OFFSHORE FUEL STORAGE FACILITY

FIELD OF INVENTION

Embodiments of the present invention provide a stand-alone offshore fuel storage facility for storing large amounts of fuel or other petrochemicals.

BACKGROUND

Currently, petroleum and petrochemical products are stored in large steel tanks located near a port facility. These tanks consume large tracts of land that could be used more productively. They also take a considerable amount of time to construct, as the sites must be engineered to support the large weight of the filled tanks. Furthermore, in geologically active areas, the tanks must be hardened or otherwise reinforced to provide for a minimum safety margin should earthquakes or other seismic activity occur.

Given the various types of petroleum and petrochemical products that may be involved, the tank farms are often a source of noxious fumes that may drift into populated areas adjacent the yards. The storage of large volumes of petroleum and petrochemical also poses an inherent risk of fire.

Another problem associated with onshore storage facilities is that access to these facilities is often limited. Ships may need to wait in line for several hours in order to deliver or receive cargo from these facilities. This is very inefficient, as well as expensive, for both the ship operator and the facility controller.

One solution to the problems discussed above is to locate the storage facility offshore adjacent to the land. This requires that a jetty or other structure be constructed to provide access from the land to the facility. However, due to their proximity to the shoreline, the issues with respect to fumes and fire still apply. Additionally, these facilities also have limited access. Alternately, expensive dredging is required to allow large tanker ships, which may have a draft of 25 meters, to reach the facility.

SUMMARY

One aspect of the present invention provides a stand-alone offshore fuel storage facility comprising a spine structure supported on a seabed; and a plurality of floating storage modules moored adjacent the spine structure, each of the floating storage modules capable of storing at least one type of liquid. The facility may also include a platform supported on the seabed capable of supporting a plurality of operational facilities. In some embodiments, the facility may also include a floating breakwater that completely encloses the plurality of floating storage modules.

In alternate embodiments, the storage facility may also include at least one jetty supported on the seabed and located adjacent the spine structure. The spine structure, platform, and jetty may be supported on the seabed using pile jackets. The spine structure may be made from pre-cast reinforced concrete and/or pre-cast pre-stressed concrete.

In other embodiments, each of the plurality of floating storage modules may be located adjacent to a plurality of mooring dolphins, wherein the mooring dolphins are attached to the seabed, such that the floating storage modules remain in a fixed lateral position with respect to each other and with respect to the spine structure.

In further embodiments, at least one of the plurality of floating storage modules may include an outer pre-stressed concrete hull, an inner pre-stressed concrete hull, at least one steel tank within said inner hull, and a plurality of bulkheads defining a plurality of compartments for storing the liquid within the tank. The floating storage module may further include a plurality of concrete beam grids disposed between the outer hull and the inner hull. The compartments may be arranged in a concentric configuration so that the floating storage module can remain uniformly loaded while charging and discharging fuel.

In some embodiments, the bulkhead may be made from a material selected from a group consisting of steel, concrete, and a steel–concrete composite. In alternate embodiments, at least one of the floating storage modules may be a tanker ship. In

further embodiments, a water depth from the seabed to the surface is less than 100 meters. The liquid may be at least one liquid selected from a group consisting of fuel, petroleum products, petrochemical products, Liquefied Natural gas, and water

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

Figure 1 illustrates a perspective view of an offshore fuel storage facility according to one embodiment of the present invention;

Figure 2 illustrates a top plan view of the offshore fuel storage facility of Figure 1;

Figure 3 illustrates a cross-sectional side view of the offshore fuel storage facility of Figure 1 along the line X1-X1 of Figure 2;

Figure 4 illustrates a perspective view of an offshore fuel storage facility according to an alternate embodiment of the present invention;

Figure 5 illustrates a top plan view of the offshore fuel storage facility of Figure 4;

Figure 6 illustrates a cross-sectional side view of the offshore fuel storage facility of Figure 4 along the line X1-X1 of Figure 5; and

Figure 7 illustrates one embodiment of a floating storage module that can be used as part of the offshore fuel storage facilities of Figures 1-6.

Figure 8 shows a schematic drawing of an offshore fuel storage facility according to another embodiment of the present invention

DETAILED DESCRIPTION

Figure 1 illustrates a perspective view of an offshore fuel storage facility, designated generally as reference numeral 100, according to one embodiment of the present invention. Figure 2 illustrates a top plan view of the offshore fuel storage facility 100, and Figure 3 illustrates a cross-sectional side view of the offshore fuel storage facility 100 of Figure 2 along the line X1-X1.

With continuing reference to Figures 1-3, the facility 100 can include a spine structure 110 supported on a seabed 102 and elevated above a surface 104 of the water. The spine structure 110 may also include a platform 112 that supports a plurality of facilities and equipment, designated generally as reference numeral 150. In some embodiments, the platform 112 may also be attached to the spine structure 110 and supported on the seabed 102. A floating breakwater 140 may be located around the floating storage modules 400. One or more jetties 114 that facilitate the docking of one or more ships 118 may be connected to the platform 112. The facility 100 also includes a plurality of floating storage modules 400. In this embodiment, the floating modules 400 are all aligned perpendicularly to the spine structure 110 which is parallel to the jetty 114. It is understood that other alignments are also possible.

The spine structure 110, platform 112 and jetty 114 may be supported on the seabed 102 using, by way of example and not limitation, a plurality of pile jackets 120. The floating storage modules 400 and floating breakwater 140 may be held laterally in place with respect to each other using a plurality of mooring dolphins 122. The mooring dolphins 122 allow the floating modules 400 to move freely in a vertical direction with respect to each other due to tidal variations and different floating heights based on the weight of the stored product. One or more mooring arms 126 may be also attached to one or more caps 124 on top of the mooring dolphins 122 to restrain the modules 400 in a lateral direction. A plurality of flexible hose towers 106, used to pump fuel into and out of the modules 400, may be located along the spine structure 110. A plurality of rubber fenders 128 may be attached to the mooring dolphins 122 and mooring arms 126 to absorb the horizontal force as the modules 400 move horizontally due to wind and wave action.

The facility 100 may also include a helipad 134 connected to the platform 112 via a gangway 136. The helipad 134 may also be supported on the seabed 102 using a plurality of pile jackets 120. In alternate embodiments, the helipad 134 may be part of the platform 112 or spine structure 110.

One advantage of the layout of the facility 100 is that it provides for easy removal and reinstallation of the floating modules 400 should there be a necessity for these modules 400 to be towed to the dockyard or be deployed elsewhere in case of emergency.

Figure 4 illustrates a perspective view of an offshore fuel storage facility, designated generally as reference numeral 200, according to an alternate embodiment of the present invention. Figure 5 illustrates a top plan view of the offshore fuel storage facility 200 of Figure 4, while Figure 6 illustrates a cross-sectional side view of the offshore fuel storage facility 200 of Figure 4 along the line X1-X1.

With continuing reference to Figures 4-6, the facility 200 can include a spine structure 210 supported on a seabed 102 and elevated above a surface 104 of the water. The spine structure 210 may also include a platform 212 that supports a plurality of facilities and equipment, designated generally as reference numeral 250. In some embodiments, the platform 212 may also be attached to the spine structure 210 and supported on the seabed 102. A floating breakwater 140 may be located around the floating storage modules 400. One or more jetties 214 that facilitate the docking of one or more ships 118 may be connected to the platform 212. The facility 200 may also include a plurality of floating storage modules 400. In this embodiment, the floating modules 400 are all aligned perpendicularly to the spine structure 210, which is perpendicular to the jetty 214. It is understood that other alignments are also possible.

The spine structure 210, platform 212 and jetty 214 may be supported on the seabed 102 using, by way of example and not limitation, a plurality of pile jackets 220. The floating storage modules 400 and floating breakwater 140 may be held laterally in place with respect to each other using a plurality of mooring dolphins 222. The mooring dolphins 222 allow the floating modules 400 to move freely in a vertical

direction with respect to each other due to tidal variations and different floating heights based on the weight of the stored product. One or more mooring arms 226 may be also attached to one or more caps 224 on top of the mooring dolphins 222 to restrain the modules 400 in a lateral direction. A plurality of rubber fenders 228 may be attached to the mooring dolphins 222 and mooring arms 226 to absorb the horizontal force as the modules 400 move horizontally due to wind and wave action. A plurality of flexible hose towers 206 for pumping fuel into and out of the floating storage modules 400 may be strategically placed along the spine structure 210.

The facility 200 may also include a helipad 234 connected to the platform 212 via a gangway 236. The helipad 234 may also be supported on the seabed 102 using a plurality of pile jackets 220. In alternate embodiments, the helipad 234 may be part of the platform 212 or spine structure 210.

One advantage of the layout of the facility 200 is that it may be more cost effective to produce since it uses having a shorter spine structure 210. The layout of the facility 200 also provides for easy removal and reinstallation of the floating modules 400 should there be a necessity for these modules 400 to be towed to the dockyard or be deployed elsewhere in case of emergency.

In some embodiments, the spine structures 110, 210 and platforms 112, 212 may be made of pre-cast reinforced concrete that is supported by the pile jackets 120, 220, respectively. In alternate embodiments, the spine structures 110, 210 and platforms 112, 212 may be made from pre-cast pre-stressed concrete. Other materials may also be used. The spine structures 110, 210 are installed with an adequate freeboard, which is the vertical distance from the normal water surface 104 to the top of the spine structures 110, 210. It is understood that the amount of freeboard may vary depending on tidal fluctuations. For example, the amount of freeboard may vary from between 1 and 6 meters. It is understood that a higher or lower amount of freeboard depending, for example, on possible weather conditions, may also be used. The overall dimensions of the spine structures 110, 120 will depend on the width and number of storage modules 400 that form the facilities 100, 200. The spine structures 110, 210 allow vehicles and workers to get access to the floating modules 400 that may be moored by dolphins 122, 222 on either one side of the spine 110 as shown in Figure 1, or both sides of the spine

210 as shown in Figure 4. The spine structures 110, 210 may also carry the power lines from the generating power plant, and pipes from the jetties 114, 214 and other supporting infrastructure facilities 150, 250.

The floating breakwaters 140 form a perimeter around the floating storage modules 400. The breakwaters 140 are designed to protect the facilities 100, 200 from large waves and ship collision. In some embodiments, the breakwaters 140 may also serve as an oil fence to restrict the flow of any spilled petrochemical product. In one embodiment, the Floating breakwaters 140 can be made from pre-stressed pre-cast concrete. Alternately, the breakwaters 140 may be made from steel. Bilge keels (not shown) may be attached to the bottom sides of the floating breakwaters 140 in order to reduce the roll motion that may result from large waves striking the breakwaters 140. These floating breakwaters 140 can be moored using, for example, the pile jacket-dolphin moorings 122, 222. In operation of the facilities 100, 200, portions of the floating breakwaters 140 may be detached so as to allow the floating storage modules 400 to be winched in or towed out for either maintenance purposes or for emergency deployment elsewhere to supply fuel.

The pile jacket founded platforms 112, 212 provide space for the supporting facilities and equipment 150, 250 used to operate the floating fuel storage facilities 100, 200. With continued reference to Figures 1-6, the supporting facilities and equipment 150, 250 may include, by way of example and not limitation, one or more utilities units, such as nitrogen tanks 152, 252 to provide for the purging of pipelines, one or more fire water tanks 154, 254 to store sea water, one or more fire water pumps for pumping seawater, one or more portable water tanks 158, 258, one or more product pumping stations 160, 260, one or more mechanical oil separators 162, 262, septic tanks (not shown), water purifications units (not shown), valve manifolds 164, 264, heater stations (not shown), one or more power generating plants 166, 266, a gas processing plant (not shown), offices, workers quarters, and any other utilities unit required for the operation of a bulk liquid terminal. It is understood that the supporting facilities and equipment 150, 250 shown on the drawings are provided by way of example only. Many other facilities may be included as desired on the spine structures 110, 210 and platforms 112, 212.

The facilities 100, 200 will also have a control building 170, 270 in which an Interoperability Conformance Specification (ICS) based system may be installed to

operate the facilities 100, 200 in a fully automatic mode. The ICS system may ensure that the correct product is transferred from the assigned jetty 114, 214 to the correct oil storage module 400. The ICS system may also be used to ensure that a transfer of a product from one oil storage module 400 is made to a compatible storage module 400. The system may also ensure that all valves are properly lined up before starting any pump to provide for the transfer of petrochemical products. The ICS system may also integrate with and control field equipment such as radar tank gauges, weighbridges equipment, batching controllers, motors, pumps, package supplied programmable logic controllers (PLC's), Variable Speed Drive Systems (VSDS), a closed-circuit television (CCTV) server, remote data entry panels, remote display panels, smart additive equipment, and/or other terminal field equipment.

The pile-supported jetties 114, 214 allow oil tankers 118 to call at the facilities 100, 200 to load and unload petrochemical products. It is understood that the jetties 114, 214 may be of any desired configuration to accommodate the docking of ships 118 and the loading and unloading of petrochemical products.

Figure 7 is an exploded view of one embodiment of the floating storage module 400 that forms a portion of the facilities 100, 200 of Figures 1-6. The floating storage module 400 can include an outer pre-stressed concrete hull 402 and a plurality of concrete beam grids 404 located within the outer hull 402. An inner pre-stressed concrete hull 406 can then be formed on top of the beam grids 404 within the outer hull 402. The beam grids 404 stiffen and integrate the inner hull 406 and outer hull 402 of the floating storage modules 400. In alternate embodiments, the concrete beam grids 404 can be replaced with concrete honeycomb. One or more steel tanks 408 can be incorporated into the inner hull 406. A plurality of bulkheads 410 can be incorporated into the steel tanks 408 to define a plurality of storage compartments 412. In some embodiments, the bulkheads 410 can be steel, concrete, a steel-concrete composite or any other material that provides sufficient structural rigidity to contain a variety of liquids. A cover 414 is provided on top of the bulkheads 410, which may be formed from concrete in one example embodiment, but is not limited to that material.

The storage compartments 412 are designed to store a variety of liquids (not shown), such that the liquid in one compartment 412 is isolated from the liquid in adjacent

compartments 412. These liquids can include, by way of example and not limitation, bunker fuel, diesel fuel, gasoline, various feedstock petrochemicals such as benzene and ethylene, fresh water, seawater, and the like. Any type of petroleum, petrochemical, or fuel product can be stored within the compartments 412, depending on the specific needs of the operators of the facilities 100, 200. Seawater or fresh water can be stored in one or more of the compartments 412 to provide ballast to the floating storage module 400, or as an offshore storage facility for fresh water. Additionally, the storage modules 400 may be adapted to store Liquefied Natural Gas (LNG), propane, or any other type of compressed gas product.

The specific design of the compartments 412 illustrated in Figure 7 is provided by way of example only. The compartments 412 in the tank 408 can be configured and arranged in a variety of ways to provide the storage capability required. In some embodiments, the storage compartments 412 can be arranged in a concentric configuration so that the floating storage module 400 remains uniformly loaded while charging and discharging the compartments 412.

The concrete hulls 402, 406 have several advantages over steel hulls. Concrete structures can be built at a lower cost. They are fire resistant and exhibit good fatigue resistance. Concrete is non-corrosive. The concrete hulls 402, 406 provide greater inertia against wave motion and vibration produced by equipment. They are longer lasting than steel and have lower maintenance costs.

In the embodiment of the floating storage module 400 illustrated in Figure 7, the floating storage module 400 can be about 180 meters long and about 80 meter wide with a depth of about 14 meters. In alternate embodiments, the length of the floating storage modules 400 can vary between 120-180m, with a width that varies between 60-80m, and a depth that varies between 10-15m. It is understood that these dimensions are provided by way of example only. The floating storage modules 400 can be constructed using any dimensions, both larger and smaller, depending on specific needs, desires or design considerations.

Using several of these modules 400, the facilities 100, 200 may be able to store a few million cubic meters of fuel. If required, the storage capacity can be easily expanded

by increasing the number and size of the modules 400. Bilge keels (not shown) may be attached to the bottom longer sides of the floating modules 400 so as to reduce the roll motion. Individual floating storage modules 400 may have their own pump stations 106, 206 and valve manifolds located on the top surface. A slop sump may also be installed in each module 400 to receive slop oil or rain water that has been accidentally contaminated. The received slop oil or contaminated rain water may be transferred to one or more settling tanks 172, 272 by using a slop pump that may be installed at the slop sump at the utilities unit.

In alternate embodiments of the facilities 100, 200, old oil tankers may be used instead of the floating storage modules 400 to store quantities of petrochemical products. Figure 8 shows a schematic drawing of such an embodiment 800, with a plurality of tankers 802 used. It is understood that a combination of old oil tankers and floating storage modules 400 may also be used to provide storage capacity for the facilities 100, 200.

The facilities 100, 200 may constructed in open water and function as stand-alone facilities. In a preferred embodiment, in order to facilitate the installation of the pile jacket supports 120, 220, the water should be between 30 and 100 meters deep. Water that is less than 30 meters deep may not be able to accommodate large tankers. Water that is more than 100 meters deep makes the installation of the pile jacket supports much more difficult.

One method of constructing the facilities 100, 200 begins with the installation of the pile jacket supports 120, 220. The spine structure 110, 210, platforms 112, 212, and jetties 114, 214 may then be fixed to the supports 120, 220, respectively. The pile jacket dolphin mooring system 122, 222 used to provide lateral support to the modules 400 and breakwater 140 may then be installed. The floating modules 400, which may be built concurrently in, for example, a nearby dockyard, are then winched and guided by tug boats into position. The mooring arms 126, 226 and the end portions of the floating breakwaters 140 may then be installed. The piping, manifolds and flexible hose towers may then be installed. The supported facilities 150, 250 may then be constructed. Operation of the fuel storage facilities 100, 200 can start once adequate operational testing has been performed. In a preferred embodiment, the facilities 100, 200 may be

oriented to face the head sea so as to minimize the wave forces acting on the facilities 100, 200, breakwaters 140, and modules 400.

Embodiments of the present invention provide several advantages over current land-based storage systems. The facilities are scalable and may be arranged in any desired configuration without considering land use issues involved in on-shore facilities. The off-shore fuel storage facilities are faster and easier to construct as the floating storage modules can be built in ship dockyards. No extensive support structure is required to provide support for the weight of the petrochemical products. The compartmentalized tanks inside the floating storage modules allow operators to trade a wide-range of petroleum products.

Located out in the sea in moderately deep waters, one can use the vast sea space and the free buoyancy force provided by the sea to cheaply store a very large amount of fuel. It is possible to construct a facility according to embodiments of the invention that provides a storage capacity of several million cubic meters of product. The storing of fuel off-shore shifts inflammable products from built up areas to isolated sea space so that the stored fuels and petrochemical fumes are far from human habitation and industrial plants.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A stand-alone offshore fuel storage facility comprising:

a spine structure supported on a seabed; and

a plurality of floating storage modules moored adjacent the spine structure, each of the floating storage modules capable of storing at least one type of liquid.

2. The storage facility of claim 1, further comprising a platform supported on the seabed, the platform capable of supporting a plurality of operational facilities.

3. The storage facility of any one of the preceding claims, further comprising a floating breakwater that completely encloses said plurality of floating storage modules.

4. The storage facility of any one of the preceding claims, further comprising at least one jetty supported on the seabed and located adjacent the spine structure.

5. The storage facility of claim 4, wherein the spine structure, platform, and jetty are supported on the seabed using pile jackets.

6. The storage facility of any one of the preceding claims, wherein the spine structure comprises at least one of pre-cast reinforced concrete and pre-cast pre-stressed concrete.

7. The storage facility of any one of the preceding claims, wherein each of the plurality of floating storage modules are located adjacent to a plurality of mooring dolphins, said mooring dolphins being attached to the seabed such that said floating storage modules remain in a fixed lateral position with respect to each other and with respect to said spine structure.

8. The storage facility of any one of the preceding claims, wherein at least one of the plurality of floating storage modules comprises an outer pre-stressed concrete hull, an inner pre-stressed concrete hull, at least one steel tank within said inner hull, and a plurality of bulkheads defining a plurality of compartments for storing the liquid within said tank.

9. The storage facility of claim 8, wherein the floating storage module further comprises a plurality of concrete beam grids disposed between said outer hull and said inner hull.

10. The storage facility of any one of claims 8 or 9, wherein said compartments are arranged in a concentric configuration so that said floating storage module can remain uniformly loaded while charging and discharging fuel.

11. The storage facility of any one of claims 8-10, wherein said bulkhead comprises a material selected from a group consisting of steel, concrete, and a steel–concrete composite.

12. The storage facility of any one of the preceding claims, wherein at least one of said floating storage modules comprises a tanker ship.

13. The storage facility of any one of the preceding claims, wherein a water depth from the seabed to the surface is less than 100 meters.

14. The storage facility of any one of the preceding claims, wherein said liquid is at least one liquid selected from a group consisting of fuel, petroleum products, petrochemical products, Liquefied Natural gas, and water.