2014 BSEE Domestic and International Standards Workshop

API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water (In Ballot)

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API 17TR12: Consideration of External Pressure in the Design and Pressure Rating of Subsea Equipment (In Working Group)

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API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water

Related Report: Formulating Guidance on Hydrotesting Deepwater Oil and Gas Pipelines – Stress Engineering Report to BSEE, Jan 31, 2013 and planned OTC Paper

The Main Challenges

- Lack of Common Definitions and understanding of Pressure Terms (MAOP, MSP, RWP, etc.) – Need to get regulators, pipeline-flowline and subsea hardware community on the same page.

- Simple design, without considerations of effect of internal and external hydrostatic fluid head, won't work in deep water.

- Subsea hardware providers need to have a better understanding of magnitude of hydrostatic test pressure applied during subsea systems hydrostatic tests (this pressure may exceed RWP and approach or even exceed 1.5 RWP)

Definitions

- RWP – Rated Working Pressure of subsea hardware components (per API 6A & 17D specifications)
    - Typically applies to Valves, Flanges, Hubs, Other End Connectors, Fittings, etc
    - Interpreted by API to mean the "absolute pressure" of the fluid contained within the component   (Ref: API 6A: "rated working pressure - maximum internal pressure that the equipment is designed to contain and/or control)
    - Introduction of new terms in API 17TR11: RWPA(Absolute) and RWPD (Differential)

- MAOP - Maximum Allowable Operating Pressure of the subsea flowline system (per pipeline code 30 CFR 250 and NTL 2009-G28)
- P_o – External pressure
- P_d – Differential Design Pressure as per API RP 1111 (difference between internal and external pressure)
- MSP – Maximum Source Pressure (internal)

API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water

- Originated in industry workgroup started in 2011 to address effects of subsea systems hydrostatic test (via deepwater riser and flowline) on subsea hardware.

- Subsea flowlines are typically hydrostatically pressure tested to 1.25 X MAOP during pre-commissioning operations .

- For flowline systems connected with risers to a floating host, and no means to isolate the riser from the flowline, the test pressure is applied at top of riser – Thus, absolute pressure (PSIA) inside flowline on seabed is increased by the seawater head pressure (**inside pressure = 1.25 x MAOP + ambient seawater pressure Po**)

- BSEE does not allow for the concept of variable design pressure in a flowline/riser system (one cannot consider the density of produced fluid/gas in a production flowline/riser). Therefore, for production flowlines the MAOP is generally required to be constant throughout the system and equal to the Wellhead shut-in tubing pressure (WHSITP). See also NTL 2009-G28.

- Net result is that in most cases, subsea equipment will be exposed to an internal test pressure equal to 1.25 MAOP + Po. **This internal test pressure may exceed the test pressure the subsea equipment was subjected to as part of onshore shop testing or other FAT.**

API 17TR11: Pressure Effects on Subsea Hardware During Pressure Testing in Deep Water

- 5 Cases and Discussion and Cautionary Comments for Each Case

Case	Internal Subsea System Hydrotest Pressure	Rating
1	At or below 1.0*RWPA (and thus below 1.0*RWPD) of the hardware components	🟢
2	Greater than 1.0*RWPA, but not above 1.0*RWPD	🟡
3	Greater than 1.0*RWPD (thus greater than 1.0*RWPA), but not above 1.5*RWPA	🟠
4	Greater than 1.5*RWPA, but not above 1.5*RWPD (or 1.25*MAOPD)	🟤
5	Greater than 1.5*RWPD	🔴

Example (Cases 3 and 4)

- Production Flowline MSP = 12,500 psi at manifold
- Water Depth = 9,000 ft (P_o = 4,000 psi)
- Subsea equipment RWP = 15,000 psi
- MAOP as per 30 CFR 250 and NTL 2009-G28 = 12,500 psi
- Flowline connected with SCR to FPS
- Surface Minimum required test pressure = 1.25 MAOP = 15,625 psi
- Fabrication Yard Internal Test Pressure likely to be 15,625 psi
- Internal Test Pressure at Subsea Manifold = 15,625 + 4,000 = 19,625 psi = 1.30 x RWP: > 1.25 RWP but less than 1.5 RWP

  Is this OK?

- Same situation but MAOP = 14,500 psi.
- Internal Test Pressure at Manifold is now 22,125 psi = 1.48 RWP

  Is this OK?

API 17TR12: Consideration of External Pressure in the Design and Pressure Rating of Subsea Equipment

API 17TR12 Design Assessment Flow Chart

Flow chart boxes (left):

Initiate Design Assessment with External Pressure

Functional Specifications
- Equipment Governing Spec
- Equipment API RWP
- Specified Water Depth
- Operational Pressure Cases
- Shut-In Pressure/Conditions

Reassessment

System-Level Analysis
- HAZID/HAZOP
- FMEA/FMECA
- Fault-Tree Analysis
- Operational Procedures

Note: 1

External Pressure ALWAYS Present? — Yes / No

Equipment is Pressure-Controlling? — Yes / No

Equipment Category:
- Pressure-Containing

Equipment Category:
- Pressure-Containing with Trapped Voids

Equipment Category:
- Pressure-Controlling

Design Analysis of Pressure-Containing Equipment
- Structural
- Functional (Gasket)

Design Analysis of Pressure-Containing Component without External Pressure i.a.w. Governing Spec.

Design Analysis of Pressure-Containing Element (i.e. valve body, bonnet, etc.)
- Structural

Design Analysis of Pressure-Controlling Element (i.e. gate, hangers, etc.)
- Structural
- Functional (Seat)

Case 1: API RWP (psia) — Notes: 2, 3

Case 2: DAWP @ SWD (psia)

Case 3: External Pressure (psia)

Case 1: API RWP (psia)

Case 2: DAWP @ SWD (psia)

Case 3: External Pressure (psia)

Define Pressure Differential based on:
- System Analysis
- Shut-in Conditions

Case 2a: DWP @ SWD (psia) — Notes: 4, 5, 6

Complies With Functional Specs? — No / Yes

Validation

Notes (to flow chart):

1. To identify equipment / component / sub-component category due to presence of external pressure:

   a) pressure-containing;

   b) pressure-containing with trapped voids; or

   c) pressure-controlling.

2. DAWP: Depth Adjusted Working Pressure (psia)

3. SWD: Specified Water Depth (ft)

4. DWP: Differential Working Pressure (psig)

5. DWP = Max Upstream Pressure – Min. Downstream Pressure, on the pressure-controlling element, where the "Max. Upstream Pressure" can be the calculated DAWP

6. DWP $\leq$ API RWP

API 17TR12 Design Assessment Flow Chart

- Thorough understanding of system/ equipment operational and functional characteristics

- Perform hazard identifications / risk assessment

- Identify equipment category:

  a) pressure-containing;

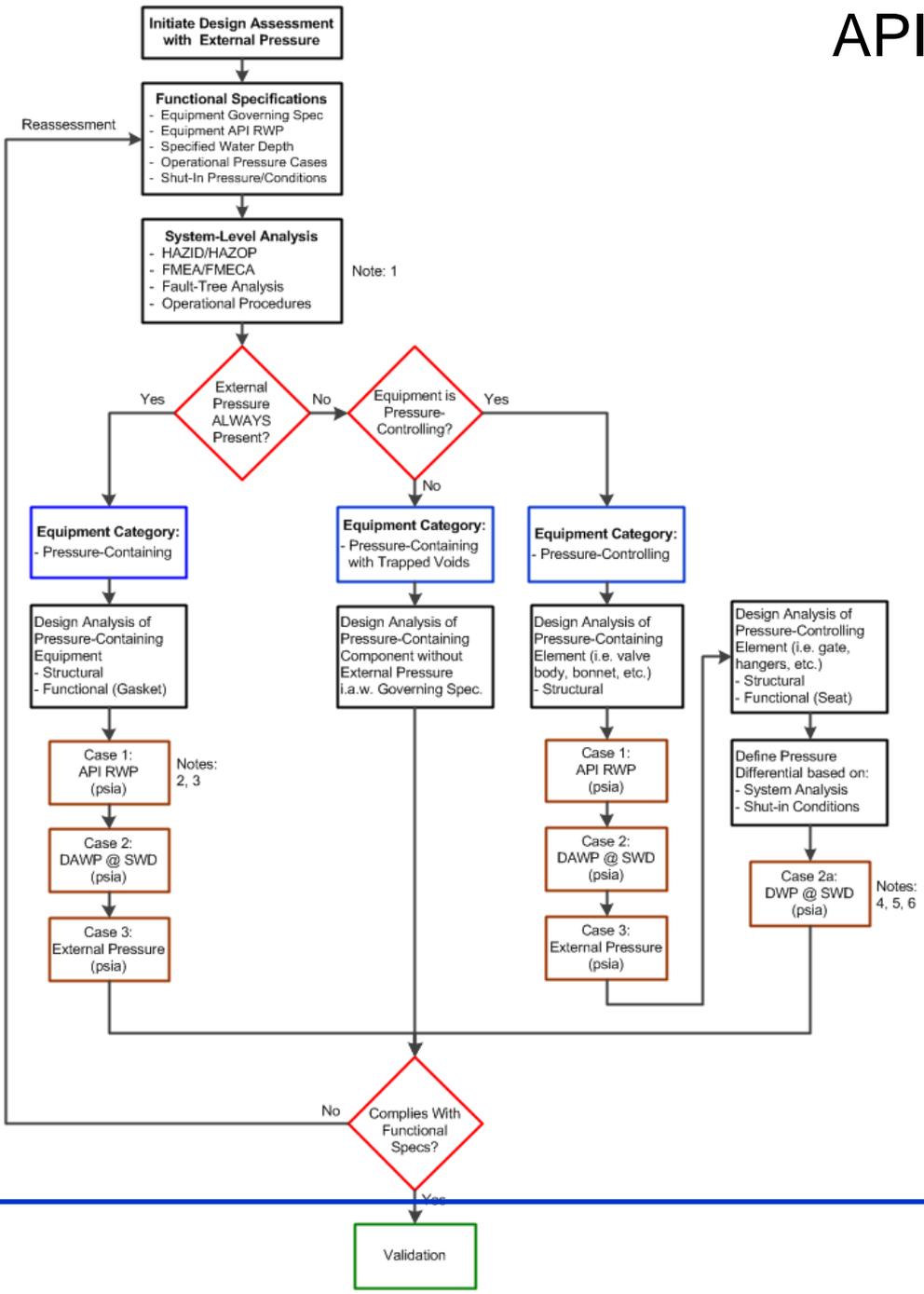 b) pressure-containing with trapped voids;

  c) pressure-controlling.
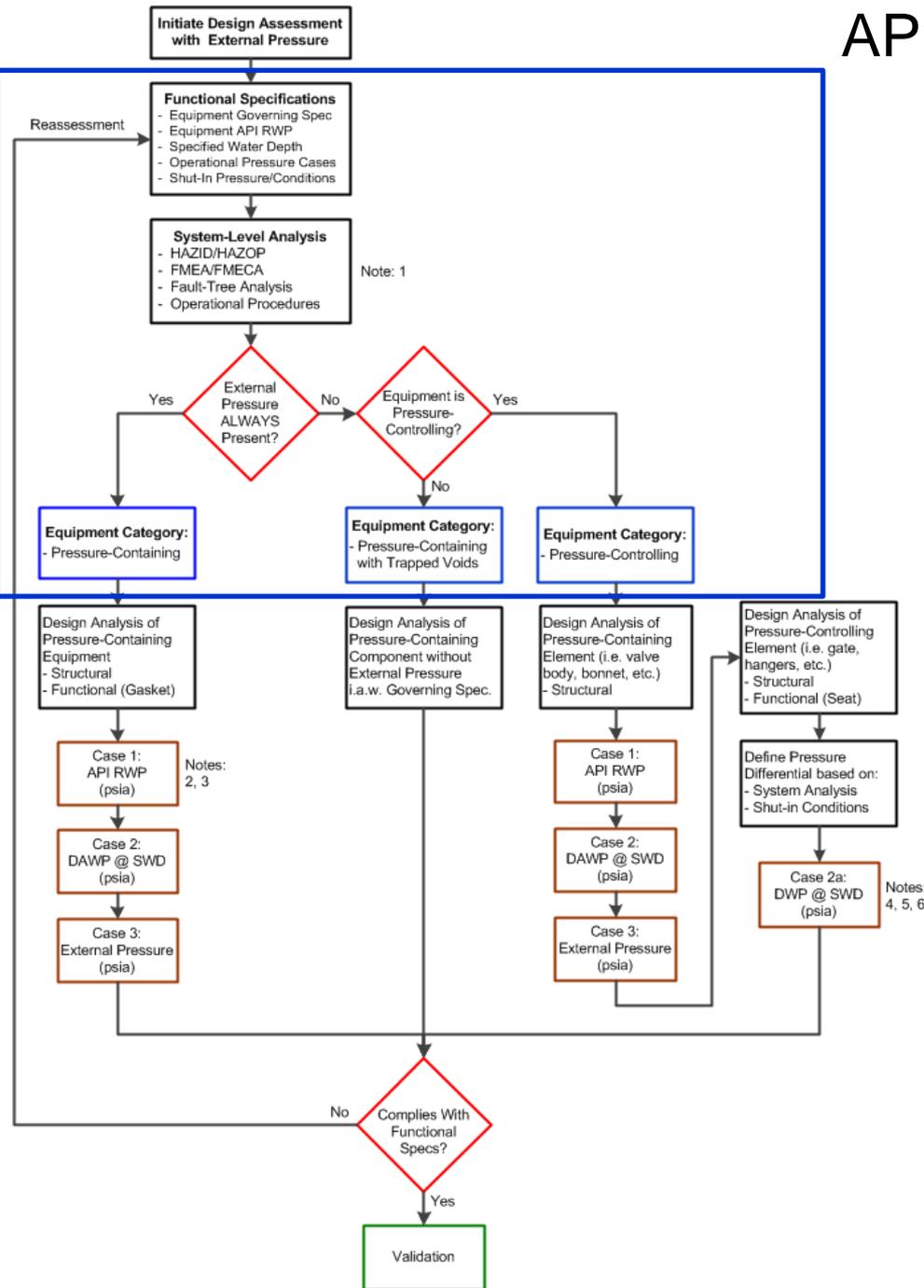
API 17TR12 Design Assessment Flow Chart
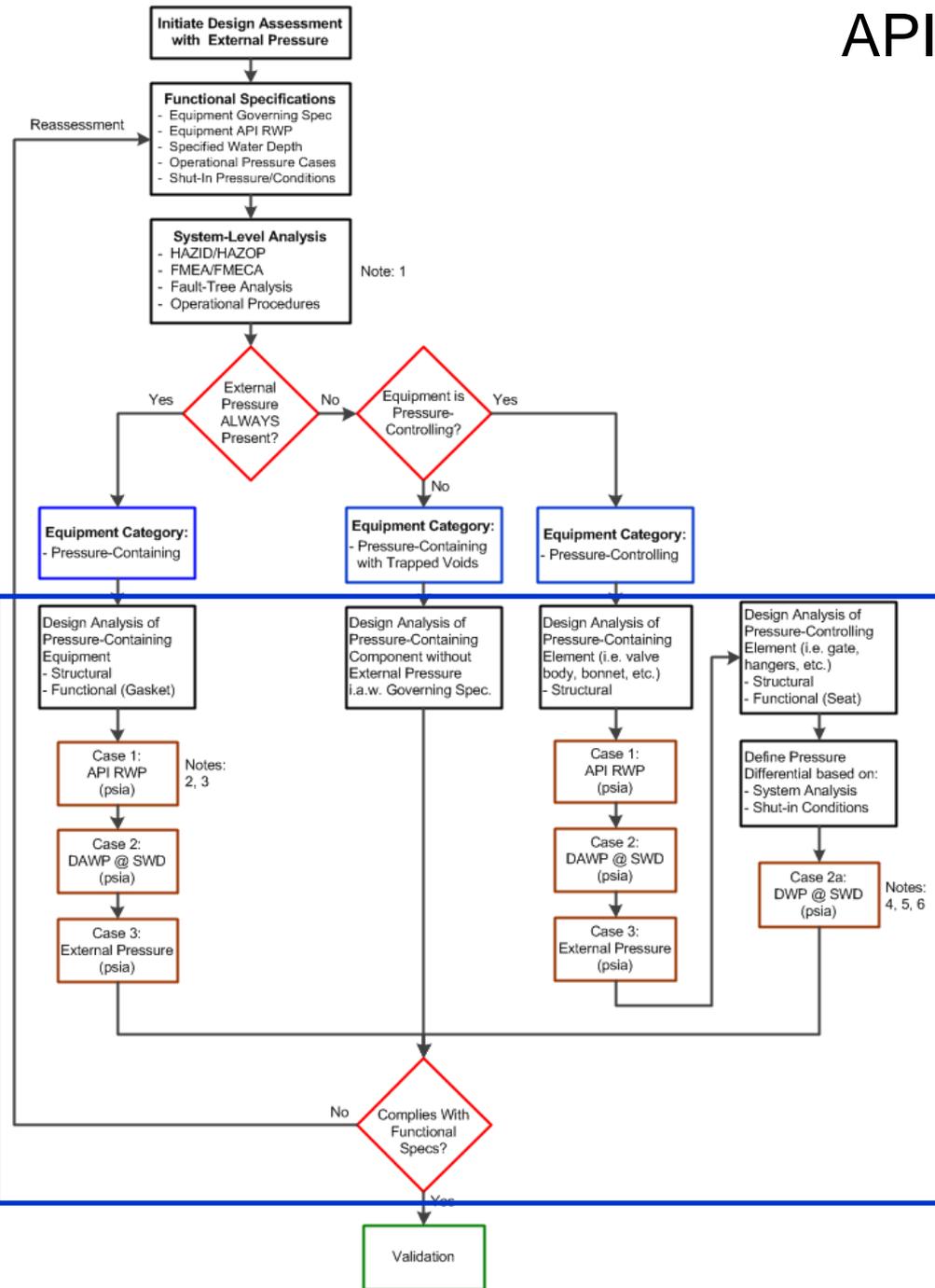
- Finite element analysis (FEA) of Case 1 - 3

- von Mises Equivalent (VME) stress should be used as it is the more accurate predictor of stress states

- Additional verifications for protection against:
  - Local failure / Localized stress concentrations
  - Ratcheting effects

- FEA results (stresses) shall comply with the applicable governing design specifications

- Test in hyperbaric chamber or simulate external pressure with test fixtures

- For larger components, where hyperbaric testing is not practical, validation of FEA is allowed through ASME V&V 10-2006, Guide for Verification and Validation in Computational Solid Mechanics

- Factory Acceptance Testing (FAT) in accordance with governing product specifications

API 17TR12 – FEA Example

Mesh Density
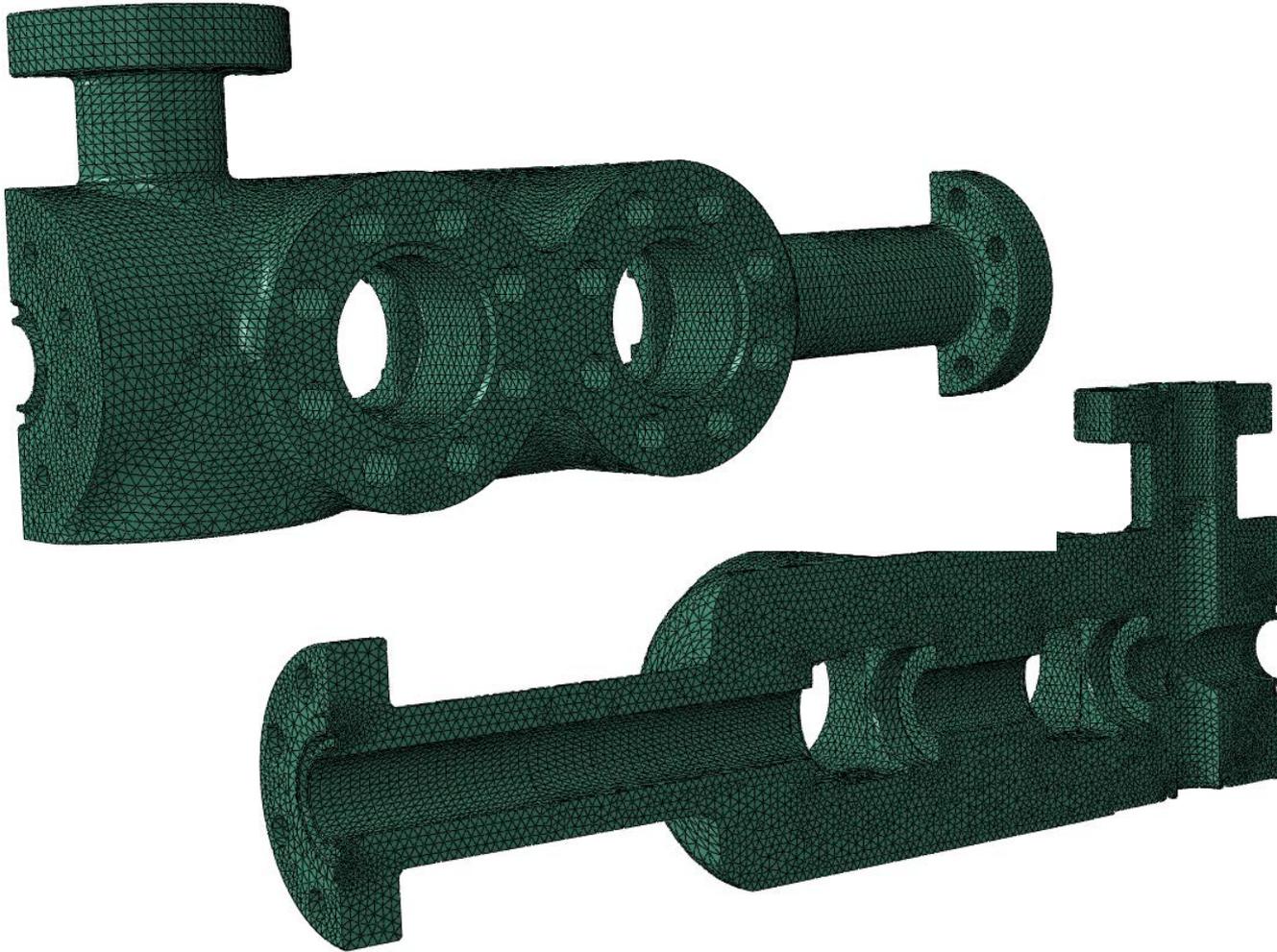
Total number of nodes: 446,850; Total number of elements: 304,200 quadratic tetrahedral elements of type C3D10

Loads & BC's
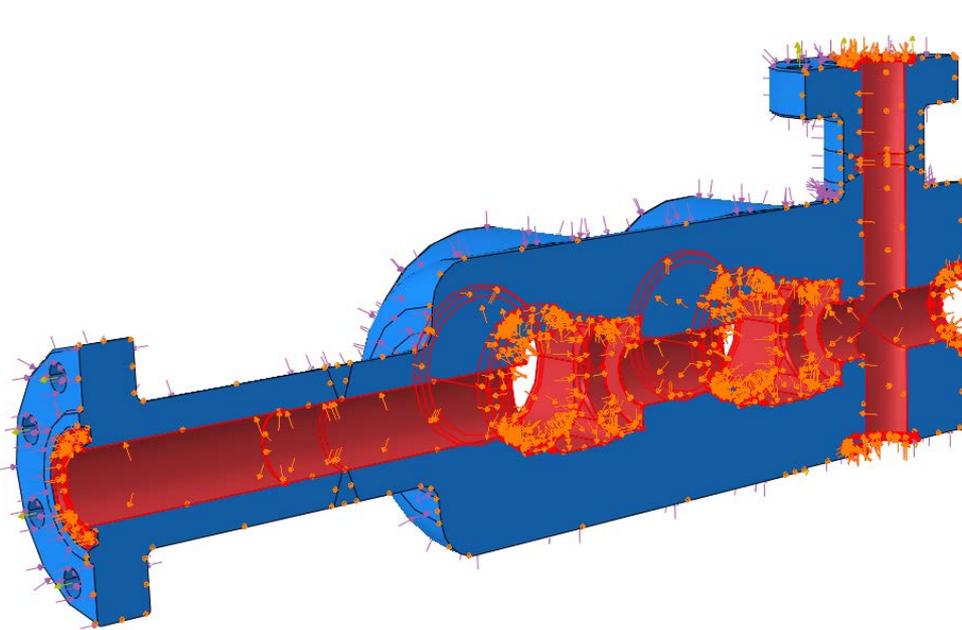
LC1:
Pi=15,000 psi
Po=0 psi
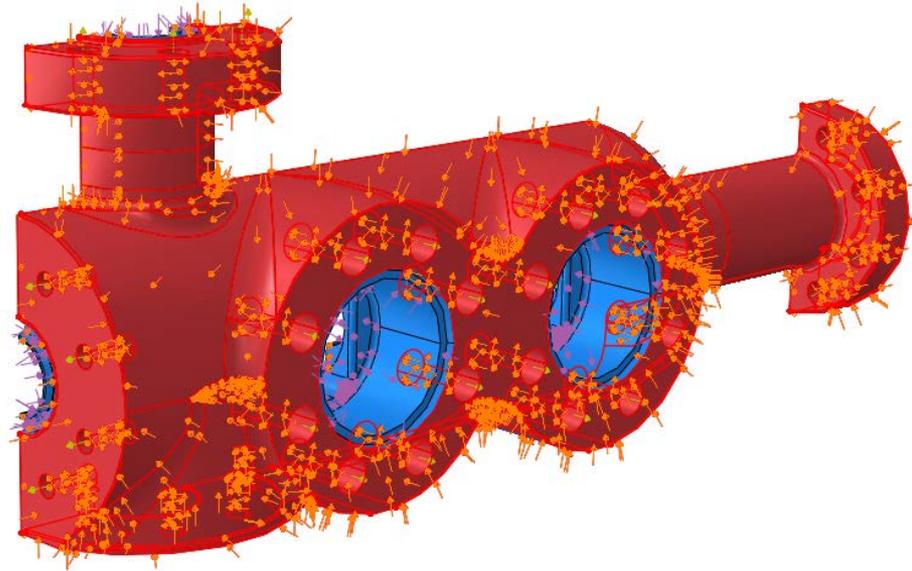
LC3:
Pi=18,000 psi
Po=3,000 psi

LC2:
Pi=20,000 psi
Po=5,000 psi

von Mises Stress Comparison

LC1:
Pi=15,000 psi
Po=0 psi

LC2:
Pi=20,000 psi
Po=5,000 psi

LC3:
Pi=18,000 psi
Po=3,000 psi

von Mises Stress Comparison

LC1:
Pi=15,000 psi
Po=0 psi

LC2:
Pi=20,000 psi
Po=5,000 psi
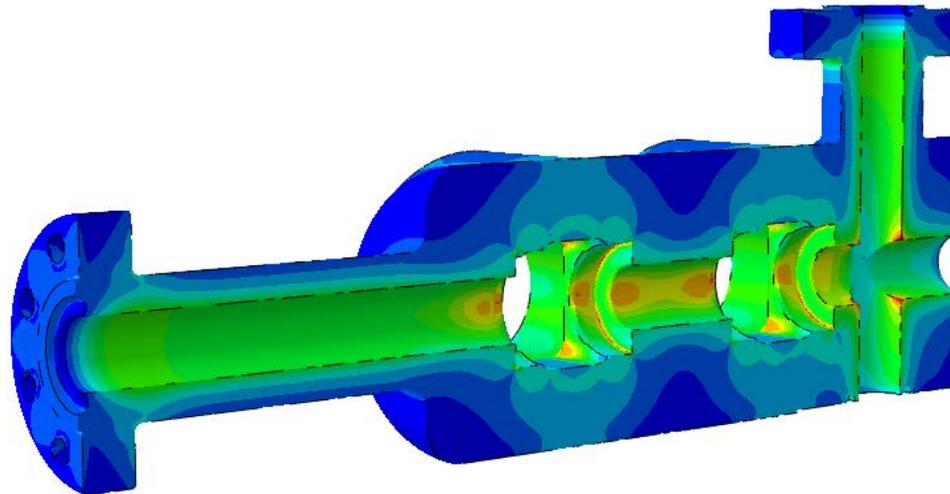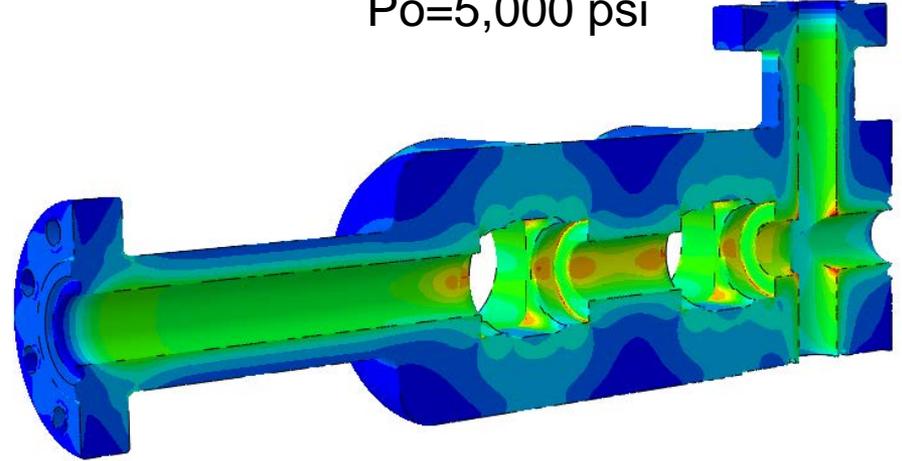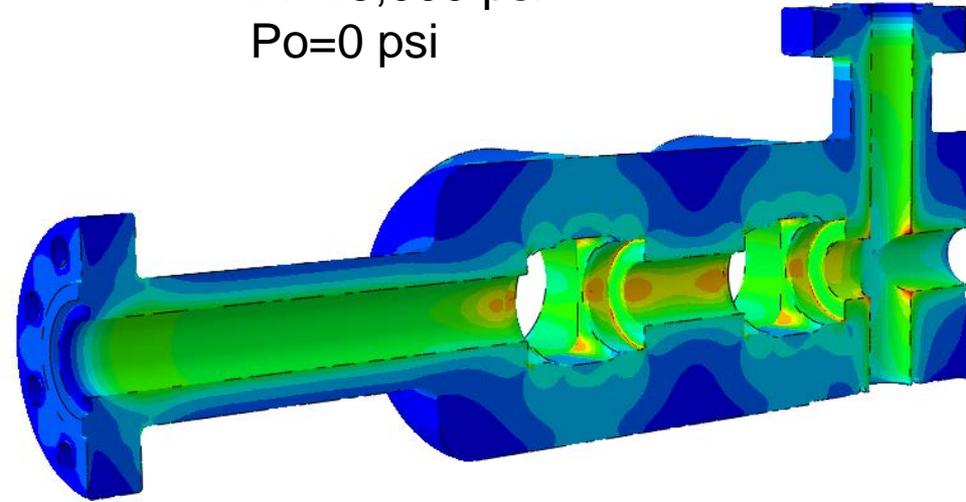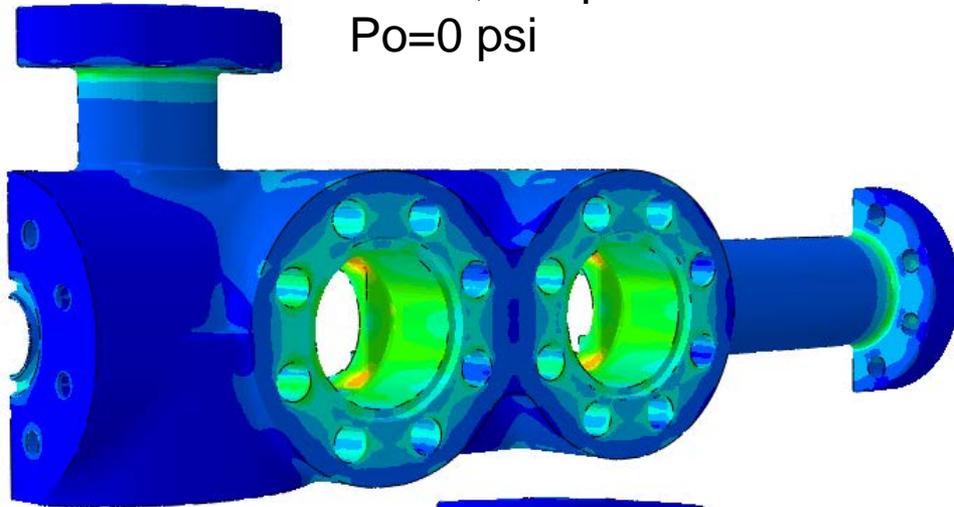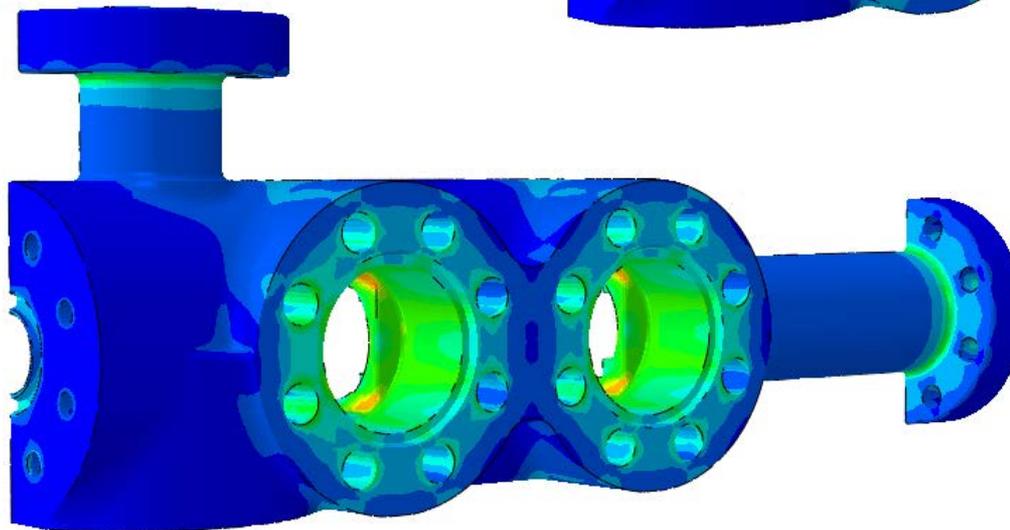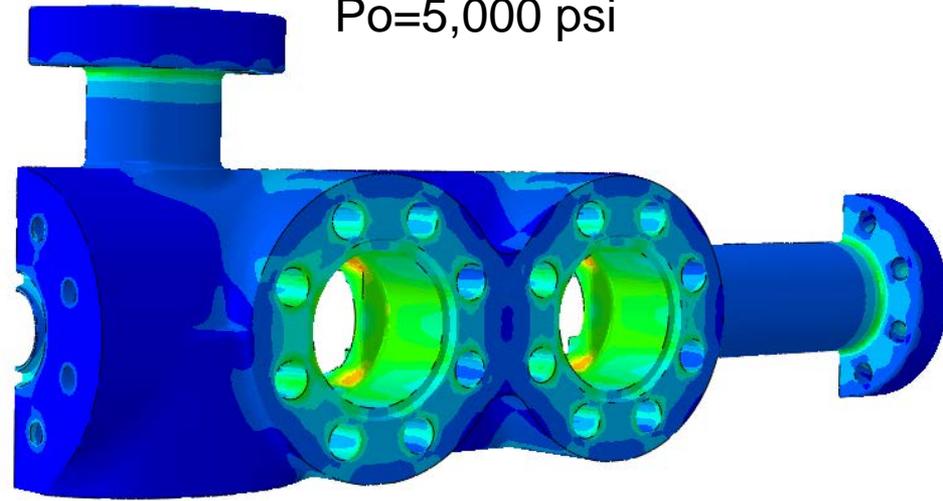
LC3:
Pi=18,000 psi
Po=3,000 psi

Stress Linearization

Stresses Comparison Results For All Nodes

Node #	LC1		LC2		% von Mises Difference	Node #	LC1		LC3		% von Mises Difference
	% von Mises Stress	% Maximum Principal Stress	% von Mises Stress	Maximum Principal Diff (psi)			% von Mises Stress	% Maximum Principal Stress	% von Mises Stress	Maximum Principal Diff (psi)	
Avg	19.98	15.72	20.02	-4889.01	0.81	Avg	19.98	15.72	20.00	-2936.83	0.38