New Generation of High Strength Sour Service Drill Pipe: A Breakthrough Innovation to Address Ultra-deep and Extended-Reach Drilling Challenges Combined With H_2S Environments

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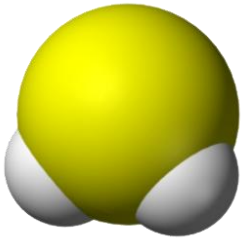
Sour Service Environment

Our challenge: Minimize risks

- What is Sour Service?
  - Sour Service: Well containing H_2S
  - Origin: H_2S 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

Failure example

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**

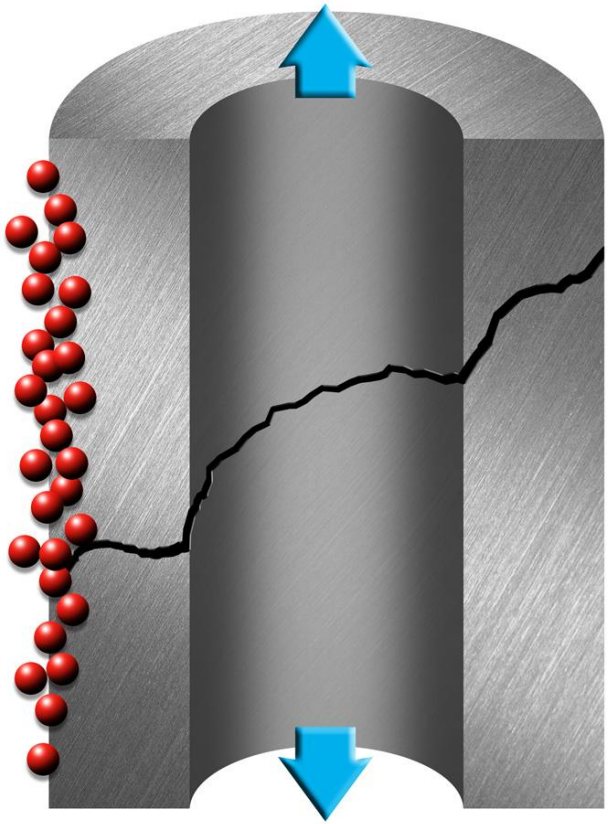
Sulfide Stress Cracking

Catastrophic Failure

Low pH
Water
High H_2S
$\Rightarrow$ Corrosion

$\Downarrow$

H Charging
Low temperature
Applied load



- **Escalation factors:**
  - When Yield strength ↗
  - Grade H_2S resistance ↘
  - SSC phenomenon occurrence
  - Failure risks ↗

NACE Testing Methods

NACE A

NACE "Tensile Test" under uniaxial tensile load.

- Failure/no failure test
- Test duration: 720h

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)

Acceptance Criteria:	
PASS	FAIL

NACE Testing Method A

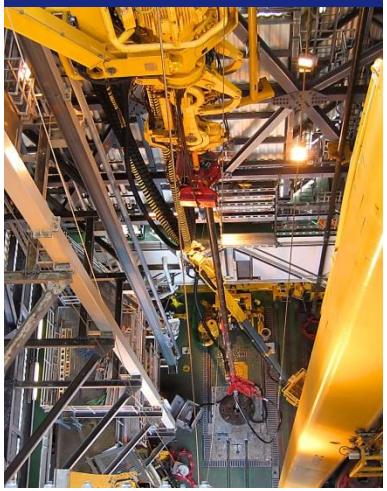
NACE Test A: Laboratory Procedure

Environmental Testing Chamber

Application of tensile load = % SMYS

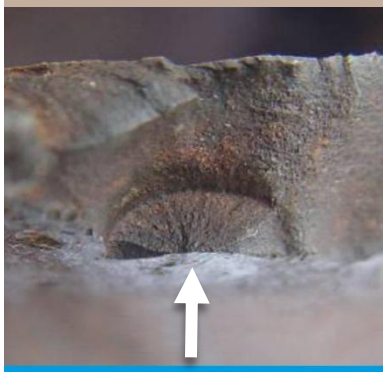
Example of samples under testing process

Evolution of the Drilling Envelope



- Complex well profiles associated to H_2S:
  - 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 H_2S 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



Half Round Flat Fracture

- 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.
- H_2S failures:
  - S-135 API drill pipe used in a well with 0.5% H_2S
  - 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

KPI	High grade performance	Added Value
H_2S Resistance	H2S resistance **above S-135** performance: 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	NACE TM-0177 Test using Method A (tensile test) Steel A: qualified using 90% AYS Steel B: 70% SMYS in Solution A
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 H_2S compared to S-135 grade	Increased by **12.5%**

Sour Service Grades

- Sour Service steel = material with resistance to H_2S

- **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

Sour Service Grades = Specific Chemistry + Specific Heat Treatment

Mechanical Properties

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

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 H_2S.
- These innovations can directly address drilling & safety challenges linked to complex well profiles associated to H_2S, 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?