G. J. MURDOCK.

SELF PUNCTURE SEALING COVERING FOR FUEL CONTAINERS.

APPLICATION FILED JAN. 16, 1918.

1,386,791. Patented Aug. 9, 1921.

2 SHEETS—SHEET 1.

Fig. 3

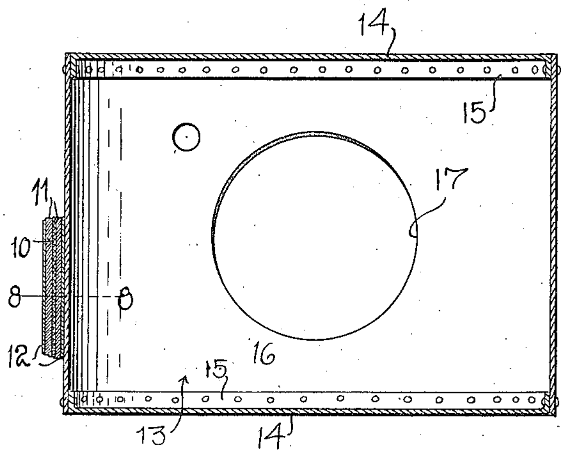


Fig. 6

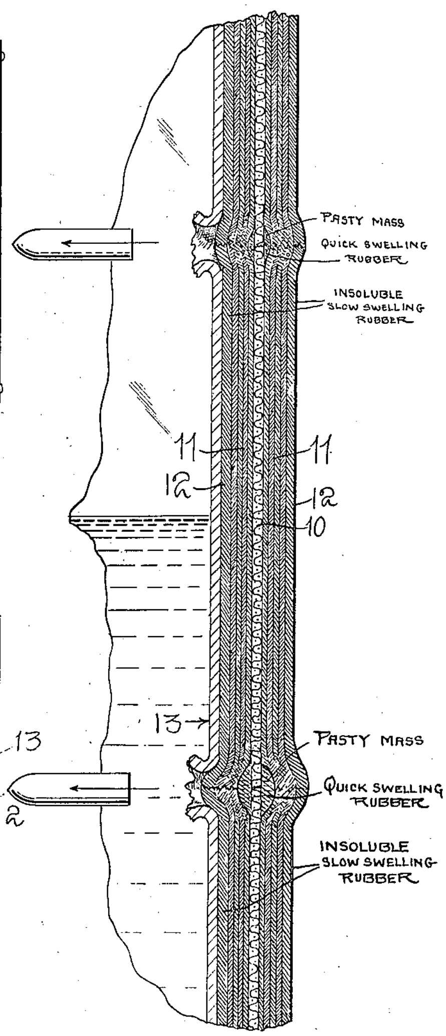


Fig. 1

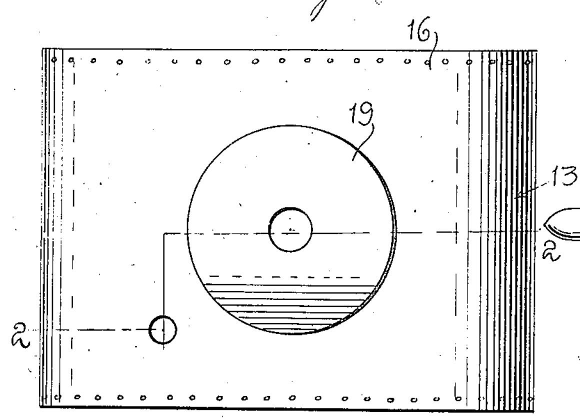


Fig. 9

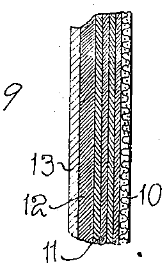
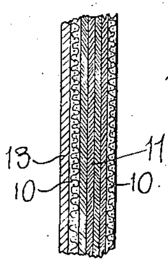


Fig. 10



Inventor

GEORGE J. MURDOCK

By Watson E. Coleman

Attorney

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2 SHEETS—SHEET 2.

Fig. 8

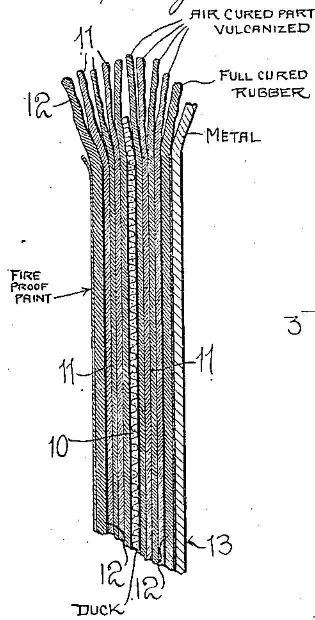


Fig. 2

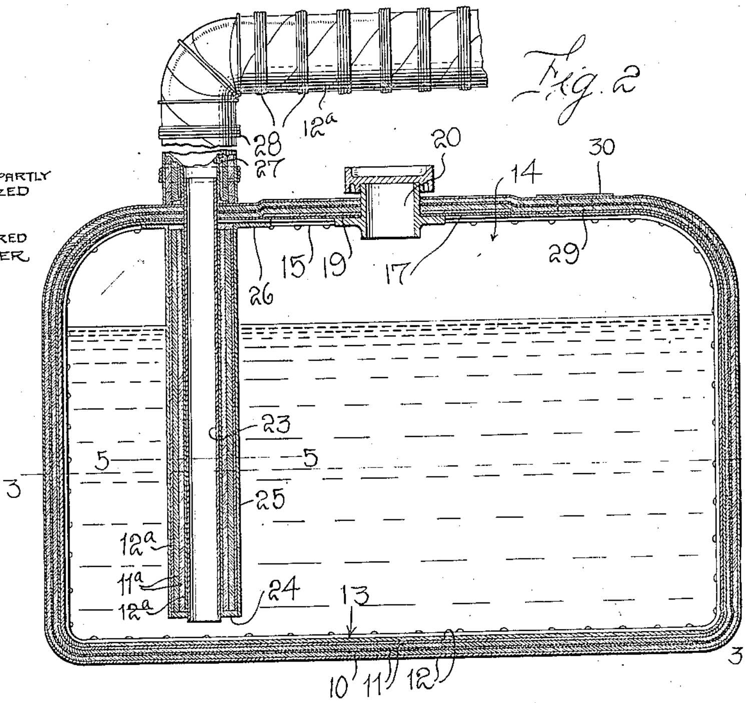
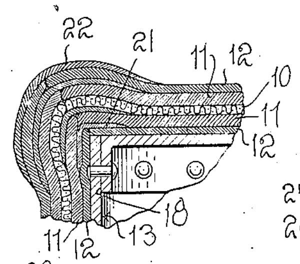


Fig. 4



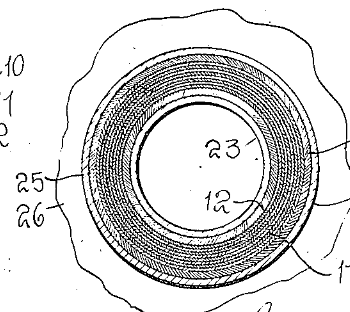


Fig. 5

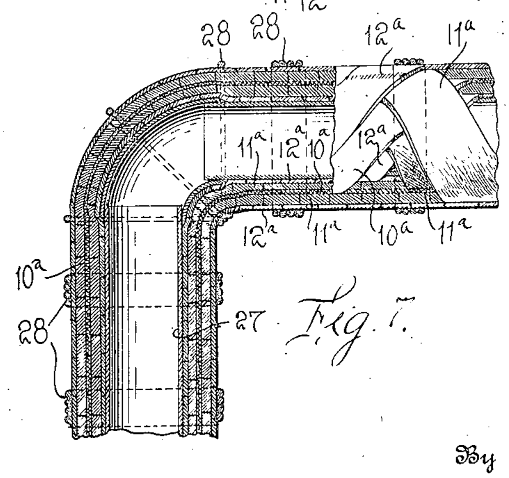


Fig. 7.

Inventor
GEORGE J. MURDOCK

By Watson E. Coleman
Attorney

UNITED STATES PATENT OFFICE.

GEORGE J. MURDOCK, OF NEWARK, NEW JERSEY.

SELF-PUNCTURE-SEALING COVERING FOR FUEL-CONTAINERS.

1,386,791. Specification of Letters Patent. Patented Aug. 9, 1921.

Application filed January 16, 1918. Serial No. 212,053.

To all whom it may concern:

Be it known that GEORGE J. MURDOCK, a citizen of the United States, residing at Newark, in the county of Essex and State of New Jersey, has invented certain new and useful Improvements in Self-Puncture-Sealing Coverings for Fuel-Containers, of which the following is a specification, reference being had to the accompanying drawings.

This invention relates to fuel containing tanks of war aeroplanes, motor trucks, and other self propelled vehicles or other structures having engines using hydrocarbon as a fuel, and generally speaking the object of the invention is to so construct the tank that punctures made therein by projectiles will automatically close so as to prevent the escape of gasolene, kerosene or other liquid hydrocarbons.

After the gasolene tank of a war aeroplane has been punctured by a projectile, the gasolene leaks out upon the fuselage and planes and is very liable to catch on fire and even if it does not catch on fire, puncturing of the tank and the consequent leakage of the fuel puts the aeroplane immediately out of the fighting and causes its return to its own lines as soon as possible for repairs. Probably more machines are caused to return to their own lines because of the loss of gasolene through puncture of the tank, than for any other reason and there has been a great loss of life due to this cause. Of course where the tank of a motor truck, car or other vehicle has been punctured there is not the same danger to the driver and mechanicians but even here the leakage of fuel requires either a stoppage of the car or truck or its return to its base. It has been proposed to provide armor for the tanks of aeroplanes, but this armor, to be of any value, must have a relatively great weight and this dead load is naturally not desired. It has also been proposed to use armor for reserve tanks from which a small amount of gasolene can be drawn if the main tank is punctured, but the puncture of the main tank, as a matter of fact, always requires that the aeroplane should return to its own lines because of the small amount of gasolene carried in the reserve tanks, a plug being pulled out of the main tank when punctured to allow the immediate drainage of this main tank.

Many efforts have been made to overcome this trouble, and tanks so constructed as to more or less prevent the leakage of gasolene after the puncture of the tank by a projectile, form the subjects of two applications for patents by me, filed respectively on the 7th day of February, 1917, Serial No. 147,170 and on the 23rd day of June, 1917, Serial Number 176,591. The tanks which form the subject matter of these applications, however, have the objection that they are relatively heavy and it is to avoid this excess weight in the tanks and further to provide a tank in which the closing action is more positive, that I have devised the present invention.

This invention is illustrated in the accompanying drawings, wherein:

Figure 1 is a top plan view of a gasolene tank of a common type used in aeroplanes and constructed in accordance with my invention;

Fig. 2 is a longitudinal sectional view on the line 2—2 of Fig. 1;

Fig. 3 is a sectional view on the line 3—3 of Fig. 2 looking toward the top of the gasolene tank to show certain details of construction;

Fig. 4 is a fragmentary detail section at a corner of the tank;

Fig. 5 is a section on the line 5—5 of Fig. 2 looking toward the top of the tank;

Fig. 6 is a fragmentary vertical sectional view through the tank wall, showing the manner in which punctures are closed both above and below the gasolene level;

Fig. 7 is a sectional view of a supply pipe of the gasolene tank provided with a self-sealing protective covering constructed in accordance with my invention;

Fig. 8 is a section on the line 8—8 of Fig. 3;

Fig. 9 is a vertical sectional view of a tank having only certain layers as a protective covering, and

Fig. 10 is a like view to Fig. 9 showing a tank having a certain other arrangement of layers as a protective covering.

Before detailing the construction of the tank and the manner in which the self-sealing envelop is applied to the tank, I will state the principles upon which my invention is based. In the course of many hundreds of experiments directed to the solution of the problem of providing a self-sealing tank, I have discovered that it is necessary to surround the metallic container with a substance which will swell when punctured so that when a projectile passes through the envelop of the tank, the puncture will be caused to close by the expansion of the material of the envelop. In my previous applications above referred to, I have provided what may be termed mechanical means for closing these punctures, that is, I have placed around the tank an envelop of rubber or like material which, as soon as the bullet passes will elastically contract and plug the opening through which the projectiles have passed, and in the last filed application I have provided means whereby a plug of wood is caused to be driven into the puncture in the rubber covering. My present application is based, however, on entirely different principles and on the fact that rubber will swell or increase in volume when exposed to the action of gasolene, kerosene or other liquids of the hydrocarbon group or to the vapor of such liquids. Furthermore, I have discovered that the speed of expansion, that is, the length of time which it takes for the rubber to swell up to a certain volume when subjected to the action of fluid hydrocarbons, depends upon the extent to which the rubber is vulcanized and also depends, to a lesser extent, upon the chemicals used in vulcanizing.

In accordance with these facts, I construct the envelop surrounding the metallic container, and by container I not only refer to a tank but to any duct, tube or chamber which will hold fluid hydrocarbon or through which the fluid passes, of a plurality of sheets or layers of rubber, certain of these layers being slightly vulcanized, as by the use of antimony sulfid or sulfuret, this layer having the property when so vulcanized of swelling up relatively rapidly. The remainder of the layers of rubber are formed of rubber known as "full cured," this rubber being cured with sulfur in the common way. Rubber cured with antimony sulfid or sulfuret is ordinarily red or orange colored while the full cured rubber, cured with sulfur by the common process, is generally gray.

While I have above referred to the use of sulfuret of antimony for slightly vulcanizing the first named element, I do not wish to be limited to this, as my invention does not lie in this particular step of slightly vulcanizing the rubber, but in the use of a slightly vulcanized rubber in the manner hereafter stated and, therefore, other chemicals or agents which are now known or which may be hereafter known and which will bring the rubber into such condition as to affect the objects hereafter stated may be used.

As before stated, I form the envelop of the tank or other container, pipe or tube of two elements, namely, rubber which has been fully cured with sulfur and rubber which is slightly vulcanized by antimony sulfuret. I have found that rubber which has been fully cured, but which is still elastic, is practically, to all intents and purposes, insoluble in gasolene or other hydrocarbon. When acted upon by gasolene, it will slowly swell in volume but it will not dissolve.

In the process of swelling under the action of the gasolene or other hydrocarbon, it absorbs the hydrocarbon and diminishes in tensile strength and elasticity but after its full expansion is attained, it does not appreciably change. I have found that after remaining six months in gasolene, if this fully cured rubber be taken out of the gasolene and dried, it will shrink to slightly under its original volume and recover its original elasticity and tensile strength. It is this peculiar characteristic which makes this fully cured rubber of such great value as one of the elements in my combination.

Pure rubber gum intimately mixed with sulfuret of antimony in a manner well known to those versed in the art and brought to a condition so that when its surface is exposed to the air will harden into what is known as the air cured state, and will quickly assume a pasty condition when brought into contact with fluid hydrocarbons. This slightly vulcanized, air cured rubber is also much more sensitive to heat than the fully cured rubber and the friction caused by the passage of a bullet through it will develop enough heat to cause it to fuse together to some extent in the path made by the projectile. The rate of expansion of this air cured, partly vulcanized rubber when submitted to fluid hydrocarbon, as well as the extent to which it may be dissolved when brought into contact with fluid hydrocarbon, may readily be governed by controlling the percentage of sulfur contained in it and controlling the extent to which vulcanization is carried.

In Fig. 8, I show diagrammatically a section of the envelop which covers the tank or container and in this enlarged sectional view, 10 designates an intermediate layer or core of fabric such as duck. On each side of this duck are disposed layers 11 of rubber which has been partly vulcanized by means of sulfur and which is air cured and exterior to these layers 11 are relatively thin layers 12 of rubber which has been "full cured" with sulfur which, as before stated, is slightly elastic but is practically insoluble in gasolene. These layers are cemented together in a manner which will be now described and cemented or otherwise attached to the metallic wall of the tank in the manner which will be stated, and these layers form an envelop of rubber extending entirely over the tank without appreciable solution of continuity and this envelop is also designed to extend around the outlet pipe leading from the gasolene tank and also around that portion of the outlet pipe which is disposed within the tank so that wherever a puncture may occur whether in the tank or in the feed pipe, the puncture will close.

In the drawings I have illustrated a tank or container, designated 13, such as commonly used in aeroplanes, the general shape of this tank being such as is used for the Curtis under seat type of tank. By referring to Fig. 3, it will be seen that the heads 14 of this tank are flanged inward as at 15 and riveted to the sides 16. In order to accomplish this riveting a large opening 17 is originally formed through the top wall so that the workman's head and shoulders may be admitted. The seams are then sweated together as at 18 (see Fig. 4) and this being done, a disk 19 is soldered on over the opening 17. This disk or cover may conveniently carry the filling nipple 20 which has the usual screw-threaded stopper. A tank constructed as above described is strong and has even corners.

The self-sealing envelop illustrated in Fig. 8 is applied around the outside of this tank at all points so as to entirely inclose or cover the wall of the tank. I have found it best in the actual construction of the tank to wind a single sheet of the full cured rubber entirely around the tank in the manner illustrated in Fig. 2, this rubber being wound around from end to end. Before doing this the sheet of full cured rubber 12 is varnished with a flexible cement such as shellac varnish insoluble in gasolene. This cement holds the rubber sheet 12 firmly to the metal and furthermore acts to localize the action of the gasolene to that particular place in the rubber where the projectile has passed through. Both heads 14 are also to be covered with a single sheet or layer of the full cured rubber 12, cemented to the heads in the manner above stated. After the body of the tank has been covered with this sheet of full cured rubber 12, a patch 21 is disposed over the joint between the head and body covering. This patch is also of full cured rubber and is cemented to the layer of full cured rubber by means of the elastic cement above referred to.

A layer of the antimony sulfuret cured rubber of the quick swelling character before referred to is now cemented with rubber cement to the inner layer 12 of the fully cured rubber. Preferably, this layer 11 is made up of a plurality of thin sheets of the rubber cured with antimony sulfuret as these thin sheets are easier to handle in constructing large units than if a single sheet was used having the full thickness of the layer. If this inner layer 11 is made up of thin sheets these sheets are scored by drawing a fine toothed saw across them, then wiped clean with gasolene and allowed to dry before the sheets are cemented together with rubber cement. The layer 10 of cotton duck is then applied to the outside face of the layer 11. This cotton duck is thoroughly impregnated with rubber cement, which is allowed to dry before the cotton duck is applied to the layer 11. It is then cemented to the layer 11 and upon the outer surface of this layer of cotton duck 10 is cemented a second layer 11 of the rubber cured with antimony sulfuret and having the quick swelling quality above referred to. This outer layer 11 may also be formed either of a single sheet of rubber or a plurality of sheets cemented to each other, though it is preferred to build this outer layer up also of thin sheets. A fourth layer 12 of rubber is now applied to the outer layer 11, this fourth layer being the outside covering layer and formed of a sheet of fully cured rubber. These sheets 12 are relatively thin in comparison with the layers 11. At the joint between the sheets 12 at the corners of the container, a patch 22 is applied, as illustrated in Fig. 4, this patch also being of fully cured rubber. The object of the cotton duck 10 is mainly to secure strength and prevent any stretching of the rubber in applying it to the tank and it is to be understood that while I have heretofore described the covering of the tank by first cementing an inner layer 12 to the tank, then cementing an inner layer 11 to the layer 12, then cementing cotton duck to the layer 11, then successively cementing the outer layers 11 and 12 to the cotton duck and each other, yet I do not wish to limit myself to this, as the envelop might be made by cementing the layers 11 to the cotton duck in the first instance, then cementing the layers 12 to the outer faces of the layers 11 and then cementing the entire composite sheet so formed to the tank. I prefer the method first described, however.

It is necessary, of course, that means be provided for protecting the outlet pipe leading from the tank from puncture, that is, providing means whereby if this pipe be punctured the puncture will be sealed. Where this outlet pipe projects into the gasolene it is necessary, of course, that the rubber be shielded from constant contact with the gasolene, as otherwise the gasolene would act deleteriously on the rubber. Where the pipe extends out of the gasolene tank, however, there is no necessity for protecting the pipe from the action of the gasolene on the rubber. That portion of the outlet pipe which extends through the top of the container and into the gasolene is designated 23. For the purpose of sealing any punctures which may occur in this portion of the pipe, I wrap the pipe with a layer 12ª of fully cured rubber, a layer 11ª of slightly vulcanized rubber, and then successively the outer layers 11ª and 12ª of the slightly vulcanized and fully cured rubber.

These layers of rubber extend from the top wall of the container downward nearly to the bottom of the pipe 23 and a head 24 is disposed upon the bottom end of the pipe and over the layers of rubber is disposed a sleeve 25 of metal the upper end of this sleeve being formed with a base 26 which is attached to the top wall of the tank by screws, rivets or in any other suitable manner. Thus it will be seen that the rubber layers 10^a, 11^a and 12^a are entirely protected by this sleeve from contact with the gasolene unless a puncture occurs.

Leading from the pipe 23 to the carbureter of the engine is a pipe 27. For this application, the composite covering of rubber formed of the layers 11^a and 12^a with intermediate duck layer 10^a may be cut into strips and wound diagonally around the pipe or elbow, the various windings crossing each other. A metal covering such as 25 is not necessary in this case for the reason before stated and bands of small copper wire 28 are wrapped at intervals around the rubber cover, the coils of each wrapping being soldered together and the purpose of these bands being to localize the action of the gasolene on the rubber in case of a puncture.

In Fig. 2 I have illustrated the fact that the sheets of composite rubber which extend around the body of the tank are overlapped upon each other as at 29, and that the joint thus formed is covered by a patch 30 of the full cured rubber such as is used for the layers 12. I, of course, do not wish to limit myself, however, to this manner of forming this joint and it is obvious that a joint may be formed at any other portion of the tank.

The action of this self-sealing covering is as follows: In Fig. 6, I show the action of a projectile passing through the wall of the tank and the covering thereof above the gasolene line. In this case the puncture is immediately closed, sufficiently to prevent the escape of gasolene vapor, by the elastically contractile character of the rubber and by either the action of the gasolene vapor upon the outer and inner layers 11 and 12 or by the gasolene which may slop about within the tank as the machine vibrates. The exterior layer, that is, the layer 12 which is next to the tank is insoluble in gasolene and expands slowly under the action of gasolene vapor and eventually the puncture is entirely closed. At no time is the puncture sufficient however to permit the leakage of gasolene vapor.

In Fig. 6 I show the action of my improved covering when punctured by a bullet below the level of the liquid gasolene. As soon as the bullet passes through the covering and the wall, a slight amount of gasolene, due to the pressure in the tank, passes through the opening made by the bullet. The perforation in the metallic tank will be relatively large, but the perforation or passage formed through the envelop will be relatively small because the rubber expands to permit the passage of the projectile and then immediately contracts. The layer of cotton duck 10 has a clean-cut hole. The gasolene leaks in through the slight puncture in the inner layer 12 and the hole through the cotton duck allows the liquid to come in contact with both layers 11 of the quick swelling rubber. The driving effect of the bullet forces the rubber away from the duck and thus a small chamber is formed on each side of the duck and immediately surrounding the perforation therethrough and gasolene enters and fills this cavity. The gasolene in this cavity, together with that which enters through the perforation in the inner lining causes an initial swelling of the slightly vulcanized air cured rubber. This swelling closes the puncture so effectively that a pressure of ten pounds per square inch, equivalent to a vertical fluid head of twenty feet, will not cause the tank the leak. If fresh gasolene could continually come in contact with the soft cured rubber 11, it would dissolve this rubber in time sufficiently so to allow the gasolene to escape through the puncture. This is rendered impossible, however, from the fact that the instant the gasolene comes in contact with the fully cured rubber wall 12, this rubber wall immediately surrounding the puncture commences to swell, although at a slower rate than the swelling in the rubber which is cured by antimony sulfid. In about ten minutes this swelling completely closes the puncture through the fully cured rubber layer 12 and, therefore, no more fresh gasolene can come into contact with the layer or layers 11, which by this time has assumed the condition of a stiff paste within the area covered by the puncture, effectively sealing the puncture even though this puncture is larger than one made by a .30 caliber bullet. What is true of the action of the bullet perforating the wall of the tank is also true of the action of perforating the pipe section 27.

For tanks which are liable to be punctured by bullets of not more than .45 caliber, I have found that the total thickness of the envelop and the metal wall of the tank need not exceed ¼″ giving a total weight of about 2¼ pounds per square foot of tank surface. If the tank is designed for use where it is liable to be punctured by projectiles of larger caliber than the above named, then the thickness and weight of the rubber composite envelop must be increased accordingly. Ordinarily, however, war aeroplanes do not carry guns shooting projectiles of a greater caliber than .30 or .45.

The cotton duck 10 is used to obtain strength and freedom from elasticity. It is not always necessary, in order to carry my invention into practical use, however. Thus, for instance, in Fig. 2 there is no absolute necessity of an intermediate layer of cotton duck, as the outside metallic sleeve 25 furnishes sufficient strength to the rubber. Where the rubber is not protected by an outer metallic tube, however, then this interlayer of cotton duck is necessary or the projectile would drive the metal away from the rubber to an injurious extent when emerging if the cotton duck were not used.

It may be remarked that in Fig. 4 I have shown the intermediate patches 21 and 22 and the layers of rubber exaggerated and, as a consequence, that the corners of the tank are bulged outward. As a matter of fact the corners are flush, or nearly so, with the wall. This is important as bulging corners, such as are shown in Fig. 4, will be in the way and prevent the tank from being placed, as is necessary with present aeroplane construction.

The rubber cement which is used for the purpose of holding the layers 11 in contact with each other and in contact with the duck and for impregnating the duck is simply raw rubber dissolved in naphtha. This cement dries up as it dispels the solvent and the surface will cease to be sticky, but it will not stand heat or contact with the hydrocarbons, as vulcanized rubber will. Shellac varnish, before referred to, makes a flexible cement, but I have found it particularly good in causing the inner layer to adhere to the tank wall and when this shellac varnish is dry, it is insoluble in gasolene, thus acting to limit the zone of action of the gasolene to the parts immediately surrounding the perforation caused by the projectile.

The cotton duck, which is used in connection with the layers of vulcanized and partly vulcanized rubber, is of considerable importance, as the result of a high power bullet striking the body of gasolene within the container is much greater than where a projectile having a low velocity is used. The tendency of the projectile is to drive a column of gasolene in front of the bullet and out at the other side of the tank. Gasolene like water is almost incompressible. It is not where the bullet goes in that the trouble is experienced, but where it comes out. Nine times out of ten the bullet will come through sidewise cutting a slit perhaps three-fourths of an inch long with a .30 caliber projectile and the blow on the gasolene will bulge the side of the tank. The cotton duck, however, prevents the rubber from being driven away from the tin container as it otherwise would be on account of its elasticity and prevents the rubber from being ruptured by the blow on the gasolene. If the duck is not used, the driving out of the rubber wall splits the outer tin container in all directions. Where duck is used in connection with the layers of rubber, however, this splitting action does not occur. I may say that I have tested this tank with all fluid hydrocarbons, in other words, practically all fluids that can possibly be used in internal combustion engines. All of the fluids of the benzene group cause the swelling of the rubber which has been heretofore described but where other fluids are used, as for instance, alcohol, the puncture will close, not by the action of the fluid itself, but because the heat generated by the passage of the projectile through the semi-soluble rubber causes the puncture to close sufficiently tight by fusion as to withstand any pressure which is likely to be used. This closure as before remarked is most effective where the rubber is semi-soluble as the further vulcanization is carried, the less sensitive the rubber is to heat. With the insoluble rubber, the bullets cut a hole that remains cut and the liquid will leak from the tank.

With reference to Figs. 9 and 10 I would say that it would be possible to construct an operative tank with a layer of insoluble rubber 12 immediately next to the container with an outer layer of semi-soluble rubber 11 and finally duck or other suitable material 10 outside of this outer layer. It is also possible, as illustrated in Fig. 10, to cover a tank and make it more or less operative, as a self-sealing tank by using duck 10 on both sides of the semi-soluble rubber 11. Such a construction, however, makes it difficult to build up the corners properly and is also inferior for use with large caliber projectiles where a distinct hole is made. Thus in the form of covering shown in Fig. 9, I have found in practical trial that the punctures will not leak even under 15 pounds of air pressure applied on the gasolene within the tank for a period of five hours. When this form of covering is punctured, it will form a carbuncular swelling on the insoluble rubber side, that is on the inside, but not on the cloth side. This is the case when the hole is formed by a .30 projectile. Afterward the carbuncular swelling, having expelled the gasolene shrinks back to its original state very nearly. With .45 bullets, however, the hole made is large enough to see through and on a pressure tank will not close quickly or entirely for the soluble rubber washes away through the large hole in the duck almost as fast as it reaches the pasty state, and as the duck will not swell (as does the insoluble rubber where it is present on the outside of the soluble rubber) the hole will remain open until the inside insoluble layer has sufficient time to close the perforation, this time being about fifteen minutes. With the construction illustrated in Fig. 10, a quick-closing seal with small caliber ammunition is secured, but this construction shown in Fig. 10 is next to useless with large bullets, for reasons already given as applying to constructions shown in Fig. 9.

One of the chief difficulties in constructing a self-sealing tank is to cause the tank to seal if a bullet or other projectile strikes the tank at an angle more acute than a right angle. With the form of tank herewith illustrated, the tank automatically seals quite as well, if not better, when the bullet strikes at an acute angle than if the bullet strikes the tank at a right angle. The rubber which constitutes the covering will stretch away from the tin when the bullet enters and the projecile does not cut a slit in it, as it otherwise would but for the elastic nature of the rubber. When the angle of fire is increased, that is, when the angle is relatively acute, the tendency of the projectile is always to dent itself into the tin until it finally punctures the tin and passes through. As the angle of the projectile to the tank wall becomes more acute, the tendency of the bullet to plow into the tin forming a groove, which may equal half the diameter of the bullet, constantly increases. Sometimes this groove will be 2″ or more in length before the bullet finally breaks through. There is never much difference in the outside appearance of the rubber or cover no matter what angle the bullet strikes, but of course when it strikes at an acute angle, the puncture must be somewhat longer than when it strikes at a right angle. The semi-soluble rubber which forms the intermediate layer or layers swells upon contact with gasolene no matter what the shape of the passage through the rubber. It has been my experience also that the plug formed upon the passage of a bullet through my tank wall or cover will resist considerable more air pressure if made at an acute angle than if made at a right angle to the tank, as the swelling formed in the intermediate wall or walls is both longer and larger as this intermediate semi-soluble rubber will swell for the entire length of the groove in the tin making a long tapered plug, whereas when the puncture is straight through the wall, that is, at right angles to the wall, the plug is relatively short. The statements made above are not based upon theory but are the result of actual experiments and tests made by me extending over a considerable length of time.

I have heretofore referred to the layers 11 of rubber as swelling rapidly when exposed to liquids of the benzene group and to the layers 12 of rubber as swelling slowly. It is to be understood, however, that both of the sheets of rubber treated as before explained swell relatively rapidly when compared with ordinary rubber. Caoutchouc or raw rubber swells only slightly before it begins to dissolve when in contact with liquids of the benzene group, and this swelling is very slow in comparison with rubber that has been even slightly vulcanized. Meanwhile, the unvulcanized, raw rubber, while it is swelling, is also dissolving so that in a short time it is entirely destroyed as a mass. Ordinary sheet rubber as usually found on the market does not swell to any useful extent when in contact with gasolene and the swelling takes place at a very slow speed. Furthermore, this ordinary sheet rubber, while it is for all practical purposes insoluble in the gasolene, when submitted to the action of gasolene or any liquid of the benzene group, breaks up and has a cheesy quality. Ordinary sheet rubber, as before explained, swells somewhat on contact with gasolene, but this swelling is at a very slow rate. Both the layers 11 and 12 of my covering, however, swell rapidly relative to this ordinary sheet rubber and caoutchouc so that where my covering is applied to a tank, the wound in the tank wall will heal or seal itself in a few minutes, whereas were ordinary sheet rubber used, which is of comparatively small elasticity and has but a small capacity to swell, the puncture would not become sealed sufficiently to accomplish the desired result.

It is to be also noted that the degree to which vulcanization is to be carried in producing the relatively slow swelling layers 12 may be definitely determined by submitting the rubber to certain tests. Thus a degree of vulcanization which is proper for these layers 12 is the same as the degree of vulcanization which will give to the rubber maximum elasticity, maximum tensile strength, and maximum expansibility, in other words rubber which has been vulcanized to an extent where it has maximum tensile strength, maximum elasticity and maximum expansibility when in contact with liquids of the benzene group, has been vulcanized to an extent where it has the qualities necessary to fit is to form the layers 12 of my tank. If rubber is vulcanized beyond the point where it has maximum elasticity, maximum tensile strength and maximum expansibility, it loses its tensile strength and elasticity and becomes more and more unfitted for my purpose until, as the vulcanization is carried still further forward, it becomes hard rubber. If rubber be vulcanized to that degree wherein the rubber is rendered of maximum elasticity and maximum tensile strength when in contact with gasolene, it is practically insoluble in liquids of the benzene group, that is it takes a relatively long time for the rubber to dissolve in liquids of the benzene group. While a practical insolubility may be secured by a less degree of vulcanization, yet the rubber will not have maximum tensile strength or maximum elasticity when in contact with gasolene, nor maximum expansibility in contact with gasolene. Therefore, it will not be fitted to form the wall 12, which should have all of these qualities. By testing the rubber, therefore, as to its elasticity and tensile strength when in contact with gasolene, it is possible to definitely set the vulcanization necessary in order to produce a rubber which shall swell relatively rapidly when in contact with gasolene. Of course, the "quick swelling" rubber which is only slightly vulcanized and which is used for the layers 11 swells more rapidly than the layers 12, but it could not ordinarily be used by itself for the reason that it does not swell without dissolution when in contact with gasoline. In other words, it is not practically insoluble but becomes soft, pasty, and unless it is protected by the relatively slow swelling rubber, would wash away and become so weakened that it would not form any protection for the tank whatsoever.

It will be noted that in the drawings I have shown a gasolene tank or container proper protected by a covering constructed in such manner that a puncture through it will become automatically sealed, and that I have also shown a gasolene pipe connected to the tank and protected by such a covering as I have disclosed. It is obvious, therefore, that this rubber covering may be applied not only to tanks but to the pipes in which gasolene is held or through which gasolene or like liquids pass, and the word "container" as used in the appended claims is intended to cover any pipe, duct, tank, reservoir, or like element for the conduction or carriage of liquids of the benzene group.

While I have illustrated certain details of construction which, in practical trials, I have found to be particularly valuable, yet I do not wish to be limited to this, as it is obvious that many changes might be made in the form of the invention without departing from the spirit thereof.

Having described my invention, what I claim is:—

1. The combination with the wall of a liquid fuel container, of a covering therefor including a layer of rubber vulcanized to an extent whereby it is rendered insoluble in the liquid contained in the container, but swelling relatively rapidly when moistened therewith.

2. The combination with the wall of a liquid fuel container, of a covering therefor comprising an inner layer insoluble in the liquid contained in the container and swelling when moistened therewith, and a relatively outer layer of material semi-soluble in said liquid and swelling when moistened therewith, the first named layer swelling more slowly than the second named layer.

3. The combination with the wall of a liquid fuel container, of a covering therefor comprising a layer disposed next to the wall and composed of material relatively insoluble in the liquid contained in the container but swelling slowly when moistened therewith, and a relatively outer layer of material semi-soluble in the liquid contained in the container but swelling rapidly when moistened therewith.

4. The combination with the wall of a fuel container, of a covering therefor comprising an outer and an inner layer of elastic material which will swell slowly when moistened with the liquid contained in the tank, and an intermediate layer of elastic material which will swell rapidly when moistened with the liquid contained in the container and form a pasty mass between the inner and outer layers by the action of said liquid when the covering and tank are punctured.

5. The combination with the wall of a liquid fuel container, of a covering therefor comprising inner and outer layers of fully cured sheet rubber, and an intermediate layer of slightly vulcanized rubber.

6. The combination with the wall of a liquid fuel container of a covering therefor, comprising an inner layer of fully cured sheet rubber and a relatively outer layer of slightly vulcanized rubber.

7. A metal fuel container having thereover a covering comprising outer and inner layers of fully cured rubber, intermediate layers of slightly vulcanized rubber, and a sheet of textile fabric disposed between the intermediate layers and to which said intermediate layers are cemented, the first named innermost layer being cemented to the metallic container and the outermost first named layer being cemented to the adjacent face of the intermediate layer.

8. A metal fuel container and an envelop inclosing the container, the envelop including a layer of rubber cemented to the container over substantially its entire surface, the rubber of the layer being vulcanized to a degree where it is rendered substantially insoluble in liquids of the benzene group and caused to swell relatively rapidly on contact with said liquids, to thereby close a perforation therethrough and through the container.

9. A metal fuel container and an envelop inclosing the container and including a layer of rubber exterior to the container, the rubber of the layer being vulcanized to an extent whereby it is rendered pasty upon an infiltration of a liquid of the benzene group through a puncture through the rubber and the container and caused to swell relatively rapidly by contact with the said liquid to thereby close the puncture.

10. The combination with the wall of a liquid fuel container, of a self puncture sealing covering therefor including an innermost

layer of material insoluble in liquids of the benzene group, but swelling upon a puncture of the layer and the container and upon the consequent moistening of the layer by the liquid contained in the container, a relatively outer layer of material semi-soluble in liquids of the benzene group and swelling rapidly when moistened therewith as by the liquid seeping through the puncture to thereby close the puncture, and a relatively outer layer of fabric insoluble in said liquid.

11. The combination with the wall of a fuel container, of a self puncture sealing covering therefor comprising a plurality of layers of rubber, the layers having different degrees of vulcanization, one of said layers being relatively insoluble in the liquid contained in the container but swelling slowly when moistened therewith and another of said layers being semi-soluble in the liquid contained in the container but swelling rapidly when moistened therewith.

12. The combination with a fuel container, of means for self-sealing a puncture through the container comprising a layer of material on the exterior of the container swelling relatively quickly on contact with a liquid of the benzene group in the container without dissolution, to close the puncture therethrough.

13. The combination with the wall of a liquid fuel container, of a covering therefor cemented to the container wall over its entire surface and comprising a layer of rubber on the exterior of the container vulcanized to an extent where it is rendered substantially insoluble in a liquid of the benzene group and swells relatively rapidly when moistened with said liquid to thereby close a puncture through the container and the layer, and a layer of fabric to which said layer of rubber is attached over its entire surface.

14. The combination with the wall of a liquid fuel container, of a covering therefor including a layer of rubber vulcanized to such an extent that it is rendered insoluble and will swell relatively rapidly when moistened with a liquid of the benzene group to thereby cause the closure of a puncture through the container and the layer of rubber, and a layer of textile fabric cemented to the container wall and to which the layer of rubber is cemented.

15. The combination with the wall of a liquid fuel container, of a covering therefor including a layer of fabric and a layer of rubber to which the fabric is caused to adhere, the rubber being vulcanized to an extent whereby it is rendered substantially insoluble in but swells quickly when moistened with a liquid of the benzene group to thereby close a puncture through the container and said layer.

16. The combination with the wall of a liquid fuel container, of a covering therefor including a layer of rubber vulcanized to an extent whereby it is rendered substantially insoluble in but will swell rapidly when moistened with a liquid of the benzene group, said covering being cemented to the container over substantially its entire surface.

17. The combination with the wall of a liquid fuel container, of a covering therefor including a plurality of layers of rubber with the said layers being vulcanized to an extent whereby it is rendered insoluble in the liquid contained in the container but swelling when moistened therewith, and another of said layers being vulcanized to an extent where it will become pasty and swell upon being moistened with liquid in the container, the layers being cemented to each other over their entire surface and the cover being cemented to the container over its entire surface.

18. The combination with the wall of a liquid fuel container, of a cover therefor including a layer of rubber vulcanized to an extent whereby it is rendered insoluble in the liquid contained in the container but swelling when moistened therewith, and means for localizing the infiltration of gasolene through the rubber when the container is punctured.

19. The combination with the wall of a liquid fuel container, of a covering therefor including a layer of rubber vulcanized to an extent where it is rendered insoluble in liquid of the benzene group but swells rapidly when moistened therewith, and a thin layer of cementitious material holding the rubber to the container wall, said cementitious material being brittle.

20. The combination with the wall of a liquid fuel container, of a cover therefor including a layer of rubber vulcanized to an extent where it is rendered insoluble in liquids of the benzene group but swelling when moistened therewith, said cover being cemented to the container over substantially its entire surface by a varnish insoluble in fluids of the benzene group, said varnish thus acting to localize the infiltration of liquid into said layer upon a puncture of the container and cover.

21. The combination with the wall of a liquid fuel container, of a cover therefor including a layer of rubber vulcanized to an extent whereby it is rendered insoluble to liquids of the benzene group but swelling when moistened therewith, said layer being cemented over substantially its entire inner surface to the wall of the container by a cement which is insoluble in liquids of the benzene group.

22. The combination with the wall of a

liquid fuel container, of a cover therefor including a layer of rubber vulcanized to an extent whereby it is rendered insoluble to liquids of the benzene group but swelling when moistened therewith, said layer being cemented over substantially its entire inner surface to the wall of the container by shellac which is insoluble in liquids of the benzene group.

23. The combination with the wall of a liquid fuel container, of a covering therefor including a layer of rubber vulcanized to an extent such that it has maximum expansibility when exposed to fluids of the benzene group and is rendered substantially insoluble in the liquid contained in the container but swells relatively rapidly when moistened therewith.

24. The combination with the wall of a self-sealing fuel container, of a covering therefor including a layer of caoutchouc vulcanized to such an extent that it is of maximum elasticity and tensile strength, said rubber being insoluble in the liquid contained in the container but swelling relatively rapidly when moistened therewith.

In testimony whereof I hereunto affix my signature in the presence of two witnesses.

GEORGE J. MURDOCK.

Witnesses:

J. P. MURDOCK,

WM. J. MURDOCK.