API Standards 17 Workshop

January 11, 2017

# Evaluation of Pressure Rating Methods Recommended by API RP 17TR8 (DRAFT)

https://anl.box.com/v/pressure-rating-methods

*A Discussion of the Draft Report*

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# The BSEE Team

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# Overview

- BSEE Interest in guiding this Study
- Background Information
- Design Criteria for the Test
- The Physical Test (quick overview)
- Results and Analysis
- Conclusions and Open Q/A

# BSEE Interests / Concerns

- HPHT, by definition, represents some of the most challenging wells under consideration
  - Questions about the relatively new approach under consideration in API 17TR8 (Div 3)
    - Div 3 not previously validated for use in O&G
      - No O&G materials in ASME Section VIII, Div 3
    - Significant reduction in design safety factor
    - **No** public Div 3 validation data in O&G space

# Background Info

- Project started with the intent to form a JIP to design and conduct a test within the context of API 17TR8
  - Initial participants included Shell, Chevron, BP, Cameron, Dril-Quip, and FMC, in addition to Argonne.
  - ***This is the team that suggested much of this test plan !***
- Transitioned in late 2014 to: "API will conduct the test"
- Argonne directed in mid 2015 to complete the test

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# Key Test Objectives I

- Generate a data point in the public domain
  - Within the context of API 17TR8
    - TR8 version of ASME section VIII Div 2 and Div 3
  - Not a vendor specific component
  - Conditions defined well enough to be reproducible
  - Test to failure
    - Failure tests are important since the equipment rating formulas are based largely on the FEA failure prediction.

# Key Test Objectives II

- Detailed comparison between Finite Element Analysis (FEA) and hydro test to failure
  - Minimize technical uncertainty
    - Relatively simple design. No cladding.
    - Typical oilfield design process, materials (F22), and manufacturing
    - NDE of the test samples
    - Use measured material properties and  stress/strain data
    - Fully calibrated test equipment

- Solid model of the "large neck" test body
- "Small neck" test body is similar

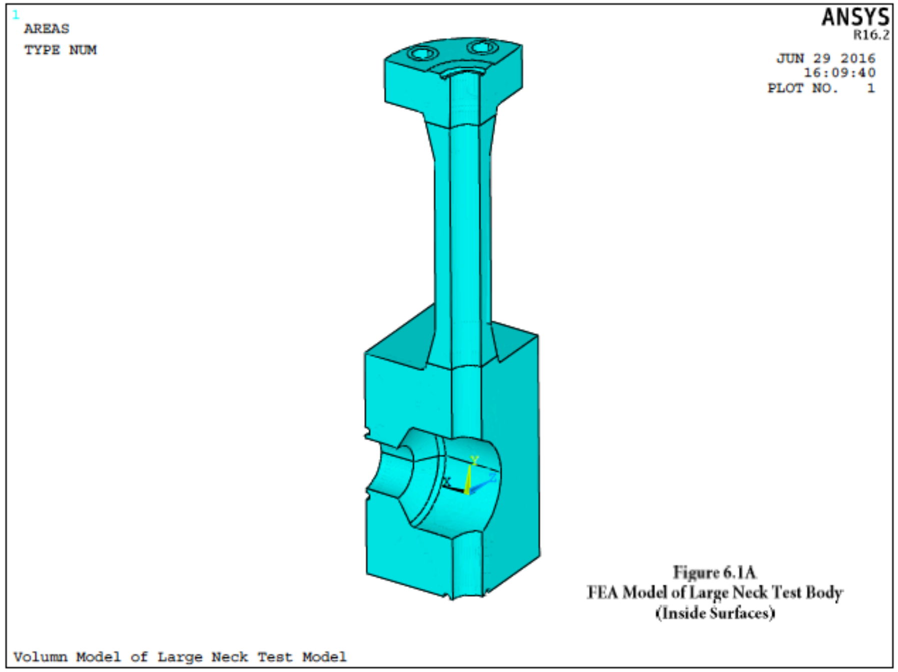



Figure 6.1A
FEA Model of Large Neck Test Body
(Inside Surfaces)

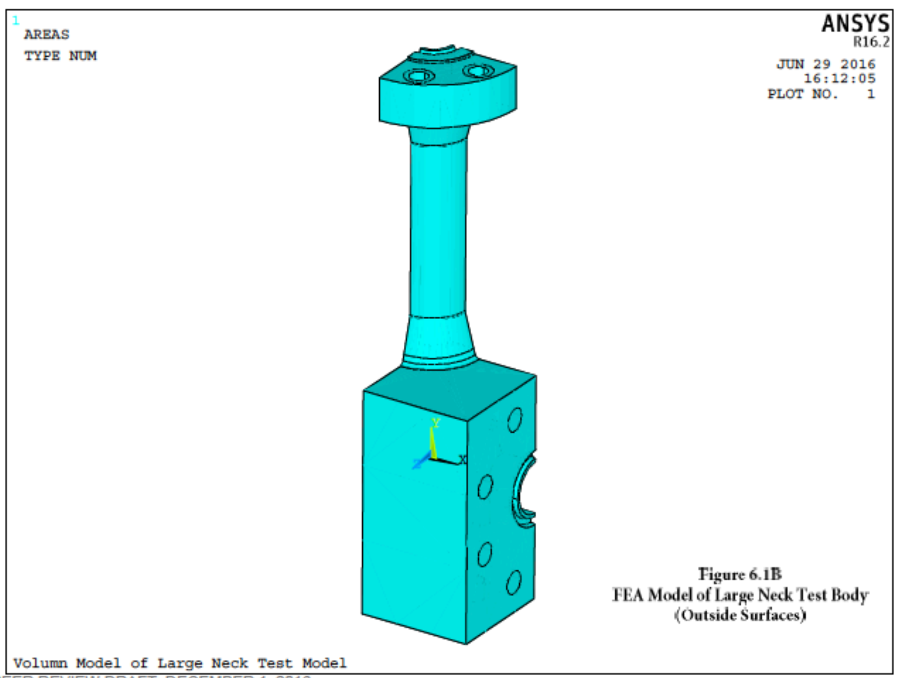
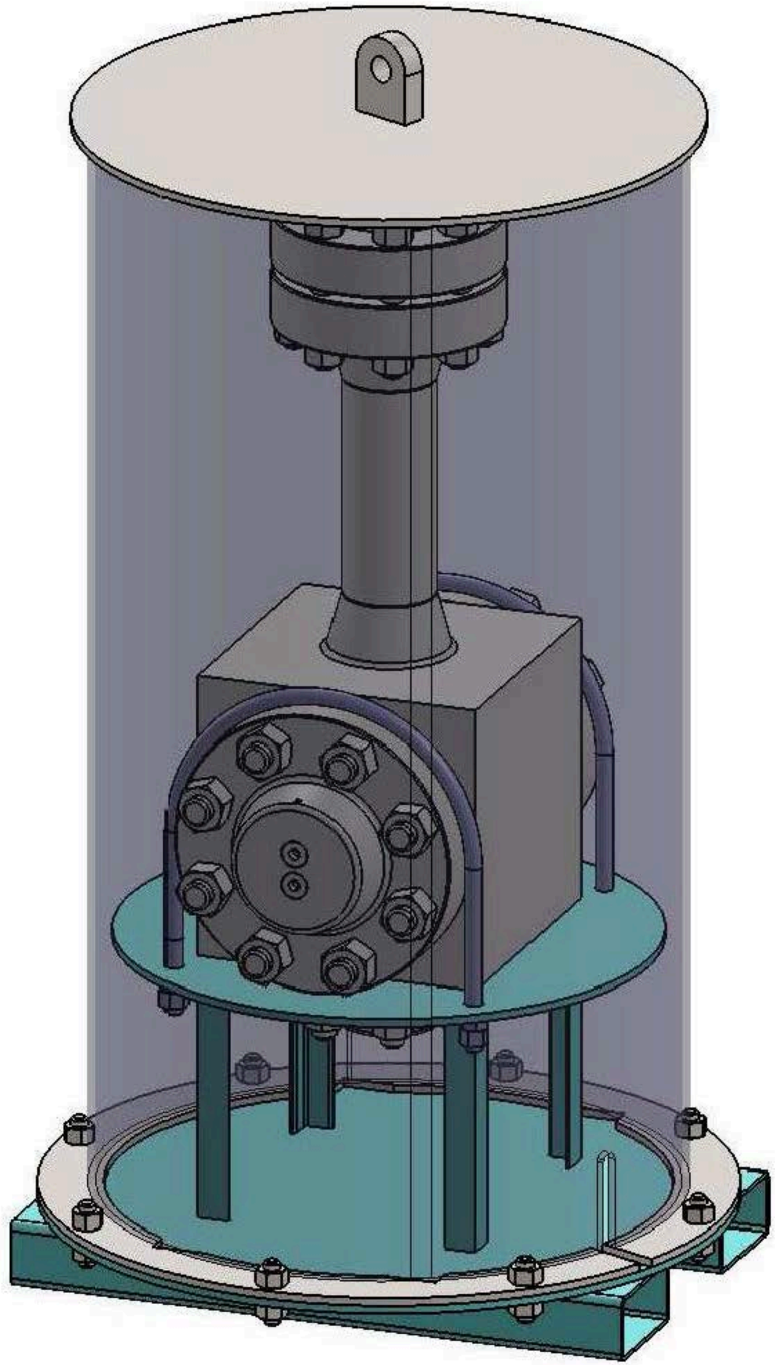



Figure 6.1B
FEA Model of Large Neck Test Body
(Outside Surfaces)

- **Assembled Test Body**

- Test Body Inside the Containment



# THE TEST

- Left side is the large neck test body
- Right side is the small neck test body
- Both clear ductile failures

# Test Team Guideline

- Avoid determination of design safety factors by using field failures
  - e.g. trial and error
- This project is NOT designed to recommend an Industry design safety factor
  - However, justification of the design safety factor is needed to meet the above guideline

# Two Part Analysis (Part I)

- Validate the TR8 Div 2 / Div 3 Elastic-Plastic Theory for Subsea Equipment (per TR8)
  - Utilize measured material properties
  - Compare:
    CP = Collapse Pressure (FEA calculated)
    with
    BP = Burst Pressure (measured)

# Two Part Analysis (Part II)

- Evaluate the application of the theory to determine the Rated Working Pressure (RWP):
  - Utilize "minimum specified material properties"
    - e.g. yield strength and tensile strength
  - RWP (6A Div2 Von Mises) = LCP(Specified) / (1.5 x yield)
  - RWP (6A Div2 Stress Intensity) = LCP(Specified) / (1.5 x yield)
  - RWP ( TR8 Div2) = CP(specified) / 2.4
  - RWP (TR8 Div3) = CP(specified) / 1.8
    - RWP = Rated Working Pressure
    - CP = FEA Calculated Collapse Pressure
    - LCP = Linearized Collapse Pressure

# FEA Pressure Rating Results

- Pressure Rating calculated for both test bodies

(Based on the Specified Material Properties)

| Descripton of Component | Plastic Collapse (psi) | Pressure Ratings (psi) | | | |
|---|---|---|---|---|---|
| | | By Linear-Elastic FEA | | By Elastic-Plastic FEA | |
| | | API 6A | Division 2 | Division 2 | Division 3 |
| Large Neck Test Body | 62,750 | 29,551 | 34,091 | 26,146 | 34,861 |
| Small Neck Test Body | 47,850 | 23,825 | 27,483 | 19,938 | 26,583 |
| API 13-5/8 x 20k Flange | 60,000 | 25,497 | 29,098 | 25,000 | 33,333 |
| API 16-3/4 x 10k Flange | 34,750 | 14,310 | 16,453 | 14,479 | 19,306 |

# Elastic Plastic
# Collapse P vs Burst P

- **Comparison of Burst and Plastic Collapse Pressures**

| Method of Determining the Failure Pressure | Failure Pressure (psi) | |
|---|---|---|
| | Small Neck | Large Neck |
| | | |
| Plastic Collapse Pressure from FEA with Actual Material Properties | 55,375 | 72,850 |
| Burst Pressure from Hydrotest of Actual Components | 51,469 | 67,959 |
| Burst Pressure Compared to Plastic Collapse of Actual Material | -7.05% | -6.71% |

*The Elastic-Plastic Analysis Theory is "non-conservative" !*

# What are the implications?

- The “non-conservative” aspect of the theory means that the effective design factor will be less than than the selected design factor.
  - E.g. if one picks a design factor of 1.8, the effective design factor will be < 1.8.

# Using Specified Minimums does NOT Remove This "Non-Conservatism"

- In our case, using the specified requirement for F22 changes the appearance:
  - The FEA comparison changes from -7% to +8% in both cases in Table 6.1.

*This only works if the actual material is NOT close to the specified minimum!*

# Two Possible Ways to Compensate

- Use TR8 Div 3 with a 1.8 design factor, but use the burst test data pressure to validate it
  - Rated P = P(Burst) x (Sy-min / Sy-actual) / 1.8
  - This requires a test to failure
- Use TR8 Div 3 with a 2.1 design safety factor
  - This puts the designer squarely on the support of historical data

*The design safety factor should also be justifiable*

# Observation / Conclusion

- A designer using Elastic-Plastic analysis should compensate for its non-conservative property
- Not doing so is akin to "trial and error."
  - The actual safety factor can easily be < than the design factor
- Our conclusion is that we cannot recommend the TR8 Div 3 methodology without
  - A) an effective compensation for the non-conservation and
  - B) a justification of the design factor

# Unknowns that still remain

- Our test object used a simple geometry
  - How will more complex geometries and multi-body contact problems compare?
- What role does Fracture Mechanics play in establishing a design margin for equipment that is not necessarily prone to brittle failure?

# Observations on the differences between ASME and API

- “Oilfield equipment are of complex geometry, far from a simple cylindrical pressure vessel or piping union design” TR8
- ASME pressure vessels almost always have pressure relief valves.
  - There is a MAWP designation; overpressure is prevented
- With Subsea equipment it is known that normal working loads **WILL** be exceeded during extreme operating conditions

*In this light, ASME Pressure vessel ratings seem more equivalent to “Extreme” oilfield equipment ratings*

# A Quote From API 6X

"In 2007, ASME totally rewrote Section VIII, Division 2, using generally more liberal design requirements and more stringent material requirements. A joint task group from SC 6, SC 16, and SC 17 reviewed the new ASME Code and recommended that, since the earlier design and material requirements have been used successfully for over 25 years, API should continue to reference the 2004 ASME Code. This recommendation was accepted by SC 6, SC 16, and SC 17."

*API Standard 6X, *Design Calculations for Pressure-containing Equipment*, First Edition, March 2014, Errata, May 2014 p. vii.

# Thank You

## Questions / Comments