

Introduction

Connectors for underwater use are an important component of many subsea systems, they make it easier to conduct onshore or offshore testing, easier to manage cabled assemblies and facilitate ease of installation during deployment. Underwater connectors come in a variety of types and configurations, a majority of the underwater connectors are either dry-mate or wet-mate having electrical or optical contacts or a combination of both, typically called hybrid connectors. These underwater connectors are being used for Permanent Reservoir Monitoring (PRM) systems, demonstrating their value to PRM projects. Currently, PRM systems are typically making use of the commercially available underwater connectors. These commercial connectors have been developed over the past decades for naval acoustic arrays, ocean science observatories and connection of umbilical's and control equipment for offshore oil and gas facilities. As the offshore industry evolves, testing and demonstrating newer surveillance systems such as PRM, brings more focus on critical technologies required for the system to perform reliably. While, certain underwater connectors are well proven with a good field history and track record, more advanced optically based PRM systems utilizing fiber optic dry-mate and wet-mate underwater connectors become an increased focus on reliability to ensure that these technologies are ready for the market.

To ensure that these underwater connection technologies are ready for the market much focus is placed on their development. Typical underwater connector development programs include; design and feasibility studies, prototyping, concept reviews, critical design reviews (CDR's), failure mode, effects, and criticality analysis (FMECA's), final design reviews (FDR's), test readiness reviews (TRR's), detailed qualification programs, and pilot project deployments. This paper reviews the processes and considerations in the specification of reliable subsea connectors for use in a PRM type system.

Underwater Connector Development Programs

A typical underwater connector development project from concept phase to deployment will typically consist of:

1. A Funding Source
2. Industry Partnership
3. Development of Operating Specification
4. Design Modelling
5. Prototype Manufacturing
6. Qualification Testing
7. Manufacturing Tooling
8. Manufacturing Procedures, Laboratory Configuration for Mass Production
9. Process Repeatability – Build units many times over in a production environment
10. Development of a successful field history over multiple deployments (typ. 3yr+)

There are no known current industry standard specifications for underwater connectors. However, there are a variety of organization specific requirements documents created by oil and gas operators and associated major equipment providers. These specifications are the main documents used in the initial development and qualification of underwater interconnect equipment. Additionally, there are industry working groups such as Subsea Fiber Optic Monitoring systems (SEAFOM), that are creating subsea industry recommended practices for subsea interconnect systems. Recommendations through SEAFOM are currently being developed and should become available to the industry over the next few years. As more requirements for underwater connectors are established greater focus will be put on their specifications and qualifications. This is now seen in some of the major offshore developments that are using fiber optic underwater connectors.

Typical offshore developments where larger quantities of fiber optic wet-mate underwater connectors are used include the Ormen Lange Field in the North Sea at 800m-1200m, Pazflor off Angola at 1000m-1200m and a variety of fields in the North Sea in the 200m to 500m depth range including Troll, Tordis and Tyrihans.

Most all underwater wet-mate fiber optic connectors in current offshore deployments are for use with umbilical termination assemblies (UTA's) and remotely operated vehicle (ROV) operated optical flying lead jumper assemblies (OFLs) connecting to optical routers in the subsea control modules (SCM's).

These offshore projects that widely use the fiber optic underwater connectors have differing architectures than that of PRM systems. Below are some illustrations of envisioned PRM systems using underwater fiber optic connectors for connection of cable arrays. These architectures or configurations will vary based on the sensing technologies utilized in the PRM system.

The illustration below (Figure 1) is a typical optical PRM system architecture utilizing optical wet mate connectors for installation of the seismic sensor arrays. In deepwater applications the complexity of installation is minimized with the use of underwater optic wet-mate connectors.

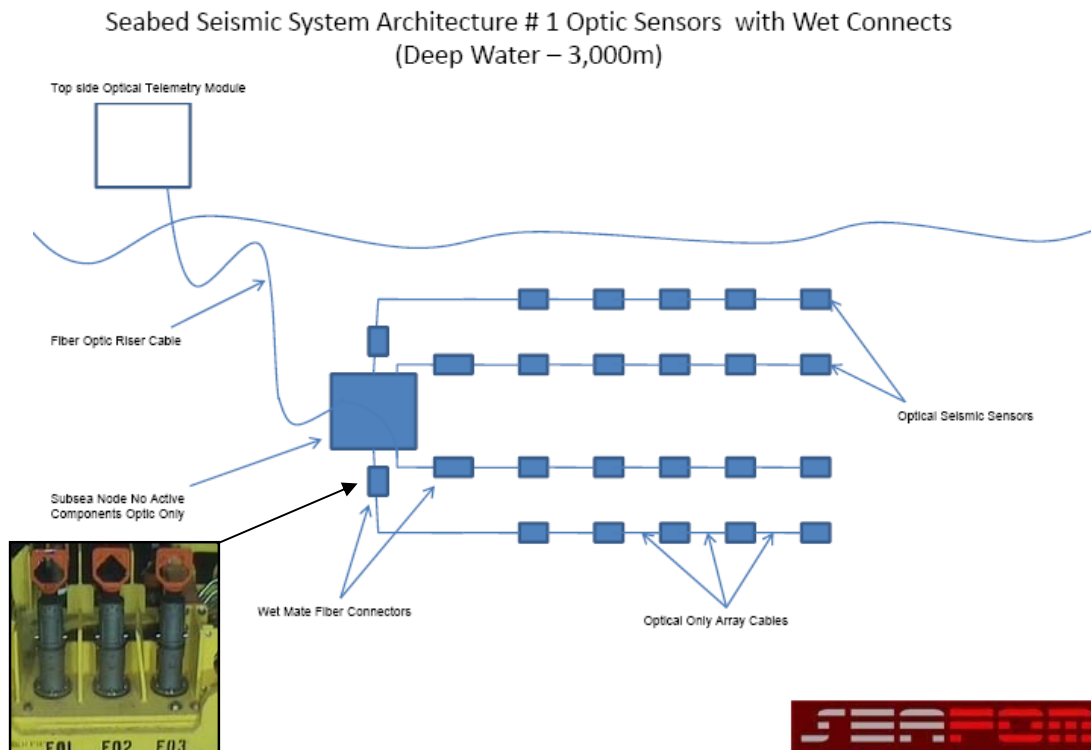


Figure 1: Deepwater array utilizing underwater fiber optic wet-mate connectors

The illustration below (Figure 2) is a typical optical PRM system architecture utilizing optical dry-mate connectors for installation of the seismic sensor arrays. In shallow water applications deployment and retrieval of arrays is less complex and installation is minimized with the use of underwater optic dry-mate connectors.

Seabed Seismic System Architecture # 2 Optic Sensors with Dry Connects (Shallow Water 500m)

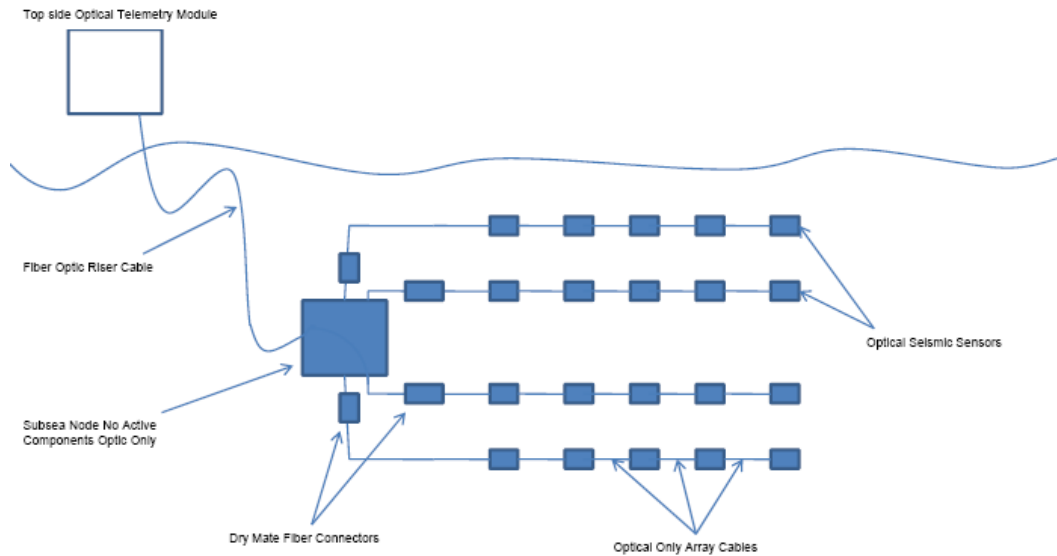


Figure 2: *Shallow water array utilizing underwater fiber optic dry-mate connectors*

Considering the differing architectures for PRM systems there will also be considerations for varying operating parameters. An underwater connector used in an offshore umbilical typically will be used for data communications. The operating performance for the underwater connectors will be evaluated for insertion loss (IL) typically less than .5dB per contact. Other parameters for these communication systems will be less important such as contact back reflection (BR) and optical power handling. Advanced sensing or surveillance systems used in offshore installations use the fiber component itself as a sensor. These sensing systems such as distributive temperature sensing systems (DTS) in down hole type applications, in addition to IL, the BR is potentially another cause for concern affecting the system performance and measurement accuracy. PRM systems, depending on their configuration will have unique requirements for underwater connectors that must be considered in the initial phases of system definition. Evaluating these requirements early on will help identify and gaps in technology that may be filled through development and qualification. Below (Table 1) illustrates some of the performance requirements that may be identified in an operating performance specification. Some of these parameters may be unique for a given PRM architecture and new performance characteristics may be required to be included.

Description	Parameter
Design Life	25 years
Optical Performance – Single Mode	
Insertion Loss (IL) 1310nm & 1550nm	Better than -0.50 dB (Average -0.12dB)
Back Reflection (BR) 1310nm & 1550nm	Better than -45.0dB
Pressure Rating	
Operational Depth	7,000m (23,000 feet)
Header Differential Pressure Rating / Test	230 Bar (3,333psi) / 345 Bar (5,000psi)
Temperature Rating	

Operating	-5°C to +45°C (23°F to +113°F)
Storage	-40°C to +60°C (-40°F to +140°F)
Mate / De-Mate	
Minimum Number Mate/De-Mate Cycles	100
Maximum Mate / De-Mate Speed	0.3 meters per second (12 inches/second) [Qualified for 0.6m/s (24 inches per second)]
Latch	Linear Mate/De-Mate, positive visual indication
Maximum mate/de-mate force	M 622N (140 lbs). D 222N (50lbs).
Mate / De-Mate	
Typical mate stroke length	121mm (4.8 inches)
Maximum Rotational / Angular / Radial misalignment	Rotational 10° / Angular 5° / Radial 6.4mm (0.25inches)
Maximum applied mating force	5000 N (1124 lbs.)
Chemical Compatibility	
Materials and components to be compatible with the following fluids:	Dow Corning DC200 Silicon Oil, Mineral Oil, Diesel, Castrol Brayco Micronic 864HT200 synthetic base hydraulic fluid, Marsten Bentley HW443 water based hydraulic fluid, Glycol, 50% Citric acid, 50% Acetic acid, Xylene, Methanol, Mono Ethylene Glycol (MEG), Water, Seawater

Table 1: Typical operating Parameters for underwater connectors in a PRM system

Conclusions

While underwater fiber optic connectors are widely used in the subsea industry, much work is still needed for their specification in applications such as PRM systems. Organizations such as SEAFOM are working to create recommended practices for equipment, however industry input is still desired as the latest PRM systems are developed and pilot projects are launched.

Underwater fiber optic connectors will continue to be a critical part of the PRM system functionality and correctly identifying their requirements are essential to long term reliability when deployed subsea.

References

- 1) E Niekrasz: "Wetmate Connector Technology", Paper OCE-6-1Ocean Community Conference 1998.
- 2) M Christiansen: "Fiber Optic Connections in the Sea" proceedings UWI '99, New Orleans
- 3) G Brown, M Christiansen: "Fiber Optic Terminations for Sub-Sea Applications" reprint Sea Technology
- 4) G Brown: "Advancements in the Reduction of Size and Weight of Electrical and Optical Connectors for Extreme Environments" presented at the IEEE OES Homeland Security Technical Workshop 2003, Warwick, USA.
- 5) G Brown, "Operational Considerations for Underwater Mateable Connectors" Oceans 2003, Paper#390