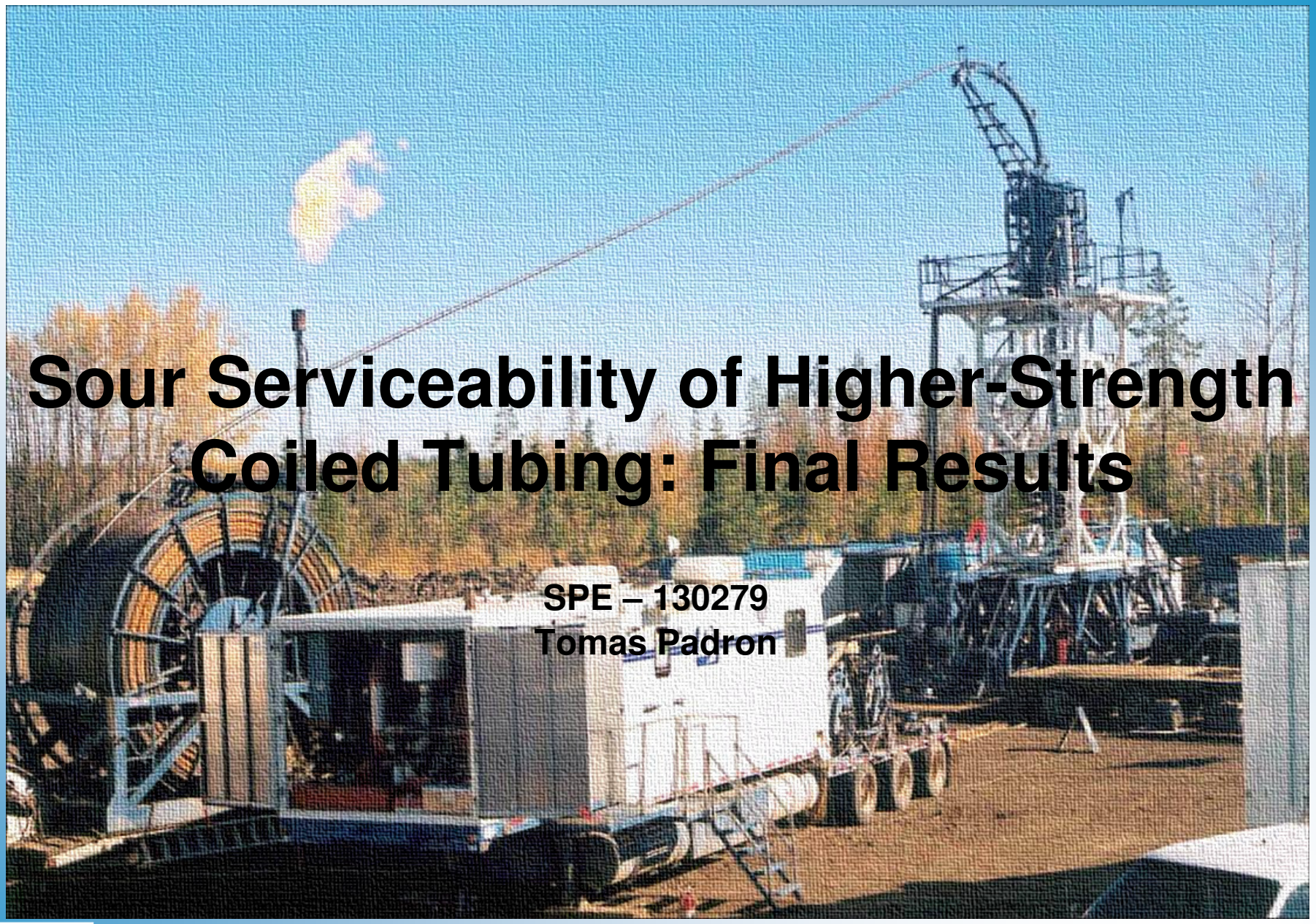

Sour Serviceability of Higher-Strength Coiled Tubing: Final Results

SPE – 130279

Tomas Padron

Sour Serviceability of Higher-Strength Coiled Tubing
Outline

- Introduction
- Experimental Procedure
- Results:
  - Pipe Body Sour Fatigue Performance
  - Effect of H_2S Anti-Cracking Inhibitor
  - Effect of Pre-Fatigue
  - CT Welds Sour Fatigue Performance
- Conclusions / Practical Applications

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Sour Serviceability of Higher-Strength Coiled Tubing
Outline

- Introduction

Sour Serviceability of Higher-Strength Coiled Tubing
Introduction

- CT sour serviceability based on small-scale specimen testing:
  - Evaluate H_2S cracking resistance – mainly below SMYS
  - No low-cycle fatigue data – String management
- Successful sour field experience with 80 grade but higher grades required for some applications
- 2004: Joint Industry Project (90 grade and up):
  - Measurement of CT sour low-cycle fatigue
  - Full body CT samples

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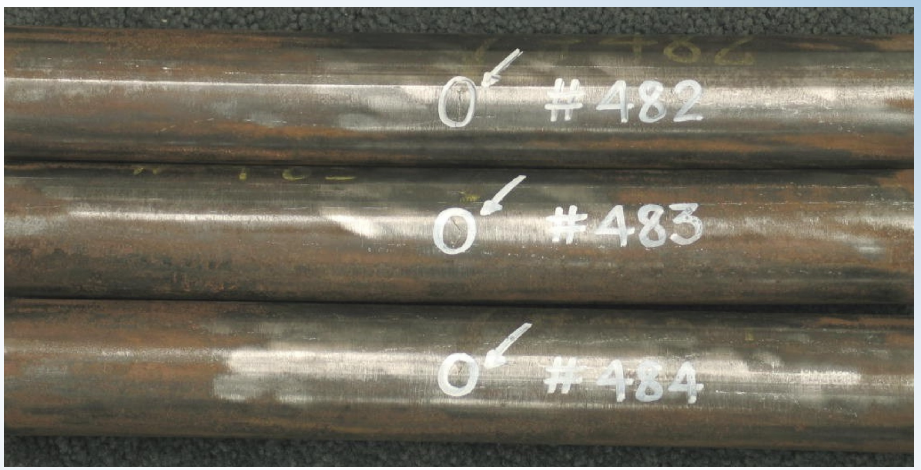
Sour Serviceability of Higher-Strength Coiled Tubing
Outline

- Introduction √
- **Experimental Procedure**

Sour Serviceability of Higher-Strength Coiled Tubing
Experimental Procedure



- CT samples:
  - Mainly 1-3/4” x 0.134”
  - Standard grades- no special grades for sour service
  - From the two manufacturers available when project started (2004)
  - More than 500 samples were tested

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Sour Serviceability of Higher-Strength Coiled Tubing

Experimental Procedure

Fatigue Tests

- 7 ft long CT samples exposed to sour environments (solution NACE A + X% H_2S) for 4 days.
- Room temperature / 1 atm (14.7 psi)

Sour Serviceability of Higher-Strength Coiled Tubing
Experimental Procedure

Fatigue Tests

- Samples were fatigue tested until failure
- Results recorded as number of cycles to failure and expressed as % of sweet life (%SL):
  - **% SL = [Cycles to failure / Cycles to failure in air without exposure]*100**

Sour Serviceability of Higher-Strength Coiled Tubing
Outline

- Introduction √
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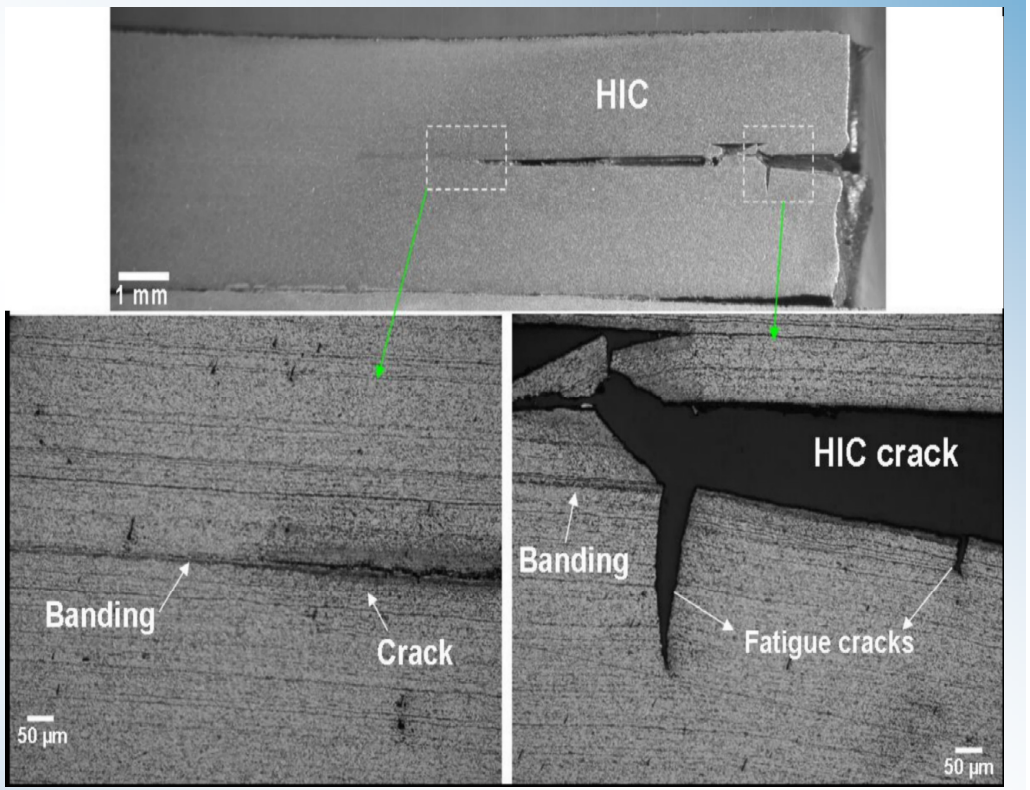
- Results:
  - Pipe Body Sour Fatigue Performance

Sour Serviceability of Higher-Strength Coiled Tubing
Results: Pipe Body Sour Performance

- Two main fatigue life reduction mechanisms:
  - Internal hydrogen embrittlement (not cracking)
  - Irreversible internal cracking – HIC (Hydrogen Induced Cracking)

HIC cracking example



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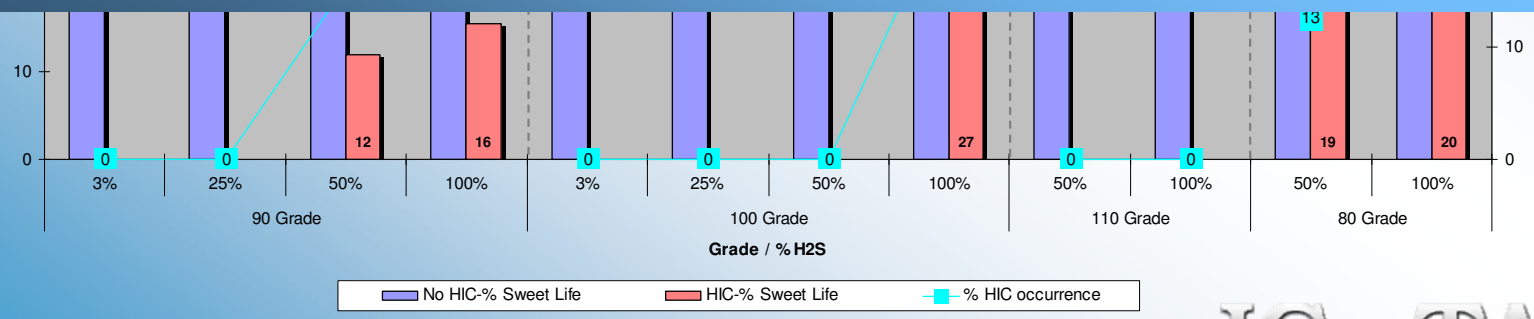
Sour Serviceability of Higher-Strength Coiled Tubing
Results: Pipe Body Sour Performance

Pipe Body Sour Fatigue Performance
(No Anti-Cracking Inhibitor)

- **Regardless grade and % H_2S – sour exposure reduced fatigue life:**
  - **No-HIC: reduction around 50's%**
  - **HIC: reduction around 85's%**
- **HIC occurrence increased with %H_2S increase**



Sour Serviceability of Higher-Strength Coiled Tubing
Outline

- Introduction √
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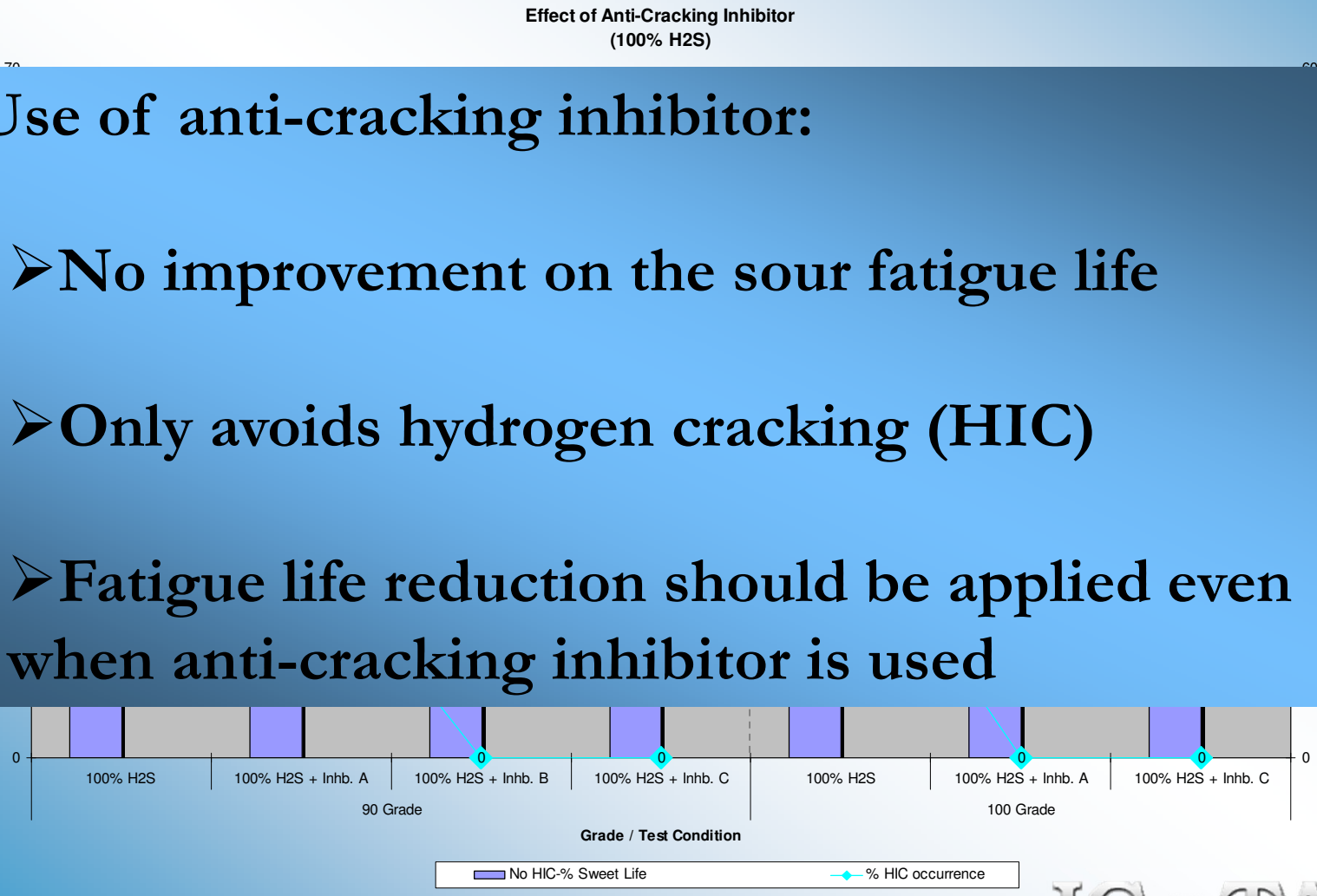
  - Effect of H_2S Anti-Cracking Inhibitor

Sour Serviceability of Higher-Strength Coiled Tubing
Effect of H_2S Anti-Cracking Inhibitor

- **Use of anti-cracking inhibitor:**
  - **No improvement on the sour fatigue life**
  - **Only avoids hydrogen cracking (HIC)**
  - **Fatigue life reduction should be applied even when anti-cracking inhibitor is used**



Sour Serviceability of Higher-Strength Coiled Tubing
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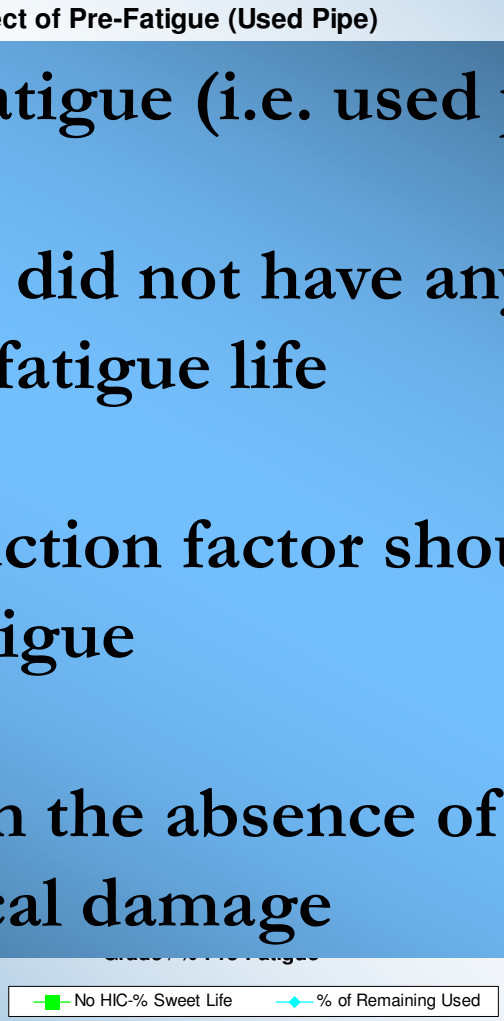
  - Effect of Pre-Fatigue

Sour Serviceability of Higher-Strength Coiled Tubing
Effect of Pre-Fatigue



- **CT with previous fatigue (i.e. used pipe):**
  - **Previous fatigue did not have any detrimental effect on the sour fatigue life**
  - **Fatigue life reduction factor should be applied to the available fatigue**
  - **All this is valid in the absence of significant external mechanical damage**

Sour Serviceability of Higher-Strength Coiled Tubing
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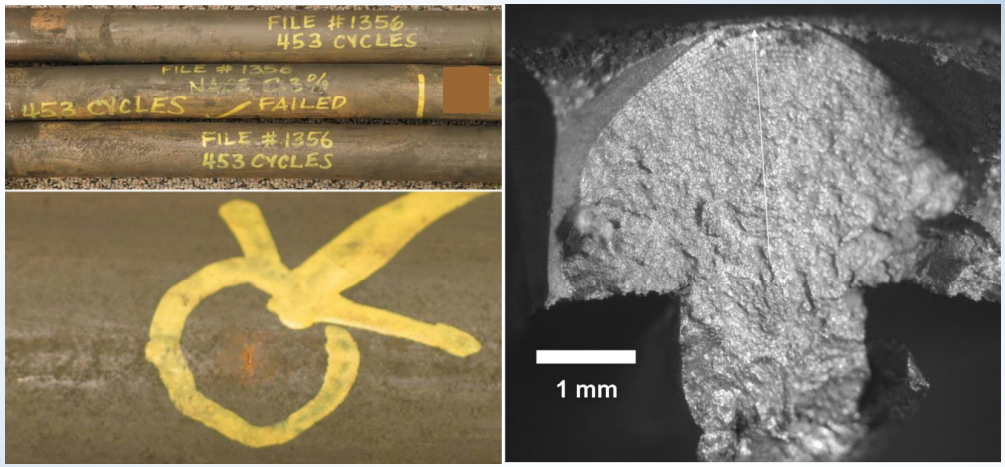
Sour Serviceability of Higher-Strength Coiled Tubing
CT Welds Sour Fatigue Performance

Seam welds

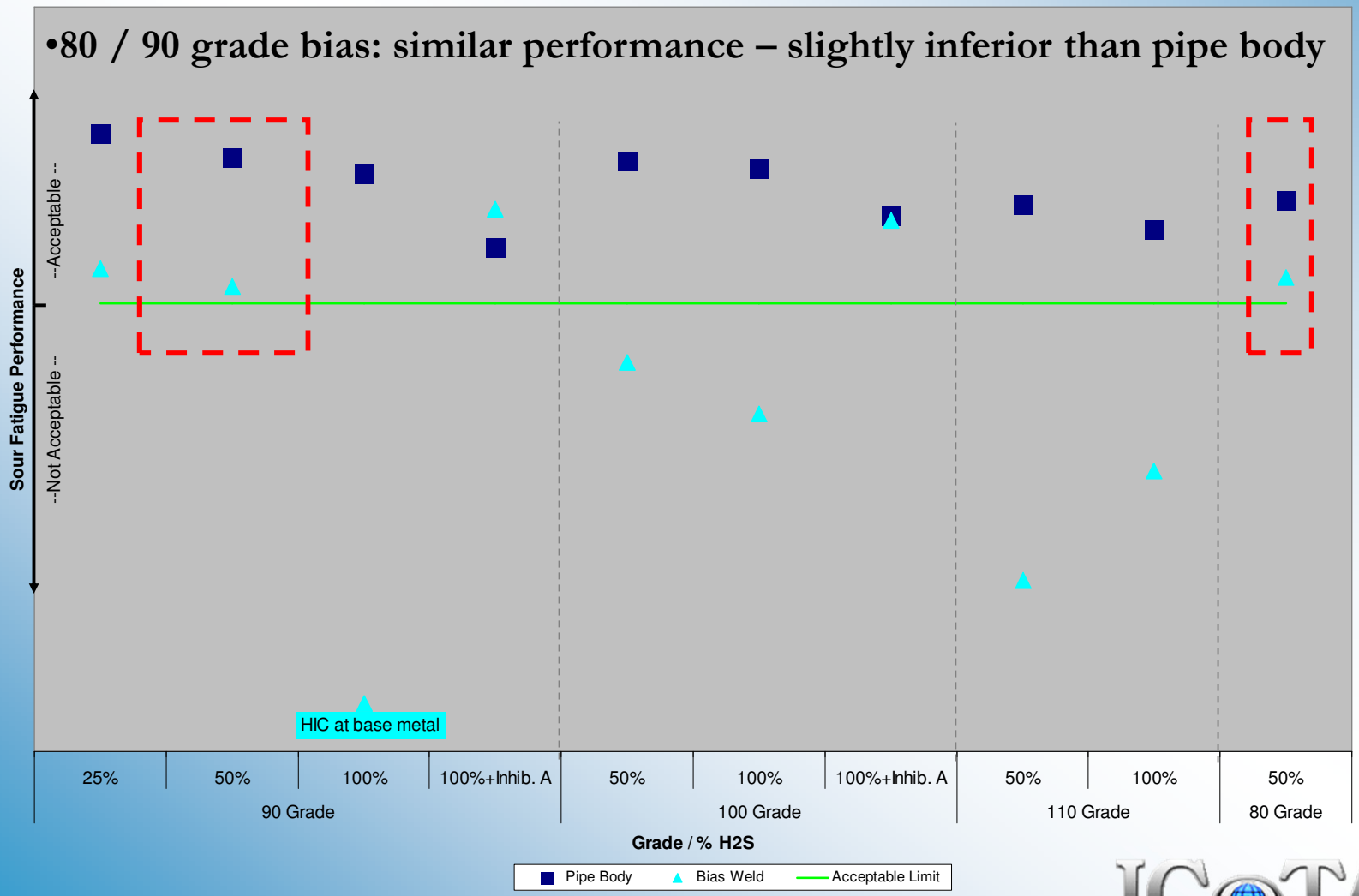


- Seam welds: similar sour fatigue performance as pipe body
- No additional considerations are required for seam welds

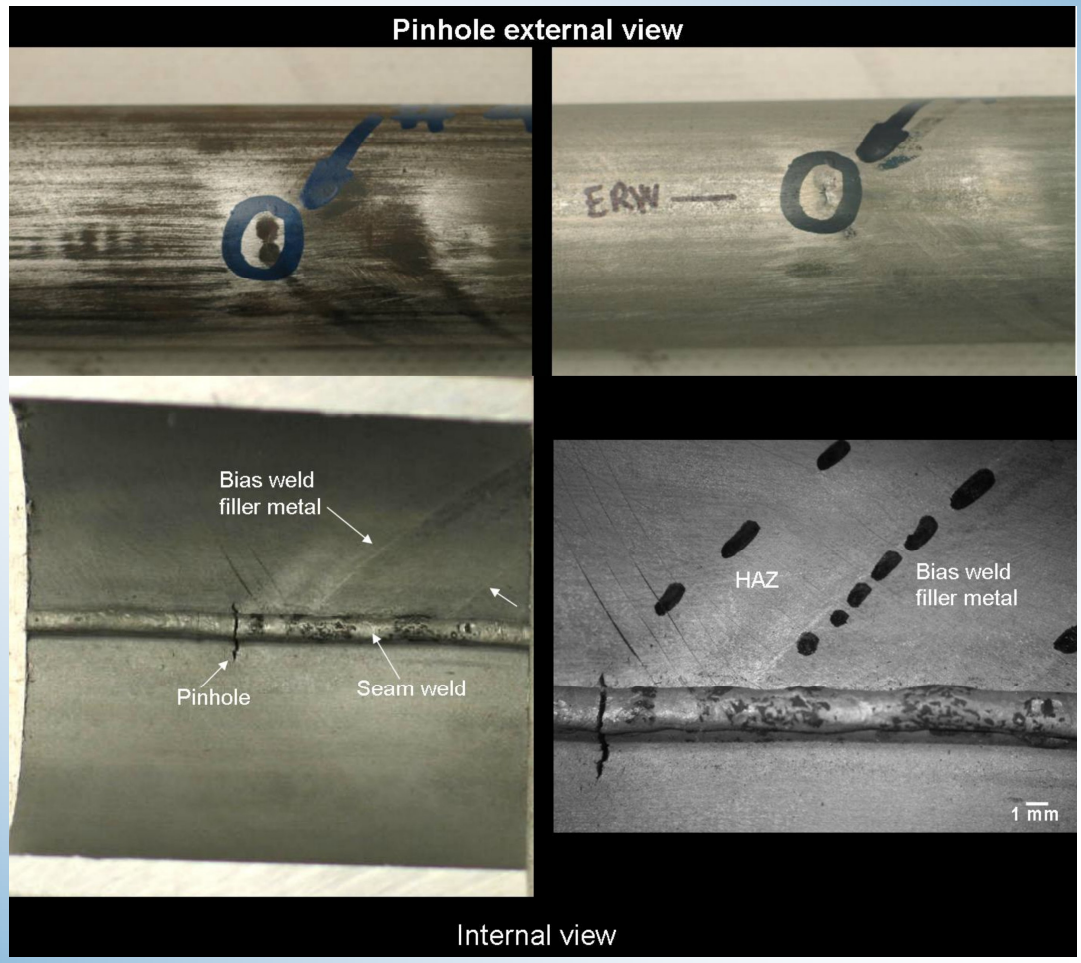
Sour Serviceability of Higher-Strength Coiled Tubing

CT Welds Sour Fatigue Performance

Bias welds



Sour Serviceability of Higher-Strength Coiled Tubing
CT Welds Sour Fatigue Performance

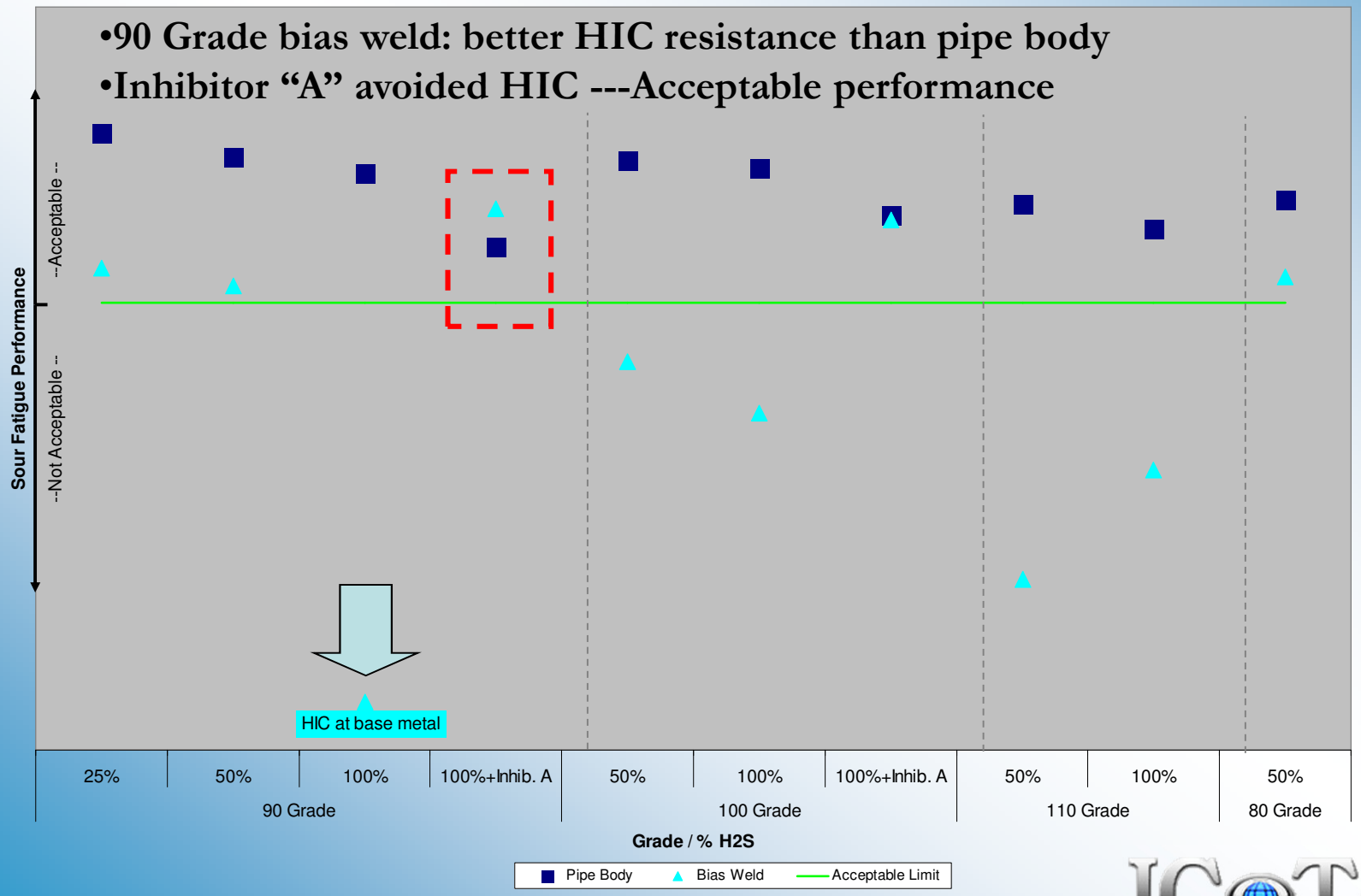


80 / 90 grade bias welds: failure at bias – seam weld intersection

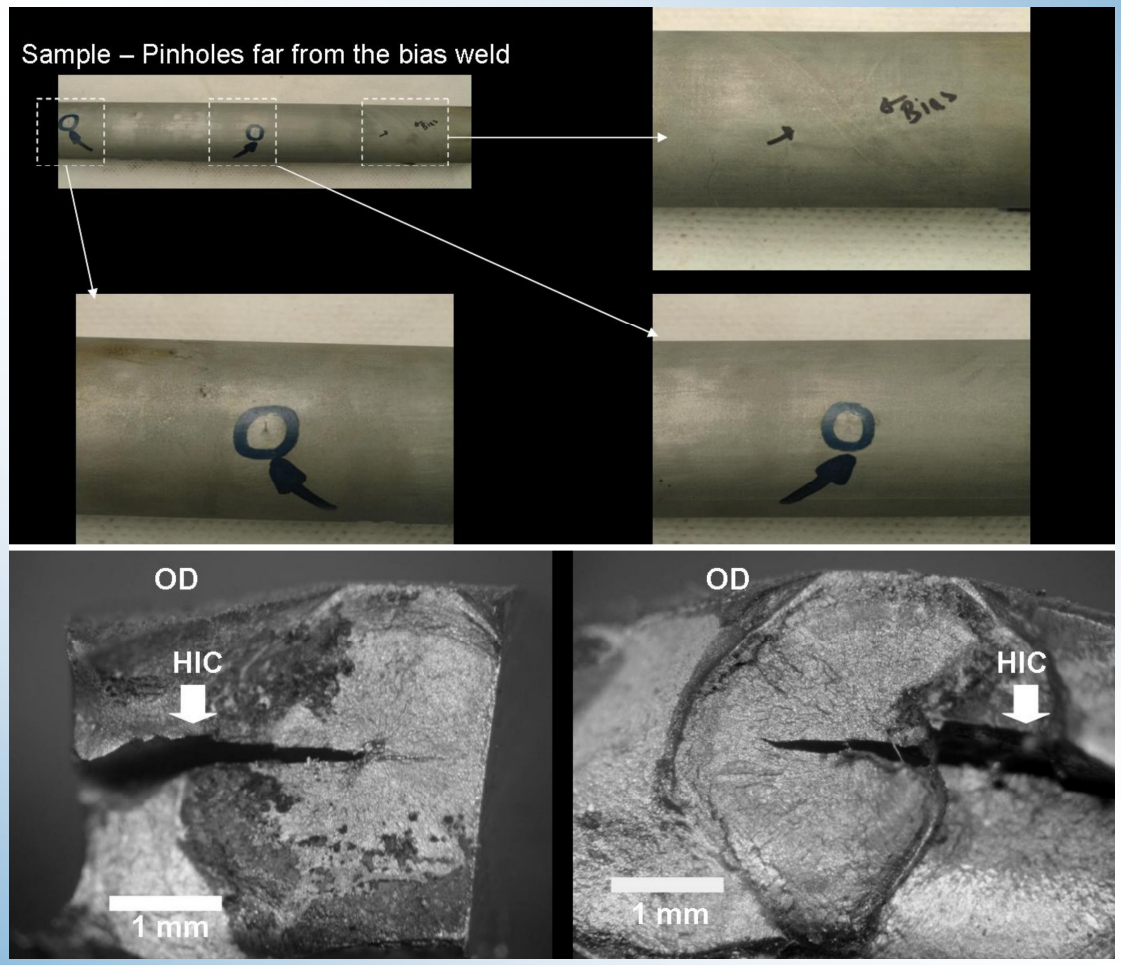
Sour Serviceability of Higher-Strength Coiled Tubing

CT Welds Sour Fatigue Performance

Bias welds



Sour Serviceability of Higher-Strength Coiled Tubing
CT Welds Sour Fatigue Performance

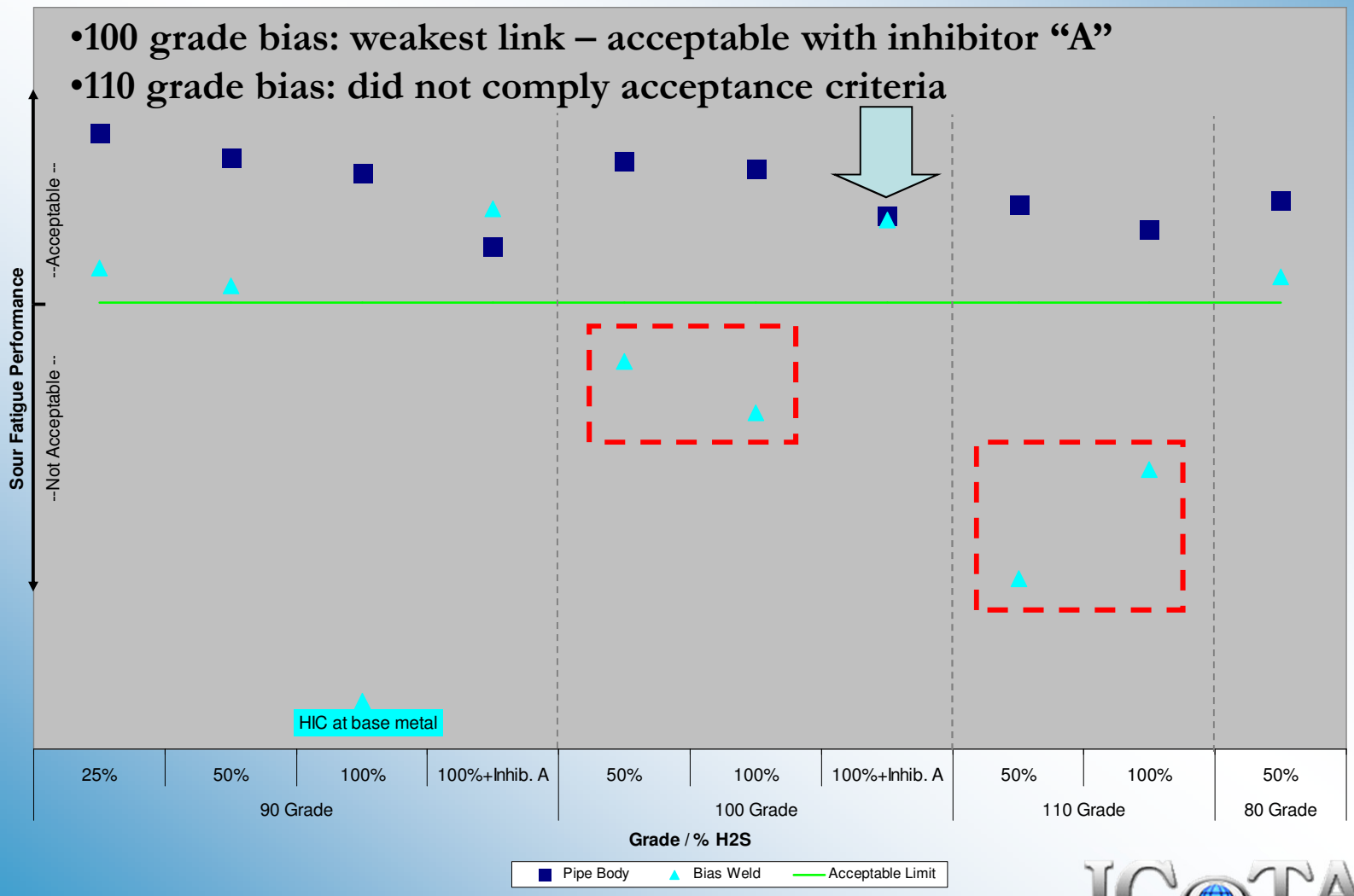


90 grade + 100% H_2S: pinholes (HIC) out of bias weld

Sour Serviceability of Higher-Strength Coiled Tubing

CT Welds Sour Fatigue Performance

Bias welds



Sour Serviceability of Higher-Strength Coiled Tubing
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  - Single vs. Double Exposure √
  - Effect of Pre-Fatigue √
  - CT Welds Sour Fatigue Performance √
- Conclusions / Practical Applications

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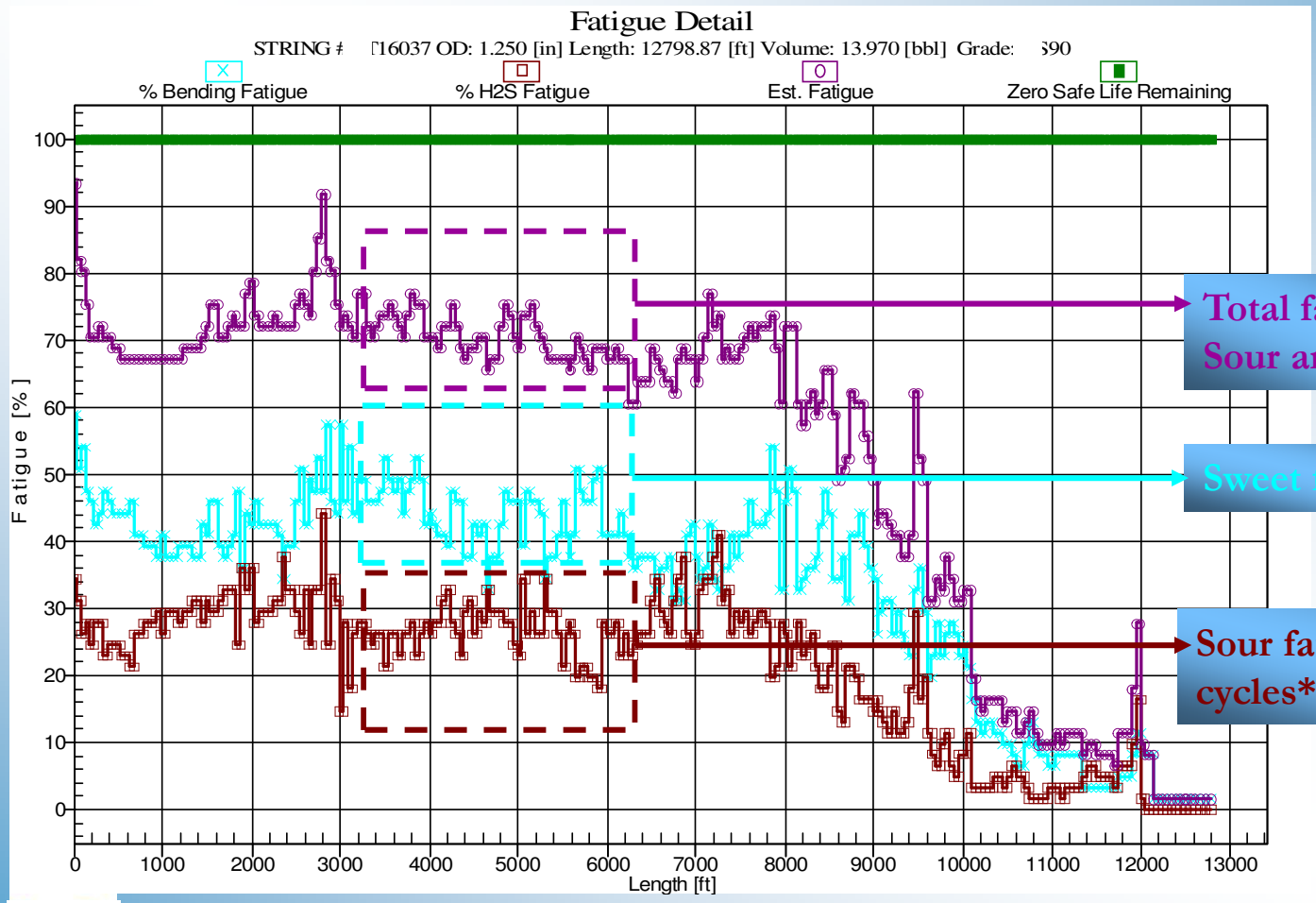
Sour Serviceability of Higher-Strength Coiled Tubing
Conclusions / Practical Applications

- Pipe body sour fatigue performance:
  - Reduction on the fatigue life due to sour exposure
  - Sour fatigue life de-rating factor – No HIC: 40%
  - Sour fatigue life de-rating factor – HIC: 15%

Sour Serviceability of Higher-Strength Coiled Tubing
Conclusions / Practical Applications



Total fatigue: Sour and Sweet

Sweet fatigue

Sour fatigue: cycles* de-rating factor

OD: 1.250 [in] Length: 12798.87 [ft] Volume: 13.970 [bb
Job Date 2009/03/06 12:55:00 Ticket #: S285874
C:\Templ

Customer: Crew
Well Number: Field:
09/09/2009 6:35:46 PM

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Sour Serviceability of Higher-Strength Coiled Tubing
Conclusions / Practical Applications

- Effect of H_2S Anti-Cracking Inhibitor:
  - Reduced or avoided HIC
  - No improvement on sour fatigue life: De-rating factor for “No-HIC” should be applied
- Effect of Pre-Fatigue (used pipe):
  - Pre-fatigue did not affect sour performance (in the absence of significant mechanical damage)

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Sour Serviceability of Higher-Strength Coiled Tubing
Conclusions / Practical Applications

- CT Welds Sour Fatigue Performance:
  - Seam weld: similar to pipe body
  - Bias weld:
    - 80 and 90 similar performance – slightly lower than pipe body
    - 100 grade:
      - Bias is the weakest link.
      - Anti-cracking inhibitor “A” improved performance

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Acknowledgements

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  - Dr. Bernie Luft
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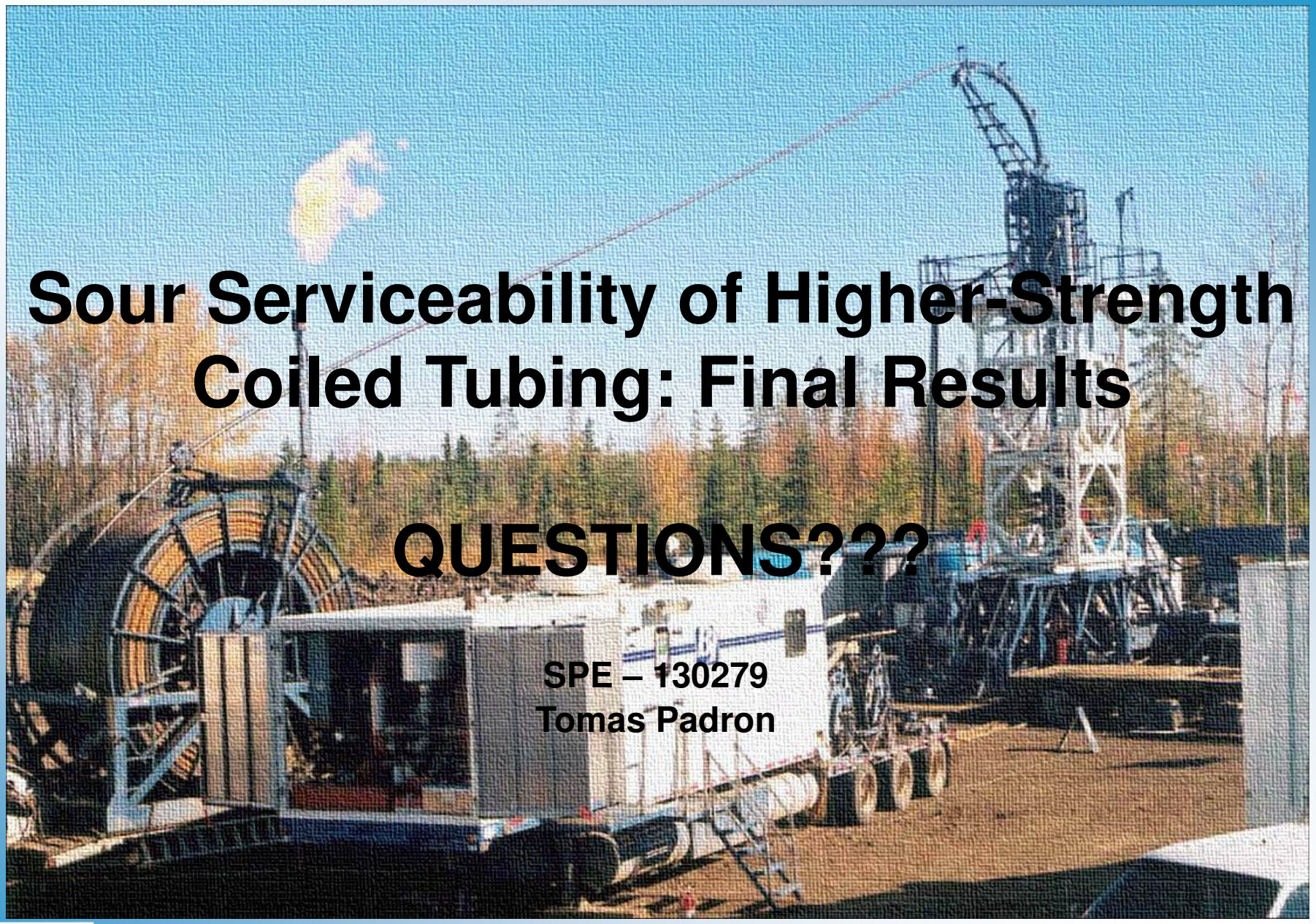
  - Ian Chapman
  - Graham Wilde
  - Manfred Sach
  - Bill Gavin



Sour Serviceability of Higher-Strength Coiled Tubing: Final Results

QUESTIONS???

SPE – 130279
Tomas Padron

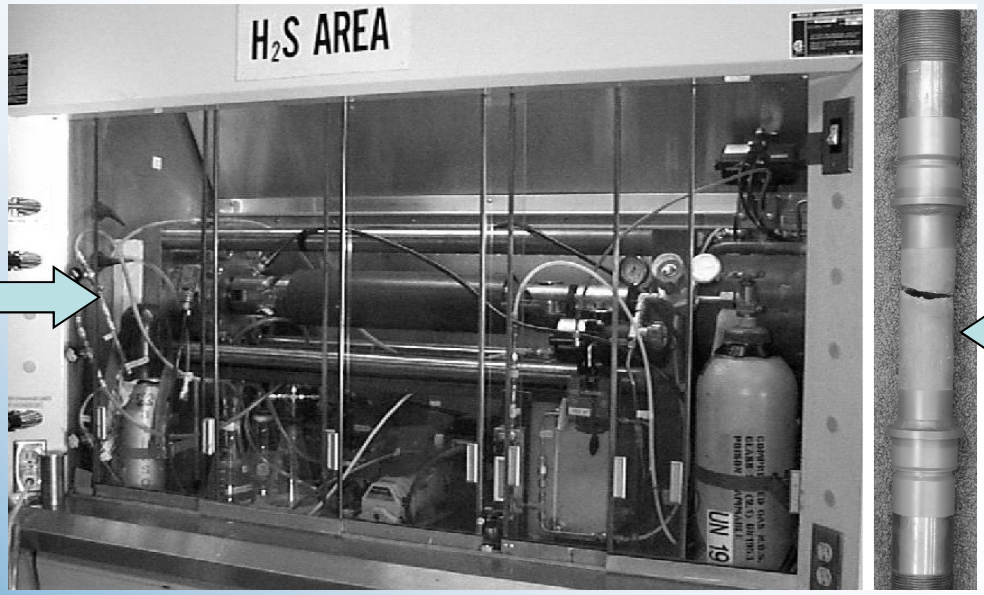
ADDITIONAL SLIDES

Sour Serviceability of Higher-Strength Coiled Tubing
Experimental Procedure

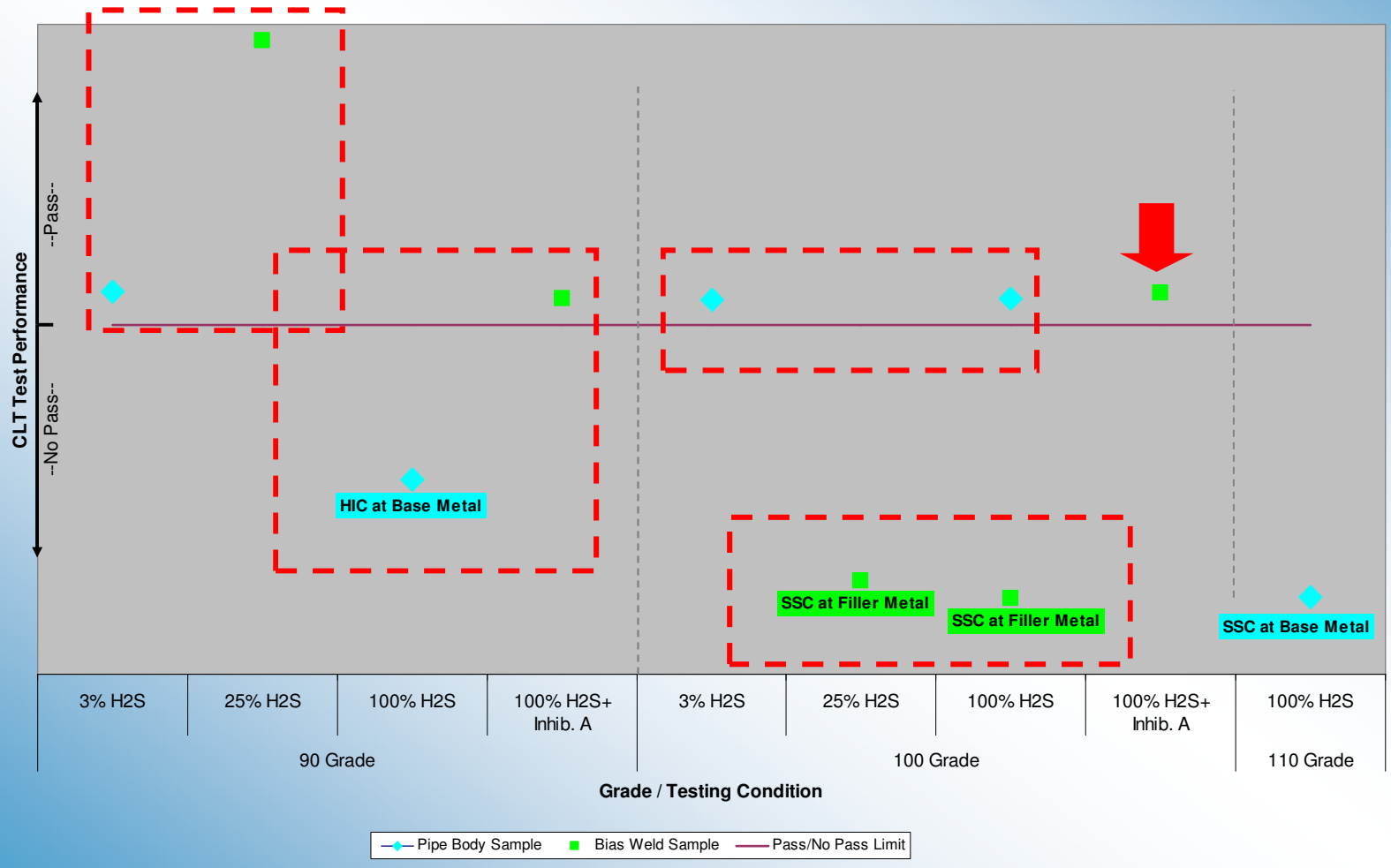
- Samples were fatigue tested until failure:
  - Bending form radius: mainly 72”
  - Internal pressure: constant hoop stress
  - Seam weld on intrados (most severe)

Sour Serviceability of Higher-Strength Coiled Tubing
Experimental Procedure

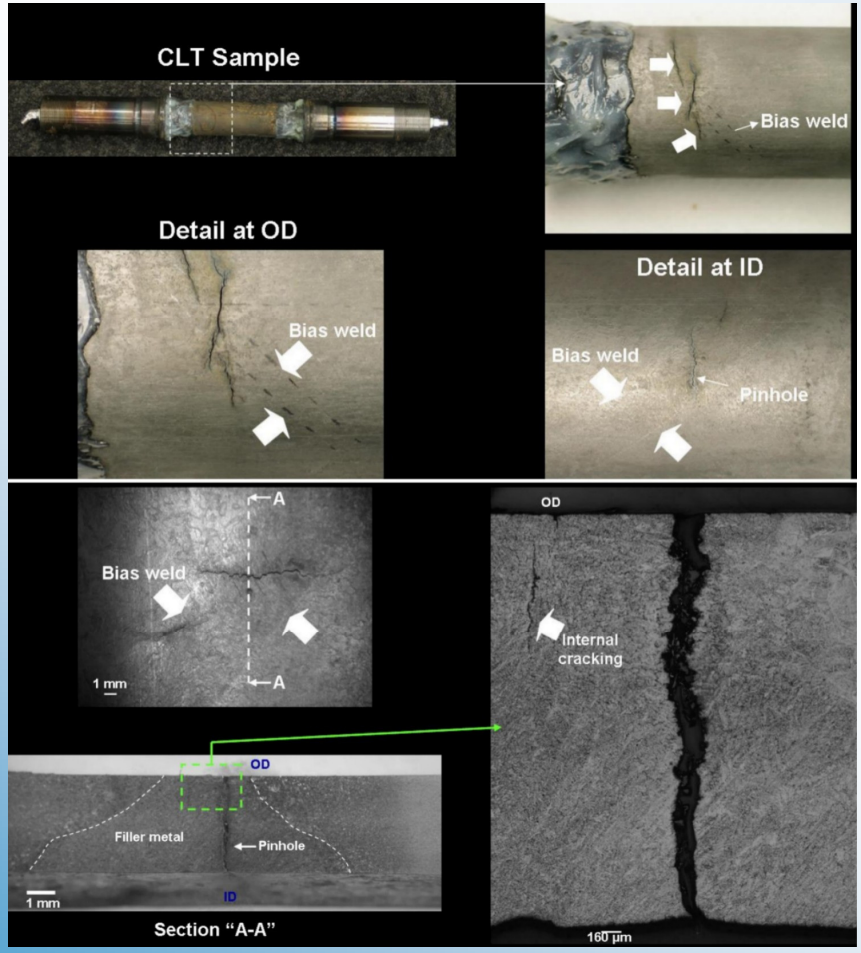
- Constant Load Test (CLT):
  - Full body CT sample (≈ 6.5” long)
  - Immersed in NACE solution “A” + X% H_2S
  - Internal pressure + Tensile load: combined stress 80% SMYS
  - Pass criterion: no failure after 92 hrs exposure

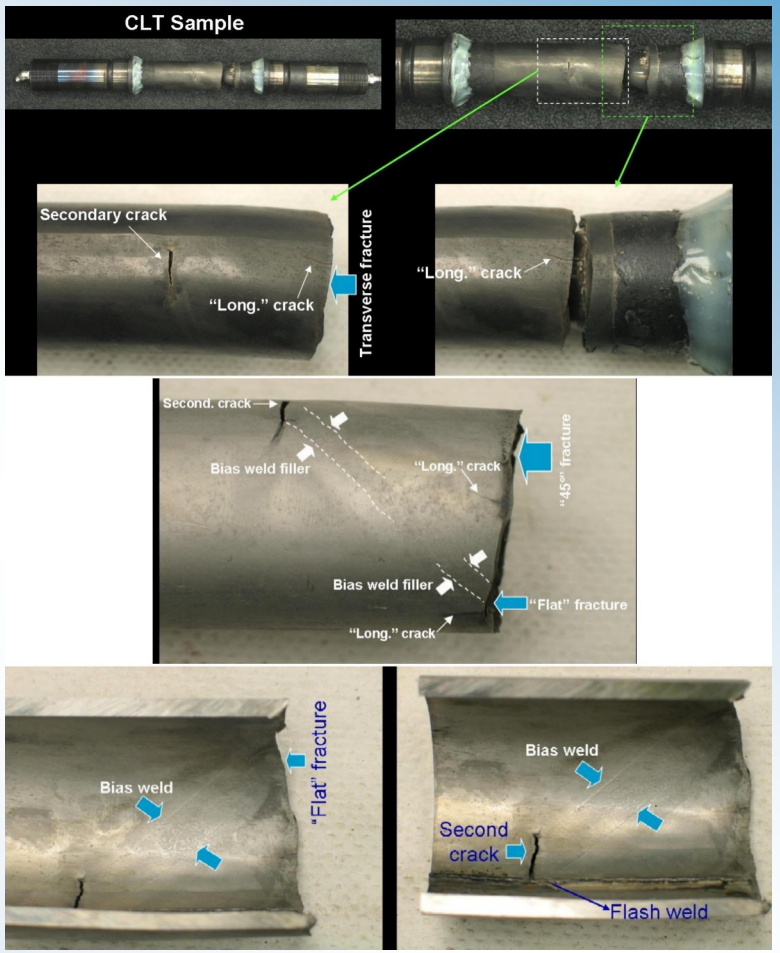


Sour Serviceability of Higher-Strength Coiled Tubing
Tensile Integrity



Sour Serviceability of Higher-Strength Coiled Tubing
Tensile Integrity

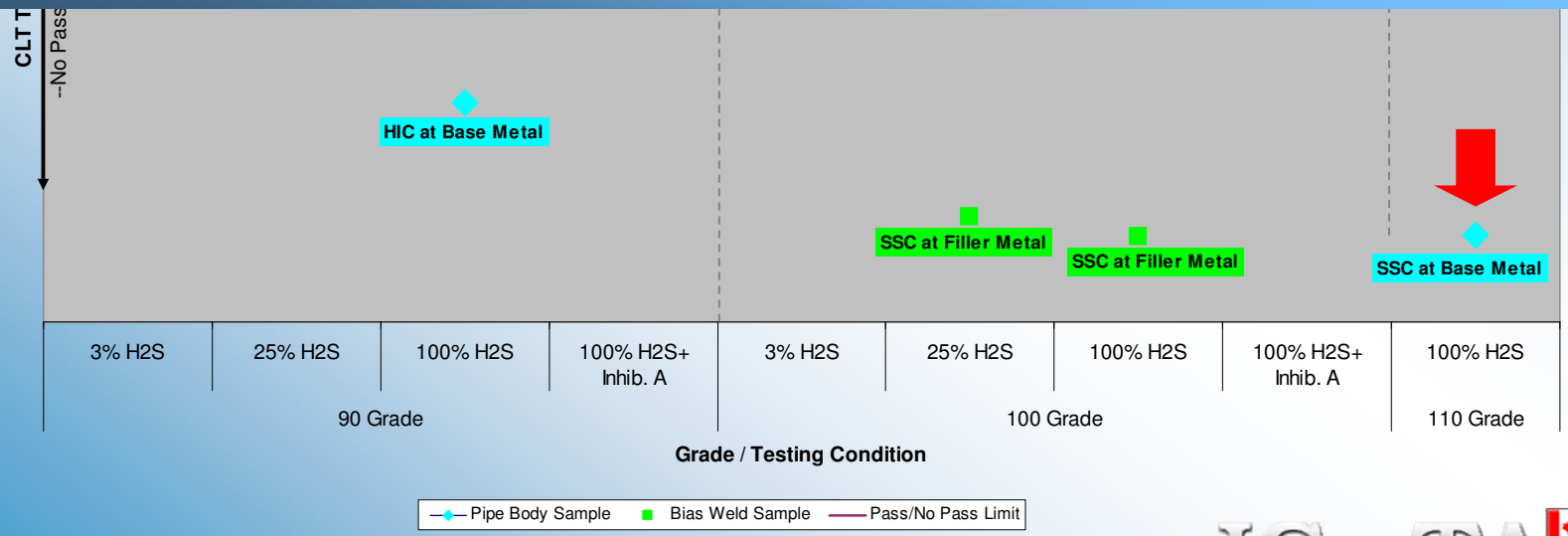




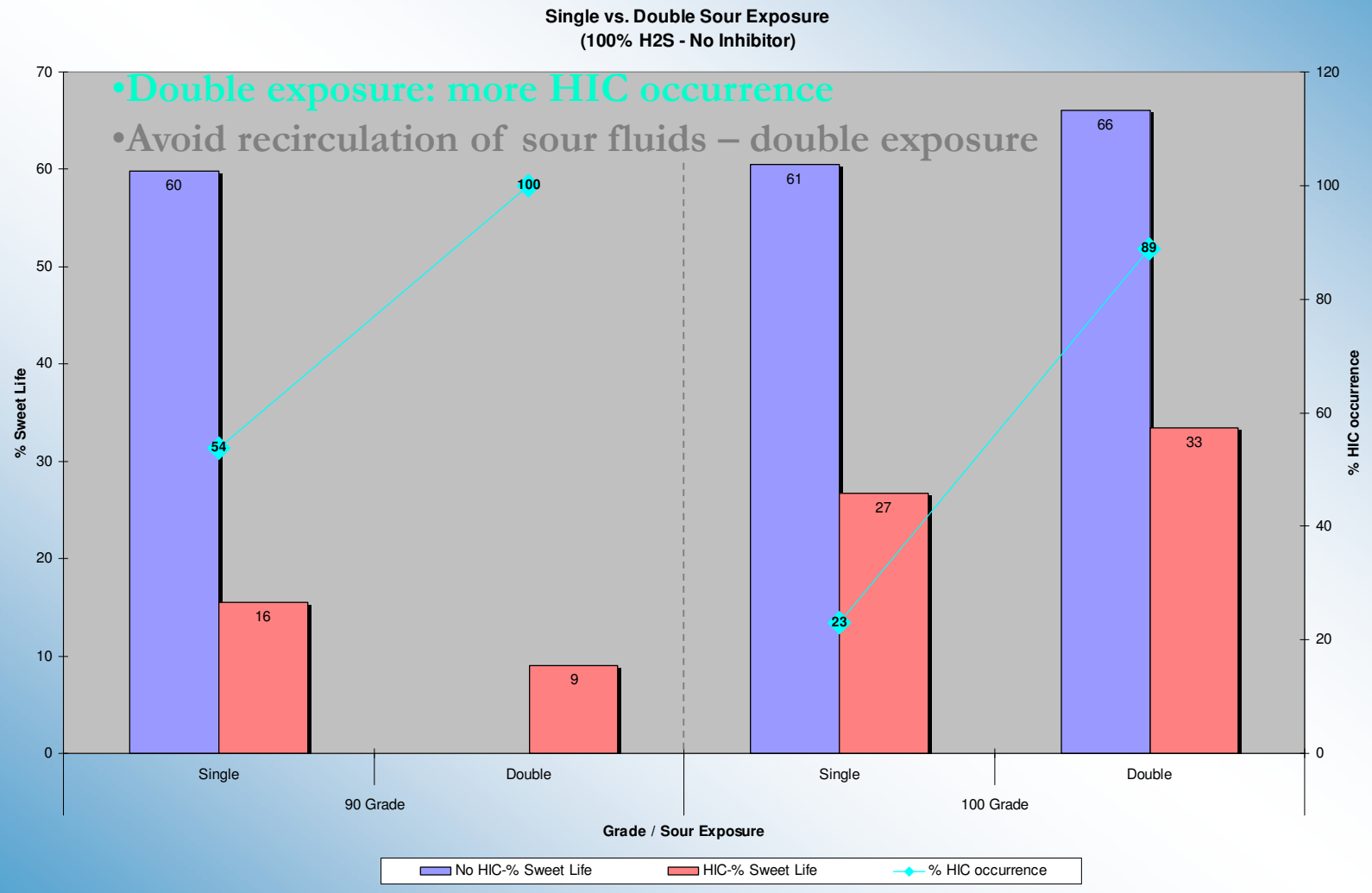
Examples of SSC failures on 100 grade bias welds

Sour Serviceability of Higher-Strength Coiled Tubing
Tensile Integrity

- **Considering restrictions regarding use of anti-cracking inhibitor, 90 and 100 grade samples maintained tensile integrity.**
- **110 grade: not acceptable performance**



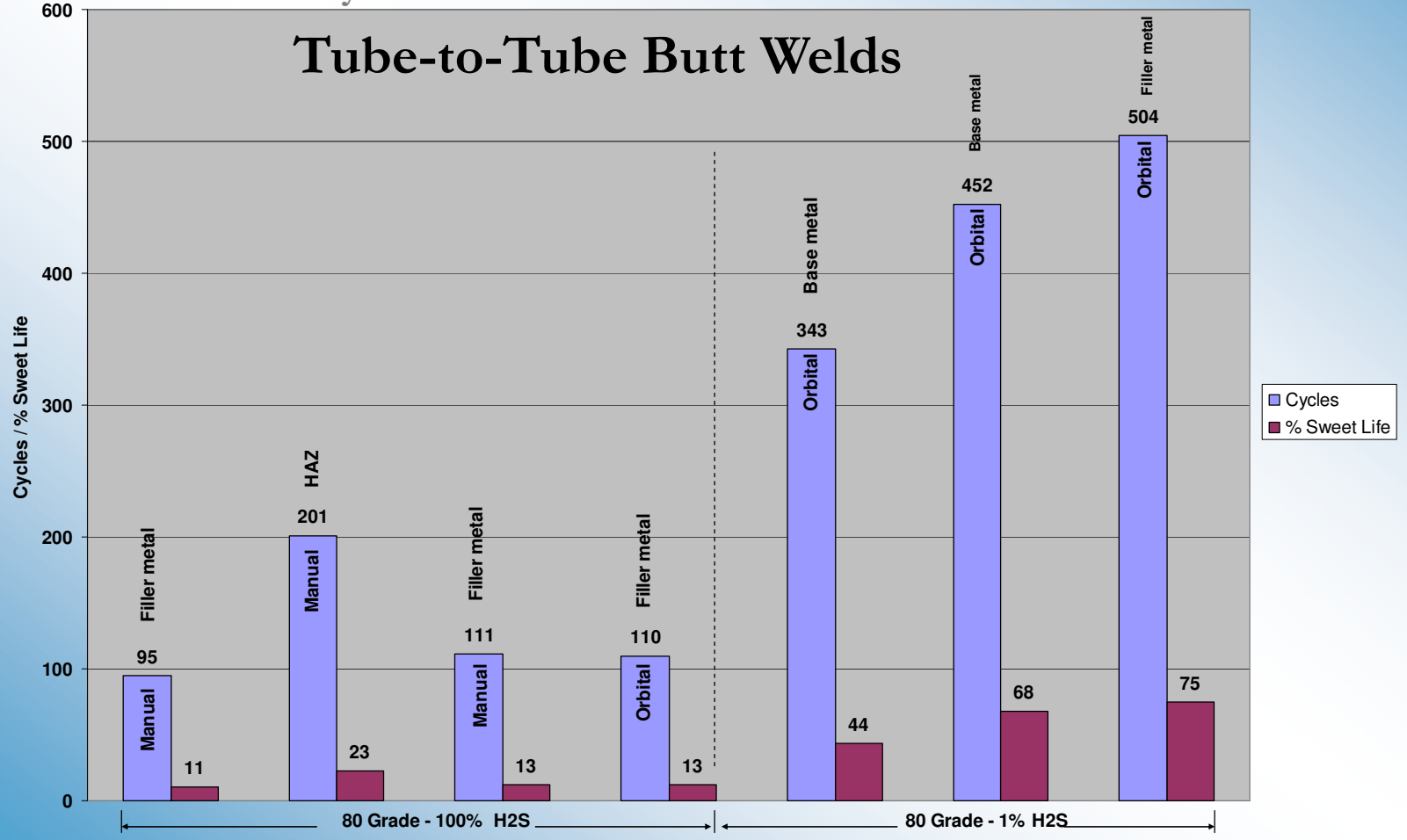
Sour Serviceability of Higher-Strength Coiled Tubing
Single vs. Double Exposure



Sour Serviceability of Higher-Strength Coiled Tubing

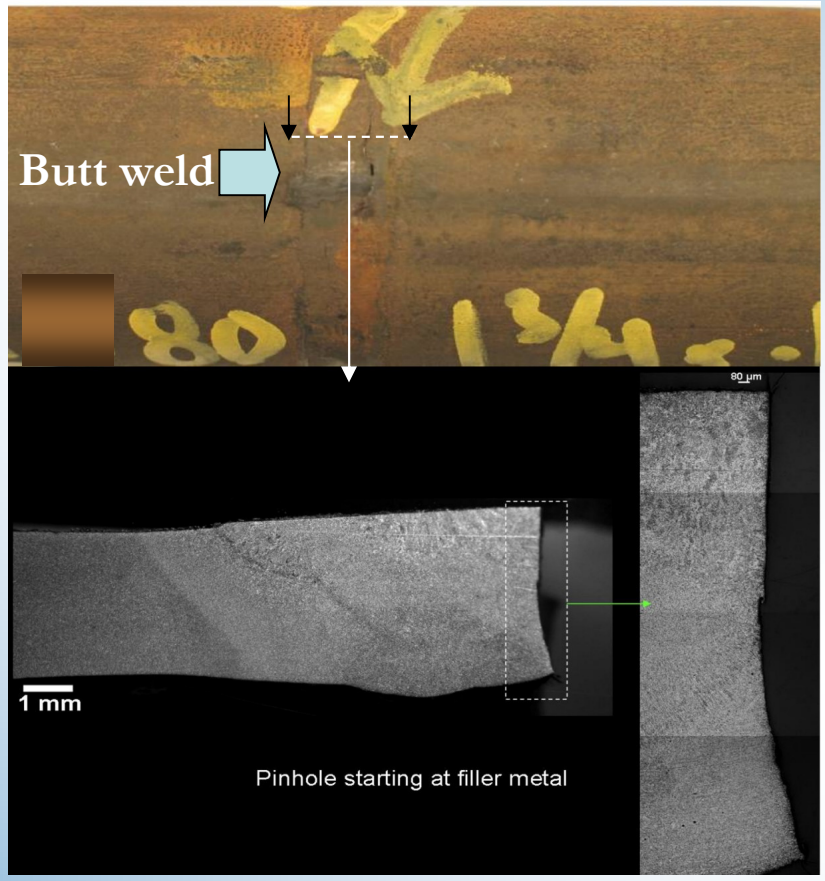
CT Welds Sour Fatigue Performance

- 80 grade+100% H_2S: worse performance than pipe body and bias weld
- Failures mainly at the weld



Sour Serviceability of Higher-Strength Coiled Tubing
CT Welds Sour Fatigue Performance

Tube-to-Tube Butt Welds



Example of failure at the butt weld filler metal

Sour Serviceability of Higher-Strength Coiled Tubing
Conclusions / Practical Applications

- 80 and 90 grade presented similar acceptable sour fatigue performance – consider restrictions
- 100 grade: more strict restrictions due to bias weld sour performance
- 110 grade did not comply acceptance criteria for sour service:
  - Not acceptable on pipe body CLT
  - Not acceptable on bias weld fatigue tests

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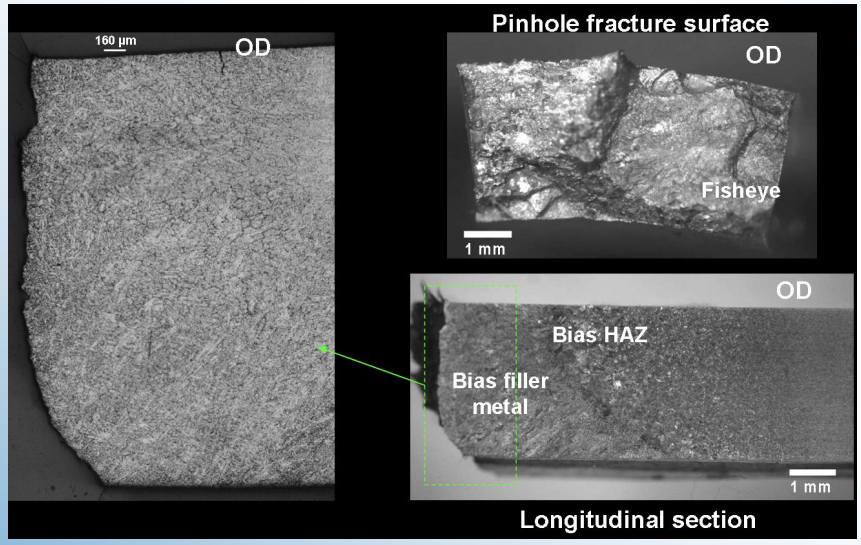
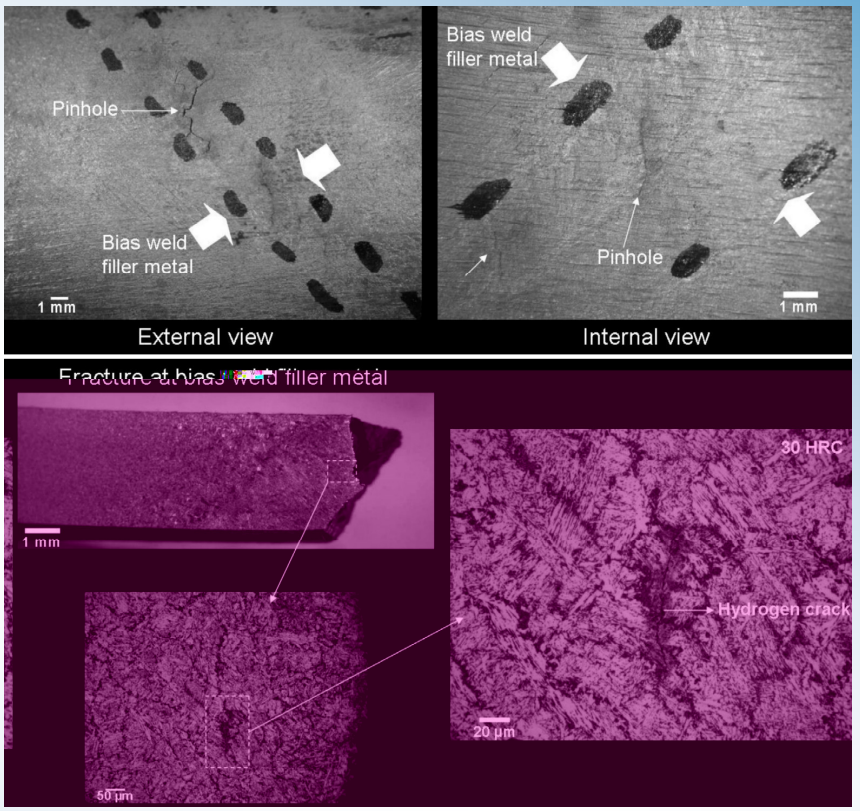
Sour Serviceability of Higher-Strength Coiled Tubing
CT Welds Sour Fatigue Performance



100 grade bias + 50% H_2S



110 grade bias + 50% H_2S

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