Designing Safe and Reliable HPHT Subsea Wellhead Systems

New Technology to Accommodate a System Approach to Verification Analysis and Validation Testing

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Outline

- **HPHT Systems Requirements and Challenges**
- **Wellhead System Overview**
  - System Verification Analysis
  - System Validation Testing – New Horizontal Test Machine
- **New HPHT Wellhead System Design Concept**
- **Advanced Product Quality Planning (APQP)**
- **Conclusions**

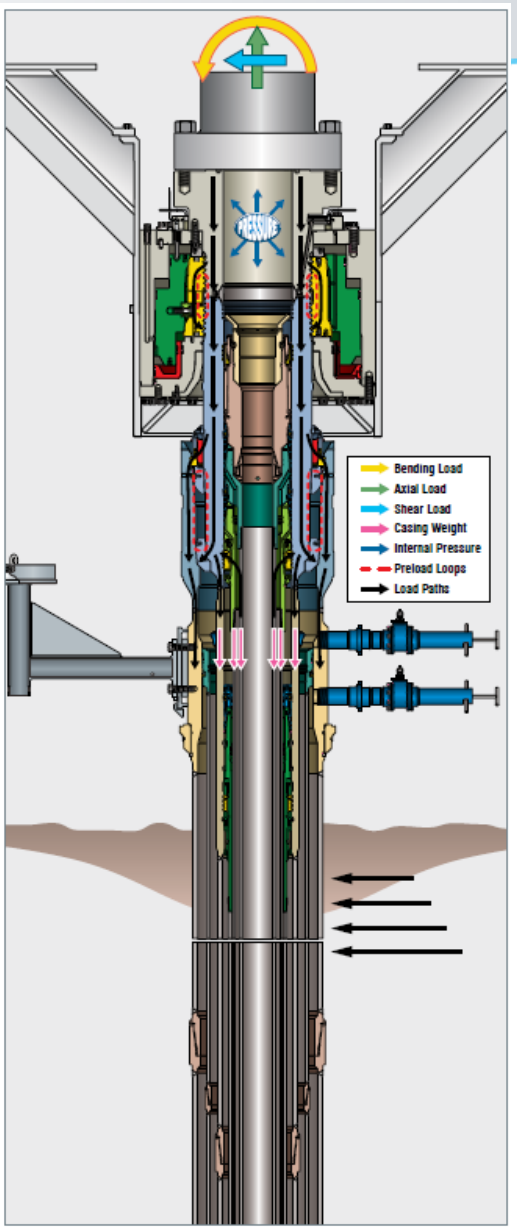
HPHT Subsea Systems

- **Requirements**
  - **Pressure > 15 Ksi (103.4 MPa) and/or Temperature > 350ºF (176.7ºC)**
  - **Higher Structural Load Capacity Requirements**
  - **Longer Fatigue Life Requirements**
  - **Need for Next Generation HPHT Equipment**
- **Challenges**
  - **Uncertainties with Environmental Effects on Material Properties**
  - **Lack of HPHT Material Properties at Different Environments**
  - **More Stringent Regulatory Requirements for Verification Analysis and Validation Testing**
  - **New Tools and Technology Needed**

Subsea Wellhead Systems Overview

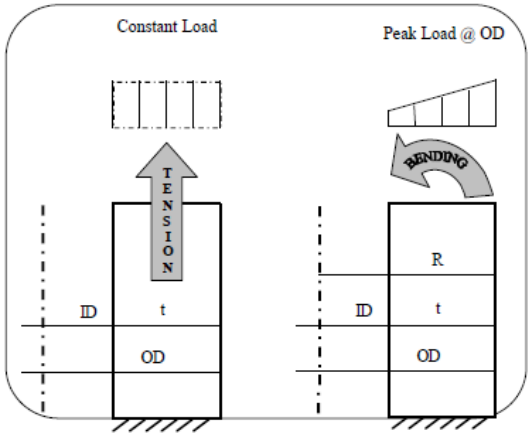
The Wellhead is the topmost component of a well, suitable for the life of the well, non-retrievable, and provides:

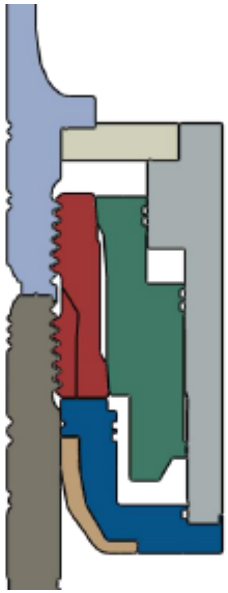
- External Load Resistance
- Pressure Containment
- Pressure Controlling Interfaces
- Hanging Interface & Weight Support
- Fatigue/Cyclic Load Resistance
- Barrier to Environment



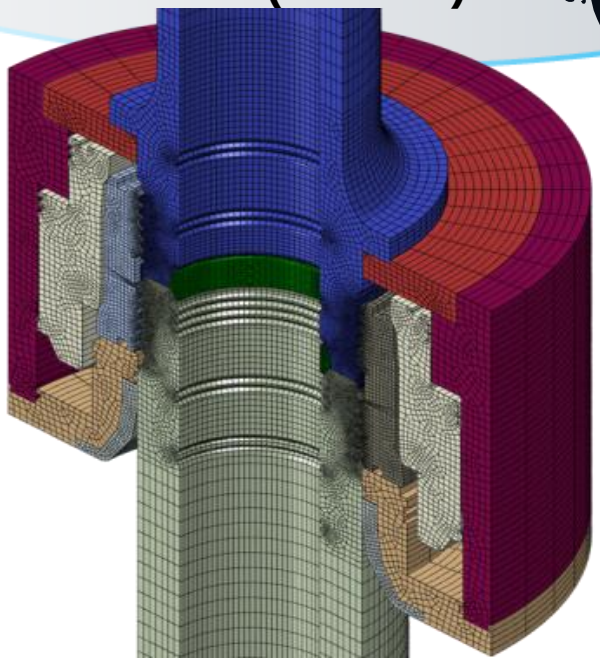
Verification Analysis

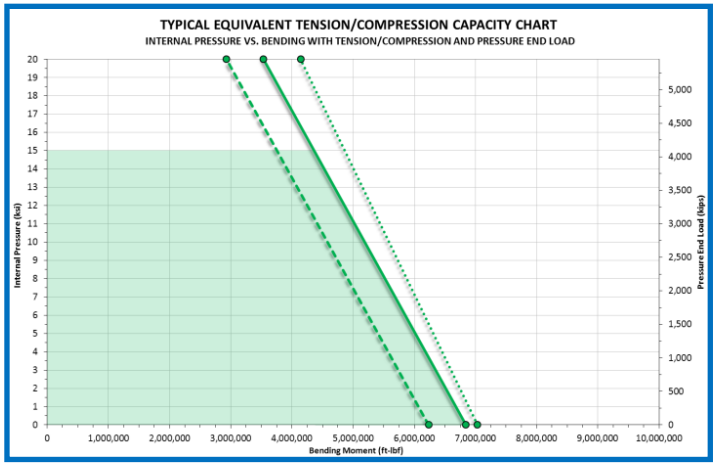
- **Traditional (Hand Calculations, Equivalent Tension, 2D FEA)**

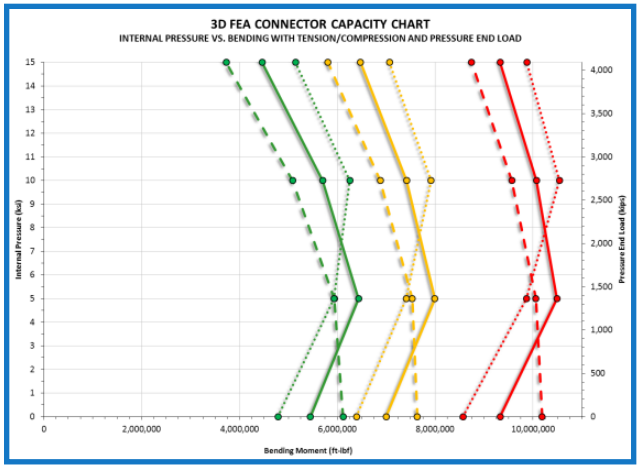




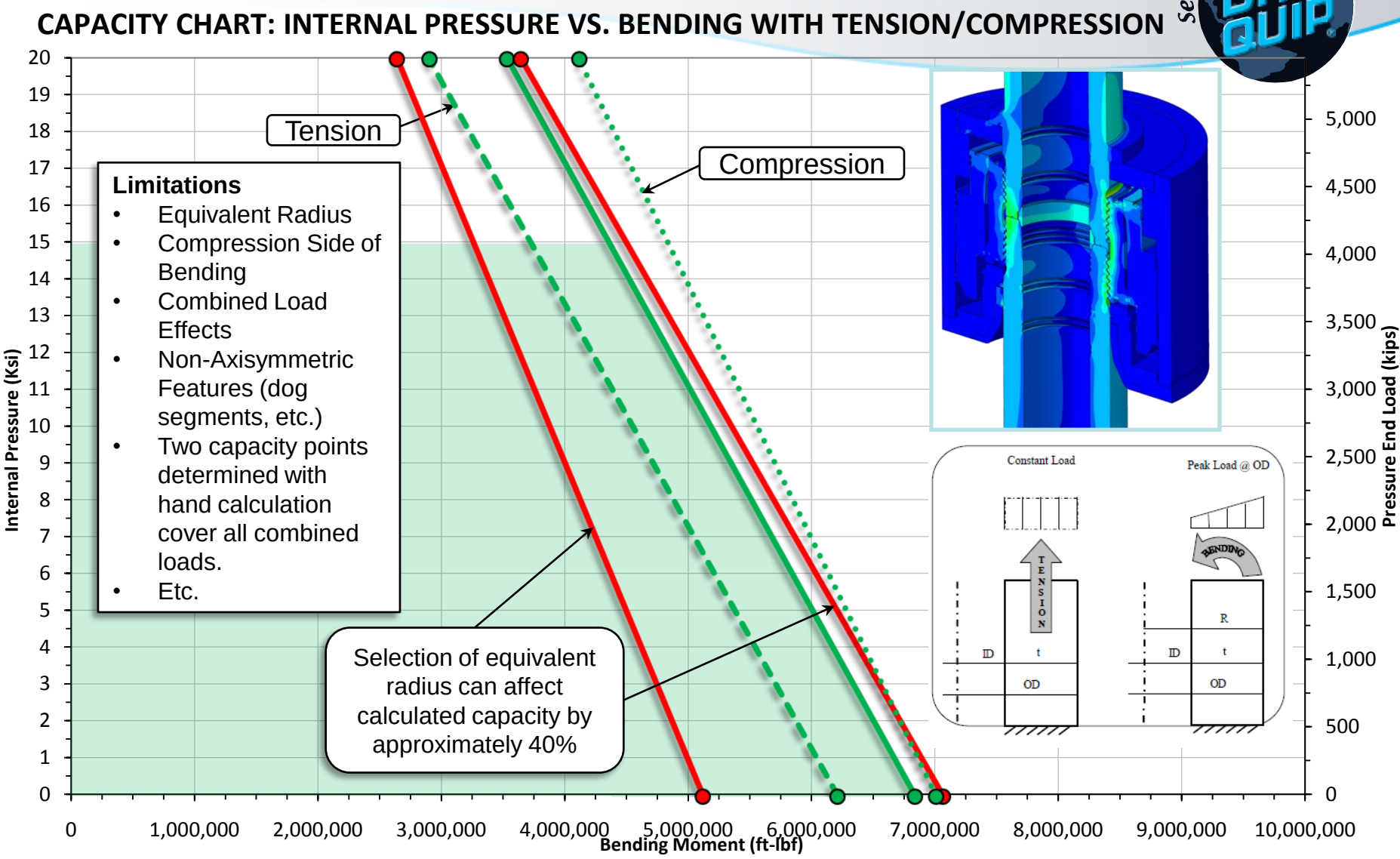
- **Advanced (3D FEA)**





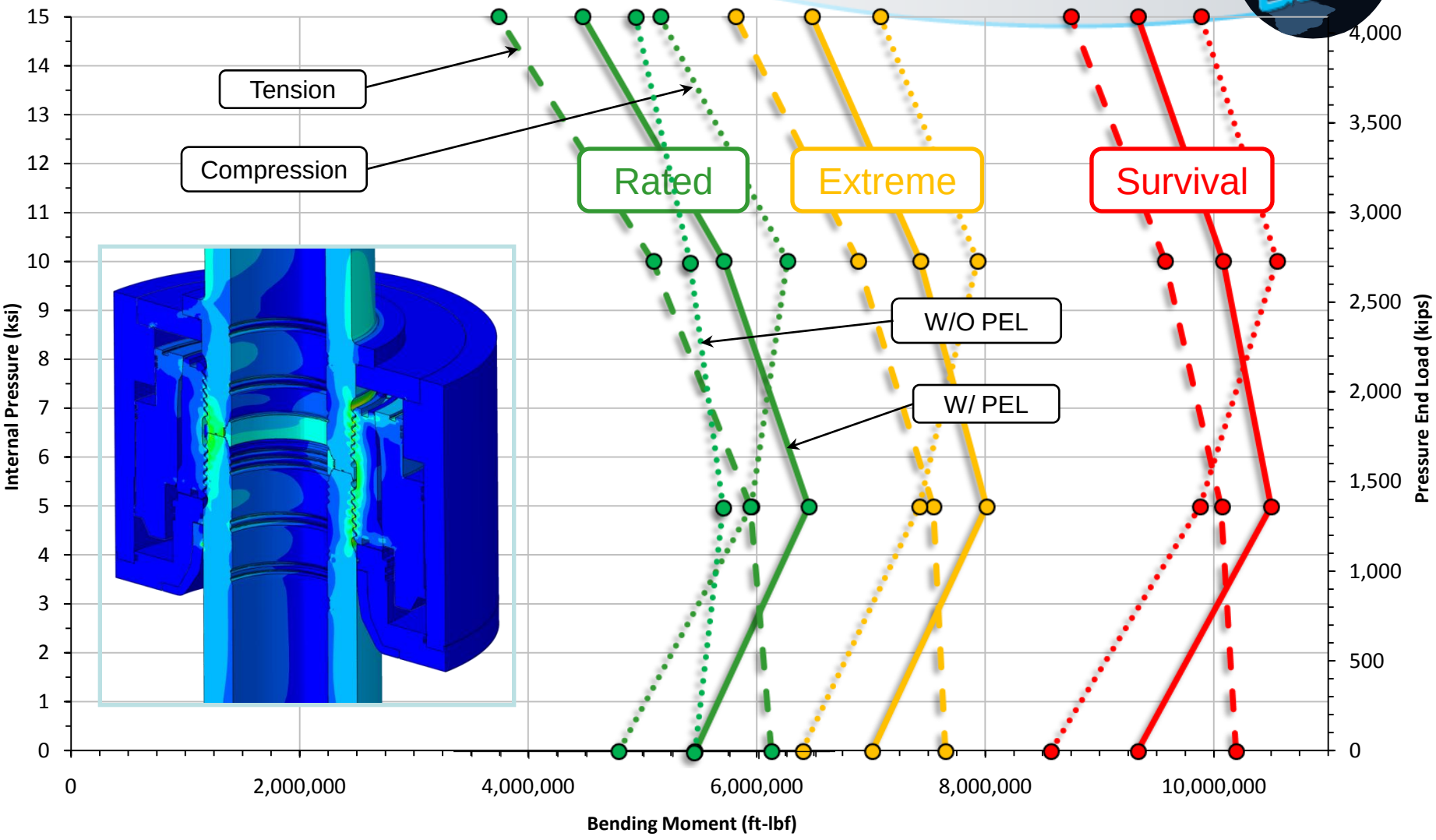


Equivalent Tension/Compression



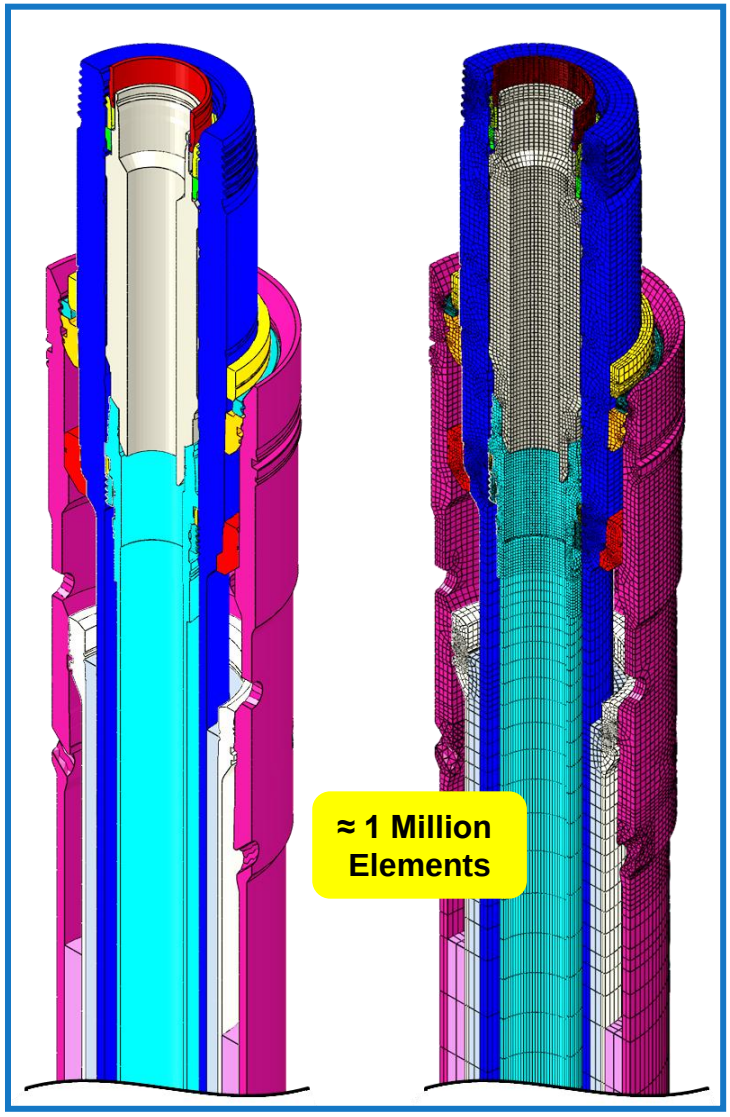
3D FEA Capacity Chart

INTERNAL PRESSURE VS. BENDING WITH TENSION/COMPRESSION AND PRESSURE END LOAD

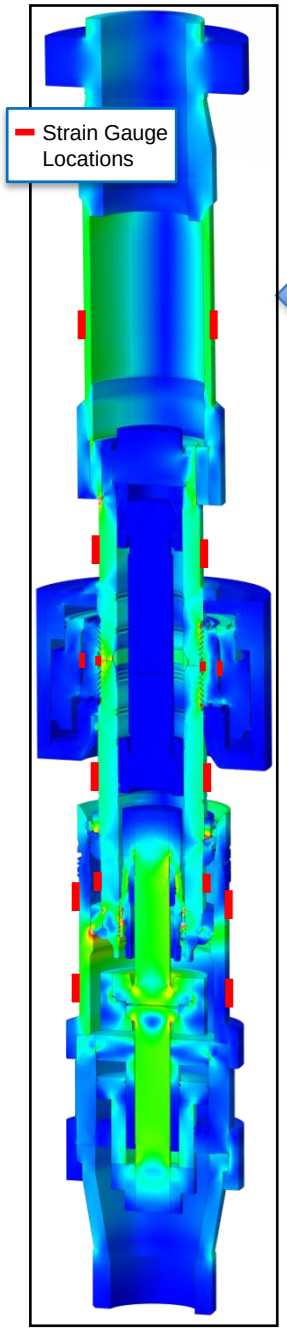


Wellhead System Global Analysis

- **Loading Conditions**
  - Mechanical Preload
  - External Loads
  - Pressure
  - Pressure End Load (i.e. shear rams closed)
  - Casing Program & Weights
  - Thermal Loads
  - Cyclic Loads
- **3D FEA Model**
  - 200 ft Below Mudline
  - Non-linear Geometry Behavior
  - Over 1 Million Elements
  - No Tied Constraints
  - Modeled with Cement
  - Soil Properties
  - Installation sequence closely mimics field conditions
- **Static and Fatigue Evaluation**

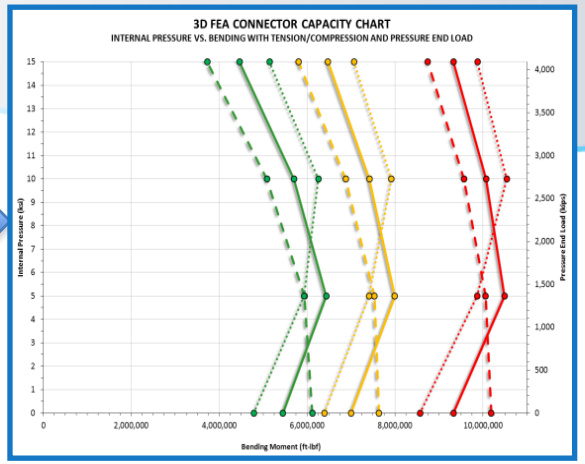


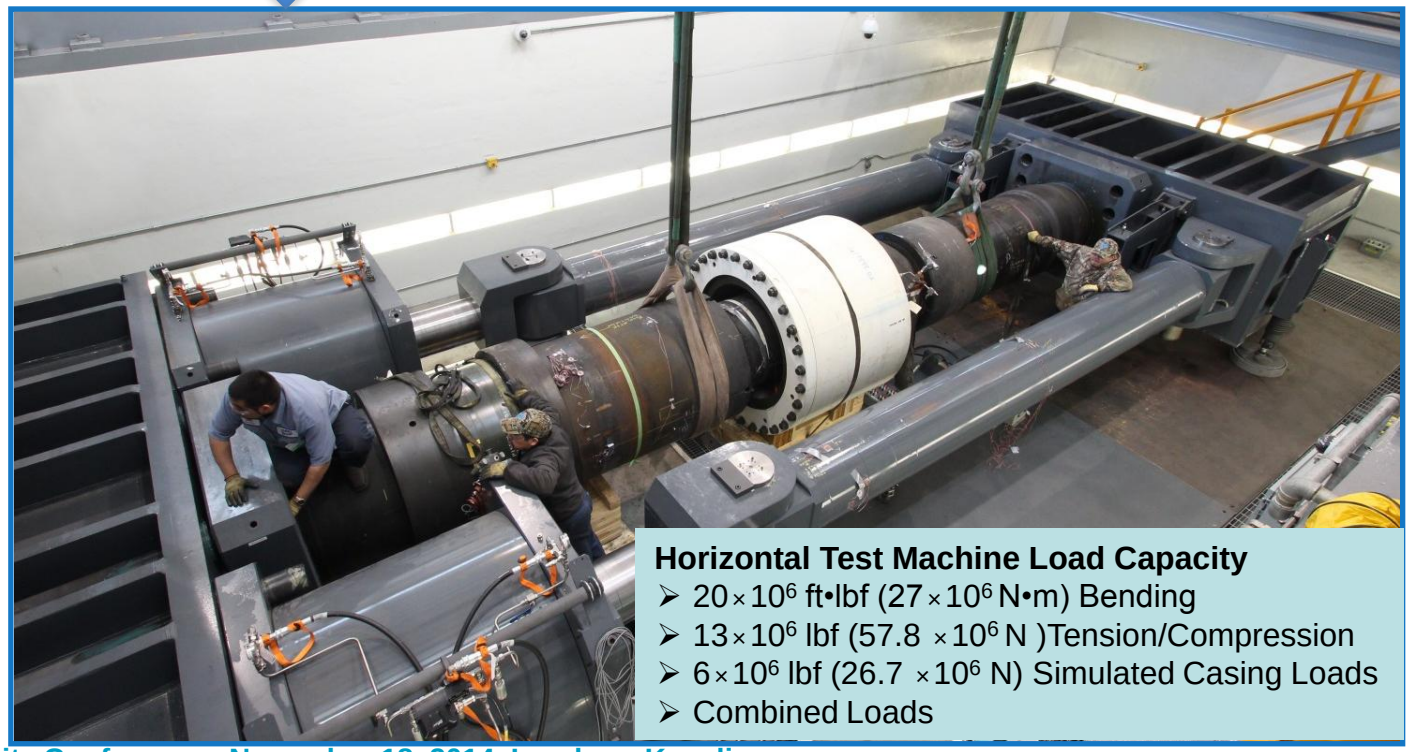
API PER15K System Analysis & Testing



Wellhead System

- Assembly:
  - Wellhead Connector
  - Low Pressure Housing
  - High Pressure Housing
- Process:
  - Preloaded System
  - 6MM lbf. Casing Weight
  - Apply Loads per Capacity Chart
  - Results Comparison
  - Inspection
  - Third Party Witness





Horizontal Test Machine Load Capacity

- 20×10^6 ft•lbf (27×10^6 N•m) Bending
- 13×10^6 lbf (57.8×10^6 N)Tension/Compression
- 6×10^6 lbf (26.7×10^6 N) Simulated Casing Loads
- Combined Loads

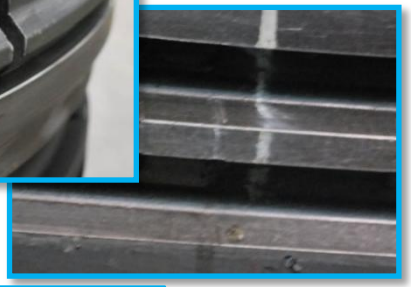
Wellhead System Post-Test Inspection

Compression

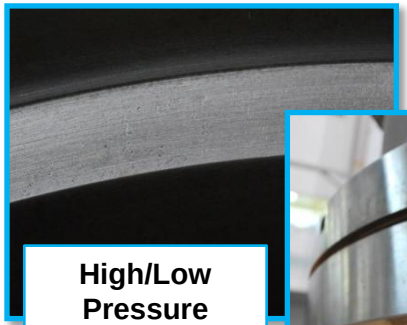
Tension

Connector Hub Face and Load Shoulders

Connector Load Shoulders



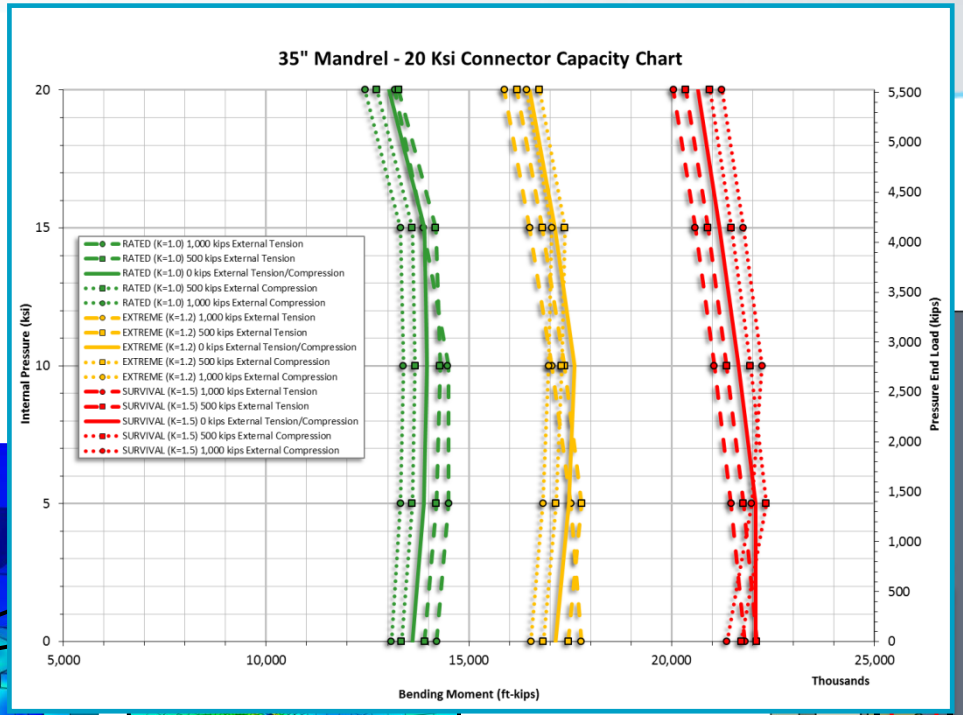
High/Low Pressure Housing Load Shoulder Interface

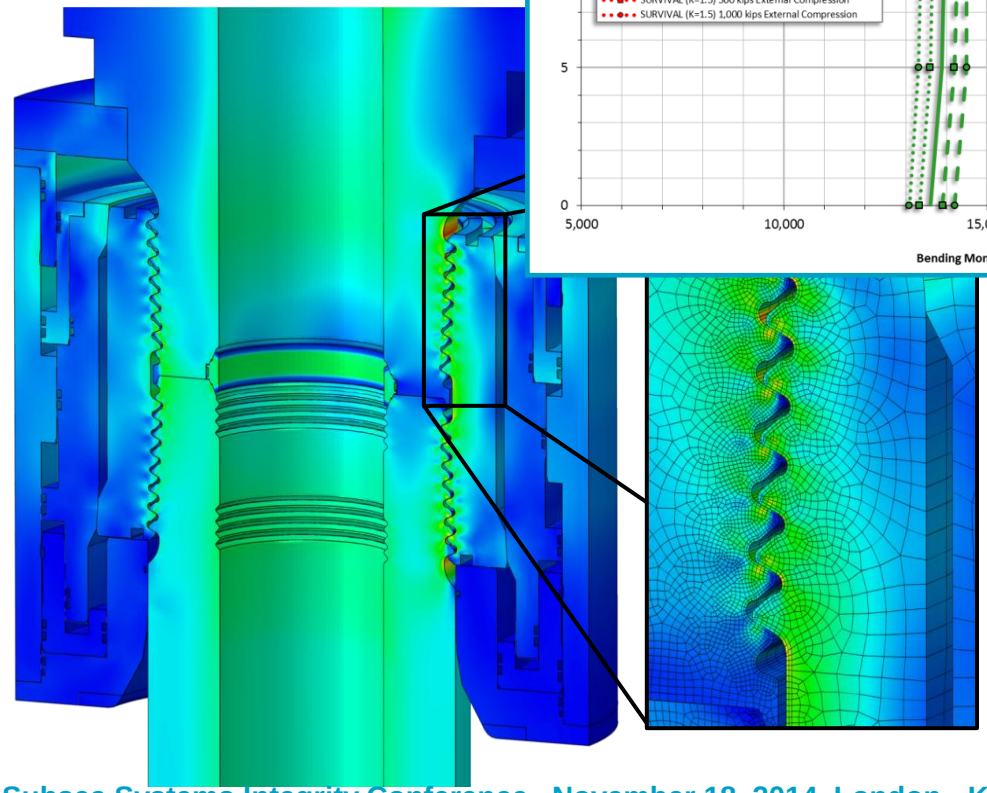


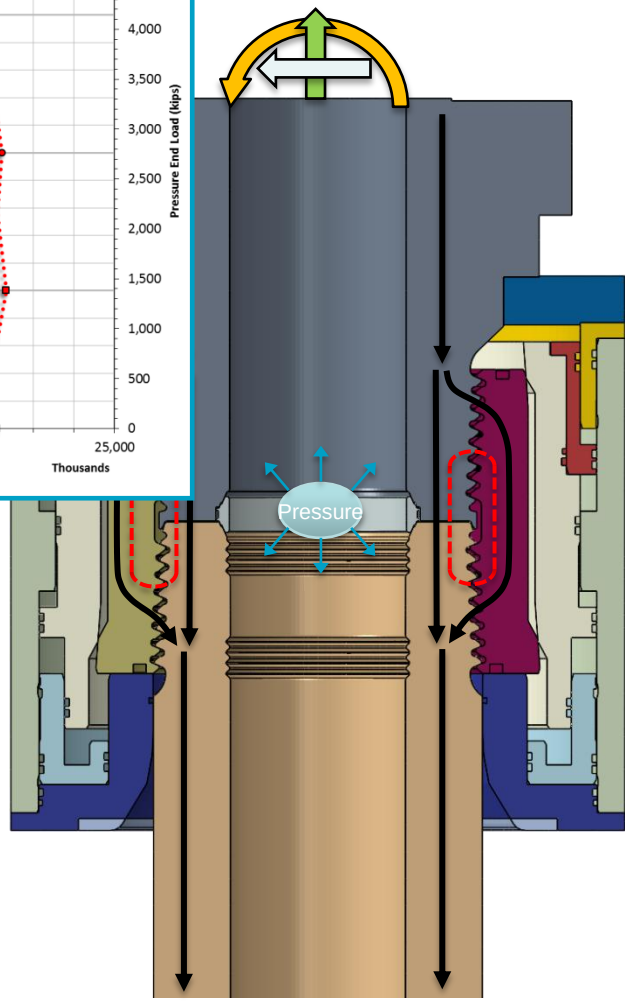
High/Low Pressure Housing Bending Reaction Ring

20Ksi Wellhead Connector

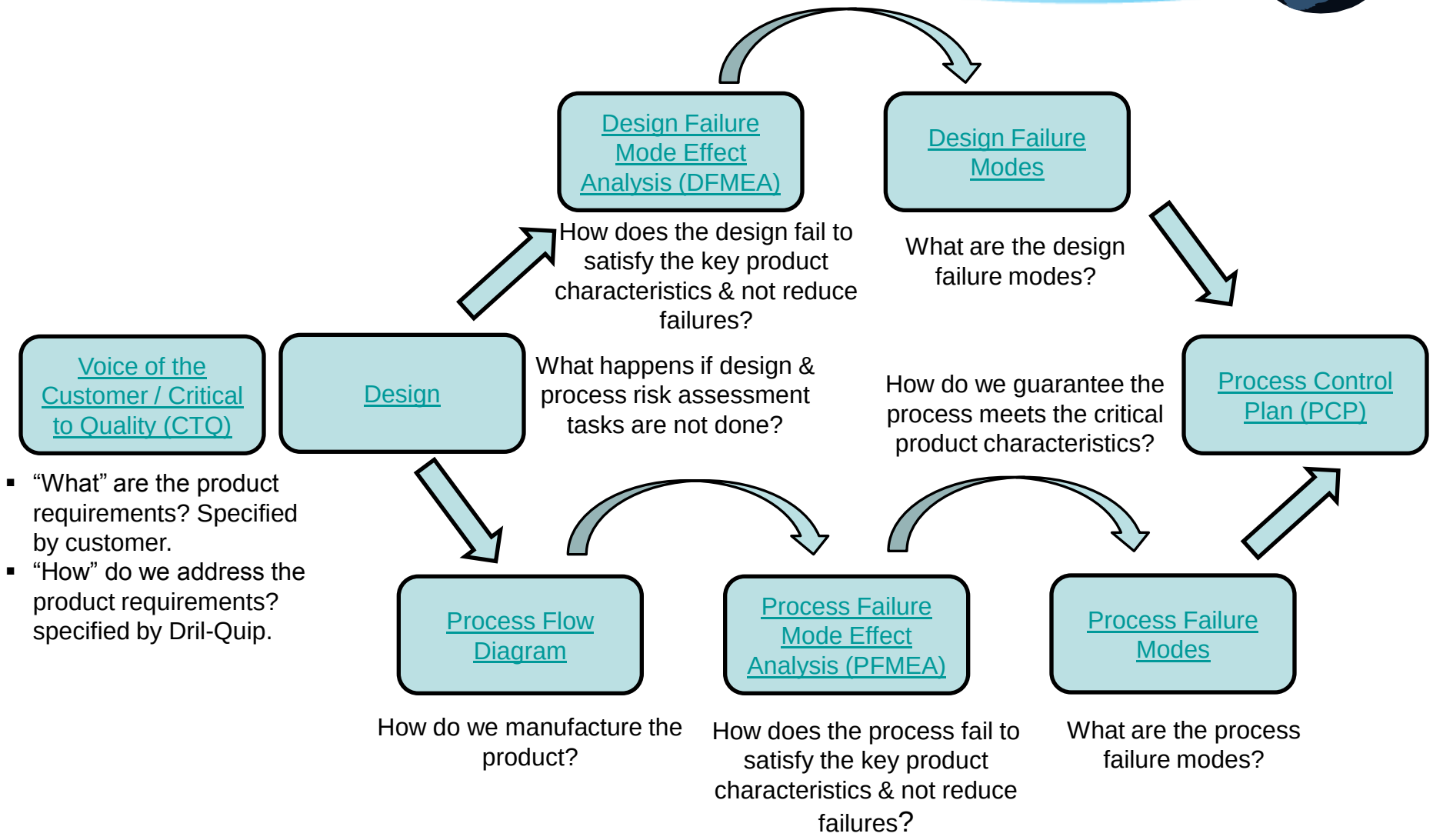
- 35″ OD Wellhead Mandrel.
- ~Twice Rated Capacity of the 15ksi Connector
- ~10 Times More Fatigue Life than Traditional 15ksi Connector
- 20 Ksi (137.9 MPa) Rated Pressure
- > 20×10^6 ft•lbf (27×10^6N•m) Survival Bending Capacity







Advanced Product Quality Planning
APQP Process



- "What" are the product requirements? Specified by customer.
- "How" do we address the product requirements? specified by Dril-Quip.

Conclusions

- A wellhead system verification analysis and validation test has been successfully completed and provided better understanding of the wellhead system performance.
- System validation testing provided critical information needed to make proper adjustments to the verification analysis methodology
- Knowledge obtained from this test program is being applied for HPHT development work of 20 Ksi (or higher) subsea systems
- A new 35″ wellhead system/connector design concept is presented with structural capacity and fatigue resistance characteristics expected to meet the HPHT industry needs for the next decades
- APQP implementation is key for safe and reliable equipment at HPHT environments

Thank You!

Questions?

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