April 8, 1941. A. WESLEY 2,237,321

GASOLINE TANKER RESISTANT TO PENETRATION BY CORROSION

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Fig. 1.

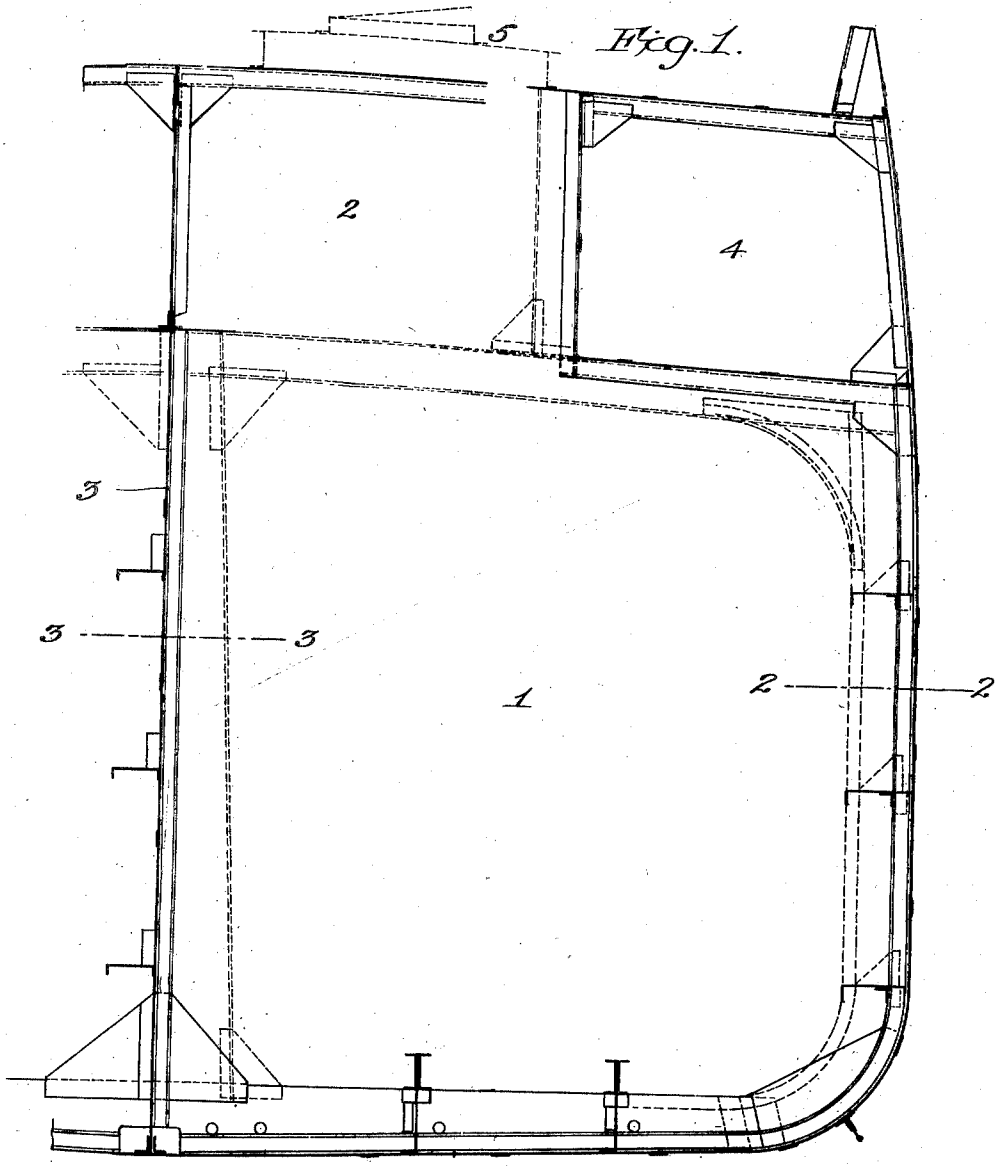


Fig. 2.

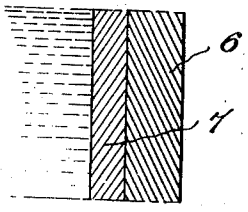
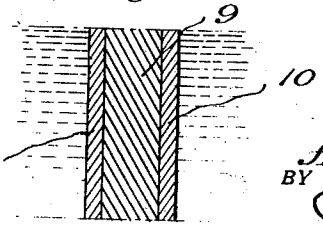


Fig. 3.



INVENTOR
Andrew Wesley.
BY
A. P. Miller
ATTORNEY

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GASOLINE TANKER RESISTANT TO PENETRATION BY CORROSION

Andrew Wesley, Plainfield, N. J., assignor to The International Nickel Company, Inc., New York, N. Y., a corporation of Delaware

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The present invention relates to a gasoline tanker which resists penetration by corrosion, and, more particularly, to a gasoline tanker having a composite steel hull and composite steel partitions forming the tanks within the hull.

It is known to those skilled in the art that in modern bulk cargo vessels, such as oil and gasoline steamers, the oil, gasoline or other liquid fills the entire hull and comes in contact with the outside shell plates and to the plates constituting the bulkheads, partitions, etc., and, the oil, gasoline or the like, like all fluids, exerts its pressure directly and normally against the surface with which it comes into contact. In addition to this, there is the increased pressure due to the inertia of the cargo itself, as the vessel rises and falls in her pitching movements, and, to a less extent, in rolling. Furthermore, the gas which rises from crude oils or refined gasoline in combination with the atmosphere becomes highly explosive at a certain point, and, unless the bulkheads are fluid-tight, seepage of oil or gas into boiler and engine compartments can occur with the accompanying danger of explosion and fire. Fluid-tightness and structural strength of the plates of the shell and bulkheads of oil and gasoline tankers are of utmost importance as those skilled in the art are well aware.

It is well known that many parts of conventional gasoline tankers are subject to corrosion which proceeds non-uniformly over the exposed surfaces. The interior of the hull and bulkheads which form ballast tanks, crude oil tanks, gasoline tanks and the like are examples of such parts. Non-uniform eating away of the metal causes far greater economic loss than would result from uniform corrosion over the entire exposed area even though the weight of the metal lost in the case of uniform attack is greater than in the case of localized corrosion. Penetrating pit formation resulting from non-uniform attack materially shortens the useful life of a tanker and greatly increases the danger of gasoline, oil, gas, etc., seeping through the bulkheads into the boiler or engine compartments.

It has been proposed to construct gasoline tankers of alloy structural steels but experience proved that any increase in life due to enhanced resistance to submerged corrosion of such steels was too small to be economically justifiable. The alloy structural steels, moreover, were susceptible to non-uniform corrosion to much the same relative degree as plain carbon steels.

It has also been proposed to construct gasoline tankers of commercially available composite or "clad" metals having a layer of metal more noble than iron or steel which was exposed to the sea water ballast, oil or other corroding agent. Unfortunately, such composite metals suffered from the disadvantage that their usefulness depended upon the integrity of the corrosion resistant layer because if there were discontinuities in the coating metal initially, or if discontinuities developed in service, so that the base or foundation metal of iron or steel was exposed to the action of a corroding medium, the attack proceeded at such points in the foundation metal at a relatively rapid rate. Insidious in nature, the extent of the attack in the base metal was often hidden behind the layer of exposed metal in which a mere pinhole was perceptible whereas the base structural metal was eaten away over a large area due to the electrolytic relations of the two metals. Inasmuch as the cargo in such vessels exerted its pressure directly against the shell and bulkhead plates which were almost entirely dependent upon the base structural metal for strength, detrimental and dangerous weakening of the structure resulted from such non-uniform corrosion, and in some instances failures occurred. The cost of steel cladded with more noble metal was very high compared with plain carbon steel and was practically prohibitive commercially.

Another proposal of the prior art was the use of heavily galvanized steel for gasoline tankers. These tankers were fairly resistant to pitting so long as the zinc coating adhered, but it is well known that the coating tended to flake off in use, particularly if the metal was bent or dented or subjected to flexing and warping. As soon as the zinc flaked off the steel was exposed and an electrolytic cell was set up between the zinc and steel causing accentuated and detrimental corrosion. The zinc coating, moreover, contributed little, if at all, to the strength of the foundation metal and served the sole function of protecting the base metal against corrosion. Other disadvantages of the use of galvanized steel for gasoline tankers are well known to the art.

The development of a satisfactory material of construction for oil and gasoline tankers has been a major problem facing the art.

I have discovered that gasoline tankers possessing adequate strength and satisfactory resistance to penetrating pit corrosion may be constructed by using composite steel plates on the surfaces exposed to corrosion provided the individual layers of the composite plate are thick enough to contribute appreciably to the strength

of the structure and the layer exposed to the corroding medium is anodic with respect to the underlying layer.

It is an object of the present invention to provide a gasoline tanker which will be resistant to perforation by localized corrosion.

It is another object of the present invention to provide gasoline tankers comprising composite steel plates and sheets in which the layers of the various steels used have different electrochemical potentials and the less noble layer is exposed to the corroding agent.

It is a further object of the invention to provide gasoline tankers comprising composite steel plates and sheets resistant to penetration by localized corrosion in which the individual layers of steel forming the composite sheets and plates are of substantial thickness, each layer contributing appreciably to the strength of the structure.

It is also within the contemplation of the invention to provide gasoline tankers in which those parts that are exposed to corrosion from only one side are made of composite metal having two layers of low alloy steel with different electrochemical potentials, the less noble of the two being exposed to the corroding agent.

The invention likewise contemplates the provision of gasoline tankers in which those parts that are exposed to corrosion from both sides are made of composite metal having three structural layers of low alloy steel, the outer layers being less noble than the inner layer.

Other objects and advantages of the present invention will become apparent from the following description taken in conjunction with the accompanying drawing in which:

Fig. 1 is a fragmentary somewhat diagrammatic midship section of a steamer for carrying oil or gasoline in bulk; and

Fig. 2 and Fig. 3 represent, on an enlarged scale, sections through the shell plates and through the bulkhead plates on the lines 2—2 and 3—3 of Fig. 1, respectively.

Generally speaking, the invention comprises gasoline tankers having shells and bulkheads plated with composite structural sheets of steel the layers of which are sufficiently thick to contribute appreciably to the strength of the structure and which have different electrochemical potentials. The layers are so arranged that the less noble layer is exposed to the corroding agent.

The steamer illustrated in Fig. 1 is of conventional design and need not be described in detail as its construction is well understood by those skilled in the art. Reference character 1 designates a hold tank for oil, gasoline, or other liquid cargo. An expansion trunk 2 is provided above the tank 1 adjacent the longitudinal bulkhead 3 to take care of change in volume of the cargo as the temperature rises or falls. The space in the between decks at the side of the expansion trunk 2 is used as a bunker 4. An oil hatch in the upper deck is shown at 5. It will be understood that the other side of the steamer is constructed in like manner and that the vessel is provided with transverse bulkheads at suitable points in accordance with the principles of conventional ship construction.

The shell plate is made up of a plurality of steel plates joined together at their juxtaposed edges, e. g., by welding or riveting. Each plate, as may be seen in Fig. 2, comprises two structural layers of appreciable thickness and strength designated by reference characters 6 and 7. Layer 7 is exposed in use to the corrosive action of the liquid cargo which attacks metal nonuniformly with the production of corrosion pits. In accordance with the principles of the present invention, layer 7 is made of steel less noble than layer 6. For example, layer 6 may be made of an alloy steel about $\frac{7}{16}$ of an inch thick containing about 1% of copper and about 2% of nickel, which is sold under the trade mark "Yoloy," and layer 7 may be plain carbon steel about $\frac{1}{16}$ of an inch thick. Similarly, layer 6 may be steel of the S. A. E. 2515 type, an alloy steel containing about 5% of nickel, and layer 7 may be a plain carbon steel, the thickness of the layers again being about $\frac{7}{16}$ and $\frac{1}{16}$ of an inch, respectively. In both cases, the layer 7 is anodic with respect to layer 6, i. e., layer 7 is less noble than layer 6. Both layers, moreover, have relatively high physical properties and are sufficiently thick to contribute substantially to the strength of the plates of the tanker. The layer 7 does not consist of a mere thin coating without structural strength, as in the prior art vessels of galvanized or clad steel sheets, but is to be considered as a structural element of the combination. This is commercially practicable in tankers embodying the present invention because the layers are composed of relatively inexpensive steels, Further and important advantages of gasoline tankers embodying the present invention are that there is no danger that the layer 7 will crack or peel off even under severe physical shocks, that corrosive attack is confined to the layer 7 until it has been substantially all eaten away even though the layer 6 may become exposed to the corroding medium though pits, perforations and the like in the layer 7, and that the true condition of the plates may be readily determined by visual inspection since hidden corrosion cannot occur in composite plates embodying the present invention. It will be clear to those skilled in the art that the hull plates could also be provided with a structural layer of higher potential metal on the surface exposed to the sea water and spray, if it were desired to take advantage of the protective action of such a structural layer in resisting pit corrosion in the layer exposed to the sea water and spray.

It will be observed from the foregoing that the structural layers of the plates of tankers embodying the present invention are arranged opposite to that of the prior art clad steel structures in which the more resistant layer had always been exposed to the corrosive fluid. The prior art arrangement was, of course, the natural and reasonable way to attack the problem in the light of existing knowledge and experience with the protection of steel against atmospheric and many other types of corrosion. Gasoline tankers, however, are subject to the foregoing peculiar and special corrosive conditions which lead to pit formation, and under these special and unique circumstances a cladding of more noble metal deters the attack on the under layer only a relatively short time, i. e., only until it is perforated by pits, after which the attack on the base metal proceeds at an accelerated rate due to the unfavorable relationship of electrochemical potentials of the two layers. By reversing the potentials of the exposed and under layers, and by making both of substantial thickness, the surprising discovery has been made that total life of a gasoline tanker is increased many times. This new and surprising result is obtained, more-

over, with cheaper materials which are easily produced in structural shapes and plates and readily fabricated into gasoline tankers.

While the mechanism of the protection afforded by a layer of less noble metal to penetration of a more noble layer of metal by local or pit corrosion is not fully understood, a probably theoretical explanation is that when, as in prior art tankers, a layer of protective metal, e. g., a metal more noble than a base layer of carbon steel, was exposed to a corroding medium and the attack proceeded non-uniformly, pits began to form in the protective metal which eventually reached the less noble layer, e. g., plain carbon steel. As soon as this layer was exposed, localized corrosion proceeded rapidly at these points until both layers were perforated. The two metals formed, in effect, an electric cell in which the base metal was the anode, the protective metal the cathode and the corrosive fluid the electrolyte. The base metal was thus anodically corroded at a relatively rapid rate depending upon the electrolyte, the difference in the potentials of the two metals, etc., as those skilled in the art will readily understand. On the other hand, when the less noble layer, e. g., the plain carbon layer, is exposed to the corroding medium as in tankers constructed in accordance with the present invention and the attack proceeds non-uniformly, pits begin to form just as above and eventually reach the more noble layer, e. g., the above mentioned 1% copper 2% nickel steel, or the 5% nickel steel. The actual time taken for the pits to reach the under layer might be shorter when a plain carbon steel layer is exposed to the corrosive agent than where a protective layer is used because of the higher corrosion resistance of the latter. This would depend upon the relative thickness of the layers, the nature of the coating, etc., as those skilled in the art will understand. The advantage of the arrangement of the structural layers according to the present invention, however, lies in the fact that substantially no corrosion of the under layer of more noble steel can occur until practically all of the outer layer of less noble steel has been corroded away. In other words, instead of pit formation proceeding at an accelerated rate as soon as the outer layer is perforated, as in the prior art structures where the more noble layer was first exposed to the corrodant, it substantially ceases in structures embodying the present invention where the less noble layer is first exposed.

In the gasoline tanker illustrated in Fig. 1, the plating on the longitudinal bulkhead **3** is exposed in use to non-uniform corrosion on both sides, as may be seen in Fig. 3. In order to prevent perforation of the plates by pit corrosion, the exposed layers **8** and **10** are both made of less noble steel, such as plain carbon steel, while the center layer **9** is made of more noble steel, such as 1% copper-2% nickel steel, 5% nickel steel or the like. In such a case, the relative thicknesses may be, for example, about ⅛ of an inch for each of the outer layers and about $\frac{7}{16}$ of an inch for the inner layer.

It is not essential to the success of my invention that the potential difference between the exposed and the under layer be large. In elctrochemical potential tests in which plain carbon steel was coupled with 1% copper-2% nickel steel, the potential difference was about 0.08 volt in a 3% sodium chloride solution. Correspondingly, the potential difference when the 5% nickel steel was coupled with plain carbon steel of the same analysis in the same solution amounted to about 0.11 volt. In general, it is preferable to maintain a difference of at least about 0.07 volt and it is unnecessary for practical purposes to exceed about 0.2 volts.

The composite plates used for constructing the gasoline tankers embodying my invention may be manufactured in any conventional commercial manner, as those skilled in the art will understand. For example, in making a two layer composite plate, a slab of low carbon steel of appropriate size may be positioned at one side of a mold with a cleaned surface exposed to the casting cavity remaining at the other side of the mold into which the nickel, nickel-copper, or other alloy steel that is to form the more noble layer is then cast to form a composite ingot. A satisfactory bond between the low carbon steel and the alloy steel is formed in this manner and the composite ingot may be rolled into composite plate by the use of conventional equipment, as those skilled in the art will readily understand. It will be understood by those skilled in the art that the preformed slab that is positioned in the mold could be the alloy steel against which the low carbon steel is cast. Similarly, if a three layer plate is desired, a slab of the alloy steel which has been cleaned on both sides may be positioned at the center of a mold with casting cavities at either side into which low carbon steel may be poured to form a three layer composite ingot; or two slabs of the low carbon steel could be placed at the sides of the mold leaving a casting cavity between them into which the alloy steel is cast to form a three layer composite ingot. The three layer composite ingot may be rolled into three layer composite plate in the conventional manner, as those skilled in the art will readily understand. Instead of casting one of the metals against a preformed slab of the other in the aforesaid manner, the composite plates may be fabricated by welding plates of the desired composition together. A well known method that may be used comprises placing the plates to be welded in superimposed relation with the juxtaposed faces of the plates suitably cleaned and prepared for welding, heating the superimposed plates to welding temperature and then passing the heated plates between rolls to effect intimate contact between the juxtaposed faces of the plates whereby welding takes place over the entire contacting areas of the plates and a composite plate is produced. The foregoing methods of producing the composite plates to be used in tankers embodying the present invention are merely illustrative and are not to be construed as the only available methods. Any method whereby composite plates of the foregoing kind may be produced may be employed to manufacture the composite plates to be used in the construction of tankers embodying the present invention, as those skilled in the art will readily understand.

It will be seen that a gasoline tanker constructed in accordance with the present invention has a number of important practical and commercial advantages. The composite plates can be made of low alloy steels which are easily bonded and welded together and readily worked to shape. The layers are of appreciable thickness so that there is no danger of peeling or rupture of a coating and each layer will structurally contribute to the strength of the tanker. Even with low alloy steels, highly satisfactory resistance to localized corrosion is obtained.

It should be noted that in this description and

in certain of the claims, the term "low alloy steel" is used not only to designate those steels having some special addition such as copper, nickel, molybdenum, chromium, cobalt, manganese, tungsten, columbium, etc., in relatively small yet effective amounts to alter the electrochemical potential, but also includes plain carbon steel.

Although the invention has been described in considerable detail with respect to gasoline tankers as a preferred embodiment, other vessels, structures, objects, etc., which are exposed to similar conditions are to be considered equivalents and to come within the scope of the invention as described in the specification and defined by the appended claims.

I claim:

1. A gasoline tanker adapted to carry liquid cargo in bulk which comprises hull plates and bulkhead plates exposed to said liquid cargo, the said hull and bulkhead plates having an outer structural layer of plain carbon steel exposed to said liquid cargo and an under structural layer of steel containing about 2% nickel and about 1% copper bonded to said plain carbon steel, each layer being of substantial thickness and contributing structurally and appreciably to the strength of said tanker.

2. A gasoline tanker adapted to carry liquid cargo in bulk which comprises hull plates and bulkhead plates exposed to said liquid cargo, the said hull and bulkhead plates having an outer structural layer of plain carbon steel exposed to said liquid cargo and an under structural layer of steel containing about 5% nickel bonded to said plain carbon steel, each layer being of substantial thickness and contributing structurally and appreciably to the strength of said tanker.

3. A gasoline tanker adapted to carry liquid cargo in bulk, which comprises composite hull plates and bulkhead plates exposed to said liquid cargo, the said hull and bulkhead plates having an outer structural plate of plain carbon steel exposed to said liquid cargo and an under structural plate of steel containing nickel, said structural plates being bonded together and being of substantial thickness and contributing structurally and appreciably to the strength of said tanker, the outer plate being anodic with respect to the under plate by a potential not over 0.2 volt and not under 0.07 volt.

4. A gasoline tanker adapted to carry liquid cargo in bulk, which comprises composite hull plates and bulkhead plates exposed to said liquid cargo, the said hull and bulkhead plates having an outer structural plate of plain carbon steel exposed to said liquid cargo and an under structural plate of steel containing alloying material in sufficient amount to render the under plate cathodic with respect to said outer plate by a potential of about 0.07 to about 0.2 volt, said outer and under plates being firmly bonded together and each having sufficient thickness to contribute structurally and substantially to the strength of the tanker

5. A gasoline tanker having structural parts with both surfaces exposed in use to the attack of a corroding agent which attacks non-uniformly, said structural parts being constructed of a triple structural layer composite steel plate, the intermediate layer containing alloying material in sufficient amount to render said intermediate layer more noble than the outside layers by a potential of about 0.07 to about 0.2 volt and all layers contributing structurally and appreciably to the strength of the structure.

6. A vessel comprising metallic parts having surface areas exposed to non-uniform attack of a corroding agent, said metallic parts resisting perforation by corrosion and being constructed of low alloy composite steel plates having structural layers of steel plate bonded together, the exposed layer being plain carbon steel and the under layer to which it is bonded being a nickel containing steel more noble than said exposed layer by a potential of about 0.07 to about 0.2 volt, both layers of steel plate contributing structurally and appreciably to the strength of the structure.

7. A metallic structure exposed in use to corrosive agents which attack non-uniformly, said structure comprising a plurality of composite plates of iron base metal joined together at their juxtaposed edges, each composite plate having a structural iron base metal plate exposed to said corrosive agents and an under structural iron base metal plate more noble than said exposed plate by a potential of about 0.07 to about 0.2 volt, said exposed plate and under plate being bonded together over substantially their entire contacting surfaces, said exposed plate being of substantially greater thickness than a mere coating and contributing structurally and appreciably to the strength of the metallic structure.

ANDREW WESLEY.