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PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Method and apparatus for the Storage of Petroleum

We, BETHLEHEM STEEL CORPORATION, a corporation organised under the laws of the State of Delaware, United States of America, of 701 East Third Street, Bethlehem, State of Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to method and apparatus for the storage of petroleum. More specifically, this invention relates to method and apparatus for the storage of petroleum under water, employing hydraulic displacement principles and providing positive separation within the storage vessel of the petroleum and the displacement water.

Hydraulic displacement type underwater petroleum storage is well known in the art today, as shown for example in U.S. Patents 3,145,539 and 3,146,458. In conventional hydraulic displacement storage apparatus which will contain varying quantities of petroleum and displacement water, the petroleum and displacement water will be in physical contact with each other at an interface. Obviously, the interface will descend as petroleum is introduced for storage in the apparatus, and the interface will ascend as petroleum is removed from storage. Ordinarily, there are few problems arising from the physical contact between petroleum and water at the interface.

The term "petroleum" as employed herein with respect to the preferred embodiment is intended to comprise crude petroleum as well as refined petroleum products such as jet fuels, all having a density less than that of water. Sometimes, under certain circumstances and with certain stored liquids, particularly jet fuels, it is desirable to prevent a petroleum-water interface and to completely physically separate the petroleum and the displacement water.

A prior proposal for maintaining complete

physical separation appears in French Patent 860,130, wherein a solid septum of density intermediate that of the stored petroleum and the displacement water is used to float between these two liquids. However, this is not a practical solution. A considerable amount of clearance between the perimeter of the septum and the interior walls of the storage apparatus must necessarily be provided to permit free vertical movement of the septum in the apparatus as the relative quantities of stored petroleum and the displacement water change, and this clearance immediately results in physical contact between the stored petroleum and the displacement water. Also, the horizontal cross-section of the storage apparatus is usually different at various horizontal planes through the apparatus, and the rigid septum would obviously not be capable of free vertical movement over anything more than a closely limited range. Further, the French patent assumes that the interior of the storage apparatus is clear of stiffeners and other structural members, but in practice, this is not true.

Another attempt at solution of the stated problem involves the installation of a flexible rubber-like membrane or diaphragm in the storage vessel, as proposed by several workers in this field and as shown, for example, in U.S. Patent 2,731,168. There are several drawbacks inherent in this method of solution. The perimeter of the membrane being fixed to the interior of the tank, the vertical movement of the membrane with changes in relative quantities of stored petroleum and displacement water is quite limited. Entrainment of air or gases in the storage apparatus will modify the shape of the membrane creating filling and emptying difficulties and loss of storage volume. Installation of the membrane makes for construction problems. The membrane is subject to mechanical damage, and maintenance of the membrane and repairs thereto are difficult if not impossible while the storage apparatus is submerged. The membrane does not lend itself

to metering the stored liquid during loading and unloading.

It has now been discovered that complete physical separation between the petroleum and water can be attained by establishing and maintaining in the storage apparatus between the body of petroleum and the body of displacement water a layer or body of a third liquid of density intermediate the density of the stored petroleum and the density of the displacement water, the third liquid being substantially insoluble or immiscible in and inert to the said stored petroleum and the displacement water.

Referring now to the drawing, in which like numerals represent like parts in the several views.

FIGURE 1 represents diagrammatically a vertical section of storage apparatus which has just been filled with water and sunk to rest on the marine floor.

FIGURE 2 represents diagrammatically a vertical section of the storage apparatus towards the end of the initial introduction of separating liquid.

FIGURE 3 represents diagrammatically a vertical section of the storage apparatus as petroleum is being introduced therein for storage.

FIGURE 4 represents diagrammatically a vertical section of the storage apparatus after it has been filled with petroleum.

FIGURE 5 represents diagrammatically a vertical section of the storage apparatus as petroleum is being discharged therefrom by hydraulic displacement.

FIGURE 6 represents diagrammatically a vertical section of the storage apparatus at the end of the petroleum discharge cycle.

The present invention, in the preferred embodiment, includes the structure disclosed in U.S. Patent 3,145,539, but all details of the present structure necessary to a clear and complete understanding of the present invention are described herein.

The underwater petroleum storage apparatus is seen as comprising a liquid-tight hull 1 (corresponding to hull 1 of U. S. Patent 3,145,539) and column 2 (corresponding to column 13 of U. S. Patent 3,145,539) communicating therewith. While only one column 2 is shown in the drawing, it will be understood that more than one such column may be employed. Also, in the drawing, hull 1 may be of much larger horizontal dimension than column 2, and this is indicated diagrammatically by the break in hull 1.

Salt water receiver 3 (corresponding to salt water receiver 42 of U. S. Patent 3,145,539) communicates with the lower portion of hull 1 through salt water line 4 (corresponding to any of salt water lines 62-68 of U. S. Patent 3,145,539) terminating in inverted funnel 5. Pump 6 has its intake end connected to line 7 communicating with the surrounding body of water 8, and discharges to salt water re-

ceiver 3 through salt water supply line 9. Salt water receiver 3 has an overflow 10.

For the purpose of clarity, salt water receiver 3 has been indicated diagrammatically as outside the column 2. It should be understood that salt water receiver 3 may be mounted within column 2 as shown in the preferred embodiment of U. S. Patent 3,145,539; alternatively, salt water receiver 3 may be supported outside column 2.

The upper portion of column 2 is provided with petroleum loading line 11, having valve 12 therein, which may communicate with a source of petroleum such as a receiver compartment 34 as shown in U. S. Patent 3,145,539. The upper portion of column 2, below petroleum loading line 11, is provided with petroleum unloading line 13, having valve 14 therein, communicating with a tanker vessel.

The present invention contemplates the interposition between petroleum and water in the underwater petroleum storage apparatus of a separating liquid 15 substantially insoluble in and inert to the petroleum and water and having a density intermediate the density of the stored petroleum and water. Line 16, having valve 17 therein, communicates between a source of separating liquid (which may, for instance, be a tank mounted on the deck structure of the apparatus, not shown) and the upper portion of column 2, whereby said separating liquid 15 may be introduced into the said underwater petroleum storage vessel as hereinafter described.

By way of example, and not of limitation, a suitable separating liquid 15 would be a castor oil, particularly of the grade known in the trade as "blown" or oxidized. As shown in the 1955 Catalogue of The Baker Castor Oil Company, blown or oxidized castor oils having specific gravities of about 0.97 are commercially available. The specific gravity of sea water is about 1.02. The specific gravity of typical jet fuels is about 0.80 and may range between about 0.83 — 0.90 for typical petroleum crudes. Therefore, these castor oils will float on sea water below a stored petroleum and can effectively separate these liquids.

The operation of the underwater petroleum storage apparatus will now be described.

It will be understood that the structure, in the preferred embodiment, is marine stable and can be transported on its own buoyancy to the desired location. Thereafter, the structure is ballasted with water 18, through conventional ballast piping (not shown) or through salt water receiver 3, filled and submerged to rest on the marine floor 19. If desired, piles, well-known in the art, may be employed to anchor the structure to marine floor 19. Also, the structure may be submerged to a position intermediate the surface of the sea 8 and marine floor 19 and stably supported in such position as by conventional piles.

The structure is now ready for the introduction of the separating liquid 15. Valve 17 is opened and separating liquid 15 flows from the source of separating liquid into the upper portion of column 2 and on to the surface of water 18. As the level of separating liquid 15 rises in column 2, water 18 in the structure will be discharged through overflow 10 of salt water receiver 3. A sufficient quantity of separating liquid 15 is introduced into the structure to provide a layer of adequate thickness when the separating liquid 15 is subsequently displaced to those parts of the structure having a greater horizontal cross section as hull 1.

The structure is now ready for the introduction of petroleum 20. Valve 12 is opened and petroleum 20 flows from the source of petroleum into the upper portion of column 2 and on to the surface of separating liquid 15. As the level of petroleum 20 rises in column 2, water 18 in the structure will be discharged through overflow 10 of salt water receiver 3. When the structure has been filled with petroleum 20, separating liquid 15 will extend completely from one side to the other of hull 1, and will function as a total barrier between water 18 and petroleum 20.

When it is desired to remove petroleum from storage in the structure, pump 6 is operated to introduce water 18 from the surrounding body of water 8 into salt water receiver 3, and valve 14 is opened. Water 18 passes through salt water line 4 into hull 1, and petroleum is displaced from the structure through unloading line 13. Any water 18 in excess of that required to displace petroleum 20 at the desired rate is discharged from salt water receiver 3 through overflow 10.

Means such as float controls responsive to the petroleum-separating liquid interface 21 and the separating liquid-water interface 22 may be employed to shut down pump 6 when the petroleum-separating liquid interface 21 approaches the level of unloading line 13, and to close valve 12 when the separating liquid-water interface 22 approaches inverted funnel 5, so as to prevent loss of separating liquid 15 through overflow 10 or unloading line 13.

The underwater petroleum storage apparatus may be deballasted by suitable conventional means and refloated to another site.

It may be desired to eliminate altogether column 2, and to employ only hull 1 for storage of petroleum 20. Such a structure would be completely submerged in the body of water 8 except for those elements which may be desired to be operated from the surface of body of water 8. Thus, petroleum loading line 11 and unloading line 13 and separating liquid line 16 can communicate directly with hull 1. If a salt water receiver 3 is to be employed, salt water line 4 can communicate with hull 1 as in the preferred embodiment shown in the drawings. Alternatively, salt water receiver 3 can be eliminated, and also hull 1 can com-

municate directly with the body of water 8, if this is desired.

It will be understood that FIGURES 1-6 are essentially diagrammatic, and the levels of the various liquids in the structure are illustrative only. Also, the present invention is capable of use with other liquids not classified as "petroleum" but lighter than and insoluble in the separating liquid, and the use of the term "petroleum" in the appended claims is intended to cover these other liquids.

Some of the advantages accruing from the present invention are:

1) The separating liquid 15 is not susceptible to mechanical damage, unlike the solid septum or flexible membrane earlier referred to.

2) The separating liquid 15 is easily introduced into the structure when the latter is on the bottom of the marine floor 19. In the unlikely event that separating liquid 15 is lost due to malfunctioning interface-responsive control means, or in the event it becomes ineffective, it may easily be replaced without having to gain entrance to the interior of the structure and without having to refloat the structure.

3) Should free water or other heavy contaminant be introduced into the structure along with petroleum 20, such constituents would pass through the separating liquid 15 and into the water 18.

4) Accurate metering of petroleum 20 is assured.

WHAT WE CLAIM IS:—

1. Hydraulic displacement petroleum storage apparatus, which comprises a storage tank having first means to pass petroleum and water into and out of the storage tank and second means to establish in the storage tank a layer of separating liquid between and in contact with the petroleum and water and floating on the water and completely physically separating the petroleum and water, said separating liquid having a specific gravity intermediate that of the petroleum and water and being substantially insoluble in the petroleum and water.

2. Apparatus according to claim 1, wherein said second means comprises a conduit communicating between a source of said separating liquid and the interior of said storage tank adjacent the upper portion thereof.

3. Apparatus according to claim 1 or 2, wherein the storage tank contains petroleum and water, with said layer of separating liquid between and in contact with the petroleum and water and floating on the water.

4. Apparatus according to claim 1, 2 or 3, wherein the storage tank is adapted to be stably supported in a marine location.

5. Apparatus according to claim 1, 2, 3 or 4, wherein said layer of separating liquid is adapted to travel vertically in said storage tank through a major portion of the height of said storage tank as the relative quantities of petroleum and water in said storage tank vary.



The structure is now ready for the introduction of the separating liquid 15. Valve 17 is opened and separating liquid 15 flows from the source of separating liquid into the upper portion of column 2 and on to the surface of water 18. As the level of separating liquid 15 rises in column 2, water 18 in the structure will be discharged through overflow 10 of salt water receiver 3. A sufficient quantity of separating liquid 15 is introduced into the structure to provide a layer of adequate thickness when the separating liquid 15 is subsequently displaced to those parts of the structure having a greater horizontal cross section as hull 1.

The structure is now ready for the introduction of petroleum 20. Valve 12 is opened and petroleum 20 flows from the source of petroleum into the upper portion of column 2 and on to the surface of separating liquid 15. As the level of petroleum 20 rises in column 2, water 18 in the structure will be discharged through overflow 10 of salt water receiver 3. When the structure has been filled with petroleum 20, separating liquid 15 will extend completely from one side to the other of hull 1, and will function as a total barrier between water 18 and petroleum 20.

When it is desired to remove petroleum from storage in the structure, pump 6 is operated to introduce water 18 from the surrounding body of water 8 into salt water receiver 3, and valve 14 is opened. Water 18 passes through salt water line 4 into hull 1, and petroleum is displaced from the structure through unloading line 13. Any water 18 in excess of that required to displace petroleum 20 at the desired rate is discharged from salt water receiver 3 through overflow 10.

Means such as float controls responsive to the petroleum-separating liquid interface 21 and the separating liquid-water interface 22 may be employed to shut down pump 6 when the petroleum-separating liquid interface 21 approaches the level of unloading line 13, and to close valve 12 when the separating liquid-water interface 22 approaches inverted funnel 5, so as to prevent loss of separating liquid 15 through overflow 10 or unloading line 13.

The underwater petroleum storage apparatus may be deballasted by suitable conventional means and refloated to another site.

It may be desired to eliminate altogether column 2, and to employ only hull 1 for storage of petroleum 20. Such a structure would be completely submerged in the body of water 8 except for those elements which may be desired to be operated from the surface of body of water 8. Thus, petroleum loading line 11 and unloading line 13 and separating liquid line 16 can communicate directly with hull 1. If a salt water receiver 3 is to be employed, salt water line 4 can communicate with hull 1 as in the preferred embodiment shown in the drawings. Alternatively, salt water receiver 3 can be eliminated, and also hull 1 can com-

municate directly with the body of water 8, if this is desired.

It will be understood that FIGURES 1—6 are essentially diagrammatic, and the levels of the various liquids in the structure are illustrative only. Also, the present invention is capable of use with other liquids not classified as "petroleum" but lighter than and insoluble in the separating liquid, and the use of the term "petroleum" in the appended claims is intended to cover these other liquids.

Some of the advantages accruing from the present invention are:

1) The separating liquid 15 is not susceptible to mechanical damage, unlike the solid septum or flexible membrane earlier referred to.

2) The separating liquid 15 is easily introduced into the structure when the latter is on the bottom of the marine floor 19. In the unlikely event that separating liquid 15 is lost due to malfunctioning interface-responsive control means, or in the event it becomes ineffective, it may easily be replaced without having to gain entrance to the interior of the structure and without having to refloat the structure.

3) Should free water or other heavy contaminant be introduced into the structure along with petroleum 20, such constituents would pass through the separating liquid 15 and into the water 18.

4) Accurate metering of petroleum 20 is assured.

WHAT WE CLAIM IS:—

1. Hydraulic displacement petroleum storage apparatus, which comprises a storage tank having first means to pass petroleum and water into and out of the storage tank and second means to establish in the storage tank a layer of separating liquid between and in contact with the petroleum and water and floating on the water and completely physically separating the petroleum and water, said separating liquid having a specific gravity intermediate that of the petroleum and water and being substantially insoluble in the petroleum and water.

2. Apparatus according to claim 1, wherein said second means comprises a conduit communicating between a source of said separating liquid and the interior of said storage tank adjacent the upper portion thereof.

3. Apparatus according to claim 1 or 2, wherein the storage tank contains petroleum and water, with said layer of separating liquid between and in contact with the petroleum and water and floating on the water.

4. Apparatus according to claim 1, 2 or 3, wherein the storage tank is adapted to be stably supported in a marine location.

5. Apparatus according to claim 1, 2, 3 or 4, wherein said layer of separating liquid is adapted to travel vertically in said storage tank through a major portion of the height of said storage tank as the relative quantities of petroleum and water in said storage tank vary.

6. Apparatus according to any one of claims 1 — 5, wherein said separating liquid is castor oil, preferably blown castor oil.

5 7. Apparatus according to claim 6, wherein the petroleum is jet fuel having a specific gravity between 0.80 — 0.90 and the water is sea water.

10 8. A method of storing petroleum, which comprises introducing petroleum and water into a storage tank, and completely physically separating the petroleum and water by floating a layer of separating liquid on top of the water, said separating liquid having a specific gravity intermediate that of the petroleum and water, and being substantially insoluble in the petroleum and water.

15 9. The method according to claim 8, wherein petroleum and water are introduced into or removed from the storage tank while maintaining the layer of separating liquid floating on the water.

20 10. The method according to claim 8 or 9, wherein the storage tank is ballasted with

water and submerged in a marine location, said separating liquid is introduced into said storage tank and floated over the entire surface of said water thereby simultaneously displacing from said storage tank less than all of the water in said storage tank and liquid petroleum is introduced into said storage tank and floated over said layer of separating liquid thereby simultaneously depressing said layer of separating liquid and displacing water from said storage tank.

11. Hydraulic displacement petroleum storage apparatus substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

12. A method of storing petroleum according to claim 8, substantially as hereinabove described.

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