(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 December 2019 (26.12.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/243436 A1

(51) International Patent Classification:
E06B 3/66 (2006.01) *E06B 5/12* (2006.01)

(21) International Application Number:
PCT/EP2019/066233

(22) International Filing Date:
19 June 2019 (19.06.2019)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
18179129.4 21 June 2018 (21.06.2018) EP

(71) Applicant: **AGC GLASS EUROPE** [BE/BE]; Avenue Jean Monnet 4, 1348 Louvain-la-Neuve (BE).

(72) Inventors: **DELLIEU, Louis**; Rue Saint-Donat 6, 5310 Waret-la-Chaussée (BE). **JEANFILS, Julien**; Rue de l'Eglise 6b bte 102, 1435 Corbais (BE). **LEYBROS, Perrine**; Rue Louis Blériot 12, 6041 Gosselies (BE). **HABIBI, Zakaria**; Rue des Roseaux 12, 1420 Braine l'Alleud (BE).

(74) Agent: **AGC GLASS EUROPE**; Rue Louis Blériot 12, 6041 GOSSELIES (BE).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(54) Title: LOW OVERPRESSURE SECURITY INSULTED GLAZING UNIT

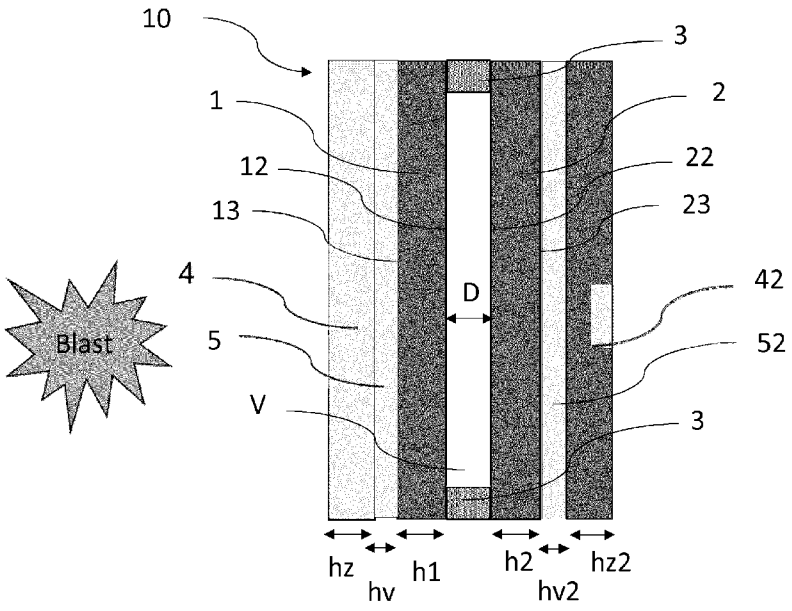


Figure 1

(57) Abstract: The present invention concerns an insulating glazing unit (10) configured for resisting to an overpressure of a blast wave, Pr, equal to or greater than 50 kPa and lower than 100 kPa. Said insulating glazing unit extends along a plane, P, defined by a longitudinal axis, X, and a vertical axis, Z; 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; and comprises 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. Within the insulating glazing unit, 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 the first glass pane has a flexural stiffness, K1, equal to or greater than 5.00 104 Nm.

WO 2019/243436 A1

[Continued on next page]

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

— *as to the identity of the inventor (Rule 4.17(i))*
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *of inventorship (Rule 4.17(iv))*

Published:

— *with international search report (Art. 21(3))*

LOW OVERPRESSURE SECURITY INSULTED GLAZING UNIT

FIELD OF THE INVENTION

The present invention relates to security insulated glazing units resisting to low overpressures of a blast wave.

BACKGROUND OF THE INVENTION

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).

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.

While dealing with explosion-resistant security glazing for building applications, the European standard to fulfil is EN 13541 (2012). 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.

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 (2010). 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 insulting 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 norm 13541 individually.

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.

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.

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.

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 waves of overpressure equal to or greater than 50 kPa and lower than 100 kPa.

SUMMARY OF THE INVENTION

The present invention relates to an insulating glazing unit configured for resisting to an overpressure of a blast wave, Pr, equal to or greater than 50 kPa and lower than 100 kPa ($50\ kPa \leq Pr < 100\ kPa$). It 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 5.00 10^4 Nm.

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

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

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, Pr, equal to or greater than 50 kPa and lower than 100 kPa (50 kPa ≤ Pr < 100 kPa).

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, Pr, equal to or greater than 50 kPa and lower than 100 kPa, such an IGU must be designed such that the first pane facing the blast wave demonstrates a 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.

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 6mm ($D \geq 6$ mm), preferably equal to or greater than 9mm ($D \geq 9$mm). In another preferred embodiment, the distance, D, is equal to or lower than 25 mm ($D \leq 25$ mm), preferably equal to or lower than 20 mm ($D \leq 20$ mm), more preferably equal to or lower than 15 mm ($D \leq 15$ mm). Typically, the distance, D, is comprised between 6 mm and 25 mm ($6 \text{ mm} \leq D \leq 25$ mm), preferably between 9 mm and 20 mm ($9 \text{ mm} \leq D \leq 20$ mm), more preferably between 9 mm and 15 mm ($9 \text{ mm} \leq D \leq 15$ mm).

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 ($L \geq 1.5$ m), preferably equal to or greater than 2 m ($L \geq 2$ m). The width, W, of the IGU of the present invention is equal or greater than 1.5 m ($W \geq 1.5$ mm), preferably equal to or greater than 2 m ($L \geq 2$ m). Typical windows' surfaces for building applications, reach 3 to 6 m^2.

FIRST PANE

It has been surprisingly found that for an insulated glazing unit to resist in its entirety to an explosion overpressure, Pr, equal to or greater than 50 kPa and lower than 100 kPa, the first pane facing the blast wave, must demonstrate a certain flexural stiffness, K1, equal to or greater than $5.00\ 10^4$ Nm. It has been found that such flexural stiffness of the

first pane facing is required to avoid said pane to touch the second pane and cause cracks up to the fracture point break of the other pane of the IGU.

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.

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.

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

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:

$$K1 = \frac{E(hef1)^3}{12(1-\nu^2)} \quad \text{Equation (A1)}$$

wherein E is the Young modulus of glass and equals to 70 10^9 Pa ;

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

wherein hef1 is the effective thickness of the first glass pane.

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 (A1).

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, hef, of a laminated assembly.

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):

$$\Gamma = \frac{1}{1+9.6\frac{EI_S h_v}{Gh_S^2 a^2}} \quad (1)$$

With

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

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

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

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

wherein E is the Young modulus of the first glass pane and equals to 70 10^9 Pa ;
wherein G is the polymer interlayer shear storage modulus, measured at a load duration 5 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 h1 is the thickness of the first glass pane, expressed in m;
wherein hz is the thickness of the at least one glass sheet, expressed in m; and
wherein hv is the thickness of the at least one polymer interlayer, expressed in m.
All thicknesses are measured in the direction normal to the plane, P.

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

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

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, hef, has been calculated and all panes and corresponding polymer interlayer(s) have been considered.

Table 1

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, h1	12 10^{-3} m
Thickness of the glass sheet, hz	12 10^{-3} m
Thickness of the PVB interlayer, hv	0.76 10^{-3}m
hs from Formula (5)	1.28 10^{-2} m
hs,z from Formula (4)	6.38 10^{-3} m
hs,1 from Formula (3)	6.38 10^{-3} m
Is from Formula (2)	9.77 10^{-7} m^3
Shear transfer coefficient, Γ	9.74 10-1
Effective thickness, hef	2.46 10^{-2} m

The flexural stiffness of the first glass pane, K1, of the example is then calculated as per equation (A1):

Poisson ratio	0.22
Flexural stiffness, K1	9.12 10^4 Nm

The IGU designed as per table 1 above meets the requirement of the present invention in that the flexural stiffness of the first pane reaches 9.12 10^4 Nm and is greater than the required minimal flexural stiffness of 5.00 10^4 Nm. Such IGU will therefore resist in its entirety to a blast wave of overpressure equal to or greater than 50 kPa and lower than 100kPa.

SECOND PANE

The IGU of the present invention is configured for resisting to an overpressure of a blast wave, Pr, equal to or greater than 50 kPa and lower than 100kPa, wherein the first glass pane of the IGU faces said blast wave.

In a preferred embodiment of the present invention, the second glass has a thickness, h2, measured in the direction normal to the plane, P; equal to or greater than 0.004 m ($h2 \geq 0.004$ m), preferably equal to or greater than 0.006 m ($h2 \geq 0.006$ m), more preferably equal to or greater than 0.008 m ($h2 \geq 0.008$ m).

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 (42) by at least one polymer interlayer (52) forming a laminated assembly, as shown in figure 1.

In the embodiment of the present invention wherein the second glass pane is a single monolithic glass pane, then the thickness, h2, 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, hef, 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.

In a 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 ER1, as per classification under the European norm NBN EN 13541 (2012). It is well known to person skilled in that art how to design glass panes of a resistance to explosion ER1 as per the European Norm NBN EN 13541 (2012), by forming a laminate assembly of 2 or more glass panes and corresponding polymer layer. One example of a suitable ER1 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 6 mm, laminated to a soda-lime glass sheet of 4 mm by a polyvinyl butyrate polymer interlayer of 1.52 mm.

PARTITION

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.

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 5.00 10^4 Nm.

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:

$$K2 = \frac{E(hef2)^3}{12(1-\nu^2)} \quad \text{Equation (A2)}$$

wherein E is the Young modulus of glass and equals to 70 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.

All parameters necessary for the calculation of K2 per Equation (A2) have been described above in relation to the first glass pane and apply correspondingly to the second glass pane.

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 (A2).

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.

In such embodiment, it is further preferred that, the outer glass pane face of the second glass pane of the IGU of the present invention is further laminated to at least one glass sheet (42) by at least one polymer interlayer (52) forming a laminated assembly.

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 (h2) 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 (hz) is coupled to the outer face pane (13) first glass pane via a polymer interlayer (5) having a thickness (hv). Another glass sheet (42) having a thickness (hz2) is coupled to the outer pane face (23) of the second glass pane via a polymer interlayer (52) having a thickness (hv2).

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.

The flexural stiffness of the first glass pane, K1, and the flexural stiffness of the second glass pane, K2, may be different.
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.

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.

GLASS PANES and SHEETS

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.

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).

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.

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.

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.

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 immerging 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.

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
SiO2	40 - 78%	60 - 78 wt%
Al2O3	0 - 18%	0 - 8 wt%, pref 0 - 6 wt%
B2O3	0 - 18%	0 - 4 wt%, pref 0 - 1 wt%
Na2O	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%
K2O	0 – 10%	0 – 10 wt%
BaO	0 – 5%	0 – 5 wt%, pref 0 - 1 wt%.

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
65 ≤ SiO2 ≤ 78 wt%	60 ≤ SiO2 ≤ 78 %	65 ≤ SiO2 ≤ 78 wt%
5 ≤ Na2O ≤ 20 wt%	5 ≤ Na2O ≤ 20 %	5 ≤ Na2O ≤ 20 wt%
0 ≤ K2O < 5 wt%	0.9 < K2O ≤ 12 %	1 ≤ K2O < 8 wt%
1 ≤ Al2O3 < 6 wt%, pref 3 < Al2O3 ≤ 5 %	4.9 ≤ Al2O3 ≤ 8 %	1 ≤ Al2O3 < 6 wt%
0 ≤ CaO < 4.5 wt%	0.4 < CaO < 2 %	2 ≤ CaO < 10 wt%
4 ≤ MgO ≤ 12 wt%	4 < MgO ≤ 12 %	0 ≤ MgO ≤ 8 wt%
(MgO/(MgO+CaO)) ≥ 0.5, pref 0.88 ≤ [MgO/(MgO+CaO)] < 1.		K2O/(K2O+Na2O) : 0.1 - 0.7.

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.

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.

Laminated assembly description

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).

Said glass sheet has typically a thickness, hz, comprised between 2 and 30 mm (2 mm ≤ hz ≤ 30 mm), preferably comprised between 4 and 25 mm (4 mm ≤ hz ≤ 25 mm), more preferably comprised between 4 and 15 mm (4 mm ≤ hz ≤ 125 mm), even comprised between 8 and 12 mm (8 mm ≤ hz ≤ 12 mm). The thicknesses are measured in the direction normal to the plane, P.

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 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

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.

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 m and 3.04 mm. To achieve the desired thickness, one or more of those layers can be used.

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 of PVB is tough and ductile, so brittle cracks will not pass from one side of the laminate to the other.

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.

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.

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 planes with electrochromic, thermochromic, photochromic or photovoltaic elements are also compatible with the present invention.

SPACER

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.

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

Examples 1 to 3 illustrate different embodiments of IGU of the present invention, demonstrating the required resistance to explosion.

	Example 1	Example 2	Example 3
Overpressure of the blast wave	*Pr = 50 kPa*	*Pr = 60 kPa*	*Pr = 70 kPa*
First Pane			
First glass pane	soda-lime silica glass h1 = 0.022 m	soda-lime silica glass h1 = 0.012 m	soda-lime silica glass h1 = 0.008 m
Polymer Interlayer		polyvinyl butyral, hv = 0.76 10^{-3} m	polyvinyl butyral, hv = 1.52 10^{-3} m
Additional glass sheet		soda-lime silica glass hz = 0.010 m	soda-lime silica glass hz = 0.008 m
hs from Formula (5)		1.18 10^{-2} m	8.76 10^{-3} m
hs,z from Formula (4)		5.35 10^{-3} m	4.38 10^{-3} m
hs,1 from Formula (3)		6.41 10^{-3} m	4.38 10^{-3} m
Is from Formula (2)		5.54 10^{-7} m^3	3.07 10^{-7} m^3
Shear transfer coefficient, Γ		9.77 10^{-1}	9.83 10^{-1}
Effective thickness, hef1		2.26 10^{-2} m	1.67 10^{-2} m
Flexural Stiffness, K1 - Equation (A1)		K1=7.09 10^{4} Nm	/
Second Polymer Interlayer			polyvinyl butyral,

			hv = 0.76 10^{-3} m
Second additional glass sheet			soda-lime silica glass, hz = 0.006 m
hs from Formula (5)			1.21 10^{-2} m
hs,z from Formula (4)			8.90 10^{-3} m
hs;1 from Formula (3)			3.20 10^{-3} m
Is from Formula (2)			6.46 10^{-7} m
Shear transfer coefficient, Γ			9.81 10^{-1}
Effective thickness, hef1			2.32 10^{-2} m
Flexural Stiffness - Equation (A1)			K1 = 7.64 10^{4} Nm

The second glass panes described in the table A below may be combined to any of the first panes of examples 1 to 3 above to form the IGUs of the present invention.

Table A - Second glass panes			
	Example 4	Exemple 5	Example 6 – ER1
Second glass pane	soda-lime silica glass h2 = 0.004 m	soda-lime silica glass h2 = 0.012 m	soda-lime silica glass h2 = 0.004 m
Polymer Interlayer	/	polyvinyl butyral, hv2 = 0.76 10^{-3} m	polyvinyl butyral hv2 = 2.28 10^{-3} m
Additional glass sheet	/	soda-lime silica glass hz2 = 0.010 m	soda-lime silica glass hz2 = 0.004 m
hs from Formula (5)	/	1.18 10^{-2} m	
hs,z from Formula (4)	/	5.35 10^{-3} m	
hs,2 from Formula (3)	/	6.41 10^{-3} m	
Is from Formula (2)	/	5.54 10^{-7} m^3	
Shear transfer coefficient, Γ	/	9.77 10^{-1}	
Effective thickness, hef2	/	2.26 10^{-2} m	
Flexural Stiffness, K2 Equation (A2)		K2=7.09 10^{4} Nm	

The value of G, the shear modulus of the PVB interlayer, is 1.17 10^{8} Pa.

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
h1	Thickness of the first glass pane
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, Pr, equal to or greater than 50 kPa and lower than 100 kPa, (50 kPa ≤ Pr < 100 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 ≥ 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 ≥ 1.5 m) and the width, W, is equal to or greater than 1.5 m (W ≥ 1.5 m); and

in that the first glass pane has a flexural stiffness, K1, equal to or greater than 5.00 10^4 Nm.

2. An insulating glazing unit according to claim 1 wherein the second glass pane has a thickness, h2, measured in the direction normal to the plane, P; equal to or greater than 0.004 m (h2 ≥ 0.006 m), preferably equal to or greater than 0.006 m (h2 ≥ 0.006 m), more preferably equal to or greater than 0.008 m (h2 ≥ 0.008 m).

3. 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 ER1 in accordance to NBN EN 13541 (2012).

4. 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 mm ≤ D ≤ 25 mm), preferably is comprised between 9 mm and 20 mm (9 mm ≤ D ≤ 20 mm), more preferably is comprised between 9 mm and 15 mm (9 mm ≤ D ≤ 15 mm).

5. 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).

6. 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).

7. An insulated glazing unit according to any one of the preceding claims, wherein the second glass pane has a flexural stiffness, K2, equal to or greater than $5.00\ 10^4$ Nm.

8. An insulated glazing unit according to any one of the preceding claims, wherein the first and/or second glass panes are made from soda-lime-silica glass, aluminosilicate glass or borosilicate glass type.

9. An insulated glazing unit according to any of the preceding claims, wherein the first glass pane and/or second glass pane are heat strengthened glass, a thermally toughened glass, or a chemically strengthened glass.

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 1 to 7 glass sheets, preferably from 1 to 4 glass sheets, more preferably from 1 to 2 glass sheets.

13. An insulated glazing unit according to any one of the claims 11 to 12, wherein the polymer interlayer is made from 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 the claims 1 to 6 and 8 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.

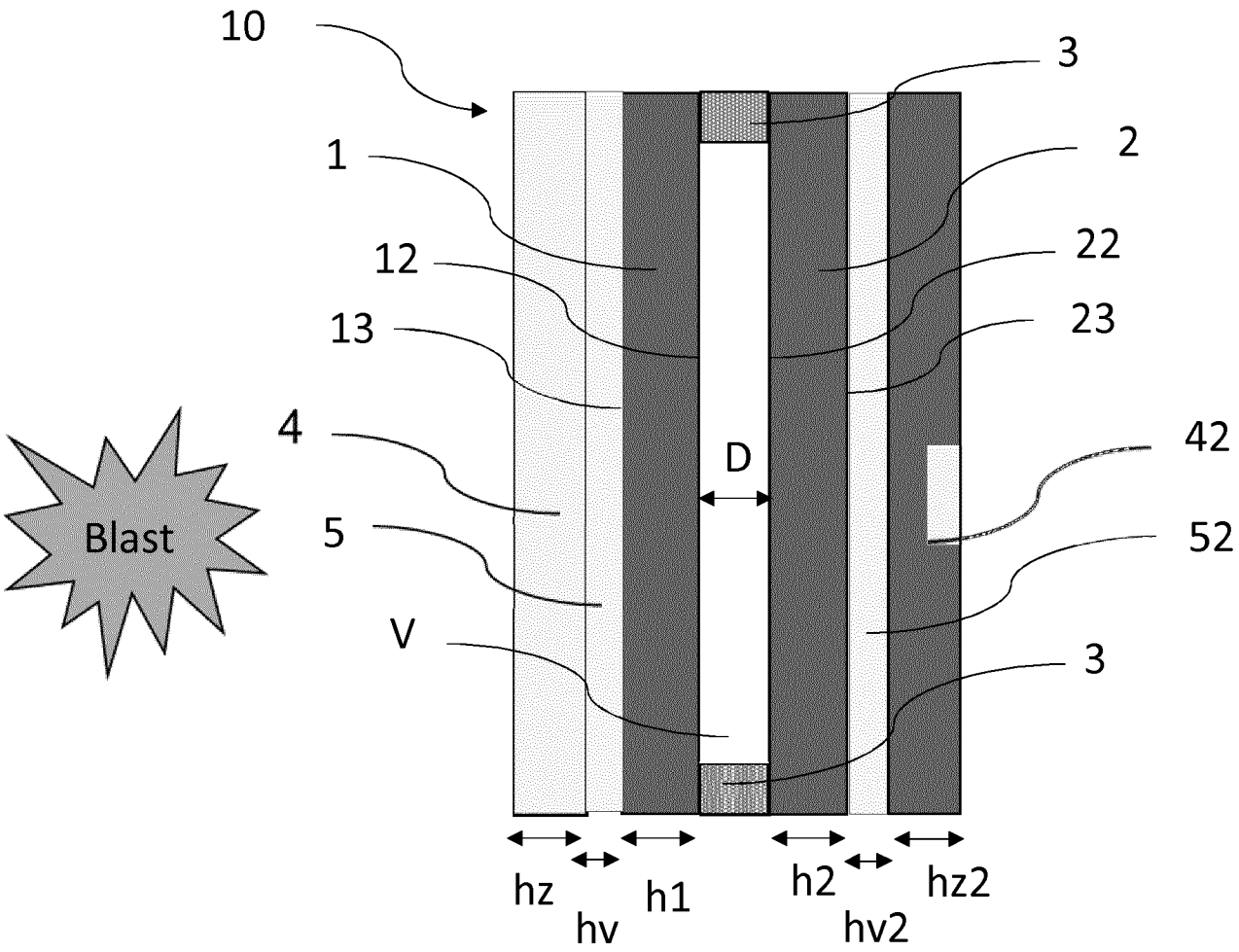


Figure 1

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/066233

A. CLASSIFICATION OF SUBJECT MATTER
INV. E06B3/66 E06B5/12
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
E06B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2 110 238 A1 (SAELZER SICHERHEITSTECHNIK [DE]) 21 October 2009 (2009-10-21) figures 1-3	1-15
A	EP 1 254 872 A1 (NIPPON SHEET GLASS CO LTD [JP]) 6 November 2002 (2002-11-06) paragraph [0022] - paragraph [0022]; figures 1, 2A, 2B	1-15

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
8 July 2019	15/07/2019

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Crespo Vallejo, D

1

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2019/066233

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2110238 A1	21-10-2009	AT 490077 T	15-12-2010
		DE 202008005366 U1	10-07-2008
		EP 2110238 A1	21-10-2009
EP 1254872 A1	06-11-2002	CN 1418177 A	14-05-2003
		EP 1254872 A1	06-11-2002
		JP 2001213645 A	07-08-2001
		KR 20020077396 A	11-10-2002
		WO 0155045 A1	02-08-2001