April 21, 1964 C. M. COCKRELL 3,129,684

INSULATED SHIP HULL

Filed Feb. 6, 1962

2 Sheets-Sheet 1

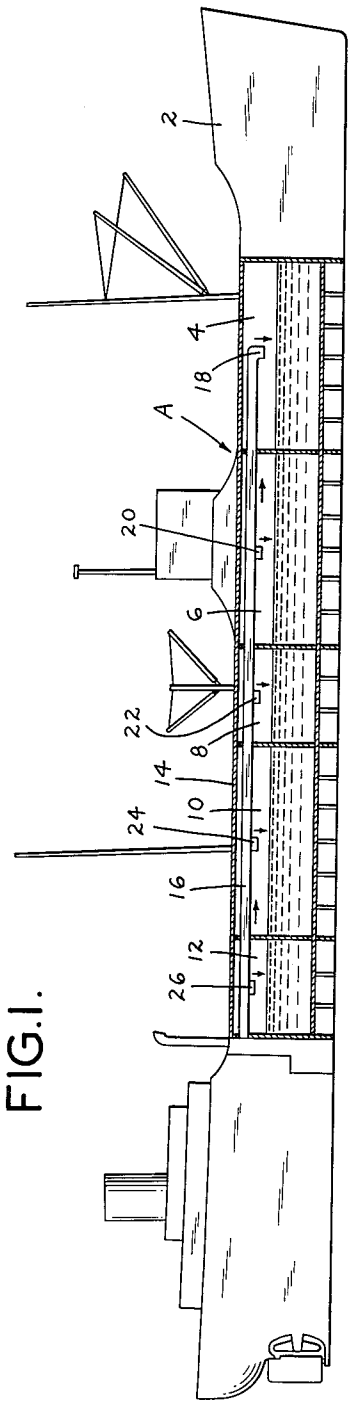


FIG. 1.

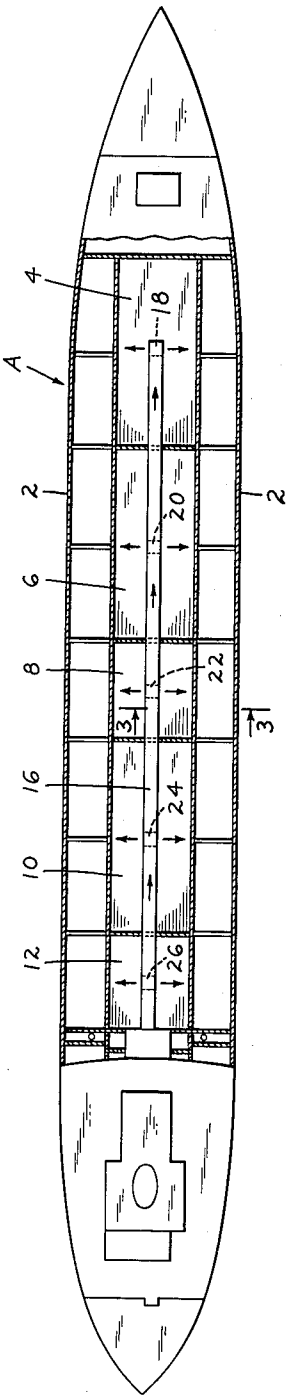


FIG. 2.

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FIG.3.

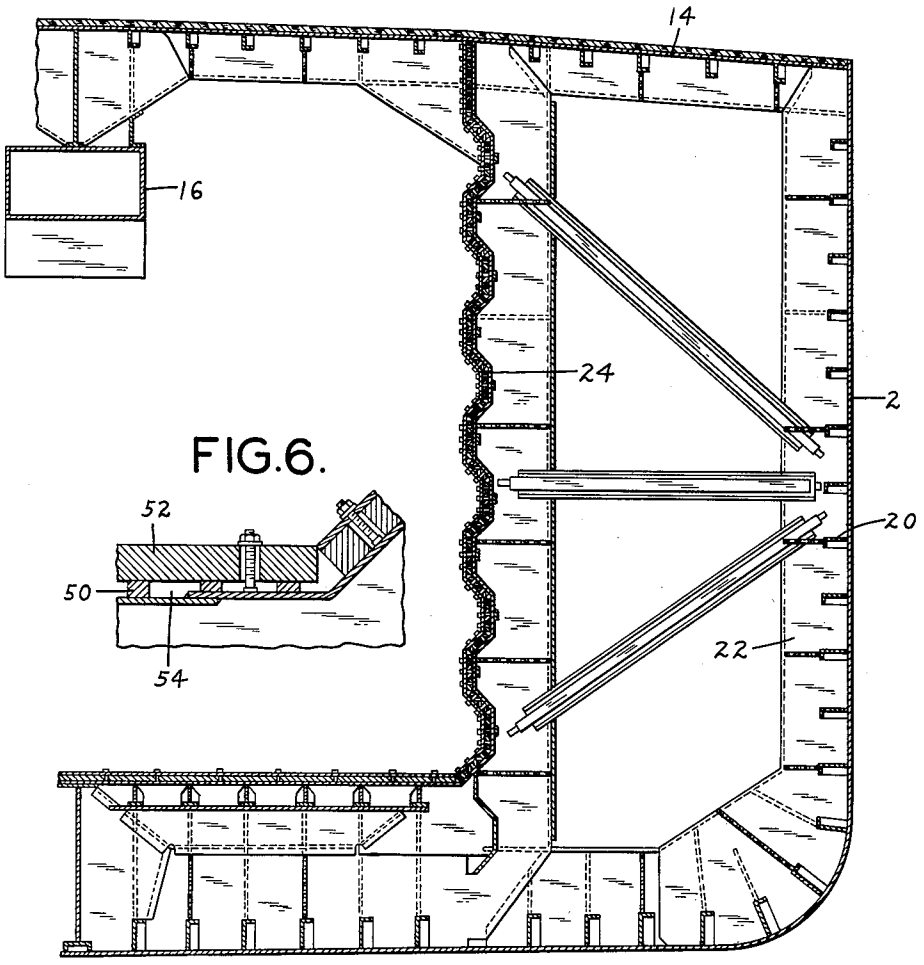


FIG.6.

FIG.4.

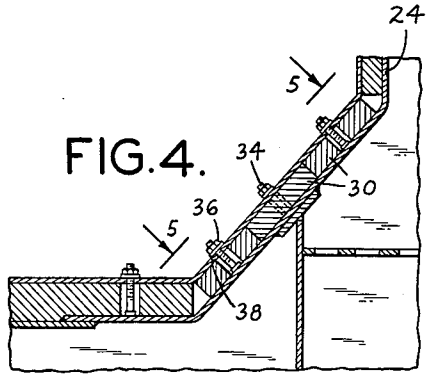
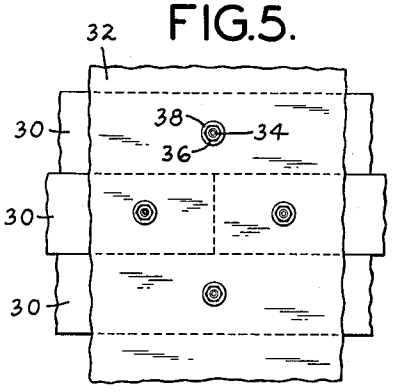


FIG.5.



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3,129,684

INSULATED SHIP HULL

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5 Claims. (Cl. 114—74)

This application relates to insulated tanks and, more particularly, to insulated tanks for transporting molten sulphur.

A large proportion of the sulphur mined in the United States is mined by the Frasch process. In such process, water, at elevated temperature and pressure, is pumped into the deposit to heat the sulphur to a temperature where the sulphur becomes liquid. Once liquid, the sulphur is pumped from the deposit to the surface with compressed air. This process of mining is well known and has been used extensively for a number of years. Sulphur mined by the Frasch process is relatively pure, that is, there is little, if any, contamination in the sulphur. Thus, as mined, the sulphur is in condition for commercial use.

For many years it has been the practice to cool and solidify the sulphur as it is mined and to ship the sulphur to customers in cold, dry bulk. Many of such customers use the sulphur in a liquid or molten state. Thus, where the sulphur is received in cold, dry bulk, it is necessary for the customer to re-heat the sulphur to a temperature where it is liquid before it is used. Since, when mined, the sulphur was initially heated to a liquid temperature, the cooling, solidifying, handling and subsequent re-heating of the sulphur constitutes an unnecessary expense. In addition, even in those instances where the sulphur is to be used in cold bulk, shipment and handling of the sulphur in its liquid form is much more economical.

Hot, liquid or molten sulphur may be stored in insulated tanks without any great difficulty. Such tanks are conventionally provided with external insulation and, where desired, may contain heaters to maintain the liquid sulphur content at the required temperature. Such tanks, while adequate for storage purposes, have numerous disadvantages when used for transportation of hot, liquid sulphur especially when such transportation is by barge or ship.

When conventional storage tanks are placed on a boat or barge, a considerable amount of dead weight is added to the boat or barge. To support the tanks and, at the same time, allow relative thermal expansion between the tank and vessel, reinforcement of the vessel is required, adding additional dead weight. In addition, substantial sulphur storage space between the tank and vessel hull is lost. To offset this lost sulphur storage space, especially on barges, it has been the practice in some instances to extend the tank above the barge deck. Such extension prevents use of the deck for cargo space and does not permit the barges to be deck loaded with a return cargo after the sulphur has been unloaded.

One means of overcoming the deficiencies of externally insulated tanks is to build the tanks into the hull and rigidly frame the tanks in the hull. Such practice would substantially reduce dead tank weight and would substantially increase ship and barge capacity. This practice would also permit flat deck design and allow deck loaded pay-loads on the return trip, where desired. However, when molten sulphur is loaded and unloaded into tanks rigidly framed to the hull, extremely high stresses are produced. These stresses are superimposed on the hull plates of the ship through the rigid frame connections between the tank and hull. It is estimated that, when handling sulphur at 280° F. at an atmospheric temperature of 60° F., the combined longitudinal and transverse stresses in the material of the tank walls are in the order of 12,000 to 20,000 p.s.i. In the tank bottom, which is more rigidly confined and where the water more readily cools the hull plates, longitudinal stresses may approach a magnitude of 26,000 p.s.i. These stresses would, of course, be transmitted to the hull through the rigid frame and exceed practical stress loads.

To relieve these stresses in such construction, an attempt was made to line the inside of the tank with an insulating material and to load the hot, liquid or molten sulphur directly into the tank against the insulation. In this attempt, foamed or cellular glass insulation was applied, as an insulated liner, to the inside of the hull. When hot, liquid sulphur was loaded into the hull the liquid sulphur penetrated the surface of the cellular glass insulation. When the molten sulphur was unloaded from the hull, a portion of the sulphur which had penetrated into the insulation remained. With the balance of the hot, molten sulphur removed, the sulphur remaining in the insulation cooled and contracted. As the sulphur cooled, voids were created in the insulation. These voids were filled when hot, molten sulphur was again loaded into the hull. However, in addition to filling the voids, the hot sulphur re-heats and re-expands the sulphur already in the insulation. Because the voids have been filled, this re-expansion tore and damaged the insulation and resulted in rapid insulation deterioration. Such deterioration not only contaminates the sulphur but completely destroys the insulation after but a short period of use. As a result of these experiences with foamed glass and similar types of insulation, internal tank insulation construction was abandoned.

It is an object of the present invention to insulate the inner surface of a vessel to provide a tank for transporting molten sulphur.

It is a further object to apply such insulation in a manner wherein the surface of the insulation can be repeatedly contacted with hot, liquid or molten sulphur without deteriorating the insulation.

It is still a further object of the invention to provide a vessel for transporting molten sulphur wherein sulphur storage is accomplished below deck permitting the deck to maintain flat for deck storage.

Still a further object of the instant invention is to provide such a vessel in an economical manner through the conversion of existing tank vessels.

A still further object is to provide such a vessel which can be used over an extended period of time and in which the tank insulation is relatively inert to the sulphur, does not readily become impregnated and, where impregnation does occur, is of sufficient resiliency to withstand repeated expansion and contraction of the sulphur.

While the instant invention has application to ship and barge constructions in general, it has particular application to ships conventionally employed as tankers for the transportation of oil and similar liquids. For purposes of illustration in the following description the invention is described as applied to a conventional oil tanker.

In the attached drawings:

FIG. 1 is a side elevational view partly in section, of a tanker embodying the instant invention;

FIG. 2 is a top plan view, also partly in section, of the tanker of FIG. 1;

FIG. 3 is an enlarged sectional view along the line 3—3 of FIG. 2;

FIG. 4 is a sectional view showing, in enlarged detail, a portion of the construction according to the instant invention;

FIG. 5 is a view taken along the line 5—5 of FIG. 4; and

FIG. 6 is a sectional view, similar to FIG. 4, showing a modified construction.

Referring first to FIGS. 1 and 2, there is shown a tanker, generally indicated A, having a hull **2** of conventional construction. A plurality of tanks **4, 6, 8, 10, 12** are supported in hull **2**, in spaced relation to the hull, deck **14** of the tanker forming a cover over the top of the tanks. A duct **16** extends longitudinal of the tanker and is provided with openings **18, 20, 22, 24, 26** for discharging dehumidified flue gas or dry air from duct **16** into tanks **4, 6, 8, 10, 12**, respectively. Duct **16** is connected to a suitable blower, not shown, for delivering air or dehumidified flue gas from duct **16** into tanks **4, 6, 8, 10, 12** and for maintaining the tanks under a slight pressure for reasons more apparent hereinafter.

As best shown in FIG. 3, the construction of tanker A, hull **2** and the support of the tanks therein is conventional. Hull **2**, deck **14** and the walls of tanks **4, 6, 8, 10, 12** may be riveted or welded. Hull **2** and deck **14** are provided, at their inner side, with conventional longitudinal ribs **20** and stiffening plates **22**, as is the exterior side of tank wall **24** (FIG. 4). The tanks are supported in spaced relation to the bottom of hull **2** by stiffening plates **22** which extend, vertically, from the inner wall of the hull to the exterior wall of the tank. At their vertical sides the tanks are supported in spaced relationship to hull **2**, by supports **26**, connected at their ends to the hull and tank, respectively. As is conventional in tankers of the type described, the space intermediate the tank and hull may be utilized on return trips as a space for ballast, such as water, as needed. With the exception of duct **16**, and the duct discharge openings extending into the tanks, the structure described hereinabove is typical of tanker construction.

Departing now from conventional construction and turning to the instant invention, it has been discovered that, when the interior surface of the tank which, ordinarily, would be in contact with the hot, molten sulfur, is covered with wood planking, the rigidly framed tanks can be filled with hot, molten sulphur without overstressing the hull plates with thermal loads. When used with the hot sulphur, the wood has been discovered to exhibit certain characteristics as an insulator which are not found with other known insulating materials. The wood planking is not readily impregnated by the molten sulphur. Because of its cellular structure, only a relatively thin outer layer of the wood is open to, and becomes filled with, the molten sulphur. Apparently because of the resilient nature of the cells contiguous with those filled with the sulphur, the expansion and contraction forces of the sulphur in the impregnated outer layer does not destroy the wood structure. Wood has been discovered to be relatively inert with respect to the sulphur and does not tend to react with the sulphur even under prolonged contact.

As best shown in FIGS. 3, 4 and 5, the interior of the longitudinal side walls, as well as the interior of the top of the tank bottom and end walls, are lined with wooden planks **30** and the wooden planks on the side and end walls are covered with a relatively thin, light-weight sheet of metal, for example, sheets of high yield strength steel or, preferably, sheets of high strength aluminum. Wooden planks **30** are positioned, with their edges abutting, longitudinally along the inside of the side, bottom and end walls of the tank. As shown in detail in FIG. 5, the abutting ends of the planks **30** are, preferably, staggered to avoid the formation of grooves or passages extending vertically along the tank walls.

In covering the side and end walls with sheet metal, it is not necessary that the metal sheets be sealed. However, sheet material with a relatively high strength is desirable. It is essential that the yield strength of these sheets be of such order that the sheets will not be stressed beyond their elastic limit when they are thermally expanded through contact with the molten sulphur. They should be of sufficient strength to permit flexing when heated and to return to their original position without metal fatigue when they are cooled; otherwise, the sheets will deteriorate rapidly. In addition, of course, the sheet material should be of sufficient strength to withstand hydraulic loading created by changes of liquid level in the tank caused by rolling of the ship or in filling and emptying the tank.

In selecting the metal sheet material, it is desirable to have a material that will withstand the corrosion of molten sulphur. The metal plate must also have an endurance limit exceeding the net thermal expansion for the temperature range multiplied by its modulus of elasticity. The thickness of the plate should be sufficient to withstand the hydraulic loading created by change of liquid level from rolling of the ship or when pumping out the tank. And, the sum of the stresses produced by thermal expansion and hydraulic loading should not exceed the endurance limit of the material.

When outfitting a ship in tropical or subtropical areas, where such ship is designed to be used only in such areas, the temperature range to which the metal plates would be subjected is determined by the ambient temperature at the time of installation, and the temperature at which the molten sulphur is transported. Ambient temperature could be as high as 100° F. and the minimum temperature at which the sulphur might be transported could be as low as 240° F., the temperature below which sulphur will solidify. In this instance, the temperature range amounts to 140° F., and the ratio of the endurance limit to product of thermal coefficient of expansion and modulus of elasticity must be at least equal to this temperature range of 140° F.

However, if it is desirable to outfit a ship to operate in colder climates, and the ship is outfitted at ambient temperatures of about 32° F., and the temperature of the sulphur is to be maintained at about 340° F., the temperature above which molten sulphur becomes viscous, the temperature range amounts to about 308° F. In this instance the ratio of the endurance limit to product of thermal coefficient of expansion and modulus of elasticity must be at least equal to about 308° F.

Planks **30** are held in position by studs **34**, or other suitable connectors, fastened to the interior of the tank wall and are covered with metal sheet **32**. The sheet metal member, together with planks **30**, are held on studs **34** by washers **36** and nuts **38**.

No attempt is made to fill or seal the spaces between the abutting edges or ends of the planks nor is any attempt made to seal the sheet metal liner positioned over the planks. In the practice of the invention, it is important that the sheet metal covering over the planks be free to expand and contract without transmitting thermal expansion and contraction forces to the hull of the ship. This is accomplished by using a relatively thin gauge metal for this purpose.

It is not necessary for the sheet metal covering and the plank lining to be impervious to molten sulphur. During loading, the molten sulphur is allowed to seep through any openings in the sheet metal liner and into any spaces between the edges of abutting planks. As the molten sulphur seeps into spaces between the planks, it is rapidly cooled and solidifies, filling such spaces. Since the sulphur has a low coefficient of heat transmission, the solidified sulphur becomes a functioning part of the insulating barrier, insulating the hot, liquid molten sulphur in the tank from the cool, exterior tank walls.

In FIG. 6 there is shown a modification of the instant invention in which the low coefficient of heat transmission and the insulating properties of the sulphur are further employed. In this embodiment the tank, other than its bottom wall, is of the construction described above. Rather than position the planks directly on the metal tank bottom, spaced wooden sleepers, which may be 2" x 6", 2" x 4", or similar dimensioned wooden strips, are first

placed, at spaced intervals, on the tank bottom. Over these sleepers, in a direction transverse to the strips, wooden planks **52** are positioned and are fastened to the bottom wall of the tank by studs.

In this embodiment, sleepers **50** are spaced so as to support planks **52** without buckling. As can be seen in FIG. 6, a space **54** is formed between the sleepers. The sheet metal cover, while used on the end and side walls of the tank, is not used on the bottom wall of this embodiment.

When the bottom wall construction of FIG. 6 is used, during the initial filling of the tank with molten sulphur, the sulphur flows between the planks and substantially fills space **54** between the tanks. This sulphur, as it enters space **54**, cools, solidifies and forms a part of the insulation on the tank bottom. Thereafter, as the tank is emptied and filled, this sulphur remains in place being, for all purposes, a composite part of the tank lining.

In the practice of the instant invention, the wooden planks are only applied to those exterior tank walls which are to be in contact with the hot sulphur, that is, the side, bottom and end walls. The sheet metal lining is applied to the side and end walls and may, if desired, be also applied to the bottom tank wall. However, insofar as the bottom wall is concerned, the sheet metal lining may be omitted. Where, as is shown in FIGS. 1 and 2, the tank is divided into a plurality of tank compartments by bulkheads, insulation of the bulkheads is not necessary, nor is it desirable to apply a lining to the underside of the deck which forms the tank top. With respect to the deck or tank top, a mastic coating containing pulverized cork is applied over the top of the metal deck to insulate the top of the deck and to keep the interior of the tank, and the sulphur therein, hot. This cork coating on the deck also prevents moisture from condensing on under surface of the deck.

To prevent corrosion to the exposed and unprotected portions of the bulkheads and to the underside of the deck, when loaded with hot sulphur the tank is maintained under slight pressure with dry, dehumidified flue gases pumped into the tanks from duct **16**. Dry, dehumidified flue gases are employed because of their low oxygen content.

Many different types of wood may be employed in the planking of the instant invention. Since soft woods are, generally, more resistant to heat and have better insulating qualities than hard woods, soft woods are preferred. Soft woods which have been found to be particularly good are Douglas fir, cypress, white spruce, sitka spruce, and pine. Standard 2" x 10" planks of soft wood, having a minimum thickness of 1⅝", have been found to be useful for insulating side and end walls. Standard 4" x 10" planks have been found useful for insulating the bottom tank wall.

As is customary in the transportation of hot liquid materials, a suitable heater, not shown, is immersed in the hot molten sulphur during transportation to maintain the sulphur at a liquid temperature. The construction shown and described herein has proved to be so effective that only 5 to 6 B.t.u.'s per pound of sulphur per day are required to maintain the sulphur in the molten state when the ship is at sea. The sulphur is loaded into the tank as a hot, molten, liquid material and is maintained hot and liquid by the heater. With the exception of that small portion of the sulphur which seeps through the metal liner and into the spaces between the planks, all of the sulphur within the tank is maintained at elevated temperature and liquid. When the ship reaches its destination, the hot, liquid, molten sulphur is pumped out of the tank with suitable pumps.

The terms and expressions which have been employed are used as terms of description and not of limitation, and there is no intention, in the use of such terms and expressions, of excluding any equivalents of the features shown and described or portions thereof, but it is recognized that various modifications are possible within the scope of the invention claimed.

What is claimed is:

1. A ship for transporting hot, liquid sulphur, comprising a hull, a tank in said hull for receiving hot, liquid sulfur, said tank having on its inner vertical and bottom surfaces for engagement with said sulphur a lining of abutting wood planks, and a cover of sheet metal over said planks on said inner vertical surfaces, said lining on said bottom surface including wooden sleepers extending at spaced intervals along said bottom surface, said abutting wood planks on said bottom surface extending in abutting contact in a direction substantially transverse to said sleepers, the spaced intervals between said sleepers being substantially filled with sulphur.

2. A ship for transporting hot, liquid sulphur as recited in claim 1 in which said planks are of soft wood.

3. A ship for transporting hot, liquid sulphur as recited in claim 2, in which said planks on said bottom surface are thicker than said planks on said inner vertical surfaces.

4. A ship for transporting hot, liquid sulphur, comprising a hull, a tank in said hull for receiving hot, liquid sulphur, said tank having on its inner vertical and bottom surfaces for engagement with said sulphur a lining of abutting wood planks, a cover of sheet metal over said planks on said inner vertical surfaces, said lining on said bottom surface including wooden sleepers extending at spaced intervals along said bottom surface, said abutting wood planks on said bottom surface extending in abutting contact in a direction substantially transverse to said sleepers, the spaced intervals between said sleepers being substantially filled with sulphur and means for maintaining said tank under pressure.

5. A ship for transporting hot, liquid sulphur as recited in claim 4 in which said means for maintaining said tank under pressure includes duct means in said tank.

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