MPSO

a new development of FPSO for ultra-deep water

The MPSO (Monocolumn Floater, Production, Storage and Offloading Unit) MONOBR was developed to meet some specific requirements of oil and gas production in ultra deep waters in harsh environments. The most restrictive requirement was to operate in the central area of the Gulf of Mexico, even under hurricane conditions, with SCR (Steel Catenary Risers) permanently connected in free hanging configuration.

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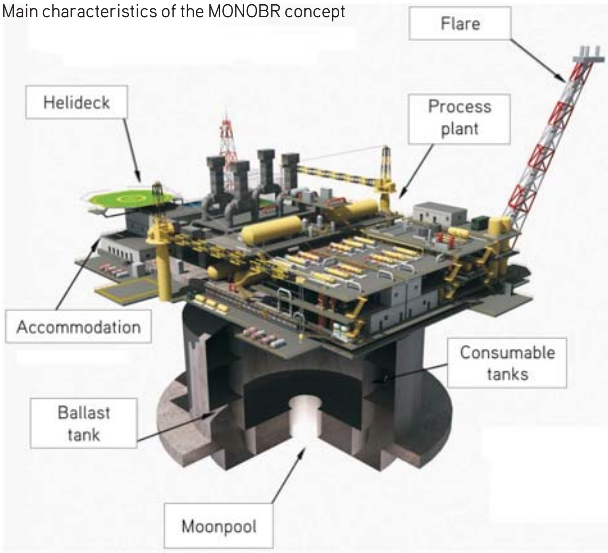
The development of the MONOBR concept started in 2003, under a Petrobras R&D Center development project of FPSO's with cylindrical hulls in cooperation with some major Brazilian universities (São Paulo and Rio de Janeiro Universities), research institutes of technology (IPT and LABOCEANO), engineering companies (SOLIDO and KROMAV), classification societies (ABS) and the Brazilian Navy. In the period from 2005 to 2009, the project received a very important contribution from JOGMEC (Japan Oil, Gas, Metals and Energy Corporation) for a deep look into correlated technologies, construction strategies, and risk analysis of offloading operations.

The Petrobras R&D Center and the Department of Naval Architecture and Ocean Engineering of Sao Paulo University centered on coordination and development of this concept, making use of full coupled dynamic simulations, calibrated by an extensive program of reduced scale model tests.

The differential characteristic of the MONOBR hull is the variation of the external diameter associated with the use of bilge keels and a central tank open to the see, referred as *hydrodynamic moonpool*. The right dimensioning of the *hydrodynamic moonpool* yields to a system that works as passive absorber of motions. The variation in diameter and the external bilge keels tune up the added mass and damping as needed.

The MONOBR motions may get very close to the SPAR's ones, but with much less draft, facilitating construction and transportation, and allowing deck-matting operation in sheltered water.

Main characteristics of the MONOBR concept



In short, the single-column platform offers significant benefits. The main features are:

- Reduced movements, allowing the use of large diameter SCRs in free catenary.
- Greater reserve of stability in damaged condition, allowing corrections in the roll angles flooding a small number of ballast tanks.
- Operational flexibility.
- Due to the cylindrical shape, it is easier to construct and conventional manufacture practices can be used; there is a reduced number of tension hot spots.
- Reduced factor structural weight / displacement of the unit.

Project overview

The MONOBR consists of a cylindrical double-hull mono-column unit designed to operate in ultra-deep waters (2,500 m water depth), moored by three groups of chain-polyester-chain anchoring lines, and presenting a high reserve of stability and very good motion response in waves to allow the use of steel catenary risers (SCRs).

For the Gulf of Mexico application, the local reference shall consider the stern of the MONOBR platform in the opposite side of the living quarters and offices and, according to the environmental data available, the MONOBR is heading to East direction (90 degrees from North).

This concept has the following capabilities:

- Transference of fluids from the subsea wells to the MONOBR through fully piggable steel catenary risers.
- Separate the produced fluids into gas, crude oil and produced water. The peak oil production shall be up to 100,000 bopd.
- Storage capacity of 800,000 barrels of crude oil, inside the double hull, with two walls barriers between the oil and the seawater.
- Oil export to dynamic positioning shuttle tankers moored in tandem to the MONOBR.
- Export the produced gas through pipeline.
- Provide accommodation for 60 persons.

The topsides are divided into three (03) levels:

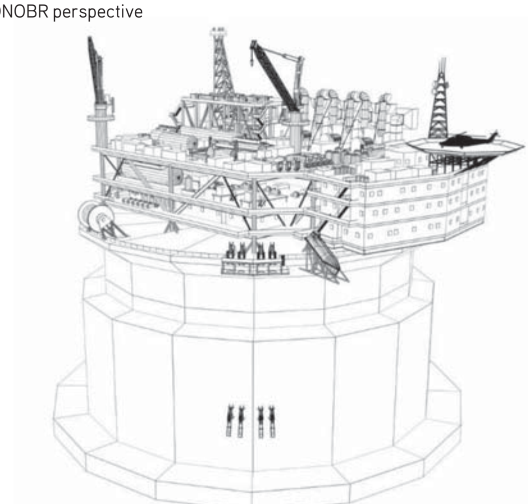
- Deck A: first level (manifolds)
- Deck B: second level (electrical rooms and utilities)
- Deck C: third level (process and main generators)

Use of Conventional Passive Fire Protection Systems:

- "H", "A" and "B" class fire integrity bulkheads and decks
- Classified doors and window frames and fire stops
- Fireproofing of structural elements
- Fireproofing of structural supporting members
- Fireproofing of the moon-pool internal bulkheads

Process equipment is separated from safe areas by barrier walls. The utilities create a physical barrier to protect living quarters. Living quarters are safely located away from storage tanks, being on a structural cantilever over the sea. The arrangement of the process plant is such the safest area is in the opposite side of the gas and oil processing area.

MONOBR perspective

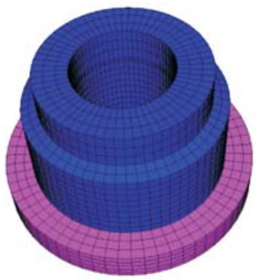


Theoretical details of MPSO concept

Let us give a deep look into the main characteristics of this hull to understand how it can work properly in harsh environments. The objective of this specific hull shape is to minimize as much as possible the first order motions of the unit, increasing the resonant periods without undesirable second order motions. Very briefly the low level of accelerations is responsible to make possible the operation with SCRs in very heavy sea states.

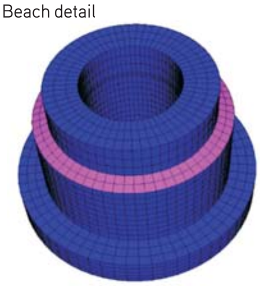
External Bilge Keel (Skirt) – The use of bilge keel to reduce the movement of ships in roll is well known. Although its effect is higher as the structure gets bigger, there is a limitation due to the increase of ship resis-

Panel Model of the Hull with external bilge keel (Skirt))



tance. As the oceanic systems are stationary, there is no hydrodynamic limitation to increasing the size of the bilge keel, turning it into a structured skirt. With that, we get two effects: the increase in damping and added mass/inertia.

Beach detail



Variation in the hull diameter (Beach or Shoulder) – Beach or shoulder is the reduction in the diameter of the hull at the water plane area. This shape increases the added mass and damping, as well as causes a loss of hydrostatic restoration, and consequently increases even more the natural period of the system.

Hydrodynamic Moonpool – Conventional moonpool, considered as an opening in the hull, is widely used to run equipment in drilling rigs. The usual projects aimed the reduction on the motions of the internal water, through the modification of its geometry, so that there is no damage to equipment that will be moved through it.

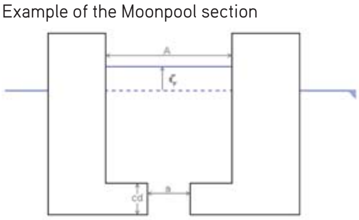
Moonpool detail

Despite having the same name, the moonpool of MPSO aims to reduce the motions of the platform, acting as a passive motion absorber, same concept enshrined in employee anti-roll tanks of ships.

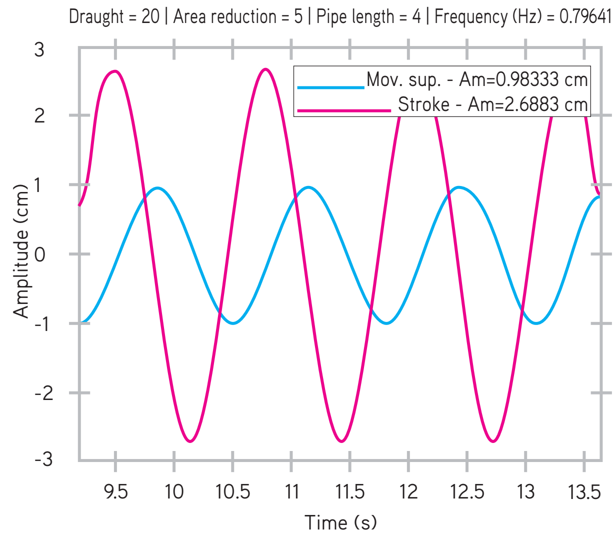
The difference from the traditional moonpools is an area restriction built near the exit of the tank. This restriction causes a difference in phase between the motions of the platform and the restrict water inside the moonpool. The challenge is to use correctly this motion to reduce the movement of the whole system.

If the moonpool sizing is not done in proper way, the device maybe totally ineffective and the internal water tank simply does not "work" for the reduction of movements. The efficiency of the moonpool is modified according to the geometric features, total diameter and draft, and the relation between areas of the moonpool and of the opening (A/a) and height of the restriction duct.

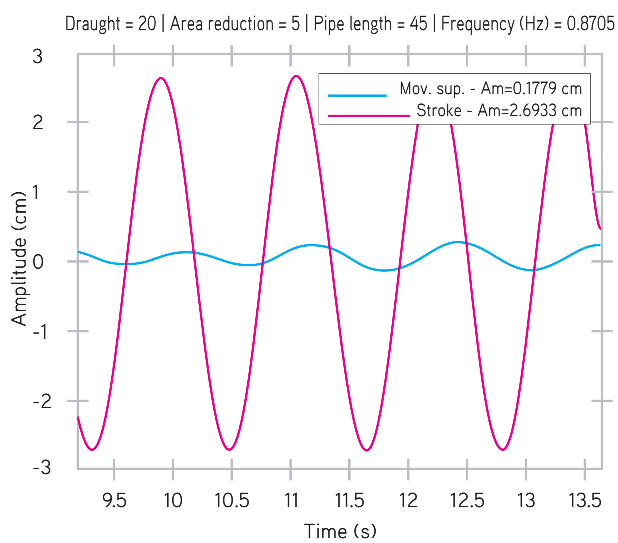
Example of the Moonpool section



Signs of water movement inside of the moonpool and the platform heave motion

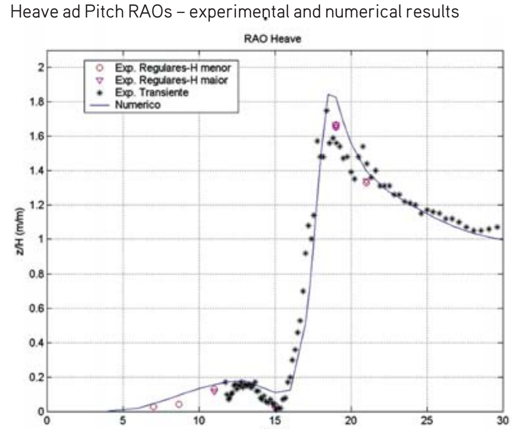


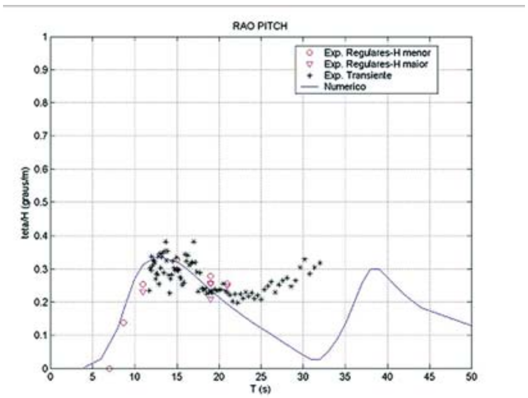
Comparison between an efficient and na inefficient moonpoll



The next pictures show an example of a monocolumn RAO for one developed case.

Heave ad Pitch RAOs – experimental and numerical results





Different geometry of monocolumn hulls

Variations in hull shape

Overall, the MPSO concept is characterized by a circular hull, equipped with systems to minimize motions.

However, rather than a solution specific to certain fields of Brazilian basins, the concept MPSO promoted the development of a complete family of units in order to meet the different needs of Petrobras. Among the key features found, we can highlight the wide range of deck-load acceptable, as well as the possibility of storage on board.

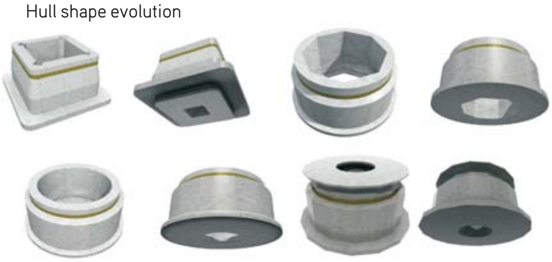
Generally speaking, we have:

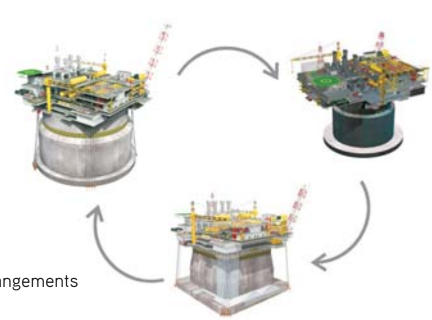
Unit without storage and high deck-load – used in fields with large volume of production and / or characterized by the existence of heavy oil. The unit can be connected to a shuttle tanker for storage or be connected to the pipelines.

Unit without storage and low deck-load – alternative to wells with small production in ultra deep waters, where the use of SCRs makes feasible the project. It is viable for marginal fields in Brazilian or in the Gulf of Mexico seas. This alternative can work together to an FSO, but preferences are given to the use of pipelines (when available), because it costs relatively lower than normally.

Unit with storage and high-load deck – supplementing the family of units of monocolumn type, this platform has internal tanks for the storage of up to 1,600,000 bbl in segregated condition. Due to the large displacement, high deck-loads can be achieved. In this configuration, the unit can be used successfully used on fields in the Campos Basin and the Gulf of Mexico.

Hull shape evolution





Different deck arrangements

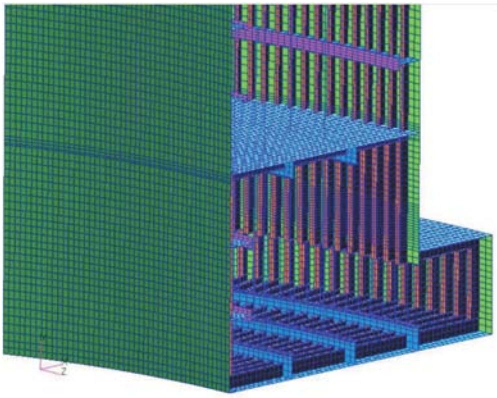
MPSO hull tuned up to provide very low heave motion aiming dry completion for Campos Basin area	
Body Diameter	122 m
Water Line Diameter	92 m
Skirt Diameter	142 m
Moonpool Diameter	60 m
Restriction Diameter	40 m
Draft	47 m
Depth	58 m
Top side	22,000 ton
Storage capacity	800,000 bbl
Displacement	288,000 ton

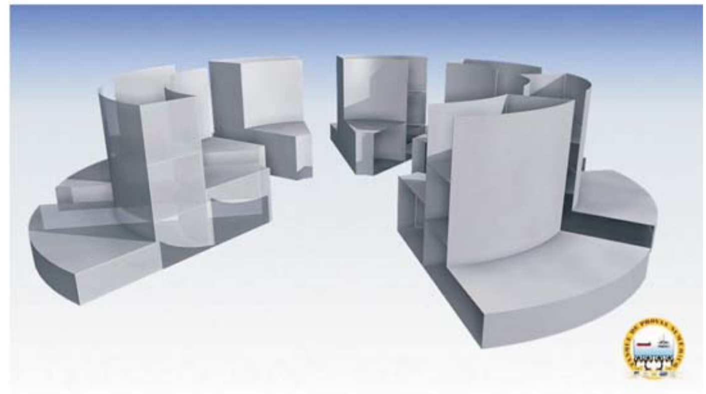
Technical advantages

In all models listed above, one can find the same technical advantages existing in the concept. In addition to the reduced motions of the unit, allowing the use of SCRs, features geared to safety, construction, installation and operation were also analyzed.

Regarding the safety of MPSO, prevailed studies on the characteristics of stability of the unit. Building on the existing international rules for evaluating the stability of floating units, studies have been conducted by seeking the best combination of the shape of the hull and the subdivision of its internal compartments. This means that the MPSO presents wide margin to meet with international criteria of stability, both intact and damaged. Moreover, after damage, you can return the position and no inclination to go to a draft suitable for repair, only with the operation of ballast.

Structural detail and blocks division





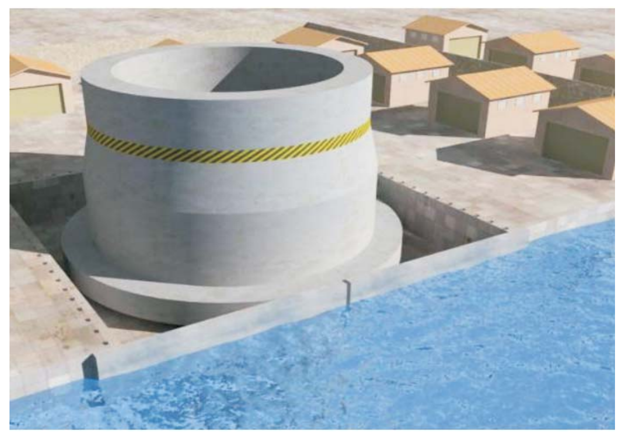
Aspects related to the strategy of building the unit were also taken into account since the beginning of the analysis. Through the determination of a structural arrangement that would allow an easy construction, it was possible to determine a strategy for building facing the use of similar blocks. In other words, the hull of the unit MPSO can be divided into blocks of the same size and structure. This fact enables the development of a learning curve in the same building, taking less time to manufacture and raising the quality of work.

In the process of installing the unit, numerous alternatives were evaluated, which may be selected in accordance with the assumptions of the project in question. In general, the more interesting alternatives are related to the construction of the hull in a dry dock, with the subsequent assembly plant process. This assembly can be held in the yard, within the dry dock, or in the open sea. In the case of assembly in the open sea, problems arise concerning the lifting of the deck modules, which can come to weigh 5000 tons. As a workaround, an alternative has been proposed to heavy-lift crane-Barges or the assembly of the deck through a marine mating. In the case of a possible assembly in Brazilian waters, were also evaluated possible sites for the operation of marine mating, coming to the conclusion that there are pockets in sheltered waters that allow the development of an operation like this.

Finally, technicians and engineers were consulted with experience in the operation of floating units, in order to provide, in early stages of the project, possible operational problems that could occur in the future. A good example was the development of a system of pull-in of Risers based on the use of a tramway located on the deck. Through the interaction between group projects and field personnel, it was able to get to a system that does not interfere with the process plant, in addition to use a simple and reliable

MPSO vs. FPSO (New building ship-shaped)

Naturally, there are several reasons to adopt each other solution, and there are no general indication what is better without going into a detailed analysis of the



Artistic view of construction in a dry dock

design premises, operational requirements, operational practices of the company and, very important, the company's strategy. Even so, it is possible to summarize in a table comparative characteristics between a new building ship-shaped FPSO and the MPSO concept.

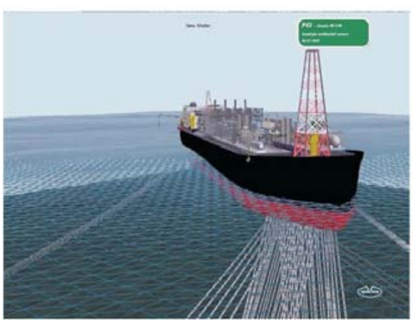
Development of new tools

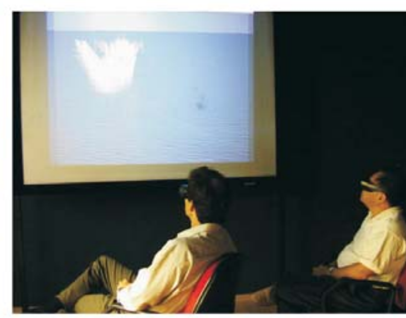
The development of the concept MPSO also promoted the use of new computational tools to aid the project. One of the highlights among the new tools used is the Numerical Offshore Tank (TPN). Developed in a partnership composed of universities from all over Brazil, under coordination of the University of Sao Paulo and the Management Methods of Scientific CENPES / PETROBRAS, the TPN is presented as a powerful tool in developing conceptual designs of the floating units.

The main purpose of TPN is simulate the dynamic behavior of floating structures coupled with anchoring systems and Risers, taking into account various other aspects such as topography of the seabed, environmental conditions even in complex arrangements of floating structures.

Acting in a manner complementary to a tank of conventional tests, the TPN can perform such "tests" generating reports and files the same way. But unlike a physical tank, the TPN can provide hundreds or thousands of tests on a direct way, faster and more economical.

CHARACTERISTICS	FPSO	MONOBR
Constructability	Well known	Flat panels
Deck-mating	Not applicable	Desirable
Operability	Well known	Piranema, Hummingbird
Offloading	Turret is easier than SMS	Similar to mono-buoy
Flexible Risers	Already in use	OK
SCRs	Difficult	Experiments, Calculation
Disconnectable riser system	STP already in use	Not necessary
Loading & unloading procedure	Possibly induces efforts	More flexible
Ballast operation	Possibly induces efforts	More flexible
Area available for process plant	Excellent and rectangular	Good but square, as SS
Installation and demobilization	Easier	Easier
Motions	Great effort to mitigate roll	Low frequency responses
Area for supply-boats	Starboard side	Smaller
Harsh environments	High level of accelerations	Response in low frequency
Greenwater	Serious in severe sea states	Could be avoided





Numerical Offshore Tank - TPN

Through the evaluation of the performance of the unit MPSO in TPN, when subject to action of wind, waves and currents, it was possible to design a mooring system suitable for each of the alternatives in use.

Development of humam resourses

Aside from the technical result obtained by a project like this, characterized by the development of a new technology being used by Petrobras and other gains should also be highlighted.

During the many years of working, professionals, including students, engineers, technicians and teachers, were able to put their skills to test and acquire new experiences and lessons on the development of offshore projects in Brazil.

During this period, more than 50 people were involved in five different institutions, resulting in a huge development of labor-specialized. The laboratories involved with the project should also be remembered, since the modernization of controllers and hiring new people was allowed.

Acknowledgements

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