

# **THREADED RISERS AND FLOWLINES FOR FIELD ARCHITECTURE**

**by**

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## **ABSTRACT**

The benefits from using threaded connectors for flowlines with installation from a drilling vessel have already been identified and documented within the industry. Threaded riser use however is currently generally limited to Spars and TLP's. The possible reasons for the lack of adoption of threaded risers are discussed. Recent improvements in connector design and new threaded riser concepts are highlighted together with their advantages. Using threaded connectors for risers as well as flowlines, conductors, tubing, and casing could allow the majority of field hardware to be installed from drilling vessels, giving substantial cost savings and field development flexibility. The challenge is to bring together those responsible for drilling and production to jointly develop all field architecture.

## **INTRODUCTION**

Threaded couplings have been used for many years in the offshore industry particularly in drilling applications and the concept of using them on flowlines and, to a lesser extent, risers is not new [1,2,3,4]. Indeed, threaded connectors have been used successfully on Spars and TLP riser systems for many years. The fact that threaded couplings have not been used more widely on other riser applications is perhaps due to:

- High confidence and track record in welded connections
- Availability of installation vessels capable of welding
- Application of medium strength, readily weldable steels
- Belief that threaded connections are more expensive than welding
- Low confidence in connector reliability
- Lack of a suitable riser system in which to apply them.

Threaded couplings however offer many benefits:

- Faster make-up speed compared to welding - Threaded connections (9-5/8 inch diameter) can be made up in 4-6 minutes compared to 30-50 minutes for a typical offshore weld and inspection procedure for a fatigue sensitive application.
- Use of drilling vessels for installation - Drilling vessels (semi-submersible or ship) are specifically designed to efficiently handle and install threaded connections. Experienced rig personnel are readily available and procedures and tooling are established.
- Application of high strength steels – Some threaded connections do not require welding and this allows the application of high strength steels. This reduces steel weight and riser buoyancy requirements leading to improved riser response.
- Improved fatigue performance – Threaded connections facilitate higher quality onshore welding or the elimination of welding all together, which can provide improved fatigue response.

To-date, those promoting threaded connectors have primarily considered their use for flowlines. The simple replacement of a welded joint with a threaded joint in a J lay situation however is unlikely to be commercially attractive particularly for risers. When the individual threaded connector features identified above are considered collectively however the impact on riser cost and performance can be dramatic. For example, the use of a high strength threaded pipe allows weight and buoyancy reductions. This reduces hydrodynamic drag loading and tension requirements, leading to general reductions in loads and fatigue damage.

A common misconception is that risers are all highly dynamic. In deep water it is typical that 90% of the riser length sees only 10% of the loading and fatigue damage. This allows lower specification, low cost connectors, similar to those designed for flowlines, to be used on the majority of the riser. Higher performance connectors need only to be used for the short dynamic sections - in the wave zone and at the TDP, for example.

The riser configuration, its functional requirements, hardware, installation procedures and dynamic response must be therefore optimised specifically for threaded connections. Only then can such systems be both technically and commercially attractive.

## **CONVENTIONAL FIELD ARCHITECTURE**

When developing a typical deep-water field there are numerous, often conflicting requirements that dictate the final field architecture. Typical considerations when deciding which technologies to adopt for flowlines and riser hardware are:

**Reservoir** - size, shape, depth and pressure, fluid properties

**Flowlines/Risers** - number of lines, type of service, size, gas lift requirements, thermal performance,

**Field Layout** - well and manifold locations, seabed topography, installation schedule, and vessel-mooring requirement,

**Host Vessel** - vessel type, riser payload, maximum number of risers, attachment location, process flow requirements.

Conventionally flowlines are constructed from welded steel pipe, often with thermal coatings and installed from a pipe lay vessel. Risers can be of various types, primary examples being:

**Simple Catenary Riser (SCR)** - Constructed from welded medium strength steel pipe and reeled, J or S-laid from a barge.

**Flexible** - Composite structure reeled from a pipe-lay vessel.

**Hybrid Tower** - Constructed primarily from welded medium strength steel pipe with distributed syntactic buoyancy and air filled buoyancy cans providing top tension. These are towed from a fabrication site and upended in the field.

A common feature of conventional flowline and riser systems is the need for special installation vessels or local construction sites. As fields are developed in increasingly deeper water, there is an increasing requirement for larger and higher specification installation vessels. Consequently installation vessel choice and availability can become quite limited and therefore a key project driver.

### **ADVANCES IN THREADED RISER AND FLOWLINES TECHNOLOGY**

Work conducted recently by pipe and coupling manufacturers and interested engineering consultants has begun to address some of the technical issues preventing wide-scale adoption of threaded connectors for risers in particular.

Sophisticated 3D elasto-plastic finite element analysis is now available to the coupling designer and manufacturer. This has been possible due to the reducing cost and increasing speed of computer hardware. This analysis has enabled an improved understanding of the response of the coupling resulting in improved ability for design optimisation.

Modern computer controlled machining technology can give the high repeatability rates, tolerances and production speeds required for large volume precision couplings. In addition, computer controlled gauging gives accurate optical gauging with hard copy output for traceability.

Upgraded test facilities to conduct cost effective fatigue testing and improved strain gauging and monitoring provides more accurate feedback to designers.

Optimum coupling make-up in the field can now be more easily achieved with the use of computer controlled feedback torque tongs. Higher pre-load can also be achieved. Additionally, low marking and friction grip torque tongs have almost eliminated

damage to pipe and couplings that can lead to corrosion sites and fatigue crack growth sites.

Modern thread coatings can provide consistent friction factors between mating threads and load shoulders allowing the correct preload to be applied and preventing damage to parts.

## **HIGH STRENGTH MATERIALS**

The use of higher strength materials for risers and flowlines has been largely limited to date. The difficulties in achieving quality welds in high strength steels like P110 have prevented its' use for risers. Modern advances in threaded connector technology however have produced minimum upset designs suitable for dynamic riser use that require no welding, either during manufacture or in the field. These can therefore be successfully manufactured in the high strength steels.

Making use of these high strength materials can result in more efficient riser designs. For those riser systems relying on buoyancy for top tension, the thinner pipe wall possible with high strength steels allows reduced buoyancy requirements which, in turn, can reduce the hydrodynamic loading on these components. On riser systems with tension reacted by the host vessel, high strength steel pipe can reduce the total vessel payload by weight reduction and steep top angles.

## **MOBILE OFFSHORE DRILLING UNIT INSTALLATION**

Adopting threaded connectors rather than welding for flowlines and risers opens up the possibility of using a wider variety of vessel types for installation. In particular Mobile Offshore Drilling Units (MODUs) (semi-submersible or ship) are specifically designed to efficiently handle and install pipe with threaded connectors.

The handling of pipes into the derrick may be a limiting factor, but procedures are well developed for installing 10,000ft of 9-5/8 inch casing in less than 20 hours. This is equivalent to about 3500m per day.

Drilling semi-submersibles are designed to handle threaded tubulars such as drill pipes, casing and risers efficiently. The drilling derrick is configured to allow connection and vertical support of tubulars normally by use of threaded connections prior to running into the wellhead or riser. The derrick capacity is variable but is usually in excess of 1.5 million pounds (670Te) for deepwater, far greater than those found on J-Lay installation vessels. This capacity is more than adequate for risers being installed in the latest deep and ultra-deep waters.

The motion characteristics of a MODU are much superior to those of a pipelay barge. The peak roll and heave response periods of MODUs are far from the wave periods that occur in installation conditions whereas barges tend to have response periods that may match. Sensitivity to vessel heading is another important consideration. Barges are generally much more sensitive to vessel heading and must be orientated during installation head to waves. This can lead to difficulties during lay operations. A barge will typically exceed its operating limits in a less severe seastate than a MODU.

Although drilling vessels have so far not been used for installation of flowlines or steel catenary risers, the facilities available for drilling operations are well suited for J lay. The available handling equipment such as spiders and torque tongs are tailored for the use of threaded connections. The storage capacity on a semi-submersible may be limited for the larger pipe sizes, and replenishment by barges may be necessary. However a drill ship will be able to store large quantities of tubulars.

The drilling derrick is designed for pipe makeup in the vertical orientation. Riser top angles of more than a few degrees are not acceptable and make stabbing and support of the riser impractical. However, it is possible for the riser to be deflected off the vertical immediately below the rotary table providing clearance with the moonpool and pontoons is assured. A fabricated stinger or bend restrictor is required below the drill floor to control the curvature.

Current day rates for a MODU are typically lower than those demanded for a specialist deepwater pipeline installation vessel. Lower cost third generation MODUs could also be suitable. Additionally the mobilisation costs for a pipe-lay vessel spread are high compared to a MODU. Often a MODU will already be on charter to the

operator are normally long-term with competitive rates. Where this is not the case, availability of MODU's will be typically significantly higher than suitable installation vessels.



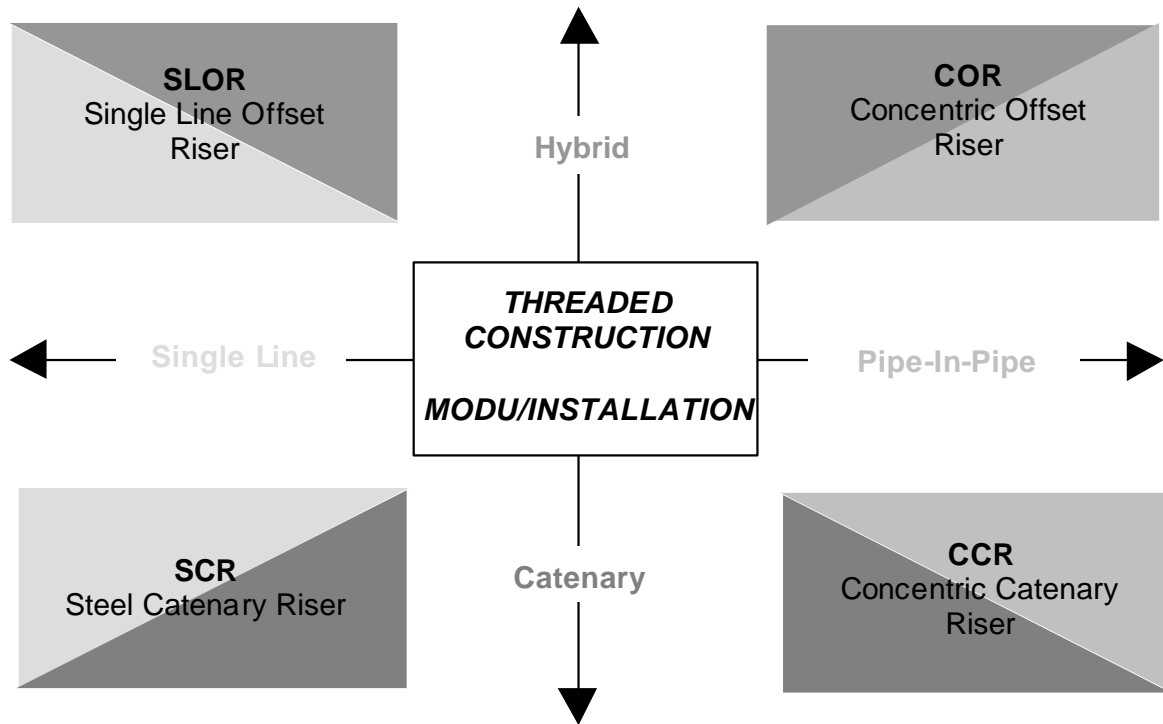
Vessel Type	Barge	MODU Semi-submersible
Example	 <p>DB50 + J Lay Tower</p>	 <p>Noble Paul Wolff</p>
Installation Rate	1200 to 1500m per day	3000+m per day
Riser Hang-off Capacity	345Te	667Te
Max Depth	3048m	2400m
Size Range	3 to 20 inch	up to 30 inch

Table 1 - Installation vessel capacities

## THREADED RISER AND FLOWLINE CONCEPTS

For maximum benefit, risers and flowlines must be specifically designed for threaded connectors. Little or no benefit is realised by simply replacing a weld with a threaded connection on an existing design. 2H Offshore Engineering have been involved in the development of four threaded riser concepts as part of the Threaded Risers and Flowlines Joint Industry Project. This includes two catenary and two free standing arrangements offering both single pipe and pipe-in-pipe geometries.



The main features of the riser concepts include:

- Speed of installation using vessels of opportunity or already in the field
- Low capital cost (compared to existing designs)
- High levels of thermal insulation (and variable)
- Riser base gas lift & active heating
- Short delivery
- Modular components

## **BENEFITS TO THE OPERATOR**

Using a MODU as an installation vessel and use of threaded pipes for risers and flowlines brings a number of benefits to the field operator.

- Savings made on the lower MODU day rates
- Benefit of long-term charters that may be in place.
- No mobilisation costs or schedules
- Flexible planning
- Installation as required by development drilling

By not relying on separate, often expensive, J-lay vessels for riser and flowline installation the field can be developed in a more flexible way. Installation vessel spreads must be booked far in advance leaving no allowance for project over-runs or changes in field development strategy. Standing-down a large installation vessel for any length of time results in major losses and remobilization is costly. For this reason the complete field architecture is often installed in a single season even though production plateau may not be achieved for four to five years. This represents a huge early investment. Using a vessel already on the field allows installation to occur when most appropriate minimising early investment but allowing early first oil.

On a subsea development with 30 wells for example, conventionally four wells may be drilled, then all flowline and riser hardware is installed requiring a large capital investment. First oil is available only from the initial four wells. The remaining wells are then drilled. With threaded risers and flowlines installed from a MODU, once the first wells are drilled, these can be tied back immediately to achieve fast first oil. The only capital investment at this stage has been for those wells, flowlines and risers actually producing. Drilling can then commence on the next group of wells and these are tied back again immediately to the production vessel.

Table 2 below gives an indication of the possible cost savings when installing a threaded flowline from a MODU instead of welding and J-laying from a barge. This simple example is for illustrative purposes and does not included items like pipe coatings, up-front engineering and the other benefits. For the example given, a possible saving of over £5.5M might be achievable.

	50 km Welded Flowline		50 km Threaded Flowline	
<b>Installation</b>	J-Lay from barge		from semi-submersible MODU	
<b>Weight</b>	50 km @ 108kg/m = 5400Te		50 km @ 108kg/m = 5400Te	
<b>Lay Duration</b>	50 km @ 1200m per day = 41.7 days		50 km @ 2500m per day = 20 days	
<b>Costs</b>		<b>£M</b>		<b>£M</b>
<b>Steel</b>	5400Te @ £750 per Te	4.05	5400Te @ £1400 per Te	7.56
<b>Mob. &amp; Demob.</b>	16 days @ £180k per day	2.88	None	-
<b>Travel</b>	6 days @ £180k per day	1.08	None	-
<b>Lay</b>	41.7 days @ £180k per day	7.51	20 days @ £150k per day	3.00
<b>Downtime</b>	£7.51M * 10 %	0.75	£3M * 1%	0.03
<b>Total</b>		<b>£16.27M</b>		<b>£10.50M</b>

Table 2- Cost comparison for a 50km steel flowline.

Conventionally, some risers can only be installed once the production vessel is in place. Some of the threaded risers being proposed lend themselves to pre-installation, ahead of the arrival of the production vessel. This brings more flexibility into a field development as delays in the delivery of the host vessel do not prevent riser installation and a fast start-up can be achieved.

Adopting similar standard technologies for conductor, casing, tubing, flowlines and riser hardware brings simplifications during both engineering and installation. By using similar hardware for the flowlines and risers higher lay rates than those seen on installation vessels could be achieved together with improved synergies and efficiency by standardising flowline, riser and downhole technologies and personnel.

## CURRENT THREADED RISER AND FLOWLINE RESEARCH & DEVELOPMENT

The Threaded Riser and Flowline Joint Industry Project (TRF JIP) is being run by 2H Offshore Engineering Ltd with the goal of developing the concepts discussed in this paper sufficiently to achieve commercial and technical confidence in threaded flowline and riser solutions and installation methods. Started in January 2000, the JIP currently has seven participants, all major oil operators. Phase I and II of the JIP scope is anticipated to last 12 months.

Trevor Jee Associates is currently completing, as part of another JIP, a new connector specification that is intended for adoption as an ISO International Standard [5]. The specification details the physical tests that will be required to quantify and demonstrate that connectors proposed for flowline and riser use are fit for purpose. This work is vital if threaded technologies are to be adopted on a large scale.

## **CONCLUSION**

The concept of using threaded connectors on flowlines is not new and the advantages gained from using a drilling vessel for installation have already been identified. To-date, however, their use on risers has been limited generally to Spars and TLP's. Recent advances in threaded connectors and the development of new riser concepts can now allow conductor, casing, tubing, flowlines and riser hardware to be installed from the same vessel using similar technology. This could bring potentially large cost savings and increased development flexibility to the operator. To achieve this, the challenge now is to create a new relationship between those responsible for drilling and those for production to make the most of their combined technologies, skills, and resources to realise significant benefits.

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