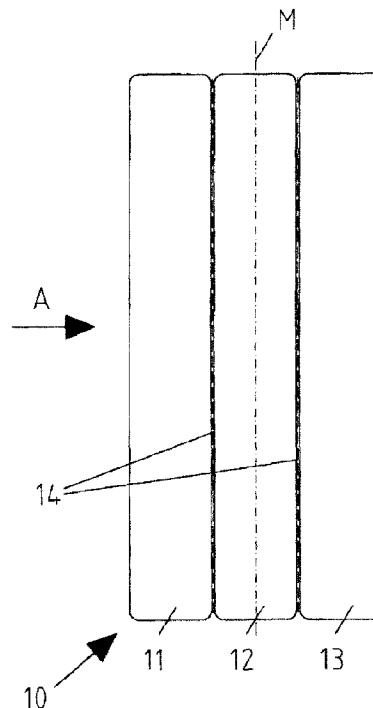




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(54) **Titre : VITRAGE COMPOSITE BLINDE**
(54) **Title: BULLET-RESISTANT LAMINATED GLASS**



(57) **Abrégé/Abstract:**

The invention relates to bullet-resistant laminated glass having at least three sheets of glass, wherein one of the sheets of glass faces the impact side as a cover sheet, and one sheet of glass is formed as a closure sheet facing away from the impact side, wherein between the cover sheet and the closure sheet one or more intermediate sheets are disposed, these sheets of glass being connected to each other by means of composite layers. The composite layers are formed by flexible and dimensionally unstable films and/or cast compounds. The composite layers do not consist of polycarbonate, polyurethane or polymethylmethacrylate. In order to prevent splinter output on the rear side, this glass composite has a closure sheet on the rear side consisting of thermally or chemically prestressed glass.

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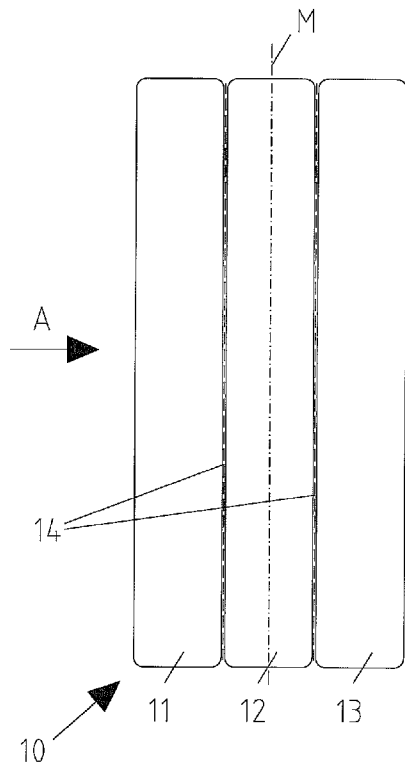
(54) **Title:** BULLET-RESISTANT LAMINATED GLASS(54) **Bezeichnung :** DURCHSCHUSSEHMENDES VERBUNDGLAS

Fig. 1

(57) **Abstract:** The invention relates to bullet-resistant laminated glass having at least three sheets of glass, wherein one of the sheets of glass faces the impact side as a cover sheet, and one sheet of glass is formed as a closure sheet facing away from the impact side, wherein between the cover sheet and the closure sheet one or more intermediate sheets are disposed, these sheets of glass being connected to each other by means of composite layers. The composite layers are formed by flexible and dimensionally unstable films and/or cast compounds. The composite layers do not consist of polycarbonate, polyurethane or polymethylmethacrylate. In order to prevent splinter output on the rear side, this glass composite has a closure sheet on the rear side consisting of thermally or chemically prestressed glass.

(57) **Zusammenfassung:** Die Erfindung betrifft ein durchschusshemmendes Verbundglas mit mindestens drei Glasscheiben, wobei eine der Glasscheiben als Deckscheibe der Angriffseite zugewandt ist, und eine Glasscheibe der Angriffseite abgewandt als Abschlusscheibe ausgebildet ist, wobei zwischen der Deckscheibe und der Abschlusscheibe eine oder mehrere Zwischenscheiben angeordnet sind, wobei diese Glasscheiben mittels Verbundschichten miteinander verbunden sind. Dabei sind die Verbundschichten von biegeschlaffen und forminstabilen Folien und/oder Vergussmassen gebildet. Die Verbundschichten bestehen nicht aus Polycarbonat, Polyurethan oder Polymethylmethacrylat. Um den rückseitigen Splitterabgang zu verhindern, weist dieser Glasverbund rückseitig eine Abschlusscheibe bestehend aus thermisch oder chemisch vorgespanntem Glas auf.

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Bullet-resistant laminated glass

The invention relates to a bullet-resistant laminated glass having at least three sheets of glass, wherein one of the sheets of glass faces the impact side as a cover sheet, and one glass sheet is formed as a closure sheet facing away from the impact side.

Bullet-resistant glass in the form of laminated glass has been known for several decades. It is usually composed of a plurality of glass sheets that are connected to one another with intermediate film layers. These laminated glasses are designed in numerous variations. For example, they are equipped with laminated plastic intermediate layers or with coatings or films that face away from the impact and bind glass splinters. They are also sealed in part with a plastic sheet facing away from the impact. Test standards, including the European Standard EN 1063, distinguish between sheets "with splinter output" and sheets "without splinter output" within the individual impact classes. These different classifications require the use of laminated glasses of different thicknesses or different glass designs.

In order to be able to fulfill the requirement of the standard for laminated glass free of splinter output in the architectural field, thick laminated glass must be provided. In particular, clearly greater glass thicknesses are necessary than in a laminated glass which simply protects against bullets. For soft-core bullets, the difference in thickness for sheets "with splinter output" and "without splinter output" amounts to up to 50% within the respective projectile or impact class. Due to the increase in thickness and in weight caused by this, the applicability of laminated glasses is made difficult or is hindered. In particular, special constructions are necessary in part for door, window and frame systems. Due to the greater weight, special fastenings are necessary, for example, hinge structures.

In order to counteract such an undesired increase in weight for laminated glasses "without splinter output", frequently a plastic sheet made of polycarbonate, polymethyl

methacrylate or the like and which faces away from the impact is laminated or glued on. Such a solution is disclosed in EP 0 157 646 or DE 10 2008 043 718.

In addition, laminated glasses are known in which a splinter-binding coating facing away from the impact is introduced onto the laminated glass. Such a design variant is disclosed in DE 692 27 344. Both the plastic sheet that is introduced and the splinter-binding coatings are mechanically sensitive; in particular, they are not scratch-resistant. They cannot be properly cleaned and can be cleaned only with special cleaning agents. In addition, they are at risk of aging, for example, due to UV irradiation. This is a serious disadvantage for use in the field of architecture.

In order to increase ballistic performance, laminated glasses in which chemically or thermally pre-stressed glasses facing the impact side are used are known from the prior art. These glasses then form a cover layer, which breaks up the penetrating bullet or deforms it. The bullet in fact then disrupts the cover sheet; however, the splinter output on the back side cannot be prevented by this measure. Therefore, frequently polycarbonate sheets or the like facing away from the impact are used in these glasses also.

An object of the invention is to provide a bullet-resistant laminated glass with low weight, which offers an effective protection from bullets and protection against splinter output.

Accordingly, a bullet-resistant laminated glass is proposed, which has at least three sheets of glass, which are connected to one another by intermediate composite layers. In this case, the composite layers are formed in the usual way by flexible and dimensionally unstable films and/or cast compounds. Polyvinylbutyral films that have a layer thickness of less than 2 mm are used, in particular, as flexible films. Films composed of other materials are also used, which have a layer thickness of less than 2 mm. Several films also are combined in part in order to obtain intermediate layers between two adjacent sheets of glass. Flexible films are characterized by the properties of low modulus of elasticity (< 100 MPa) and high deformation (elongation at break $> 200\%$) as a consequence of small force and torque loads. These types of flexible and dimensionally unstable films have the advantage that the composite is held together even after the breaking of single, several, or all sheets of glass. Cast compounds are particularly suitable, since the laminated glass can be produced in a

simple manner in this way. For example, with composite layers having thicknesses equal to or greater than 1 mm, the individual sheets of glass can be mechanically decoupled.

According to the invention, it is additionally provided that the closure sheet is designed as a thermally or chemically pre-stressed glass sheet. This glass sheet therefore closes the laminated glass facing way from the impact side.

In one aspect, the present invention provides a bullet-resistant laminated glass having at least three sheets of glass, wherein one of the glass sheets faces the impact side (A) as a cover sheet, and one glass sheet that faces away from the impact side (A) is formed as a closure sheet, wherein one or more intermediate sheets are disposed between the cover sheet and the closure sheet, wherein the glass sheets are connected to one another by composite layers, which are formed by flexible and dimensionally unstable films and/or cast compounds, and wherein the closure sheet is formed as a thermally or chemically pre-stressed glass sheet, wherein the cover sheet and the one or more intermediate sheets are composed of non-pre-stressed glass, wherein the thermally pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and the tensile bending strength of the closure sheet in the range between $1:15 \leq x \leq 1:50$, or wherein the chemically pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and a tensile bending strength of the closure sheet in the range between $1:50 \leq x \leq 1:1000$, and wherein the closure sheet has a thickness in the range of 4 to 10 mm.

In another aspect, the present invention provides a bullet-resistant laminated glass having at least three sheets of glass, wherein one of the glass sheets faces the impact side (A) as a cover sheet, and one glass sheet that faces away from the impact side (A) is formed as a closure sheet, wherein one or more intermediate sheets are disposed between the cover sheet and the closure sheet, wherein the glass sheets are connected to one another by composite layers that are not composed of polycarbonate, polyurethane or polymethyl methacrylate, and wherein the closure sheet is formed as a thermally or chemically pre-stressed glass sheet, wherein the cover sheet is composed of non-pre-stressed glass and wherein the pre-stressed glass sheet extends at maximum up to half the total thickness of the laminated glass, wherein the thermally pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and the tensile bending strength of

the closure sheet in the range between $1:15 \leq x \leq 1:50$, or wherein the chemically pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and a tensile bending strength of the closure sheet in the range between $1:50 \leq x \leq 1:1000$, and wherein the closure sheet has a thickness in the range of 4 to 10 mm.

In the case of this construction of a laminated glass, when a projectile impacts it, first the cover sheet and consequently the intermediate sheet(s) adjacent to the cover sheet is (are) broken due to the impact of the projectile. The energy of the projectile in this case is transferred onto the broken sheet(s) and this leads to a shock-like bending load that is taken up by the pre-stressed closure sheet. It has been surprisingly shown that due to the pre-stressing, a break of the closure sheet does not occur. Consequently, there is also no splinter output on the back side. This type of construction of a laminated glass equally also displays a good protection against an explosion effect. In the case of a pressure wave occurring in the region of the impact side, tensile stresses are produced on the closure sheet, which can be effectively broken down as a consequence of the pre-stressing, so that a break in the material does not occur here.

An object of the invention is also achieved by a bullet-resistant laminated glass having at least three sheets of glass, wherein one of the sheets of glass faces the impact side as a cover sheet, and another glass sheet is formed as a closure sheet facing away from the impact side, wherein one or more intermediate sheets are disposed between the cover sheet and the closure sheet, wherein the glass sheets are connected to one another by means of composite layers that are not composed of polycarbonate, polyurethane or polymethyl methacrylate. Also, in the case of these design variants, the closure sheet is formed as a thermally or chemically pre-stressed glass sheet.

It has been shown surprisingly that by dispensing with the composite layers that are usually used for bullet-resistant laminated glasses and that are composed of polycarbonate, polyurethane or polymethyl methacrylate, an advantageous effect can be achieved relative to prevention of splinter output on the back side. The energy of the impacting projectile is not influenced by such intermediate layers introduced into

the closure sheet, so that the energy of the projectile can be reliably taken up without danger of breaking this closure sheet. Also, a bullet-resistant laminated glass is obtained with this solution without splinter output on the back side.

With the two above-named solutions for laminated glasses, architectural glasses in particular can be created, which can be produced with low component weights and which are closed on the impact side and also on the back side by glass material. Therefore, they can be easily cleaned, and they are resistant to scratching and aging. Costly support structures can be dispensed with due to the low component weight.

It has been shown that an optimized bending load for the closure sheet then occurs if the cover sheet and the intermediate sheet(s) have a greater thickness than the closure sheet.

For the construction of the laminated glass, the glass sheets can be formed by a borosilicate glass, a soda-lime glass, an aluminosilicate glass and/or a lithium aluminosilicate glass. Therefore, recourse can be made to commercially available components. Ideally, all glass sheets are composed of a glass material, preferably of borosilicate glass, which has been shown to be particularly suitable for this application objective and in the case of impact with soft-core bullets. Particularly preferred, the cover sheet should be composed of borosilicate glass in order to effectively break the impact energy of a soft-core bullet.

Especially preferred, the composite layer is formed by one or more films, in particular, composed of polyvinylbutyral. These films can be processed in the autoclaving process and lead to a reliable, large-area connection of the glass sheets lying next to one another. The films essentially guarantee the holding together of the broken glass components after the impact of a projectile.

In order to be able to assure the reliable transfer of the bending load onto the closure sheet upon impact with a projectile, the composite layer should have a thickness of less than 2 mm, in particular a thickness of less than 1 mm. Thicknesses of less than 2 mm assure a high safety against splinter output on the back side. They also form a kind of elastic buffer, which contributes to the purpose of absorbing the energy of an impacting projectile. With thicknesses of less than 1 mm, reliable operating values are still achievable.

In order to fulfill the standard requirements according to DIN EN 1063, the tensile bending strength of the closure sheet should be $\geq 100 \text{ N/mm}^2$. More preferably, the tensile bending strength lies above 140 N/mm^2 . Then certain manufacturing inaccuracies in the laminated glass are reliably equilibrated and a splinter output on the back side is always prevented. Clearly higher strengths can be obtained with the use of chemically pre-stressed sheets. The latter can be used in order to reduce the sheet thickness of the remaining sheets of the laminated glass in favor of a small overall component weight. For example, pre-stressing in the range between 500 N/mm^2 and 1100 N/mm^2 can be achieved with chemically pre-stressed glasses. Such chemically pre-stressed glasses are particularly suitable within the scope of the invention.

In the case when a thermally pre-stressed closure sheet is used, then the latter should have a thickness in the range between 4 and 10 mm, in order to make it sufficiently resistant to bending. In this case, thicknesses of more than 10 mm introduce an improved safety against splinter output on the back side only to a limited extent. However, they significantly increase the weight of the component.

In the case of chemically pre-stressed closure sheets, the thickness should lie in the range between 3 and 12 mm. Chemically pre-stressed sheets have the advantage that they can be manufactured with greater pre-stressing and consequently compensate also for greater bending loads. The layers of glass sheets positioned upstream can be produced with lesser thicknesses in this way, which acts positively on the total weight of the component.

A particularly preferred variant of the invention is configured such that, in the case of the thermally pre-stressed closure sheet, the ratio between the thickness of the closure sheet and the tensile bending strength of the closure sheet is selected in the range between $1:15 \leq x \leq 50$, preferably $1:20 \leq x \leq 30$. In the case of the chemically pre-stressed closure sheet, this ratio should be selected in the range between $1:50 \leq x \leq 1:1000$, preferably $1:100 \leq x \leq 1:200$. These closure sheets are optimized with respect to their weight and tensile bending strength in such a way that the glass sheets positioned upstream can be designed with relatively small thickness. In this way, the overall component weight of the laminated glass can be optimized.

Glass compositions for the closure sheet that are composed as follows have been demonstrated to be particularly suitable:

Aluminosilicate glass	Composition in mol. %
SiO ₂	63 – 67.5
B ₂ O ₃	0.0 – 7.0
Al ₂ O ₃	10 – 12.5
Na ₂ O	8.5 – 15.5
K ₂ O	0.0 – 4.0
MgO	2.0 – 9.0
CaO + SrO + ZnO	0 – 2.5
TiO ₂ + ZrO ₂	0.5 – 1.5
CeO ₂	0.0 – 0.5
As ₂ O ₃ + Sb ₂ O ₃	0.0 – 0.4
SnO ₂	0.05 – 0.5
F	0 - 1

Alternatively, glass compositions for the closure sheet that are composed as follows have also been demonstrated as suitable:

Lithium aluminosilicate glass	Composition in mol. %
SiO ₂	60 – 70
Al ₂ O ₃	10 – 13
B ₂ O ₃	0.0 – 0.9
Li ₂ O	9.6 – 11.6
Na ₂ O	8.2 - < 10
K ₂ O	0.0 – 0.7
MgO	0.0 – 0.2
CaO	0.2 – 2.3

ZnO	0.0 – 0.4
ZrO ₂	1.3 – 2.6
P ₂ O ₅	0.0 – 0.5
Fe ₂ O ₃	0.003 – 0.100
SnO ₂	0.0 – 1.0
CeO ₂	0.004 – 0.2

In the case of the laminated glass combination according to the invention, intermediate sheets with a thickness in the range of ≥ 4 mm have been demonstrated to be particularly suitable for sufficiently breaking the impact of the projectile.

Several examples of embodiment for the bullet-resistant laminated glasses according to the invention are listed below:

Construction 1 – Bullet resistance BR 2 NS according to DIN EN 1063

Component dimensions 1500 mm x 1000 mm

L No.	Thickness	Material
1	8 mm	Float glass - cover sheet
2	2 mm	Cast resin
3	5 mm	Float glass – intermediate sheet
4	1 mm	Cast resin
5	5 mm	Float glass – intermediate sheet
6	1 mm	Cast resin
7	8 mm	ESG (thermal prestressing ≥ 100 N/mm ²) - closure sheet

Production of laminate:

Principle: Cast resin bonding; JenUV-Pleximer JPM-012-05

Process parameters: UV curing at room temperature; 20 minutes

Testing of the bullet resistance class according to EN 1063: Result: BR 2 NS

Construction 2 – Bullet resistance BR 4 NS according to DIN EN 1063

Component dimensions 800 mm x 800 mm

L No.	Thickness	Material
1	10 mm	Borosilicate glass Boro 33 - cover sheet
2	1.52 mm	PVB film
3	7 mm	Borosilicate glass Boro 33 – intermediate sheet
4	1,52 mm	PVB film
5	7 mm	Borosilicate glass Boro 33 – intermediate sheet
6	0.76 mm	PVB film
7	7 mm	Borosilicate glass Boro 33 – intermediate sheet
8	0.76 mm	PVB film
9	5 mm	Borosilicate glass Boro 33 – intermediate sheet
10	0.76 mm	PVB film
11	5 mm	PYRANC® white (thermal prestressing (≥ 100 N/mm ²) - closure sheet

Production of laminate:

Principle: Bag method; autoclave manufacture

Process parameters: Total duration: 8 hrs. Max. temperature: 150 °C,
Max. pressure, 5 bars

Testing of the bullet resistance class according to EN 1063: Result: BR 4 NS

Construction 3 – Bullet resistance BR 6 NS according to DIN EN 1063

Component dimensions 1000 mm x 2200 mm

L No.	Thickness	Material
1	4 mm	Borosilicate glass Boro 33 - cover sheet
2	1,52 mm	PVB film
3	6 mm	Borosilicate glass Boro 33 – intermediate sheet
4	0.76 mm	PVB film
5	6 mm	Borosilicate glass Boro 33 – intermediate sheet
6	0.76 mm	PVB film
7	6 mm	Borosilicate glass Boro 40 – intermediate sheet
8	0.76 mm	PVB film
9	8 mm	Borosilicate glass Boro 40 – intermediate sheet

10	0.76 mm	PVB film
11	10 mm	Borosilicate glass Boro 40 – intermediate sheet
12	0.76 mm	PVB film
13	12 mm	Borosilicate glass Boro 40 – intermediate sheet
14	0.76	mm PVB film
15	4 mm	LAS 80 (chemical prestressing ≥ 250 N/mm ²) - closure sheet

Production of laminate:

Principle: Bag method; autoclave manufacture

Process parameters: Total duration: 8 hrs. Max. temperature: 150 °C,
Max. pressure, 5 bars

Testing of the bullet resistance class according to EN 1063: Result: BR 6 NS

Construction 4 -- Bullet resistance BR 2 NS according to DIN EN 1063 and explosion resistance ER 4 NS according to DIN EN 13541

Component dimensions 900 mm x 1100 mm

L No.	Thickness	Material
1	5 mm	Borosilicate glass - cover sheet
2	0.38 mm	PVB film
3	7.5 mm	Borosilicate glass – intermediate sheet
4	0.38 mm	PVB film
5	5 mm	Borosilicate glass – intermediate sheet
6	0.76 mm	PVB film
7	5 mm	PYRAN® S - closure sheet

Production of laminate:

Principle: Bag method; autoclave manufacture

Process parameters: Total duration: 9 hrs. Max. temperature: 145 °C,
Max. pressure: 5 bars

Testing of the bullet resistance class according to EN 1063: Result: BR 2 NS

Testing of the explosion resistance class according to EN 13541: Result: ER 4 NS

Construction 5 – Bullet resistance BR 7 NS according to DIN EN 1063

Component dimensions 500 mm x 500 mm

L No.	Thickness	Material	[%]	[%]	Total
1	7.5 mm	Borosilicate glass - cover sheet	11.8	11.8	100.0
2	0.38 mm	PVB film	0.6	12.4	88.2
3	7.5 mm	Borosilicate glass – intermediate sheet	11.8	24.3	87.6
4	0.38 mm	PVB film	0.6	24.9	75.7
5	7.5 mm	Borosilicate glass – intermediate sheet	11.8	36.7	75.1
6	0.76 mm	PVB film	1.2	37.9	63.3
7	9 mm	Borosilicate glass – intermediate sheet	14.2	52.1	62.1
8	0.38 mm	PVB film	0.6	52.7	47.9
9	7.5 mm	Borosilicate glass – intermediate sheet	11.8	64.5	47.3
10	0.38 mm	PVB film	0.6	65.1	35.5
11	5 mm	Borosilicate glass – intermediate sheet	7.9	73.0	34.9
12	0.76 mm	PVB film	1.2	74.2	27.0
13	8 mm	AS 87 - intermediate sheet	12.6	86.8	25.8
14	0.38 mm	PVB film	0.6	87.4	13.2
15	8 mm	AS 87 - closure sheet	12.6	100.0	12.6
Total	63.42		100		

Production of laminate:

Principle: Bag method; autoclave manufacture

Process duration: Total duration: 8 hrs. Max. temperature: 150 °C,

Max. pressure: 5 bars

Testing of the bullet resistance class according to EN 1063: Result: BR 7 NS

Construction 6 – Bullet resistance BR 6 NS according to DIN EN 1063

Component dimensions 500 mm x 500 mm

L No.	Thickness	Material	[%]	[%]	Total
1	9 mm	Borosilicate glass – intermediate sheet	17.8	17.8	100,0
2	0.76 mm	PVB film	1.5	19.3	82.2
3	9 mm	Borosilicate glass – intermediate sheet	17,8	37.0	80.7
4	0.38 mm	PVB film	0.8	37.8	63.0
5	9 mm	Borosilicate glass – intermediate sheet	17.8	55.5	62.2
6	0.38 mm	PVB film	0.8	56.3	44.5
7	8 mm	AS 87 - intermediate sheet	15.8	72.1	43.7
8	0.76 mm	PVB film	1.5	73.6	27.9
9	8 mm	AS 87 - intermediate sheet	15.8	89.4	26.4
10	0.38 mm	PVB film	0.8	90.1	10.6
11	5 mm	AS 87 - closure sheet	9.9	100.0	9.9
Total	50.66	100			

Production of laminate:

Principle: Bag method; autoclave manufacture

Process parameters: Total duration: 8 hrs. Max. temperature: 145 °C,
Max. pressure: 6 bars

Testing of the bullet resistance class according to EN 1063: Result: BR 6 NS

In the above-described constructions, a commercially available type of glass is employed as borosilicate glass, as can be obtained, for example, under the trade names BOROFLOAT® 33 and BOROFLOAT® 40 of Schott AG. Chemically pre-stressed types of glass are described, such as AS 87 and LAS 80 that can be

obtained under the trade names SCHOTT® AS87 and SCHOTT® LAS80 of Schott AG.

PYRAN® S and PYRAN® white are trade names of pre-stressed borosilicate glasses obtainable from Schott AG.

In all of the above-described constructions, the stated borosilicate glasses employed always involve glasses that are not pre-stressed. In particular, the cover sheet is formed by a glass that is not pre-stressed. This has the advantage that in the case of a bullet test according to DIN EN 1063, an impact triangle is formed; the first hit does not greatly splinter the cover sheet. In particular, a splinter pattern that extends into the region where subsequent hits occur does not arise. A high bullet resistance is thus offered in this way.

In the constructions, pre-stressed glasses having a thickness of > 4 mm (thermally pre-stressed) or of > 3 mm (chemically pre-stressed) are always employed for the closure sheet. Starting from these glass thicknesses, a high resistance against splinter output on the back side is achieved, as can be seen from the preceding tables.

Only one pre-stressed sheet is used (closure sheet) in the constructions 1 to 4.

Constructions 5 and 6 use another pre-stressed intermediate sheet (AS 87 — intermediate sheet) adjacent to the pre-stressed closure sheet. In principle, other or all intermediate sheets may also be pre-stressed. Of course, it is advantageous if all pre-stressed intermediate sheets are disposed on the tensile side of the laminated glass. Therefore, they should be disposed behind the mid-point transverse plane of the laminated glass, facing away from the impact side. There, they can optimally decompose bending stresses in the laminated glass when impacted by a projectile. For this reason, the closure sheet should also always be completely disposed behind the mid-point transverse plane in the laminated glasses according to the invention.

The pre-stressed glass parts should thus extend at maximum up to half the total component thickness of the laminated glass. It has been shown that extending the pre-stressed glass parts even up to one-third of the total component thickness offers excellent resistance to bullets and also reliably protects against explosion effects.

The invention will be explained in further detail on the basis of examples of embodiment shown in the drawings.

Figure 1 shows in a schematic representation and in lateral view a bullet-resistant laminated glass 10, which is composed of three glass sheets. In this case, a cover sheet 11 that is backed by means of an intermediate sheet 12 is provided facing the impact side A, i.e., the side that is subjected to the projectile. A closure sheet 13 is connected to the intermediate sheet 12 on the back side, facing away from the impact side A. These three glass sheets (cover sheet 11, intermediate sheet 12 and closure sheet 13) are connected to one another by means of composite layers 14. In this case, the composite layers 14 are formed from flexible films, preferably polyvinylbutyral films. The composite layers 14 are heated in the autoclave process and the glass sheets are pressed together under pressure. The glass sheets can be bonded to one another in this way.

Whereas the cover sheet 11 and the intermediate sheet 12 are composed of non-pre-stressed glass, the closure sheet 13 is formed by a thermally or chemically pre-stressed glass material. As can be recognized in Figure 1, the side of the closure sheet 13 facing away from the impact side A is neither provided with a coating, nor is it backed by means of a cover layer.

Figure 2 shows in a schematic representation and in lateral view the bullet-resistant laminated glass according to the construction 6 described above. As can be recognized from this presentation, the two pre-stressed glasses (AS 87) are disposed behind the mid-point transverse plane M, which extends parallel to the two end faces of the laminated glass 10, and face away from the impact side A.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A bullet-resistant laminated glass having at least three sheets of glass, wherein one of the glass sheets faces the impact side (A) as a cover sheet, and one glass sheet that faces away from the impact side (A) is formed as a closure sheet, wherein one or more intermediate sheets are disposed between the cover sheet and the closure sheet, wherein the glass sheets are connected to one another by composite layers, which are formed by flexible and dimensionally unstable films and/or cast compounds, and wherein the closure sheet is formed as a thermally or chemically pre-stressed glass sheet, wherein the cover sheet and the one or more intermediate sheets are composed of non-pre-stressed glass, wherein the thermally pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and the tensile bending strength of the closure sheet in the range between $1:15 \leq x \leq 1:50$, or wherein the chemically pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and a tensile bending strength of the closure sheet in the range between $1:50 \leq x \leq 1:1000$, and wherein the closure sheet has a thickness in the range of 4 to 10 mm.
2. The bullet-resistant laminated glass according to claim 1, further comprising that the closure sheet has a glass material that closes the bullet-resistant laminated glass and no foil and/or film is applied on the outside onto the closure sheet.
3. The bullet-resistant laminated glass according to claim 1 or 2, wherein the cover sheet and at least one intermediate sheet have a greater thickness than the closure sheet.
4. The bullet-resistant laminated glass according to any one of claims 1 to 3, wherein the cover sheet, intermediate sheet, and closure sheet are formed by a

glass which is a borosilicate glass, a soda-lime glass, an aluminosilicate glass, a lithium aluminosilicate glass, or any combination thereof.

5. The bullet-resistant laminated glass according to any one of claims 1 to 4, wherein at least one composite layer is formed by one or more films.

6. The bullet-resistant laminated glass according to any one of claims 1 to 5, wherein at least one composite layer has a thickness of less than 2 mm.

7. The bullet-resistant laminated glass according to any one of claims 1 to 6, wherein the closure sheet has a tensile bending strength that is 100 N/mm².

8. The bullet-resistant laminated glass according to any one of claims 1 to 7, wherein a glass composition (mol %) of the closure sheet is selected as follows:

Aluminosilicate glass

SiO ₂	63 - 67.5
B ₂ O ₃	0.0 - 7.0
Al ₂ O ₃	10 - 14.0
Na ₂ O	8.5 - 15.5
K ₂ O	0.0 - 4.0
MgO	0 - 9.0
CaO + SrO + ZnO	0 - 2.5
TiO ₂ + ZrO ₂	0 - 1.5
CeO ₂	0.0 - 0.5
As ₂ O ₃ + Sb ₂ O ₃	0.0 - 0.4
SnO ₂	0.05 - 0.5
F	0.0 - 1.0.

9. The bullet-resistant laminated glass according to any one of claims 1 to 8, wherein one of the one or more intermediate sheets has a thickness in the range of ≥ 4 mm.

10. The bullet-resistant laminated glass according to any one of claims 1 to 9, further comprising at least one more intermediate sheet that is formed as a thermally or chemically pre-stressed glass sheet.

11. The bullet-resistant laminated glass according to claim 10, wherein the closure sheet and/or all other thermally and/or chemically pre-stressed intermediate sheets are disposed behind the mid-point plane of the laminated glass, facing away from the impact side (A), and are disposed parallel to the two end faces formed by the cover sheet and the closure sheet.

12. The bullet-resistant laminated glass according to claim 10, wherein the closure sheet, the thermally and/or chemically pre-stressed one or more intermediate sheets and the composite layers have a total thicknesses that is less than or equal to half the total thickness of the laminated glass.

13. The bullet-resistant laminated glass according to any one of claims 1 to 12, wherein the cover sheet and/or at least one of the one or more intermediate sheets is disposed in front of the mid-point transverse plane facing the impact side (A) and is formed by a non-pre-stressed glass material or a glass ceramic or the cover sheet and all of the one or more intermediate sheets are formed by a non-pre-stressed glass material or a glass ceramic.

14. The bullet-resistant laminated glass according to any one of claims 1 to 13, wherein the glass composition (mol %) of the closure sheet is selected with the following molar ratios:

SiO ₂ /Al ₂ O ₃	5.0 - 6.8
Na ₂ O/K ₂ O	2.1 - 12.0
Al ₂ O ₃ /K ₂ O	2.5 - 12.0
Al ₂ O ₃ /Na ₂ O	0.6 - 1.5
(Na ₂ O + K ₂ O)/(MgO + CaO + SrO)	0.95 - 6.5.

15. A bullet-resistant laminated glass having at least three sheets of glass, wherein one of the glass sheets faces the impact side (A) as a cover sheet, and one glass sheet that faces away from the impact side (A) is formed as a closure sheet, wherein one or more intermediate sheets are disposed between the cover sheet and the closure sheet, wherein the glass sheets are connected to one another by composite layers that are not composed of polycarbonate, polyurethane or polymethyl methacrylate, and wherein the closure sheet is formed as a thermally or chemically pre-stressed glass sheet, wherein the cover sheet is composed of non-pre-stressed glass and wherein the pre-stressed glass sheet extends at maximum up to half the total thickness of the laminated glass, wherein the thermally pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and the tensile bending strength of the closure sheet in the range between $1:15 \leq x \leq 1:50$, or wherein the chemically pre-stressed closure sheet is selected and has the ratio (x) between the thickness of the closure sheet and a tensile bending strength of the closure sheet in the range between $1:50 \leq x \leq 1:1000$, and wherein the closure sheet has a thickness in the range of 4 to 10 mm.

16. The bullet-resistant laminated glass according to claim 15, further comprising the closure sheet has a glass material that closes the bullet-resistant laminated glass and no foil and/or film is applied on the outside onto the closure sheet.

17. The bullet-resistant laminated glass according to claim 15 or 16, wherein the cover sheet and at least one intermediate sheet have a greater thickness than the closure sheet.

18. The bullet-resistant laminated glass according to any one of claims 15 to 17, wherein the cover sheet, intermediate sheet, and closure sheet are formed by a glass which is a borosilicate glass, a soda-lime glass, an aluminosilicate glass, a lithium aluminosilicate glass, or any combination thereof.

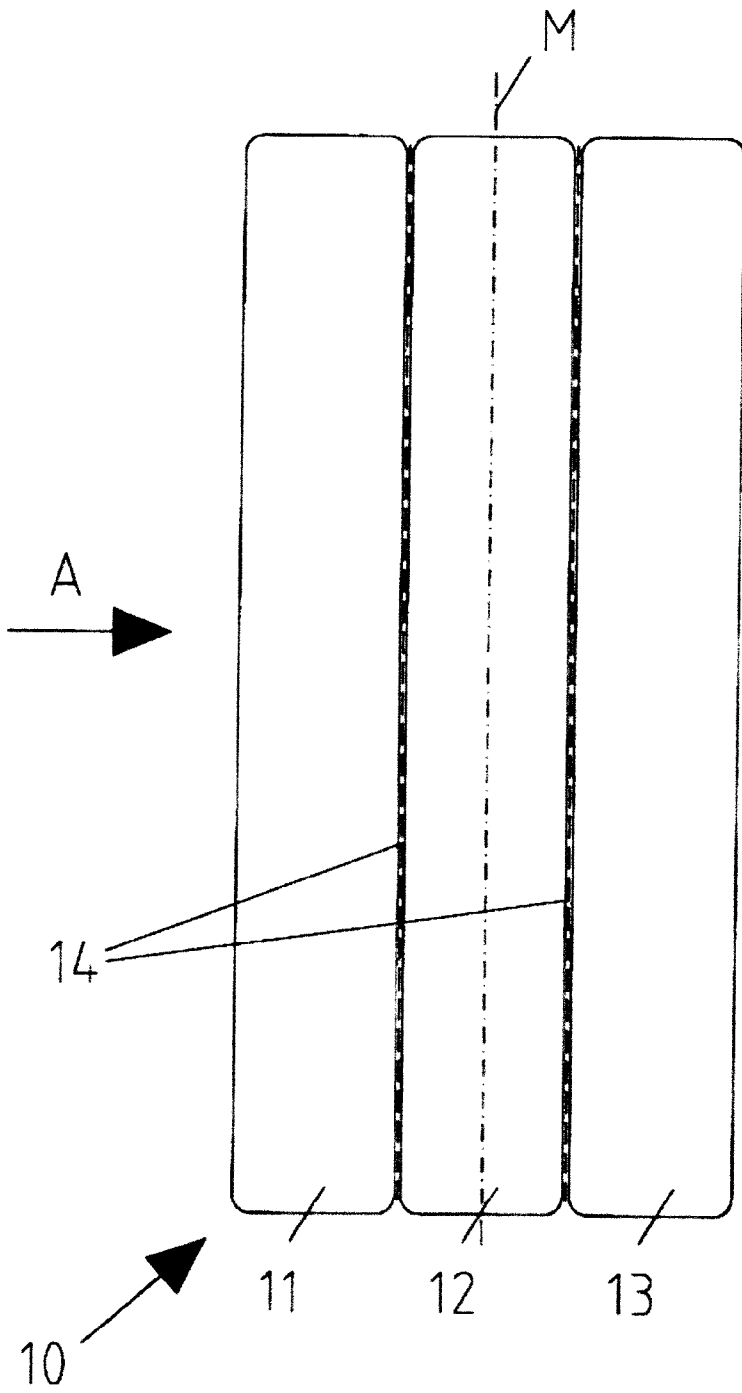


Fig. 1

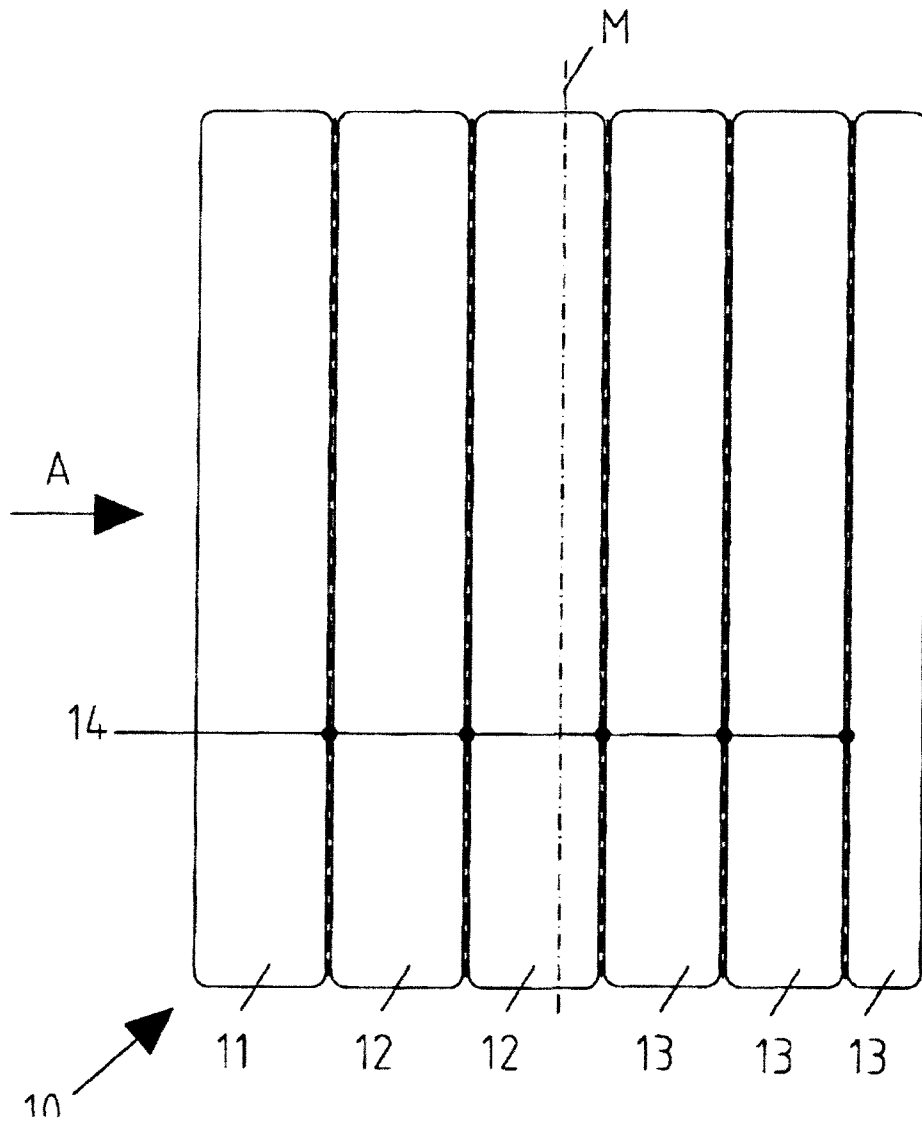


Fig. 2

A



M



14



10



11

12

13

