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Testing of Completion Tubular Connections for HPHT / Deepwater Environment to API RP 5C5: 2017 Case Study & Lessons Learned

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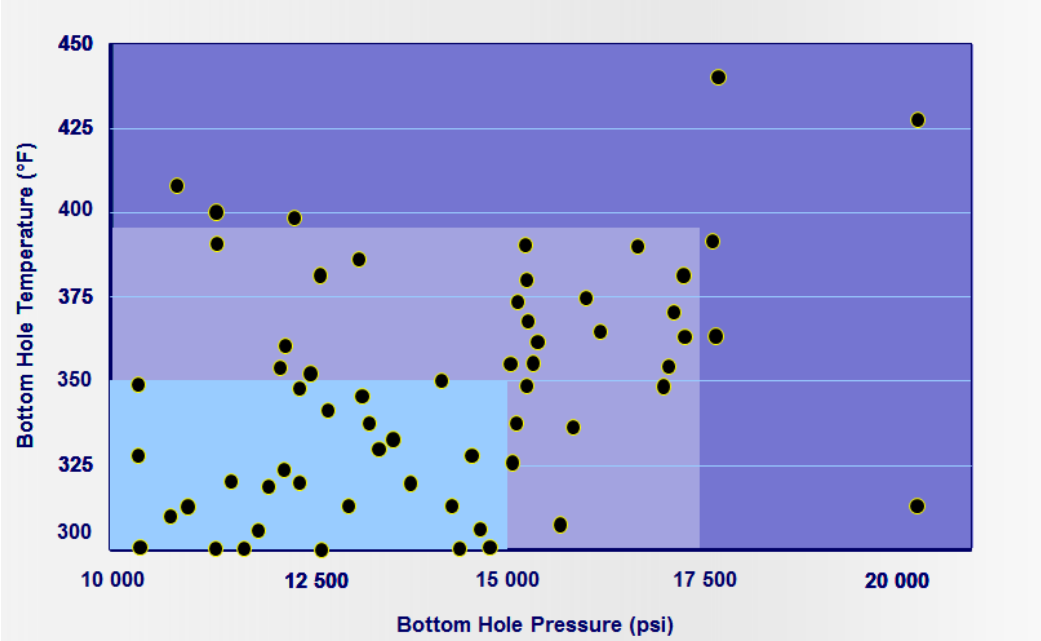
Overview

- There is an increased focus, from both operators and governments, on the targeting of deep water and HPHT wells globally.
- This leads to products that are mandated to meet the latest and most stringent qualification levels.
- For OCTG connections, API RP 5C5: 2017 is the latest standard to perform testing.
  - This is a more rigorous protocol and is aimed to be representative of the potential deepwater HPHT environment



Agenda

- API Recommended Practice (RP) 5C5: 2017 Overview
- Connection Selection Process
- Testing Protocol
- Material Characterization
- Connection Machining
- Make-up & Break-out (M&B) Testing
- Specimen Characterization
- Test Frame & Strain Gauges
- Sealability Testing (Series B, C and A)
- Limit Load Testing
- Coordination, Communication & Key Lessons Learned
- Conclusion

Overview of API Recommended Practice 5C5:2017

Fourth edition released on January 2017.

Stringent testing requirement to address severity of HPHT well loads.

Less samples – Each tested to a wider variety of loads.

Addition of Test Series A at elevated temperature.

Addition of Quadrant 1 – Quadrant 3 cycling.

More comprehensive understanding of material behaviour (eg. Compressive hoop yield).

Inclusion of extreme specimen geometries.

These changes lead to higher testing complexity, more time-consuming, and increased testing costs!

Connection Selection Process

- Review technical specifications of the connections.
- Review Technical Readiness Level (TRL) of each connection.
- Review testing history on relevant dimensions
- Review field experience
- Assessed supplier confidence and performed gap assessment to achieve a successful API RP 5C5: 2017 CAL IV test.

VAM 21

Threaded & coupled premium connection

Metal-to-metal seal

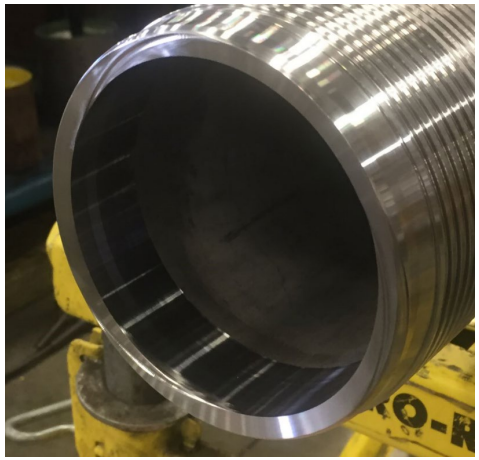
100% efficiency

Seal independent from shoulder

Double taper guide

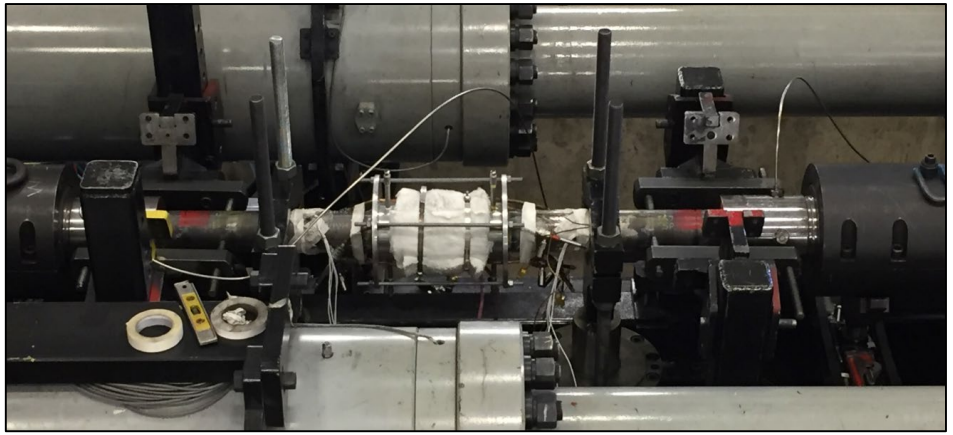
Multi-grooving

Cylindrical thread roots & crests



Testing Protocol

- Through conversation between the operator and supplier, the sizes to be tested were agreed with associated protocols and abbreviations.
  - 4.5” 18.9 ppf, VAM® 21 (full CAL IV)
  - 3.5” 12.7 ppf, VAM® 21 (abbreviated CAL IV)
    - Specimens 1, 4, and 5
  - 5.0” 23.2 ppf, VAM® 21 (abbreviated CAL IV)
    - Specimens 1, 4, and 5



- Materials
  - 25Cr (4.5”, 3.5”)
    - Application for producers & injectors
  - Super 13Cr (5.0”)
    - Application for producers only

- Testing Temperature deviation
  - 300 ºF (load testing)
  - 327 ºF (material testing)
- Thread compound applied

Material Characterization

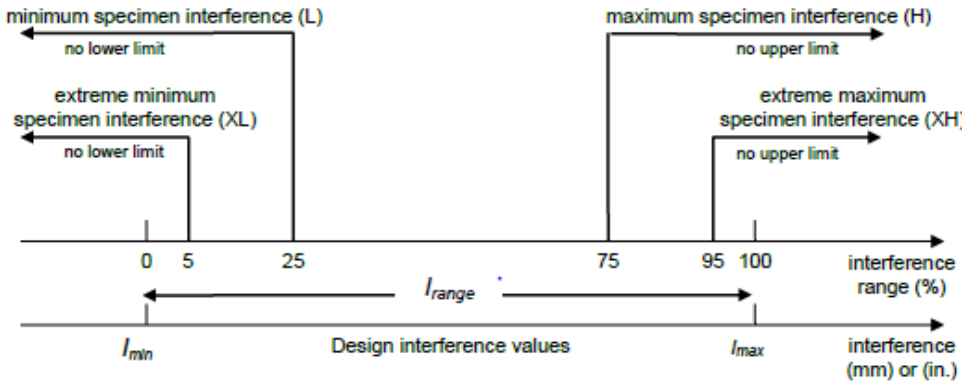
- Pipe/coupling stock mechanically tested to determine yield strength.
- One pipe and coupling stock coupon used to determine scaling factors.
  - Elevated tensile & compression
  - Transverse tensile
  - Ambient compression
- Yield strength measured:
  - At ambient & elevated temperature
  - Taken in longitudinal & transverse directions
  - With tensile & compressive loading
- Wall thicknesses & ODs measured on made-up specimens.

Connection Machining

- Aim is to test worst-case performance combinations.
- Four interference categories:
  - XL – extreme min. specimen interference (<5%)
  - L – min. specimen interference (<25%)
  - H – max. specimen interference (>75%)
  - XH – extreme max. specimen interference (>95%)

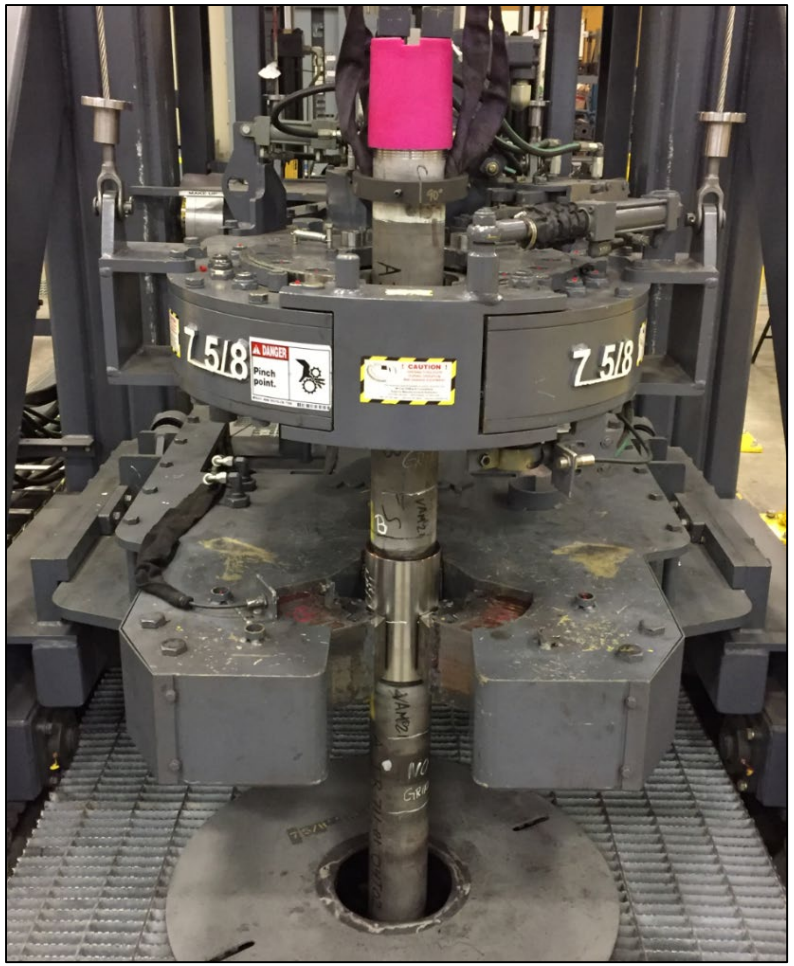
Specimen Number	Summary of Objectives	Made-up Condition	Thread Interference	Seal Interference	Pin Thread Taper	Box Thread Taper	Final Torque
1	Thread galling and sealing	Minimum seal interference	Extreme high	Extreme low	Slow	Fast	Minimum
2	Sealing	Minimum seal interference	Extreme high	Extreme low	Slow	Fast	Minimum
3	Seal galling and sealing	Maximum seal interference	Low	High	Fast	Slow	Maximum
4	Sealing	Maximum torque into shoulder	Low	Low	Slow	Fast	Maximum
5	Galling	Maximum overall tightness	High	High	Fast	Slow	Maximum

- Interferences applied to connection thread/seal diameters & thread taper.
- Grooved torque shoulder:
  - Not required with VAM® 21 due to multi-grooving feature



Make-up & Break-out (M&B) Testing

- Aim to evaluate galling sensitivity of the VAM® 21 connection design.
- Target is 9 M&B's plus Final Make-Up.
- M&Bs: SP1,4 (B-side), SP3 (A-side), SP5 (A/B-sides).
- Thread compound utilized is Jet-Lube Seal Guard to represent field conditions
- Make-up Torque
  - High Torque > 80% max torque + 20% min torque
  - Low Torque < 80% min torque + 20% max torque
  - M&B (high); FMU (SP1,2 – low; SP3,4,5 - high)
- SP5 was tested first to avoid damaging a sealability specimen; allowed for interim adjustments if needed, none were required.

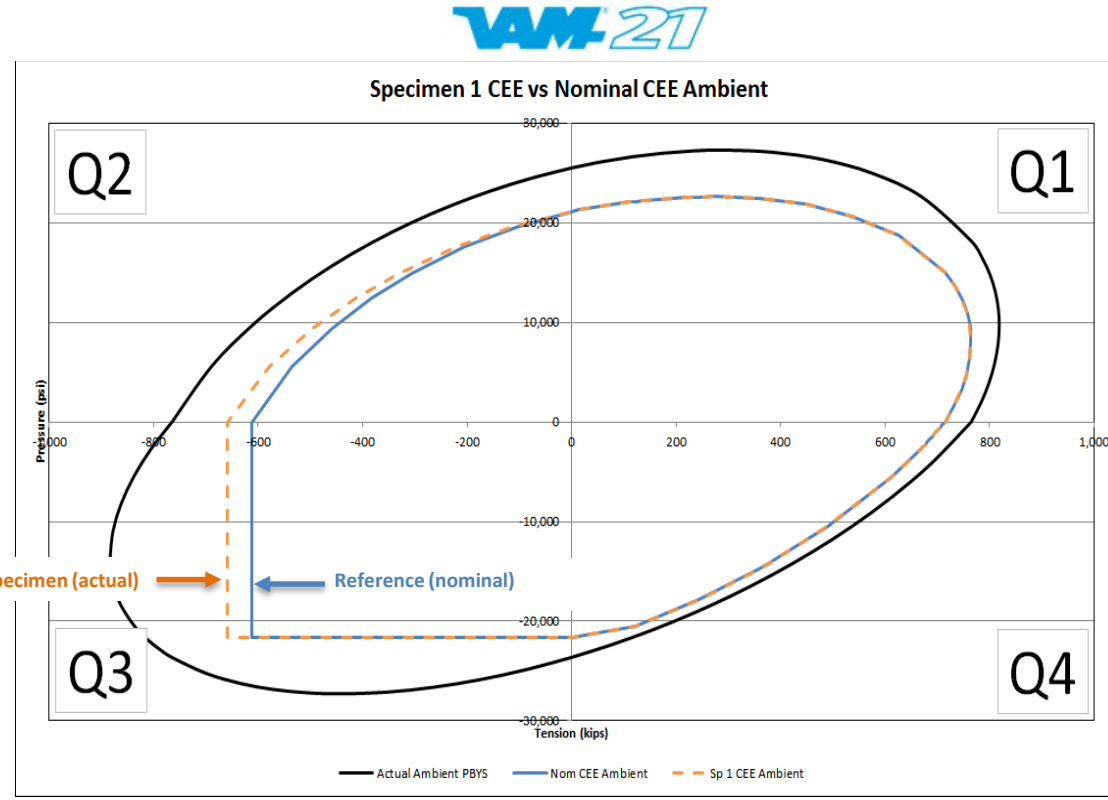


Specimen Characterization

- Specimen-specific Connection Evaluation Envelope (CEE) is developed using the actual material.
- Each specimen tested to its actual performance capabilities based on material properties.

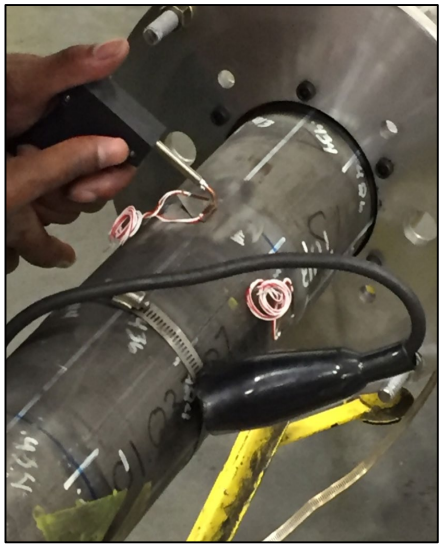
Example

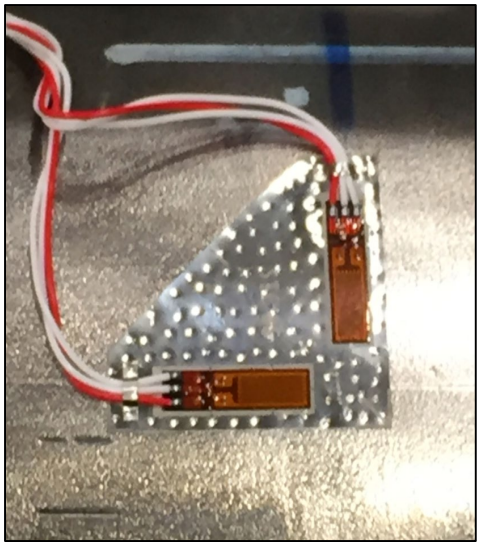
- Reference curve (planning phase) truncated based on 80% PBYS in compression.
- Actual compression: 86% PBYS based on material testing.



Test Frame & Strain Gauges

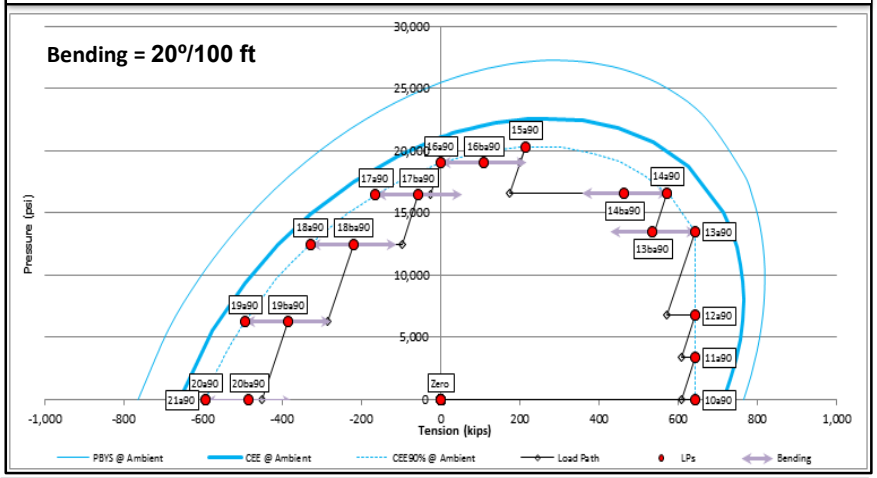
- Combined Load Frame (CLF) capable of 5 load components:
  - Internal pressure – up to 35k psi
  - External pressure – up to 35k psi
  - Tension
  - Compression
  - Bending
- CLF equipped with anti-buckling fixtures.
- Biaxial strain gauges mounted on both sides of the connection.
- Strain gauges only used during Series B and C testing.
- Used (primarily) to quantify bending loads.
- Temperature applied with induction coils (carbon steel) or ceramic heating blankets (CRA).



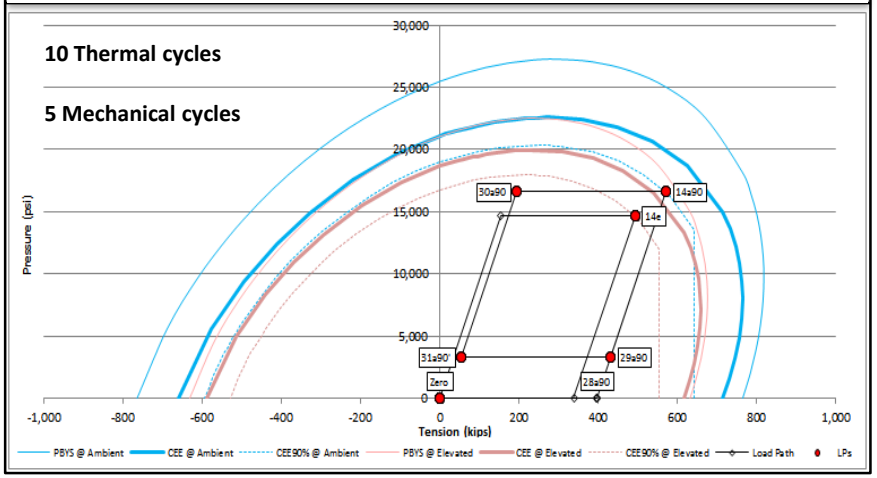


Sealability Testing (Series B, C, and A)

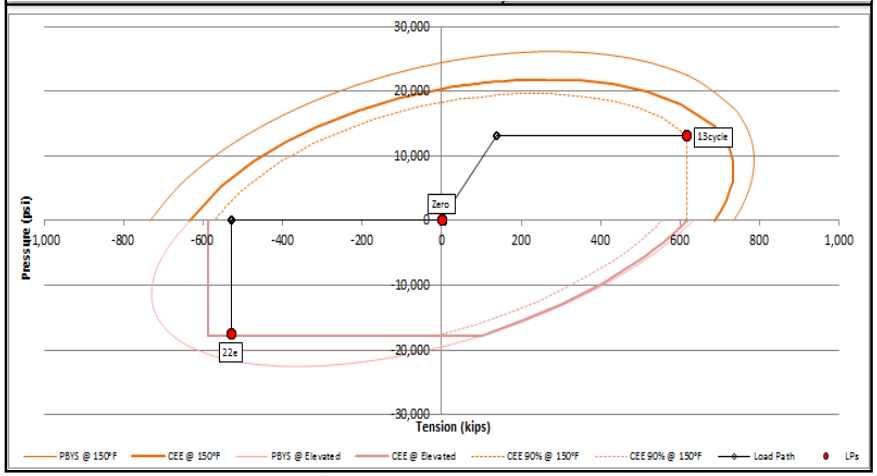
Series B



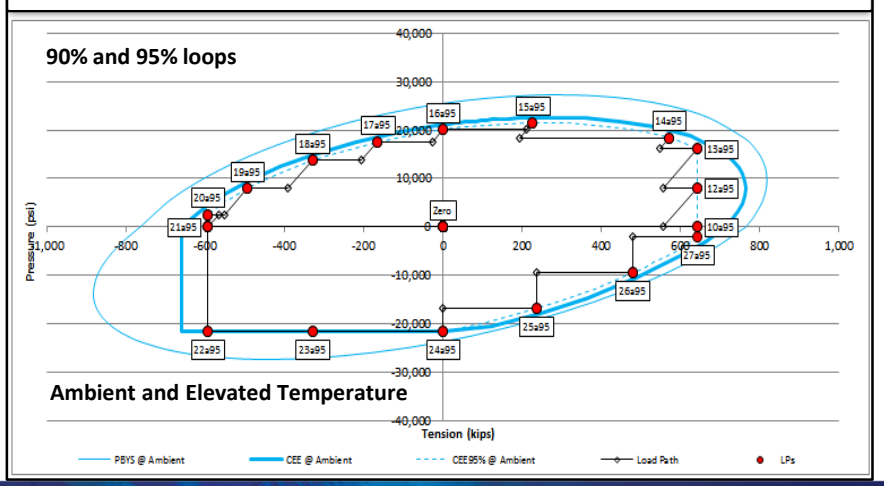
Series C



Q1 – Q3 Cycles

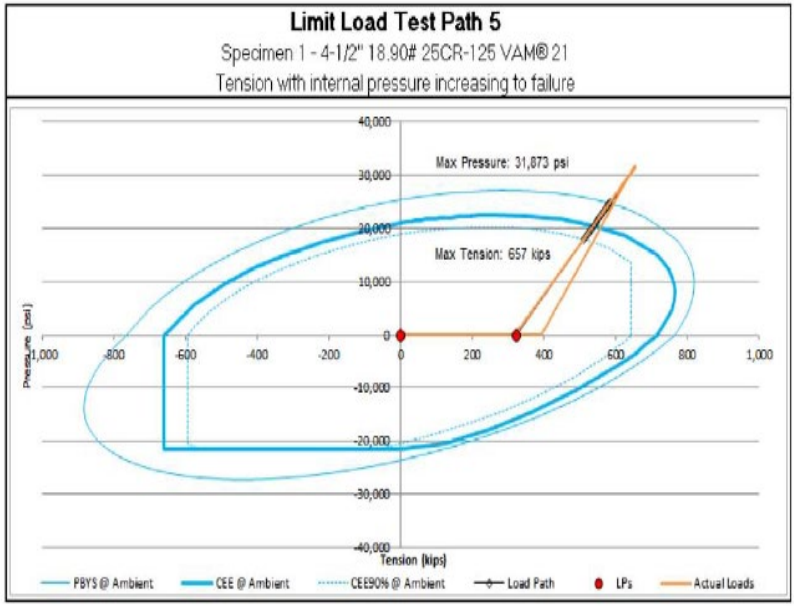


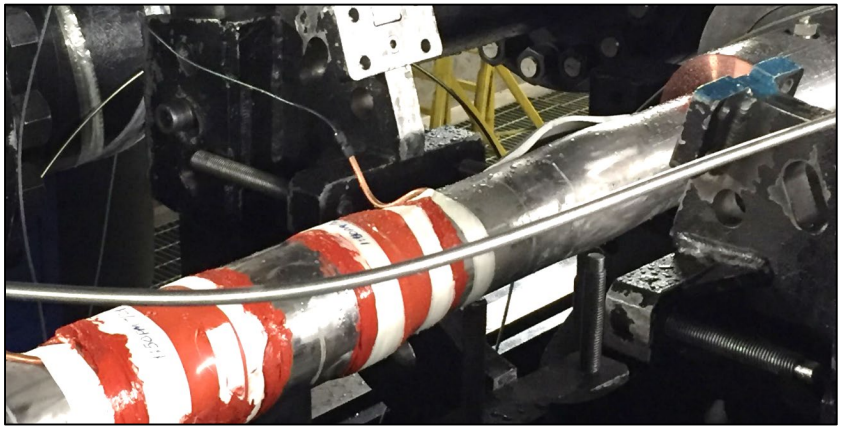
Series A



Limit Load Testing

- Purposes:
  - To establish structural limits of the specimen.
  - To demonstrate structural performance beyond CEE.
- 5 limit load (LL) paths
  - Specimen 1: LL5 – Tension + IP increase to failure
  - Specimen 2: LL4 – IP + compression increasing to failure
  - Specimen 3: LL3 – IP + tension increasing to failure
  - Specimen 4: LL2 – Compression + EP increasing to failure
  - Specimen 5: LL1 – Tension increasing to failure





Key Learnings from this Case Study

- Both operator and supplier were aware of the inherent challenges in the testing program.

- Enhanced communication
  - Frequent and transparent communication between operator and supplier is essential to success.
  - In-depth kick-off meetings to communicate performance needs (operator) and connection capabilities (supplier).
  - Regular and Milestone meetings ensured everyone kept up to date during testing.
  - Detailed weekly reports issued by supplier.
  - Any testing issues were dealt with promptly and with full agreement of both parties.
  - Deviations from 5C5 were agreed upon before any actions were taken.

Conclusions

- At the conclusion of the program, both parties were fully aware of all the program details, thus:
  - The supplier has confidence that the VAM® 21 connection was tested to its full capacity.
  - The operator has confidence that the VAM® 21 connection is qualified for deepwater/HPHT service.
- API RP 5C5: 2017 introduces an increased testing rigor to address the severity of HPHT well environments.
- Qualification process works to validate the structural integrity and sealability of the OCTG connections for use in deepwater/HPHT projects.
- Collaboration and proactive communication between operator and supplier leads to success.
- The rigorous testing approach demonstrated the connection was suitable for all foreseeable field loads.

Questions

Thank you