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(54) **SECURITY INSULATED GLAZING UNIT**

SICHERHEITSISOLIERTE VERGLASUNGSEINHEIT

UNITÉ DE VITRAGE ISOLÉE DE SÉCURITÉ

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Description**FIELD OF THE INVENTION**

[0001] The present invention relates to security insulated glazing units.

BACKGROUND OF THE INVENTION

[0002] The overall terrorist threat to the security of the population has increased over recent years and remains on a sharp upward trajectory. Therefore, there is an increasing demand for a safer environment. Taking this on board, the security glazing industry needs to respond to a demand for large building façade security. In particular, the question arises whether current standards for explosion resistant glazing systems, are still adapted to fulfil the security requirements of the market. The current European standards dedicated to the security glazing resistance against explosion pressure are provided in NBN EN 13541 (European Committee for Standardization EN 13541, April 2012, ICS 13.230; 81.040.20). The pendant International ISO standards are the ISO 16934 with its alternative ISO 16933 (01 July 2007).

[0003] Based on numerical simulations, the current extension rule, NBN EN 1279-5:2005+A2 (European Committee for Standardization EN 1279-5:2005+A2, May 2010 - ICS 81.040.20), applies to the specific case of the explosion resistance of insulating glazing units. Indeed, most commonly used windows to provide thermal insulation in buildings, are insulated glazing units (IGUs) wherein a first glass pane and a second glass pane are held apart by a spacer and a wherein secondary seal typically surrounds the spacer.

[0004] While dealing with explosion-resistant security glazing for building applications, the European standard to fulfil is EN 13541. The glazing is assumed to be resistant against a given blast wave if the glazing does not have any "through" holes, from the front to the back. The procedure for certification requires the definition of an attack face. This is the face of the explosion pressure resistant glazing, marked by the manufacturer and/or supplier, as designed to face the explosive blast.

[0005] The specific case of insulated glazing unit (IGU) comprising a first pane and a second pane separated by a spacer maintaining a certain distance between the panes, is dealt within the extension rules described within EN 1279-5. Such European norm states that, if an explosion resistant glass component certified according to EN 13541 is used as the non-attack face of an IGU, then there is no need to test further the insulating glazing unit. The classification of the entire insulating glazing unit shall be considered as the same as the classification granted to the single glass pane which fulfils the requirements of the EN 13541 norm individually.

[0006] However, it has been surprisingly found that this might not be the case in real life practice. Indeed, such extension of the EN norm may lead to an over-estimation of the security performance of the IGU. Actually, it can happen that the two panes of the IGU enter in contact under the pressure of the blast wave. If the resulting shock is substantial, the pane facing the blast wave may deform, touch and cause cracks formation eventually up to the fracture pointbreak of the second pane of the IGU. In such instance, the IGU in its globality, does not pass the testing criteria, to be classified according to EN 13541, even if it should, according to the extension norm EN 1279-5.

[0007] Moreover, natural illumination of interior spaces, especially buildings, is a critical parameter for creating pleasant and healthy environment for people. The daylight is the most interesting source of such illumination and it is important to have some transparent parts in building envelopes, to bring this light to the interior of the building. Therefore, there is a trend in the market to increase the size of the windows and transparent doors while requesting high-performance insulation. Consequently, there is a demand to increase the size of insulated glazing units. However, the European Norm EN 13541 requires an 1100x900 mm size for the tested glazing, which is well below the larger market size. Similarly, the International standard requires as well the test to be run on small sizes. It has been found however, that the glazing blast response is truly dependent on its size: for a given glass composition and structure, the larger the size, the weaker is the resistance to a given blast wave.

[0008] EP 1 828 530B discloses an improved window pane, attenuating the effect of a pressure or shock wave after an explosion in the manner of an insulating pane, which can be provided with retention safety elements and which can be manufactured simply and economically. According to the disclosure, a flexible, elongated safety element, for example in the form of a metal cable or wire, is placed in the edge groove of the window pane, at least one end of the safety element being fed out of the edge groove and thus emerging beyond the outer dimensions of the window pane. The window pane is therefore captured with the aid of its safety element, which is attached to an element of sash or of building by its end fed out of the edge groove, and is prevented from making an uncontrolled movement.

[0009] However, the prior art does not recognize nor address the technical problem of configuring an insulated glazing unit, especially of a larger size, that meets the security requirements and resist to blast wave of overpressures comprised between 100 and 250 kPa.

[0010] DE202008005366U1 discloses an insulating glazing unit configured for resisting to an overpressure of a blast wave.

SUMMARY OF THE INVENTION

[0011] The present invention relates to an insulating glazing unit configured for resisting to an overpressure of a blast wave, Pr, comprised between 100 kPa and 250 kPa. The IGU extends along a plane, P, defined by a longitudinal axis, X, and a vertical axis, Z, having a width, W, measured along the longitudinal axis, X, and a length, L, measured along the vertical axis, Z, wherein the length, L, is equal to or greater than the width, W. The IGU comprises a first glass pane facing the blast wave, a second glass pane and a spacer, maintaining a distance, D, between the first glass pane and the second glass pane. The IGU of the present invention is characterized in that the length, L, is equal to or greater than 1.5 m and the width, W, is equal to or greater than 1.5 m; and in that the first glass pane has a flexural stiffness, K1, equal to or greater than a minimal flexural stiffness, Kmin, ($K1 \geq Kmin$) :

$$Kmin = \frac{2 E f^3}{3 (1-\nu^2)} \text{ (Nm) Equation (A)}$$

wherein E is the Young modulus of glass and equals to $70 \cdot 10^9$ Pa ; ν is the Poisson's ratio of glass and equals to 0.22 ; and f is the following Function:

$$f = \alpha_0 + \alpha_1 L + \alpha_2 W + \alpha_3 Pr + \alpha_4 (L - L_0)^2 + \alpha_5 (W - W_0)^2 + \alpha_6 (Pr - Pr_0)^2 + \alpha_7 (W - W_0)^3 + \alpha_8 (L - L_0)(Pr - Pr_0) + \alpha_9 (W - W_0)(Pr - Pr_0) + \alpha_{10} (W - W_0)^2 (Pr - Pr_0) + \alpha_{11} (W - W_0)(Pr - Pr_0)^2 \text{ Function (f)}$$

wherein L is the length of insulating glazing unit;
wherein W is the width of the insulating glazing unit; and
wherein the parameters to be used in Function f, are:

α_0	-89.88E-3	m
α_1	8.09E-03	/
α_2	1.27E-02	/
α_3	6.27E-07	m/Pa
α_4	-1.58E-03	m^{-1}
α_5	-5.45E-03	m^{-1}
α_6	3.97E-12	m/Pa^2
α_7	-1.14E-11	Pa^{-1}
α_8	5.28E+1	m^{-2}
α_9	2.71E-07	Pa^{-1}
α_{10}	-1.43E-07	$m^{-1}Pa^{-1}$
α_{11}	3.54E-12	Pa^{-2}
L_0	3,468.75E-3	m
W_0	2,25E-3	m
Pr_0	148.44E+3	Pa

[0012] According to the invention, the minimal flexural stiffness, Kmin, prevents the contact between the first glass pane and the second glass pane under the overpressure of the blast wave, Pr.

[0013] Other aspects and advantages of the embodiments will become apparent from the following detailed description taken in conjunction with the accompanying drawings which illustrate, by way of example, the principles of the described embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Figure 1 shows a cross sectional view of an insulated glazing unit according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0015] The object of the present invention is to provide an insulated glazing unit (hereinafter referred to as IGU) configured for resisting to an overpressure of a blast wave, P_r , comprised between 100 kPa and 250 kPa ($100 \text{ kPa} \leq P_r \leq 250 \text{ kPa}$).

[0016] It has been surprisingly found that for an IGU of a minimal size of 1.5 m x 1.5 m, to resist to an overpressure of a blast wave, P_r , comprised between 100 kPa and 250 kPa, such an IGU must be designed such that the first pane facing the blast wave demonstrates a minimal flexural stiffness preventing the contact between the first pane and the second pane of the IGU and thereby avoiding the formation of cracks eventually up to the fracture point of the second glass pane. Flexural stiffness is defined as the force couple required to bend a non-rigid structure in one unit of curvature or as the resistance offered by a structure while undergoing bending.

[0017] As illustrated in Figure 1, the IGU (10) comprises a first glass pane (1) and a second glass pane (2) and a spacer (3) maintaining a distance, D , between the first and second glass panes defining an internal volume, V . In a preferred embodiment, the distance, D , is equal to or greater than 6 mm ($D \geq 6 \text{ mm}$), preferably equal to or greater than 9 mm ($D \geq 9 \text{ mm}$). In another preferred embodiment, the distance, D , is equal to or lower than 25 mm ($D \leq 25 \text{ mm}$), preferably equal to or lower than 20 mm ($D \leq 20 \text{ mm}$), more preferably equal to or lower than 15 mm ($D \leq 15 \text{ mm}$). Hence, the distance D is typically comprised between 6 mm and 25 mm ($6 \text{ mm} \leq D \leq 25 \text{ mm}$), preferably between 9 mm and 20 mm ($9 \text{ mm} \leq D \leq 20 \text{ mm}$), more preferably between 9 mm and 15 mm ($9 \text{ mm} \leq D \leq 15 \text{ mm}$).

[0018] The IGU extends along a plane, P , defined by a longitudinal axis, X , and a vertical axis, Z . It has a width, W , measured along the longitudinal axis, X , and a length, L , measured along the vertical axis, Z , wherein the length, L is equal to or greater than the width, W ($L \geq W$). The length, L , of the IGU of the present invention is equal to or greater than 1.5 m ($L \geq 1.5 \text{ m}$), preferably equal to or greater than 2 m ($L \geq 2 \text{ m}$). The width, W , of the IGU of the present invention is equal or greater than 1.5 m ($W \geq 1.5 \text{ m}$), preferably equal to or greater than 2 m ($W \geq 2 \text{ m}$). Typical windows' surfaces for building applications, reach 3 to 6 m².

FIRST PANE

[0019] As known to persons skilled in the art, elastic materials such as glass, are generally characterized by a Young's modulus, E , and a Poisson's ratio, ν . The young's modulus is a measure of the rigidity whereby larger values indicate glasses that will hardly deform under applied stress. The Poisson's ratio measures the Poisson effect, being a phenomenon whereby glass tend to expand in directions perpendicular to the direction of compression.

[0020] In order to prevent contact between the first glass pane and the second glass pane under the overpressure of the blast wave, the first glass pane of the IGU of the present invention has a flexural stiffness, K_1 , equal to or greater than the minimal flexural stiffness, K_{min} , ($K_1 \geq K_{min}$) expressed in Nm and calculated as per equation (A) below.

$$K_{min} = \frac{2 E f^3}{3 (1-\nu^2)} \quad \text{Equation (A)}$$

wherein E is the Young modulus of glass and equals to $70 \cdot 10^9 \text{ Pa}$;

wherein ν is the Poisson's ratio of glass and equals to 0.22 ; and

wherein f is the following function:

$$f = \alpha_0 + \alpha_1 L + \alpha_2 W + \alpha_3 P_r + \alpha_4 (L - L_0)^2 + \alpha_5 (W - W_0)^2 + \alpha_6 (P_r - P_{r0})^2 + \alpha_7 (W - W_0)^3 + \alpha_8 (L - L_0)(P_r - P_{r0}) + \alpha_9 (W - W_0)(P_r - P_{r0}) + \alpha_{10} (W - W_0)^2 (P_r - P_{r0}) + \alpha_{11} (W - W_0)(P_r - P_{r0})^2 \quad \text{Function (f)}$$

wherein L is the length of insulating glazing unit;

wherein W , is the width of the insulating glazing unit;

wherein P_r is the overpressure of the reflected blast wave and is comprised between 100 kPa and 250 kPa, and

wherein the parameters to be used to calculate function f , are listed in Table 1 below.

Table 1- Values and units of the parameters within the function, f.

α_0	-89.88E-3	m
α_1	8.09E-03	/
α_2	1.27E-02	/
α_3	6.27E-07	m/Pa
α_4	-1.58E-03	m^{-1}
α_5	-5.45E-03	m^{-1}
α_6	3.97E-12	m/Pa ²
α_7	-1.14E-11	Pa ⁻¹
α_8	5.28E+1	m^{-2}
α_9	2.71E-07	Pa ⁻¹
α_{10}	-1.43E-07	$m^{-1}Pa^{-1}$
α_{11}	3.54E-12	Pa ⁻²
L_0	3,468.75E-3	m
W_0	2,25E-3	m
Pr_0	148.44E+3	Pa

[0021] It has been surprisingly found that for an insulated glazing unit to resist in its entirety to an explosion overpressure, Pr , comprised between 100 kPa and 250 kPa, it is needed that the pane facing the blast wave has a certain flexural stiffness, K , equal to or greater than a minimal flexural stiffness, K_{min} , calculated as per above equation (A) which depends on the force of the blast wave and the size of the IGU. It has been found that such flexural stiffness of the pane facing the blast wave is required to avoid said pane to touch the other pane and cause cracks up to the fracture point break of the other pane of the IGU.

Table 2 illustrates the minimal flexural stiffness, K_{min} that needs to be met by the first glass pane facing the blast wave, at specific overpressures.

	Example 1	Example 2	Example 3
IGU			
Length of the IGU, L	1.5 m	2 m	4 m
Width of the IGU, W	1.5 m	2 m	2 m
Overpressure, Pr	$Pr = 100$ kPa	$Pr = 150$ kPa	$Pr = 200$ kPa
First pane			
Minimal flexural stiffness, K_{min} Equation (A)	$5.90 \cdot 10^4$ Nm	$4.39 \cdot 10^5$ Nm	$5.67 \cdot 10^6$ Nm

[0022] As illustrated in Table 2, for an IGU having a size of 1.5 m x 1.5 m, to resist to a blastwave of overpressure of 100 kPa, the first glass pane facing the blast wave must demonstrate a flexural stiffness, K_1 , equal to or greater than $5.90 \cdot 10^4$ Nm (= K_{min}). For an IGU having a size of 2 m x 2 m, to resist to a blastwave of overpressure of 150 kPa, the first glass pane facing the blast wave must demonstrate a flexural stiffness, K_1 , equal to or greater than $4.39 \cdot 10^5$ Nm (= K_{min}). For an IGU having a size of 4 m x 2 m, to resist to a blastwave of overpressure of 200 kPa, the first glass pane facing the blast wave must demonstrate a flexural stiffness, K_1 , equal to or greater than $5.67 \cdot 10^6$ Nm (= K_{min}).

[0023] For the first glass pane to achieve the required flexural stiffness, the glass pane of the IGU of the present invention may be a single monolithic pane or form a laminated assembly.

[0024] Within the IGU, the first glass pane has an inner pane face (12) and an outer pane face (13). The second glass pane has an inner pane face (22) and an outer pane face (23), as shown in figure 1. The inner pane faces are facing the internal volume, V, of the IGU. The outer pane faces are facing the exterior of the IGU.

[0025] In a preferred embodiment, the outer pane face of the first pane of the IGU of the present invention is further laminated to at least one glass sheet (4) by at least one polymer interlayer (5) forming a laminated assembly, as shown in figure 1. Indeed, the polymer interlayer used in the laminate assembly of the present invention provides the following

contribution to the security of the IGU of the present invention: firstly, the polymer interlayer distributes impact forces across a greater area of the panes, thus increasing the impact resistance of the pane. Secondly, the polymer interlayer binds the resulting shards if the glass is ultimately broken. Thirdly, the polymer interlayer undergoes plastic deformation during impact and under static loads after impact, absorbing energy and reducing penetration by the impacting object as well as reducing the energy of the impact that is transmitted to impacting object.

Calculation of the flexural stiffness

[0026] The flexural stiffness of the first glass pane, K1, can be calculated based on its Young modulus, E, expressed in Pa; on its Poisson's Ratio, v, and its thickness, h, in m, as per the equation (B) below and is expressed in Nm:

$$K1 = \frac{E(h_{ef1})^3}{12(1-v^2)} \quad \text{Equation (B1)}$$

wherein E is the Young modulus of glass and equals to $70 \cdot 10^9$ Pa ;
wherein v is the Poisson's ratio of glass and equals to 0.22 ; and
wherein hef1 is the thickness of the first glass pane.

[0027] In the embodiment of the present invention wherein the first glass pane is a single monolithic glass pane, then the effective thickness of such pane, hef1, is simply the thickness of the pane measured in the direction normal to the plane, P. In the preferred embodiment of the present invention wherein the first glass pane forms a laminated assembly, then the effective thickness, hef1, is calculated as per Equation (B1).

[0028] Calderone, I & Davies, P.S. & Bennison, S.J. & Xiaokun, Han & Gang, L. (2009), "Effective laminate thickness for the design of laminated glass", Glass. Performance Days 2009. 1-5; on page 2, provides a method of calculating the effective thickness, hef1, of a laminated assembly.

[0029] The first step is to calculate the shear transfer coefficient, Γ , between the several glass panes and polymer interlayer(s) forming the laminated assembly. The shear transfer coefficient, Γ , is a measure of the transfer of shear stresses across the laminated assembly. The shear coupling depends primarily on the polymer interlayer shear storage modulus, G, glass properties, the laminate geometry and the length scale, as per formula below (1):

$$\Gamma = \frac{1}{1 + 9.6 \frac{EI_s h_v}{G h_s^2 a^2}} \quad (1)$$

With

$$I_s = h_1 h_{s,z}^2 + h_z h_{s,1}^2 \quad (2)$$

$$h_{s,1} = \frac{h_s h_1}{h_1 + h_z} \quad (3)$$

$$h_{s,z} = \frac{h_s h_z}{h_1 + h_z} \quad (4)$$

$$h_s = 0.5(h_1 + h_z) + h_v \quad (5)$$

wherein E is the Young modulus of the first glass pane and equals to $70 \cdot 10^9$ Pa ;
wherein G is the polymer interlayer shear storage modulus, measured at a load duration $5 \cdot 10^{-3}$ s and at a temperature of 25°C and expressed in Pa;
wherein a is the length scale (shortest bending direction) and equals to equals to 1 m;
wherein h_1 is the thickness of the first glass pane, expressed in m;
wherein h_z is the thickness of the at least one glass sheet, expressed in m; and

wherein h_v is the thickness of the at least one polymer interlayer, expressed in m.

[0030] All thicknesses are measured in the direction normal to the plane, P.

[0031] The second step is to calculate the effective thickness of the laminated assembly, h_{ef} , provided by formula (6) and expressed in m:

$$h_{ef} = \sqrt[3]{h_1^3 + h_z^3 + 12\Gamma I_s} \quad (6)$$

[0032] The above method teaches how to calculate the effective laminate thickness of a laminated assembly comprising the first glass pane and one glass sheet. For laminated assemblies comprising more than one glass sheets, the calculation method between 2 panes, must be iteratively continued until a unique effective thickness, h_{ef} , has been calculated and all panes and corresponding polymer interlayer(s) have been considered.

[0033] Table 3 illustrates the calculation of the effective thickness of a laminate assembly comprising a first glass pane having a thickness of 15 mm, laminated to a glass sheet having a thickness of 20 mm, by a polyvinyl butyral (PVB) polymer interlayer having a thickness of 0.76mm.

Table 3

Young modulus of glass, E	70 10 ⁹ Pa
Shear modulus of PVB, G	1.17 10 ⁸ Pa
Length scale, a	1 m
Thickness of the first glass pane, h_1	15 10 ⁻³ m
Thickness of the glass sheet, h_z	20 10 ⁻³ m
Thickness of the PVB interlayer, h_v	0.76 10 ⁻³ m
h_s from Formula (5)	1.83 10 ⁻² m
$h_{s,z}$ from Formula (4)	1.04 10 ⁻² m
$h_{s,1}$ from Formula (3)	7.83 10 ⁻³ m
I_s from Formula (2)	2.86 10 ⁻⁶ m ³
Shear transfer coefficient, Γ	0.964
Effective thickness, h_{ef1}	35.42 10 ⁻³ m

[0034] The flexural stiffness of the first glass pane, K1, of the example is then calculated as per equation (B):

Poisson ratio	0.22
Flexural stiffness, K1	2.72 10 ⁵ Nm

[0035] To configure an IGU having a length of 3 m and a width of 2 m and capable of resisting to an overpressure of 100kPa, the minimal flexural stiffness, Kmin, calculated as per equation (A) above, equals to 2.03 10⁵ Nm. The IGU designed as per table 3 above meets the requirement of the present invention in that the flexural stiffness of the first pane, K1, equals to 2.72 10⁵ Nm and is greater than the required minimal flexural stiffness, Kmin, of 2.03 10⁵ Nm. Therefore, such IGU will resist in its entirety to a blast wave of overpressure of 100 kPa.

SECOND PANE

[0036] The IGU of the present invention is configured for resisting to an overpressure of a blast wave, Pr, comprised between 100 kPa and 250 kPa, wherein the first glass pane of the IGU faces said blast wave.

[0037] In a preferred embodiment of the present invention, the second glass has a thickness, h_2 , measured in the direction normal to the plane, P; equal to or greater than 0.006 m ($h_2 \geq 0.006$ m), preferably equal to or greater than 0.008 m ($h_2 \geq 0.008$ m), more preferably equal to or greater than 0.010 m ($h_2 \geq 0.010$ m).

[0038] For an IGU configured for resisting to an overpressure, Pr, of a blast wave equal to or greater than 150 kPa, ($Pr \geq 150$ kPa), is then preferred that the thickness of the second glass pane is equal to or greater than 0.008 m ($h_2 \geq 0.008$ m),

preferably equal to or greater than 0.010 m ($h_2 \geq 0.010$ m). For an IGU configured for resisting to an overpressure, P_r , of a blast wave equal to or greater than 200 kPa, ($P_r \geq 200$ kPa), it is then preferred that the thickness of the second glass pane is equal to or greater than 0.010 m ($h_2 \geq 0.010$ m).

[0039] The second glass pane of the IGU of the present invention may be a single monolithic pane or form a laminated assembly. In a preferred embodiment, the outer pane face of the second pane of the IGU of the present invention is further laminated to at least one glass sheet (4) by at least one polymer interlayer (5) forming a laminated assembly, as shown in figure 1.

[0040] In the embodiment of the present invention wherein the second glass pane is a single monolithic glass pane, then the thickness, h_2 , of such pane is simply measured in the direction normal to the plane, P. In the preferred embodiment of the present invention wherein the second glass pane forms a laminated assembly, then it is the effective laminate thickness, h_{ef} , that needs to be considered. The two-steps procedure to calculate the effective thickness, described above in relation to the laminated assembly of the first glass pane applies herein respectively.

[0041] In a further preferred embodiment of the present invention, the second glass pane of the IGU of the present invention provides a resistance against an explosion pressure of classification ERx, wherein $x = 2, 3$, or 4, as per classification under the European norm NBN EN 13541 (2012) and as defined by the overpressure, P_r , of the blast wave to which the IGU must resist. NBN EN 13541 (2012) in Table 1, paragraph 4 on page 6, classifies indeed explosion-pressure-resistant glazing according to the classification codes ERx according to the maximum overpressure of the reflected blast wave, P_r , as copied below.

Classification, ERx	P_r (kPa)
ER2	$100 \leq P_r < 150$
ER3	$150 \leq P_r < 200$
ER4	$200 \leq P_r < 250$

[0042] It is well known to person skilled in that art how to design glass panes of a specific resistance to explosion ERx as per the European Norm NBN EN 13541 (2012), by forming a laminate assembly of 2 or more glass panes and corresponding polymer layer (s). Examples of such glass panes are illustrated below.

[0043] One example of a suitable ER2 glass pane to be used as the second glass pane of the IGU of the present invention can be made of a soda-lime glass pane of 10 mm, laminated to a soda-lime glass sheet of 12 mm by a polyvinyl butyrate polymer interlayer of 1.52 mm. Another example of a suitable ER2 glass pane to be used as the second glass pane of the IGU of the present invention can be made of a soda-lime thermally tempered glass pane of 8 mm, laminated to a soda-lime thermally tempered glass sheet of 10 mm by a polyvinyl butyrate polymer interlayer of 0.76 mm.

[0044] One example of a suitable ER3 glass pane to be used as the second glass pane of the IGU of the present invention can be made of a soda-lime glass pane of 8 mm, laminated to two soda-lime glass sheets of 8 mm by polyvinyl butyrate polymer interlayers of 3.08 mm, each.

[0045] One example of a suitable ER4 glass pane to be used as the second glass pane of the IGU of the present invention can be made of a soda-lime glass pane of 10 mm, laminated to a first soda-lime glass sheet of 10 mm and to a second soda-lime glass sheet of 12 mm by Sentryglass® ionoplast polymer interlayers of 0.76 mm, each. Sentryglass® ionoplast is a ionomer commercially available from the chemical company DuPont de Nemours.

Table 3 illustrates preferred embodiments of the present invention requiring the flexural stiffness, of the first glass pane and the corresponding resistance to explosion, ERx for the second pane.

	Example 1	Example 2	Example 3
IGU			
Length of the IGU, L	1.5 m	2 m	4 m
Width of the IGU, W	1.5 m	2 m	2 m
Overpressure, P_r	$P_r = 100$ kPa	$P_r = 150$ kPa	$P_r = 200$ kPa
First pane			
Minimal flexural stiffness, Kmin Equation (A)	$5.90 \cdot 10^4$ Nm	$4.39 \cdot 10^5$ Nm	$5.67 \cdot 10^6$ Nm
Second pane			
Required Explosion resistance	ER2	ER3	ER4

[0046] In the preferred embodiments illustrated in Table 3, for an IGU having a size of 1.5 m x 1.5 m, to resist to a blast wave of overpressure of 100 kPa, the first glass pane facing the blast wave must demonstrate a flexural stiffness, equal to or higher than $5.90 \cdot 10^4$ Nm (= Kmin) and the second glass pane must demonstrate a resistance to explosion ER2. For an IGU having a size of 2 m x 2 m, to resist to a blast wave of overpressure of 150 kPa, the first glass pane facing the blast wave must demonstrate a flexural stiffness, equal to or higher than $4.39 \cdot 10^5$ Nm (= Kmin) and the second glass pane must demonstrate a resistance to explosion ER3. For an IGU having a size of 4 m x 2 m, to resist to a blast wave of overpressure of 200 kPa, the first glass pane facing the blast wave must demonstrate a flexural stiffness, equal to or higher than $5.67 \cdot 10^6$ Nm (= Kmin) and the second glass pane must demonstrate a resistance to explosion ER4.

PARTITION

[0047] The IGU of the present invention is typically used to close an opening within a partition such as in general-purpose glazing units, a build wall automotive glazing units or architectural glazing units, appliances... This partition separates an exterior space from an interior space, typically separating the exterior space from the interior space of a building. Depending on the threat and the probability of occurrence of the explosion, the IGU of the present invention will close an opening of a partition separating an exterior space from an interior space, whereby the first glass pane is facing the exterior space for an external threat or whereby the first glass pane is facing the interior space for an internal threat. Unfortunately, it may happen in some circumstances that the external threat and internal threat have the same criticality and therefore, the IGU of the present embodiment could be configured to resist to the overpressure of a blast wave on both first and second glass panes.

[0048] Therefore, in a preferred embodiment of the present invention, the second glass pane of the IGU of the present invention has a flexural stiffness, K2, equal to or greater than the minimal flexural stiffness, Kmin, ($K2 \geq Kmin$) expressed in Nm and calculated as per the above equation (A) and copied herebelow:

$$Kmin = \frac{2 E f^3}{3 (1-v^2)} \quad \text{Equation (A)}$$

[0049] All parameters necessary for the calculation of Kmin per Equation (A) have been described above in relation to the first glass pane and apply correspondingly to the second glass pane.

[0050] The flexural stiffness of the second glass pane, K2, is to be calculated as per the equation described above in relation to the first pane and adapted herebelow:

$$K2 = \frac{E(hef2)^3}{12(1-v^2)} \quad \text{Equation (B2)}$$

wherein E is the Young modulus of glass and equals to $70 \cdot 10^9$ Pa ;
wherein v is the Poisson's ratio of glass and equals to 0.22 ; and
wherein hef2 is the thickness of the second glass pane.

[0051] All parameters necessary for the calculation of K2 per Equation (B2) have been described above in relation to the first glass pane and apply correspondingly to the second glass pane.

[0052] In the embodiment of the present invention wherein the second glass pane is a single monolithic glass pane, then the effective thickness of such pane, hef2, is simply the thickness of the pane measured in the direction normal to the plane, P. In the preferred embodiment of the present invention wherein the second glass pane forms a laminated assembly, then the effective thickness, hef2, is calculated as per Equation (B2).

[0053] All embodiments and preferred technical features of the glass sheet and polymer interlayer described above in relation to the laminated assembly of the first glass pane apply respectively to the laminated assembly of the second glass pane.

[0054] The flexural stiffness of the first glass pane, K1, and the flexural stiffness of the second glass pane, K2, may be different to respond to blast waves of different overpressures. However, in a preferred embodiment of the present invention, for ease of production and placement, the first glass pane and the second glass panes have identical flexural stiffness ($K1 = K2$) and more preferably are identical laminated assemblies, even more preferably positioned in an orthogonal symmetry.

[0055] The present invention also relates to the use of an insulated glazing unit as defined above, to close the opening of a partition separating an exterior space from an interior space, and preferably wherein the first glass pane is facing the exterior space.

[0056] Figure 1 illustrates one preferred embodiment of the present invention wherein the first glass pane (1) has a

thickness (h_1) and is coupled to the second glass pane (2) having a thickness (h_2) via a spacer (3) maintaining a distance, D, between the two glass panes and delimiting a volume, V. The first pane faces the blast wave. A glass sheet (4) having a thickness (h_z) is coupled to the outer face pane (13) first glass pane via a polymer interlayer (5) having a thickness (h_v). Another glass sheet (42) having a thickness (h_{z2}) is coupled to the outer pane face (23) of the second glass pane via a polymer interlayer (52) having a thickness (h_{v2}).

GLASS PANES and SHEETS

[0057] The first and second glass panes of the IGU of the present invention as well as the additional glass sheets within laminated assemblies can be chosen among all flat glass technologies, among them: float clear, extra-clear or colored glass. The term "glass" is herein understood to mean any type of glass or equivalent transparent material, such as a mineral glass. The mineral glasses used may be irrespectively one or more known types of glass such as soda-lime-silica, aluminosilicate or borosilicate, crystalline and polycrystalline glasses. The glass pane can be obtained by a floating process, a drawing process, a rolling process or any other process known to manufacture a glass pane starting from a molten glass composition. The glass panes can optionally be edge-ground. Edge grinding renders sharp edges into smooth edges which are much safer for people who could come in contact with the insulating glazing unit, in particular with the edge of the glazing. Preferably and for reasons of lower production costs, the glass pane according to the invention is a pane of soda-lime-silica glass, aluminosilicate glass or borosilicate glass.

[0058] In some embodiments of the present invention, films such as low emissivity films, solar control films (a heat ray reflection films), anti-reflective films, anti-fog films, preferably a heat ray reflection film or a low emissivity film, can be provided on at least one of the inner pane faces (12, 22) and/or outer pane faces (13, 23) of the first and/or second glass panes (1, 2) of the insulated glazing unit (10).

[0059] In a one embodiment, to improve further the resistance against the overpressure of the blast wave of the IGU, the first and second glass panes of the IGU of the present invention as well as the additional glass sheets within the laminated assembly can be prestressed glass. By prestressed glass, it means a heat strengthened glass, a thermally toughened glass, or a chemically strengthened glass.

[0060] Heat strengthened glass is heat treated using a method of controlled heating and cooling which places the glass surfaces under compression and the core of the glass under tension. This heat treatment method delivers a glass with a bending strength greater than annealed glass but less than thermally toughened safety glass.

[0061] Thermally toughened glass is heat treated using a method of controlled heating and cooling which puts the glass surface under compression and the core glass under tension. Such stresses cause the glass, when impacted, to break into small granular particles instead of splintering into jagged shards. The granular particles are less likely to injure occupants or damage objects.

[0062] The chemical strengthening of a glass article is a heat induced ion-exchange, involving replacement of smaller alkali sodium ions in the surface layer of glass by larger ions, for example alkali potassium ions. Increased surface compression stress occurs in the glass as the larger ions "wedge" into the small sites formerly occupied by the sodium ions. Such a chemical treatment is generally carried out by immersing the glass in an ion-exchange molten bath containing one or more molten salt(s) of the larger ions, with a precise control of temperature and time. Aluminosilicate-type glass compositions, such as for example those from the products range DragonTrail® from Asahi Glass Co. or those from the products range Gorilla® from Corning Inc., are also known to be very efficient for chemical tempering.

[0063] Preferably, the composition for the first and second glass panes and/or the at least one glass sheet comprises the following components in weight percentage, expressed with respect to the total weight of glass (Comp. A). More preferably, the glass composition (Comp. B) is a soda-lime-silicate-type glass with a base glass matrix of the composition comprising the following components in weight percentage, expressed with respect to the total weight of glass.

	Comp. A	Comp. B
SiO ₂	40 - 78%	60 - 78 wt%
Al ₂ O ₃	0 - 18%	0 - 8 wt%, pref 0 - 6 wt%
B ₂ O ₃	0 - 18%	0 - 4 wt%, pref 0 - 1 wt%
Na ₂ O	0-20%	5 - 20 wt%, pref 10-20 wt%
CaO	0 - 15%	0 - 15 wt%, pref 5 - 15 wt%
MgO	0 - 10%	0 - 10 wt%, pref 0 - 8 wt%
K ₂ O	0 - 10%	0 - 10 wt%
BaO	0-5%	0 - 5 wt%, pref 0 - 1 wt%.

[0064] Other preferred glass compositions comprise the following components in weight percentage, expressed with respect to the total weight of glass:

	Comp. C	Comp. D	Comp. E
5	$65 \leq \text{SiO}_2 \leq 78 \text{ wt\%}$	$60 \leq \text{SiO}_2 \leq 78 \%$	$65 \leq \text{SiO}_2 \leq 78 \text{ wt\%}$
	$5 \leq \text{Na}_2\text{O} \leq 20 \text{ wt\%}$	$5 \leq \text{Na}_2\text{O} \leq 20 \%$	$5 \leq \text{Na}_2\text{O} \leq 20 \text{ wt\%}$
	$0 \leq \text{K}_2\text{O} < 5 \text{ wt\%}$	$0.9 < \text{K}_2\text{O} \leq 12 \%$	$1 \leq \text{K}_2\text{O} < 8 \text{ wt\%}$
10	$1 \leq \text{Al}_2\text{O}_3 < 6 \text{ wt\%}$, pref $3 < \text{Al}_2\text{O}_3 \leq 5 \%$	$4.9 \leq \text{Al}_2\text{O}_3 \leq 8 \%$	$1 \leq \text{Al}_2\text{O}_3 < 6 \text{ wt\%}$
	$0 \leq \text{CaO} < 4.5 \text{ wt\%}$	$0.4 < \text{CaO} < 2 \%$	$2 \leq \text{CaO} < 10 \text{ wt\%}$
	$4 \leq \text{MgO} \leq 12 \text{ wt\%}$	$4 < \text{MgO} \leq 12 \%$	$0 \leq \text{MgO} \leq 8 \text{ wt\%}$
15	$(\text{MgO}/(\text{MgO}+\text{CaO})) \geq 0.5$, pref $0.88 \leq [\text{MgO}/(\text{MgO}+\text{CaO})] < 1$.		$\text{K}_2\text{O}/(\text{K}_2\text{O}+\text{Na}_2\text{O}) : 0.1 - 0.7$.

[0065] In particular, examples of base glass matrixes for the composition according to the invention are described published in PCT patent applications WO2015/150207A1, WO2015/150403A1 WO2016/091672 A1, WO2016/169823A1 and WO2018/001965 A1.

[0066] It can be contemplated that the first glass pane, the second glass pane or the at least one glass sheet may be an organic glass such as a polymer or a rigid thermoplastic or thermosetting transparent polymer or copolymer such as, for example, a transparent synthetic polycarbonate, polyester or polyvinyl resin.

25 Laminated assembly description

[0067] The laminated assembly within the IGU of the present invention may typically comprise from 1 to 7 additional glass sheet(s), preferably from 1 to 4 additional glass sheet(s), more preferably from 1 to 2 additional glass sheets and corresponding additional layers of polymer interlayer(s).

30 **[0068]** Said glass sheet has typically a thickness, h_z , comprised between 2 and 30 mm ($2 \text{ mm} \leq h_z \leq 30 \text{ mm}$), preferably comprised between 4 and 25 mm ($4 \text{ mm} \leq h_z \leq 25 \text{ mm}$), more preferably comprised between 4 and 15 mm ($4 \text{ mm} \leq h_z \leq 125 \text{ mm}$), even comprised between 8 and 12 mm ($8 \text{ mm} \leq h_z \leq 12 \text{ mm}$). The thicknesses are measured in the direction normal to the plane, P.

35 **[0069]** The polymer interlayer to be used in the present invention typically comprises a material selected from the group consisting ethylene vinyl acetate (EVA), polyisobutylene (PIB), polyvinyl butyral (PVB), polyurethane (PU), polyvinyl chlorides (PVC), polyesters, copolyesters, polyacetals, cyclo olefin polymers (COP), ionomers and/or an ultraviolet activated adhesive, and others known in the art of manufacturing glass laminates. Blended materials using any compatible combinations of these materials can be suitable as well. In a preferred embodiment, the at least one polymer interlayer comprises a material selected from the group consisting of ethylene vinyl acetate, and/or polyvinyl butyral, more preferably 40 polyvinyl butyral. The polymer interlayer is also designated as a "bonding interlayer" since the polymer interlayer and the glass pane form a bond that results in adhesion between the glass pane and the polymer interlayer

[0070] In a preferred embodiment, the polymer interlayer to be used in the present invention is a transparent or translucent polymer interlayer. However, for decorative applications, the polymer interlayer may be colored or patterned.

45 **[0071]** Typical thicknesses (measured in the direction normal to the plane, P) for the at least one polymer interlayer, h_v , are 0.3 mm to 3.5 mm, preferably 0.75 mm to 1.75 mm. Commercially available polymer interlayers are polyvinyl butyral (PVB) layers of 0.38 mm, 0.76 mm, 1.52 mm, 2.28 mm and 3.04 mm. To achieve the desired thickness, one or more of those layers can be used.

50 **[0072]** To form the laminate assembly within the IGU of the present invention, polyvinyl butyral polymer interlayers are preferably used. Polyvinyl butyral (or PVB) is a resin known for applications that require strong binding, optical clarity, adhesion to many surfaces, toughness and flexibility. It is prepared from polyvinyl alcohol by reaction with butyraldehyde. Trade names for PVB-films include KB PVB, Saflex, GlasNovations, WINLITE, S-Lec, Trosifol and EVERLAM. The bonding process takes place under heat and pressure also designated as autoclave process which is well known in the art. When laminated under these conditions, the PVB interlayer becomes optically clear and binds the two panes of glass together. Once sealed together, the laminate behaves as a single unit and looks like normal glass. The polymer interlayer 55 of PVB is tough and ductile, so brittle cracks will not pass from one side of the laminate to the other.

[0073] Another process known in the art and preferred for the present invention, is the autoclave free laminated glass production. This process reduces energy costs but has the drawback of limiting the types and thickness of polymer interlayer. Autoclave free oven makes preferentially EVA and dedicated PVB laminated glass. In such case, to achieve the

desired thickness and security requirements, one or more of those autoclave free polymer interlayers can be used. Another process to produce a laminated glass is the vacuum bag process.

[0074] In another embodiment, the present invention also applies to multiple glazing units comprising three or more panes, defining bounding insulating or non-insulating internal spaces. In one embodiment, a third additional glass pane can be coupled to the outer pane faces (23) of second glass pane along the periphery of the IGU via another peripheral spacer bar, creating a second internal volume sealed by a peripheral edge seal. Said peripheral spacer bar maintained a certain distance between the third glass pane and the at least one of the outer pane face one of the first and second glass panes.

[0075] Other options, such as heat insulation with low emissivity (low-E) coatings, solar control coatings, anti-reflective coating provided on at least one of the surface of at least one glass pane of the IGU, reinforced acoustic insulation with acoustic laminated glass are also compatible with the present concept to improve the performances of the window or door. Glass panes with electrochromic, thermochromic, photochromic or photovoltaic elements are also compatible with the present invention.

SPACER

[0076] As shown in Figure 1, the insulated glazing unit comprises a spacer (3) maintaining the first glass pane and the second glass pane at a certain distance, D, and defining an internal volume, V, extending between the first and second glass panes from the spacer to the peripheral edges. The spacer has consequently a surrounding shape which spaces apart the glass plates on their periphery. It can be made of one piece or can alternatively comprise a plurality of elements having their extremities abutted to form the surrounding shape. The spacer can be metallic, polymeric, a composite material reinforced by glass fibres or a mix of several of these materials. The spacer can be hollow in order to be able to receive for example some drying material. Such spacer is then perforated to allow the drying material to trap water vapor that is coming in the cavity of the IGU.

[0077] As is usual with insulated glazing, the spacer is inserted between the glass plates generally by means of butyl or silicone adhesive strips. Thereby, forming an encompassing surrounding edge joint, as usual for insulated glazing, which is provided with a cordon of sealant. Thus, the internal volume, V, between the glass plates is sealed with respect to the exterior in a gas and moisture-sealed type manner. Said internal volume is filled with a predetermined gas selected from the group consisting of air, dry air, argon (Ar), krypton (Kr), xenon (Xe), sulfur hexafluoride (SF₆), carbon dioxide or a combination thereof or it can be (partially) evacuated. Said predetermined gas are effective for preventing heat transfer and/or may be used to reduce sound transmission. Use of warm-edge spacers, often made of plastics tightened and/or reinforced with a metallic foil, is preferred to reduce thermal fluxes at the periphery of the insulating glass what is indeed particularly critical for frameless glass casements since the periphery of the glazing is not embedded in a frame.

EXAMPLES

Examples 1 to 3

[0078] Examples 1 to 3 illustrate different embodiments of IGU of the present invention, demonstrating the required resistance to explosion. The value of G, the shear modulus of the PVB interlayer, is $1.17 \cdot 10^8$ Pa.

	Example 1	Example 2	Example 3
Overpressure of the blast wave	Pr = 100 kPa	Pr = 150 kPa	Pr = 200 kPa
Length and width of the IGU	L = 1.5 m W = 1.5 m	L = 2 m W = 1.5 m	L = 1.5 m W = 1.5 m
First Pane			
Minimal flexural stiffness, Equation (A)	Kmin = $6.01 \cdot 10^4$ Nm	Kmin = $2.51 \cdot 10^5$ Nm	Kmin = $7.00 \cdot 10^5$ Nm
First glass pane	soda-lime silica glass h1 = 0.012 m	soda-lime silica glass h1 = 0.022 m	soda-lime silica glass h1 = 0.025 m
Polymer Interlayer	polyvinyl butyral hv = $0.76 \cdot 10^3$ m	polyvinyl butyral $0.76 \cdot 10^{-3}$ m	polyvinyl butyral hv = $1.52 \cdot 10^{-3}$ m

(continued)

First Pane			
Additional glass sheet	soda-lime silica glass $h_z = 0.012$ m	soda-lime silica glass $h_z = 0.022$ m	soda-lime silica glass $h_z = 0.025$ m
h_s from Formula (5)	$1.28 \cdot 10^{-2}$ m	$2.28 \cdot 10^{-2}$ m	$2.65 \cdot 10^{-2}$ m
$h_{s,z}$ from Formula (4)	$6.38 \cdot 10^{-3}$ m	$1.14 \cdot 10^{-2}$ m	$1.33 \cdot 10^{-2}$ m
$h_{s,1}$ from Formula (3)	$6.38 \cdot 10^{-3}$ m	$1.14 \cdot 10^{-2}$ m	$1.33 \cdot 10^{-2}$ m
I_s from Formula (2)	$9.7 \cdot 10^{-7}$ m ³	$5.7 \cdot 10^{-6}$ m ³	$8.79 \cdot 10^{-6}$ m ³
Shear transfer coefficient, Γ	$9.51 \cdot 10^{-1}$	$9.14 \cdot 10^{-1}$	$9.02 \cdot 10^{-2}$
Effective thickness, h_{ef1}	$2.44 \cdot 10^{-3}$ m	$4.38 \cdot 10^{-3}$ m	$5.02 \cdot 10^{-2}$ m
Flexural Stiffness, K_1 Equation (B1)	$K_1 = 8.95 \cdot 10^4$ Nm	$K_1 = 5.14 \cdot 10^5$ Nm	$K_1 = 7.75 \cdot 10^5$ Nm

[0079] The second glass panes described in the tables A and B below may be used with the corresponding first glass panes of examples 1 to 3 above to form the IGUs of the present invention.

Table A - Second glass panes			
	Example 1A	Example 2A	Example 3A
Second glass pane	soda-lime silica glass $h_2 = 0.006$ m	soda-lime silica glass $h_2 = 0.004$ m	soda-lime silica glass $h_2 = 0.006$ m
Polymer Interlayer	/	polyvinyl butyral $h_{v2} = 0.76 \cdot 10^{-3}$ m	polyvinyl butyral $h_{v2} = 0.76 \cdot 10^{-3}$ m
Additional glass sheet	/	soda-lime silica glass $h_{z2} = 0.004$ m	soda-lime silica glass $h_{z2} = 0.006$ m
h_s from Formula (5)	/	$4.76 \cdot 10^{-3}$ m	$6.76 \cdot 10^{-3}$ m
$h_{s,z}$ from Formula (4)	/	$2.38 \cdot 10^{-3}$ m	$3.38 \cdot 10^{-3}$ m
$h_{s,2}$ from Formula (3)	/	$2.38 \cdot 10^{-3}$ m	$3.38 \cdot 10^{-3}$ m
I_s from Formula (2)	/	$4.53 \cdot 10^{-8}$ m ³	$1.37 \cdot 10^{-7}$ m ³
Shear transfer coefficient, Γ	/	$9.91 \cdot 10^{-1}$	$9.87 \cdot 10^{-1}$
Effective thickness, h_{ef1}	/	$8.74 \cdot 10^{-3}$ m	$1.27 \cdot 10^{-2}$ m

Table B - Second glass panes			
	Example1B - ER2	Example2B - ER3	Example3B - ER4
Second glass pane	soda-lime silica glass $h_2 = 0.01$ m	soda-lime silica glass $h_2 = 0.008$ m	soda-lime silica glass $h_2 = 0.01$ m
Polymer Interlayer	polyvinyl butyral $h_{v2} = 1.52 \cdot 10^{-3}$ m $G = 1.17 \cdot 10^8$ Pa	polyvinyl butyral $h_{v2} = 1.52 \cdot 10^{-3}$ m $G = 1.17 \cdot 10^8$ Pa	polyvinyl butyral $h_{v2} = 1.52 \cdot 10^{-3}$ m $G = 1.17 \cdot 10^8$ Pa
Additional glass sheet	soda-lime silica glass $h_{z2} = 0.012$ m	soda-lime silica glass $h_{z2} = 0.008$ m	soda-lime silica glass $h_{z2} = 0.012$ m

Example 4

[0080] Example 4 illustrates one embodiment of an IGU of the present invention, demonstrating the required resistance to explosion of a blast wave of overpressure, P_r , of 150kPa.

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Example 4	
Overpressure of the blast wave	Pr = 150 kPa
Length and width of the IGU	L = 2 m and W = 1.5 m
Minimal flexural stiffness - Equation (A)	Kmin = 2.51 10 ⁵ Nm
First Glass Pane	
First glass pane	soda-lime silica glass, h1 = 0.015 m
Polymer Interlayer	polyvinyl butyral, hv = 0.76 10 ³ m, G = 1.17 10 ⁸ Pa
Additional glass sheet	soda-lime silica glass, hz = 0.015 m
hs from Formula (5)	2.58 10 ⁻² m
hs,z from Formula (4)	7.88 10 ⁻³ m
hs,1 from Formula (3)	7.88 10 ⁻³ m
Is from Formula (2)	1.86 10 ⁻⁶ m
Shear transfer coefficient, Γ	9.68 10 ⁻¹
Effective thickness, hef1	30.51 10 ⁻³ m
Second Polymer Interlayer	polyvinyl butyral, hv = 7.6 10 ⁻³ m
Second additional glass sheet	soda-lime silica glass, hz = 0.015 m
hs from Formula (5)	2.35 10 ⁻² m
hs,z from Formula (4)	7.75 10 ⁻³ m
hs, 1 from Formula (3)	1.58 10 ⁻² m
Is from Formula (2)	5.56 10 ⁻⁶ m
Shear transfer coefficient, Γ	9.57 10 ⁻¹
Effective thickness, hef1	45.73 10 ⁻³ m
Flexural Stiffness - Equation (B1)	K1 = 5.86 10 ⁴ Nm
Second glass pane being ER3	
Second glass pane	soda-lime silica glass, h2 = 0.015 m
Polymer Interlayer	polyvinyl butyral, hv2 = 1.52 10 ⁻³ m
Additional glass sheet	soda-lime silica glass, hz2 = 0.015 m

Example 5

[0081] Example 5 illustrates one embodiment of an IGU of the present invention, demonstrating the required resistance to explosion of a blast wave of overpressure, Pr, of 100kPa.

Example 5	
Overpressure of the blast wave	Pr = 100 kPa
Length and width of the IGU	L = 1.5 m and W = 1.5 m
Minimal flexural stiffness - Equation (A)	Kmin = 6.01 10 ⁴ Nm
First Pane	
First glass pane	soda-lime silica glass, h1 = 0.025 m
Flexural Stiffness - Equation (B1)	K1 = 9.58 10 ⁴ Nm
Second glass pane being ER2	
Second glass pane	soda-lime silica glass, h2 = 0.01 m

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(continued)

Second glass pane being ER2	
Polymer Interlayer	polyvinyl butyral, $h_{v2} = 1.52 \cdot 10^{-3} \text{ m}$
Additional glass sheet	soda-lime silica glass, $h_{z2} = 0.012 \text{ m}$

Example 6

[0082] Example 6 illustrates one embodiment of an IGU of the present invention, wherein both the first glass pane and the second glass pane can face the blast wave and have the required minimal flexural stiffness to resist to explosion of a blast wave of overpressure, P_r , of 150kPa.

Example 6	
Overpressure of the blast wave	$P_r = 150 \text{ kPa}$
Length and width of the IGU	$L = 2 \text{ m}$ and $W = 2 \text{ m}$
Minimal flexural stiffness - Equation (A)	$K_{\min} = 1.02 \cdot 10^5 \text{ Nm}$
First Glass Pane	
First glass pane	soda-lime silica glass, $h_1 = 0.015 \text{ m}$
Polymer Interlayer	polyvinyl butyral, $h_v = 0.76 \cdot 10^{-3} \text{ m}$, $G = 1.17 \cdot 10^8 \text{ Pa}$
Additional glass sheet	soda-lime silica glass, $h_z = 0.012 \text{ m}$
Effective thickness, h_{ef1}	$2.76 \cdot 10^{-2} \text{ m}$
Flexural Stiffness, K_1 - Equation (B1)	$K_1 = 1.28 \cdot 10^5 \text{ Nm}$
Second Glass Pane	
Second glass pane	soda-lime silica glass, $h_2 = 0.015 \text{ m}$
Polymer Interlayer	polyvinyl butyral, $h_{v2} = 0.76 \cdot 10^{-3} \text{ m}$, $G = 1.17 \cdot 10^8 \text{ Pa}$
Additional glass sheet	soda-lime silica glass, $h_{z2} = 0.012 \text{ m}$
Effective thickness, h_{ef2}	$2.76 \cdot 10^{-2} \text{ m}$
Flexural Stiffness, K_2 - Equation (B2)	$K_2 = 1.28 \cdot 10^5 \text{ Nm}$
Ref.#	Feature
10	Insulated glazing unit
1	First glass pane
12	Inner pane face of the first glass pane
13	Outer pane face of the first glass pane
2	Second glass pane
22	Inner pane face of the second glass pane
23	Outer pane face of the second glass pane
3	Spacer
4	Glass sheet coupled to the first glass pane
42	Glass sheet coupled to the second glass pane
5	Polymer interlayer coupling the first glass pane to the glass sheet
52	Polymer interlayer coupling the second glass pane to the glass sheet
V	Internal volume
D	Distance between the first glass pane and the second glass pane
h_1	Thickness of the first glass pane

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(continued)

Ref.#	Feature
h2	Thickness of the second glass pane
hz	Thickness of the glass sheet (4) coupled to the first glass pane
hz2	Thickness of the glass sheet (42) coupled to the second glass pane
hv	Thickness of the polymer interlayer (5)
hv2	Thickness of the polymer interlayer (52)

Claims

1. An insulating glazing unit (10) configured for resisting to an overpressure of a blast wave, P_r , comprised between 100 kPa and 250 kPa, ($100 \text{ kPa} \leq P_r \leq 250 \text{ kPa}$); extending along a plane, P, defined by a longitudinal axis, X, and a vertical axis, Z; having a width, W, measured along the longitudinal axis, X, and a length, L, measured along the vertical axis, Z, wherein the length, L, is equal to or greater than the width, W, ($L \geq W$); and comprising a first glass pane (1) facing the blast wave, a second glass pane (2) and a spacer (3), maintaining a distance, D, between the first glass pane and the second glass pane;

characterized in that the length, L, is equal to or greater than 1.5 m ($L \geq 1.5 \text{ m}$) and the width, W, is equal to or greater than 1.5 m ($W \geq 1.5 \text{ m}$); and

in that the first glass pane has a flexural stiffness, K1, equal to or greater than a minimal flexural stiffness, Kmin, ($K1 \geq Kmin$) :

$$Kmin = \frac{2 E f^3}{3 (1-\nu^2)} \text{ (Nm) Equation (A)}$$

wherein E is the Young modulus of glass and equals to $70 \cdot 10^9 \text{ Pa}$; ν is the Poisson's ratio of glass and equals to 0.22 ; and f is the following function:

$$f = \alpha_0 + \alpha_1 L + \alpha_2 W + \alpha_3 P_r + \alpha_4 (L - L_0)^2 + \alpha_5 (W - W_0)^2 + \alpha_6 (P_r - P_{r0})^2 + \alpha_7 (W - W_0)^3 + \alpha_8 (L - L_0)(P_r - P_{r0}) + \alpha_9 (W - W_0)(P_r - P_{r0}) + \alpha_{10} (W - W_0)^2 (P_r - P_{r0}) + \alpha_{11} (W - W_0)(P_r - P_{r0})^2 \quad \text{Function (f)}$$

wherein L is the length of insulating glazing unit;
wherein W is the width of the insulating glazing unit; and
wherein the parameters to be used in Function f, are:

α_0	-89.88E-3	m
α_1	8.09E-03	/
α_2	1.27E-02	/
α_3	6.27E-07	m/Pa
α_4	-1.58E-03	m^{-1}
α_5	-5.45E-03	m^{-1}
α_6	3.97E-12	m/Pa^2
α_7	-1.14E-11	Pa^{-1}
α_8	5.28E+1	m^{-2}
α_9	2.71E-07	Pa^{-1}
α_{10}	-1.43E-07	$m^{-1}Pa^{-1}$

(continued)

α_{11}	3.54E-12	Pa ⁻²
L_0	3,468.75E-3	m
W_0	2,25E-3	m
Pr_0	148.44E+3	Pa

wherein the minimal flexural stiffness, K_{min} , prevents the contact between the first glass pane and the second glass pane under the overpressure of the blast wave, Pr .

2. An insulating glazing unit according to claim 1, wherein the second glass pane has a thickness, h_2 , measured in the direction normal to the plane, P ; equal to or greater than 0.006 m ($h_2 \geq 0.006$ m), preferably equal to or greater than 0.008 m ($h_2 \geq 0.008$ m), more preferably equal to or greater than 0.010 m ($h_2 \geq 0.010$ m).
3. An insulating glazing unit according to claim 2, configured for resisting to an overpressure of a blast wave, Pr , equal to or greater than 150 kPa, ($Pr \geq 150$ kPa) and wherein the thickness of the second glass pane is equal to or greater than 0.008 m ($h_2 \geq 0.008$ m), preferably equal to or greater than 0.010 m ($h_2 \geq 0.010$ m).
4. An insulating glazing unit according to claim 3, configured for resisting to an overpressure of a blast wave, Pr , equal to or greater than 200 kPa, ($Pr \geq 200$ kPa) wherein the thickness of the second glass pane is equal to or greater than 0.010 m ($h_2 \geq 0.010$ m).
5. An insulating glazing unit according to any one of the preceding claims wherein the second glass pane provides a resistance against an explosion pressure of classification ER_x, wherein $x = 2, 3$, or 4, as defined by the overpressure of the blast wave, Pr , in accordance to NBN EN 13541 (2012).
6. An insulated glazing unit according to any one of the preceding claims, wherein the distance, D , is comprised between 6 mm and 25 mm ($6 \text{ mm} \leq D \leq 25 \text{ mm}$), preferably is comprised between 9 mm and 20 mm ($9 \text{ mm} \leq D \leq 20 \text{ mm}$), more preferably is comprised between 9 mm and 15 mm ($9 \text{ mm} \leq D \leq 15 \text{ mm}$).
7. An insulated glazing unit according to any one of the preceding claims, wherein the length, L , is equal or greater than 2 m ($L \geq 2$ m).
8. An insulated glazing unit according to any one of the preceding claims, wherein the width, W , is equal or greater than 2 m ($W \geq 2$ m).
9. An insulated glazing unit according to any one of the preceding claims, wherein the second glass pane has a flexural stiffness, K_2 , equal to or greater than the minimal flexural stiffness, K_{min} , ($K_2 \geq K_{min}$).
10. An insulated glazing unit according to any one of the preceding claims, wherein the first glass pane and/or second glass pane are monolithic glass pane(s).
11. An insulated glazing unit according to any one of the any preceding claims, wherein the first glass pane has an outer pane face (13), the second glass pane has an outer pane face (23) and wherein at least one of the outer pane faces is laminated to at least one glass sheet (4) by at least one polymer interlayer (5) forming a laminated assembly.
12. An insulated glazing unit according to claim 11, wherein the laminated assembly comprises from one to seven glass sheets, preferably from one to four glass sheets, more preferably from one to two glass sheets.
13. An insulated glazing unit according to any one of the claims 11 to 12, wherein the polymer interlayer is a material selected from the group consisting of ethylene vinyl acetate, polyisobutylene, polyvinyl butyral, polyurethane, cyclo olefin polymers, ionomer and/or ultraviolet activated adhesive, preferably is polyvinyl butyral.
14. An insulated glazing unit according to any one of the claims 11 to 13, wherein the first glass pane and the second glass panes are identical laminated assembly, preferably positioned in an orthogonal symmetry.
15. A insulating glazing unit according to any one of claims 1 to 8 and 10 to 14, wherein the second glass pane has an outer

pane face (23) coupled to a third glass pane along the periphery of the insulating glazing unit via a peripheral spacer bar, creating an insulating cavity sealed by a peripheral edge seal.

5 Patentansprüche

1. Isolierverglasungseinheit (10), dafür gestaltet, einem Überdruck einer Druckwelle, P_r , zwischen 100 kPa und 250 kPa ($100 \text{ kPa} \leq P_r \leq 250 \text{ kPa}$) zu widerstehen; sich entlang einer Ebene P erstreckend, die durch eine Längsachse X und eine vertikale Achse Z definiert ist; mit einer Breite W, gemessen entlang der Längsachse X, und einer Länge L, gemessen entlang der vertikalen Achse Z, wobei die Länge L gleich der oder größer als die Breite W ist ($L \geq W$); und umfassend eine erste Glasscheibe (1), die der Druckwelle zugewandt ist, eine zweite Glasscheibe (2) und einen Abstandshalter (3), der einen Abstand D zwischen der ersten Glasscheibe und der zweiten Glasscheibe aufrechterhält;

dadurch gekennzeichnet, dass die Länge L gleich oder größer als 1,5 m ist ($L \geq 1,5 \text{ m}$) und die Breite W gleich oder größer als 1,5 m ist ($W \geq 1,5 \text{ m}$); und die erste Glasscheibe eine Biegesteifigkeit K_1 gleich einer oder größer als eine minimale Biegesteifigkeit K_{min} aufweist ($K_1 \geq K_{min}$):

$$K_{min} = \frac{2 E f^3}{3 (1 - \nu^2)} \text{ (Nm) Gleichung (A)}$$

wobei E der Young-Modul von Glas ist und gleich $70 \cdot 10^9 \text{ Pa}$ ist; V das Poissonsche Verhältnis von Glas ist und gleich 0,22 ist; und f die folgende Funktion ist:

$$f = \alpha_0 + \alpha_1 L + \alpha_2 W + \alpha_3 P_r + \alpha_4 (L - L_0)^2 + \alpha_5 (W - W_0)^2 + \alpha_6 (P_r - P_{r0})^2 + \alpha_7 (W - W_0)^3 + \alpha_8 (L - L_0) (P_r - P_{r0}) + \alpha_9 (W - W_0) (P_r - P_{r0}) + \alpha_{10} (W - W_0)^2 (P_r - P_{r0}) + \alpha_{11} (W - W_0) (P_r - P_{r0})^2 \text{ Funktion (f)}$$

wobei L die Länge der Isolierverglasungseinheit ist; wobei W die Breite der Isolierverglasungseinheit ist; und wobei die in Funktion f zu verwendenden Parameter sind:

α_0	-89,88E-3	m
α_1	8,09E-03	/
α_2	1,27E-02	/
α_3	6,27E-07	m/Pa
α_4	-1,58E-03	m^{-1}
α_5	-5,45E-03	m^{-1}
α_6	3,97E-12	m/Pa^2
α_7	-1,14E-11	Pa^{-1}
α_8	5,28E+1	m^{-2}
α_9	2,71E-07	Pa^{-1}
α_{10}	-1,43E-07	$m^{-1}\text{Pa}^{-1}$
α_{11}	3,54E-12	Pa^{-2}
L_0	3.468,75E-3	m
W_0	2,25E-3	m
P_{r0}	148,44E+3	Pa

wobei die minimale Biegesteifigkeit K_{min} den Kontakt zwischen der ersten Glasscheibe und der zweiten Glasscheibe unter dem Überdruck der Druckwelle P_r verhindert.

2. Isolierverglasungseinheit nach Anspruch 1, wobei die zweite Glasscheibe eine Dicke h_2 , gemessen in der Richtung

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senkrecht zu der Ebene P; von gleich oder größer als 0,006 m ($h_2 \geq 0,006$ m), vorzugsweise gleich oder größer als 0,008 m ($h_2 \geq 0,008$ m), bevorzugter gleich oder größer als 0,010 m ($h_2 \geq 0,010$ m), aufweist.

3. Isolierverglasungseinheit nach Anspruch 2, dafür gestaltet, einem Überdruck einer Druckwelle, P_r , von gleich oder größer als 150 kPa ($P_r \geq 150$ kPa) zu widerstehen, und wobei die Dicke der zweiten Glasscheibe gleich oder größer als 0,008 m ist ($h_2 \geq 0,008$ m), vorzugsweise gleich oder größer als 0,010 m ($h_2 \geq 0,010$ m).
4. Isolierverglasungseinheit nach Anspruch 3, dafür gestaltet, einem Überdruck einer Druckwelle, P_r , von gleich oder größer als 200 kPa ($P_r \geq 200$ kPa) zu widerstehen, wobei die Dicke der zweiten Glasscheibe gleich oder größer als 0,010 m ist ($h_2 \geq 0,010$ m).
5. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei die zweite Glasscheibe einen Widerstand gegen einen Explosionsdruck der Einstufung ERx gemäß NBN EN 13541 (2012), wobei x = 2, 3 oder 4, wie durch den Überdruck der Druckwelle P_r definiert, bereitstellt.
6. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei der Abstand D zwischen 6 mm und 25 mm beträgt ($6 \text{ mm} \leq D \leq 25 \text{ mm}$), vorzugsweise zwischen 9 mm und 20 mm beträgt ($9 \text{ mm} \leq D \leq 20 \text{ mm}$), bevorzugter zwischen 9 mm und 15 mm beträgt ($9 \text{ mm} \leq D \leq 15 \text{ mm}$).
7. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei die Länge L gleich oder größer als 2 m ist ($L \geq 2$ m).
8. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei die Breite W gleich oder größer als 2 m ist ($W \geq 2$ m).
9. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei die zweite Glasscheibe eine Biegesteifigkeit K_2 aufweist, die gleich oder größer als die minimale Biegesteifigkeit $K_{\min}$ ist ($K_2 \geq K_{\min}$).
10. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei die erste Glasscheibe und/oder die zweite Glasscheibe monolithische Glasscheibe(n) sind.
11. Isolierverglasungseinheit nach einem der vorstehenden Ansprüche, wobei die erste Glasscheibe eine äußere Scheibenfläche (13) aufweist, die zweite Glasscheibe eine äußere Scheibenfläche (23) aufweist und wobei wenigstens eine der äußeren Scheibenflächen durch wenigstens eine Polymerzwischenschicht (5) an wenigstens eine Glasscheibe (4) laminiert ist, um eine laminierte Anordnung zu bilden.
12. Isolierverglasungseinheit nach Anspruch 11, wobei die laminierte Anordnung von einer bis sieben Glasscheiben, vorzugsweise von einer bis vier Glasscheiben, bevorzugter von einer bis zwei Glasscheiben umfasst.
13. Isolierverglasungseinheit nach einem der Ansprüche 11 bis 12, wobei die Polymerzwischenschicht ein Material ausgewählt aus der Gruppe bestehend aus Ethylenvinylacetat, Polyisobutyl, Polyvinylbutyral, Polyurethan, Cycloolefinpolymeren, Ionomer und/oder UVaktiviertem Klebstoff ist, vorzugsweise Polyvinylbutyral ist.
14. Isolierverglasungseinheit nach einem der Ansprüche 11 bis 13, wobei die erste Glasscheibe und die zweiten Glasscheiben eine identische laminierte Baugruppe sind, die vorzugsweise in einer orthogonalen Symmetrie angeordnet sind.
15. Isolierverglasungseinheit nach einem der Ansprüche 1 bis 8 und 10 bis 14, wobei die zweite Glasscheibe eine äußere Scheibenfläche (23) aufweist, die entlang des Rands der Isolierverglasungseinheit über eine periphere Abstandsleiste an eine dritte Glasscheibe gekoppelt ist, um einen isolierenden Hohlraum zu bilden, der durch eine periphere Randdichtung abgedichtet ist.

Revendications

1. Unité de vitrage isolant (10) configuré pour résister à une surpression d'une onde de souffle, P_r , comprise entre 100 kPa et 250 kPa, ($100 \text{ kPa} \leq P_r \leq 250 \text{ kPa}$) ; s'étendant le long d'un plan, P, défini par un axe longitudinal, X, et un axe vertical, Z ; ayant une largeur, W, mesurée le long de l'axe longitudinal, X, et une longueur, L, mesurée le long de l'axe

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vertical, Z, la longueur, L, étant égale ou supérieure à la largeur, W, ($L \geq W$) ; et comprenant un premier panneau vitré (1) faisant face à l'onde de souffle, un deuxième panneau vitré (2) et un espaceur (3), maintenant une distance, D, entre le premier panneau vitré et le deuxième panneau vitré ;

caractérisée en ce que la longueur, L, est égale ou supérieure à 1,5 m ($L \geq 1,5$ m) et la largeur, W, est égale ou supérieure à 1,5 m ($W \geq 1,5$ m) ; et

en ce que le premier panneau vitré a une rigidité à la flexion, K1, égale ou supérieure à une rigidité à la flexion minimale, Kmin, ($K1 \geq Kmin$) :

$$Kmin = \frac{2 E f^3}{3 (1-\nu^2)} \quad (\text{Nm}) \quad \text{Équation (A)}$$

E étant le module d'Young du verre et étant égal à $70 \cdot 10^9$ Pa ; ν étant le coefficient de Poisson du verre et étant égal à 0,22 ; et f étant la fonction suivante :

$$f = \alpha_0 + \alpha_1 L + \alpha_2 W + \alpha_3 Pr + \alpha_4 (L - L_0)^2 + \alpha_5 (W - W_0)^2 + (Pr - Pr_0)^2 + \alpha_7 (W - W_0)^3 + \alpha_8 (L - L_0) (Pr - Pr_0) + \alpha_9 (W - W_0) (Pr - Pr_0) + \alpha_{10} (W - W_0)^2 (Pr - Pr_0) + \alpha_{11} (W - W_0) (Pr - Pr_0)^2 \quad \text{Fonction (f)}$$

L étant la longueur de l'unité de vitrage isolant ;
W étant la largeur de l'unité de vitrage isolant ; et
les paramètres à utiliser dans la fonction f étant :

α_0	-89.88E-3	m
α_1	8.09E-03	/
α_2	1.27E-02	/
α_3	6.27E-07	m/Pa
α_4	-1.58E-03	m^{-1}
α_5	-5.45E-03	m^{-1}
α_6	3.97E-12	m/Pa^2
α_7	-1.14E-11	Pa^{-1}
α_8	5.28E+1	m^{-2}
α_9	2.71E-07	Pa^{-1}
α_{10}	-1.43E-07	$m^{-1}Pa^{-1}$
α_{11}	3.54E-12	Pa^{-2}
L_0	3 468.75E-3	m
W_0	2,25E-3	m
Pr_0	148.44E+3	Pa

la rigidité à la flexion minimale, Kmin, empêchant le contact entre le premier panneau vitré et le deuxième panneau vitré sous la surpression de l'onde de souffle, Pr.

- Unité de vitrage isolant selon la revendication 1, le deuxième panneau vitré ayant une épaisseur, h2, mesurée dans la direction normale au plan, P ; égale ou supérieure à 0,006 m ($h2 \geq 0,006$ m), de préférence égale ou supérieure à 0,008 m ($h2 \geq 0,008$ m), plus préférablement égale ou supérieure à 0,010 m ($h2 \geq 0,010$ m).
- Unité de vitrage isolant selon la revendication 2, configuré pour résister à une surpression d'une onde de souffle, Pr, égale ou supérieure à 150 kPa, ($Pr \geq 150$ kPa) et l'épaisseur du deuxième panneau vitré étant égale ou supérieure à 0,008 m ($h2 \geq 0,008$ m), de préférence égale ou supérieure à 0,010 m ($h2 \geq 0,010$ m).
- Unité de vitrage isolant selon la revendication 3, configuré pour résister à une surpression d'une onde de souffle, Pr,

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égale ou supérieure à 200 kPa, ($P_r \geq 200$ kPa), l'épaisseur du deuxième panneau vitré étant égale ou supérieure à 0,010 m ($h_2 \geq 0,010$ m).

- 5 **5.** Unité de vitrage isolant selon l'une quelconque des revendications précédentes, le deuxième panneau vitré offrant une résistance contre une pression d'explosion de classification ER_x, avec $x = 2, 3$ ou 4 , telle que définie par la suppression de l'onde de souffle, P_r , conformément à la norme NBN EN 13541 (2012).
- 10 **6.** Unité de vitrage isolant selon l'une quelconque des revendications précédentes, la distance, D , étant comprise entre 6 mm et 25 mm ($6 \text{ mm} \leq D \leq 25 \text{ mm}$), de préférence étant comprise entre 9 mm et 20 mm ($9 \text{ mm} \leq D \leq 20 \text{ mm}$), plus préférablement étant comprise entre 9 mm et 15 mm ($9 \text{ mm} \leq D \leq 15 \text{ mm}$).
- 15 **7.** Unité de vitrage isolée selon l'une quelconque des revendications précédentes, la longueur, L , est égale ou supérieure à 2 m ($L \geq 2$ m).
- 20 **8.** Unité de vitrage isolant selon l'une quelconque des revendications précédentes, la largeur, W , étant égale ou supérieure à 2 m ($W \geq 2$ m).
- 25 **9.** Unité de vitrage isolant selon l'une quelconque des revendications précédentes, le deuxième panneau vitré ayant une rigidité à la flexion, K_2 , égale ou supérieure à la rigidité à la flexion minimale, $K_{\min}$, ($K_2 \geq K_{\min}$).
- 30 **10.** Unité de vitrage isolant selon l'une quelconque des revendications précédentes, le premier panneau vitré et/ou le deuxième panneau vitré étant des panneau (x) vitré(s) monolithique(s).
- 35 **11.** Unité de vitrage isolant selon l'une quelconque des revendications précédentes, le premier panneau vitré ayant une face extérieure de vitre (13), le deuxième panneau vitré ayant une face extérieure de vitre (23) et au moins une des faces extérieures de vitre étant feuilletée sur au moins une feuille de verre (4) par au moins une couche intermédiaire de polymère (5) formant un ensemble feuilleté.
- 40 **12.** Unité de vitrage isolant selon la revendication 11, l'ensemble feuilleté comprenant de une à sept feuilles de verre, de préférence de une à quatre feuilles de verre, plus préférablement de une à deux feuilles de verre.
- 45 **13.** Unité de vitrage isolant selon l'une quelconque des revendications 11 et 12, la couche intermédiaire de polymère étant un matériau choisi dans le groupe constitué par l'éthylène-acétate de vinyle, le polyisobutylène, le butyral de polyvinyle, le polyuréthane, les polymères de cyclo-oléfine, l'ionomère et/ou l'adhésif activé par les ultraviolets, de préférence étant le butyral de polyvinyle.
- 50 **14.** Unité de vitrage isolant selon l'une quelconque des revendications 11 à 13, le premier panneau vitré et le deuxième panneau vitré étant un ensemble feuilleté identique, de préférence positionné selon une symétrie orthogonale.
- 55 **15.** Unité de vitrage isolant selon l'une quelconque des revendications 1 à 8 et 10 à 14, le deuxième panneau vitré ayant une face extérieure de vitre (23) couplée à un troisième panneau vitré le long de la périphérie de l'unité de vitrage isolant par l'intermédiaire d'une barre d'espacement périphérique, créant une cavité isolante scellée par un joint de bord périphérique.

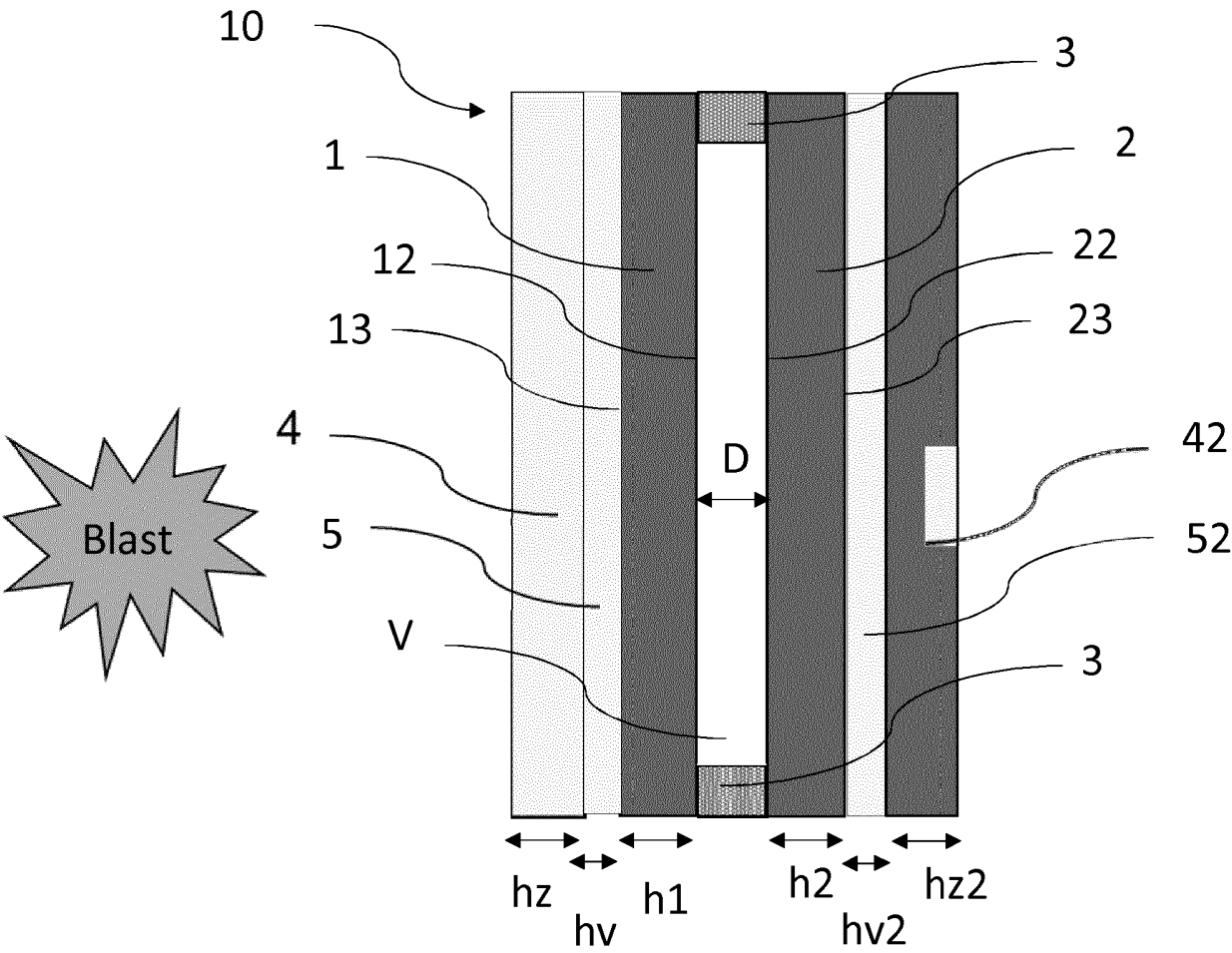


Figure 1

REFERENCES CITED IN THE DESCRIPTION

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