

(19)



Europäisches Patentamt

European Patent Office

Office européen des brevets



(11)

EP 0 819 817 A2

(12)

EUROPEAN PATENT APPLICATION

(43) Date of publication:

21.01.1998 Bulletin 1998/04

(51) Int Cl.⁶: **E06B 3/67**

(21) Application number: **97305251.7**

(22) Date of filing: **15.07.1997**

(84) Designated Contracting States:

**AT BE CH DE DK ES FI FR GB GR IE IT LI LU MC
NL PT SE**

(30) Priority: **16.07.1996 US 682059**

16.05.1997 US 857714

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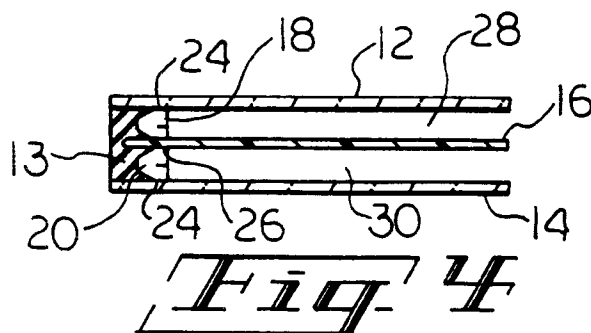
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(54) Method of manufacturing multiple-pane window units containing intermediate plastic films

(57) Sealed insulating glass units, with multiple-pane construction contain an intermediate, flexible heat-shrunk and taut plastic sheet (16), are made using a sil-

icone edge sealant (13) that exhibits a sheet creep of less than 0.018 cm after 500 hours at 71°C. Said plastic sheet (16) remains substantially wrinkle free in this construction by use of silicone edge sealants (13).



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Description

This invention relates to multiple-pane window units of insulated glass and the manufacture thereof. Insulating glass units for windows or doors commonly comprise two or more parallel glass panes that are separated from one another by spacers along their edges. Various multiple-pane configurations are known in the art. Certain of these configurations have employed plastic sheets in a parallel spaced relation to the glass panes.

If a multiple pane glass unit is assembled with a plastic sheet held in spaced relationship between two glass panes, the unit is usually manufactured by applying a marginal spacer along the edges of one glass pane, the spacer extending away from the plane of the pane, by adhering a heat-shrinkable film to the spacer and by then heat-shrinking the film to draw the film taut and wrinkle-free. The second pane, also provided with a marginal spacer, is then attached, and said film becomes sandwiched between the opposed marginal spacers of the two panes.

In another embodiment, the film may be grasped by small springs that are held by, or form a part of, the spacers separating the two glass panes from one another. Generally, unbreakable mirrors are formed by adhering a marginal spacer about the periphery of a sheet of plywood or like structural element, then adhering a heat-shrinkable, silvered, plastic film to the spacers, and thereafter heat-shrinking said film so it becomes taut and wrinkle-free to provide a mirrored surface.

In the above embodiments using a heat-shrinkable plastic film, the film is stretched over spacers held at the edge of a stiff pane or structural element and the plastic film is then heated directly, typically by hot air flow. For multiple-pane glass units, wherein the plastic film is deployed as an internal sheet between parallel glass panes, the above manufacturing methods are difficult and time consuming. Also, these methods necessitate piecemeal construction methods.

U.S. Patent 4,335,166 describes manufacture of multiple-pane glass units by supporting a flexible, heat-shrinkable plastic sheet between parallel, spaced apart glass panes, which are spaced from one another and from the plastic sheet (film) by means of spacers arranged about the edges of the glass panes. The panes are sealed to one another along their edges by the spacers and by a sealant adhered to edges of the plastic sheet to provide, with the heat-shrinkable plastic sheet, a sealed and integral unit. The unit itself is then heated for a sufficient time, and at a sufficient temperature, to cause the plastic sheet to shrink and become taut and wrinkle-free. Upon cooling, the resulting integral unit requires no further manufacturing steps, and is directly insertable into an appropriate window frame as an insulating glass unit.

Further evaluation of the above patent found that successful construction was dependent upon the sealant materials used. For example, the edge sealant utilized therein was a two-part, room-temperature vulcanizable (RTV) resin, identified as GE3204™ (manufactured by General Electric Company, U.S.A.). While the necessary adhesion to hold the glass panes together along with the spacers was provided, our efforts found that the plastic sheet became wrinkled in a short time after manufacture. In addition to GE3204™, various silicone sealants were tried by us as edge sealants in making window units with an intermediate plastic sheet. As far as we know, however, no silicone sealant appeared completely satisfactory.

U.S. Patent 4,613,530 teaches that the edge sealant should be polyurethane. Although polyurethanes are useful for the multiple-pane glass units described by U.S. Patent 4,335,166, they are degraded by exposure to UV radiation if installed without a proper glazing cap to protect the sealant. Similarly, U.S. Patent 5,308,662 discloses the pros and cons of various kinds of edge sealants and then proposes a mechanical means to overcome the degradation effects of UV radiation. The silicone sealants of this latter patent are resistant to light induced cross-linking and hardening which cause serious problems in other sealants, but they are also very permeable to water vapor. The organic sealants, such as polyurethanes and polysulfides, are damaged by sunlight and their constructions require a nonreflective dark tape to be positioned exactly right to overcome the impact of UV radiation on the edge sealant.

U.S. Patent 5,156,894 provides suitable edge sealants for multiple-pane glass units that are manufactured from curable, high modulus, low-creep, low-moisture, low-vapor transmitting sealants, such as polyurethanes, for example, the two-component polyurethanes marketed by Bostik, such as Bostik™ 3180-HM or 3190-HM. U.S. Patent 4,853,264 claims the same kind of edge sealants for use on curved triple-pane glazing in which a plastic sheet is positioned intermediate between two glass panes. This plastic sheet is anchored along the parallel curved edges but is not attached to the other edges. Further, the plastic sheet heat shrinks in the direction that it is anchored.

It is an object of our invention to provide a multiple-pane glass unit containing a heat-shrunk flexible plastic sheet made with a silicone sealant as an edge sealant. It is also our object to provide a method of manufacturing such a unit.

This invention is a sealed insulating glass unit comprising at least one flexible, heat-shrunk plastic sheet positioned between parallel, spaced panes. Therein, each sheet is parallel to, but spaced apart from, confronting surfaces of the panes or another plastic sheet; and each sheet is fixed at its edges with respect to edges of the panes. A silicone edge sealant is used between adjacent edges of said panes to provide an integral sealed unit, at least two opposing edges of said unit having each plastic sheet embedded into the silicone edge sealant. An essential feature therein is a silicone edge sealant that exhibits a sheet creep of less than 0.018 cm after 500 hours at 71°C.

This invention also provides a method of manufacturing a multiple-pane insulating glass unit comprising

- (a) forming a sealed integral unit comprising supporting at least one flexible, heat-shrinkable plastic sheet between parallel, spaced apart glass panes, the sheet being substantially parallel to, but spaced apart from, confronting surfaces of the panes and being fixed at its edges with respect to edges of the panes;
- (b) applying a curable silicone edge sealant composition between adjacent edges of the panes to provide an integral sealed unit and embedding into said curable silicone edge sealant composition at least two opposing edges of each flexible, heat-shrinkable plastic sheet;
- (c) curing the silicone edge sealant composition; and then
- (d) heating the unit to cause each plastic sheet to shrink and become taut or wrinkle-free between the panes, where said silicone edge sealant exhibits a sheet creep of less than 0.018 cm after 500 hours at 71°C.

FIG. 1 is a perspective view, partly broken away and in section, of a window unit.

FIG. 2 is an exploded cross-sectional view showing elements of the window unit ready for assembling.

FIG. 3 is a cross-sectional view similar to that of FIG. 2 but showing the window elements assembled.

FIG. 4 is a cross-sectional view similar to that of FIG. 3 and showing the window unit after the heating step.

FIG. 5 is a cross-sectional view similar to FIG. 4 but enlarged to show the constructional relationships more clearly.

FIG. 6 is an enlarged, fragmentary cross-sectional view of a window unit showing an embodiment in which an electrical lead is electrically coupled to the plastic sheet and ground.

FIG. 7 and FIG. 8 are cross-sections of alternative configurations for single seal, triple glazed sealed units incorporating a plastic inner sheet.

FIG. 9 is a cross-section of a quad glazed window unit incorporating two plastic inner sheets.

FIG. 10 is a perspective illustration showing a curved glazing structure in use in a greenhouse.

FIG. 11 is a cross-sectional view of a curved glazing structure taken parallel to the straight sides of the structure of FIG. 10.

FIG. 12 is a cross-sectional view of a glazing panel taken parallel to the curved side of the structure of FIG. 10.

FIG. 13 is a perspective view of the sheet creep test assembly.

FIG. 14 is a side sectional view of the sheet creep test assembly showing the dimensions.

FIG. 15 is a front sectional view of the sheet creep test assembly showing the dimensions.

Reference Numerical Key

- 10 multiple-pane window unit
- 12 spaced pane
- 13 silicone edge sealant
- 14 spaced pane
- 15 flexible heat shrinkable plastic sheet
- 16 taut, flexible, heat-shrunk plastic sheet
- 17 electrically conductive lead coupling plastic sheet 16 to ground
- 18 spacer
- 20 spacer
- 21 foam spacer
- 22 outer window frame
- 23 pressure sensitive adhesive
- 24 gas barrier sealant
- 25 gas barrier sheet
- 26 gas barrier sealant
- 28 gas filled space
- 30 gas filled space
- 31 curved edge
- 32 curved edge
- 33 curved glass pane
- 34 curved glass pane
- 35 flexible heat shrunk plastic sheet
- 36 spacer
- 37 spacer
- 38 spacer
- 39 spacer

	41	spacer
	42	spacer
	43	spacer
	44	spacer
5	45	frame member
	46	straight edge
	47	straight edge
	50	greenhouse structure
	52	flat wall window unit
10	53	flat roof window unit
	54	curved window unit
	56	clear float glass panel
	57	clear float glass panel
	59	test edge sealant
15	61	aluminum bar
	62	aluminum bar
	64	screw and nut fastener to clamp
	65	screw and nut fastener to clamp
	67	aluminum foil
20	68	hole for hanging weights
	70	spacer
	71	spacer
	H1	0.33 cm height
	H2	5.08 cm height
25	H3	2.235 cm height
	H4	15.57 cm height
	H5	6.35 cm height
	D	0.356 cm diameter
	L1	7.09 cm length
30	L2	5.08 cm length
	L3	2.54 cm $\pm$ 0.038 cm

We have found that certain silicone sealants used as an edge sealant 13 in a multiple-pane window unit 10 having at least one internal taut, flexible, heat-shrunk plastic sheet 16, keeps the plastic sheet wrinkle-free for longer time periods than previously known silicone sealants. Also, our edge sealant 13 exhibits UV stability for longer time periods than polyurethanes or polysulfides. When window units 10 are made using our silicone edge sealants 13 which have a sheet creep of less than 0.018 cm after 500 hours at 71°C., preferably less than 0.018 cm after 1,000 hours at 71°C., the heat-shrunk plastic sheet is retained in a taut condition and is wrinkle-free. In contrast, those silicone sealants which have a sheet creep of greater than 0.018 cm after 500 hours at 71°C. will fail by exhibit of wrinkling in the plastic sheet and by the resulting optical distortions or waves producted therefrom that are unacceptable to the end user.

Although not bound by the following theory, we believe that those silicone sealants, having a sheet creep greater than 0.018 cm after 500 hours at 71°C., do not contain one or more ingredients that are present in sufficient quantities, either singly or collectively, to achieve an acceptable sheet creep property. It is thought that such ingredients are active after the sealant is cured, either during the heat shrink step or during the window unit life, causing said sealant to change properties and yielding unacceptable distortions in the plastic sheet. For instance, some silicone sealants, having a sheet creep greater than 0.018 cm after 500 hours at 71°C., were found to contain either a plasticizer or a bond rearranging ingredient that remained active after the sealant cured; or said sealants contained both plasticizer and a bond rearranging ingredient. Our taut, flexible, heat-shrunk plastic sheet 16 is embedded in our silicone edge sealant 13 to anchor the plastic sheet. If the silicone edge sealant allows the anchored portion of the plastic sheet 16 to relax, which is under tension, then the undesirable effect of wrinkling will occur. Because optical properties are very sensitive to any distortion, even slight wrinkling or waves produce unacceptable windows.

Silicone sealant compositions curable under ambient conditions, such as in atmospheric air at room temperature, have now been found capable of meeting our low sheet creep requirements of less than 0.018 cm after 500 hours at 71°C. In particular, these silicone sealants are known as one-package or two-package RTV silicone sealant compositions that are characterized by being void of ingredients that cause sheet creep to increase to greater than 0.018 cm after 500 hours at 71°C. Two-package RTV silicone sealant compositions can be used to provide faster curing products than one-package compositions.

It is believed that ingredients which cause such an increase in sheet creep include plasticizers and/or siloxane

bond rearranging ingredients that remain active after the RTV composition has cured to a sealant. Examples of suitable silicone sealant compositions that are useful as edge sealants which exhibit a sheet creep of less than 0.018 cm after 500 hours at 71°C are: Dow Corning(R) 3-0117 Silicone Insulating Glass Sealant (hereinafter DC 3-0117) comprising a polysiloxane, calcium carbonate and methyltrimethoxysilane; Dow Corning(R) 3145 RTV MIL-A-46145 Adhesive/Sealant (hereinafter DC 3145) comprising a hydroxy-terminated dimethylsiloxane, trimethylated silica, titanium dioxide and methyltrimethoxysilane; and Dow Corning(R) 995 Silicone Structural Adhesive (hereinafter DC 995) comprising a polysiloxane, calcium carbonate and methyltrimethoxysilane. These sealant compositions do not contain plasticizer or a siloxane bond rearranging ingredient that remains active after the sealant composition is cured.

When similar silicone sealant compositions do contain plasticizer and/or a siloxane bond rearranging ingredient, they exhibit a sheet creep of greater than 0.018 cm after 500 hours at 71°C. Such products include Dow Corning(R) 982 Silicone Insulating Glass Sealant (hereinafter DC 982) comprising a two-package product of a base and curing agent, wherein the mixed composition contains a hydroxy-terminated dimethylsiloxane, calcium carbonate, tetrapropyl orthosilicate, gamma-aminopropyltriethoxysilane, carbon black, polydimethylsiloxane and dibutyltin dilaurate and where the polydimethylsiloxane acts as a plasticizer and the dibutyltin dilaurate acts as a siloxane bond rearranger within the cured sealant; and Dow Corning(R) 795 Silicone Building Sealant (hereinafter DC 795) which is a one-package sealant composition hydroxy-terminated dimethylsiloxane, calcium carbonate, amorphous silica, methyltrimethoxysilane and polydimethylsiloxane, wherein the polydimethylsiloxane acts as a plasticizer. Both DC 982 and DC 795 exhibit sheet creep of greater than 0.018 cm after 500 hours at 71°C. Other silicone sealants in this category include a one-package silicone sealant, known as GE SCS 2501™ and a two-package sealant, known as GE3204™, both from General Electric Company.

When DC 3-0117, DC 3145 and DC 995 were used as a silicone edge sealant 13, they exhibited a sheet creep of less than 0.018 cm after 1,000 hours at 71°C. In comparison, those silicone sealants which failed and exhibited wrinkling of plastic sheet 16 exhibited sheet creeps of more than 20 times greater after only 500 hours at 71°C.

The methods of making window units and the construction of windows for the embodiments of this invention are similar to those which are described in the prior art. The principle difference is using our silicone sealant composition to produce an edge sealant 13 where the resulting cured silicone sealant exhibits a sheet creep of less than 0.018 cm after 500 hours at 71°C. A silicone edge sealant is easily penetrated by water vapor; and thus there is a requirement to provide a means to prevent egress of the insulating gas used to fill spaces 28 and 30, and to also prevent the ingress of water vapor into these spaces 28 and 30. One means to prevent gas egress and water vapor egress is the use of gas barrier materials as illustrated by gas barrier sealant 24 and 26 or gas barrier sheet 25. The phrase "gas barrier sealant" means that neither water vapor or inert gases will pass through said sealant in any substantial amount which alters the functioning of the resulting window construction for the expected lifetime of consumer use.

FIG. 1 shows a completed multi-pane window unit 10 resulting from a method of this invention comprising at least a pair of parallel, spaced apart panes 12 and 14 and an intermediate flexible, heat-shrunk plastic sheet 16 that is parallel to said panes, but spaced inwardly from each pane. Although panes 12 and 14 are referred to as being glass throughout this description, it is understood that these panes may be made of other construction materials, such as rigid plastics like polyacrylic or polycarbonate. However, glass is the most common material for window construction and panes are typically referred to as glass panes. The panes 12 and 14 are provided with opposing spacers 18 and 20, about their peripheral edges, the spacers supporting said panes in their spaced, parallel relationship to our plastic sheet 16. Plastic sheet 16 may be coated or tinted, as desired, to provide any known window effect used in the art. The thickness of plastic sheet 16 in FIG. 1 is slightly exaggerated to merely illustrate the position of said sheet relative to panes 12 and 14. Window frame 22 illustrates that glass window units are produced with frames which are well-known in the art and that there is no need for further details here.

In our method of manufacturing window units, panes 12 and 14 are provided and are cut to the same length and width dimensions. To one surface of each of the panes is adhered a spacer (18 and 20 as shown in FIG. 2), the spacer extending about the periphery of the pane and spaced inwardly from the pane edge, as shown in FIG. 5, which is also enlarged for illustrative purposes. Each spacer comprises an elongated shape of aluminum, plastic or other rigid material, the shape desirably having walls formed to provide hollow interior and flattened, parallel exterior wall portions. The hollow portion may also contain a desiccant, such as a silica gel. The spacer is adhered, for example, to the surface of the glass pane by a gas barrier sealant (24 and 26) such as polyisobutylene which is capable of withstanding temperatures of 121°C. without substantial deterioration.

A flexible heat shrinkable plastic sheet 15 is drawn across spacers 20 carried by one of the panes and is pulled as taut as practical, as illustrated by FIG. 2, so the sheet 15 comes into contact with a sealant, such as the gas barrier sealant 26, on spacer 20 as shown. The other pane 12, with its peripheral spacer 18 is oriented with respect to the first pane 14 so that gas barrier sealant 26 on spacer 18 is opposite to spacer 20 and in a direct opposed relationship, plastic sheet 15 being captured between the opposing sealants 26. The plastic sheet 15, being flexible, ordinarily contains waves and wrinkles at this stage, as shown diagrammatically and in exaggerated form in FIG. 3. Edge sealant 13 is then applied between the edges of the glass panes which extend outwardly of the spacers 18 and 20, such edges

forming, with the spacers, a slight depression or trough in the edge of the assembled unit. The edges of plastic sheet 15 extend into the depression as shown in FIG. 3 and FIG. 5. The silicone edge sealant is then cured in place to adhere the panes together strongly enough to allow movement of the units. The panes, the outwardly exposed portions of the spacers, and the edges of the plastic sheet thus form an integral unit.

Plastic sheet 15 is preferably oriented midway between the surfaces of confronting panes 12 and 14. It is understood that the plastic sheet, when shrunk, exerts inwardly directed forces on the spacers which in turn cause compressive forces to be exerted on, and in the plane of, said panes. By having the plastic sheet midway between the confronting pane surfaces, the compressive load borne by each pane, although slight, is expected to be approximately equal.

The integral unit is then heated, such as by placing it into a forced air oven, for a period sufficient to cause the heat shrinkable plastic sheet to shrink to the extent necessary to remove all wrinkles or waves in the sheet. The sheet is held at its edges by spacers 18 and 20 and silicone edge sealant 13. Edge sealant 13 will resist softening during the heating step to heat-shrink the plastic sheet; it will not deteriorate during the heating step; and the sealant anchors the edges of the sheet and prevents its movement with respect to the panes. The silicone edge sealant holds the plastic sheet in position and does not relax, either during the heating step or thereafter. Such relaxation or sheet creep will undesirably result in wrinkles or waves that yield unacceptable optical distortions. It is important to equalize the gas pressure between gas filled spaces 28 and 30. This pressure equalization is accomplished by providing one or more perforations in the plastic sheet. FIG. 4 illustrates a multi-pane window unit 10 after the heating step and with the heat-shrunk plastic sheet 16 in its taut condition. FIG. 5 illustrates, in an enlarged view, the positioning of the taut heat-shrunk plastic sheet 16 with respect to panes 12 and 14, the gas barrier sealant 24 and 26, the spacers 18 and 20 and edge sealant 13.

Flexible heat shrinkable plastic sheets 15 are known in the art and are available commercially. Such sheets are produced by stretching the sheets in their length and width dimensions at temperatures below their melting point to provide molecular orientation in the sheets. Subsequently heating the sheets reduces the molecular orientation thereby causing the sheets to shrink in length and width dimensions. One preferred plastic for making these sheets is a polyester known as polyethylene terephthalate. Common temperatures for causing such materials to shrink are in the range of 90 to 121°C. Plastic sheets 15 preferably have thicknesses of from 0.01 to 0.5 mm. These sheets can be coated or tinted with dye to provide desirable or pleasing window effects. The sheets may also be coated on one or both sides with coatings which are highly transmissive of visible light, but are highly reflective of long wave infrared radiation. For additional details regarding conventional window construction and the method of manufacturing window units which contain an intermediate plastic sheet, see U.S. Patent 4,335,166.

In buildings or enclosures, it is desirable to provide windows and doors which will allow natural light to enter said building or enclosure that are also shielded from electromagnetic radiation, such as microwave radiation. Yet, these window units should also be heat insulating while remaining transparent to visible light. Such buildings or enclosures might be used for housing digital computers or sensitive electronic equipment which are adversely affected by high or low level radiation in the range from kilohertz to gigahertz frequencies. There also exists a security need in many government and military buildings for shielding interiors thereof to prevent electronic eavesdropping or espionage. The ability to remotely access information through electronic monitoring is significantly reduced by the use of electronic shielding techniques when combined with properly designed shielded walls, roofs and floors.

U.S. Patent 4,613,530 shows window units containing a heat-shrunk plastic sheet 16 which is coated with an electrically conductive coating as a transparent thermally insulating sheet that also serves as a shield for electromagnetic radiation. Such electrically conductive heat-shrunk plastic sheets are made with a metallic coating deposited to one or both sides of the sheet. These coatings are produced by vacuum deposition of materials which result in optically transparent films in the 400 to 700 nm range (visible region) but which also have electrical conductivity sufficient to attenuate electromagnetic energy in the longer wavelength range, 10^4 to 10^{10} nm, of radio frequencies. FIG. 6 illustrates an electrically conductive heat-shrunk plastic sheet 16 with an electrically conductive lead 17 from said sheet to ground. Thus, it may become necessary to extend the plastic sheet through the edge sealant to make such a connection.

This invention includes insulating glass units which contain one or more intermediate taut, flexible, heat-shrunk plastic sheets and also other kinds of spacers such as in U.S. Patent 5,007,217, shows in more detail glass units with more than one taut plastic sheet, other kinds of spacers or combinations of spacers, and other methods of making such glass units. FIG. 7 and FIG. 8 show triple glazed units with an intermediate plastic sheet 16. As illustrated in the aforementioned patent, such plastic sheets are coated with a low-emissivity coating, such as a product of Southwall Technologies, Palo Alto, California, and sold under the name of Heat Mirror™.

FIG. 7 shows a conventional metal T-shaped spacer 18 with a foam spacer 21 that typically contains desiccant. The flexible or semi-rigid foam spacer 21 is manufactured from thermoplastic or thermosetting plastics. Suitable thermosetting plastics include silicone and polyurethane and suitable thermoplastics include thermoplastic elastomers such as Santoprene™. Preferably, the foam is a silicone because of its advantages, including good durability, minimal outgassing, low compression set, good resilience, high temperature stability and cold temperature flexibility. Silicone foam is also moisture permeable so moisture vapors can readily reach the desiccant material within the foam. An

assembled metal spacer frame is laid on top of said plastic sheet and the sheet is adhered to the spacer with a pressure sensitive adhesive 23. The sheet is then cut to size in a conventional way so it extends into the groove created by spacer 18. A foam spacer 21 is then laid on top of the plastic sheet in line with spacer 18 below and adhered to said sheet with pressure sensitive adhesive 23. The plastic sheet 15, spacer 18 and foam spacer 21 combination is then sandwiched between panes 12 and 14. The outward facing perimeter is next filled with edge sealant 13. This edge sealant composition cures and bonds strongly to the plastic sheet, glass panes and spacers to hold the unit in position. Plastic sheet 15 is then heat-shrunk by exposing the assembled unit to heat by placing it in an air circulating oven thereby producing a taut, flexible, heat-shrunk plastic sheet 16 intermediate between panes 12 and 14. A gas barrier sheet 25 is also shown in the unit construction of FIG. 7.

FIG. 8 is an alternate construction of a glazed unit, similar to the one illustrated by FIG. 7, but where both spacers are foam spacers 21. FIG. 9 shows a quad glazed unit containing two taut, flexible, heat-shrunk plastic sheets 16 which are adhered to spacer 18 with pressure sensitive adhesive 23. On either side of spacer 18, there is a foam spacer 21 typically containing desiccant and backed with gas barrier sheet 25. This window unit of FIG. 9 is constructed using essentially the same method of manufacturing as described above using foam spacers, except it incorporates an additional flexible heat shrinkable plastic sheet 15 and foam spacer 21. The three interconnected gas filled spaces 28 are then filled with a very low heat conductive gas such as krypton. This type of window construction is further illustrated by U.S. Patent 4,831,799, which can be consulted for more details on multiple layer insulating glazing units with foam spacers.

Silicone edge sealant 13 of this invention also finds use in constructing curved glazing structures, such as those described in U.S. Patent 4,853,264. FIG. 10 shows a greenhouse structure 50 which is an assembled curved glazing structure having a frame member 45, flat wall window unit 52, flat roof window unit 53, curved window unit 54, straight edges 46 and 47, and curved edges 31 and 32. The two curved edges are parallel to one another and the two straight edges are parallel to one another.

FIG. 11 is a cross-section taken along lines 11-11' in FIG. 10 and shows two curved panes 33 and 34 with flexible heat-shrunk plastic sheet 35. Plastic sheet 35 can have a heat-reflective layer on its outer side, i.e. the side facing out of a building. Glass panes 33 and 34, and plastic sheet 35, are spaced apart from one another by gas filled spaces 28 and 30 by means of spacers 36, 37, 38 and 39. The spacers together with edge sealant 13 and gas barrier sealant, grip and adhere plastic sheet 35 into the structure along curved edges 31 and 32. In contrast, and as shown in FIG. 12, plastic sheet 35 is not affixed to curved panes 33 and 34 at the edges parallel to straight sides 46 and 47. At these edges, spacers 41, 42, 43, and 44 serve to join panes 33 and 34. The spacers 36, 37, 38, 39, 41, 42, 43, and 44 are illustrated as individual components, but in actual practice can be assembled into cured rectangular open frames.

Typical spacer materials are plastic extrudates and aluminum or steel extruded and roll-formed channels, such as those described U.S. Patents 4,335,166 and 4,853,264. These spacers can be of any cross-section and the distorted circles shown in FIG. 11 and FIG. 12 are merely representational since they can also be generally rectangular or square cross-sections. To achieve a good parallel relationship among the two panes and the intermediate plastic sheet, the heat-shrinkable plastic sheet will shrink, preferentially, perpendicular to the curved edges to which the plastic sheet is attached. For example, using a 0.0254 cm polyester as the plastic sheet and heating at 93 to 104°C., it is possible to obtain an overall shrinkage in the range of 0.4-0.5% in one direction and a shrinkage in the range of only 0.1-0.2% in the other direction. Such plastic sheets are typically oriented with the high-shrink direction being between the two curved edges. In fabricating such window units, one can use plastic sheet coated with a dielectric-metal, dielectric-interference filter or heat and light-reflecting layers, such as taught by U.S. Patent 4,337,990 which details plastic sheets containing coatings for various purposes.

Edge sealant 13 as described herein, in a variety of window constructions containing intermediate taut, flexible, heat-shrunk plastic sheets, imparts said window constructions with a longevity of the plastic sheets not previously observed. The utility of heat-shrunk plastic sheets depends upon its maintaining its taut condition over the expected life of the window construction without permitting formation of waves or wrinkles that create optical or reflective distortions. It is the use of our silicone edge sealant 13 which provides these advantages in these window units and the employment of our methods of manufacturing a variety of constructions.

Silicone edge sealants, suitable for the construction of window units by our invention and our methods of manufacturing such window units, must have a sheet creep of less than 0.018 cm after 500 hours at 71°C. The sheet creep was determined by a high temperature sealant creep test which follows:

A 5.08 cm H2 by 5.08 cm L2 cross-section of an insulating glass test unit was constructed as illustrated by FIG. 13, FIG. 14 and FIG. 15, where an aluminum strip 67 having a thickness of 0.381 mm, was substituted for a plastic sheet. A load of 3.6 kg was applied by hanging weights from hole 68 having a 0.356 cm diameter D for a test period measured in hours at 71°C ± 1°C. A fixed reference point was used to monitor the relative movement due to sealant creep (sheet creep). The amount of creep allowed by the test edge sealant 59 was observed and recorded identifying the load and length of time of the test. FIG. 13 illustrates the positioning of spacers 70 and 71, test edge sealant 59, aluminum bars 61 and 62 which were held in place by screw and nut fasteners 64 and 65 to clamp the aluminum bars

to the aluminum sheet 67 to measure the amount of creep. Spacers 70 and 71 were 5.08 cm long and 0.8 cm wide. The glass panes of the test units were 5.08 cm squares of clear float glass with a 0.3 cm thickness. Aluminum sheet 67 was 5.08 cm by 15.24 cm by 0.381 mm. The aluminum bars 61 and 62 were 0.635 cm by 0.635 cm by 7.94 cm.

Each edge sealant compositions to be tested were used to prepare insulating glass test units as described by FIG. 13, FIG. 14 and FIG. 15, along with the description provided here. Epoxy resin was used to adhere the spacers to the glass test panes and the aluminum sheet in the construction as identified by the drawings. Within one hour after the epoxy resin was applied, a sealant composition, mixed if a two package composition, was applied to complete the glass test unit. Each test unit was cured for at least 21 hours at 21°C. The aluminum bars were attached to the aluminum sheet and secured with the screw and nut fasteners as shown. The glass test unit was then mounted along with a linear displacement measurement device as the reference point.

Each edge sealant composition was tested at least three times. Each test unit was placed in a forced-convection oven at 71°C. where the temperature was maintained within 1°C. An oven with a transparent door was used so the movement of the aluminum bar could be observed without disturbing the test units. It was required that the fixtures for mounting the glass test units in the oven evenly supported the two glass panes in each sample and that the aluminum sheet with attached weights did not touch the fixture. The fixtures also kept the glass panes parallel to each other with an allowable deviation from parallel of 0.127 mm maximum. The load on each test unit aluminum sheet acted along the vertical centerline of the sheet. The device used to measure the linear displacement of the aluminum bars had a range of 0 to 2.54 cm with minimum marked increments of 0.025 mm.

Each creep test was started within 72 hours of the application of the edge sealant composition. The test units were placed in the test oven, load (weights) was placed on the aluminum sheet being careful to avoid impact loading. The measuring device was zeroed between 2 and 5 minutes after loading the weights. Creep data were recorded daily by recording the hours from zeroing the measuring device, the observed displacement and sheet creep. Each edge sealant composition was at least tested three times and the average was recorded as shown in the Table. Sheet creep of less than 0.018 cm after 500 hours at 71°C. was considered to be acceptable for our silicone edge sealants. Also, extrapolating the data out to 10 years by observing the rate of change, was considered an acceptable sheet creep if such an extrapolation was found to be less than 0.018 cm at the 10 year time.

The sealant compositions tested for sheet creep were as follows: DC 3-0117, DC 3145, DC 995, DC 982, DC 795, GE SCS 2501, Bostik™ 3180-HM, Novaguard™ 470 and GE3204. The values for the resulting sheet creep are given in the Table, except it was observed that GE3204 resulted in wrinkling of a taut, heat-shrunk plastic sheet in a relatively short time period.

TABLE

HOURS	<u>DC 3-0117</u>	<u>DC 3145</u>	<u>DC 995</u>	<u>DC982(1)</u>	<u>DC 795(1)</u>	<u>BOSTIK™</u> <u>3180-HM(1)</u>	<u>NOVAGUARD™</u> <u>470(1)</u>	<u>GE2501(1)</u> <u>>0.018(2)</u>
24	0	0.0015	0.002	0.009	0.009	0.009	---	---
288	---	---	---	---	---	0.031	---	---
336	0	0.001(5)	0.0025(4)	0.024	0.018(3)	---	>0.018(2)	---
504	0.0013	---	---	0.028	---	---	---	---
1008	---	---	---	---	---	0.036	---	---
1030	0.0025	---	---	0.038	---	---	---	---
1872	---	---	---	---	---	0.039	---	---
2031	0.0025	---	---	0.050	---	---	---	---

- (1) edge sealant composition used for comparative purposes
- (2) test stopped
- (3) rate of sheet creep increasing at approximately same rate as DC 982
- (4) no observable change in rate of sheet creep increase from 48-336 hours
- (5) decrease observed in sheet creep from first 24 hours

Claims

1. A method of manufacturing a multiple-pane window unit (10) comprising:

- (a) forming a sealed integral unit comprising supporting at least one flexible, heat-shrinkable plastic sheet (15) between parallel, spaced apart panes (12 and 14), each sheet being substantially parallel to, but spaced apart from, confronting surfaces of the panes and being fixed at its edges with respect to edges of the panes;
 (b) applying a curable silicone edge sealant (13) between adjacent edges of the panes to provide an integral sealed unit and embedding into said curable silicone edge sealant at least two opposing edges of each flexible, heat-shrinkable plastic sheet;
 (c) curing the silicone edge sealant composition; and then
 (d) heating the unit to cause each plastic sheet to shrink and become taut or wrinkle-free between the panes, where said silicone edge sealant exhibits a sheet creep of less than 0.018 cm after 500 hours at 71°C.

2. The method of claim 1 in which the silicone edge sealant (13) is a room temperature vulcanizable silicone sealant composition that does not contain one or more ingredients which are present in sufficient quantities, either singly or collectively, to increase the sheet creep after 500 hours at 71°C to greater than 0.018 cm.

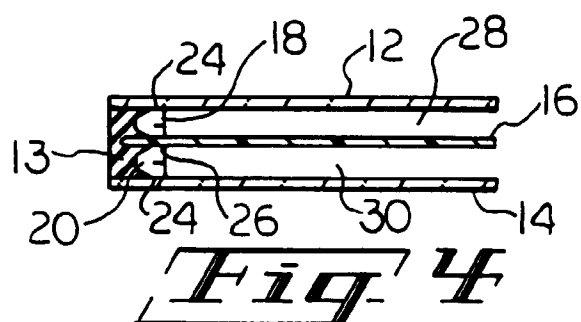
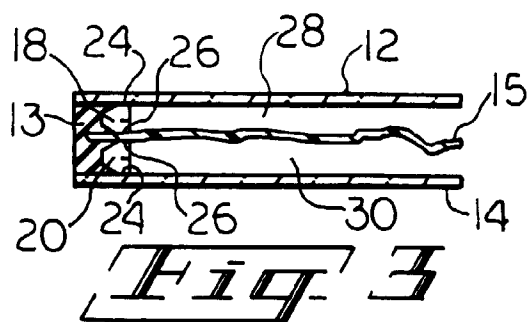
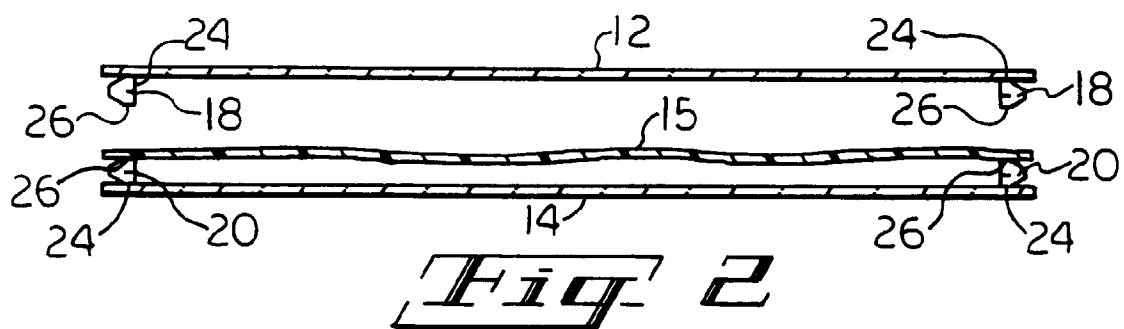
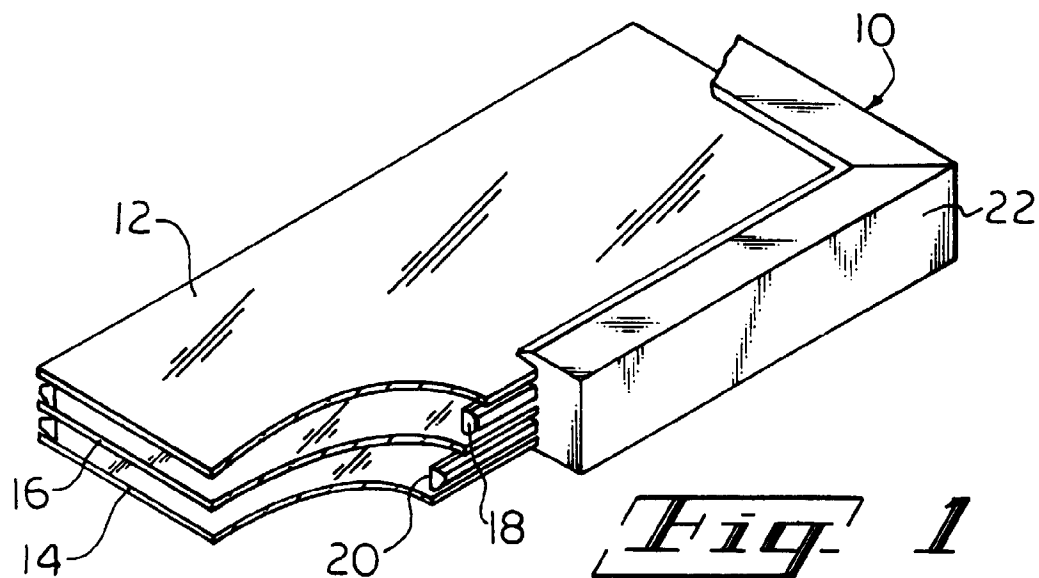
3. The method of claim 2 in which said silicone sealant (13) does not contain a plasticizer or a bond rearranging ingredient or both a plasticizer and a bond rearranging ingredient that remain active after the sealant has cured.

4. A multiple-pane window unit (10) comprising at least one flexible, heat-shrunk plastic sheet between parallel, spaced apart panes (12 and 14), each sheet being substantially parallel to, but spaced apart from, confronting surfaces of the panes or another plastic sheet (15), and being fixed at its edges with respect to edges of the panes, a cured silicone edge sealant (13) between adjacent edges of the panes to provide an integral sealed insulating unit, at least two opposing edges of the unit having each plastic sheet embedded into said silicone edge sealant, where said silicone edge sealant exhibits a sheet creep of less than 0.018 cm after 500 hours at 71°C.

5. The multiple-pane window unit (10) of claim 4 in which the silicone edge sealant (13) exhibits a sheet creep of less than 0.018 cm after 1000 hours at 71°C.

6. The multiple-pane window unit (10) of claims 4 or 5 in which the silicone edge sealant (13) exhibits a sheet creep such that each heat-shrunk plastic sheet (16) does not wrinkle or deform to cause optical distortions during usage.

7. The multiple-pane window unit (10) of claim 4 in which spacers (18 and 20) separate the surfaces of each pane (12 and 14) at the periphery of said unit, each spacer having a generally flattened continuous surface lying in a plane parallel to, but spaced apart from, the surface of the pane to which it is attached by a gas barrier sealant (24), and the spacer attached to one pane being congruent to the spacer attached to other panes, supporting between the flattened surfaces of the spacers of at least two opposing edges at least one heat-shrunk plastic film (16) attached to the spacers but spaced apart from the surface of each plastic film, to which it is attached by a gas barrier sealant.



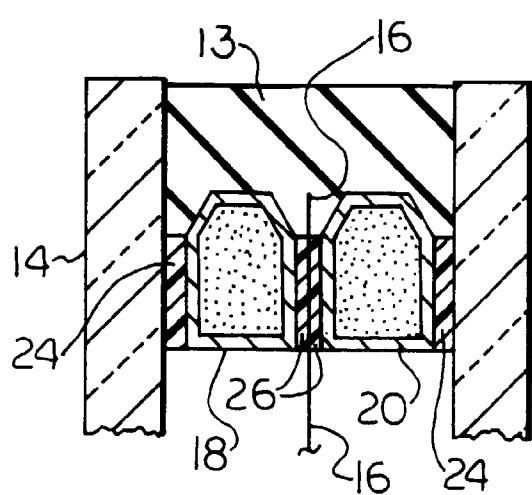


Fig. 5

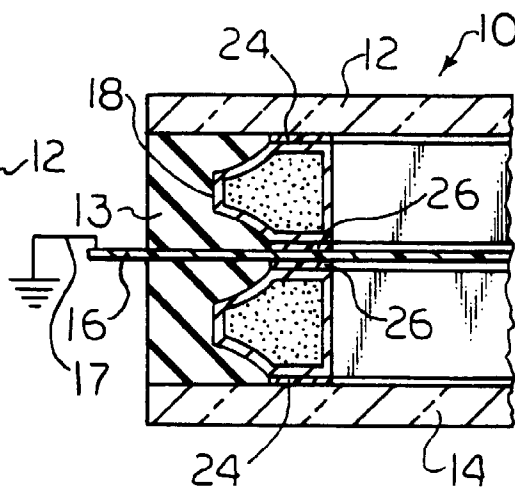


Fig. 6

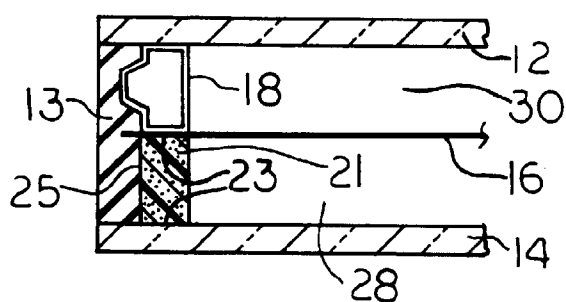


Fig. 7

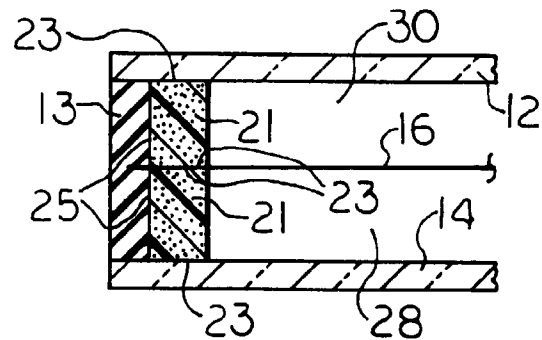


Fig. 8

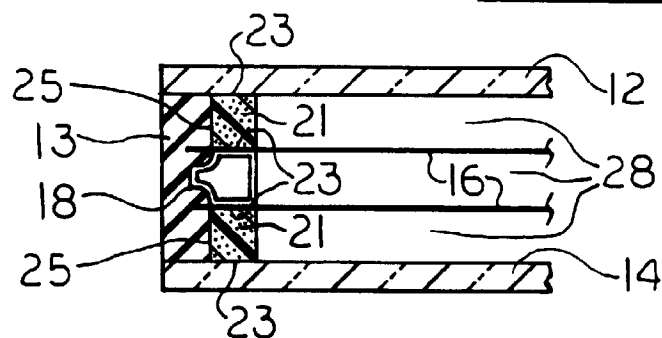
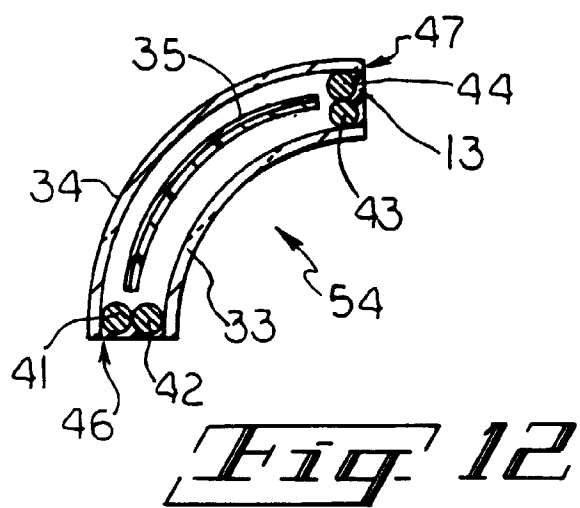
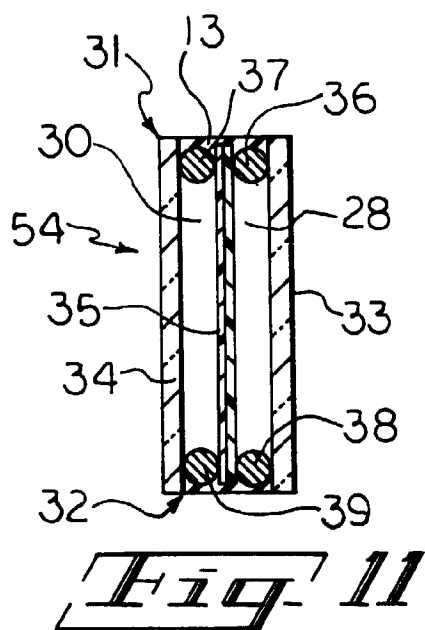
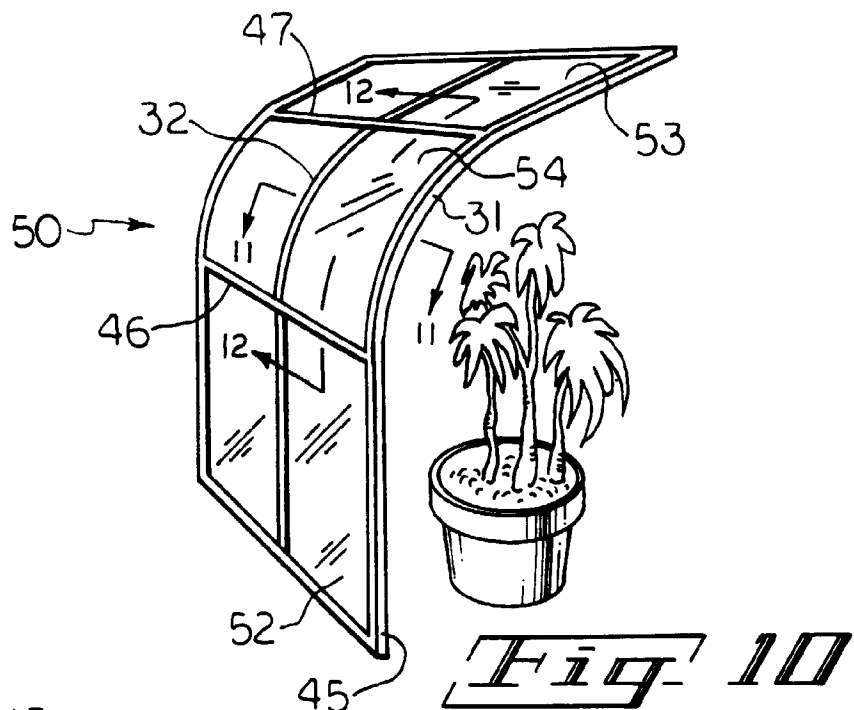


Fig. 9



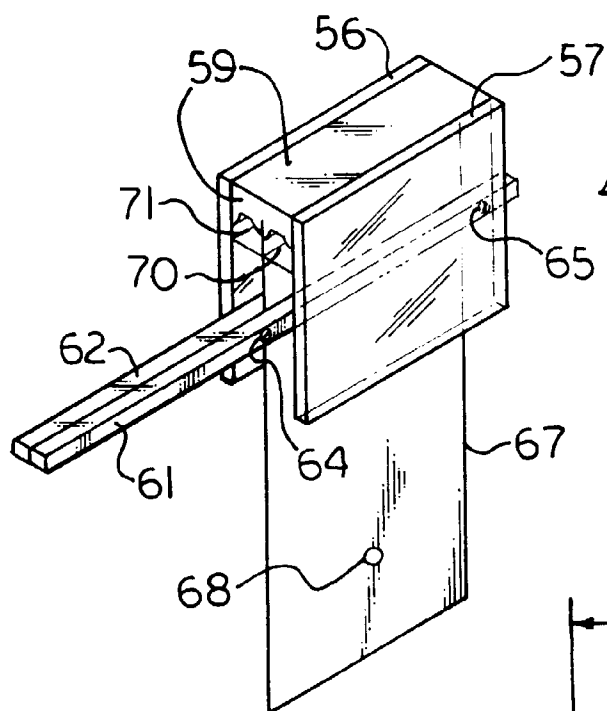


Fig. 13

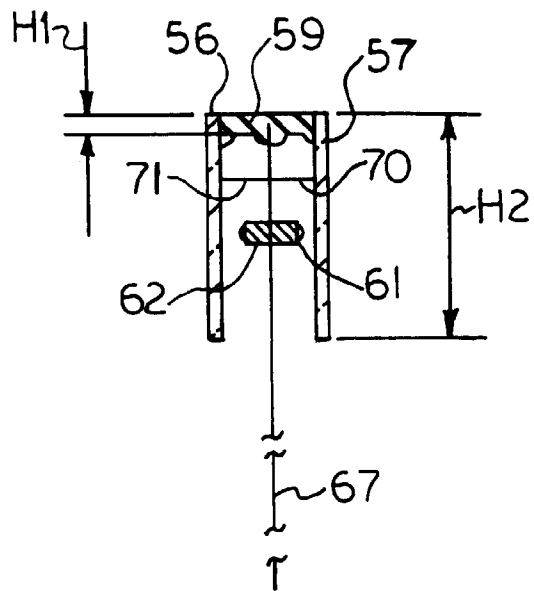


Fig. 14

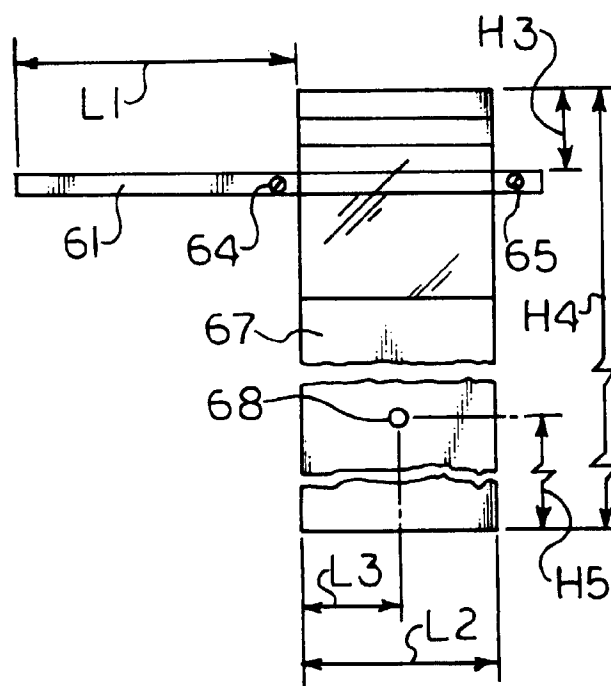


Fig. 15