes 2, 3 above the level 12 so that the whole system or space between the panes 2, 3 is filled with liquid. This other liquid must then have a refractive index which substantially departs from that of the material 13 so that the arrangement is non-transparent.

It is also possible to make the one or other liquid diffusing or colored, for example the liquid above the level 12 can be colored or can even be diffusing, so that the transparency of the arrangement is further increased when the level 12 has moved down to the bottom of the frame. It is, however, also possible to color the liquid with a refractive index substantially the same as the refractive index of the mounted material 13 so that on pulling up a curtain there is at the same time an upward movement of a correspondingly colored filter in accordance with the upward movement of the level 12 which though it does not impair the transparency or only slightly impairs it, absorbs a part of the radiation passing through the arrangement.

Preferably for the mounted material 13, use is made of a glass fiber woven fabric or felted fabric. It is also possible, however, to use a synthetic material. Such material can be obtained commercially. The refractive index of the material can be determined in any conventional manner.

In the case of the embodiment shown in FIG. 4, a piece of fabric such as woven or knitted fabric is mounted on the pane 3, for example a piece of fabric made of glass fibers or the like, as denoted by reference numeral 14. When the liquid level 12 moved downwards, fine droplets of liquid collect on this fabric so that the glass pane 3 becomes diffusing. This diffusing action ceases immediately when the liquid level 12 moves up again in the space between the panes 2, 3 through operation of the pump 9.

The small droplets are denoted in FIG. 4 by references numeral 15.

The fabric or the like which can consist of glass, synthetic resin or a similar material is applied directly to the glass pane 3. It may even be glued to the pane. It may, however, also be sufficient to fix it in front of the glass pane.

FIG. 5 shows the front view of a double pane in which the two panes 16 and 17 are connected by a connecting piece 18 so that the space between the two panes 16, 17 can be filled with liquid which is held in the space by the connecting piece 18 in a leak-proof manner. The connecting piece 18 has an opening at 19, in which a supply tube or duct 20 is mounted and sealed in position. The duct 20 leads to a flexible tube 21 which is filled with a liquid whose refractive index is equal to that of the pane in the pair of panes 16 and 17 which is provided with the unevenness. The flexible tube 21 can, as indicated in the embodiment shown in FIG. 6, be attached to a base plate 22. On the base plate 22 there are rails 23, 24 which fit under the ends of a shaft or pin 25 carrying a roller 26 which is provided with a handle 27. If the handle is pulled in the direction of the arrow to the right, the filled flexible tube 21 is pressed together or caused to collapse and the liquid flows out of it via the supply duct 20 into the space between the panes 16 and 17. Since the liquid has the same refractive index as the pane with the unevenness, the arrangement becomes practically completely transparent as the liquid is raised in the space between the panes, that is to say the unevenness disappears. In order to provide protection against an unintended return flow of the liquid, a check valve 28 is provided in the duct 20, and this check valve can be overridden by means of a handle 29.

FIG. 7 shows a somewhat modified embodiment of the invention. In this case the flexible tube 21 is filled with liquid between its end and the roller 26 is replaced by a pair of rollers 30, which can also be moved by a handle 27. In this case displacement of the pair of rollers 30 in the direction of the arrow, that is to say to the right in FIG. 7, causes liquid to be moved out of the flexible tube 21 via the duct 20 into the space between the panes 16 and 17.

In the case of both embodiments of the invention there is also the provision of the spring arrangement 31 and 32, and 33, which automatically returns the unit comprising the roller and the handle to the starting position so that to remove the liquid between the pane in order to decrease transparency, it is sufficient to open the check valve 28 using the handle 29 and thus allow the liquid to flow back into the flexible tube 21 again.

We claim:

1. A window arrangement comprising in combination:
- a frame having a top, bottom and side portions;
- two substantially plane panes of a transparent material disposed in a generally parallel spaced apart relationship with respect to each other defining a space therebetween;
- said panes being sealably mounted in said frame;
- means defining a hollow channel in, and extending around the periphery of said frame, said hollow channel openly communicating with said space between said panes at a top and a bottom of said space;
- at least one of said panes having an uneven surface comprising a transparent fabric material adjacent said space between said panes;
- a liquid having a refractive index approximately equal to the refractive index of said transparent material of said panes;
- a container disposed interior to said bottom portion of said frame in said hollow channel adapted to hold said liquid;
- a bottom portion of said panes extending into said container such that said bottom of said space openly communicates with the interior of said container and said liquid to be contained therein to allow said fluid to enter said space from said container; and
- means to pump said liquid from said container in said bottom portion of said frame into said space between said panes.

2. A window arrangement as defined in claim 1, further comprising:
- at least one partition disposed in said channel in each side portion of said frame laterally to said hollow channel to divide said hollow channel into an upper part and a lower part;
- said pumping means being a pressure creating pump operatively connected to said upper part and said lower part of said hollow channel in said frame;
- when said pump is operatively connected to said lower part of said hollow channel a pressure is created in said lower part which forces said liquid out of said container and into said space between said panes causing said panes to become transparent, and
- when said pump is operatively connected to said upper part of said hollow channel a pressure is created in said upper part which forces said liquid out of said space between said panes and into said container causing said panes to become translucent.

3. A window arrangement as defined in claim 2, further characterized in that said uneven surface is comprised of a transparent fabric material affixed to a face of one of said panes adjacent said space.

4. A window arrangement as defined in claim 2, further characterized in that said uneven surface is comprised of a transparent fabric material disposed between said panes in said space.

5. A window arrangement as defined in claim 2, further characterized in that said pump is disposed in said hollow channel interior to said frame.

6. A window arrangement as defined in claim 5, further characterized in that:
- said pump is electrically powered; and
- a liquid and gas-tight seal is disposed around the electrical connection between said pump and the source of electrical power in said frame at the location where the electrical connection passes through said frame to prevent said fluid from leaking from said frame.

7. A window arrangement as defined in claim 5, further characterized in that said uneven surface is comprised of a transparent fabric material affixed to a face of one of said panes adjacent said space.

8. A window arrangement as defined in claim 5, further characterized in that said uneven surface is comprised of a transparent fabric material disposed between said panes in said space.

9. A window arrangement as defined in claim 2, further characterized in that said upper part of said hollow channel in said frame is filled with a liquid having a refractive index different than the refractive index of

said transparent material of said panes, and being immiscible with said liquid, having a refractive index approximately equal to the refractive index of said transparent pane material, in said container,

when said pump is operatively connected to said upper part of said hollow channel said liquid in said upper part of said hollow channel is forced into said space between said panes it displaces said liquid having a refractive index equal to said refractive index of said pane material downwardly out of said space causing said panes to become opaque, preventing said liquid in said upper part of said hollow channel from mixing with said liquid having a refractive index equal to said transparent pane material.

10. A window arrangement as defined in claim **9**, further characterized in that:

said pump is disposed in said hollow channel interior to said frame;

said pump is operatively connected to a source of electrical power; and

a liquid and gas-tight seal is disposed in a wall of said frame around the electrical connection where said electrical connection passes through said frame to prevent said liquid from leaking from said frame.

11. A window arrangement as defined in claim **10**, further characterized in that said uneven surface is comprised of a transparent fabric material affixed to a face of one of said panes adjacent said space.

12. A window arrangement as defined in claim **10**, further characterized in that said uneven surface is comprised of a transparent fabric material disposed between said panes in said space.

13. A window arrangement as defined in claim **1**, further comprising:

a base plate;

said container is a flexible tube attached to said base plate;

a supply tube adapted for the passage of said liquid operatively communicating at one end with said space between said panes, and at its other end to said flexible tube container;

a shaft located transversely to said base plate;

a handle operatively associated with said shaft;

two spaced apart generally parallel rails spaced from said base plate, each disposed under opposite ends of said shaft; and

a roller rotatably mounted on said shaft disposed adjacent said flexible tube container, the distance between said base plate and a point on the periphery of said roller nearest said base plate being less than the thickness of said flexible tube container,

when said roller is caused to translate over said flexible tube container by a force exerted on said handle, said flexible tube container collapses forcing said liquid contained therein through said supply tube into said space between said panes.

14. A window arrangement as defined in claim **13**, further characterized in that said uneven surface is comprised of a transparent fabric material affixed to a face of one of said panes adjacent said space.

15. A window arrangement as defined in claim **13**, further characterized in that said uneven surface is comprised of a transparent fabric material disposed between said panes in said space.

16. A window arrangement as defined in claim **1**, further comprising:

a pair of spaced apart rollers;

said container is a flexible tube;

a supply tube adapted for the passage of said liquid operatively communicating at one end with said space between said panes, and at its other end with said flexible tube container;

a pair of spaced apart rollers disposed on opposite sides of said flexible tube, the distance between said spaced apart rollers being less than the thickness of said flexible tube; and

a handle operatively affixed to said pair of rollers,

when said pair of rollers are caused to translate over said flexible tube container by a force exerted on said handle, said flexible tube container collapses forcing said liquid through said supply tube into said space between said panes.

17. A window arrangement as defined in claim **16**, further characterized in that said uneven surface is comprised of a transparent fabric material affixed to a face of one of said panes adjacent said space.

18. A window arrangement as defined in claim **16**, further characterized in that said uneven surface is comprised of a transparent fabric material disposed between said panes in said space.

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