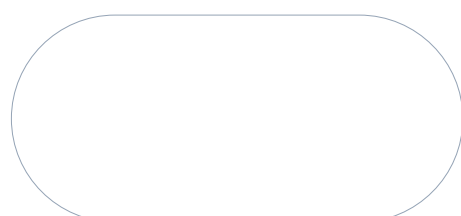
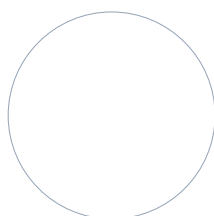
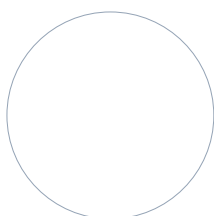
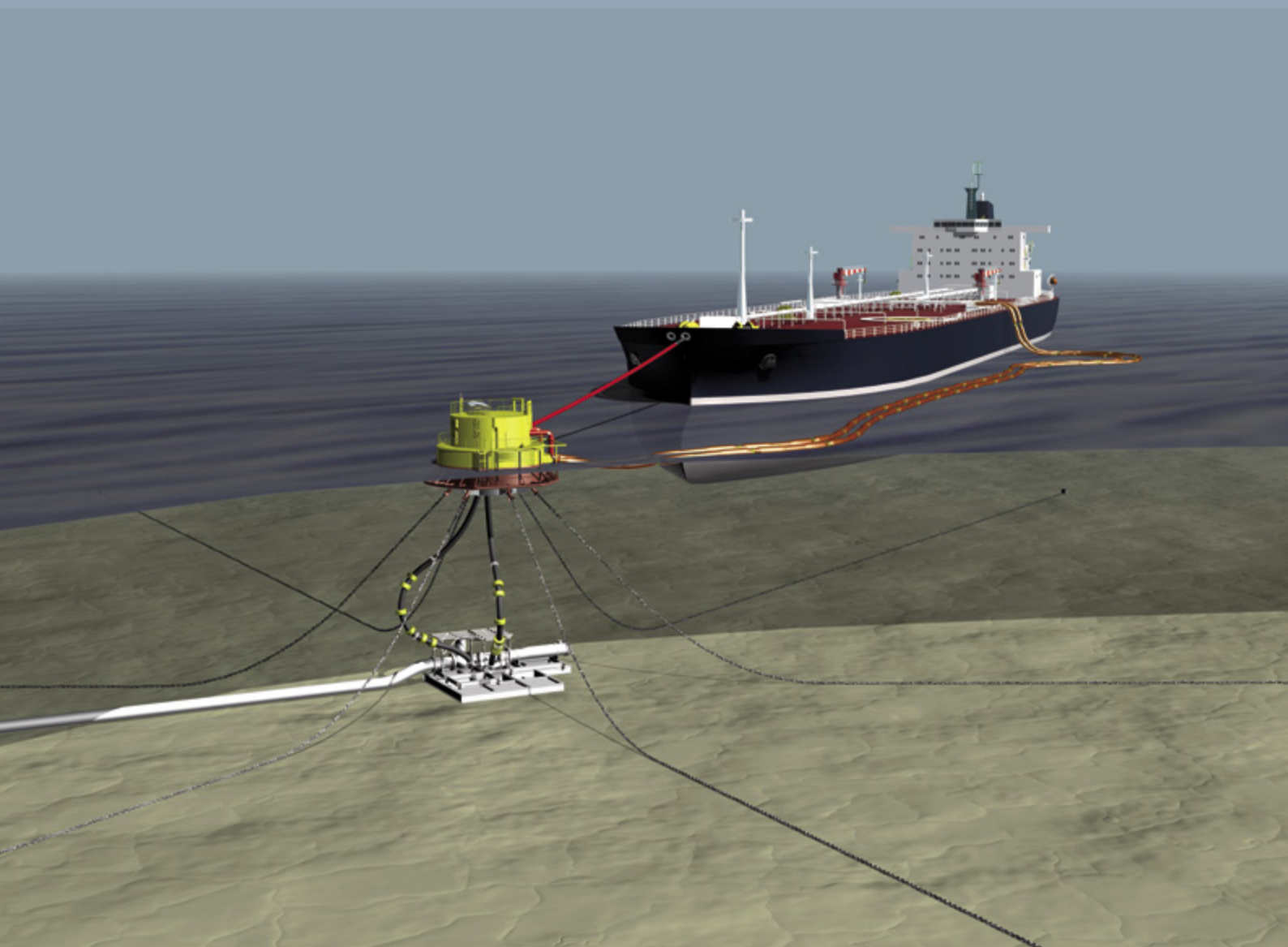


bluewater

Bluewater Turret Buoy

Technical Description





“ The Bluewater turret buoy eliminates the disadvantages of the turntable buoy. The buoy body with deckhouse rotates around a central turret fixed to the seabed. The deckhouse protects the main bearing and all mechanical and electrical equipment and offers a safe place to work during operations and maintenance. From experience with this buoy design, Bluewater is confident in offering an extended guarantee on the main bearing for the design life time of the turret buoy system.”

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1 Introduction

1.1 Bluewater Company

At Bluewater, we design and supply innovative CALM buoys and other Mooring and Transfer Systems.

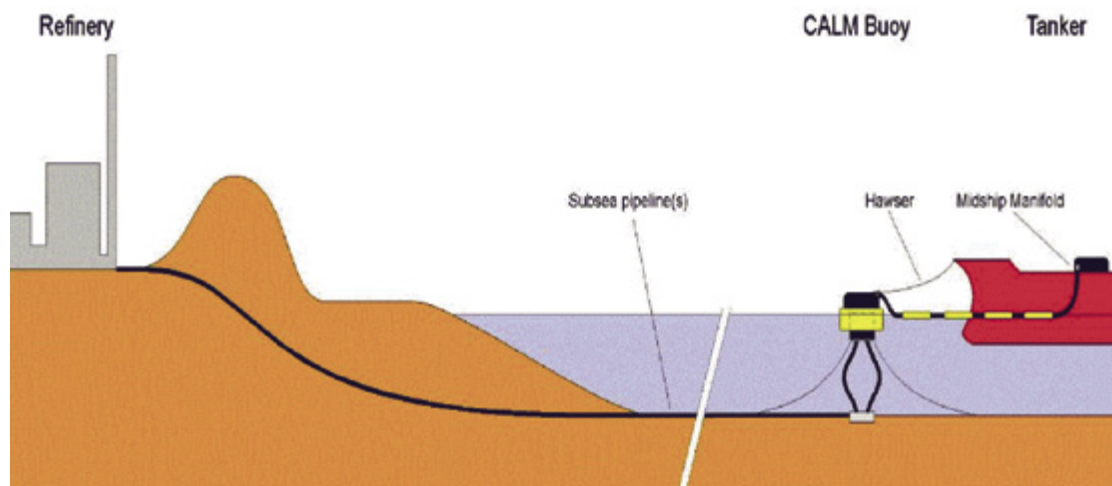
Bluewater has supplied more than seventy (70) of these SPM and CBM/MBM systems worldwide, such as:

- Single Point Mooring (SPM) Systems including Catenary Anchor Leg Mooring (CALM) Buoys, Turret Buoys and Turntable buoys
- Conventional Buoy Moorings (CBM)
- Disconnectable, External and Internal Turret Mooring Systems complete with their fluid Swivel Assemblies
- Tower Mooring Systems

1.2 General application of SPM systems

SPM systems are typically used for loading or offloading tankers, offshore near the coast. The SPM system is normally a point of export or import for a refinery, tank farm, power plant or other onshore installations, for the transfer of crude or any liquid or gas product

SPM systems can also be used for the export of crude oil at an offshore oil production location.



1.3 Summary of the Advantages of the Turret Buoy

Bluewater has designed and supplied various Turntable and Turret type SPM buoy systems worldwide. Both CALM buoy types are large successes in the market and both have impressive track records.

The Turret Buoy is the third generation of SPM buoy design. The difference between the Turret Buoy and earlier generation SPM buoys, the conventional Turntable buoy and the Bogey Wheel buoy, is in the geometry of the buoy. Whereas with the earlier generations the vulnerable parts are outside and exposed to seawater, the Turret Buoy offers the possibility to keep all critical equipment protected inside the deckhouse.

Based on Bluewater's experience with both CALM buoy types, and based on the experience of our Clients, the most prominent advantages of the Turret Buoy concept are:

- **Safety** due to flat, not obstructed deck, no rotating or moving parts on the outside, easy access to the buoy from a workboat and the presence of a protected deckhouse,
- **Operational reliability** due to the effective protection and ventilation of the main bearing, overboard piping and all equipment.
An SPM buoy is normally a critical equipment since another large capital investment like a refinery, tankers farm, production facilities or electrical plant depends on the buoy. Therefore, the availability of the SPM buoy is important for the overall investment. Turret Buoys have a proven track record of 20-25 years of uninterrupted service to the main asset (refinery, etc), without the need for periodic removal or change-out and the associated downtime of the entire facility.
- **Lower maintenance costs** due to easier and accessible maintenance and the possibility of keeping the buoy in the water for long periods without overhaul (main bearing and all equipment is well protected inside the deckhouse). Only preventive maintenance is needed; no replacement of heavy parts offshore, in contrast with, for example, the wheel-and-rail buoy design.
Due to effective protection of the main bearing and other equipment inside the weatherproof deckhouse and other technical design benefits, so far none of the Turret Buoys worldwide has seen the need for periodic overhaul during its lifetime.
- Turret Buoys have the largest resistance against tanker collisions. The facts show that, despite that many Turret Buoys have suffered severe collisions with workboats or tankers; no Turret Buoy has been taken out of service due to these collisions. However, in the case of turntable buoys, many have been taken out of service after collisions.

The benefits of the Turret Buoy result in the lowest Total Cost of Ownership for this SPM buoy compared to others. The track record of the Turret Buoy has proven that the Turret Buoy, which is designed to stay in the water during its lifetime, is far more economical to the end-user than any other SPM buoy type (non-Turret type) which needs periodic removal.

2 Development overview of the different SPM buoy types

2.1 History of the SPM loading buoys

CBM or MBM systems

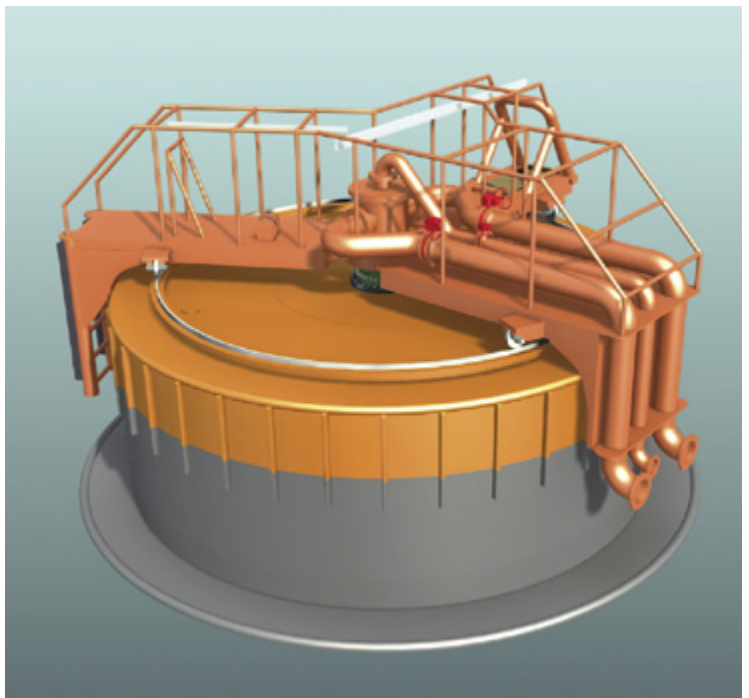
The development of loading buoys started in about 1920, when the growth in tanker sizes demanded the extension of harbour facilities into deeper water. Up to the installation of the first generation of Single Point Mooring (SPM) systems, tankers were moored within a pattern of four to eight mooring points, consisting of rigid buoys moored to the seabed by a chain and anchor. This Conventional Buoy Mooring (CBM) or Multi-Buoy Mooring (MBM) system does not enable tankers to weathervane and has therefore operational limitations.

SPM systems

The 1st generation (wheel and rail), 2nd (turntable) and 3rd (turret) generation buoy systems are collectively called “Single Point Mooring” (SPM) systems. Due to the characteristic catenary curve of the anchor chains fixing the SPM buoy systems to the seabed, the mooring systems with these buoy systems are also called “Catenary Anchor Leg Mooring” (CALM) systems.

First generation CALM buoy: Wheel and Rail buoy

The first buoys we can indicate as the forerunner of the current buoy types were built and installed in Sweden in 1959 for the Swedish Navy. These first generation buoys were of the Wheel and Rail (or Bogey Wheel) type. It has a buoy body with a central moonpool and a rotating bogey platform on wheels, allowing the tanker to weathervane around the buoy. The fluid transfer runs through a swivel. This buoy has only one bearing, the swivel bearing. The bogey wheel table is supported by wheels running on rails.



Wheel and Rail buoy

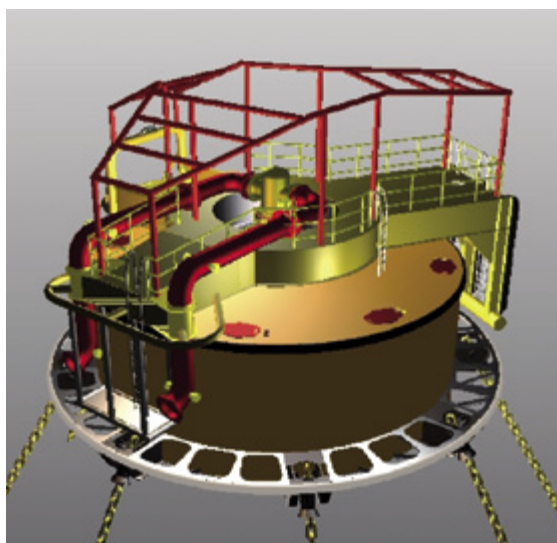
The wheel and rail buoy has several disadvantages, therefore second generation CALM buoy was quickly developed with active involvement of oil major Shell. In co-operation with an engineering company in the Netherlands a buoy system was developed which is characterised by a cylindrical buoy body, moored to the seabed by four to eight anchor chains and a rotating platform structure on top, the turntable. The tanker mooring hawser and the flexible floating loading hoses are connected to the rotating platform, enabling the tanker to weathervane around the buoy. This buoy type, schematically depicted in the figure below, is called the “Turntable Buoy”.

Second generation CALM buoy: Turntable buoy

The Turntable buoy, the second generation CALM buoy, has been a worldwide success and many of these buoys were sold until 1980. However, the experience has shown that the turntable buoy needs periodic off-location overhaul (dry-docking), which in itself is of a client’s disadvantage.

- There is a Direct cost involved from offshore dismantling, transport, dry-docking, yard repairs and re-installation offshore.
- Indirect cost: non-availability of the Turret Buoy during the overhaul period, typically a period of two months or longer, during which the terminal can not service the connected asset (e.g. refinery or production facility) and which may therefore be forced to stop its operations, causing downtime.
- Often this downtime is solved by purchasing a spare buoy. This means a double purchase expenditure, increased maintenance, storage and conservation costs as an additional buoy needs to be stored and maintained.
- Risk is involved in the marine removal and reconnect operations, transport and repair works and uncertainty is introduced for the return date and hence availability to the asset it services, e.g. refinery or plant.

Furthermore, in between the periodic overhauls, the maintenance in the water requires a considerable effort. The



Turntable buoy

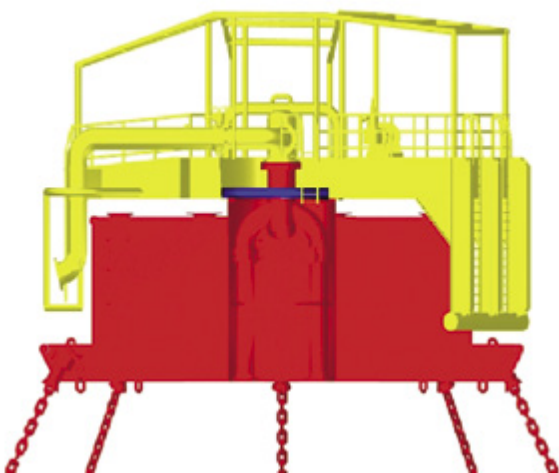
deck is obstructed by the turntable and walking on the buoy means climbing up and down to various levels. Due to the rotating turntable there is no safety hand railing around the perimeter of the buoy, no protecting deckhouse to cover the vulnerable equipment such as the main bearing and it is difficult to moor a maintenance or operational workboat to the buoy.

Third generation CALM buoy: Turret Buoy

Bluewater developed a new, improved buoy concept in order to overcome the disadvantages of the Turntable and CALM buoys. In this design, the buoy body itself can freely rotate around a turret structure. The turret is moored to the seabed by the anchor chains. The buoy offers an enormous improvement in terms of safety, ease of maintenance, protection and durability. The experience worldwide has shown that the Turret Buoy can remain in operation at its original location for a period of at least 25 years, without periodic off-location overhaul and without replacement of heavy parts (such as wheels or rails of the bogey wheel buoy). The new type of buoy is called the 'Turret Buoy'.

Since 1980 the Turret Buoy has been very successful in the market and is the preferred choice of many marine terminal operators. After the development of the Turret Buoy, the concept of turret mooring has become the leading technology for the permanent mooring of tankers as Floating Production, Storage and Offloading (FPSO) and FSO units.

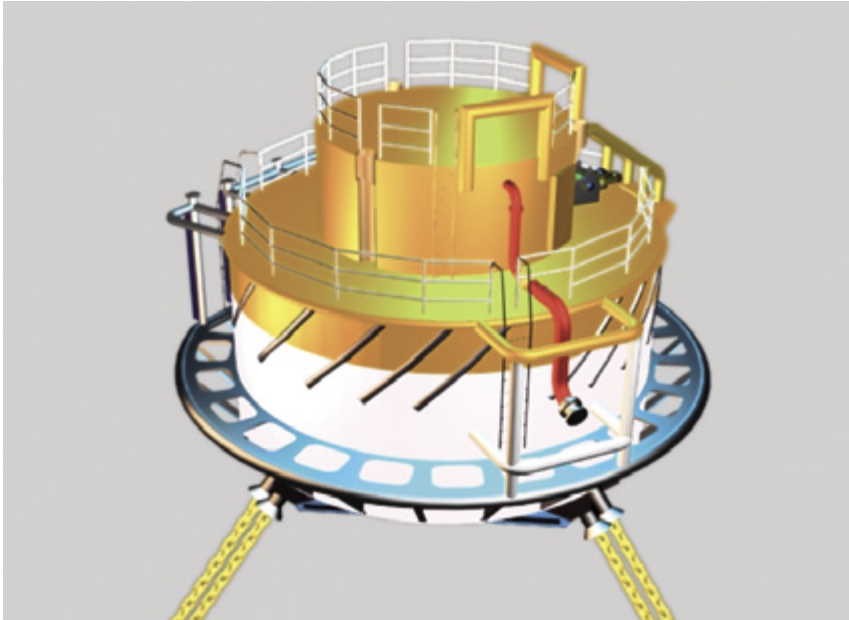
The schematics below illustrate the difference in cross section of the Turntable and Turret Buoy:



Turntable Buoy



Turret Buoy



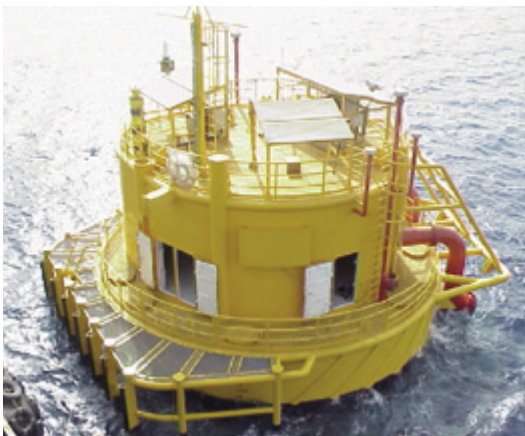
Turret Buoy

2.2 Thirty years of experience with both Turntable and Turret Buoy

Over the past 30 years, Bluewater has designed and supplied many Turntable (2nd generation) and Turret (3rd generation) SPM buoy systems.

Since Bluewater is the only fabricator of both Turret and Turntable types of buoys, we have been able to compare the operational performance of both buoy types.

However, after almost 30 years fabricating both systems and receiving operational feedback from our clients and from other users of buoys, it has shown a big difference in the client satisfaction of each type of buoy.



2.3 Technical highlights of the Bluewater Turret Buoy

The Bluewater Turret Buoy concept eliminates the drawbacks of earlier generation buoy designs and profits from several distinct advantages inherent to the rotating buoy body.

The most prominent advantages of the Turret Buoy are highlighted below:

1. **Safety:** The Turret Buoy has a flat deck, not obstructed by a turntable or any other moving parts and is easily accessible via a proper boat landing designed to moor a work boat alongside the buoy.



Personnel on deck of a Turret Buoy.
Safety: no moving parts; safety handrail around the perimeter of the buoy. Also visible is the large boat landing



Personnel on the deck of a turntable buoy near to the rotating arm of the turntable which can move. The personnel is not protected by a handrailing.

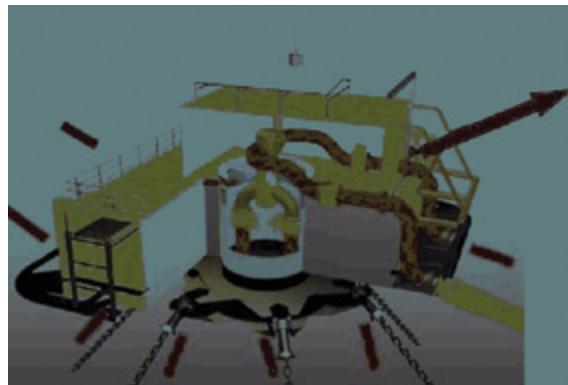
2. **Safety:** The Turret Buoy has a large boat landing to which a work boat can be safely moored, giving operating personnel safe access to the buoy. Downtime due to inaccessibility is therefore less than with other types of buoys.
3. **Durability:** The Turret Buoy is provided with a deckhouse. The most important component for the mechanical functioning of the buoy, the main bearing, is positioned inside the deckhouse and is therefore optimally protected against all forces from the environment.



4. **Durability** and maintenance friendly: Extra features, such as additional electronic (control) equipment, winch, instruments and valves are also fitted inside the protected area of the deckhouse.
5. **Durability:** The hawser load, as well as loads generated by tanker-buoy contact (tanker kissing) or by work boat, is directly transferred into the buoy body. Due to the large mass of the buoy body (incl. deckhouse and all equipment) and the added mass of the water around the buoy body, loads and vibrations from the hawser are absorbed, resulting in only a limited transfer of these loads to the main bearing. As a result, the operational life time of the main bearing is better ensured.



Turntable buoy: external loads on the turntable will pass 100% through the main bearing

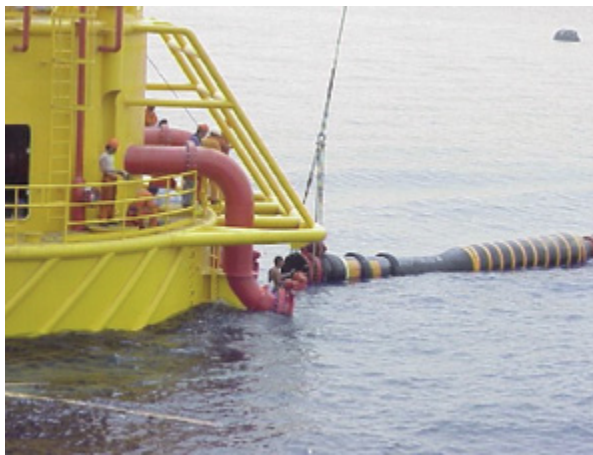


Turret Buoy: external loads on the buoy body are absorbed by mass and water added mass, resulting in only a limited transfer of these loads to the main bearing.

6. **Durability:** The loads generated by tanker-buoy contact (tanker kissing) and by mooring a work boat against the boat landing, are absorbed by the mass of the buoy body and surrounding water as described above, thus protecting the main bearing from excessive shock loads.
7. **Maintenance friendly:** The flat and “clean” deck structure combined with the enclosure of all equipment in the deckhouse reduces significantly the maintenance and repair costs throughout the lifetime of the buoy system.
8. **Safety and maintenance friendly:** Operating, inspection and maintenance crews can board the buoy and work under safe circumstances, protected from sun or rain and allows work even in relatively rough seas as most of the work is done inside the deckhouse. Downtime due to restriction in maintenance and repair is therefore lower than with other types of buoys.
9. **Durability:** By locking the doors of the deckhouse, unauthorised access to the equipment can be prevented.
10. **Durability:** The overboard piping is at the lower part, close to the water line, directly supported by the buoy structure. An adequate fender system protects the piping from tanker collisions.



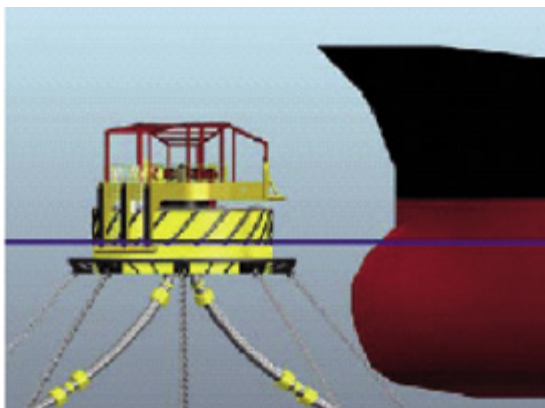
Overboard piping directly connected to buoy hull – strong support



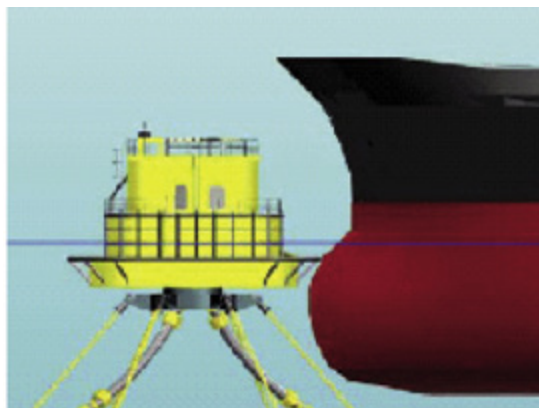
Overboard piping well protected by fender below and above the flanges.

11. **Durability:** With any CALM buoy, at slack weather, the floating hose string may wrap around the buoy body. The advantage of the Turret Buoy design – where the rotating buoy body can be seen as a reel - is that the hoses automatically unwrap when the weather picks up, or when the hose is pulled out by a small service craft.

12. **Durability:** As the chain stoppers are not fitted at the outer perimeter of the buoy body, but in the spider underneath and well within the contours of the buoy body, they are not prone to damage by tanker contact.



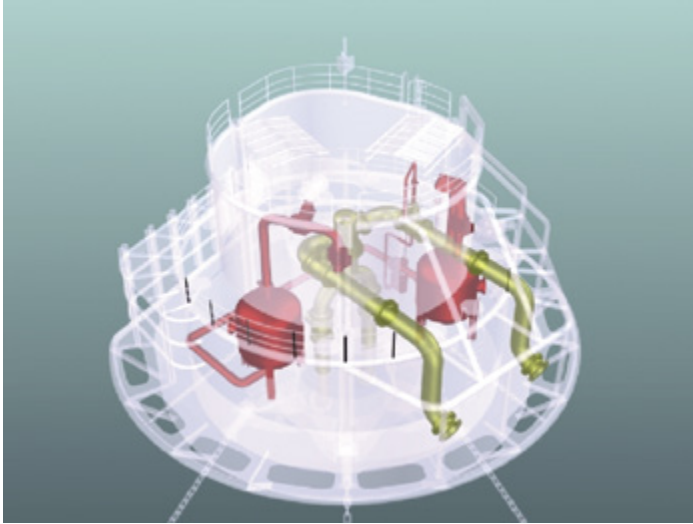
Turntable Buoy



Turret Buoy

13. **Durability:** Thanks to the inward position of the chain stoppers, the clearance between the tanker bow and the anchor chain catenary is larger, thus eliminating the risk of a tanker hitting the chainstoppers and reducing the risk of tankers damaging the anchor chain.
14. **Durability:** The centre of gravity of the Turret Buoy is relatively low, providing a higher stability during installation, operation and maintenance of the buoy. It also reduces wear on the upper chain links.
15. **Flexibility:** The shape of the Turret Buoy is not restricted to a cylindrical shape only. The square shape is structurally ideal to fit hinges for a wishbone Mooring arm, permanently or semi-permanently mooring of a tanker:





Full integration of a Surge Relief System is possible in the Turret Buoy, with all parts protected inside the deckhouse and buoy body.



The surge relief valves are protected inside the deckhouse together with the swivel and as shown in this picture, together with the flexible joints and the main bearing.

16. **Flexibility:** Extra features like a surge relief system, encompassing relief valves, tanks and pumps, can be fitted in the deckhouse and in the buoy body.
17. **Safety:** HAZOP studies on the Turntable and Turret Buoy concept have revealed that the Turret Buoy is safer for personnel and environment. In particular the probability for spillage in case of Turret Buoy is considerably less than in case of Turntable buoy.

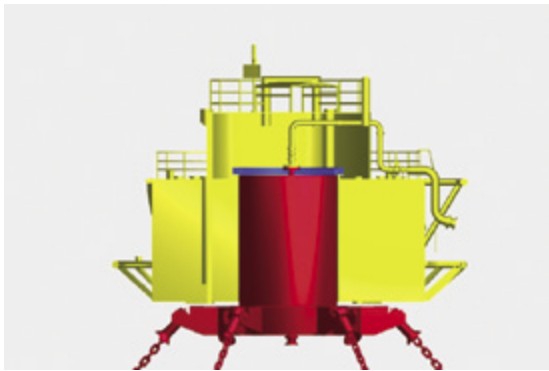
As a result of the advantages described above, both the operation and maintenance costs of a Turret Buoy are substantial lower than with a Turntable Buoy. Most important for the user is the more reliable, higher availability of the Turret Buoy system, reducing cost on demurrage and on delays in the transfer of cargo.

To most of the foregoing aspects can be seen in the pictures of recent Bluewater Turret Buoy projects which are enclosed in this report.

3 Technical description of the Turret Buoy

3.1 General

The Turret Buoy consists of two structural main components, the turret structure (the part that is fixed to the seabed) and the buoy body (rotating part). The turret structure is located in the centre of buoy body. The turret and buoy body are connected at deck level by means of a roller bearing. The connection between the piping sections in the turret and in the buoy body is made by means of a fluid swivel also outfitted with a roller bearing. The tanker is moored to the buoy body via a hawser and can freely weathervane in response to changing weather conditions, thereby rotating the buoy body around the turret.



The main components of the Turret Buoy system will be highlighted in the following subsections.

3.2 Buoy body

The buoy body for a Turret Buoy can be a rectangular or circular construction. The buoy body is divided in water-tight compartments, each of them accessible via a manhole in the deck. The compartments are designed to meet the existing Class requirements related to the damaged stability situation. The manholes giving access to the buoy compartments are flush with the deck surface.

3.3 Skirt and protection

Along the periphery of the buoy body, just above bottom level, a skirt is fitted to protect the buoy body against direct contact with ships. The free side(s) of the buoy body are protected against contacts with very small crafts and floating objects by means of fenders (half –pipes), welded diagonally to the hull plating.

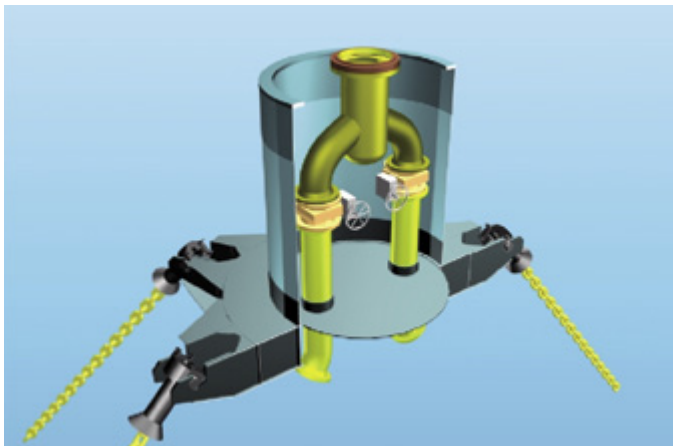
3.4 Flat, unobstructed deck

The deck of the buoy body is flat, unobstructed and with a hand railing all along its periphery.

3.5 Turret and spider

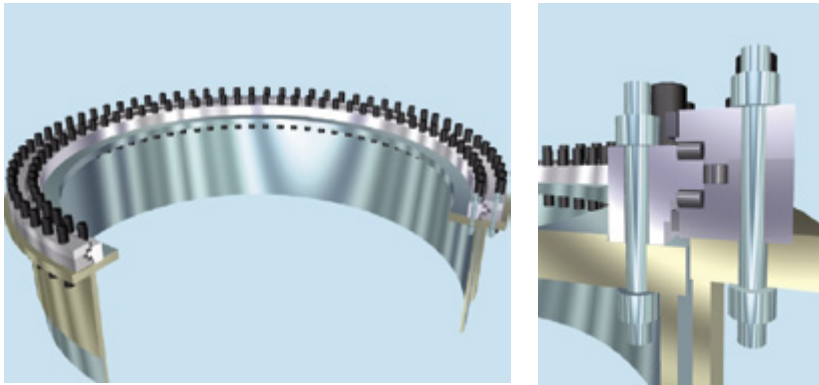
The turret assembly consists of a turret shaft and a chain table or spider. The turret shaft is a large diameter conical section. At the topside the main bearing is fitted, at the bottom side the turret is closed by a diaphragm plate. The inside of the turret is therefore a dry compartment, which is directly accessible from the deckhouse. Inside the turret, valves between submarine hoses and swivel as well as geostatic (control) equipment can be mounted.

The spider or chain table is a box girder framing, which supports the chain stoppers through which the anchor chains are attached to moor the buoy at location.



3.6 The Main Bearing

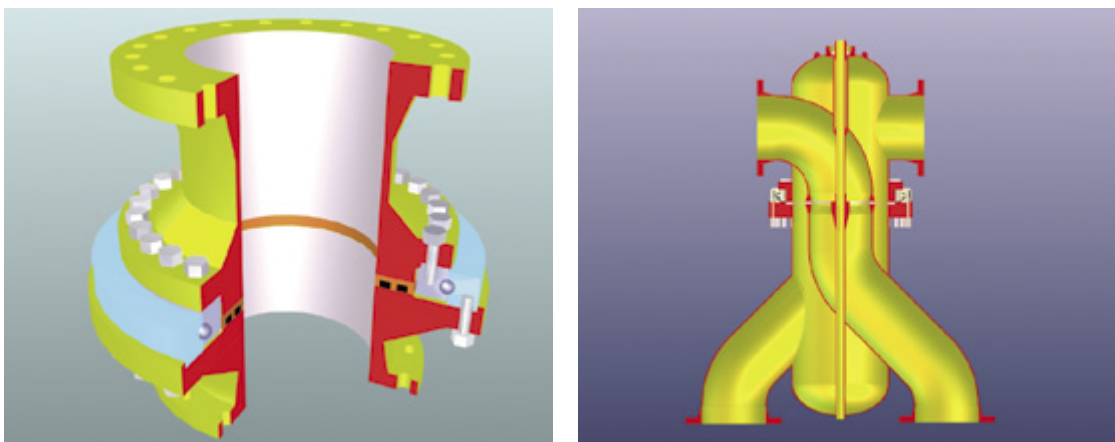
The buoy body and the turret shaft are interconnected by means of a large diameter bearing located at deck level. This main bearing is the largest of the two bearings in a Turret Buoy; the other bearing is part of the product swivel. The main bearing is a three-race roller bearing and is mounted on reinforced, machined foundation flanges, fixed by high tension mounting bolts. The bearing is the most critical mechanical component of the buoy. Maximum attention is therefore given to the correct machining of the bearing supports and the fitting of the bearing. The bearing is positioned in the dry environment of the deckhouse and internal seals provide additional protection of the bearing against ingress of water and dust.



Lubrication of the main bearing can be done through the greasing points provided in the bearing rings. Grease sampling points to monitor the condition of the bearing are located at the bearing upper surface. If required, the lubrication can also take place from one or two manifolds with grease pipes to the greasing points. As an extra feature, a fully automated greasing system can be ordered.

3.7 The Product Swivel

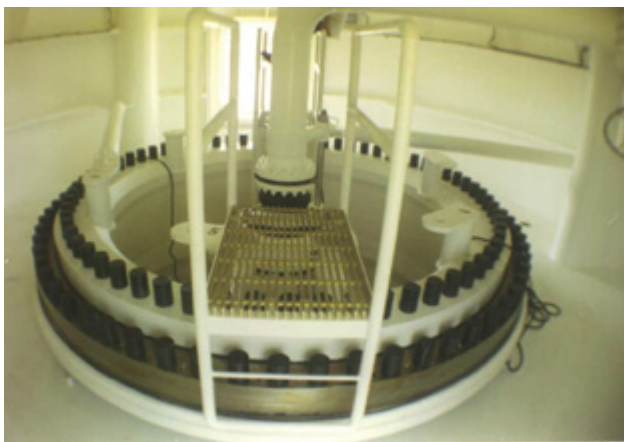
While the main bearing provides the mechanical connection in the Turret Buoy, the swivel provides the fluid transfer between the fixed and the rotating parts of the Turret Buoy. The swivel allows unlimited rotation of the buoy without mixing the different product channels. It is equipped with its own bearing and several product seals. Being one of the most critical components of the buoy system, Bluewater designs and builds the swivels itself. Bluewater has extensive experience in the design and fabrication of different types of product swivels, such as single and multi-product swivels, and high-pressure swivels for special applications.



Easy access enables regular inspections on the product swivel to detect leakage or oil seepage at the flange connections. The swivel bearing is generally manually greased at periodic intervals via the grease points/nipples on the fixed flange between the bearing bolts. The swivel has a dual seal construction. Any leakage of the first, inner seal can be monitored by leak detection in the space between the inner and outer seal. In the unlikely event that leakage through the inner and outer seal occurs, the spillage will be contained in the turret compartment, preventing pollution of the environment. As an extra feature, an automatic leak detection system can be provided.

3.8 Protection deckhouse

One of the main advantages of the Turret Buoy: a watertight deckhouse is fitted over the central area of the Turret Buoy. It protects the turret, main bearing, product swivel, electrical equipment, winch and all other equipment against all environmental forces such as sun, rain, wind and sea water. At the same time, it allows ventilation of the main bearing to avoid accumulation of condensed water. Shielded louver panels located close to the deckhouse roof level ensure permanent ventilation of the interior.



The deckhouse is designed to withstand all loads due to wind and overcoming waves. The deckhouse has two doors in opposite walls. One of the doors near to the boat landing is extra wide and has a lifting beam extending from the inside to the outside of the deckhouse to enable the transfer of equipment to and from the central area inside the deckhouse. In the ceiling of the deckhouse a rail beam is fitted over which a little trolley hoist (which is part of the standard delivery) can be run to perform small lifting operations in the deckhouse. This greatly facilitates repair or maintenance works to the equipment in the deckhouse.

On the roof of the deckhouse a deck has been created, which is provided with hand railing. The deck is generally large enough to fit the battery boxes, solar panels, navigation lights and antennas. The deck is accessible via a fixed or removable ladder with safety cage.

3.9 Boat Landing

Another strong point of the Turret Buoy: along the entire side of the buoy body, a generously sized boat landing is fitted to provide safe access to the deck of the buoy. The boat landing is constructed from tubular steel members and comprises horizontal fender pipes integrated at deck and skirt level and vertical members with rubber fenders to prevent ship-to-steel contacts. The boat landing is outfitted with a ladder in a recess, for safe access from smaller boats, with bollards for berthing small crafts and with a lifting device to facilitate the transport of equipment onto the buoy.



3.10 Floating Hose Installation Platform & Protection Frames

At the location of the overboard piping, a work platform is provided to facilitate the disconnection and re-connection of the floating hose(s). The platform is constructed from tubular steel sections and galvanised steel grating. At main deck level a solid protection frame of tubular steel is provided to give further protection to the overboard piping.

3.11 Mooring Lug

On the deck of the buoy body a mooring lug has been fitted for connecting the mooring hawser. From practical experience, the floating hose string(s) and the hawser attachment point on the buoy body should apparently be kept apart, but the angle between them should be less than 90 degrees. On the square Turret Buoy type this is achieved by placing the mooring lug at a corner of the buoy body on the side where the overboard piping is fitted.

Over the mooring lug location, a protection frame from tubular members is fitted to provide protection in case of failure of the hawser under tension.



The mooring lug can be fitted with an electronic hawser load-measuring device. The monitoring equipment for this device is positioned in the deckhouse. Depending on the requirements, warnings for overloading the hawser can be signalled through the navigation lamps, the foghorn or, via a telemetry system to a mobile or fixed shore station.

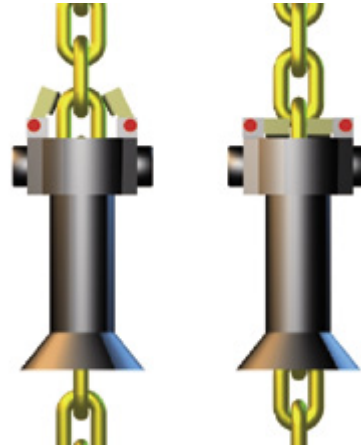
3.12 Chain Hawse-pipes and turret locking system

Depending on the number and configuration of the mooring legs, two or three hawse-pipes are fitted in the buoy body and deckhouse wall to facilitate fast installation of the mooring legs. Several anchor legs can be pulled in at each position,

The turret can be easily locked into the required positions by means of a straightforward locking pin in the deckhouse. This locking pin can also be used to fix the turret to the buoy body for general transport, installation and maintenance purposes.

3.13 Chain Stoppers

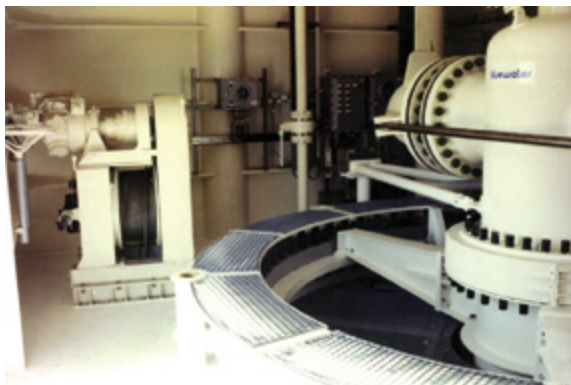
The chain stoppers are able to freely oscillate vertically and to align with the chain angle, preventing wear on the first chain links below the chain stopper. The locking of the chains in the chain stoppers is achieved by two automatic latches, which allow the chain to be pulled in until the required position or chain angle and then lock the chains in the stopper automatically.



3.14 Ancillary Equipment

Winch

A winch is installed on the buoy deck, inside the deckhouse. This allows the winch to be easy maintained and always available to function. The winch is protected inside the deckhouse and there is no need, as with previous generation buoy types, to remove the winch from the buoy. The compressed air or hydraulics necessary to run the winch has to be provided from a workboat. The winch can be used for the re-tensioning of the anchor chains, to pull in and connect the submarine and floating hose strings and to perform lift operations for any buoy component, such as swivel, valves, flexible joint(s) etc. For enabling these different lift operations and to guide the winch wire to the work location, sheaves are present at various locations in and on top of the buoy deckhouse.



Navigation Aids

An obstruction light, fog horn, and radar reflector are provided and mounted on the buoy as a navigation aid for shipping and to reduce any hazard to happen. The electronic equipment runs on the power packs installed in a large battery box. The position of the battery box is outside the deckhouse in order to prevent vapour build-up in the deck house. The batteries are re-charged by solar panels which are positioned on the deckhouse roof.



Safety Equipment

The standard safety equipment delivered on board of the buoy encompasses two portable fire extinguishers, each stored in a watertight red cabinet, and two life-buoys fitted with self illuminating lights and buoyant lifelines.



4 Auxiliary Equipment

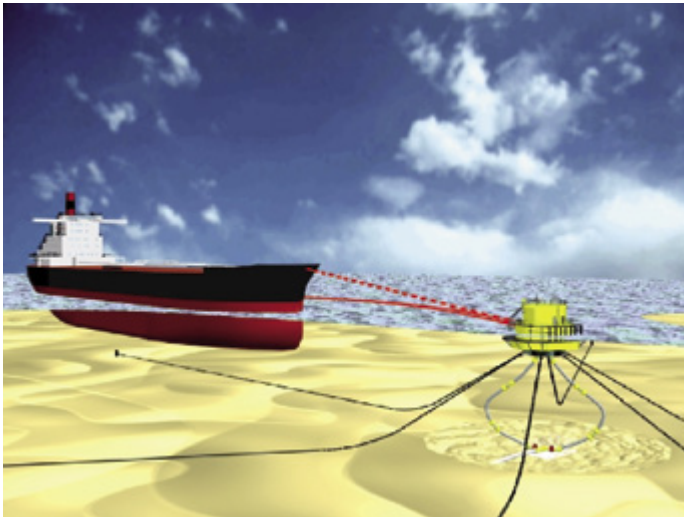
4.1 General

The main component of a complete SPM terminal system is the SPM buoy itself. In addition, a number of auxiliary equipment components are an integral part of such a SPM system. These components are described in the following subsections.

4.2 Buoy Mooring Arrangement

The Turret Buoy is securely anchored to the seabed by means of a set of mooring lines (legs) which are fixed to the seabed with anchor points. Generally, an average buoy system is fixed to the seabed with six mooring legs. Sometimes this number is increased to eight or nine legs. Depending on the project situation, the six mooring legs are equally spaced or clustered in three series of two or three legs, 120 degrees spaced. (typical mooring patterns...; Turret Buoy can accommodate any)

The mooring lines are in most cases heavy chains with link diameter sizes ranging from three to six inches. The length of the legs varies with the water depth, the tanker size and the load conditions. Lengths of 200 to 600 meters are common.



Each mooring leg will be connected to an anchor point. These can be High Holding Power (HHP) marine anchors, driven or drilled piles (open tubular sections), suction piles and gravity boxes or frames (boxes filled with gravity material), respectively frames with gravity material on top. The final selection of the anchor point concept will depend on the soil conditions and the availability of required installation equipment.

4.3 Tanker Mooring Arrangement

In principle two tanker mooring situations can be identified: the temporary mooring of a tanker for the duration of a loading operation (generally 24 hours) and the (semi-) permanent mooring of a tanker for duration in excess of weeks like in a Floating Storage and Offloading (FSO) system. For the (semi-)permanent situation, several buoy-to-tanker mooring constructions exist, like wishbone, yoke and rigid arm connection structures. Whereas these structures are very project specific, the focus of this document is on the typical loading or offloading situations, whereby the tanker is moored for about 24 hours

The tanker mooring arrangement is a hawser arrangement, encompassing a polyester mooring line with chain sections on both sides to prevent wear and tear at the connection points. The polyester section of the mooring line has certain elasticity capacities, which dampens the loads and tanker movements in the overall mooring system. For the design, fabrication and use of these hawser systems extensive codes and standards exist. (OCIMF publication “Standards for Equipment Employed in the Mooring of Ships at Single Point Moorings”).

4.4 Floating Hoses

The connection of the tanker with the buoy piping is made by the use of one or more floating hose strings. The number and size of the strings depends on the maximum size of the tankers to be moored and loaded via the buoy system and the related pumping capacity. Also for the design, construction and use of floating hoses extensive codes and standards exist. (OCIMF publication “Buoy Mooring Forum Hose Standards”)

The floating hoses from the buoy to the tanker will be electrically continuous up to the last three hoses at the tanker end. The hoses have a minimum reserve buoyancy of 20%.



Aids for the Installation and Maintenance

Adequate equipment is provided on the buoy to simplify the installation and maintenance of the floating hose string(s).

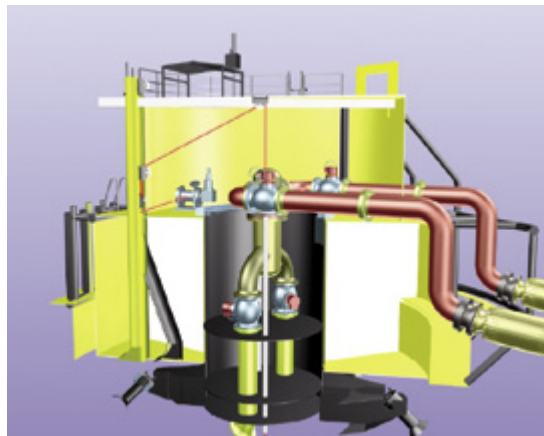
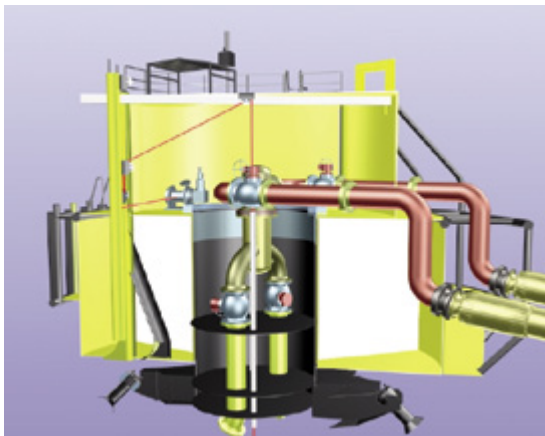
4.5 The Submarine Hose String(s)

The submarine hose system will be designed, manufactured and tested according to the requirements of the latest OCIMF publication “Buoy Mooring Forum Hose Standards”.

The submarine hose string(s) connects the PLEM to the buoy’s piping and will be designed with sufficient length to adapt to the excursions and heave motions of the buoy.

Aids for the Installation and Maintenance

A hose pull-in hawser pipe runs from the main buoy deck level down through the turret. The lift line from the winch is run through this pipe, pulling the submarine hose string(s) until it meets its connection point with the buoy piping.



5 Environmental Protection

5.1 General

The Turret Buoy system has been designed to operate to the highest standards of safety and to minimize the risk for personnel injuries and/or damage to the environment. All aspects with an impact on safety in operating the buoy system have been analyzed and measurements are taken where possible to enhance the safety. This also comprehends the training of operation personnel and the provision of adequate operation documents in achieving the safety goals. The subsections below highlight the main aspects where safety has been of particular importance.

5.2 Stability buoy

Compared to other buoy designs, the Turret Buoy has a relative low centre of gravity and a subsequent high stability. This enhances the motion behaviour of the buoy, making it a safer place to work on.

The buoy body is divided into six or eight watertight compartments. The design of these compartments is such that, in case the buoy is involved in an accident and two adjoining compartments are penetrated and flooded, the buoy has sufficient residual buoyancy and stability left to remain afloat and do not capsize.

5.3 Enclosed system

The Turret Buoy is designed as an enclosed system, i.e. all mechanical components in the product lines in the buoy system are situated in a confined space. This space is the deckhouse and the turret space. As described before, the turret is closed at the bottom side and is therefore a dry space. Also, the floor in the deckhouse is watertight and with the high thresholds of the doors, no fluids can stream in or out of the deckhouse.

In case of the unlikely event that a leakage occurs in any of the mechanical components in the product line (product swivel, valves, and flexible joints), the spillage from this leaking will be contained in the deckhouse and/or the turret space. The chances that such a leakage occurs without being noticed is unlikely, as the buoy is always manned during loading operations and because certain piping components like the product swivel have an active leak detection system.

5.4 Double seals product swivel

The product swivel is one of the most critical components in a buoy system. To have full control over the quality of this component, Bluewater designs and builds the product swivels for its own buoy and turret system projects. These swivels are provided with a roller bearing, a dual main sealing construction and a leakage monitoring system. In case the primary, inner seal starts leaking, the leakage can be noted by the monitoring system, but no spillage can occur as the secondary seal will contain the fluid within the swivel.

5.5 Flexible joints

In the piping system, between the fluid swivel and the fixed pipe work onboard the buoy, high quality flexible

joints are fitted. These flexible joints prevent any secondary forces to be introduced to the swivel and to the piping system which may result from small misalignments between the buoy and the turret part of the buoy system during rotation. These secondary forces may introduce unexpected fatigue to the piping system, which on its turn may result into cracks and leakage.

5.6 Leak detection & recuperation system

All Bluewater swivels are standard provided with a mechanical leak detection system. As an optional extra, the system can be extended with an electronic monitoring system, which can either be connected to the onboard navigation light and foghorn, or can be connected via a telemetry system to a (mobile) monitoring station on board the tanker or on a shore base. In addition the system can be extended by a recuperation system, which collects the leaked fluid and re-injects it automatically into the main piping system.

5.7 Remote PLEM valve operating system

The PLEM has been outfitted with valves with the purpose of isolating the pipeline(s) and or the riser(s) from the rest of the facility. This in case a replacement or repair of any of the components is required. If the valves are used for this purpose only, the operation of the PLEM valves by means of diver assistance is the most common, widely accepted procedure.

It will enhance the safety of the buoy system substantially if, during the periods between loading operations, the valves are closed and the fluid path is divided into several compartments. This can be combined with provisions for flushing the line in whole or partly to replace the product with water. In particular this is worthwhile to be considered for the risers, buoy piping and floating hoses.

In order to make the regular opening and closing of PLEM valves practically feasible, these valves have to be operated remotely, i.e. from the buoy or via a telemetry system from the shore base. To achieve this, an electrical/hydraulic umbilical can be installed between the PLEM and the buoy (to the turret part). In the turret space a nitrogen/hydraulic power pack and operating console is installed. Due to the geo-static position of the turret, no electrical/mechanical swivels are required in the umbilical line.

5.8 Remote operation & monitoring

If desired, the valve operations can be commanded and /or monitored at the shore base via a telemetry system.

5.9 Surge relief system

Surge is the phenomenon of high-pressure shock waves in a piping system due to sudden drastic changes in the flow. This can for instance be caused by the sudden closure of a valve or the activation of a break-away coupling. These sudden high pressures may cause damage to the buoy piping systems and/or to the hose arrangements, which may be followed by a spillage.

From experience it is known that the surge phenomenon occurs in practice. To prevent the possible subsequent damage, a surge relief system can be installed as a fully integrated safety system. For this, surge relief valves

are installed in the upper section of the main piping system. These valves open automatically when a certain predetermined pressure level is exceeded and a small volume of the product flows directly into tanks fitted into one of the buoy body compartments.

After such a surge occurrence, the tank can be emptied by re-injecting the fluids back into the main piping by means of an electrical or air-driven pump.

5.10 Break-away couplings

During the loading operations, the tanker is moored to the buoy system by means of a hawser and the loading takes place via the floating hoses between the tanker and the buoy. In case the hawser fails and the tanker drifts away, there is a large risk that the floating hoses can not be disconnected and closed properly before the lines are stretched.

To prevent the breaking of the hose(s) and a certain spillage of the product into the sea, automatic, mechanical break-away couplings can be installed in each of the floating hose strings. These couplings will function when a pre-set tension force in the coupling is exceeded. The coupling will split and the open ends of the coupling will close off very fast, limiting the spillage to an absolute minimum.

5.11 Double carcass hoses

During the operation of the buoy system, the floating hoses are subject to wear and tear. This wear and tear can be on the inside from erosion of particles in the product fluids and on the outside from UV light, seawater and from mechanical damage. The double carcass hoses have a double skin, which lay loose over each other. Whether the damage is coming from the inside or the outside, once one of the skins is penetrated and leaking, the hoses can still be used for completion of the ongoing loading operation. This prevents demurrage costs of the tanker in case hose replacement cannot be postponed.

6 Requirements to start an SPM project

6.1 Introduction

The need for a marine terminal is always subsequent to decisions on much larger projects like the erection of a refinery, power plant or storage facility. Once the need for a marine terminal has been defined and the type of terminal is determined, consultants are contracted to prepare a recommendation. It is often in this phase that Bluewater is contacted by either a consultant or by the client directly for information and advice regarding the application of an SPM system. Bluewater has always taken an active approach in informing clients on the possibilities of SPM systems, which mostly concerns SPM buoy systems. Most important in this process is to explain the functioning of an SPM buoy system and to provide information on what is technically possible and what should be included in the functional specification for such an SPM buoy system.

6.2 Information required

In order to be of assistance in the selection process and to come to a satisfactory, cost efficient (pre-) design for a new SPM buoy system, two kinds of information are required:

- Environmental information
- Functional information

The Client has to make available encompass on the following environmental information:

- Geographical information (where is the project)
- Meteorological information (weather conditions)
- Nautical information (wave conditions, current, temperature)
- Bathometric information (sea bed condition)
- Soil survey report.

If certain information is not available with the Client, Bluewater can assist in obtaining this information from expert companies.

The functional information provided by the Client should include:

- **Site information:**
 - Detailed site map
 - Lay-out of the project facilities

- **Product data:**
 - Products to be imported or exported
 - Composition of product(s)
 - Temperature
 - Viscosity
 - Gravity

- **Tanker data:**
 - Size (or range of sizes)

- **Frequency loading operations**

- **Max. operating conditions:**
 - Significant wave height
 - Wave period range
 - Current
 - Wind
 - Tidal range
 - Water depth

- **Piping requirements:**
 - Flow rate
- **Pigging requirements**
- **Design pressure**
- **Subsea pipeline diameter(s)**

Dependent on the experience of Client with similar terminal operations, Bluewater advises to mutually develop the functional requirements prior to the start of any budget or pricing exercise. Bluewater has a vast experience with designing and building SPM systems all over the world. This experience might prevent the definition of insufficient or exuberant requirements, what may result in an unsatisfactory performance of the SPM facility or in too high project costs.

6.3 Contracting strategy

The marine part of an SPM buoy terminal includes two main components: the SPM buoy system and the pipeline(s) connecting this system with the facilities onshore. For the design, construction and installation of the SPM and the pipeline, two expert contractors are involved, being the SPM designer/supplier, like Bluewater and the pipeline designer, supplier and installation contractor. This second party is generally also involved in the installation of the SPM system.

The Client has the options to either subcontract each portion of the marine terminal directly to a specialized

company or to subcontract the complete marine part of the terminal to one EPCI contractor. In the first case, Client has to manage the two contracts, the interface between the two contracts and the interface with the connection to the onshore plant. In the second case, Client has to manage only one contract and one interface (at the connection to the shore plant).

Bluewater offers to execute the complete marine part of the terminal as an EPIC contractor. Dependent on the situation and the extent of each of the scope parts, Bluewater offers to execute the project as a main contractor or as a consortium with a pipeline contractor.

Photo Report of a Bluewater Turret Buoy

In this section a photo report is enclosed showing a variety of buoy projects Bluewater has executed in the recent years. The photos provide a further impression of the Turret Buoy design and the advantages of this design as highlighted in this booklet.



Ocensa, Colombia, TLU-2, Turret Buoy with work boat moored to boat landing



Apache Stag Field, Australia, Turret Buoy during installation



Apache, Stag Field, Australia, FSO moored to Turret Buoy



Ocenca, Colombia, TLU-2 Terminal, Interior deckhouse with Bluewater swivel



Figure 1 Large and Easy Access Boatlanding

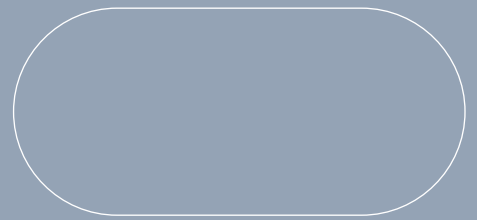
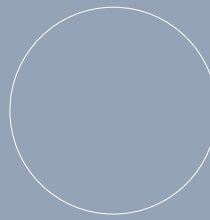
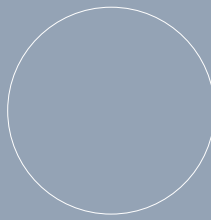


Ocensa, Colombia, TLU-2 Terminal; Piping for Surge Relief System inside deckhouse



Woodside, Legendre Field Australia;
Overboard piping solid connected to buoy and well protected





The Netherlands

Bluewater Energy Services B.V.

Marsstraat 33
2132 HR Hoofddorp
The Netherlands

Tel +31 (0)23 568 2800
Fax +31 (0)23 565 2053

United Kingdom

Bluewater Services (U.K.) Ltd.

Bluewater House, Badentoy Crescent Portlethen
Aberdeen AB12 4YD
United Kingdom

Tel +44 (0)1224 403 300
Fax +44 (0)1224 403 340

Angola

Bluewater International B.V. “Sucursal”

Trav. Do Teatro de Providencia
No. 9, 3 Andar-Apto 1, Coqueiros
Ingombotas, Zona 4
Luanda, Angola

Tel/Fax +244 (0)222 330 573