Title: ANTI SPALLING GLASS CONSTRUCTION

Abstract: There are disclosed glazing cross section constructions and the relevant concept for an transportation armoured ballistic construction having improved durability, anti spalling and ballistic performances. These constructions comprise one or more than one thin chemically strengthened glass plies that can be soda-lime, borosilicate or aluminoisilicate. Said chemically strengthened glass ply will be manufactured with a suitable residual stress profile that prevent or limits the effect of splinters projection in case of ballistic impact and improve the overall ballistic performances of the glazing.
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.
1. Description

2.1. Field of the invention

Armoured glazing constructions has as main objective to provide protection against ammunition of a defined type and energy/velocity characteristics. The most important applications include military and civil vehicles, cash & transit vehicles, marine ships, aircrafts and government buildings and all of these can be either flat or curved. These glazing constructions and specially the transportation ones must comply with a series of basic functional requirements as a) high scratch/abrasion resistance b) high durability under environmental conditions b) free splinter projection (anti-spall) c) residual field of vision d) minimum weight e) minimum thickness and f) optical quality (free of distortions).

The anti-spall protection requirement is critical because the splinters projected to the internal environment to be protected have such a high energy that they are normally more devastating than even the bullet itself. Along with the previous statement the glass industry has developed two basic ways to reduce the severity of this problem i) incorporating a polymeric ply adhered to the rear most face of the armour construction facing the environment to be protected which brings several difficulties in the manufacturing processes, in the optical performance (distortion and double vision effect) and in the scratch resistance of the armoured construction, in the chemical stability under a lot of substances and worst, in the durability of its surface by the small hardness and ii) Multi layered glass and plastic construction with an increased thickness (regularly 2 times thicker than the most efficient compositions available of i). By increasing the total thickness of the armoured construction, this prevents the breakage of the last glass layer because all the energy is absorbed in the previous layers. The main weaknesses of this solution are a much heavy, thicker and less functional construction, making this solution the less common in the market nowadays. Summarizing, up to today no constructions gives an effective solution for the problem of having an efficient BRG construction.
achieving the mechanical durability and chemical stability requirements that demand the transportation application.

This invention covers new and improved cross sections based on one or more thin chemically strengthened glasses to improve the splinter projection protection performances, to optimise the ballistic behaviour of the glazing, to extend the life span of the product and to achieve a considerable reduction on the complexity of the actual manufacturing techniques which finally reflects on a lower production cost.

2.2 - Description of the prior art

It is known that splinter projection resulting from armoured glass after a ballistic impact is a major problem potentially producing injuries to people protected by the glazing itself. Splinters are projected as a result of the ballistic impact because, after breakage of the glass layer facing the not impacted side, glass fragments from this layer can be detached out and still having enough kinetic energy to be projected towards the internal environment (see figure 1 for terminology description). In this way, even if the object which caused the ballistic impact (a bullet for anti-bullet glazing or any massive element projected intentionally or accidentally towards the glazing) did not penetrate the glazing entering the environment to be protected, the glass splinters generated as a result of the impact may be potentially very dangerous. To prevent this problem several solutions have been used in the bullet resistant glass (BRG) applications all based on the substitution of the inner layer of the glazing construction with a polymeric material that can be a thick layer (normally Polycarbonate) or in other embodiments a plastic film (Polyethylene Thereftalate – PET) in any case laminated with the main glass layers cross section. This solution solve the spalling problem because it prevents splinters to be projected from the inside of the glazing. Even if this solutions may be effective towards the splinters projection other problems are generated because of the plastic/polymeric nature of the inner layer of the armoured glass cross section. Optical, mechanical, chemical compatibility and durability problems come out because of the physical and chemical properties of these inner plastic layers. The most effective protection against
splinters projection is offered by Polycarbonate, this material has a great impact resistance and it is the most used solution in the armoured glass applications. Nevertheless Polycarbonate is very sensitive to scratches, abrasion effects and if not suitably coated in a very short time it can become hazy because of scratches and abrasions and also because of stress crazing induced by coupled mechanism of chemical attack (coming from solvent and chemicals of sealants and adhesive materials used in glazing assembly) and tensile condition. Its surface cannot be re-generated, that means that an anti scratch coating has to be always considered when using Polycarbonate as an inner layer of an armoured glass. The other problem related to Polycarbonate is its great sensitivity to chemical attack from agents as solvents, lubricants and many chemicals. This chemical attack when coupled with a mechanical stress situation produce a crazing effect on the Polycarbonate surface (stress-crazing). The other problem connected with Polycarbonate is coming from the difference in the thermal expansion coefficient (TEC) with glass (Polycarbonate TEC = 7*10^-5/°K; Soda/Lime Glass TEC = 8.9*10^-6 1/°K at room temperature) this means that lamination processes should be performed with suitable interlayer materials that compensate the differences in the TEC between the two materials and also is chemically compatible with the Polycarbonate (Polyurethane interlayers are normally used). This last point creates another problem because normally glass layers are laminated with PVB (Polyvinyl Butyrral film) which has in general a different lamination temperature of Polyurethane. Optical problems like images distortion and deformation and double images may arises from the need of polycarbonate as an inner splinter protection layer. All these problems make the Polycarbonate not supply completely all the properties required by its application as an anti spalling layer in transportation BRG glazing constructions.

Similar mechanical, optical and maybe at a less extent chemical problems result from the use of PET films as inner splinter protection layers. Coated PET is maybe less sensitive to chemical attack than Polycarbonate but its ballistic and splinters protection performances are far less effective than Polycarbonate and there is not a cross section advantage (in terms of weight and thickness) of using PET instead of Polycarbonate. Another problem common to any polymeric splinter protection solution is that environmental conditions like ultraviolet solar radiation, temperature excursions and
water vapour coming from the atmosphere may cause a durability issue causing a significant reduction in the material lifetime.

In either ways, using Polycarbonate and/or PET, a buffer or cover plate, usually being of soda lime glass must be used on top of the inner surface of said polymer within the manufacturing process (autoclave cycle) to achieve a relatively high flatness of the surface of said polymer and a good optical quality but, in the other hand, having an additional glass represents higher costs on raw materials, longer bending and autoclave processes and increased hand labour, reworks and rejected product on production, decreasing the productivity. All these reasons explain the need of having a ballistically efficient and mechanical and chemically durable solution for our transportation application.

Some Patents can be found in the patent literature that claim partial solutions to this problem:


Field of application: Armoured Anti Bullet Glazing
Cross Section Concept: Single glazed composite element

They claim a three sections cross-section concept of their construction namely: the impact striking section, the transition section and the impact absorption section.
They claim a glass as innermost sheet (in the impact absorption section) to minimize spall effect but they claim only one glass layer with a thickness of 1.98 mm (2 mm) and they do not mention even a normal chemical strengthening treatment. Our Patent introduces a different concept of multi-layered impact (anti-spall section), made of thin (< 0.7 mm and preferred 0.4 mm) specially chemically strengthened glasses. Today very thin (below 1 mm) glass is available and chemical strengthening possibilities are fully understood. So the elements that differentiate our patent with these two is the use of specially tailored
chemically strengthened thin glass that solve efficiently (with a considerable lower thickness) the anti-spall problem in an armoured glass construction.

US PATENT 4,312,903 (Molari, 1982)

Field of application: Armoured Anti Bullet Glazing
Cross section concept: Double glazed element

This patent is limited in all its parts to double glazed structures to solve the spall problem. Even if they consider to use partially thin glass laminate (0.7 to 5.1 mm) they never mention chemical strengthening. Also because of the double glazed structure it will be nearly impossible or at least impractical to consider it for curved armoured windscreens or sideteles and also this solution will present plenty of optical problems in armoured transportation applications.

US PATENT 4,595,624 (Greathead, 1986)

Field of application: Laminated anti-bandit glazing
Cross section concept: Single glazed composite element

In US Patent 4595624 they speak of chemically strengthened glass as strength element and also relates it to the ability to reduce the spall problem, anyway there are several points to be considered:

This patent is related to security glazing for anti-bandit applications and all examples and embodiments are referred to this type of manual attacks as hammers, pick-axes, crowbars, bricks, it can be seen that the lower spall generated by the impacts on their preferred embodiments is rated between 13 gr. and more than 200 gr.; it is important to understand that for BRG applications the weight for the total spall generated is more than 500 times lower, it is impossible to have a BRG construction with the level of spall shown on the mentioned patent, this spall would destroy the witness foil of the standard
ballistic test and would cause as much injures as the caused by the bullet by itself. So, it is evident that the claimed construction of the mentioned patent is far away from the field of application of our invention.

In their claim 1 they speak of "a rearmost glass layer no more than 2 mm thick .." that means 1 layer. And also they claim (always on claim 1) that this rearmost glass "resists spalling" that means it does not break, while we allow breakage of this layer with no spall effect and this is only possible with a thickness less than 0.7 mm and a specially tailored stress profile.

They speak about producing the claimed composition using Polyvinyl Butyral as bonding material, it is important to understand that a composition that only uses Polyvinyl Butyral as an adherent is restricted to not use most of the commercial impact energy absorbers, as Polycarbonate, by the chemical incompatibility, so, the last solution of having this kind of construction as a BRG is with an extremely heavy composition. It is evident that its invention is not designed for transportation BRG compositions.

Additionally, the lowest thickness for its rearmost glass is 16% of the thickness of the thicker one in the composition; in our invention we are considering a thin glass with thickness less than 0.7 mm and preferred 0.4 mm whose thickness is much lower than 16% of the thickest glass on a typical construction (thickest glass on a BRG composition is ranged between 6 and 15 mm).

Finally they do not fully understand how the glass should be chemically strengthened to prevent significant spalling effect (thin glass with a very deep case depth).

US Patent 6,156,417 (Edwards, d’Hooghe, 2000)

Field of application : Anti-intrusion glazing (not armoured nor anti-bullet)
Cross section concept : Lightweight Single glazed composite element (thickness < 6 mm)
This patent is outside our specific application field, even if they consider application of thin glass (0.7 to 2 mm) because they consider this only for weight reduction and not for armoured anti bullet no-spall applications.

They do not mention chemical strengthening at all.

US PATENT 6,265,054 B1 (2001)

Field of application : Lightweight automotive glazing
Cross section concept : Lightweight Single glazed composite element (thickness < 5 mm)

Even for this case the situation is similar as the one we discussed above for patent 6,156,417. Here they consider even to use thinned glass (0.5 mm) but again for weight reduction and not for armoured anti bullet no-spall applications. Chemical strengthening is not mentioned.

Other Patents like DE 3 42 1 571 related to the US 5,496,643 (Von Alpen) introduces traditional cross section designs with a rearmost layer of polycarbonate coated with a self healing polymer that again presents problems with abrasion resistance, chemical resistance and compatibility, our solution based on a completely inorganic (chemically strengthened glass) rearmost layer(s) solve this problem and also present advantages about the problem of the different thermal expansion of the layers that should be compensated with some intermediate metallic film.

Traditional manufacturing techniques based on separate bending and laminating processes (because of the utilization of different materials for the plies and for the plastic interlayers) takes time and are pretty expensive, this new solution improve the logistic and economy of these manufacturing processes eliminating some critical passages as well as eliminates the need of an additional cover plate for the inner surface polymer reducing raw material costs, bending and autoclave processes and hand labour.
It is an object of this invention to provide a new efficient solution for the splinters projection problem in transportation bullet resistant glass, optimising the anti spalling cross section design in terms of weight (mass per unit area) and thickness reduction, but without generating other mechanical (scratches, abrasion) or chemical durability (materials compatibility) or optical problems or problems on its production characteristics of transportation bullet resistant glasses.

2.3 – Brief Description of the Drawings

Figure 1 - Ballistic impact on an armoured glazing
Figure 2a – Residual Stress Profile of a Thick Chemically Strengthened Glass
Figure 2b – Residual Stress Profile of a Thin Chemically Strengthened Glass
Figure 3a – Cross Section of a Single Thin Chemically Strengthened Glass Ply
Figure 3b – Cross Section of a Multiple Thin Chemically Strengthened Glass Plies system
Figure 3c - Cross Section of Single or Multiple Thin Chemically Strengthened Glass Plies system coupled with an inner plastic impact energy absorber

2.4 - Summary of the Invention

The concept that underlay this invention is that an inorganic scratch resistant and chemically inert material has to be used as the protecting ply against splinter projection (anti spall or no spall layer) in order to achieve the durability requirements demanded by the transportation application and keeping an efficient ballistic performance (as for total thickness vs. ballistic resistance). In accordance with this invention, glass itself is the material to be used as the last inner layer in an armoured glazing construction. This is because glass has an abrasion, scratches and chemical resistance far superior to any polymeric, plastic material (see Table 1).

Table 1 – Abrasion resistance comparison in terms of Percent of Haze increase

<p>| Abrasion Test – Taber Abraser 100 Cycles | 8 |</p>
<table>
<thead>
<tr>
<th>Uncoated Polycarbonate</th>
<th>Coated Polycarbonate Martec®</th>
<th>Coated PET Spallshield®</th>
<th>Coated Polycarbonate HYZOD®</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 %</td>
<td>2-4 %</td>
<td>0.7 %</td>
<td>0.8 %</td>
<td>0.5 %</td>
</tr>
</tbody>
</table>

Even though the above table shows a significant difference between glass and any of the mentioned polymers, when the Taber Abraser test is performed with more than 100 cycles (500 and 1000) the difference grows considerably.

It is known that thermally tempered glass breaks in small fragments when broken but this is not a good solution for armoured ballistic glazing as splinter protection because:

1. it prevents residual vision when broken,
2. it cannot be fully tempered down to a thickness below 2.5 mm (with these thickness splinters are still large enough to produce injuries when projected with high kinetic energy)

It is known that chemically strengthened glass by ion-exchange has a far superior impact resistance when compared with thermally tempered glass, and the ion-exchange process, which is a surface inter diffusion process, has no limitations in terms of glass thickness. This means that it is possible to produce very thin layers (thickness down to 0.03 mm) of chemically strengthened glass offering:

1. a superior impact resistance
2. a large bending capability without breaking
3. in case of breakage residual vision and breaking fragments can be tailored to avoid large splinters to be projected (only small tiny fragments and powder are generated)

The chemical strengthening process introduces in the glass a residual stress profile with a compression layer on the surfaces and an inner tensile area. Fragmentation after breakage can be controlled to some extent by controlling the ion-exchange process parameters
resulting in suitable values of the compression layer depth (Case depth \( C_D \)), surface compression (\( S_C \)), and central tension (\( \tau \)) (see Figure 2). The leading ideas in using thin CS glass in armoured constructions are:

1. Having a chemically strengthened thin glass (less than 0.7mm and preferred 0.4mm thickness) as the inner layer, so that the construction have the mechanical durability and the chemical stability of a glass.
2. Use a thin CS glass as inner layer that breaks in very tiny fragments that produce no injury still maintaining a residual vision after breakage.
3. Use a system of CS layers as last layers in an armoured glazing construction that offers subsequent ballistic and splinters protection according to the requested levels.
4. Use a system of Chemically Strengthened layer(s) as an anti splinter projection construction, with thickness comparable and even smaller than the thickness normally used in actual anti spalling constructions, allowing the armoured construction be more efficient as for relation thickness / durability and ballistic performance.

The key point in obtaining the results is in the possibility of tailoring the residual stress profile in order to achieve the envisaged bending/impact strength and the fragmentation behaviour (see figure 2b). Original glass strength, surface compression and case depth controls the impact/bending strength while the internal tension and glass thickness control the fragmentation behaviour. Let us explain in more detail the effect on the fragmentation of thin Chemically Strengthened glass. Normally in laminated glazing glass plies have a minimum thickness of 2 - 2.5 mm. Down to 2 mm it is even no more possible to induce a residual stress profile by thermal tempering. Thermal tempering has the advantage to induce a compression layer of 20% of original glass thickness resulting in a pretty high inner central tension that means enough energy to generate tiny fragmentation upon glass breakage. The compression layer depth introduced in soda-lime float glass by ion-exchange chemical strengthening is typically ranging from 10 \( \mu \text{m} \) to 50 \( \mu \text{m} \). With a 30 \( \mu \text{m} \) compression layer depth on a 2 mm (2000 \( \mu \text{m} \)) glass the compression
depth over thickness ratio is 1.5 % and the resulting fragmentation is coarse because of the low inner tensile stress. If we reduce the glass thickness down to 0.5 mm (500 μm) the compression depth over thickness become 6 % and considering that surface compression will be increased of at least 3 times (300 MPa) over the surface compression of a thermally tempered glass (100 MPa) we get an increase in the inner tensile level resulting in a tiny fragmentation behaviour upon glass breakage. From another point of view the increased ultimate tensile strength (MOR) of chemically strengthened glass (250 MPa) versus thermally tempered glass (150 MPa) allows a significant deformation of chemically strengthened glass without breakage. This effect of increased internal tensile stress (which generates the tiny fragmentation) can be understood and described (see figures 2a and 2b) as follows: let us consider in figure 2 a normal thick glass (3 mm = 3000 μm) chemically strengthened, with a compression layer depth of 30 μm. The inner part of the glass (2940 μm) will be interested by a pretty low tensile stress and, upon breakage, large fragments will be generated. Now, if we imagine to squeeze the glass thickness down to 0.5 mm (500 μm), as the compressed part of the near surface glass will remain the same (because ion-exchange is a surface inter diffusion process), the inner tensile region will be reduced to 500-60 = 440 μm against the original 2940. This will modify the inner tensile stress increasing it is a significant way and generating (upon glass breakage) tiny fragmentation.

Another approach which is covered by the present invention is to introduce a plastic core ply as an outer layer of the anti spalling construction, that can be any low or high modulus polymer from Polycarbonate, to thick (0.13-25 mm) PVB to thick polyurethane (0.13-25 mm), to Polyethylene ionomer, Acrylic, EVA, Polyethylene therefaltate PET, to any ionomeric modification of said polymers like Surlyn (Sentry Glas Plus) that, in this case, it is not affected by surface scratch problems as an energy impact absorber and an inner (facing the internal environment in accordance with figures 3a and 3b) controlled injury free splinter projection system consisting in a thin chemically strengthened glass layer or layers which may be treated with a coating process like silk-screening, CVD, PVD, Sputtering, sol-gel, painting or masking among others. The different systems will be accordingly used for the different ballistic protection levels required.
The underlying concept of the invention is that the armoured glazing cross section should be divided in two parts:

A. Front most part facing the impact, this part has the purpose to break or deviate the bullet and to have a first stopping power and consist of multi-plies of thick (2-25mm) annealed glass.

B. Rearmost part facing the environment to be protected, has mainly the purpose of absorbing the residual impact energy without splinter projection towards the environment.

As it can be easily understood this invention is related to the part B. of the cross section.

There are several ballistic requirements based on international standards like:

Comite European de Normalization (EN - 1063), Underwriters Laboratory (UL - 752), and National Institute of Justice (NIJ – 0108.01).

Normally these requirements are assessed by ballistic tests described in the above mentioned standards. A typical ballistic test (EN 1063) describe all the necessary conditions to perform the ballistic attack (Bullet type and weight, bullet velocity, number of strikes (typically 3) and striking distance, striking points – hit spacing (normally are the vertex of an equilateral triangle) samples number (typically 3 samples have to be tested), sample mounting system, and witness aluminium foil (0.02 mm thickness mass density 54 g/m²).

2.5 - Description of the preferred embodiments

According with this invention there will be three general preferred embodiments :
1. Single chemically strengthened construction with controlled injury free splinter projection (facing internal environment according to Figure 3a) of an armoured cross section.

In this embodiment a single thin glass layer will be considered in the cross section of the armoured glazing as the external layer facing the environment to be protected. This ply will have the impact/bending strength sufficient to withstand the requested level of ballistic protection. The ply will have a chemical strengthening process with its central tension being tailored to release injury free splinters without generating perforations on the aluminium witness foil of the respective standard(s) ballistic test(s) for the given ballistic level. The thin glass may be treated with a coating process like silk-screening, CVD, PVD, sputtering sol-gel, painting or masking among others, in order to keep a residual vision through the armoured construction after the first and subsequent shots based on the pre-defined ballistic level. The single thin glass may have some of the following compositions: Soda Lime, Borosilicate or Aluminosilicate or may be a layer of Aluminium Oxynitride, Magnesium Aluminate, Aluminium Oxide or some other armour ceramic.

2. Multiple Thin Glass Chemically Strengthened plies system composing a construction with controlled injury free splinter projection (facing internal environment according to Figure 3b) of an armoured cross section.

In this embodiment a system of multiple thin glass layers will be considered in the cross section of the armoured glazing as the external layer facing the environment to be protected. Each ply of the system will have the impact/bending strength sufficient to withstand the requested level of ballistic protection. The one or more plies of the embodiment will have a chemical strengthening process in order that the multiple plies system be tailored to release injury free splinters without generating perforations on the aluminium witness foil of the respective standard(s) ballistic test(s) for the given ballistic level. In this construction, one or more plies may be treated with a coating process like silk-screening, CVD, PVD, sputtering sol-gel, painting or masking among others, in order
to keep a residual vision through the armoured construction after the first and subsequent shots based on the pre-defined ballistic level. The thin glass plies system may have some of the following compositions: Soda Lime, Boro or Aluminosilicate or may be composed by plies of Aluminium Oxynitride, Magnesium Aluminate, Aluminium Oxide or some other armour ceramic or their combination.

3. Single or Multiple construction with controlled injury free splinter projection (as described in 1 and 2) Coupled with a polymeric impact energy absorber (according to figure 3c).

In this embodiment a system composed by single or multiple thin glass layers will be considered as the external layer facing the environment to be protected in the cross section of the armoured glazing coupled with an intermediate plastic energy absorber which may be composed by one or more plies of polymeric materials. Each ply of the system will have the impact/bending strength sufficient to withstand the requested level of ballistic protection. The central tension of the last ply facing the environment will be tailored to release injury free splinters without generating perforations on the aluminium witness foil of the respective standard(s) ballistic test(s) for the given ballistic level.

The decision of placing one layer of chemically strengthened glass or a multi ply system will vary depending on the level of ballistic protection requested and requirements to keep a residual vision through the armoured construction after the first and subsequent shots.

The front most section is a construction composed by one or more plies of inorganic components with an individual thickness between 0.03 and 25mm.

The layer or multiple layers of polymer connecting the rearmost section (single or multiple plies chemically strengthened glass) to the intermediate and to the front most section should be with a thickness from 0.13 up to 12 mm and the polymeric material can be: PVB (Polyvinyl butyral), Polyurethane, Thermoplastic Polyurethane, Polycarbonate,
Acrylic, EVA, Polyethylene Thereftalate, Polyester (PET), Polyethylene ionomer, Surlyn (Sentry Glas Plus), acrylic resin and any Ionomeric modification of said polymers.

Within the possible embodiments it should be considered a glazing construction wherein metallic substrates, plates, meshes or fibbers can be attached to the edge of said construction for protection purposes within that said region of the window.

In the next table can be seen the average weight for the total spall generated in a BRG construction with different options for its anti spalling glazing construction. The test was performed in accordance with the standard NIJ 0108.01 for a given level of ballistic resistance.

**Table 2.**

<table>
<thead>
<tr>
<th>Group of Samples (different anti spalling constructions)</th>
<th>Average weight (gr.) of the total spall generated on each sample for a given level of ballistic resistance</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,4ATG/0,62PU/0,4CSTG(1)</td>
<td>0,85</td>
<td>4 Foil penetrations</td>
</tr>
<tr>
<td>0,4ATG/0,62PU/0,4CSTG(2)</td>
<td>0,42</td>
<td>4 Foil penetrations</td>
</tr>
<tr>
<td>0,4CSTG(1)</td>
<td>0,54</td>
<td>No foil penetrations</td>
</tr>
<tr>
<td>0,4CSTG(1)/0,62PU/0,4CSTG(1)</td>
<td>0,27</td>
<td>No foil penetrations</td>
</tr>
<tr>
<td>0,4CSTG(2)/0,62PU/0,4AG</td>
<td>0,20</td>
<td>No foil penetrations</td>
</tr>
<tr>
<td>0,3CSTG(2)/0,62PU/0,4 CSTG(1)</td>
<td>0,13</td>
<td>No foil penetrations</td>
</tr>
</tbody>
</table>

* It is not specified the part A of the BRG composition

** Spall recollected over a distance of 15cm from the rearmost side of the sample to the aluminium foil

ATG – Annealed Thin Glass
PU – Urethane
CSTG(1) – Chemically Strengthened Thin Glass with a chemical strengthening process A (given by the process variables).
CSTG(1) – Chemically Strengthened Thin Glass with a chemical strengthening process B (given by the process variables).

2.6 –Examples of Preferred Embodiments

Example No1A -

A typical cross section of an armoured glazing is:

6AG / 0.76PVB / 6AG / 0.76PVB / 4AG / 2.5PU / 3PC

Total thickness = 22-23 mm

Example No1B - A typical cross section of an armoured glazing without an Impact Energy Absorber is:

6AG / 0.76PVB / 6AG / 0.76PVB / 6AG / 0.76PVB / 6AG / 0.76PVB / 6AG / 0.76PVB / 6AG / 0.76PVB / 6AG

Total thickness = 45-46 mm

AG – Annealed Glass
PVB – Polyvinil Butyrral
PU – Urethane
PC – Polycarbonate

All dimensions are in millimetres (mm). This glasses (1A. & 1B.) has no-spall performances upon the standardized EN-1063 / B4 NS, 3 test shot (44 Magnum- Full Metal Jacket bullet – Impact Energy 1500 J). This cross sections can be substituted according to the present invention with:
5AG / 0.76 PVB / 5AG / 0.76PVB / 5AG / 4SGP / 0.5CSTG

or with:

5AG / 0.76 PVB / 6AG / 0.76PVB / 4AG / 1,24PU / 3PC / 0.62PU / 0.5 CSTG

SGP – Sentry Glas Plus® (Surlyn Ionomer)

Total thickness = 20-21 mm

Example No. 2 -

Another typical cross section of an armoured glazing is:

8AG / 0.76 PVB / 9AG / 0.76PVB / 8AG / 0.76PVB / 8AG / 2.5PU / 2.5PC

Total thickness = 39-40 mm

AG – Annealed Glass
PVB – Polyvinil Butyral
PU – Urethane
PC – PolyCarbonate
CSTG – Chemically Strengthened Thin Glass

All dimensions are in millimetres (mm). This glass has no-spall performances upon the standardized EN-1063 / B6 NS, 3 test shot (7.62 NATO Full Metal Jacket bullet – Impact Energy 3400 J). This cross section can be substituted according to the present invention with:

8AG / 0.76 PVB / 12AG / 0.76PVB / 9AG / 1.9PU / 2.5PC / 1.2PU / 0.5CS / 0.76PVB / 0.5CSTG
Total thickness = 37-38 mm

**Example Нo3** -

Another typical cross section of an armoured glazing is:

6*[9AG / 0.76 PVB] / 4AG / 2.5PU / 2.5PC

Total thickness = 72/73 mm

AG – Annealed Glass
PVB – Polyvinyl Butyral
PU – Urethane
PC – Polycarbonate
CSTG – Chemically Strengthened Thin Glass
ATG – Annealed Thin Glass

All dimensions are in millimetres (mm). This glass has no-spall performances upon the standardized EN-1063 / B7 NS, 3 test shot (7.62 NATO Armoured Piercing – Impact Energy 3300 J). This cross section can be substituted according to the present invention with:

9AG / 0.76 PVB / 4*[12AG / 0.76 PVB] / 3AG / 1.9PU / 2.5PC / 1.2PU / 0.5CS / 2*[0.76PVB/0.5CSTG]

Total thickness = 71/72 mm
3. Claims

We claim

1. A transportation anti bullet glazing concept construction with controlled injury free splinter projection based on inorganic rearmost ply materials with scratch and abrasion resistance and chemical durability comparable to soda-lime glass with the central tension of the last ply facing the environment tailored to release injury free splinters without generating perforations on the aluminium witness foil of the respective standard(s) ballistic test(s) for a given ballistic level and an induced residual field of vision after impact and said construction having an optimised cross section design in terms of weight (mass per unit area) and thickness reduction upon a ballistic level specific requirement.

2. A glazing construction in accordance with Claim 1 wherein it is composed by one or more thin glass(es) and one or more of said glass(es) are chemically strengthened.

3. A glazing construction in accordance with Claim 2 wherein one or more of said glass(es) have a controllable bending /impact strength and fragmentation pattern.

4. A glazing construction in accordance with Claim 2 wherein the thickness of the said individual thin glasses are between 0.03mm and 0.7mm.

5. A glazing construction in accordance with Claim 2 coupled to an intermediate plastic polymeric film or layer(s) used as impact energy absorber.

6. A glazing construction in accordance with Claim 3 coupled to an intermediate plastic polymeric film or layer(s) used as impact energy absorber.

7. A glazing construction in accordance with Claim 4 coupled to an intermediate plastic polymeric film or layer(s) used as impact energy absorber.

8. A glazing construction in accordance with Claims 2, 3 or 4 wherein the inorganic components are treated with a coating process like silk-screening, CVD, PVD, sputtering, sol-gel, painting or masking among others, in order to keep a residual
vision through the armoured construction after the first and subsequent shots based on the pre-defined ballistic level.

9. A glazing construction in accordance with any one of Claims 5 to 7 wherein the inorganic components are treated with a coating process like silk-screening, CVD, PVD, sputtering, sol-gel, painting or masking among others, in order to keep a residual vision through the armoured construction after the first and subsequent shots based on the pre-defined ballistic level.

10. A glazing construction as are claimed in any one of Claims 5 to 7 in which the intermediate plastic polymeric film(s) or layer(s) used as impact energy absorber is composed by one or more plies of polymeric materials with a total thickness between 0.13 and 25mm.

11. A glazing construction in accordance with Claim 10 with an outer construction composed by one or more plies of inorganic components.

12. A glazing construction in accordance with Claims 1 or 11 wherein the inorganic components can be Soda Lime or Borosilicate or Aluminosilicate glass plies or their combination.

13. A glazing construction in accordance with Claims 1 or 11 wherein the components can be Aluminium Oxynitride, Magnesium Aluminate, Aluminium Oxide or some other armour ceramic or their combination.

14. A glazing construction in accordance with Claims 1 or 11 wherein there can be one or more of said thin glass components having a hardened edge generated by a manufacturing process free from micro cracks on the thin glass edge.

15. A glazing construction in accordance with Claim 12 wherein said inorganic components have an individual thickness between 0.03 and 25mm.

16. A glazing construction in accordance with Claim 13 wherein said ceramic components have an individual thickness between 0.03 and 25mm.

17. A glazing construction in accordance with Claim 14 wherein inorganic components have an individual thickness between 0.03 and 25mm.

18. A glazing construction in accordance with Claim 1 wherein metallic substrates, alloys, films and/or electronic processors can be included within the components.
of the construction for solar protection, defrosting, demisting, de-icing, touch screen and/or displays or monitors purposes.

19. A glazing construction in accordance with Claim 1 wherein metallic substrates, plates, meshes or fibbers can be attached to the edge of said construction for protection purposes within that said region of the window.

20. A glazing construction in accordance with Claim 1 wherein a double or triple glazing construction can be considered and said couple or triplet of single glazed elements can be accommodated on a non parallel configuration to improve the ballistic performance of the construction.
Figure 1 –

- Bullet
- External side
- Internal side
- Armoured Glazing
- Glass Splinters
- Aluminium foil Witness
Figure 3a -

Front Armoured Glass Cross Section

Figure 3b -

Front Armoured Glass Cross Section

Anti Spall multi-ply CS glass layers
Figure 3c -

Front Armoured Glass Cross Section

Inner Impact Energy Absorber

Anti Spall multi-ply CS glass layers

Glass
PVB
CS Glass
Urethane
Polycarbonate
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

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<tr>
<th>IPC</th>
<th>B32B17/10</th>
<th>C03C21/00</th>
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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)

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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 practical, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

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<td>US 4 595 624 A (GREATHEAD THOMAS W) 17 June 1986 (1986-06-17) cited in the application column 1, line 36 -column 3, line 51; figure 1</td>
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**X** Further documents are listed in the continuation of box C. **X** Patent family members are listed in annex.

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Date of the actual completion of the international search

2 June 2003

Date of mailing of the international search report

11/06/2003

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016

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Lindner, T
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