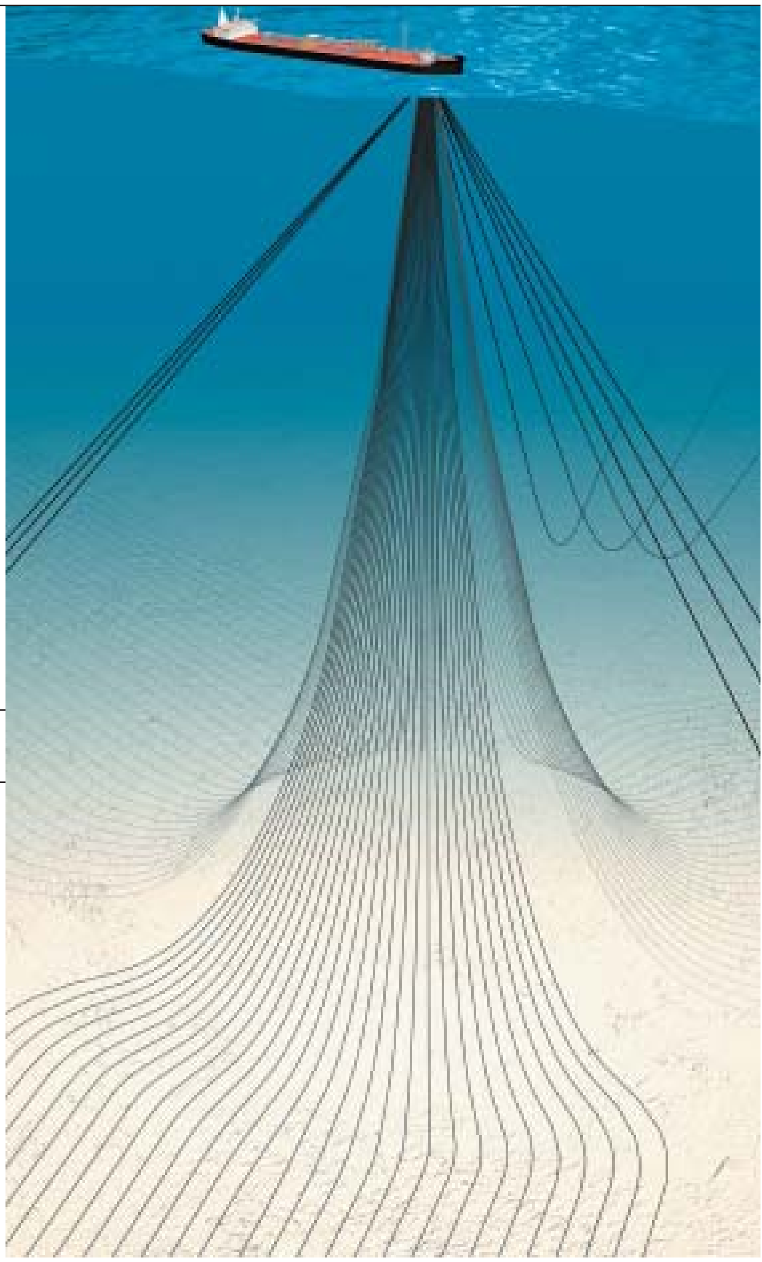
Very Large Turret

A new turret system has been developed that could revolutionise FPSO design



In a conventional single point turret moored system, all the risers pass through the turret, effectively limiting the maximum number of risers to around 50. In recent years however, the maximum production capacity of Floating Production, Storage and Offloading units (FPSOs) has steadily increased, with rates currently reaching as high as 250 000 b/d. These demands have necessitated an increase in the quantity and size of risers. FMC has responded by designing the Very Large Turret (VLT), a cost effective single point mooring system with the capacity for 100+ risers.

'It is generally considered that riser congestion, available space and bearing size as well as load carrying capacity, are factors limiting the number of risers that can enter an FPSO through a turret,' said Chuck Garnero, Project Engineering Manager at FMC SOFEC. In order to achieve the necessary production flow capacity demanded in some fields, the industry employs two alternatives.

[ ] Overview of the VLT arrangement

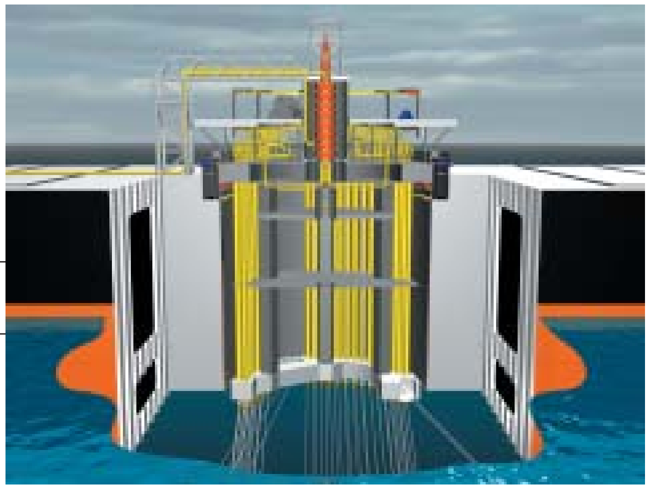
The first is a spread moored layout, with riser porches on either side of the vessel beam. The spread moored Barracuda P43 FPSO for example, will include riser porches for accommodating over 100 risers.

The other has been to maximise the architecture and manifolding subsea, and bring the hydrocarbons up through fewer but larger risers. The Marlim FPSO for example, includes 47 risers.

This prompted FMC SOFEC to examine ways in which large numbers of risers might be brought onto a ship-shaped FPSO, which would maximise production, minimise subsea costs and allow use of a weathervaning mooring system. The result was the Very Large Turret (VLT).

VLT

'The VLT system has similar components to those of smaller turrets, however due to the unique arrangement, it can support over twice the number of risers,' said Garnero.

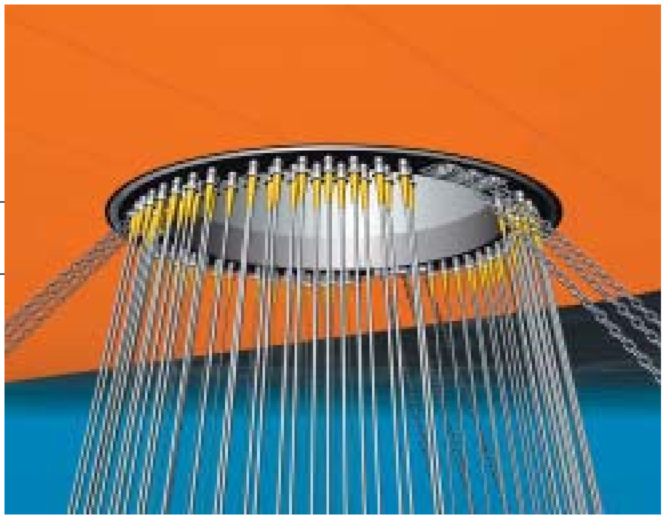


[ ] Cut-away of the turret

'The difference is that the frame has inherent flexibility, permitting the turret main deck to conform to the deflected shape of the vessel under dynamic loading conditions.'

At the top, the main deck – a large wheel shaped structure including spokes and a hub – carries the entire vertical loading imparted on the VLT, including loading from the mooring, risers and self-weight of the turret. It is designed with sufficient strength to support these loads, yet compliant enough to flex with the vessel under extreme hogging and sagging conditions while providing a preferred bearing load distribution.

At the keel level, the doughnut-shaped chain table provides the means of securing the mooring leg chains to the turret. The risers pass through the chain table but do not impart any vertical load on it. The mooring system includes three groups of three anchor legs, which provide large corridors for the risers.



[ ] The chain table

'The mooring leg components would likely be chain/wire/chain, or possibly polyester line rather than wire. Anchor selection would likely to favour suction embedded piles,' said Chuck Garnero.

The main deck and chain table are connected by six tubular support columns which transmit loading. Vertical I-tubes individually encase and protect each riser within the moonpool. They have a large diameter (in comparison with riser diameter) to allow passage of pull-in connection equipment and acceptance of bend stiffeners below the chain table.

The pull-in and equipment deck are located above the turret main deck, while access decks lie below turret main deck. In comparison, these are relatively light structures that provide a minor contribution to the overall stiffness of the turret structure. The swivel torque tube is also a structural item. The top of the torque tube is secured to the torque arm while its base rests on a bearing assembly. This allows it to rotate on the turret main deck as the vessel weathervanes. Individual torque arms secure the outer housing of each swivel to the torque tube.

There are three main bearings. The vertical bearing supports all the vertical loads from the mooring, risers and turret self weight while the radial bearing reacts the horizontal loads in the plane of the vessel main deck elevation. The quantity of radial bearing cartridges varies from 24 to 60 units depending on turret size and loading conditions. A portion of the horizontal mooring load at the chain table location is set against the lower moonpool using a sliding type lower bearing.

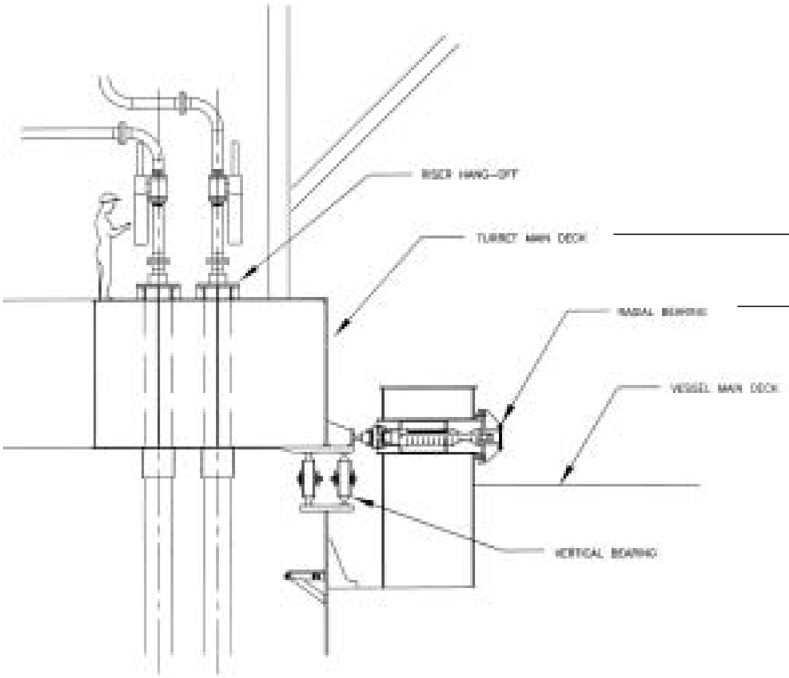
So what sort of vessels are suitable for such a turret? As the VLT is designed for large fields and a large throughput, the mother vessel requirements would dictate a new build or conversion Very Large Crude Carrier (VLCC) or Ultra Large Crude Carrier (ULCC) sized vessels with beams ranging from 50-70m.

'The removal of the vessel's hull structure to make room for a large cylindrical moonpool is a very important design issue,' said Garnero. 'The bending and shear loading in the vessel hull must be closely analysed to determine the required vessel reinforcement. A Finite Element Analysis (FEA) program has been completed on three VLT sizes, including 60, 90 and 120 riser turrets. It was found that the most onerous potential condition is the vessel in a sagging condition with risers installed in a 100-year storm environment,' he said.

BENEFITS OF THE VLT

The VLT has a number of clear benefits in comparison with existing turret and spread moored systems.

For the large spread moored FPSOs in deepwater West Africa, collision risk during the approach of a shuttle tanker is mitigated with the use of remote offloading systems that include midwater pipeline and, a large CALM (Catenary Anchor Leg Mooring) buoy. The weathervaning feature of the VLT however, allows offloading export crude to shuttle tankers in a tandem configuration. Its ability to point into the weather, results in much lower mooring load tensions and permits offloading operations a greater portion of time than that for spread moored FPSOs. A compari-

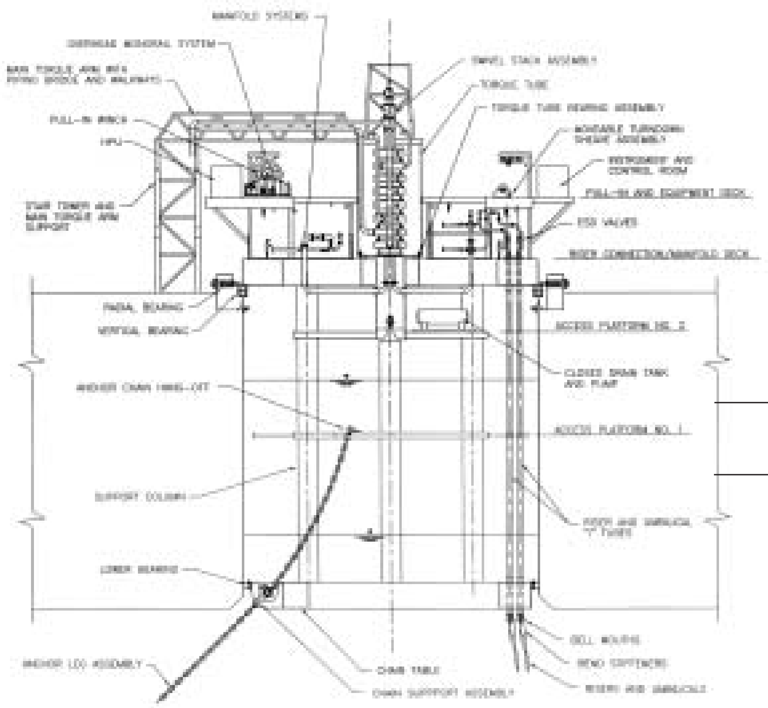


[ ] Detail of the bearing

son of CAPEX and OPEX for spread verses turret moored systems has concluded that spread moored systems with remote offloading, results in a higher overall field development cost.

[ ] The bearings on the VLT

Another advantage is that the VLT is capable of supporting multiple types of risers, including flexible pipe, steel pipe or a hybrid combination. In ultra-deep water, steel pipe risers are likely to be specified. For a steel riser, no I-tube is required and a split insert is used rather than a bend stiffener required with flexible pipe.



[ ] Elevation of the turret

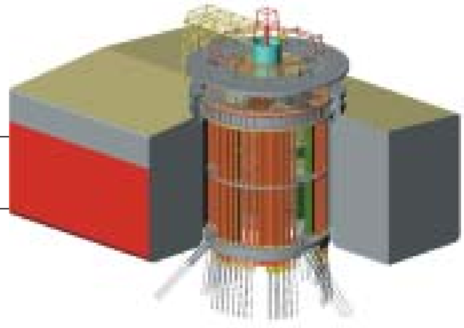
Flexible pipe has a heavier wet weight than steel pipe, therefore a VLT using steel risers will have a lower vertical bearing load. This configuration has the added advantage of allowing the upper portion of the flowline within the turret to be rotated, thus allowing the riser declination departure angle to be selected later in the project schedule, including after turret construction has begun.

'The riser and flowline congestion is still a design consideration in all offshore field developments,' said Garnero. 'This is especially true in large fields requiring many risers. The maximum spacing between riser touchdown points is preferred to limit midwater riser interaction and possible overlap of the seabed flowlines due to current loading and vessel offsets. A common misconception is that a spread mooring, with its relatively long riser porches, provides a greater riser spacing. In fact, the turret mooring actually provides greater riser touchdown spacing at water depths greater than approximately 500m.'

In contrast to conventional turret systems, the VLT arrangement provides generous space for placing turret equipment. The main deck diameter is large enough to locate all turret piping from riser hang-off to swivel inlet, including manifolding and pig launching/receiving facilities. The large area allows skidded piping modules, lowering fabrication costs and minimising installation time. Less expensive, non-compact manifolding valves can also be used as well as flow metering requiring long straight inlet and outlet runs.

Another benefit of the VLT arrangement is the ability to locate the swivel stack base directly on the turret main deck, thereby reducing the overall turret height. This becomes possible by use of a torque tube that eliminates the need for individual torque arms between each outer swivel housing and a turret surround structure secured to the vessel main deck.

In addition to supporting the winch, hydraulic power unit and turndown sheaves, the pull-in and equipment deck has generous space for placing any other possible turret equipment. The inner portion of this deck is virtually clear of equipment to allow unobstructed rigging of lines for riser and pull-in operations. The outer area of this deck is sized for turret equipment as required, including control room, chemical injection equipment etc.



[ ] The bearings on the VLT

The VLT bearing has its roots in offshore heavy lift crane designs. Extremely high peak loads are accommodated by increased wheel and rail width. The design life is substantially extended by selected heat treatment of wheel and rail surfaces. The vertical, radial and lower bearings are simple configurations that allow easy access for maintenance and inspection. Removal and replacement of bearing components can be accomplished in-situ without disturbing the turret operation.

'In conventional turrets, the vertical bearing typically incorporates a three-row roller bearing and requires extremely tight tolerances on the bearing mounting surfaces (+/-0.30 mm) to prevent binding during rotation. The VLT vertical bearing however, can tolerate much larger machining tolerance on the rail mounting surfaces (+/- 1.0 mm),' Garnero said. 'Another major advantage of the VLT results in its lower tolerance on the concentricity requirement between turret and moonpool.'

'The VLT lower bearing gap is in the range of 25 to 75mm. Design and fabrication controls to prevent pinching of the chain table during a hogging condition is no longer a critical issue as it is with conventional turrets where the lower bearing gap is in the range of 5 to 15 mm.'

Yet another fabrication benefit is the ability to install all turret components from above. The constant diameter cylindrical moonpool allows the chain table and other structural items to be lowered from above. This takes delivery of the lower turret structure off the critical path of vessel dry-dock schedule for construction or conversion.

Furthermore, fabrication and inspection is reduced by omitting the need to weld the I-tubes in place. They are simply installed by lowering them through the deck openings. Their weight is carried at the upper end by the turret main deck and the lower end is guided in openings within the chain table.

'The last point is the turret weight,' said Garnero. 'A major advantage of the VLT is its efficient use to turret steel required to carry the riser payload. The VLT is, by far, more efficient than other turrets installed in shallower water, requiring nearly half the amount of turret steel per riser,' he said.

With the capacity to support over 100 risers in water depths up to 3000m, the VLT should be considered as a viable alternative to spread moorings for large field developments requiring FPSOs with many risers. [ ]