Downhole Control Line Wet Connectors: Hydraulic, Electric And Fiber Optic Connectors. Are They Reliable Completion Options Today?

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Fiber Optic Down Hole connectors

- Task is worth the effort
  - Value is in the monitoring, otherwise effort would have long been abandoned by the operating companies and service companies

- Service Companies efforts
  - Fiber Optic down hole wet connect in West Africa. Limited details avail
  - Baker Hughes. Testing and stack up completed. Target in well deployment 3Q2011

- How do we get to a reliable down hole wet connect?
  - Just like eating an elephant. One bite at a time
  - So, let’s size the elephant!
Sizing the elephant

• On one side. The light source
  – Interrogator (Optical budget, stability, reliability, cost)

• On the other side. The light path
  • Surface cable
  • Umbilical
  • UTA (umbilical termination and the bulkhead connector)
  • Flying lead or infield umbilical
  • SDU
  • Flying lead or infield umbilical
  • Another SDU ?
  • Tree and penetrator – ROV bulkhead - TH connector – Dry mate
  • Down hole cable
  • Down Hole connector
  • Down hole cable
  • Monitoring zone of interest

• And, quality of the fiber itself: How will it age under the environment ?

If reliability is desired, focus needs to be at the system level
Slide courtesy of Deutsch Offshore
Subsea & Downhole Optical connectors:

Topside
60 bar

Seabed
450 bar

DownHole
1000 bar to 2000 bar

Optical Feedthrough System

Xmas Trée

Umbilical

FPSO Platform Tanker

Subsea Distribution Unit
The balancing act: “Managing your losses”

<table>
<thead>
<tr>
<th>For illustration purpose only</th>
<th>Optical Losses</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>(for illustration purpose only. Change losses as needed)</td>
</tr>
<tr>
<td>Umbilical</td>
<td>0.7 db/km (assuming SM)</td>
</tr>
<tr>
<td>UTA</td>
<td>0.5 db (umbilical) + 0.5 db (Bulkhead)</td>
</tr>
<tr>
<td>Flying lead</td>
<td>0.7 dB/km</td>
</tr>
<tr>
<td>SDU</td>
<td>0.5 dB</td>
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<tr>
<td>SDU</td>
<td>0.5 db</td>
</tr>
<tr>
<td>Tree and penetrator</td>
<td>0.5 BK – 0.5 Dry – 1 Wet – 0.5 Dry</td>
</tr>
<tr>
<td>Down hole Cable</td>
<td>0.7 db/km (assuming SM)</td>
</tr>
<tr>
<td>Down Hole Wet mate</td>
<td>0.5 db</td>
</tr>
<tr>
<td>Down hole Cable</td>
<td>0.7 db/km (assuming SM)</td>
</tr>
<tr>
<td>Splice</td>
<td>0.5 dB</td>
</tr>
<tr>
<td>Down Hole cable</td>
<td>0.7 db/km (assuming SM)</td>
</tr>
<tr>
<td><strong>Summary of losses</strong></td>
<td><strong>0.7 dB x XX km + 6 dB losses (pristine fiber)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Versus YY dB optical buget of the interrogator</strong></td>
</tr>
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# Reliability: Some of it + Rest of it = All of it !!!!

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<tr>
<th>For illustration purpose only</th>
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<tbody>
<tr>
<td>Umbilical</td>
<td>99%</td>
<td>98%</td>
</tr>
<tr>
<td>UTA (umbilical + bulkhead)</td>
<td>99%, 99%</td>
<td>98%, 98%</td>
</tr>
<tr>
<td>Flying lead</td>
<td>99%</td>
<td>98%</td>
</tr>
<tr>
<td>SDU</td>
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<td>Flying lead</td>
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</tr>
<tr>
<td>SDU</td>
<td>99%</td>
<td>98%</td>
</tr>
<tr>
<td>Tree and penetrator (bulkhead, dry mate, TH wet mate, dry mate)</td>
<td>99%, 99%, 99%, 99%</td>
<td>98%, 98%, 98%, 98%</td>
</tr>
<tr>
<td>Down hole Cable</td>
<td>99%</td>
<td>98%</td>
</tr>
<tr>
<td>Down Hole Wet mate</td>
<td>99%</td>
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<tr>
<td>Down Hole cable</td>
<td>99%</td>
<td>98%</td>
</tr>
<tr>
<td><strong>Overall success rate</strong></td>
<td><strong>99% (\times 16 = 85%) success rate</strong></td>
<td><strong>98% (\times 16 = 72%) success rate</strong></td>
</tr>
</tbody>
</table>
Reliability: Some of it + Rest of it = All of it !!!!

Reliability: 85%-72% or lower to be expected based on system architecture discussed.

Should we declare the reliability of the (monitoring) system hopeless, or should we revise the aim and accept the above?
Roles and responsibilities - Defining the objective

Which requirement are we working with?

– Need to have DTS at XX,000 ft in lower completion

Or

– Measurement capable of detecting 0.5 deg C over 1 hour interrogation time under XYZ field layout with given BHT and BHP across zone between 17,050 and 17,120 ft?
– Field is expected to have a work-over in XX years

From above should we (as in svc companies and operator)

– Review the optical budget, optimize the layout ?
– Perform simulations. Will the interrogator yield the desired results ?
– Revising the SOR as needed  ?
– Documented accepted expected results ?
Are the expectations aligned?
- Setting the right expectation (svc company/operator)
  It is accepted that wells will require remedial actions (i.e. work-over) in XX years, yet the connectors are expected to make it to life of field (20 yrs-30 yrs). Should this be revisited?
- Should the connectors be put on automatic work-over schedule?

Understanding the well environment HT/HP/H2S, H2 etc. and impact on DH monitoring the system (including down hole connector)
- Life time of the monitoring system (connectors included) and reservoir conditions (fluid properties, T, P, protection, maintenance etc). Are they compatible? How do we test for it.
- What standards do we go to?

Planning for the right technology – Top to Bottom !!!!
- "A chain is only as strong as its weakest link”
- What standards do we go to?
Cables/Connectors/Monitoring -

- Deployment procedures or practices.
  - Aligned goals or conflicting goals between various parties involved in the deployment?

- Operators involved (i.e. Experience and expectation)
  - Simple things such as a splice takes time. Does the operator understand this, and level of work involved?

- Interrogators and Power source(s)
  - Is the right interrogator deployed for the right job, meeting the environment (power, humidity, temperature), and requested task.

- Data management
  - Bits and bites dripping at the WHO.
  - Than what do we do with it, how do we manage the data?
One bite at a time. Focus on Down Hole connector

- **Step One**
  - Key components evaluation
  - Selection of technology

**Step Two**
- Component and System Design evaluation

**Step Three**
- Field Test the hardware.
- Full stack ups
- Refine well clean up procedures

**Step Four**
- Manufacture production equipment
- Test (SIT)
- Review results
- Train and practice deployment, do it again
- Deploy
One bite at a time: Monitoring progress

• Agreed to quality plan

• Quality is not measured in weight of the paperwork
  – Monitor the relevant factors
    • Standards available? Than enforce them!
    • Seafom starting development of tree TH and sea floor connectors.
      → Need to enlarge standards (SEAFOM or others) to down hole connectors
    • Review test and test conditions

• Collaboration/team-spirit between operators and all 3rd party suppliers
  (umbilical, tree, connector, etc) to minimize the chances of unintended failures, or unintended consequences of one’s action.
  → CWOPS, complete SIT’s
One bite at a time: SIT done, job complete?

- SIT Completed (and passed) => All good to go. Is this the end?

Next in line:
- Deployment techniques
- Training, training and more training of Field Engineers
- Down hole environment.
  - Different crews will have different success
    - Post Mortem. Looking at the good-the bad-the ugly
- Managing the goals and potential conflicts.
  - Rig crew. As fast as possible
  - Monitoring crew. Slow and steady wins the race
One bite at a time: Conclusion

• Resolve conflicts in system approach and restrictions between suppliers and operator.

• Define the monitoring objective clearly

• Manage your losses. “Less is more”

• Reliability. Define, test, verify

• Success.
  – Define into measurable quantities, plan for it, measure it

• Learn from experience
The Baker Hughes “elephant” – DHWC

Down Hole Wet connect objectives
  – Two different sizes down hole wet connect.

Project Challenges
  – Debris, pipe dope, scale, sand and proppant, scale etc
  – Must align 6 fibers with sub-micron accuracy
  – Must be compatible/tolerant with dowhole environment
  – Required close collaboration work with customer, vendors, internal cross division engineering groups
  – Show repeatability in connection (lab-stack up)
  – Testing lab, in well and SIT
  – QRD
How are fiber connections made?

- **Multimode Fiber**
  - 50μm Core
  - 125 μm Cladding

- **Singlemode Fiber**
  - 9μm Core
  - 125 μm Cladding
Subsea & Downhole Optical connectors:

- DO3000
- Seabed
- X-tree (customer)
- horizontal OFS
- vertical OFS
- ODH
Baker Hughes Down Hole Wet connects

- 2 packer sizes FP and GP
- Production packer with Feed through
- Multiple length expansion joint for lower and upper expansion joints
- Packer reconnect (FO receptacle connector)
- Sand Control Packer (FO plug connector)
- Sand screen w FET with Dry Mate Connectors
- Sand Control Cross Over Tool
  - Sand Control Frac tools
- Retrieval tools

**Summary of BHI down hole wet connect:**
- Six fiber optic connections per Connector
- Two Connectors per Packer
- Designed and tested as a system
- Designed 15K, 150 deg C
Prototype Testing

• Debris Testing
• Lab Testing
• Downhole Testing
Prototype Testing – Stack Up

- 2 generic sizes
- Repeated Downhole Mate/de-mate cycles
- Connectors populated with 4 to 6 fiber optic channels simultaneously connected each mate
Prototype Testing – Stack Up

- Integration test
- Achieved mate/demate specs in downhole environment
- All fiber optic channels simultaneously connected each mate
Prototype Testing – Deployment

- Full gravel pack and completion
- Two downhole wet connectors
- Two downhole wet mate/De-mates
- All fiber optic channels simultaneously connected downhole
Baker Hughes down hole wet connect Status

• Surpassed downhole, multiple channel, fiber optic wet connections specification

• Tested gravel pack system with completion equipment

• Horizontal and vertical gravel packs tested

• Tested Frac Pack system with completion equipment

• Hardware build – ready for deployment
Down Hole Wet Connect - Summary -

- Project Scope
  - Adopt system approach
  - Define objective
- Do your homework.
  - Optimize the system
  - Resolve conflicting goals
  - Manage your losses. More is less for optical systems
- Size your elephant
- One byte at a time
- Fiber Optic Wet Connector Design
- Testing – Prototype, Stack ups, production, SIT
- Review Status, open communication
Thank you

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