AMETEK SCP
NDIA Technical Program 24 Sept 2014

PBOF Sensor Cabling Systems

Dave Jenkins PE
VP - BD and Sales
Ametek SCP

Unclassified
Agenda

- Quick Company Overview
- Rugged Outboard Conduit System (PBOF)
  - Configuration
  - Track Record, Qualification
  - Comparison to PU Solutions
- PE Technology Introduction
- Q&A
AMETEK, Inc. is a leading global manufacturer of electronic instruments and electromechanical devices with annualized sales of $3.6B US

AMETEK has nearly 14,000 colleagues at over 120 manufacturing locations around the world. Supporting those operations are more than 80 sales and service locations across the United States and in more than 30 other countries around the world.

NYSE: AME
AMETEK SCP: Mission, And Vision

**Mission**: To be the preferred supplier in providing *highly reliable, harsh environment interconnect solutions* (*copper or fiber*)

**Vision**: We Are The Go-To Supplier, and Technology Leader in our Undersea Market Segments
AMETEK SCP: What We Do…

- **Our Products:** Cable assemblies, hull penetrators, and connectors for Mil 24231, Mil 24217 and proprietary designs for both military and commercial harsh environment (Fiber Optics or Copper) solutions

- **Our Services:** Design, analysis and testing of interconnect systems, with expertise in glass to metal sealing, cable molding, hydrostatic testing, extended life test, installation, repairs etc.

- **Our Talent:** New Product Development Expertise, Harsh Environment Submarine Penetrators and Custom System Solutions. If you have something difficult to connect or terminate, “Just bring it….”
Ametek SCP Manufacturing Facility

- 32,000 sq. ft. owned facility, In Westerly RI
- Management, sales, engineering, manufacturing and test
- U.S. Navy certified molding operation (PRO-020)
- Hydrostatic and accelerated life testing
- Hermetic glass-to-metal sealing
- Transfer injection rubber molding process
- New Product Development, Rapid prototyping
Quality

ISO 9001: 2008 (Originally certified in 2000; recertified in December 2010)
AMETEK SCP - Custom Cable Assemblies For Electrical and Optical Distribution

Connector Wiring Harnesses and Terminations

Submarine Hull Penetrators and Cable Assemblies

PBOF Wet Mate Connector Assembly and Integration
AMETEK SCP-Glass to Metal Sealed Penetrator and Connectors

High Density Penetrator

Glass Sealed Connectors

Instrument Penetrator

HTHP Down Hole Feedthrough
Some Interesting Questions We Hear:

- Surely you keep that custom 12O/22E hybrid connector that I need right now on the shelf, right?

- What do you mean, the cable design I need isn’t sitting on a reel? And it takes how long? And there is a minimum run of how many feet?

- It’s just a connector, how hard can it be?

- You mean this PU overmolded cable lasts how long?
Here Is A Scenario: You Are Designing a new Outboard System With a Unique Conductor and/or Fiber Configuration:

Q1: Will you need a custom designed cable and connector? (read: $ NRE, lead time)

Q2: Will you need to pay for a minimum run of that custom cable?
Q3: How long will you have to wait for your custom cable? (16-18 weeks?)

So … What if you used what the Oil&Gas industry has been using for 20+ years? And what if you this cable solution had a design life of 25-30 years, and was also a “configurable” solution?
### Something Like ..... ROCS - Rugged (PBOF) Outboard Conduit System

<table>
<thead>
<tr>
<th></th>
<th>PU Molded Cable</th>
<th>ROCS (PBOF) Cabling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Navsea PRO 020</td>
<td>Statoil TR2390</td>
<td></td>
</tr>
<tr>
<td><strong>Design Life ?</strong></td>
<td>7-10 years typical</td>
<td>25-30 years</td>
</tr>
<tr>
<td><strong>Maintainable ?</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Configurable ?</strong></td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Lead Times ?</strong></td>
<td>14-16 Weeks for Custom</td>
<td>Standard hose lengths and</td>
</tr>
<tr>
<td></td>
<td>Cable Solution</td>
<td>fittings are on the shelf</td>
</tr>
<tr>
<td></td>
<td></td>
<td>for standard sizes (13mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and 20mm)</td>
</tr>
<tr>
<td><strong>Initial Cost</strong></td>
<td>Comparable for Short</td>
<td>Comparable for Short</td>
</tr>
<tr>
<td></td>
<td>Runs (~30ft)</td>
<td>Runs (~30ft)</td>
</tr>
<tr>
<td><strong>Life Cycle Cost</strong></td>
<td>2-3X</td>
<td>1X</td>
</tr>
<tr>
<td>(assumes replaced 2-3x in 25 years)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Navy Polymold Certification

- NAVSEA S9320-AM-PRO-020/MLDG REV 2

- Process Controls
- Cleanliness
- Humidity
OFH’s in Service in Oil&Gas:
A 2004 Bennex Q and Data point

Q: How many hoses are in service?

Ans: The first Bennex Anguila hose system was installed in 1993, and is still in reliable operation. Since that time, well over 10,000 systems have been installed.

10,000 x 20m (avg) = ~ 200 km (123 miles) in service
OFH Reliability Snapshot 1994 - 2004
(Bennex OFH Data)

<table>
<thead>
<tr>
<th>Yr Installed</th>
<th>Nr of Jumpers</th>
<th>Op Hrs (x1000)</th>
<th>Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>38</td>
<td>3612</td>
<td>1 (40 hr repair)</td>
</tr>
<tr>
<td>1995</td>
<td>67</td>
<td>5789</td>
<td></td>
</tr>
<tr>
<td>1996</td>
<td>333</td>
<td>25894</td>
<td></td>
</tr>
<tr>
<td>1997</td>
<td>810</td>
<td>55987</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>650</td>
<td>39312</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>1125</td>
<td>58320</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>799</td>
<td>34517</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>825</td>
<td>28512</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>575</td>
<td>14904</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>576</td>
<td>9953</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>330</td>
<td>2851</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>6128</td>
<td>279,651</td>
<td></td>
</tr>
</tbody>
</table>
OFH – Some Additional Questions

- Q: What is the longest OFH Supplied?
  Ans: About 485m (1591 ft)

- Q: What is the longest OFH (Practical Limit):
  Ans: Approximately 500m (1640 ft)

- Q: Can an OFH be used on a winch system?
  Ans: OFH cannot be used for subsea winching systems, although the hose may be transported and stored on typical cable reels

- Q: Can the OFH be supplied black, and with a specific marking, or possibly unmarked?
  Ans: Yes
**History**

--- | --- | --- | --- | --- | ---

**PBOF Hose Development**

- Single Layer OFH (Clear Tubing)
- Ruggedized Single Layer Designs
- Ruggedized Multilayer OFH, Ti / SS Fittings

**Wet Mateable Connector Development For Control Systems**

- Wet Mateable (Pluggable) Electrical Connector Designs
  - Gen 1 O WMC
  - Gen 2 O WMC
  - Gen 3 O WMC
The Swimming Pool Compensator Thought Experiment (Beer optional)

Pressure Under A column of Water Is:
\[ P = \rho g H \], or a bit less than \( \frac{1}{2} \) psi per Foot

Patm = 0 psi on a gage At the Surface Or In a Water filled Balloon

\[ \text{6 ft} \]

\[ \text{12 ft} \]
The Swimming Pool Compensator Thought Experiment

Let's jump in the pool and take the balloon down halfway. What is the pressure inside the balloon here?

Pressure Under A column of Water Is: \( P = \rho g H \), or a bit less than \( \frac{1}{2} \) psi per Foot

\[ P = 2-3 \text{ psi here} \]
The Swimming Pool Compensator Thought Experiment

Pressure Under A column of Water Is:
\[ P = \rho g H \], or a bit less than \( \frac{1}{2} \) psi per Foot

Now lets take the balloon down to the bottom of the pool. What is the pressure inside the balloon here?

\[ P = 5-6 \text{ psi here} \]
Conclusion: Since the balloon is made from a very flexible material, the pressure of the surrounding water will be felt on the inside fluid, and will therefore match the pressure of the water at that depth.

But, the pressure inside a strong structure like a protected/steel pressure vessel will remain at whatever pressure the inside was at the time it was closed up.
Typical Molded Assy, Pressure State

- Ocean **Differential Pressure** Exists To Interior of Cable, Overmold and Connector Interior
- Thus Ocean Force Exists to Penetrate Interior of Cable and Overmold Bond Line
Typical OFH Assy, Pressure State

- Virtually No Ocean Differential Pressure Exists To Interior of Cable, and Across Seals
- No motive force (DP) for entry of seawater to Cable or Connector Backshell
Elite Series Dry Mate Connector

* Designed from Ground Up To Accommodate Either Overmolded or PBOF Backshell Designs
Ametek SCP Elite Dry Mate Connector with Oilfield Mk 2 PBOF Connection

- Oil Fill Port
- Dual Orings
- PBOF Backshell
ELITE SERIES
DRY MATE CONNECTOR

Introducing the ELITE SERIES Dry-Mate Connector

General Description and Advantages
- Design Life 25 Years
- ISO/API Compliant Design
- 316SS Standard, Ti Gr 2, 5 Available
- Dual O-ring Seals at All Points of Seawater Entry
- O-rings Captured for Retention
- Fully Modular Design
- 19 Positions for Electrical or Optic Contacts
- Industry Standard Shell Sizes
- APC Contacts Available for Fiber Optic Version
- Permits Very High Back Reflection Performance
- Cable Termination or PBOF Designs Available
- Glass Sealed Electrical Version Available

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Specification, BCR or FCR</td>
<td>316SS nominal, Ti Available</td>
</tr>
<tr>
<td>Material Specification, CCP</td>
<td>316SS nominal, Ti Available</td>
</tr>
<tr>
<td>Design Life</td>
<td>25 Years</td>
</tr>
<tr>
<td>Number of Contacts</td>
<td>1-10E</td>
</tr>
<tr>
<td>Design Water Depth</td>
<td>3000m</td>
</tr>
<tr>
<td>Test Pressure</td>
<td>4500m</td>
</tr>
<tr>
<td>Environmental Operating Temp in air/water</td>
<td>-5 C to +40 C</td>
</tr>
<tr>
<td>Equipment Storage Temperature</td>
<td>-25 C to +50 C</td>
</tr>
<tr>
<td>Max Voltage - Mated and Unmated</td>
<td>1500VDC/1000VAC</td>
</tr>
<tr>
<td>Insulation Resistance</td>
<td>&gt; 200g/km at 1000 VDC</td>
</tr>
<tr>
<td>Rated Current (16 amps)</td>
<td>13 amps</td>
</tr>
<tr>
<td>Contact Size, nominal</td>
<td>16AWG</td>
</tr>
<tr>
<td>Insertion Loss (EU/UPC)</td>
<td>Less than 0.05dB @ 1310/1550nm</td>
</tr>
</tbody>
</table>
# Dry Mate – ELITE Series - Specifications

<table>
<thead>
<tr>
<th>Design Parameters</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Material Specification, BCR or FCR</strong></td>
<td>Electrical: 316SS nominal, Ti Available</td>
</tr>
<tr>
<td>Material Specification, CCP</td>
<td>Fiber Optic: 316SS nominal, Ti Available</td>
</tr>
<tr>
<td>Design Life</td>
<td>25 Years</td>
</tr>
<tr>
<td>Number of Circuits</td>
<td>1-19E</td>
</tr>
<tr>
<td>Design Water Depth</td>
<td>1-19FO</td>
</tr>
<tr>
<td>Test Pressure</td>
<td>1-19FO</td>
</tr>
<tr>
<td>Environmental Operating Temp in air/water</td>
<td>1-19FO</td>
</tr>
<tr>
<td>Equipment Storage Temperature</td>
<td>1-19FO</td>
</tr>
<tr>
<td>Mate/Demate Cycles</td>
<td>250 in spec, 1000 durability</td>
</tr>
<tr>
<td>Max voltage - Mated and Unmated</td>
<td>1500VDC/1000VAC</td>
</tr>
<tr>
<td>Insulation Resistance</td>
<td>&gt; 20gohm at 1000 VDC</td>
</tr>
<tr>
<td>Rated Current (16 awg)</td>
<td>13 amps</td>
</tr>
<tr>
<td>Contact Size, nominal</td>
<td>16AWG</td>
</tr>
<tr>
<td>Insertion Loss (IL) (UPC)</td>
<td>Less than 0.5dB @ 1310/1550nm</td>
</tr>
</tbody>
</table>
Dry Mate – ELITE Series - Features

- Dual O-Rings
- Captured Mating O-Rings
- PBOF, FITA, Molded Terminations
- Modular Electric or Optic Contacts
- Wire Boot Seals
- PEEK™ Pins
Utilizing Pressure Balanced Oil Filled (PBOF) Hose Cable Assemblies with Electric and Fiber Optic Connectors

David Jenkins, SEACON/Braintree and Associates, Steven Thumbeck, SEACON Advanced Products, LLC

Oceans 2008 Technical Program

Abstract: Many subsea electrical and optical cable and connection systems now utilize Pressure Balanced Oil Filled (PBOF) cable solutions. These cables utilize an elastomeric tube as a conduit for electric waves and fiber optic lines. The elastomeric conduit is filled with a compensating fluid, allowing the cable to freely communicate with the interior oil volume, equalizing the pressure in the assembly. This option for cable provides for a reliable, and configurable cable system suitable for many subsea applications. This technology has been widely utilized in ocean science observatories, towed array, drilling systems, protection control systems, and Remotely Operated Vehicles (ROV) systems to name a few. They have become a critical component in many subsea systems today. This paper will review the history of the PBOF cable, associated components such as terminations and connectors, technical considerations for its use, and advancements made over the past decade leading to the state of current PBOF technology.

I. BACKGROUND

Within the subsea industry there are two main methods for packaging electrical and fiber optic lines for subsea cables. The first option, as a necessity in the subsea cable industry, is to utilize commercial or custom manufactured industrial cables. The industry has seen literally thousands of different cable cross-sections manufactured for subsea deployment utilizing this technique. The jacketing method utilizes many conductor wire gauges, optical fiber types, jacket and strength materials. These custom cables have been developed to handle electrical and fiber lines for power, data and communications functions, as well as mechanical loads, all for long-term use within marine or subsea environments. The second option is to employ the use of PBOF hose as a protective conduit for electrical and fiber optic cabling. This option along with the associated termination and connector implications will be the focus of this paper.

II. INTRODUCTION

The PBOF type cable assembly has been utilized for many years while gaining a substantial field history. The PBOF approach utilizes an elastomeric tube (or hose) as a mechanically protective conduit for electrical wave and/or fiber optic cores. The elastomeric conduit is filled with a pressure-compensating fluid (typically a dielectric) allowing the cable assembly to continuously monitor the interior oil volume. Equalizing the pressure and temperature in the assembly allow for the internal pressure pressure to be reliably communicated across the flexible hose walls, to the interior oil volume. Equalizing the pressure and temperature in the assembly allows for the variable effects of ambient pressure and temperature during typical storage and operational regimes. PBOF hose has been field proven for many years throughout the marine and subsea industries, this option for cable allows for a reliable, configurable system suitable for many subsea applications. As the subsea industry continues to expand in breadth and depth, all facets of PBOF technology are being explored. This paper will review the history of the PBOF cable, associated components such as terminations and connectors, technical considerations for its use, and advancements made over the past decade leading to the state of current PBOF technology.

Essential Design And Risk Management For A Next Generation Ocean Dry Mate Connector

Dana Jenkins, Matt Christiansen and Steve Thumbeck

AMETEK SCP
WASHINGTON, RHODE ISLAND

Oceans 2013 Technical Paper

djenkins@amebek.com, mchristiansen@amebek.com, sthumbeck@amebek.com

Abstract: Dry mate connectors perform essential power and communications interconnect functions. An equalized pressure feature for subsea connectors is to protect the cable and sensitive electronics from flooding, thereby minimizing risk for large, capital intensive projects. This paper will address the technology needed to reduce risk, leap forward in design, and incorporate the very latest design improvements, while demonstrating compliance to evolving industry standards, such as ISO and API.

This paper will broadly review the industry’s current dry mate connector options, with a focus on reliability and functionality. A Failure Mode and Criticality Analysis (FMECA) will be presented, which will be used to examine typical dry mate connector failure modes. As analysis of these failure modes will be presented, with a focus on the attributes that can be improved on, from the current design state. The paper then will introduce a next generation dry mate connector, which addresses the current design issues, providing to take the next leap in high reliability, interconnect technology for ocean dry mate connectors. Starting with a fresh, ground up look at the requirements from industry, this paper will begin with a blank slate design, and then develop the desired interconnect attributes offer a clear look at both new-age and legacy system requirements, and the products that are currently on the market. Designed to be a dry mate connector that is API compliant, the AMETEK SCP dry mate connector is designed to be fully modular. This modularity allows the incorporation of interchangeable electrical or optical circuits, with exceptional high performance. This modular design then takes a step further, and makes possible the use of a standard approach for either hard cable termination designs, as well as pressure balanced oil filled designs.

This new product leaps forward from current industry offerings, and makes a number of improvements and enhancements that reset the bar. Modularity for electrical and optical contacts is one improvement, as is the incorporation of an option for a higher performing fiber optic connection, which incorporates angled polished contacts. These higher performing contacts, affords enhanced optical performance, specifically with improved back reflection. This enhancement will help satisfy an increasing industry demand for distributed sensing systems. These types of systems are coming online now as part of Intelligent Well System designs, and other emerging, distributed acoustic and temperature monitoring systems.

Praised to enter both Defense and Oil Gas markets, and improve the status quo, this new product offering takes stock of where the industry is, considers risk elements, and provides a fully up to date design, with options that actually fit industry needs, while reducing risk. This paper will review existing technology, and then introduce this new product, while pointing to improvements over existing designs, explaining the incorporated design attributes, clearly a leap forward in technology.

I. Introduction

There are fundamentally two different types of connectors available in the undersea market for physical connections. These are basically Wet Mateable, connectors, and Dry Mateable connectors (non-metallic seal mates connectors, or WMC’s, and Dry mates connectors, or DMC’s). Wet mateable connectors are of a type that can be connected while underwater Dry mateable, or Dry mates connectors, on the other hand, are connected (made) above the waterline, and then the connector and cable assembly, and it’s related equipment, are taken into the ocean environment. This paper presents the design approach for an innovative Dry mate connector, focusing on Technology Gap Assessment, Requirements Analysis and Prioritization, and Risk Management. Much like a new product is developed for a specific industry application, the development of a new line of dry mate connectors would logically proceed from a thorough analysis of industry requirements.

Accordingly, a thorough review of Industry Specifications that drive the design of Dry mate connections is undertaken, to ensure that a product is developed that is consistent with these specifications. This innovative new connector also includes an innovative new design that looks forward to the next generation of technology. The key references are noted below in order to:

II. Brief History of Dry Mate Connectors

A. Brief History

Underwater cables and connections have been in existence since the first successful transatlantic cable laying, which occurred in 1858. Underwater connectors appeared in the 1950’s, driven by the post war submarine technology needs, so
**Dry Mate – ELITE Series – Full FMECA Conducted**

<table>
<thead>
<tr>
<th>Potential Failure mode</th>
<th>Design Feature</th>
</tr>
</thead>
<tbody>
<tr>
<td>O-Ring Missing</td>
<td>Captured O-ring</td>
</tr>
<tr>
<td>Pressure Vessel Flooding</td>
<td>Pressure Rated Contacts Unibody Construction</td>
</tr>
<tr>
<td>Low Insulation Resistance (IR)</td>
<td>PEEK™ Contacts</td>
</tr>
</tbody>
</table>
ROCS - Rugged (PBOF) Outboard Conduit System Fittings

- Robust SS or Ti Mechanical Connections
- Dual Orings at Mk 2 Interface
- 13mm and 20mm ID Nominal
Oil Filled Hose: Engineered Fittings, Not Hose Clamps

**Anguila Mk2 Fitting**
with fill valve

**FEATURES**
- Double O-ring barriers
- Double electrical barriers
- Metallic components in Titanium grade 2
- Crimped hose interface
- Built-in wire fixture to protect termination areas
- Integrated fill valve, if needed
- All wires protected against metal contact
- Modular design
- Swivel nut
- Bends, 0 - 90° - 180°
- 25 years design life

**APPLICATIONS**
- Connectors
- Electrical penetrators
- Instruments and sensors
- Umbilical terminations
- Junction/ splice boxes

**DESCRIPTION**
The Anguila Mk2 fitting, specifically developed for the Anguila Subsea Electrical Distribution System, connects the Anguila Hose Conduit to mechanical interfaces such as subsea connectors or instruments. The fitting is attached to the Anguila Hose Conduit by crimping. The mechanical interface features a swivel nut and double O-ring seals.
Q: What about EMP? Could you put a Mu Metal shield inside the pbof hose?

Ans: Sure, here is an example of 20mm ID PCOF Hose, showing a braided internal mu metal shielding material. The conductors and/or fiber would be loose inside this magnetic shielding material (within the dielectric fluid).
• Today’s PBOF Cabling Systems
Designed for 25-30 year lifetime
Engineered fittings, multilayered hose
Hundreds of km currently in use in Ocean Systems
The Preferred cabling method of Oil-gas control systems
# Murene Specifications

<table>
<thead>
<tr>
<th>Model</th>
<th>DN 12</th>
<th>DN 20</th>
</tr>
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<tbody>
<tr>
<td>Qualification standards</td>
<td>TBA</td>
<td></td>
</tr>
<tr>
<td>Dimensions (inner dia.)</td>
<td>13mm (½ inch)</td>
<td>19 mm (¼ inch)</td>
</tr>
<tr>
<td>Dimensions (outer dia.)</td>
<td>25 mm (1 inch)</td>
<td>32 mm (1 ¼ inch)</td>
</tr>
<tr>
<td>Material</td>
<td>Tube: NBR, Cover: NVC/SBR</td>
<td></td>
</tr>
<tr>
<td>Colour</td>
<td>Tube: Black, Cover: Orange</td>
<td></td>
</tr>
<tr>
<td>Marking</td>
<td>Model, prod., quarter, batch number</td>
<td></td>
</tr>
<tr>
<td>Work pressure</td>
<td>10 bar</td>
<td></td>
</tr>
<tr>
<td>Burst pressure</td>
<td>&gt;90 bar</td>
<td></td>
</tr>
<tr>
<td>Elongation at 10 bar</td>
<td>+/-2%, typical &lt;1% at 2500N tension</td>
<td></td>
</tr>
<tr>
<td>Volumetric expansion</td>
<td>&gt;10% at 10 bar internal pressure.</td>
<td></td>
</tr>
<tr>
<td>Storage temperature</td>
<td>-40 to +60 °C (-40 to 140 °F)</td>
<td></td>
</tr>
<tr>
<td>Work temperature</td>
<td>-5 to +40 °C (23 to 104 °F)</td>
<td></td>
</tr>
<tr>
<td>Bending radius</td>
<td>100mm</td>
<td></td>
</tr>
<tr>
<td>Compatibility</td>
<td>Tube: silicone, synthetic hydraulic oil,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Cover: seawater</td>
<td></td>
</tr>
<tr>
<td>End terminations</td>
<td>Titanium gr. 2 Mk2 fittings, straight,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>90 deg. bend or 45 deg. bend</td>
<td></td>
</tr>
<tr>
<td>Breakouts</td>
<td>Splitboxes in Titanium gr. 2 with 1-4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>inlets and 1-4 outlets. NBR/NR splitters</td>
<td></td>
</tr>
</tbody>
</table>

Courtesy of Transmark Subsea
PBOF: The Concept Works with Both Dry and Wet Mate Connectors!

- **Dry mate connectors can be used with PBOF Cable**  
  (Pressure at connector backside)
  Elite Dry Mate Was Designed For PBOF Systems Upfront
  Glass-Metal type inserts are available

- **Wet mate connectors can be used with PBOF Cable**
  Good cable flexibility
  (Works Well with ROV flying lead)
  Easy interface to connector
  Bend restrictor is typical
  Facilitates repair if needed
Q: Has It Been Qualified? Bennex Qualification Summary, Page 1 of 2

<table>
<thead>
<tr>
<th>Code</th>
<th>Test Description</th>
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<tbody>
<tr>
<td>100206 B</td>
<td>ELONGATION TEST PROCEDURE AND TEST REPORT 100726 A</td>
</tr>
<tr>
<td>100224 C</td>
<td>BREAK LOAD TEST AND TEST REPORT 100730 A</td>
</tr>
<tr>
<td>100226 F</td>
<td>SETTLING TIME INTERNAL PRESSURE</td>
</tr>
<tr>
<td>100262 B</td>
<td>COMPABILITY TEST SEAWATER &amp; SILICONE OIL</td>
</tr>
<tr>
<td>100265 A</td>
<td>PRESSURE VS. TEMPERATURE &amp; COMPENSATION VOLUME VS. PRESSURE TEST</td>
</tr>
<tr>
<td>100284 E</td>
<td>INNER ELECTRIC BARRIER INSULATION TEST.</td>
</tr>
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<td>INTERNAL VS. EXTERNAL PRESSURE AT CONSTANT TEMPERATURE</td>
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<td>INTERNAL PRESSURE VS. VARIABLE TEMPERATURE</td>
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<td>LIFE TIME TEST PE TAPE FOR MARKING &amp; TAGGING.</td>
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<td>QUALIFICATION TEST OF MK2 TITANIUM PARTS.</td>
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<td>ANGUIA MK2 JUMPER SYSTEM QUALIFICATION FOR 2500 M</td>
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<td>HEAT RESISTANCE ANGUIA</td>
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<td>100732 A</td>
<td>OZONE RESISTANCE ANGUIA HOSE CONDUIT WITH FITTINGS AND TEST REPORT 100732-33-34.</td>
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<td>100733 A</td>
<td>ULTRA VIOLET RADIATION ANGUIA HOSE CONDUIT WITH FITTINGS AND TEST REPORT 100732-33-34.</td>
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<td>100734 A</td>
<td>THERMAL SHOCK ANGUIA HOSE CONDUIT WITH FITTINGS AND TEST REPORT 100732-33-34.</td>
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<td>100735 B</td>
<td>SEAWATER ABSORPTION, COMPENSATION AND AGING</td>
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<td>100736 B</td>
<td>TENSILE LOAD TEST ANGUIA JUMPER SYSTEM.</td>
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</table>
Bennex Qualification Summary

100737 B  BURST PRESSURE TEST ANGUIILA JUMPER SYSTEM.
100738 B  CRUSH RESISTANCE TEST ANGUIILA JUMPER SYSTEM.
100740 B  B KINK TEST ANGUIILA JUMPER SYSTEM.
100779 B  QUALIFICATION TEST REPORT ACCORDING TO NORSK HYDRO
           TEST REQUIREMENT NHI-I52-0073 REV.03M - SUBSEA MATEABLE
           ELECTRICAL /OPTICAL CONNECTORS.
100911 A  QUALIFICATION TEST ANGUIILA MK2 FILL-PORT
100921 B  SNAG LOAD TEST ANGUIILA JUMPER SYSTEM.
100924 A  5000N TENSION WITHSTAND TEST ANGUIILA JUMPER SYSTEM.
100932 O  QUALIFICATION TEST MK2 O-RINGS.
100954 O  DELTA P TEST ANGUIILA HOSE CONDUIT 0 - 450 BAR.
100955 A  ANGUIILA MK2 JUMPER SYSTEM QUALIFICATION FOR 4500 M
           AND TEST REPORT 101011 A.
100956 A  MAX HANDLING LOAD TEST ANGUIILA JUMPER SYSTEM AND
           TEST REPORT 101012 A.
100957 A  BURST PRESSURE ANGUIILA JUMPER SYSTEM AND TEST REPORT
           101013 A.
100958 A  BREAKING STRENGTH ANGUIILA JUMPER SYSTEM AND TEST REPORT
           101014 A.
100959 A  ABRASION RESISTANCE TEST ANGUIILA HOSE CONDUIT AND TEST REPORT
           101015 A.
100964 A  OSCILLATING TEST ANGUIILA JUMPER SYSTEM WITH SPLIT BOX AND CONNECTOR.
Statoil TR2390
Electrical/Optical Connectors and Jumpers for Subsea Control Systems
Statoil TR2390
Electrical/Optical Connectors and Jumpers for Subsea Control Systems

The “Oil Patch” Wants Oil Filled Hose Only! (No Overmolded Cables)
1 Objective, target group and provision

This specification covers minimum requirements for design, fabrication, testing and qualification of the following types of Wet Mateable Subsea Connectors and Jumper Assemblies for subsea production equipment:

- Electrical (Low Voltage / Low Power)
- Electrical (Low Voltage / Low Power) / Optical - Hybrid
- Optical

The target group for this document is personnel involved in technology development, project planning and project execution.

This document is provided in TR3070, Subsea Technology, Technical Requirements and Standards.

2 Requirements

2.1 Performance

The specific requirements for subsea mateable electrical, electrical/optical and optical connectors shall be:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design life</td>
<td>30 years</td>
</tr>
<tr>
<td>Water depth</td>
<td>3000 m</td>
</tr>
<tr>
<td>Minimum External Design Pressure / Test Pressure</td>
<td>300 bar / 450 bar</td>
</tr>
<tr>
<td>Maximum continuous operational voltage (mated and demated at least one connector half) UD</td>
<td>1500VDC, 1000VAC RMS</td>
</tr>
<tr>
<td>Maximum differential voltage between conductors</td>
<td>2628VAC peak</td>
</tr>
<tr>
<td>Make / break under power</td>
<td>Not required</td>
</tr>
<tr>
<td>Maximum continuous operational current</td>
<td>10A DC, 10A AC RMS</td>
</tr>
<tr>
<td>Maximum in-rush current</td>
<td>100A for ½ Sec. Duration</td>
</tr>
<tr>
<td>Insulation Resistance - Connector body to conductor(s)pin</td>
<td>&gt;2000Ω</td>
</tr>
<tr>
<td>Insulation Resistance - Conductordpin to conductordpin</td>
<td>&gt;2000Ω</td>
</tr>
<tr>
<td>Optical communication wavelength (single-mode)</td>
<td>1550nm &amp; 1625nm</td>
</tr>
<tr>
<td>Optical communication wavelengths (multi-mode)</td>
<td>850nm &amp; 1300nm</td>
</tr>
<tr>
<td>Maximum optical attenuation (per mated connector pair) as defined within G.671 (11/96)</td>
<td>0.8dB single-mode 1dB multi-mode</td>
</tr>
<tr>
<td>Maximum fusion splice attenuation</td>
<td>&lt;0.05dB</td>
</tr>
<tr>
<td>Maximum optical cross talk between lines</td>
<td>-60dB</td>
</tr>
<tr>
<td>Maximum optical back reflection for single-mode</td>
<td>-45dB</td>
</tr>
<tr>
<td>Minimum number of mate/demate cycles</td>
<td>250</td>
</tr>
<tr>
<td>Connector / Jumper assembly maximum handling load - Jumper to Connector interface</td>
<td>2500N</td>
</tr>
</tbody>
</table>

2.2 General Requirements

The subsea mateable electrical, electrical/optical and optical connectors and cable assemblies:

1. shall be designed for long term subsea use without cathodic protection.
2. shall support electrical insulation from cathodically protected structure.
3. shall be suitable for deepwater applications.
4. shall utilise electrical connections of a conductive type and optical connections of a low loss design.
5. shall be previously developed and operating with proven components and designs.
6. shall have successfully completed a full qualification test programme.
7. shall have a minimum of dual sealing barriers between seawater and electrical conductors. Both barriers shall be designed for continuous operation in seawater and the selected dielectric fluid.
8. shall be capable of installation/retrieval at subsea depth by diver, ROV/ROT or hydraulic cradle with configuration changes to suit the method of installation.
9. shall ensure that electrical and optical contact between the two connector halves take place in an insulating fluid filled environment.
10. shall be maintenance free over the connectors design life and when used within its rated number of mate/demate cycles.
11. shall support bulkhead mounting towards a pressure vessel or an oil filled, pressure compensated enclosure, stab plate mounting, individual diver and ROV/ROTN Installation / Retrieval formats and it shall be possible to configure either the plug or the receptacle as the fixed half.
12. shall be available for termination towards an oil filled hose (containing electrical conductors / fibres).
13. shall be robust to withstand the stresses and strains normally experienced during subsea handling and installation by ROV.
14. shall withstand environmental extremes normally experienced during shipping, storage and deployment.
15. housing and latch mechanism shall be tolerant to sit and fine sand deposits.
16. latch mechanism shall be provided with visual indicator clearly visible from ROV camera.
17. connectors in stab plate application shall be constructed from materials suitable for marine duty to the lifetime specified or suitable for marine duty to the lifetime specified with cathodic protection.
**Hard Cable vs ROCS**

**Initial Cost Comparison**

- Approach: Normalize the analysis by making the typical cost of a 8 way hard cable run with stainless steel connectors on either end = 1.0, compare entries to this value

- Evaluate Cost of Various Lengths of Both Hard Cable and OFH

- Conclusion: Cost of Short Runs (~30ft) About the Same for Hard Cable vs PBOF

![Hard Cable vs OFH, Relative Costs](image)
PBOF Hose Sizes Available

- 13 mm (.512 in)
- 20 mm (.787 in)
- 42 mm (1.653 in)
- 51 mm (2.007 in)
- 63 mm (2.480 in) (development)

(Dimension shown is ID)
PBOF: Desirable Attributes

- PBOF Hose: Attributes
  Good cable flexibility
  Enhanced visibility (orange, yellow or black)
  Deployment similar to jacketed cable
  Facilitates ROV maneuverability
  Easy interface to connector (Mk 2 Industry interface, 2 orings)
  Ease of repair
PBOF: Desirable Attributes

– Oil Filled Hose
  • Oil Filled Hose (OFH) is a rugged alternative that provides a reliable, maintainable conduit for electrical or fiber pathways

– Oil Filled Hose
  • Not your father’s tygon tube and hoseclamps!
  • Rugged and extensively qualified
  • Reliable, and *Maintainable*
A Paradigm Shift?

Polyurethane Molded Cables
- Have been the default system
- 10 years life typical
- Cable Issues: Sailor says, “Float test it…” (Requires replacement)

Oil Filled Hoses
- Reliable and Maintainable, 25 Years Oil&gas track record
- Engineered Fittings
- Cable Issues: IMA (Or O Level) Capable Repairable
  (at $\ll$ Cost of replacement)
Summary

• **ROCS (PBOF) Hose Assemblies:**
  - Are a reliable, rugged conduit for electrical or fiber pathways
  - Are the Preferred Cabling System for Oil-gas control systems applications (Statoil TR2390)
  - Have Costs that compare favorably to molded assemblies
  - Have An Impressive Subsea Reliability Track Record. Design life 2-3x PU molded assemblies
  - Are configurable, and repairable
Polyethylene Molding @ SCP

Fiber Optic or Electric
  • Subsea Cable Splices
  • Connector Terminations
  • Cable Breakouts

Factory Terminations and Field Terminations

PE Machine Is Available For PE Molding Projects
SCP Technology: ROCS (PBOF) Interconnect Cable Solution

Thank You For Your Time!

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