New Generation of High Strength Sour Service Drill Pipe: A Breakthrough Innovation to Address Ultra-deep and Extended-Reach Drilling Challenges Combined With H₂S Environments

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Sour Service Environment

Our challenge: Minimize risks

• What is Sour Service?
  – Sour Service: Well containing H₂S
  – Origin: H₂S comes from decomposition of organic material.

• Consequences?
  – Hazardous to human health, living organisms and environment.
  – Loss of well due to Sulfide Stress Cracking (SSC)
Risks Associated to Sour Service

Risks on standard API grades (= non Sour Service grade):

- **Sulfide Stress Cracking**
  - Unpredictable brittle failure
  - Fishing costs
  - Non-productive time for drilling contractors

- **Failure example on 5” DP, S-135 API grade**
Sulfide Stress Cracking

**Escalation factors:**
- When Yield strength
- Grade $\text{H}_2\text{S}$ resistance
- SSC phenomenon occurrence
- Failure risks

**Catastrophic Failure**

- Low pH
- Water
- High $\text{H}_2\text{S}$

$\Rightarrow$ Corrosion

$\downarrow$

H Charging

Low temperature

Applied load

[Diagram showing a pipeline with corrosion and cracking, indicating the factors leading to catastrophic failure.]
NACE Testing Methods

NACE TM 0177 (2005) defines 4 testing methods
- **Method A** is the most used for drilling products
- **Solution A** is the most used environment (Severe Sour environment)

**NACE A**

NACE “Tensile Test” under uniaxial tensile load.
- Failure/no failure test
- Test duration: 720h

<table>
<thead>
<tr>
<th>Acceptance Criteria:</th>
<th>PASS</th>
<th>FAIL</th>
</tr>
</thead>
</table>

![Image of test setup with PASS and FAIL criteria](image-url)
NACE Test A: Laboratory Procedure

Environmental Testing Chamber

Application of tensile load $= \% \text{ SMYS}$

Example of samples under testing process
Evolution of the Drilling Envelope

- Complex well profiles associated to $\text{H}_2\text{S}$:
  - Deep wells (ex: Canada, China, North Iraq)
  - Deepwater projects (ex: Brazil)
  - Highly deviated and ERD wells (Ex: Middle East)

- Tensile limitations:
  - Current Sour Service grades on the market are limited with 105 ksi YS max.
  - Operators and drillers are pushed to use S-135 in $\text{H}_2\text{S}$ environments with high risk
  - S-135 failures in such wells are being reported

- Technological challenges:
  - higher YS is generally detrimental to Sulfide Stress Cracking
  - Not always possible to increase dimensions with existing Sour Service grades
Example of S-135 Failure

- **Tarim basin:**
  - Tarim is China’s largest petroliferous basin, in which a total of 27 oil & gas fields have been discovered by CNPC since 1989.
  - Operated by Petrochina Tarim Oilfield.

- **H₂S failures:**
  - S-135 API drill pipe used in a well with 0.5% H₂S
  - Failure of the top of the string (tension max):
    - Failure at 648 m TVD
    - Bit depth 5,900 m

- **Root cause: Sulfide Stress Cracking**
  - Improper grade selection: S-135 instead of Sour Service DP
  - Incident and root cause analysis reported:
    - *Materials Performances, page 69, March 2010*
## High Strength Steels Benefits

The Sour Service solution for complex well profiles

<table>
<thead>
<tr>
<th>KPI</th>
<th>High grade performance</th>
<th>Added Value</th>
</tr>
</thead>
</table>
| **H₂S Resistance**         | H₂S resistance **above S-135** performance:                                              | NACE TM-0177 Test using Method A (tensile test)  
Steel A: qualified using 90% AYS  
Steel B: 70% SMYS in Solution A |
|                            | Steel A: qualification tests in Region 1 of the NACE MR0175                            |                                                                                                 |
|                            | Steel B: tested at a frequency of 1 sample per heat / heat treatment batch / 200 jts   |                                                                                                 |
| **Tensile Capacity**       | Higher YS than current 105 ksi- Sour Service grades on the market  
Can address ERD and Deep well profiles | **+12.5%** Tensile Capacity                                                                      |
| **Torque and Drag**        | Thin wall option at iso-performance compared to 105 ksi-Sour Service grades on the market  
Light weight string | Ex: 5 ½” DP  
→ Weight reduction of -9.2% for the same tensile capacity                                |
| **Overpull Capacity**      | Additional overpull compared to 105 ksi-Sour Service grades on the market  
Lower risk of failure with presence of H₂S compared to S-135 grade | Increased by **12.5%**                                                                       |
Sour Service Grades

- Sour Service steel = material with resistance to $\text{H}_2\text{S}$

- Key processes control:
  - Steelmaking:
    - Supreme cleanliness
    - Dedicated steel chemistries
  - Heat treatment:
    - Homogeneous and fine microstructure
    - Specific heat treatments (double Q & T)
  - Welding:
    - Controlled hardness
    - Dedicated tempering
# Mechanical Properties

<table>
<thead>
<tr>
<th>Grade name</th>
<th>Steel A</th>
<th>Steel B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sour Domain</td>
<td>Mild Sour</td>
<td>Intermediate Sour</td>
</tr>
<tr>
<td><strong>Pipe Body</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yield Strength (ksi)</td>
<td>120-135</td>
<td>120-135</td>
</tr>
<tr>
<td>Minimum Ultimate Tensile Strength (ksi)</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>Controlled Maximum Hardness (average)</td>
<td>37 HRC</td>
<td>35 HRC</td>
</tr>
<tr>
<td>Minimum Single Charpy Impact Value (at room temperature, ¾ size sample)</td>
<td>38 J (28 ft-lbs)</td>
<td>38 J (28 ft-lbs)</td>
</tr>
<tr>
<td>Minimum Average Charpy Impact Value (at room temperature, ¾ size sample)</td>
<td>44 J (32 ft-lbs)</td>
<td>44 J (32 ft-lbs)</td>
</tr>
<tr>
<td>NACE TM-0177 Method A Solution A Threshold in % SMYS pipe</td>
<td>None</td>
<td>70% SMYS</td>
</tr>
<tr>
<td><strong>Tool Joint</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Yield Strength (ksi)</td>
<td>120</td>
<td>110</td>
</tr>
<tr>
<td>Minimum Ultimate Tensile Strength (ksi)</td>
<td>140</td>
<td>125</td>
</tr>
<tr>
<td>Hardness (single)</td>
<td>285 BHN Min.</td>
<td>32 HRC Max.</td>
</tr>
<tr>
<td>Minimum Single Charpy Impact Value (at room temperature, full size sample)</td>
<td>38 J (28 ft-lbs)</td>
<td>47 J (34 ft-lbs)</td>
</tr>
<tr>
<td>Minimum Average Charpy Impact Value (at room temperature, full size sample)</td>
<td>44 J (32 ft-lbs)</td>
<td>54J (39 ft-lbs)</td>
</tr>
<tr>
<td>NACE TM-0177 Method A Solution A Threshold in % SMYS Tool Joint</td>
<td>None</td>
<td>50% SMYS</td>
</tr>
</tbody>
</table>
Conclusions

• Thanks to years of research and development, a new “120ksi” Sour Service grades family has been successfully manufactured and commercialized.

• These material offer solutions to overcome Sulfide Stress Cracking issues often found in sour drilling applications:
  • Steel A is SSC resistant at milder test conditions (region 1, ISO1516 part 2) with a large safety margin.
  • Steel B sustained 84 ksi minimum stress in NACE TM0177 - Solution A saturated by 1 bar H₂S.

• These innovations can directly address drilling & safety challenges linked to complex well profiles associated to H₂S, such as deep wells profiles (ex: Canada, China, North Iraq), deepwater projects, or highly deviated and ERD wells.

• A first drillstring of this high strength material (steel A) is already being used for the first time in offshore wells by a major international operating company in the North Sea.
Thank you!
Any question?