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"Design Improvements to Vacuum Glazing"

INTRODUCTION

This invention concerns design improvements to vacuum glazing. Vacuum glazing consists of two sheets of glass, hermetically sealed around the edge, with a thermally insulating internal vacuum. In order to maintain the separation of the glass sheets under the influence of the large forces due to atmospheric pressure, an array of very small support pillars is placed over the surface of the glass sheets.

BACKGROUND OF THE INVENTION

The design of vacuum glazing involves a complex set of trade offs between thermal performance and stress. In particular, the support pillars serve to concentrate the forces due to atmospheric pressure, leading to high levels of stress in the glass in the immediate vicinity of the support pillars. Such stresses can lead to local fractures of the glass. Further, the glass sheets bend over the support pillars giving rise to regions of tensile stress on the external surfaces of the glass sheets immediately above the support pillars. In addition, the pillars themselves experience high levels of stress, and must be made out of a material which has a very high compressive strength. Finally, the support pillars themselves act as thermal bridges between the glass sheets, leading to heat flow through the glazing.

Substantial progress has been made in the design and manufacture of vacuum glazing over the last few years. Vacuum glazings up to 1 m x 1 m have been produced with high levels of thermal insulation. It has been shown that reasonable design compromises can be achieved between the competing constraints

associated with mechanical tensile stress on the one hand, and heat flow through the glazing on the other.

1. SHEAR STRESSES NEAR THE SUPPORT PILLARS

The support pillars concentrate the forces due to atmospheric pressure leading to high stresses in the glass and in the pillars. The nature of this stress concentration is well understood. The probability of fracture due to the concentrated forces can be determined by reference to the literature on indentation fracture of glass. In the design approach for vacuum glazing, dimensions of the pillar array are chosen to ensure that the formation of classical conical indentation fractures in the glass due to the support pillars should not occur.

Experience with the production of vacuum glazing has shown that there is another mode of fracture which can occur in the glass sheets near the support pillars. These fractures arise because of shear (sideways) stresses between the glass sheets and the pillars. The shear stresses are associated with in-plane movement of one glass sheet relative to another. Such movement can occur because of bending of the glass sheets, particularly complex bending modes in which the sheets are not deformed spherically, or because of temperature non-uniformities in either glass sheet. Either influence tends to cause the interface between the pillar and one glass sheet to move sideways relative to this interface on the other sheet. The large axial force between the pillars and the glass sheets prevents the contacting surfaces from moving relative to each other. This results in shear force between the support pillar and the glass sheets and leads to small crescent shaped fractures in the glass sheets adjacent to the pillars. The fact that these fractures are associated with shear stress can be confirmed by

observing that they tend to be seen in pairs, on opposite edges of the support pillars in either glass sheet.

One of the reasons why these shear stresses occur is because, in practical designs of vacuum glazing, the support pillars must be made of material of very high compressive strength. If the pillars are not of high enough compressive strength, they deform inelastically during the establishment of the vacuum in the glazing, leading to large bending of the glass sheets in the vicinity of the edge seal. The fact that the support pillars are of high strength means that they do not deform significantly when shear forces are present.

1a: SUMMARY OF THE INVENTION

According to a first aspect, as currently envisaged, the invention provides vacuum glazing comprising two sheets of glass, hermetically sealed around the edge, with a thermally insulating internal vacuum, and an array of support pillars placed between the glass sheets, wherein the pillars consist of a core, made of a material of high compressive strength, with at least one end covered by a layer of softer material. A pillar of this construction can have a very high compressive strength overall, provided that the layer of soft material on the end of the pillar is relatively thin. However, under shear, the soft material can deform, permitting a small amount of lateral sideways movement. This reduces the magnitude of the stress in the glass plates, and thus decreases the chance of formation of a shear crack.

The dimensions of the support pillars are relatively non-critical. Typically, support pillars are 0.1 to 0.2 mm in height overall, and approximately 0.2 to 0.3 mm in diameter. The layer of soft material on one or both ends of the pillar can be up to 30 μm (0.03 mm) thick without causing stresses near the edge of the



glazing which are too large. The materials of the pillars and the soft layers must be capable of withstanding the high temperature (about 500°C) which is necessary for formation of the edge seal without excessive oxidation or annealing. They must also be compatible
5 with the high internal vacuum. Suitable materials to use as the soft material include metals, such as nickel, iron, chromium, copper, silver, gold, aluminium, and alloys of these materials. In addition, soft films of carbon can be used.

One method to produce support pillars with a soft layer on
10 one, or both ends is to begin with a composite sheet of material consisting of a high strength central layer, and a soft layer on one, or both sides. The pillars are then formed from this sheet by conventional techniques. The pillars can be made mechanically, by stamping, punching, abrading or sawing the composite sheet.
15 Alternatively they can be chemically or electrolytically etched from the sheet using photolithographic methods.

An alternative way of producing the pillars is to deposit the soft layer after the formation of the hard cores. The layer can be deposited using conventional electrolytic, or electroless plating
20 methods. In this case, the soft layer also coats the sides of the pillars, but this does not affect the operation of the soft layer on the ends. Pillars of this type can also be made by plastically deforming a hard core into a flat disk. The core may be coated with soft material either before, or after the deformation process.

25 A further advantage of the composite pillar construction described here is that it ensures that the ends of the pillars contact the glass uniformly over the entire area of the pillar. There is some evidence that very hard pillars do not contact the glass uniformly and that this increases the local stresses in the glass, thus
30 increasing the chance of fracture. The small deformation that



occurs in the soft material on the end of the pillars overcomes this problem.

1b. SUMMARY OF THE INVENTION

According to another aspect, as currently envisaged, the invention provides vacuum glazing comprising two sheets of glass, hermetically sealed around the edge, with a thermally insulating vacuum, and an array of support pillars placed between the glass sheets, wherein the array includes a small number of fused solder glass pillars located over the surface of the glazing, between pillars of higher compressive strength, such as ceramic or high strength metal. The fused solder glass pillars may be formed during the same process that makes the hermetic solder glass edge seal around the periphery of the glass sheets. The solder glass pillars make a strong mechanical bond to the internal surfaces of both glass sheets. When shear is present in the vacuum glazing, the solder glass pillars can absorb the shear forces, reducing the magnitude of these forces on the majority of the pillars.

The solder glass pillars may be larger than the 0.2 to 0.3 mm diameter typically used for support pillars, to be strong enough to absorb the shear forces. Only a relatively small proportion of the pillars will usually be made from solder glass, otherwise a substantial increase in the thermal conductance of the vacuum glazing will occur due to heat flow through these pillars. Up to about 10% of the pillars can be made from solder glass without resulting in too large an increase in the thermal conductance of the glazing associated with heat flow through the support pillars.

Typical dimensions of the solder glass pillars are up to 2 mm in diameter, although generally these pillars would be smaller than this - no more than 1 mm in diameter. The glass from which the solder glass pillars are made can be highly transparent, so that



these pillars do not result in a substantial degradation of the optical properties of the glazing.

2. DESIGN OF THE SUPPORT PILLARS

A typical vacuum glazing contains a large number of mechanical support pillars - approximately 1500 per m². These pillars must be placed on the surface of the glazing using an automated technique. Typical dimensions of the pillars are 0.2 to 0.3 mm in diameter, and 0.1 to 0.2 mm high. Satisfactory vacuum glazing requires that the height of all the support pillars should be very nearly the same. If this is not the case, substantial stresses occur in the glass sheets of the glazing near the contact of those pillars which are slightly higher than the adjacent pillars. Vacuum glazing has been made with pillars having round ends (cylinders) or square ends (square or rectangular prisms).

During the manufacture of vacuum glazing, it is extremely important that all pillars should lie on the surface of the glass in the same orientation. For example, for cylindrical pillars, the flat end faces of the pillars must contact the glass with the axis of the pillar perpendicular to the glass. If a pillar should lie on the glass on its edge, the height of this pillar will be different than its neighbours, and large stresses will develop in the glass sheets when the vacuum is applied. It is therefore very important that all of the pillars should lie on the surface of the glass sheet in the orientation for which they are designed.

2. SUMMARY OF THE INVENTION

According to another aspect, as currently envisaged, the invention provides a support pillar for vacuum glazing, comprising two flat parallel ends shaped to provide stable equilibrium, and sides shaped to provide unstable equilibrium, to ensure that the pillars

when placed on a glass sheet will fall onto one of the flat faces and thereafter lie on that face. The sides can be curved outwards in a cuspodial shape, or tapered outwards. The cuspodial or tapered shape can be symmetric with respect to both sides of the pillars, or
5 asymmetric, with one face of the pillar larger than the other.

The pillars may have circular cross-section; alternatively the pillars may have other cross-sectional shapes including squares, rectangles, polygons or irregular shapes.

This aspect of the invention also incorporates vacuum
10 glazing comprising two sheets of glass, hermetically sealed around the edge, with a thermally insulating internal vacuum, and an array of support pillars placed between the glass sheets, wherein the support pillars each comprise two flat parallel ends shaped to provide stable equilibrium, and sides shaped to provide unstable
15 equilibrium, to ensure that the pillars when placed on a glass sheet will fall onto one of the flat faces and thereafter lie on that face.

3. VACUUM GLAZING STRUCTURE

The manufacture of vacuum glazing requires that the temperature of the glass sheets forming the glazing be held at a
20 high value whilst the solder glass edge seal is formed. This process essentially prevents the use of heat tempered glass for the manufacture of glazing, because the high temperature edge forming process removes most of the temper from the glass. It is also not possible to use conventional laminated glass for the glazing because
25 the temperatures required for formation of the edge seal cause the plastic adhesive in laminated glass to deteriorate.

3. SUMMARY OF THE INVENTION

According to another aspect, as currently envisaged, the invention provides vacuum glazing comprising two sheets of glass,

hermetically sealed around the edge, with a thermally insulating internal vacuum, and an array of support pillars placed between the glass sheets, wherein at least one of the sheets of glass is laminated after the vacuum glazing has been manufactured.

5 According to a further aspect, as currently envisaged, the invention provides a method of manufacturing vacuum glazing, comprising the steps of:

 holding the glass sheets at a high temperature while a solder glass edge seal is formed; and

10 subsequently laminating at least one of the glass sheets with a further sheet of glass.

 This procedure may consist of placing a layer of plastic material on one surface of the glazing, and then locating the further glass sheet above this material. The entire assembly is forced
15 together, and then heated to a temperature at which the plastic material softens and bonds to both sheets. The lamination may be performed on one side of the glazing only, or on both sides, as desired. This method of manufacture overcomes the problems associated with the inability of the laminated glass to withstand the
20 high temperature edge sealing process. The vacuum glazing itself is, however, quite capable of withstanding the relatively low temperatures associated with the formation of the bonding between the glass sheets during the laminating process.

BRIEF DESCRIPTION OF DRAWINGS

25 The invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

 figure 1a is a perspective view of conventional vacuum glazing, and figure 1b is a cross-sectional view of the glazing of figure 1a;

figure 2 is a scratch-section illustrating the formation of crescent cracks due to shear forces;

figure 3 is a scratch-section illustrating a first aspect of the present invention;

5 figure 4 illustrates a method of making a composite pillar for the first aspect of the present invention, from a laminated sheet of high strength material and soft material;

figure 5 illustrates a method of making a composite pillar for a first aspect of the present invention, from an individual high
10 strength core;

figure 6a, b, c and d illustrates examples of the design of support pillars embodying a further aspect of the present invention; and

figure 7a, b and c illustrates steps in the manufacture of a
15 laminated vacuum glazing.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to figure 1 vacuum glazing 1 comprises two sheets of glass 2 and 3, hermetically sealed around the edge with a solder glass seal 4 to enclose a vacuum. An array of support pillars
20 5 placed between the glass sheets maintains their separation against the large forces due to atmospheric pressure. Internal transparent low emittance coatings on one, or both of the glass sheets, may be used to reduce radiative heat transport to low levels.

25 The vacuum will often be established after formation of the structure by pumping atmosphere from between the sheets out through a pump-out tube 6. Pump-out tube 6 will be sealed into a hole in glass sheet 2 by the use of a solder glass seal 7. A cavity 8 is machined into the other glass sheet 3 in registration with the end
30 of the pump-out tube in order to accommodate it in a small place

provided between the sheets of glass. A second cavity 9 machined into the outer face of the first glass sheet 2 accommodates the external stump of the pump-out tube 6 after it has been tipped-off and closed, following its use to evacuate the panel.

5 Sideways, or shear stresses between the glass sheets and the pillars will arise when there are in-plane movements of one glass sheet relative to the other. These movements occur during bending of the glass sheets or as a result of temperature differences between the sheets. As shown in figure 2 this results in shear
10 forces 10 building up between the support pillars and the glass sheets, and to regions of high tensile stress 11. Small crescent shaped cracks 12 can arise and be observed in pairs on opposite edges of the support pillars in either glass sheet.

COMPOSITE PILLARS

15 Referring now to figure 3, the support pillar 5 is of a composite design having a high compressive strength core 13, and soft ends 14. This pillar has a very high compressive strength overall, provided that the layers of soft material on either end are relatively thin. However, under shear the soft material can deform
20 permitting a small amount of lateral sideways movement, and reducing the magnitude of the stress in the glass sheets and decreasing the chance of formation of shear cracks.

The support pillars are usually 0.1 to 0.2 mm in height overall, and approximately 0.2 to 0.3 mm in diameter. Layers of
25 soft material 14 can be up to 30 μm thick without causing stresses near the edge of the glazing which are too large. The materials of the pillars and the soft layers are capable of withstanding about 500°C which is experienced during the formation of the edge seal, without excess of oxidation or annealing. The materials must also
30 be compatible with high internal vacuum, and metals such as nickel,

iron, chromium, copper, silver, gold, aluminium, and alloys of these metals, and in addition soft films of carbon may be used for the soft material 14.

Composite support pillars may be produced, as indicated in
5 figure 4, from a composite sheet of material consisting of a high strength central layer 13 and a soft layer 14 on one or both sides. The pillars 5 are then formed from this sheet by stamping, punching, abrading or sawing, or other mechanical means. Alternatively they may be chemically or electrolytically etched from
10 the sheet using photolithographic methods.

An alternative way of producing pillars is to deposit the soft layer 14 after the formation of the hard cores 13. As shown in figure 5 the layer can be deposited using conventional electrolytic or electrolysis plating methods. In this case, the soft layer also coats
15 the sides of the pillars, but this does not affect the operation of both layers on the ends. Pillars of this type can also be made by plastically deforming a hard core into a flat disk. The core may be coated with soft material either before or after the deformation process.

20 FUSED SOLDER GLASS PILLARS

Some of the pillars 5 may be made of fused solder glass, while the majority of the pillars may be made of a material having a high compressive strength, such as ceramic or high strength metal. The fused solder glass pillars may be formed during the same
25 process that makes the hermetic solder glass edge seal around the periphery of the glass sheets.

The solder glass pillars make a strong mechanical bond to the internal surfaces of both glass sheets. When shear is present in the vacuum glazing, the solder glass pillars can absorb the shear

forces, reducing the magnitude of these forces on the majority of the pillars.

The solder glass pillars are larger than the 0.2 to 0.3 mm diameter typically used for support pillars, to be strong enough to absorb the shear forces. Only a relatively small proportion of the pillars will usually be made from solder glass, otherwise a substantial increase in the thermal conductance of the vacuum glazing will occur due to heat flow through these pillars. Up to about 10% of the pillars are made from solder glass without resulting in too large an increase in the thermal conductance of the glazing associated with heat flow through the support pillars.

The solder glass pillars are up to 2 mm in diameter, although generally these pillars would be smaller than this - no more than 1 mm in diameter. The glass from which the solder glass pillars are made can be highly transparent, so that these pillars do not result in a substantial degradation of the optical properties of the glazing.

DESIGN OF SUPPORT PILLARS

Referring now to figure 6, the support pillars 5 comprising two flat parallel ends 15 and 16 shaped to provide stable equilibrium, and sides 17 shaped to provide unstable equilibrium, to ensure that the pillars when placed on a glass sheet will fall onto one of the flat faces and thereafter lie on that face.

The sides 17 are tapered outwards in figures 6(a) with one end larger than the other. In figure 6(b) the sides taper from both ends in a cuspidal shape. In figure 6(c) the sides are curved and in figure 6(d) the sides are curved from both ends in a cuspidal shape.

VACUUM GLAZING STRUCTURE

In figure 7 the steps in a process of producing a laminated evacuated panel are illustrated. First the evacuated panel is produced as shown in figure 7(a). Then a layer of plastic laminate material 20 is placed on one surface of the glazing. A further glass sheet 21 is located above this material as shown in figure 7(b). The entire assembly is forced together, and then heated to a temperature at which the plastic material 20 softens and bonds to both sheets of glass 2 and 21 as shown in figure 7(c). The laminating process may be performed on one or both sides of the glazing to produce a laminated evacuated panel.

Although this invention has been described with reference to specific embodiments it should be appreciated that it could be embodied in other forms. A glazing structure may incorporate one or more of the improvements according to the aspects of the invention.

THE CLAIMS

1. Vacuum glazing comprising two sheets of glass, hermetically sealed around the edge, with a thermally insulating internal vacuum, and an array of support pillars placed between the glass sheets, wherein the pillars consist of a core, made of a material of higher compressive strength, with at least one end covered by a layer of softer material.
2. Vacuum glazing according to claim 1, wherein the support pillars are 0.1 to 0.2 mm in height, and 0.2 to 0.3 mm in diameter.
3. Vacuum glazing according to claim 1 or 2, wherein the layer of soft material on one or both ends of the pillars is up to 30 μm (0.03 mm) thick.
4. Vacuum glazing according to any preceding claim, wherein the soft material is metal, such as nickel, iron, chromium, copper, silver, gold, aluminium, and alloys of these materials, or a soft film of carbon.
5. Vacuum glazing comprising two sheets of glass, hermetically sealed around the edge, with a thermally insulating vacuum, and an array of support pillars placed between the glass sheets, wherein the array includes a small number of fused solder glass pillars located over the surface of the glazing, between pillars of higher compressive strength.
6. Vacuum glazing according to claim 5, wherein the solder glass pillars are between 0.2 and 2 mm in diameter.
7. Vacuum glazing according to claim 5 or claim 6, wherein up to 10% of the pillars are made from solder glass.
8. A support pillar for vacuum glazing, comprising two flat parallel ends shaped to provide stable equilibrium, and sides shaped to provide unstable equilibrium, to ensure that the pillars



when placed on a glass sheet will fall onto one of the flat faces and thereafter lie on that face.

9. A support pillar according to claim 8, wherein the sides are curved outwards in a cuspidal shape, or tapered
5 outwards.

10. A support pillar according to claim 9, wherein the cuspidal or tapered shape is symmetric with respect to both sides of the pillars.

11. A support pillar according to any one of claims 8 to
10 10, wherein the pillars are circular in cross-section.

12. Vacuum glazing comprising two sheets of glass, hermetically sealed around the edge, with a thermally insulating vacuum, and an array of support pillars placed between the glass sheets, wherein the support pillars each comprise two flat parallel
15 ends shaped to provide stable equilibrium, and sides shaped to provide unstable equilibrium, to ensure that the pillars when placed on a glass sheet will fall onto one of the flat faces and thereafter lie on that face.

13. Vacuum glazing comprising two sheets of glass,
20 hermetically sealed around the edge, with a thermally insulating internal vacuum, and an array of support pillars placed between the glass sheets, wherein one of the sheets of glass is laminated, after the vacuum glazing has been manufactured.

14. A method of manufacturing vacuum glazing,
25 comprising the steps of:

holding the glass sheets at a high temperature while a solder glass edge seal is formed; and

subsequently laminating at least one of the glass sheets with a further sheet of glass.

15. A method according to claim 14, wherein the
30 procedure consists of:



placing a layer of plastic material on one surface of the glazing, and then locating the further glass sheet above this material;

- 5 forcing the entire assembly together; and then heating the assembly to a temperature at which the plastic material softens and bonds to both sheets.

16. A method according to claim 15, wherein the laminating process is performed on both sides of the vacuum glazing.

This Sheet Has Been Replaced

