Vallourec Umbilicals:
a new technology to meet the challenges of offshore umbilical steel tubes

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Society of the Petroleum Engineers – 14th of January, 2014
Vallorec innovating in Umbilicals

*Introduction: VU Offer*

Vallorec is now offering SuperDuplex Seamwelded tubes for Umbilicals

- Vallorec Umbilical customers are the Umbilical Manufacturers
- Laser seamwelded SD tube with GTAW orbital welds
- 2507 Super Duplex steel: most commonly used and perfectly well known
- Packaging: spooled on reels up to 40 km
- Making use of Best Available Technologies for Premium Quality and Performance
Vallourec innovating in Umbilicals

Innovation : The case for change

- Existing technology limitations and/or Market expectations
  - Growing market
  - Constrained steel tube supply (*long lead time, few tube suppliers,...*)
  - More challenging design conditions
  - Umbilical Manufacturing and laying out constraints

- Key factors triggering the development of VU
  - 30+ years manufacturing experience with high alloys seamwelded tubes (Valtimet, now Vallourec Heat Exchanger Tubes)
  - Vallourec’ historical partnership with Super Duplex supplier leading to development of strip supply material, meeting dedicated specifications for VU
  - Oil and Gas partner (TOTAL) as Technical Sponsor since 2008
  - Key process and product innovations becoming mature thanks to Valtimet and Vallourec Research Centre developments
  - R&D Partnerships with equipment suppliers
1- New technical challenges for umbilicals

- Subsea umbilical systems for deep offshore become more and more demanding regarding
  - Injection capacity
  - Functionalities
  - Water depth
  - Tiebacks length and number

  Operating conditions and requirements are significantly impacting the performance of the main umbilical

- The most common solution
  - To design
    - Thicker tubes to improve the strength of the umbilical
    - Larger cross section to increase capacity
  - Drawbacks:
    - Weight increase and fatigue performance degradation (higher loading)
    - Larger cross section area unsuitable with packing constrains

  Need to improve properties of the steel tube to reduce wall thickness and improve fatigue and collapse resistance while keeping suitable corrosion resistance
2- Process description

- Manufacturing process composed by:
  - Longitudinal welding line
  - Orbital welding line
  - Hydrotest bench

- In-house laboratory dedicated to Production Quality Control:
  - Mechanical tests (tensile, technological, burst and collapse tests)
  - Corrosion tests (according to ASTM G48 method A and B)
  - Macro and Microscopic analyses (ferrite content, inclusion assessment, inter metallic compounds assessment)
  - Other tests (hardness, roughness)

An uncompromised quality-driven production process
3- Product properties

**Innovative Product setting new limits**

- **Grade Super Duplex 2507 (UNS S32750; EN 1.4410)**
  - high mechanical properties combined with very good corrosion resistance
    (PREN > 42.5; pitting, crevice, stress corrosion; fatigue corrosion, HISC,..)

- **Higher mechanical properties**
  - (YS$_{0.2}$ > 750 MPa; UTS > 900 MPa)

- **Reduced number of orbital welds**
  - 300m to 800m between two sections
  - reduced number of sensitive areas on the umbilical

- **Tighter tolerances**
  - 5% Wall thickness against 10% required by ASTM A789;
  - +/- 0.1 mm tolerance on Outside Diameter (including out of roundness)
3- Product properties

*Innovative Product setting new limits*

- **Manufacturing range**
  - ½” to 1 ½” ID
  - 1 to 3 mm WT

- **Manufacturing process and product certified by Bureau Veritas in October 2012**

- **Qualified by Total in April 2013 for static applications**

  - Wall thickness reduction, hence lighter umbilical (typically 10% to 15%)
  - Easier installation and manufacturing process (radius reduction)
  - Outstanding fatigue performance
4- Qualification Protocol

- Jointly defined (TOTAL + Vallourec Umbilicals)
- Certified by recognised independent body (Bureau Veritas)
- Raw material and its manufacturing process
  - ASTM A240, ASTM A789, NORSOK M650
  - Most stringent Umbilical manufacturers and end-users specifications
- Tube and its manufacturing process
  - ASTM A789, NORSOK M650,
  - Most stringent umbilical manufacturers and end-users specifications
- 3 tubes dimensions, 2 phases, 250km produced, 10 heats, 1 year
  - "Pre Production" : Establish production parameters to meet specifications
  - "Full Production" : Demonstrate production capability (i.e. sustainable and repeatable)
- More than 11000 tests results:
  - Mechanical: Tensile, Hardness, Burst and Collapse tests
  - Chemical composition
  - Roughness measurements
  - Dimensional checks
  - Microstructures: Ferrite content, Intermetallic compounds
  - Corrosion tests (according to ASTM G48A,B, E&F; SSC; HISC)
  - "Technical" tests (i.e. reverse flattening, flaring, flange, bending)
  - Fatigue testing
5- Main results

**Dimensional checks**

- **PP dim 1 = 15.25mm OD x 1.15mm WT**
- **FP dim 1 = 28.5mm OD x 1.45mm WT**
- **PP dim 2 = 18.1mm OD x 1.00mm WT**
- **PP = pre production**
- **FP = full production**

**Evolution of the WT of the tube during the qualification**

**Evolution of the out-of-roundness of the tube during the qualification**

<table>
<thead>
<tr>
<th>Tube OD mm</th>
<th>Ovalisation</th>
<th>Conformes</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 0,10 OD nominal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OD nominal = 18,95</td>
<td>18,98 18,94 18,95 18,94</td>
<td>Conformes</td>
</tr>
<tr>
<td>18,85 - 19,05</td>
<td>18,95 18,94</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tube WT mm</th>
<th>Conformes</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- 5% WT nominal</td>
<td></td>
</tr>
<tr>
<td>WT nominal = 1,3</td>
<td>1,31 1,31 1,31 1,33</td>
</tr>
<tr>
<td>1,24 - 1,36</td>
<td>1,34 1,34 1,33 1,33</td>
</tr>
</tbody>
</table>
5- Main results

Mechanical properties

![Graphs showing YS₀.2 and UTS values for different dimensions.](image)

- YS₀.2 average and minimum acceptance
- UTS average and minimum acceptance
5- Main results
Burst & Collapse tests

Burst

Collapse

• Comfortably above spec
• The Longitudinal Weld is **not** a weak point
5- Main results

Corrosion tests

Pitting corrosion resistance of the tube following ASTM G48A at 50°C

Crevice corrosion resistance of the tube following ASTM G48B at 30°C

Pitting corrosion resistance of the girth weld following ASTM G48A at 40°C

Crevice corrosion resistance of the girth weld following ASTM G48B at 20°C
6- Corrosion resistance in marine environment
Operating conditions (1/2)

- **Aim**: Aggressive environment for comparison purpose
  - Seamless vs seam welded
  - Weld vs base metal
  - 3 samples per point

- **Natural seawater**
  - 3 months immersion
  - Heated at 30°C, 50°C and 70°C
  - One complete renewal of seawater every two days
  - Open circuit potential (OCP) and +100mV/OCP

<table>
<thead>
<tr>
<th>Test ref. (desired temperatures, °C)</th>
<th>30</th>
<th>50</th>
<th>70</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>30 ±1°C</td>
<td>50 ±1°C</td>
<td>70 ±1°C</td>
</tr>
<tr>
<td>pH</td>
<td>8.1 ±0.1</td>
<td>8.1 ±0.1</td>
<td>8.1 ±0.1</td>
</tr>
<tr>
<td>Conductivity</td>
<td>54 ±1 mS/cm</td>
<td>54 ±1 mS/cm</td>
<td>54 ±1 mS/cm</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>6.7 ±0.2 ppm</td>
<td>4.9 ±0.2 ppm</td>
<td>Not measured</td>
</tr>
</tbody>
</table>
6- Corrosion resistance in marine environment
Operating conditions (2/2)

- **Crevcorr type assembly**
  - Torque = 1Nm (≈ 550N)
  - PVDF crevice washer
  - Ti fasteners

- **Tubes**
  - 25.4mm OD x 2mm WT x 50 or 300mm L
  - Seam welded
    - 25.7Cr 6.8Ni 3.9Mo 0.29N (PREN = 43.2)
  - Seamless tubes
    - 25.6Cr 6.5Ni 3.9Mo 0.29N (PREN = 43.1)

- **Evaluation**
  - Potential or current vs time
  - Observations
  - Max pit or crevice depth
6- Corrosion resistance in marine environment – Crevice test
Observations – $T = 30^\circ C$

- **Seam welded tubes**
  - Laser weld
  - Average maximum crevice depth
    - 355µm

- **Seamless tubes**
  - 360µm

Laser weld seam is not especially sensitive to crevice corrosion

Max corrosion attack

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6- Corrosion resistance in marine environment – Pitting and crevice results

Summary (max average corrosion depth in µm)

<table>
<thead>
<tr>
<th>T(°C)</th>
<th>Potential</th>
<th>Seam welded*</th>
<th>Seamless</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OCP</td>
<td>355 ± 30</td>
<td>360 ± 36</td>
</tr>
<tr>
<td>30</td>
<td>OCP + 100mV</td>
<td>333 ± 57</td>
<td>397 ± 31</td>
</tr>
<tr>
<td></td>
<td>OCP</td>
<td>25</td>
<td>&lt;10</td>
</tr>
<tr>
<td>50</td>
<td>OCP + 100mV</td>
<td>45 ± 18</td>
<td>97 ± 70</td>
</tr>
<tr>
<td>70</td>
<td>OCP</td>
<td>25</td>
<td>&lt;10</td>
</tr>
<tr>
<td></td>
<td>OCP + 100mV</td>
<td>50 ± 28</td>
<td>18 ± 14</td>
</tr>
<tr>
<td></td>
<td>OCP</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>50</td>
<td>OCP + 100mV</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>70</td>
<td>OCP</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>OCP + 100mV</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Severe crevice corrosion
Superficial crevice corrosion (or discoloration)
No corrosion

* Maximum corrosion located on base material and not at the longitudinal weld
6- Corrosion resistance in marine environment - Conclusion

- Very similar behaviours are observed for both seam welded and seamless tubes:
  - Immerged in natural seawater from 3 to 12\textsuperscript{[1]} months (with or without crevice washer)
  - In terms of pitting and repassivation potentials measured during potentiodynamic study (not shown today but presented in Maastricht SSW conf)

- For seam welded product, the longitudinal laser weld has a pitting and crevice corrosion resistance equivalent to the base metal

7- Fatigue testing

 Protocol

- Reference to DNV-RP-C203 section 2.4.12
- Jointly defined with TOTAL
- Same (3) dimensions tested as for initial Qualification
- Samples with and without Orbital Welds
- Testing conditions more constraining than design values
- 3 Stress Ranges,
  - 200, 300 and 400 MPa for tubes w.o. OW
  - 150, 200 and 300 MPa for tubes with OW
- Axial testing, max 60Hz to limit sample heating
- Samples pre-strained @ 15% APS
7- Fatigue testing

Results

- Acceptance curve (TOTAL): $2\sigma$ above DNV design curve

- Same results for all 3 dimensions (i.e. 15 samples per triangle)

- All (90) tests interrupted at Run-out ➔ better than 4 to 5$\sigma$ above DNV design curve

- No impact of the Longitudinal seam weld

- Performance obtained thanks to stringent production standards on:
  - Tube internal and external surface condition
  - Tube roundness & WT distribution (very tight tolerances)
  - Tube alignment (for OW)
  - OW geometry and repeatability

• Outstanding fatigue performance
7- Fatigue testing

Type Approval Certificate

MARINE AND OFFSHORE DIVISION
CERTIFICATE OF TYPE APPROVAL
E&P/11931-C-12-001 Rev.1

This is to confirm that the general certification procedure described in Appendix 2 has been satisfactorily applied, with respect to conformity of VALLOUREC UMUBLICALS manufacturing, control and testing procedures against standards here below and results successfully evaluated for:

Manufacturing Unit
VALLOUREC UMUBLICALS - VENAREY LES LAUMES, FRANCE

Product
Super Duplex Stainless Steel Seam Welded Tubes

Material
Super Duplex UNS – 832750 / EN 1.4410

Yield strength
Min. 750MPa (Rm)

Tensile strength
Min. 960MPa (UTS)

Range
12.7 mm (1/2 in) ≤ internal diameter ≤ 51.8 mm (2 in)

Application
Stainless steel tubes for static and dynamic subsea umbilicals

Appendix 1

Range of Super Duplex tubes covered by Type Approval

Standards / References:
- ISO 13608-1, 2009
- ASTM A789
- ANI/F1G_CO_002 Rev F – Product Data Sheet

In the process, the qualification protocol refered NTQ-001 Rev.Ox – "Qualification program" taking into account umbilical and operators specifications has been followed:
- Two qualification phases (pre-production and full-production) have been witnessed and surveyed, covering 3 sizes of stainless steel tubes,
- Mechanical (tensile tests at different temperatures, hardness, ...), corrosion (ASTM G68A, B, E and F), dimensional control, roughness, chemical analysis on strip, reverse flattening, flange, ferrite content (grid techinc and picture analysis), sigma phase tests / measurements as well as hydrottest, burst, collapse and fatigue tests have been carried out and evaluated,
- Raw material specifications have been evaluated,
- Fabrication and Control procedures, including welding and NDT issues have been assessed, for ability to meet requirements included within above references,
- The stability of the process and the homogeneity of the performances of the produced stainless steel tubes have been examined,
- QA / QC system has been confirmed as independently certified to ISO 9001.

The results of this evaluation being satisfactory, within the limitations specified in the Technical Report n° RL353, the present certificate is valid up to October 2015.

To whom it may concern,
Neuilly-sur-Seine, December 29th 2013

L. Merillon / F. Conti / F. Mitglin
Marine and Offshore Division – Lead Engineers
This certificate is delivered within the scope of the BUREAU VERITAS General Conditions of Service.

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8- Conclusion

- Increased yield strength
- Tight tolerances on wall thickness
- Reduced ovality

- Wall thickness reduction
- Weight reduction
- Increase tube and ombilical flexibility
- Reduction of size of ancillaries equipment

Wall thickness vs internal diameter for seam welded and seamless tube

Weight of the tube vs internal diameter for seam welded and seam less tube
8- Conclusion
Quality & Performance acknowledged by the Industry

- **November 2011:** ISO 9001 Certified in 2011
- **October 2012:** Type Approval Certificate by Bureau Veritas for Static applications
- **February 2013:** Approved supplier for TOTAL ("ProQual")
- **June 2013:** First project award (Prototype for Statoil)
  Joint Paper with TOTAL to OMAE conference
- **December 2013:** B.V. TAC extension to dynamic applications
  First VU deliveries to 2 customers
- **Pending:** Qualification for Duco and Nexans
- **2014 (TBC):** Extension of qualification to full manufacturing range
  Development of VU tubes Fatigue (S/N) design curves
  First full scale orders