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(54) **TRANSPARENT ARMOR STRUCTURE**

(56) **References Cited**

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(73) Assignee: **The United States of America as
represented by the Secretary of the
Army**, Washington, DC (US)

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(57) **ABSTRACT**

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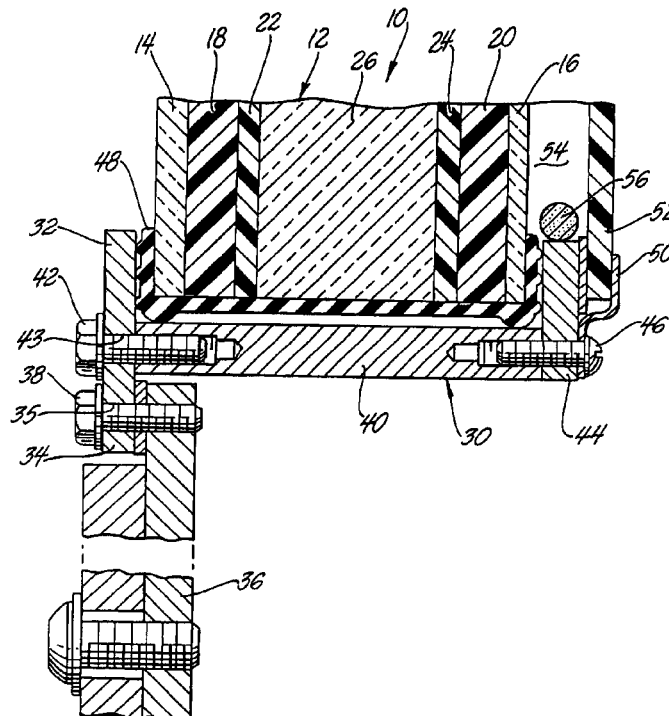
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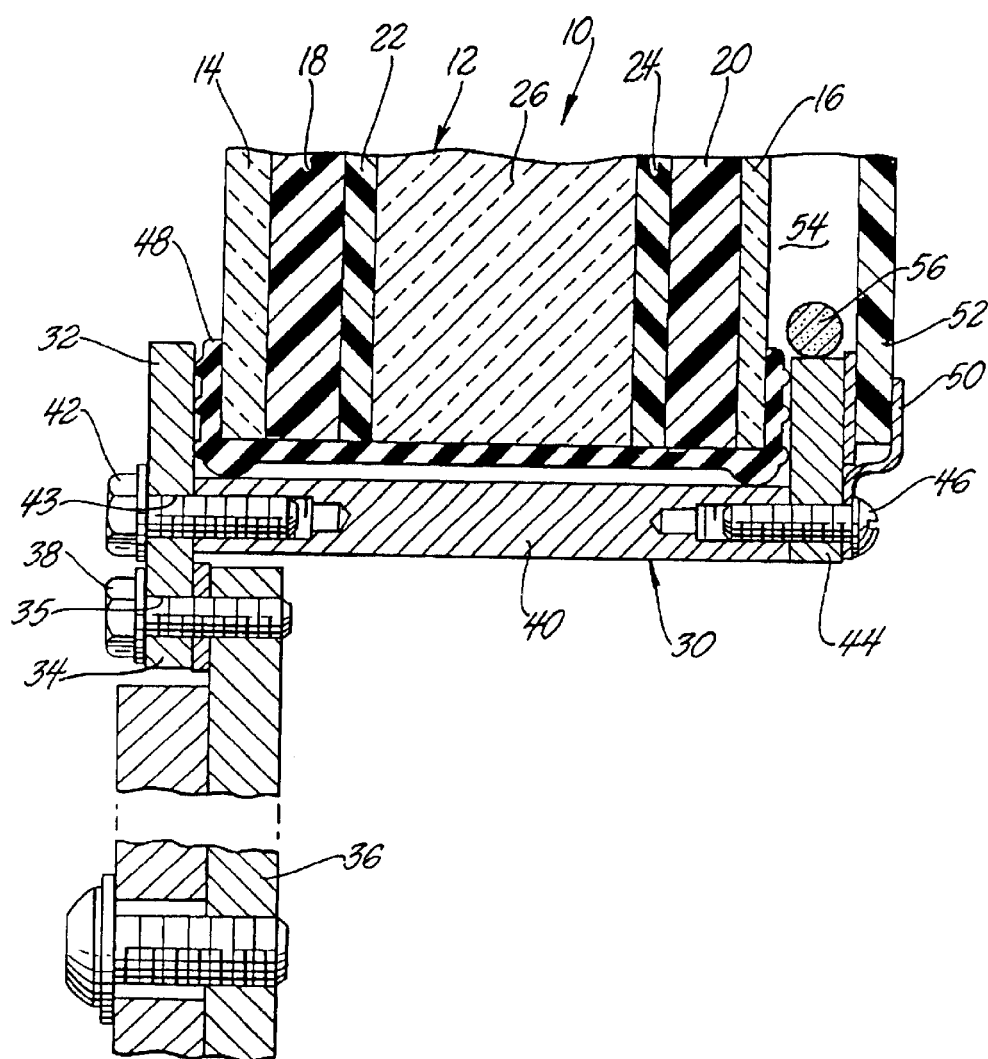
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An improved transparent armor structure for use in a vehicle includes a first sheet of transparent armor composite comprising at least one layer of polymeric material and at least one layer of tempered silica glass bonded to form a laminated bullet resisting structure and also having a bracket member adapted to hold a second transparent spall resisting layer parallel to and slightly spaced from the inner surface of the first transparent composite layer. A spacing means between the first and second layers forms a chamber between the first and second panels and a desiccant is located within the chamber to minimize the amount of condensation on the surface of the transparent armor surfaces.

6 Claims, 1 Drawing Sheet



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TRANSPARENT ARMOR STRUCTURE**CROSS REFERENCE TO RELATED APPLICATIONS**

This application is a continuation in part of application Ser. No. 10/117,556, filed Apr. 3, 2002, now abandoned.

GOVERNMENT INTEREST

The invention described here may be made, used and licensed by and for governmental purposes without paying me any royalty.

BACKGROUND OF THE INVENTION**1. Field of the Invention**

In one aspect this invention relates to armored vehicles. In a further aspect this invention relates to a transparent armor structure useful in military and security vehicles. In yet a further aspect, this invention relates to architectural structures for security purposes.

2. Prior Art

Security has become increasingly important. With respect to vehicle structures in general, military vehicles require greater than average protection for the occupants. This has given rise to various transparent armor structures for windshields and side windows that are designed to resist the incursion of small arms projectiles and shrapnel. This work has been ongoing for many years. In constructing transparent armor, "bullet proof glass", sandwiches made from tempered glass, and plastic layers are bonded together to form complex laminated composites all the. The resulting composites must be transparent and free of optical distortion while maximizing the ballistic protection from penetrators. In use, the inner and out of layers of the composite will be subjected to shock, scratching, abrasion and adverse weather conditions, particularly when a transparent armor composite is used in military applications.

The various layers used in the composite are chosen for their different projectile resisting characteristics and functions. For example, glass layers are hard and thus readily erode bullets and are highly abrasion resistant. However, glass layers are brittle which causes any glass layers opposite a penetration threat to spall, which in turn creates shrapnel fragments. The shrapnel creates numerous projectiles upon the interior surface of the vehicle and the resulting spall or fragments can be more dangerous than the original penetrator. Plastic material layers used as part of a composite sandwich provide a means to introduce flexibility into the transparent armor composite. The addition of one more plastic layers to the composite changes the failure mode of the transparent armor so it fails in a more ductile manner rather than spalling. Acrylic, polyurethane and polycarbonate based materials are among the polymeric materials which have been shown to have utility in making transparent armor composites.

One example of a transparent sheet composite useful as transparent armor is shown in U.S. Pat. No. 5,506,051. This particular patent discloses a laminated glass and polycarbonate construction with the addition of one or more transition layers of cured aliphatic urethane. The urethane provides a tension absorbing transmission layer within the composite. This patent also describes glasses and plastic materials useful in forming laminates that can be used as transparent armor.

One class of plastics that has proven both useful and reliable in constructing transparent armor composites and

architectural bandit type barriers is polycarbonate. Polycarbonate has proved to have superior characteristics in terms of providing overall protection because it is the plastic with the highest spread between brittleness transition temperature and heat distortion temperature. This makes polycarbonates generally preferred materials in transparent armor composites. Unfortunately, polycarbonate and the other useful plastic materials useful in the practice of this invention are soft and easily abraded by the action of dirt and dust. Further, these materials are frequently adversely affected by solvents and cleaning solutions when used to remove dirt. Thus, if plastics are used as the inner layer of a transparent armor composite, cleaning the surface dirt and grime will inevitably cause scratching. This causes the optical properties to be adversely effected. The scratching can cause the transparency of the transparent armor composite to substantially degrade in under one year. The substantial degradation of transparency necessitates replacement of the composite. Since the transparent armor composites are expensive, frequent replacement creates a substantial financial burden on maintenance budgets.

It appeared the only alternative to a degrading composite was to have an innermost glass layer. This carries an increased spalling risk. The transparent armor assembly of the present invention provides a system with separate, parallel elements combined in a basic structure. The first element is a transparent armored composite that can defeat a penetrator and has an outer layer which withstands the abrasion of the ambient environment outside the vehicle. The second element is located between the first element and the vehicle's interior, removed from the first element so that the shock of the penetrator is absorbed by the first element and is not transmitted to the second element. This structure allows the use of a sacrificial inner element which permits cleaning without degradation of the expensive portion of the structure while providing a good spall retaining to inner layer. As an added advantage, the second element of this invention is easily changed so we can easily switch from a heat limiting sun screen to a clear screen compatible with night vision devices. This allows enhanced daytime operation without adversely affecting nighttime operation

SUMMARY OF THE INVENTION

Briefly the present invention is an improved transparent armor structure for use in protecting an opening in a vehicle. The armor structure includes a multipart C-shaped frame mounted to a vehicle, the frame surrounding the opening. The frame is adapted to firmly hold a sheet of laminated transparent armor composite. The laminated armor composite has inner and outer layers of tempered silica glass material. The laminated armor composite has at least one layer of a polymeric material, such as polycarbonate, integrally bonded with the layers of tempered silica glass. The laminated armor composites useful in practicing this invention will comprise at least three layers integrally bonded to form a laminated bullet resisting structure. The bonding adhesives and other consolidating materials are chosen so that the composite is optically clear and non-yellowing. Of course, the laminated armor composite can be more than three lamellas thick. In constructing the laminated armor composite the various lamella are chosen from among assorted transparent materials chosen for their unique projectile resistance and flexibility characteristics.

The C-shaped frame that encloses the transparent armor composite is attached to the vehicle and extends into the vehicle interior. The C-shaped frame supports the transparent armor composite and associated parts of the structure in

place. A y-shaped member is attached to the C-shaped frame, the y-shaped member being adapted to hold a free-standing transparent spall resisting layer parallel to and spaced from the innermost surface of the transparent armor composite. The y-shaped member is positioned on the inside of the vehicle and attached to the C-shaped frame in a manner to allow easily removal and replacement of the spall layer.

The spall layer can be formed from a transparent material generally chosen from the types of material used in the transparent armor composite. While the spall layer can be scratched, or otherwise adversely affected by cleaning solvents and abrasives, it can be easily and inexpensively replaced. The separation between the spall resistant layer and the transparent armor composite protects the spall resistant layer from shock waves induced in the transparent armor by penetrators. Also, having the spall resistant layer separately mounted and easily changed allows the spall resistant layer to have a sunshade or other optical coating suitable for daytime operation while allowing the spall resistant layer to be easily changed for nighttime operation.

A spacing means is located between the transparent armor composite and the spall resisting layer along their edges to form a chamber. The chamber contains a desiccant to minimize or eliminate the amount of moisture within the chamber so as to control any condensation, which would create an impediment to vision.

BRIEF DESCRIPTION OF THE DRAWING

In the accompanying drawing:

The FIGURE is a partial side view in section of one embodiment of this invention.

DETAILED DESCRIPTION

Referring to the accompanying drawing, an improved transparent armor structure according to this invention is designated generally as **10**. A transparent laminated armor composite **12** is shown with a plurality of lamella. Tempered silica glass lamella **14**, **16** form the innermost and outermost layers of the composite. The tempered silica glass provides ballistic strength and abrasion resistance to the transparent armor. Silica glass is also highly resistant to common chemicals which can attack and degrade the transparency of the armor composite if plastic layers are exposed to the chemicals. Using silica glass as the outer layers allows the present transparent armor composite **12** to be cleaned using solvents or abrasive cleaners without substantial degradation of optical properties. The glass lamella **14**, **16** each have a layer of plastic material **18**, **20** laminated to their inner surfaces. As shown and as is common in transparent laminated armor composites **12** there are additional inner layers of material **22**, **24** and a central layer **26**. These inner layers will generally be additional layers of tempered glass and energy absorbing layers of plastic material or similar strengthening materials designed to absorb shock and provide the composite with additional penetration resistance. The particular materials chosen for the inner layers **22**, **24**, and **26** will be chosen based on the particular threat expected. The materials useable for inner layers **22**, **24** and **26** are generally known in the transparent armor art and the material of choice and thickness will be dictated by threat protection, weight allowance, optical properties, manufacturing considerations and cost considerations. The innermost **14** and outer most layer **16** used in the present transparent laminated armor **12** are tempered silica glass since that is the material which provides the greatest resistance to scratching

and chipping and thus is the most desirable material on the outermost surfaces of the transparent laminated armor **12** composite to preserve and maintain optical integrity. The choice of particular materials for each individual lamella within the transparent laminated armor composite **12** is within the skill of the art and further description is omitted in the interest of brevity.

The transparent laminated armor **12** is mounted in a multi-part C-shaped frame **30** attached to a vehicle, not shown. The multiplied-part C-shaped frame **30** surrounds and encloses the edge of the transparent laminated armor composite's **12**. The multi-part C-shaped frame **30** is formed to securely mount the transparent laminated armor composite **12** in position over an opening in the vehicle normally a vehicle window or windshield. In the multi-part C-shaped frame **30** shown, a first leg **32** forms one side of the C-shape of the frame and extends vertically beyond the frame's lower boundary so as to provide a flange **34**. Flange **34** has a first plurality of apertures **35** that allow the flange to be attached to the vehicle's frame **36** surrounding the opening to be protected.

The flange **34** is secured to the vehicle frame **36** using a first plurality of threaded fasteners **38** passing through the first plurality of apertures **35**. The threaded fasteners **38** are disposed at intervals around the periphery of the vehicle opening to provide proper support about circumference of the opening. The first vertical leg **32** of frame **30** is attached to a horizontal member **40** extending orthogonally from the first vertical leg into the vehicle's interior. As shown, first vertical leg **32** is firmly secured to horizontal member **40** by a second plurality of threaded fasteners **42** passing apertures **43** in the first vertical leg **32** and engaging a mating threaded aperture in the horizontal member. At the opposite end of the horizontal member **40**, distal the first vertical leg **32** is a second vertical leg **44**. The second vertical leg **44** is held in place on the horizontal member by a third plurality of threaded fasteners **46** passing through the second vertical leg **44** and engaging complementary threaded apertures in the horizontal member **40**. The resulting C-shaped frame structure **30** surrounds and holds the transparent laminated armor composite **12** in position and allows it to be secured about the periphery of the vehicle opening so as to cover the opening and protect the vehicle's interior.

As noted before, silica glass while having good strength and abrasion resistance is brittle and the shock wave set up in transparent armor by the incursion of a projectile will cause fracture and spalling. This may happen when the edges of the transparent laminated armor **12** are exposed to chipping and stressing even absent projectile incursion. Therefore, to protect the transparent laminated armor **12** edge and provide a seal, a shaped polymeric gasket **48** is disposed between the transparent laminated armor composite **12** and the C-shaped frame **30**. The gasket **48** can be formed of various natural or synthetic polymeric sealing materials that will serve to seal the transparent laminated armor composite **12** image.

Because the transparent laminated armor composite **12** of this invention has silica glass layers as the innermost and outermost lamella **14**, **16** to provide abrasion resistance, any spall over fragments created by the shock wave of a projectile incursion, must be retained. The, the structure of this invention provides full protection by means of a y-shaped bracket designated generally **50**, which holds a transparent spall resisting pane **52** parallel to and slightly spaced from the inner lamella **16** of the transparent laminated armor composite **12**, the spall resisting pane being positioned on the inside face of the transparent laminated armor when

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mounted on the vehicle. The y-shaped bracket **50** and spall resisting pane **52** operate is a unit which allows easy removal and replacement of the spall resisting plate. The y-shaped bracket **50** is attached to the C-shaped bracket **30** using the third set of threaded fasteners **46** which allows easy removal of the spall resisting pane **52**. Removal makes it easy to clean the inner surface of the transparent laminated armor composite **12** as needed. When it is necessary to replace the spall resisting pane **52** due to scratching or discoloration, a new pane can be substituted at cleaning. The spall resisting pane **52** can be formed from the same types of plastic materials as the flexible ballistic layers in the transparent laminated armor composite **12**, for example, polycarbonate or acrylic materials. Thus even if the spall pane **52** is subject to scratching, and can be adversely effected by cleaning with solvents and abrasive cloths, once the spall pane **52** has deteriorated a new one is easily installed. The expense of changing a spall plate **52** is minimal as compared to replacing the entire composite **12** that is many times more expensive just in material costs.

Placing the spall resisting pane **52** spaced from the transparent armor composite **12** protects the spall resistant pane **52** from the shock wave generated by the incursion of the penetrator. Because the spall resistant pane **52** is not subject to the shock wave it can also be made of tempered glass. The ease of replacement also allows a sunscreen glass or plastic to be used as the spall resistant plate **52** on sunny days and replaced with a transparent sheet at night or on overcast days.

The second vertical leg **44** of C-shaped bracket **30** acts as a spacer between the composite **12** and the spall pane **52** forming a chamber **54** which protects the spall resistant plate **52** from shock waves and collects spall. The chamber **54** has a desiccant **56** disposed within the chamber, the desiccant serving to minimize or eliminate the moisture within the chamber to control the condensation. Condensation on surfaces will interfere with vision and results in safety problems. The easy removal ability of the y-shaped bracket, spall resistant pane **52** unit will allow the desiccant **56** to be rapidly replaced when it becomes saturated.

Various alterations and modifications will become apparent to those skilled in the art without departing from the scope and spirit of this invention and it is understood this invention is limited only by the following claims.

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What is claimed is:

1. An improved transparent armor structure for use in protecting an opening in a vehicle the armor including: a multi pieced C-shaped frame mounted to a vehicle and extending into the interior of the vehicle, the frame surrounding the opening; a sheet of laminated transparent armor composite comprising a plurality of lamella at least one of said lamella being formed from a polymeric material, an innermost and outermost lamella each being formed of tempered silica glass, all of the lamella of said sheet of laminated transparent armor being bonded to form a coherent laminated bullet resisting structure, said laminated transparent armor composite being surrounded by said frame to hold said laminated transparent armor in position over said opening; a y-shaped bracket attached to the C-shaped bracket in the interior of the vehicle by means of a plurality of fasteners, the y-shaped member adapted to hold a transparent spall resisting layer parallel to and slightly spaced from the inner surface of the laminated transparent armor, to form a chamber between the first and second panels; and a desiccant located within the chamber the desiccant serving to minimize the amount of condensation in the space between the laminated transparent armor and the surface of the transparent armor and the transparent spall resisting layer.

2. The transparent armor structure of claim 1 where said C-shaped bracket comprises a first vertically extending leg attached to the vehicle about the opening, a horizontal member extending orthogonally into the vehicle from the first vertically extending leg and a second vertical leg attached to the horizontal member at the end distal the first vertical leg.

3. The transparent armor structure of claim 1 where the transparent spall resisting layer has a tint for limiting light transmission.

4. The transparent armor of claim 1 where the transparent spall layer is polycarbonate.

5. The transparent armor structure of claim 1 wherein the c-shaped multi-pieced frame has a C-shaped polymeric material located between the C-shaped frame and the transparent armor.

6. The transparent armor of claim 1 where the transparent spall layer is tempered glass.

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