

## The storm<sup>TM</sup> Production System

### A Riser Focused Floating Production System For Deep Water

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#### Introduction

Floating production systems using dry tree production risers are an industry recognised technology for deepwater. Over 15 systems are in production and a further 9 are in the development phase see Figure 1. The main benefit provided by dry trees is direct access to the tree for production control and ease of wellbore access for workover. This feature allows lower operational costs and higher production rates to be achieved compared to an equivalent subsea development. This is particularly beneficial where reservoirs are complex.

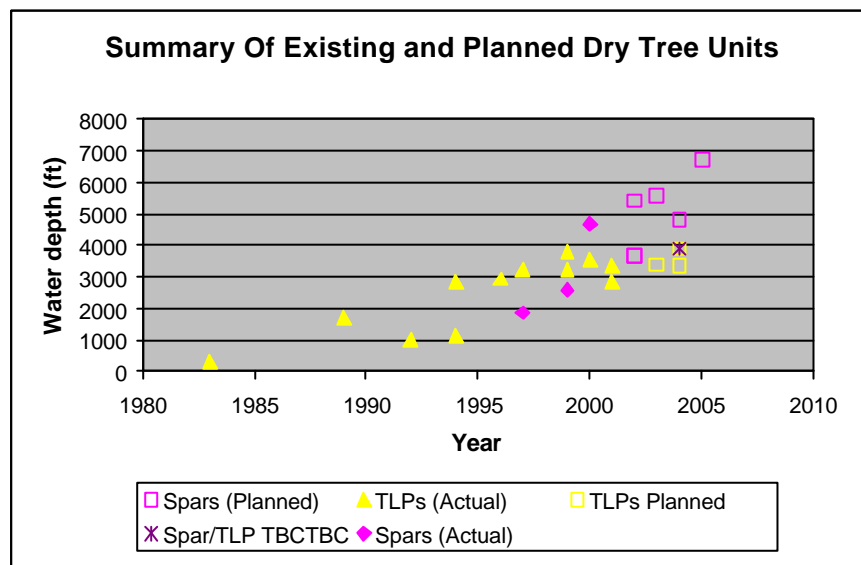


Figure 1 – Summary of Dry Tree Units (Years verse Water Depth)

In recent years, dry tree technology has been extrapolated to increasing water depths, and increasing reservoir size. However, it has become apparent that dry tree systems are not such a good solution for deep and ultra deep water (4,000ft+), despite the potential benefits. The justification for this view is based on consideration of the inherent design problems associated with dry tree systems, which become increasingly significant as water depth increases. Despite this, the industry continues to propose dry tree technology for increasing water depths and appears willing to accept the increasing design problems as an inevitable consequence of deepwater development. The question needs to be asked whether this is the most appropriate technology ?

To date an alternative production configuration that provides similar functionality to that of a dry tree system has not been identified. The possible reasons for this are:

- **Focus** - the industry has focussed on dry tree vessel technology rather than wellsystems and riser technology. The fact that drilling Capex and well systems Opex have an order of magnitude higher cost than the vessel has been largely ignored. A disproportionate effort has been expended optimising dry tree platform design whilst risers and wellsystems have been regarded as a simple 'add-on'.
- **Contractors** - the industry is dominated by a small number of large contractors that have significant interest in dry tree technology and little interest in development of alternative solutions.
- **Novelty** - the industry prefers an extrapolated field proven solution rather than a new solution and this fact greatly discourages innovation

2H, is an independent riser engineering company that has been able to take a step back to review the fundamental deepwater drivers, focussing on the important riser and well systems issues. By this approach they have identified a new field development solution, called storm<sup>TM</sup> that offers an improved solution for deep and ultra deep water compared to current dry tree systems. Importantly, storm<sup>TM</sup> uses existing and proven technology, but configured in a way that provides a stepwise improvement over dry tree systems. This is largely realised by simplifying system interfaces at design, execution and operational phases.

### Dry Tree Systems – Overview

Dry tree floating production systems have been around for almost 20 years with the pioneering Conoco Hutton TLP installed in the early 1980s. The dry tree arrangement allows direct access to surface trees and vertical well access, mimicking the functionality of a bottom founded shallow water system. For developments with high well count or deep and complex reservoirs it is possible to achieve lower drilling costs by avoiding the need for a high cost mobile drilling unit. For smaller well counts predrilling and pull-over drilling can be considered and this is often more economical than providing a full drilling spread.

The two main dry tree solutions are the spar and the TLP. Alternatives include the TPG3300 and the wellhead barge recently proposed for mild environments such as West Africa. Over the years there has been considerable rivalry between supporters from spar and TLP camps. However the

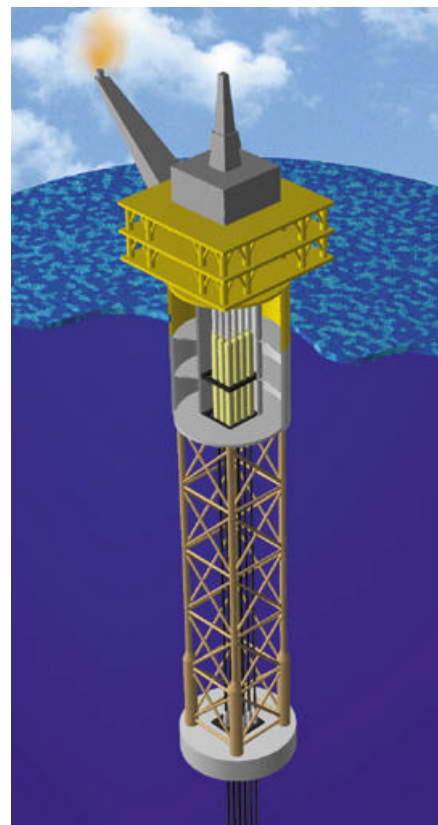


Figure 2 – Spar Dry Tree Unit

objective of both systems is the same and that is to provide a stable platform with minimum motions, particularly heave. One achieves this by optimising hydrodynamic loading and the other by tethering to the seabed. Both concepts provide good solutions for what are now considered medium water depths 600-1000m, however, both concepts are considered fundamentally flawed for deep and ultra deep water application.

The problem with the TLP is associated with the tether design and the practical ability to provide adequate levels of axial stiffness as water depth increases. Thus TLPs have a practical depth limitation of around 4,000ft. The Spar requires a high concentration of risers in a confined centrewell where it is difficult to provide tensioning and accommodate motions. In addition the riser-vessel interface is complex and has resulted in differing designs for each of the 3 Spars currently installed. These problems are compounded with increasing depth, requiring greater tensions and resulting in larger relative motions.

Despite this, and as demonstrated in Figure 1, Spars have recently been selected by a number of Operators as the vessel of choice for deep water developments. The Spar concept has been promoted as having a simple riser design. A design in which the risers 'are shielded from current and wave loading and where the risers are tensioned using low cost aircans'. However it is now well known that the complexity of the spar/riser interface has been underestimated and this has led to a number of high profile problems on existing developments. On future developments it has required significant redesign resulting in increased riser design complexity and cost. It is noted that every spar has a different riser tensioning design including all manner of aircan designs and recent proposals for hydraulic tensioning systems in order to get away from aircan problems. It is claimed that these design iterations solve the riser design problems. However, it is believed that they simply move the problems around, as they do not tackle the fundamental problem of the Spar - the centre well is too small to safely and reliably configure all but a small number of deepwater top tensioned risers.

Whilst a Spar system is feasible in medium water depths, since the aircan size and stroke are smaller, the design problems escalate with increasing water depth. This is particularly true for dual casing systems where riser weight is more than doubled by the inclusion of a second pressure containing string. Whilst the need for the second casing is subject to some discussion, the need for dual casings generally becomes greater with depth and with higher pressure reservoirs.

### **The storm<sup>TM</sup> System**

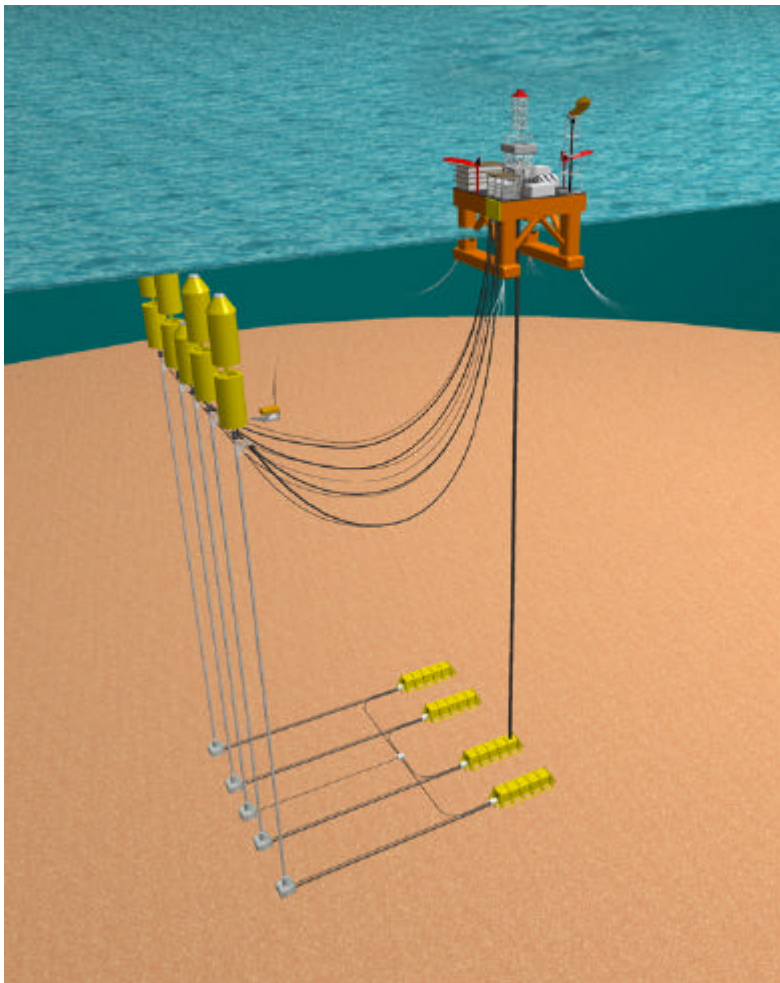
The storm<sup>TM</sup> system has been developed by 2H Offshore and is unique in that unlike other field development concepts, which are vessel and naval architecture focused, storm<sup>TM</sup> has been developed with the prime focus on risers and well systems.

Compared to a dry tree system the storm<sup>TM</sup> arrangement offers improved technical performance, higher levels of safety, reduced interface complexity, improved development flexibility and lower cost. It also enables the step into deep and ultra deep water developments to be made with confidence, using proven components and systems.

The focus and drivers for the storm<sup>TM</sup> systems are:

- Minimise riser numbers and simplify their design interfaces
- Simplify execution by providing contractual flexibility
- Provide direct well access for cost effective drilling and workover
- Eliminate requirement for heave optimised vessel such as spar or TLP
- Take advantage of low cost and reliable subsea trees
- Provide development flexibility for future wells without pre-investment

The storm<sup>TM</sup> system uses subsea wellheads located below a permanently moored floating production vessel. This may be either a barge for application in a mild environment West African development or a semi-submersible for Brazil and the Gulf of Mexico, Figure 3 The wells are drilled using a high pressure drilling riser and surface BOP in the same manner as currently conducted from a dry tree unit. The surface BOP provides efficient drilling and minimum down time. The wells are completed with 'horizontal' or 'drill through' trees that locate the tubing hanger in the tree spool. Importantly this arrangement facilitates direct vertical access through the drilling riser or a smaller diameter workover riser into the wellbore.



The subsea wells are grouped in clusters and may be situated on or off a manifold that allows up to 5 wells to be commingled. This allows the number of risers to be reduced by up to 75%. Each manifold is connected via a rigid seabed spool to the base of a free-standing riser. The riser may be either a single pipe (Single Line Offset Riser - SLOR<sup>TM</sup>) or a pipe in pipe design (Concentric Offset Riser - COR<sup>TM</sup>) that provides additional insulation and allows riser base gas lift and active heating through the annulus. These risers have a threaded construction and are tensioned by an upper aircan.

Figure 3 – storm<sup>TM</sup> Semi-submersible Arrangement

Each freestanding riser is connected to the production vessel by a near surface flexible jumper. The risers, including aircan and flexible jumpers, can be quickly installed from a drilling vessel, construction vessel or from the production vessel itself giving a high degree of installation flexibility. In addition freestanding risers can be used for export, enabling a fast development installation schedule by pre-installing all risers prior to arrival of the host facility. These SLOR<sup>TM</sup> and COR<sup>TM</sup> risers have been developed by 2H as part of the TRF (Threaded Risers and Flowlines) JIP, which is currently in its third phase, conducting qualification testing of key riser components and are currently being implemented offshore West Africa.

The flexible jumper between the riser and vessel offers two key advantages: firstly they can accommodate large vessel motions allowing lower cost non-motion optimised vessels to be considered, and secondly they can be connected to the vessel at a location to best suit the vessel layout. Normally this would be away from the central drilling moonpool area, providing segregation of drilling and production activities.

The reduction in the number of risers compared to a conventional dry tree arrangement reduces the riser steel weight and aircan buoyancy. For a typical application requiring 20 wells in 1500m water depth this may be a saving in the order of 9,000Te of steel and 12,000Te of buoyancy. This provides significant riser cost savings and greatly reduces the sensitivity to increasing water depth.

It is noted that the storm<sup>TM</sup> system is neither a classic subsea system or a dry tree system but it offers the best features of each and avoids many of the disadvantages. The arrangement is suited to a wide range of field development types and environments. The storm<sup>TM</sup> system is particularly suited to developments where reserves are uncertain as the system configuration allows the addition of future wells without pre investment of additional wellbay space or vessel buoyancy requirements. Storm<sup>TM</sup> is effectively a 'self contained' system that can develop the reservoir in a phased execution without the requirement for additional installation vessel to be mobilised to install risers or flowlines.

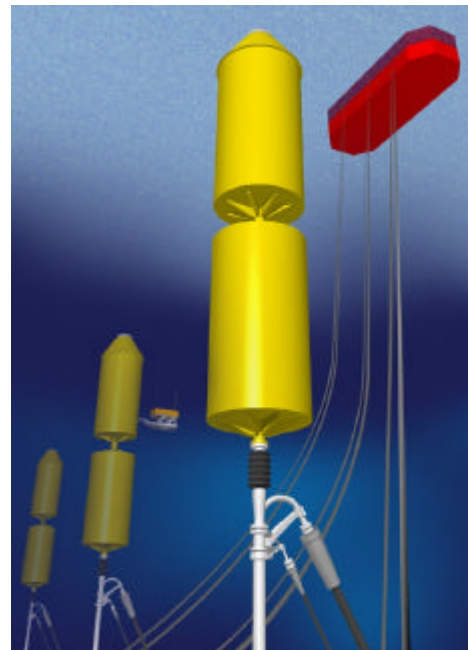


Figure 4 - COR aircan  
Arrangement

The following table compares and summarises main features of a spar and storm<sup>TM</sup> semi-submersible solution:

**Table 1 - Spar and storm<sup>TM</sup> Evaluation**

	<b>SPAR</b>	<b>storm<sup>TM</sup></b>
<b>1.0</b>	<b>Safety</b>	
1.1	Congested production and drilling wellbay located at centre of vessel	- Single drilling riser, no production wellbay. Separated production, drilling and export
1.2	Multiple high pressure production risers with no subsea isolation	- Riser numbers reduced by 75%, subsea isolation provided at subsea tree and manifold
1.3	Potential for riser clashing due to limited available space	- Reduced riser numbers and increased spacing eliminates possibility of clashing
1.4	Inability to disconnect vessel in an emergency	- Riser and vessel disconnect feasible in an emergency
1.5	Poor inspection and replaceability of critical aircans and hull guides	- Easy access and ability to replace aircans; no wear components
1.6	Heavy offshore lift required for mating hull and deck and for aircan installation	- No heavy lift required. storm <sup>TM</sup> system integrated and tested prior to tow out
1.7	Enclosed centre well with possibility of hydrocarbon build-up	- No centrewell
<b>2.0</b>	<b>Cost</b>	
2.1	High cost due to riser steel weight and large aircan tension requirement	- Reduced cost due to reduced riser numbers
2.2	Proprietary motion optimised vessel required to achieve workable riser solution	- Non motion optimised vessel such as a standard semi-submersible from international market or possible conversion
2.3	Complex dynamic riser/vessel interface requiring hull guides and structure	- Simplified static vessel interface and reduced riser number.
2.4	Skidable derrick required to access each well slot	- Fixed central derrick as per conventional MODU arrangement
2.5	High cost to provide spare wellslots	- Negligible capital cost to provide for additional wells
2.6	Heavy lift required for vessel and aircan installation	- No heavy lift required
2.7	Complexity of abandonment, deck removal and upending	- Simple abandonment by disconnecting flexible jumpers and mooring
2.8	Low residual value at end of field life	- Good residual value as early production system or drilling conversion
<b>3.0</b>	<b>Flexibility</b>	
3.1	Limited number of qualified vessel contractors	- Use of standard semi-submersible or barge available from many contractors worldwide
3.2	Number of wellslots need to be fixed early in development schedule	- Well and riser numbers can be kept flexible without significant technical impact
3.3	Complex interfaces sensitive to small design changes	- Simplified interfaces with reduced criticality. Increased ability to accommodate design changes
3.4	Pre-installation of production and export risers not possible	- All risers (production and export) can be pre-installed saving schedule and providing contractual flexibility

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|------|--|---|--|
| 3.5  | Offshore mating of hull and deck requires heavy lift vessel  | - | No heavy lift vessel, minimum offshore construction  |
| 3.6  | Inability to easily incorporate early production capability  | - | Well suited to early production capability   |
| <br> |  |   |  |
| 4.0  | <b>Technical Features</b>  |   |  |
| <br> |  |   |  |
| 4.1  | Surface tree allowing direct vertical access to wellbore and ability to use surface wirelining and coiled tubing WO                                  | - | Vertical access to subsea tree for workover. Similar functionality to surface tree system but wirelining and coiled tube must be conducted through drilling or workover riser. |
| 4.2  | Efficient drilling through use of surface BOP with HP drilling riser   | - | Efficient drilling through use of surface BOP with HP drilling riser   |
| 4.3  | Requires special joints and interface hardware such as stem guides, centralisers, preloaded aircan guides, wear spools and fatigue resistant spools. | - | Standard proven interfaces, no special components  |
| 4.4  | Complex analytical procedures to accurately capture riser response and riser/vessel interaction, roller guide and stick slip etc.                    | - | Standard analysis features adequately capture riser/vessel response  |
| 4.5  | Riser and well count limited by hull and aircan dimensions   | - | No practical limit to wellcount  |
| 4.6  | Vessel response uncertainties such as stick-slip, centre well hydrodynamics and hull VIV   | - | Semi-submersible response well proven and understood   |
| 4.7  | Wake interference between closely spaced risers  | - | No effects to consider due to large spacing  |

## The Future

Storm<sup>TM</sup> has wide ranging scope for potential application covering small to large developments and a range of environments from mild to harsh. However, its real potential is for water depths greater than 4000ft. Whilst there is little engineering development required, the main challenge for storm<sup>TM</sup> is to overcome the inertia in the industry that has developed around dry tree production systems.

Despite this inertia there is confidence that the benefits of the storm<sup>TM</sup> system will be seen to be attractive and storm<sup>TM</sup> systems will be used in preference to dry trees. This will lead to more widespread application of semi-submersible technology in the Gulf and barge technology in West Africa. Conversely the number of new Spar and TLP vessels are likely to be reduced.

## Conclusions

It is concluded that the best technology for deepwater is not necessarily that extrapolated from shallower water depths. Deepwater solutions are required for deepwater problems.

Storm<sup>TM</sup> provides a new way of developing deep and ultra deepwater reservoirs and offers improved levels of safety, reliability, flexibility, simplicity and cost effectiveness.

In deep water we need to refocus on the most important design aspects relating to drilling and well systems and re-evaluate the most appropriate means of meeting the functional requirements.

In deep water it is not considered practical or logical to tieback individual wells. Superior well systems arrangements are possible offering step change improvements.

Storm<sup>TM</sup> is a development solution, which is less sensitive to water depth increase than dry tree production systems.

Development contract strategies will be simplified if the need for 'hi-tech' motion optimised vessels can be substituted by proven semi-submersible technology.

The storm<sup>TM</sup> system offers important benefits and sets new standards for deepwater development technology.