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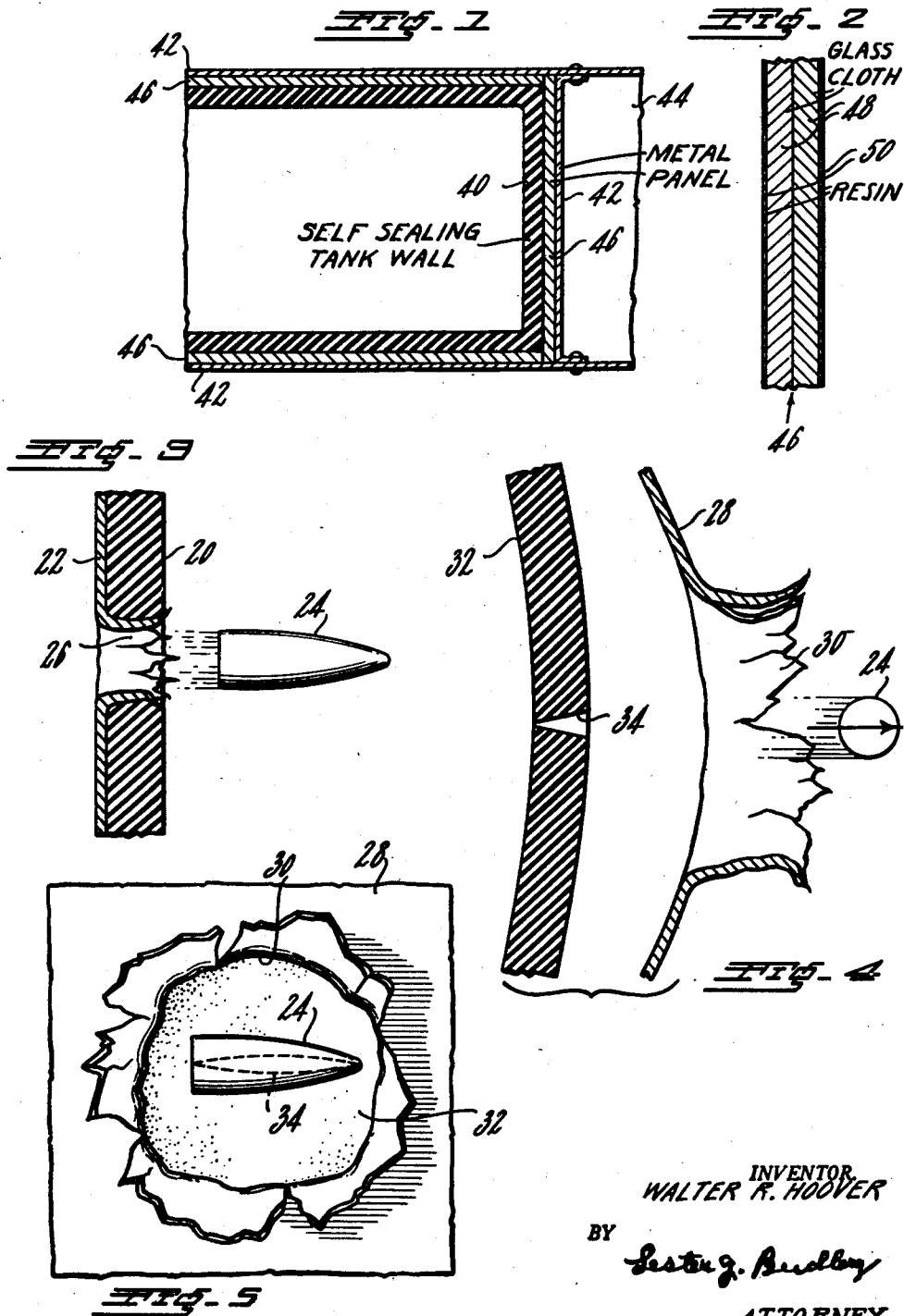
W. R. HOOVER

2,429,688

FUEL TANK

Filed April 17, 1943

2 Sheets-Sheet 1



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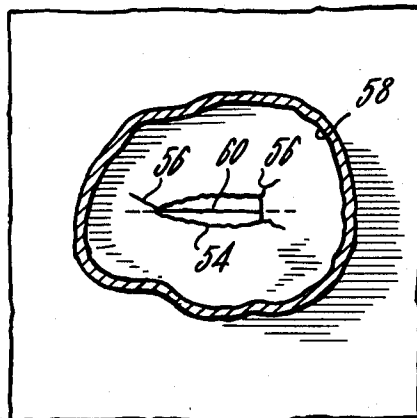
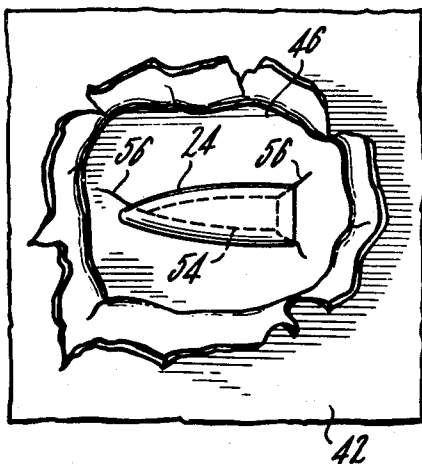
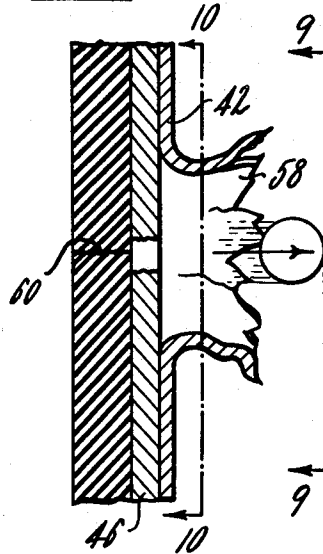
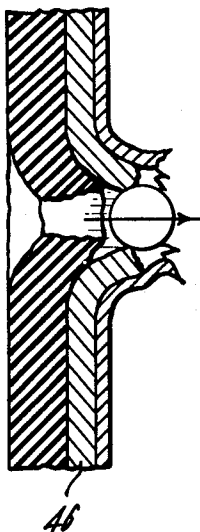
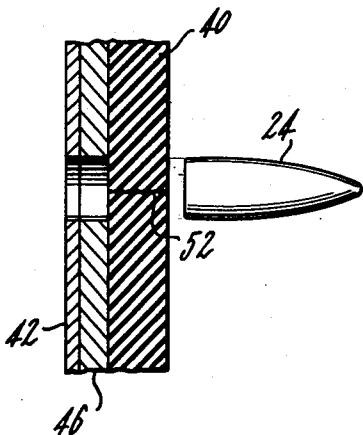
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2,429,688

FUEL TANK

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2 Sheets-Sheet 2



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2,429,688

FUEL TANK

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Application April 17, 1943, Serial No. 483,457

4 Claims. (Cl. 154—43.5)

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This invention relates to bullet-sealing fuel and oil tanks for combat vehicles, particularly airplanes.

It is usual to provide combat vehicles with bullet-sealing tanks so constructed that they inherently and automatically tend to close and seal holes made by projectiles. The bullet-sealing characteristics may be due to inherent chemical or physical characteristics of the material used, and may be obtained by various constructions of walls embodying varying kinds of rubber compositions and other elastic materials, as is known in the art. Usually such bullet-sealing walls are flexible, and are contained in and supported by outer containers made of metal and formed by the walls and bulkheads of the vehicle itself.

It has been found that when such a bullet-sealing tank is enclosed in a metal outer container, such as the aluminum skin of an airplane wing, a projectile entering the tank drags the metal with it, forming sharp and irregular edges on the metal skin, which remain attached to the skin and project in to the hole formed by the projectile in the sealant layer. This prevents the sealant material from closing on itself to seal the hole. This action of the metal is referred to as flowering. The exit hole formed in the metal outer container by the projectile as it leaves the tank is frequently larger than the entering hole. In addition the extremely high hydraulic pressure developed by the impact of the projectile in the liquid in the tank tends to deform the metal outer container into a sphere, and this leaves the exit wall bumped or dished away from the flexible sealant wall that it formerly supported. The result is that either due to this deformation or to the tearing away of the metal of the wall by a leaving projectile, or both, a large area of the flexible sealant wall about the hole is left unsupported against the static pressure of the liquid inside. This pressure bends the sealant layer outward, and tends to prevent the edges of the hole from coming together so that they may be sealed to close the hole.

In attempting to eliminate the disadvantages described, it has been proposed to enclose the sealing tank within a relatively stiff, non-flowering container or liner (made for example of plywood) between the sealant layer and the outer metal container. All such proposals which have come to my attention have various disadvantages, and none of them meet all of the conditions imposed on planes in actual combat.

I have discovered that certain novel combinations of materials when formed into a sup-

porting wall for a bullet sealing tank prevent the carrying of metal into the sealing tank from outer containers, and permit a projectile to pass through the supporting wall leaving an opening no larger than the projectile, and in some instances smaller than the projectile, and that these characteristics are preserved over wide ranges of temperature. I have also discovered that such novel combinations of materials are substantially completely resistant to oils, aromatic hydrocarbon fuels, and to water, and to mixtures of them and that all these characteristics are maintained over wide ranges of temperature. The fact that the projectile in passing through such material makes a clean-cut hole no larger than the projectile is due largely to the high tear resistance, toughness and elastic properties which render the material substantially rigid or stiff with respect to forces of low intensity making it suitable for supports for heavy tanks of fuel, and highly flexible and elastic, tough and non-shattering when exposed to the forces incident to impact by high velocity projectiles having great kinetic energy.

It is, therefore, an object of the invention to provide a material particularly adapted to supports for self-sealing fuel tanks which is chemically inert to water, oil and aromatic hydrocarbon fuels, which is tough and non-shattering, which exhibits rigidity to low velocity impacts and exhibits elasticity and flexibility to high velocity impacts, and which will retain these characteristics throughout wide ranges of temperature.

Other objects and advantages of the invention will be apparent from the accompanying description and annexed drawings in which:

Fig. 1 is a section taken through a portion of an airplane wing and tank embodying the invention;

Fig. 2 is an enlarged sectional view of a portion of a tank support, corresponding to Fig. 1;

Fig. 3 is a section of a portion of a wall of a fuel tank not embodying the invention, showing the action of an entering projectile;

Fig. 4 is a sectional view corresponding to Fig. 3 of a tank showing the action of a leaving projectile;

Fig. 5 is an elevation of the tank taken from the right of Fig. 4;

Fig. 6 is a sectional view of a portion of a wall of a bullet sealing tank embodying the invention showing the action of an entering projectile;

Fig. 7 is a corresponding section of a tank

embodying the invention showing an intermediate stage of a projectile leaving the tank;

Fig. 8 is a view corresponding to Fig. 7 just after the projectile has left the tank;

Fig. 9 is an elevation taken from the right of Fig. 8 at a plane represented by the line 9—9; and

Fig. 10 is a section on the line 10—10 of Fig. 8.

Figs. 3 to 5 represent the effect of projectiles on fuel tanks of prior construction which my invention seeks to eliminate. In these figures 20 designates the flexible bullet sealing wall of a fuel tank which is contained in an aluminum alloy outer container or housing 22. A bullet 24, represented as having just passed through the wall, has formed a hole into which the metal wall 22 has flowered, forming an obstruction 26 in Fig. 3 which holds the hole open. This action is typical of projectiles entering self-sealing tanks enclosed in metal housings. Obviously such a hole will continue to leak, causing loss of fuel, if not destruction of the vehicle from fire.

Figs. 4 and 5 show a typical action of a projectile leaving the tank. After a projectile of the form shown in Fig. 3 enters a tank it usually does not maintain its alignment with its own trajectory, but tumbles end over end, and consequently is frequently traveling sideways when it passes through the exit wall as shown in Fig. 5. The metal wall 28 is both deformed or dished outwardly by the pressure of the liquid in the tank under the impact of the projectile, and a large jagged exit hole 30 has been made by the bullet. This deformation has carried the wall 28 away from the flexible wall 32 on the exit side of the tank, leaving the wall 32 unsupported against the pressure of liquid within the tank. Under the influence of this pressure the wall 32 is pressed outward and the hole 34 made by the bullet is held open, as shown in section in Fig. 4 and as indicated in elevation by the dotted lines in Fig. 5. This hole will also continue to leak because its edges are held apart and closing and sealing are prevented.

The above described disadvantages are eliminated by my invention, constructed as shown in Figs. 1 and 2 and in Figs. 6 to 10. A puncture-sealing tank having walls 40 of any suitable construction is contained in a metal compartment, housing or outer container formed by the metal plates or sheets 42, which are usually integral parts of a vehicle, such as the airplane wing 44. One good practical construction, known heretofore, for making the walls 40 puncture sealing is to form these walls of natural or synthetic rubber that is unvulcanized, and cover the inner face of these walls with a protecting film of synthetic rubber that is capable of resisting the action of the tank contents; the outer face of the unvulcanized material preferably has a strong backing fabric of the cord type secured thereto. Between each of the walls 40 and the corresponding metal plate 42, I, in accordance with the present invention, insert a hardboard panel or sheet 46, constructed as shown in the enlarged section, Fig. 2. Usually the flexible inner tank formed by walls 40 is slightly larger than the compartment formed by the plates 42 into which it is inserted, in order to insure the firm and continuous support of the walls 40 by the walls 42, as is known in the art. The panels 46 are cut to fit the corresponding walls 40 and are placed between the tank and the plates 42. When the fuel containing tank 40 is larger than the compartment of the plane in which it is inserted it

must be non-rigid and collapsible to some degree to permit its introduction into this compartment. The panels may be loosely inserted when the tank is put in place, so that when the tank is filled, the walls 40 press firmly against the panels and press the panels firmly against the metal outer container 42, or the panels may be secured to the walls 42, ribs of the plane or to other structural members.

The hardboard panels 46 are constructed of a novel combination of materials and have novel characteristics which appear to be peculiar to this combination of materials. Referring to Fig. 2, each panel is preferably constructed of layers 48 of glass cloth impregnated and bonded together by a suitable resin. For clarity the resin is indicated by the enlarged or exaggerated layers 50. In practice the layer of resin on the outside of the glass cloth is extremely thin or even imperceptible.

The glass cloth is any suitable cloth or fabric woven from yarn spun from fine glass fibers, as known in the art, but the thickness and number of threads are such that the glass cloth alone has a tensile strength in excess of about 45,000 pounds per square inch.

Both the chemical and physical characteristics of the bonding resin are important in order that the resulting panel may have the necessary chemical and physical qualities. The panel must be inert to lubricating oils, to aromatic hydrocarbons, to water, and to mixtures of these. It has been found for example, that some materials which appear inert to aromatic hydrocarbons and to water when tested with any of these substances alone, for some reason are not wholly inert to water and aromatic hydrocarbons when shaken together in the same container. This is a condition frequently met with in airplanes due to condensation of moisture from the air in fuel tanks.

As to physical characteristics, the panel must be sufficiently stiff or rigid to function as a support for flexible walls under the head of liquid ordinarily encountered in airplane fuel tanks, yet it must be sufficiently elastic to receive without permanent deformation the sudden increase of pressure of liquid when the tank is struck by a projectile. It must not shatter nor tear when struck, and so will break cleanly, leaving a small hole. And finally all these characteristics must be maintained throughout wide temperature ranges.

I have found that glass cloth impregnated and bonded together with a thermo-setting resin made by the Columbia Chemical Company, Barberton, Ohio, and sold under the designation CR39 is effective in accomplishing the objects of my invention. I do not know the composition of this resin, but it is believed to be a polymer of the diallyl ester of oxydiethylenedicarbonic acid. Further information about this resin is given on page 143 of "Plastics Catalog, the 1944 Encyclopedia of Plastics," published by Plastic Catalogue Corporation, 122 East 42d Street, New York, N. Y. The resin itself, when polymerized has a tensile strength of about 3000 pounds per square inch. In practice two or more sheets of glass cloth, sufficient to give the desired thickness and having a tensile strength of 45,000 pounds per square inch are superposed and saturated with the CR39 resin, held flat with or without pressure, and baked at a temperature of about 160° F. for about four hours and subsequently at a temperature of about 230° F. for about two

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hours, all as more fully disclosed in my joint application with Michael A. Zirelle, Serial No. 483,458 filed April 17, 1943, for Paneling and method of making same. For example, two layers of heavy glass cloth impregnated and bonded in this manner provide a panel .050" thick having a density of .40 pound per square foot and a tensile strength of about 29,000 pounds per square inch. The panel contains about 50% resin and 50% glass cloth, and appears quite rigid, and will adequately support a large area of flexible bullet-sealing wall against the static pressure of liquid attained in the usual fuel tank. The panel does not shatter or tear when struck by a .50 caliber bullet at temperatures above about -30° F., and it does not soften or lose its stiffness or elasticity at temperatures below about 160° F. The material is inert to oil, aromatic hydrocarbon fuels and water between these temperatures.

I have also made satisfactory panels by bonding and laminating glass cloth with a resin sold by the American Cyanamid Company under the designation Laminac P4122, the composition of which I do not know, but which I believe to be a mixture of an alkyd resin and a polymerizable olefine (styrene) which is further described on page 137 of the above mentioned publication. When using this resin, I proceed as described above with respect to the CR39 resin, but bake the laminate about two hours at a temperature of about 220° F. I have also made successful panels with a resin marketed under the name Plaskon, a melamine resin made by the Plaskon Division of Libbey-Owens-Ford Glass Company of Toledo, Ohio, the composition of which I do not know, but which I believe to be a urea formaldehyde type resin; with a resin marketed under the name Melmac made by the American Cyanamid Co., Plastic Division, New York, N. Y., the composition of which I do not know, but which I believe to be a melamine resin.

The action of panels made as described above is illustrated in Figs. 6 to 10. The bullet-sealing container 40 is enclosed by the outer metal container 42 and panels 46 made in accordance with my invention. In Fig. 6 the bullet 24 has just pierced the walls in entering the tank, leaving a clean hole in the metal wall 42 and the panel 46, which permits the edges or faces of the hole in the wall 40 to come together along the line or seam 52. They are urged together by the inherent action of the wall 40, and sealed by the action of the hydrocarbon fuel, or by the inherent mechanical action of the material of the wall 40, as the case may be, as is known in the art. Fig. 6 represents the conditions actually encountered in practice. It is believed that this action is due to the inherent characteristic of the panel to form a clean break or hole, when backed up by the wall 40 and the head of liquid within the tank, and when struck by a projectile of high velocity. Likewise the inherent stiffness of the panel is such that the metal is mechanically held against flowering into the wall 40, and a clean hole is formed in the metal, of approximately the size of the projectile. Thus, if the projectile is small, for example of a diameter of 20 millimeters, the unsupported area of the wall 40 is not sufficient to prevent it sealing itself.

Referring to Figs. 9 and 10 it has been observed that a projectile, tumbled and leaving the tank sidewise, leaves a hole in the panel which is smaller than the profile of the projectile, as shown at 54. There are a number of cracks, as indicated at 56, leading from the hole 54, and

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it is believed that the portion of the panel between the cracks bends to permit the bullet to pass through, then snaps back as shown in Figs. 7 and 8. Fig. 8 shows a section of an actual exit wall, after the projectile has passed through. The wall 42, being unsupported against the impact of the bullet, flowers away from the bullet, leaving a large hole as indicated at 58. There may also be some dishing or permanent deformation of the wall 42, but my experience has been that this is largely reduced or completely eliminated where the panel 46 is used. It is believed that the action of the composite wall at the instant the projectile passes through it is as illustrated in Fig. 7. The portion of the panel 46 enclosed within the line 54 in Figs. 9 and 10 is carried away, the panel is cracked as indicated at 56 and the parts between the cracks 56 bend outward as indicated in Fig. 7 to permit the bullet to pass. When the bullet has left the wall, the portions of the panel 46 between the cracks snap back into the position shown in Fig. 8, pressing the sealant layer 40 back into its former plane and permitting the edges or faces of the hole to close upon themselves and be sealed. The result is a large hole 58 in the metal wall 42, a hole in the panel 46 smaller than the bullet and surrounded by cracks, and a tightly closed seam 60 in the sealant wall.

Experiments indicate that the above action occurs throughout the wide ranges of temperature indicated above, and under substantially all conditions of shooting which are encountered in combat.

Having thus described my invention, what I claim and desire to protect by Letters Patent is:

1. A reservoir for liquid hydrocarbons comprising in combination an inner container including a flexible wall of puncture-sealing material, an outer container surrounding the inner container and including a metal wall that indirectly supports the flexible wall, and a stiff, elastic, strong, tough and shatter resistant panel between and in contact with said walls and which is adapted to be installed before the inner container, said panel comprising a woven glass cloth impregnated with a resin and characterized by the property that an entering projectile passing through the panel and walls will cut a clean hole in the panel no larger than the projectile and thereby prevent the metal of the adjacent wall from being flowered into the wound of the sealing material, and the panel will not split under the high hydraulic pressure of the liquid displaced by the projectile traveling through the liquid but will spring back after it is pierced by the leaving projectile to hold the sealing material from bulging.

2. A reservoir for liquid hydrocarbons comprising in combination an inner container including a flexible wall of puncture-sealing material, an outer container surrounding the inner container and including a metal wall that indirectly supports the flexible wall, and a stiff, elastic, strong, tough and shatter resistant panel between and in contact with said walls and which is adapted to be installed before the inner container, said panel comprising a plurality of layers of woven glass cloth impregnated and bonded together with a resin having a tensile strength of about 3000 pounds per square inch and characterized by the property that an entering projectile passing through the panel and walls will cut a clean hole in the panel no larger than the projectile and thereby prevent the metal of the adjacent wall

from being flowered into the wound of the sealing material, and the panel will not split under the high hydraulic pressure of the liquid displaced by the projectile traveling through the liquid but will spring back after it is pierced by the leaving projectile to hold the sealing material from bulging.

3. A reservoir for liquid hydrocarbons comprising in combination an inner container including a flexible wall of puncture-sealing material, an outer container surrounding the inner container and including a metal wall that indirectly supports the flexible wall, and a stiff, elastic, strong, tough and shatter resistant panel between and in contact with said walls, said panel comprising a plurality of layers of woven glass cloth impregnated and bonded together with a resin and having a tensile strength of about 29,000 pounds per square inch and characterized by the property that an entering projectile passing through the panel and walls will cut a clean hole in the panel no larger than the projectile and thereby prevent the metal of the adjacent wall from being flowered into the wound of the sealing material, and the panel will not split under the high hydraulic pressure of the liquid displaced by the projectile travelling through the liquid but will spring back after it is pierced by the leaving projectile to hold the sealing material from bulging.

4. A reservoir for liquid hydrocarbons comprising in combination an inner container including a flexible wall of puncture-sealing material, an outer container surrounding the inner container and including a metal wall that indirectly supports the flexible wall, and a stiff, elastic, strong, tough and shatter resistant panel between and in contact with said walls, said panel comprising a plurality of layers of woven glass cloth impreg-

nated and bonded together with a resin, the resin having a tensile strength of about 3000 pounds per square inch and the panel having a tensile strength of about 29,000 pounds per square inch and characterized by the property that an entering projectile passing through the panel and walls will cut a clean hole in the panel no larger than the projectile and thereby prevent the metal of the adjacent wall from being flowered into the wounds of the sealing material, and the panel will not split under the high hydraulic pressure of the liquid displaced by the projectile traveling through the liquid but will spring back after it is pierced by the leaving projectile to hold the sealing material from bulging.

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