API 17TR8 – HPHT Design Guideline for Subsea Equipment
API 17D Future with HPHT

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FMC Technologies

We put you first.
And keep you ahead.

In the Beginning…

API 6HP – primarily focused on burst before leak and 25k BOP equipment being too heavy – 1.5 x RWP vs. 1.25 x RWP? External hydrostatic pressure to compensate?

Next was API PER 15K to identify *all* wellbore issues and challenges associated with HPHT (anything above 15k RWP) from sand face to pipeline – looked at things holistically

But PER 15K points to the problems that each API Subcommittee needs to address – never intended to "solve" them… *it is not a design guideline*

API 17TR8 is Subsea' s attempt at providing some of the guideline solutions.

Holistic View – 1PER15K-1

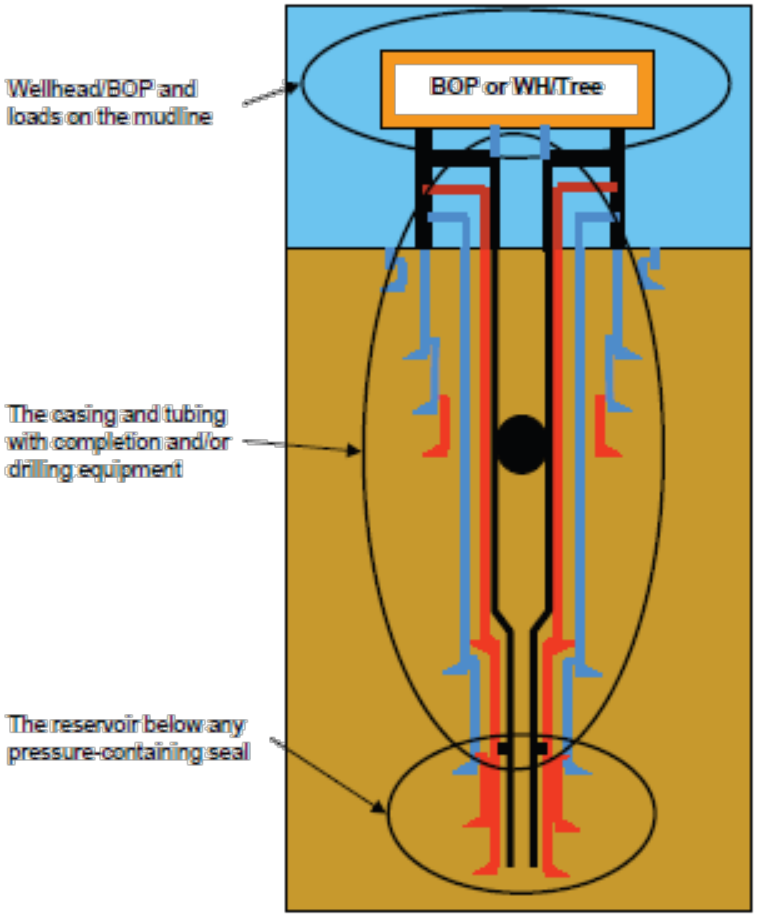


Figure 1—System Analysis Specification Breaks (Completion)

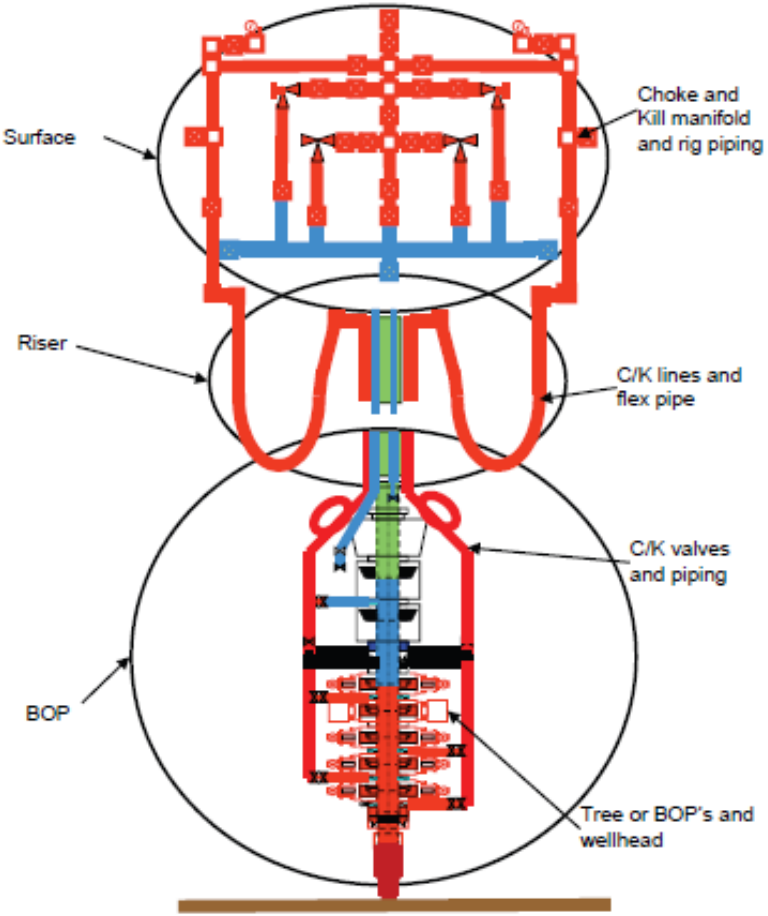
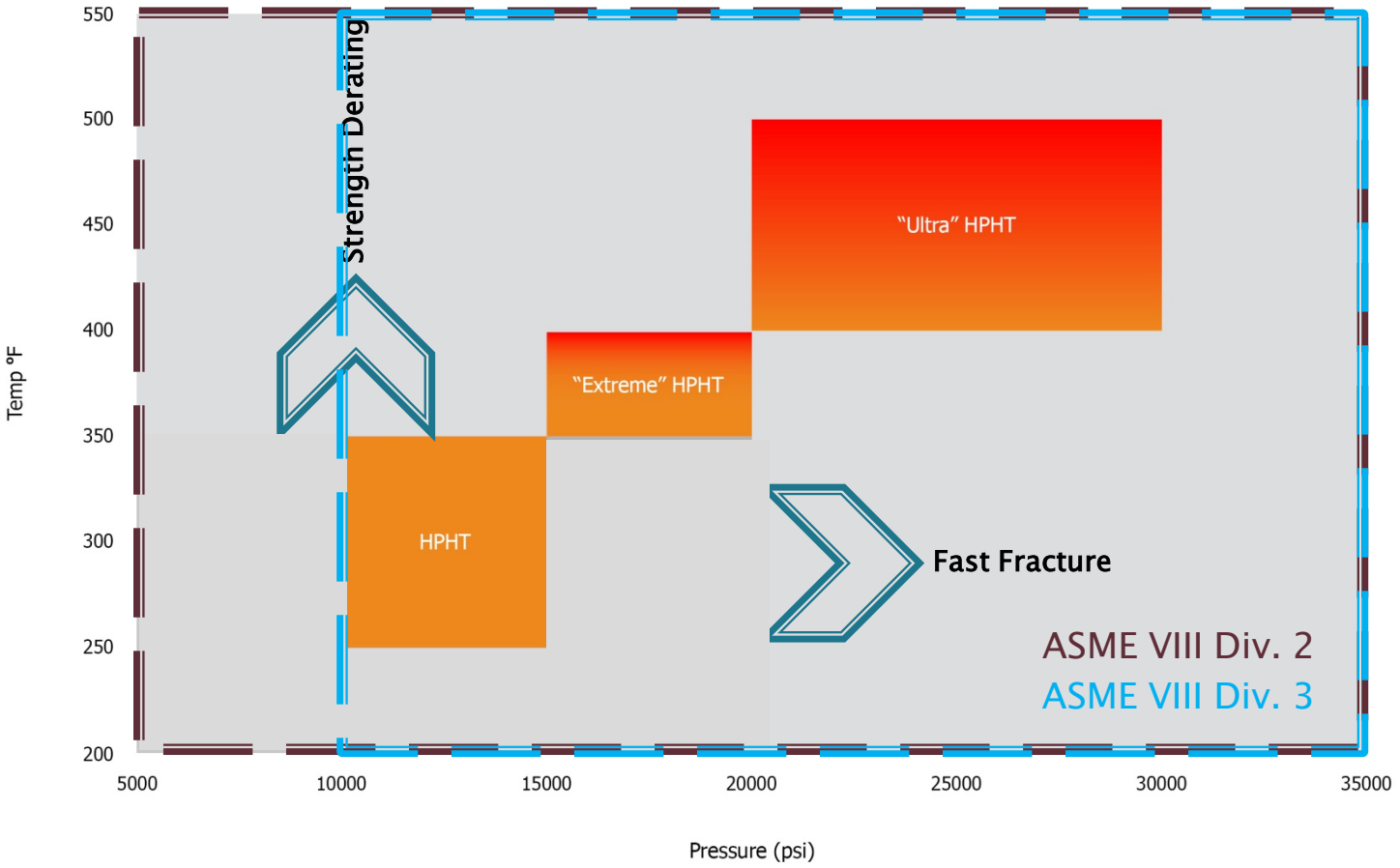


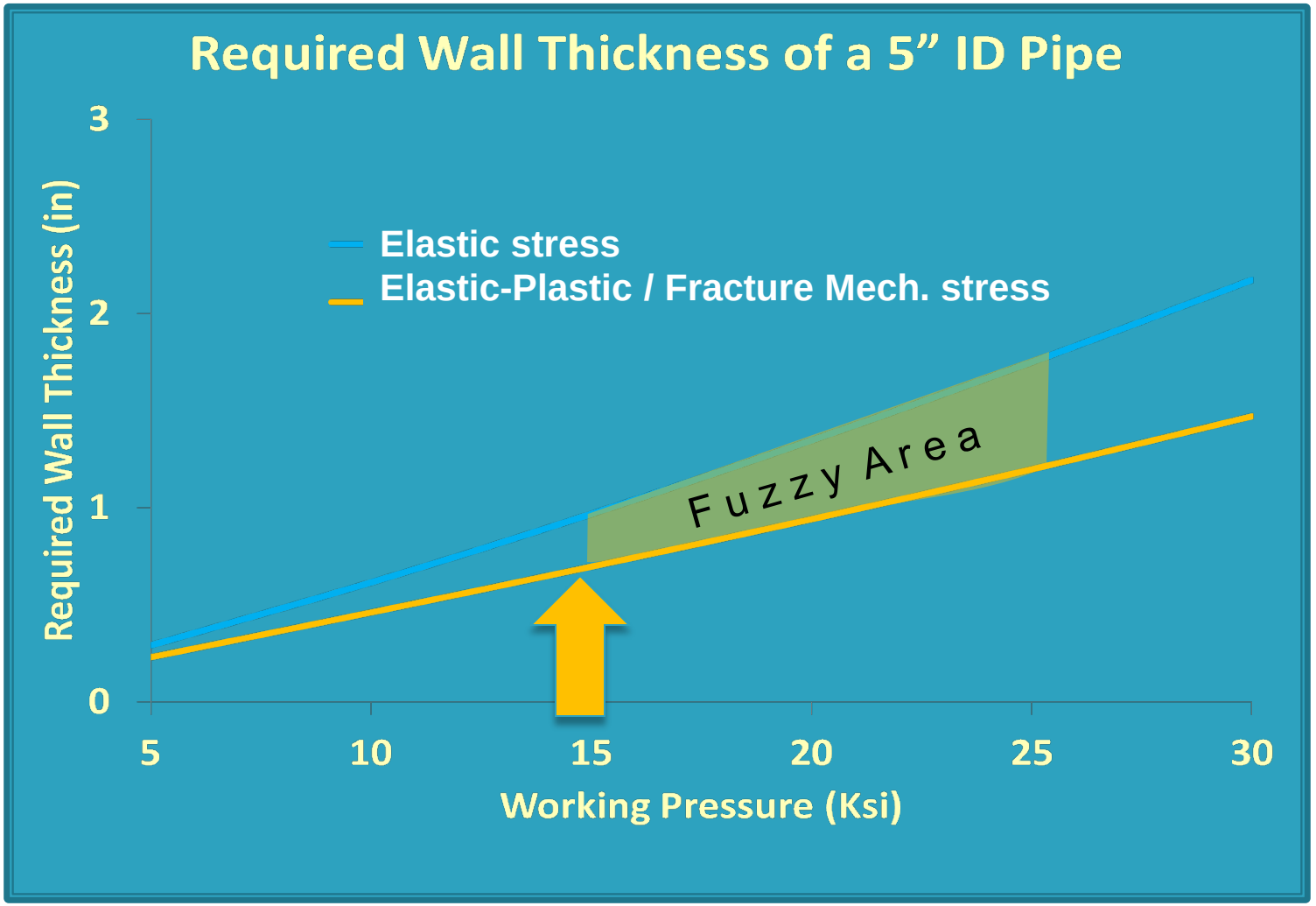
Figure 2—System Analysis Specification Breaks (Drilling)

How is HPHT Defined? What Code Rules?



Source: OTC 17927, 23943, 25376

15k to 25k a design transition zone

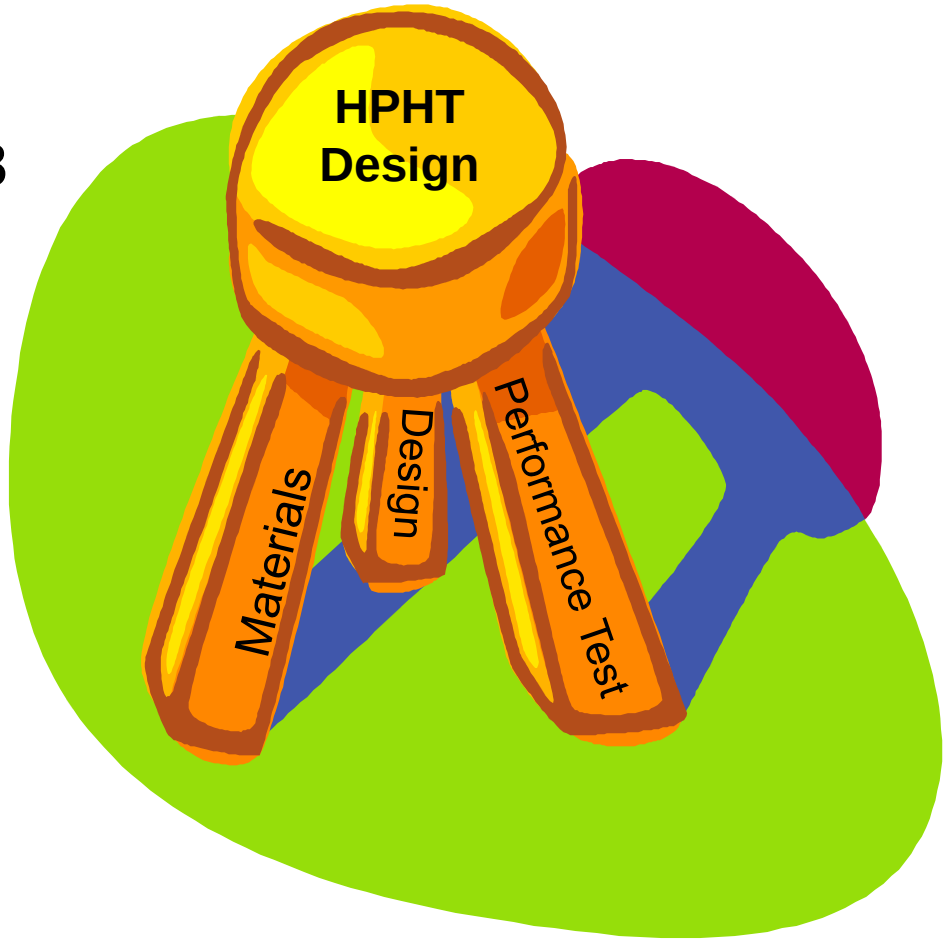


Thicker wall sections changes the “pressure vessel model”, but where?
Don’t know where leak before burst ends and fast fracture failure begins

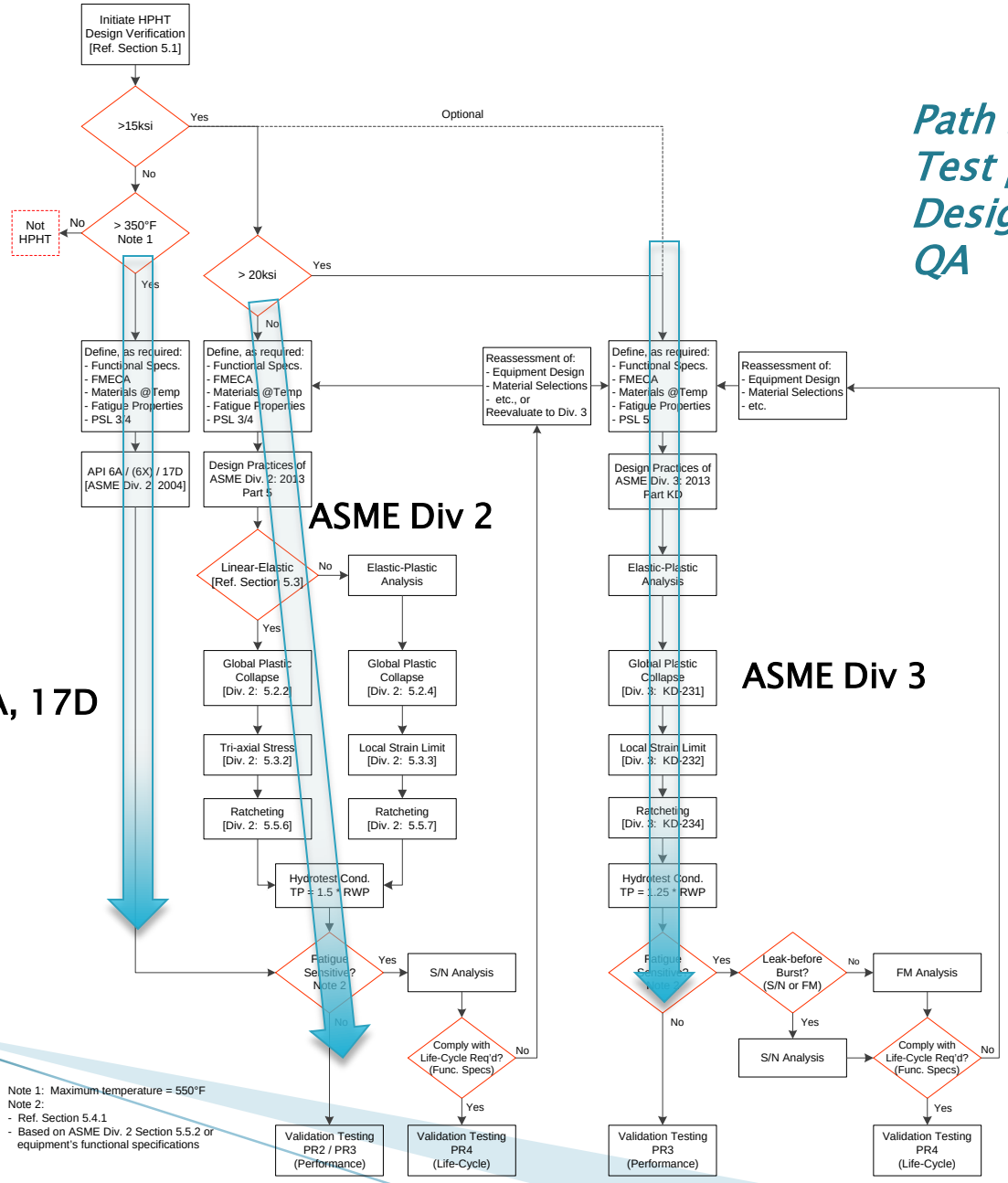
Source: OTC 23621

17TR8: The HPHT Method

- Design Methodology – roadmap for transition from Div 2 to Div 3
- Populate oil field material data sheets at elevated temperatures
  - Establish physical properties and QA lists
- Establish HPHT validation tests
  - Extended function testing standard
  - Guidance for project specific testing



17TR8: HPHT Design Flow Chart



Path selected determines:
Test pressure,
Design margins,
QA

"All codes are created equal: some more equal than others"

Quality and Qualification Requirements

“Buckets” to capture physical properties and performance tests:

PSL 5 to address tighter QA requirements in material strength (+/- range), ovality, cross section thinning, chemistry, prolongations, stress relaxation properties, etc.

PR 3 to address extended functioning component at HPHT conditions; gas test medium, blow down safety, more temperature cycles, etc.

PR 4 to address cyclic loading, fracture mechanics S-N fatigue, criticality and project specific cyclic design life

17TR8: HPHT Materials Properties

Design Properties *

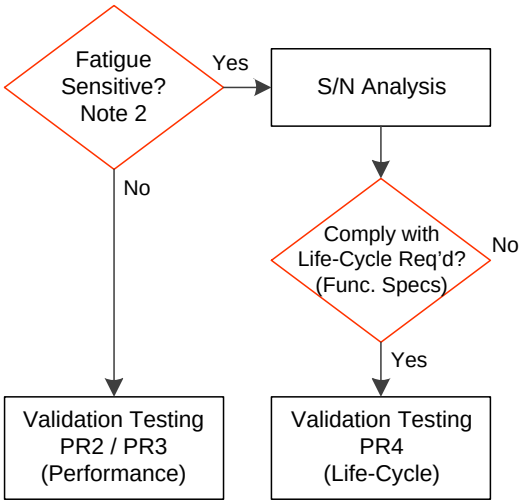
- **Mechanical Properties**
  - *Tensile Properties (including tensile modulus)*
  - *Fracture Toughness (K_{1c})*
  - *Crack Growth Rate (da/dN)*
  - *Fatigue S-N curve*
- **Physical Properties**
  - *Thermal conductivity*
  - *Specific heat capacity*
  - *Density*
  - *Thermal expansion*
  - *Poisson Ratio*
  - *NACE Test (2% or defined strain limit)*
  - *Stress Relaxation*

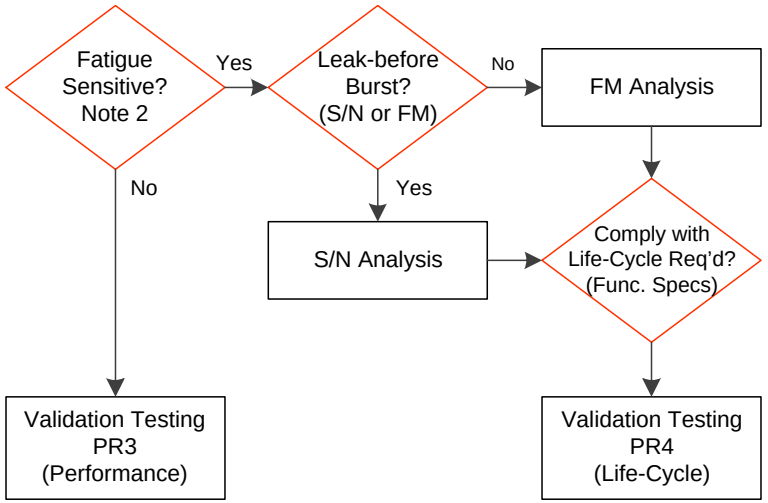
Quality Control **

- **Chemistry / Composition Requirements**
- **Mechanical Properties**
  - *Tensile Properties (tight range)*
  - *Charpy , CTOD*
  - *Hardness*
- **Microstructure and Grain Size**
  - *NDE*
  - *Minimum Crack Size*
- **Process Control**
  - *Melting, Forging*
  - *Heat Treatment, QTC Prolongation Testing*
  - *Dimensional – Ovality, Thinning*

**** For discrete temperatures 75, 350, 450, 550, 650 F***
***** For QC temperatures defined by ASME VIII, Div 3***

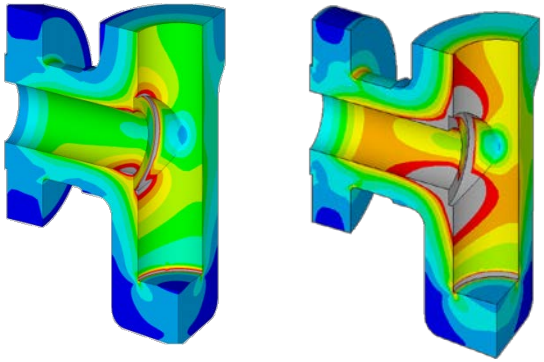
17TR8: Design Flow Chart – Fatigue Assessment





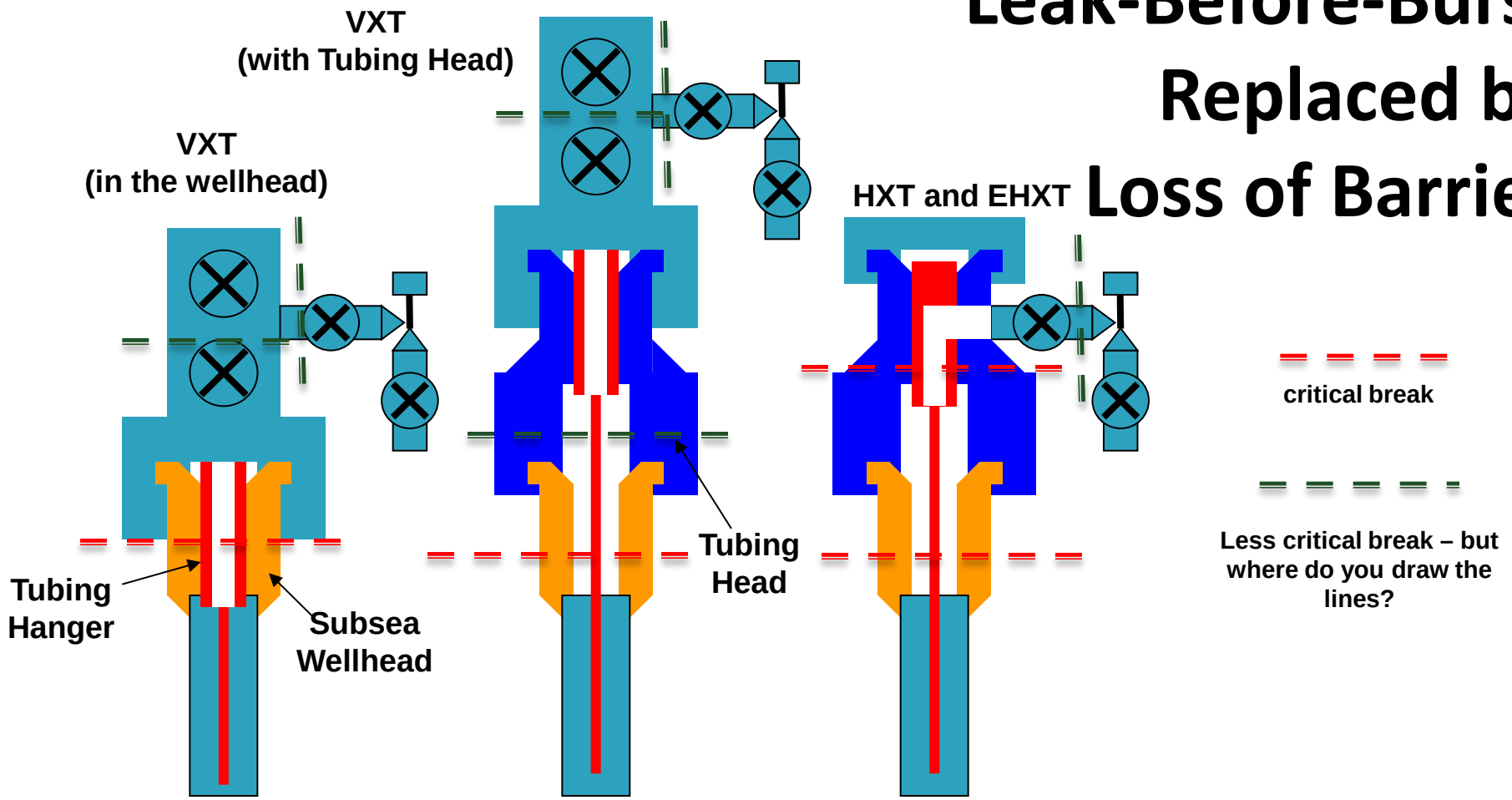
Fatigue Assessment:

- Determine if equipment is fatigue sensitive
  - ASME fatigue screening criteria (ASME Div. 2 Section 5.5.2)
    - internal – pressure/temperature; external – mechanical
- Fatigue analysis:
  - S-N approach
  - Fracture Mechanics (FM) approach
- May require:
  - Load-monitoring
  - NDE method capability and its probability of detection (PoD) to identify flaws
  - Multiple flaws assessment



Non-uniform stress field – gray "above yield"
Autofrettage Effect
Source: OTC 23063, 23621

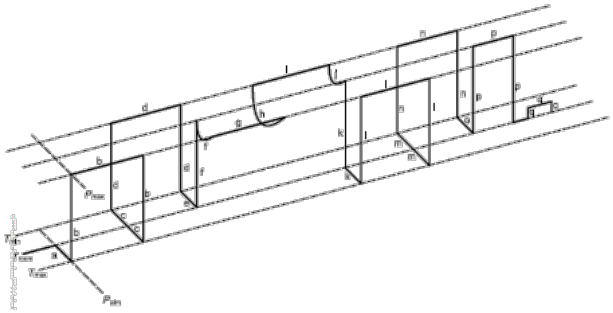
Leak-Before-Burst Replaced by Loss of Barrier



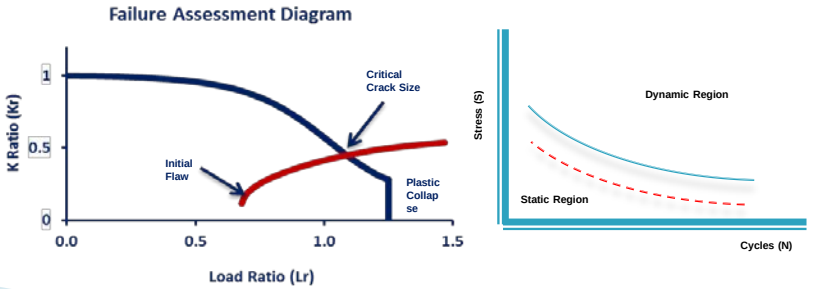
- ***Both Leak or Burst are catastrophic events because it's hard to turn off a reservoir*.**
- **Need a different differentiator**
- **Oil industry has "two barrier" rule for safe operation.**
- **Locations where a fatigue failure could compromise primary barrier are critical and more detailed analysis – fracture mechanics**

17TR8: HPHT Validation

- Can define within a "standard"
- Additional Function Testing
  - Extended testing at Temperature



- Can't define within a "standard"
- Fatigue Design Requirements
  - *S-N Curve for machined parts, welds, notches, etc.*
  - *Fracture Mechanics*
    - *Define crack size, material toughness*
  - *Define cycle life and cyclic testing*
- FMECA of Critical Components
  - *Additional project specific tests*



HPHT Future of 17D

- Task Group to start Next Revision in 2015 – 16 time frame
- Task Group's intent is to stay synchronized with API 6A ; especially manufacturing
- HPHT intent is to offer higher RWP and Operating Temperature by expanding tables.
  - Keep 5ksi increments
  - 50 or 100 °F temperature class increments
- Decide how much extended testing at temperature (% more) is required for PR 3
- Intent is to cite as much of 17TR8 and 6A/6X instead of re-writing
  - 15ksi & below – API 6X
  - 25ksi & above – Div 3 path of 17TR8
  - 20ksi ? – but can't have multiple paths or test pressures

Future of 17TR8

- First edition to be balloted for publication in 2014
- Second edition – work still to be done in 2014 – 15
  - Welding and cladding and associated crack design issues
  - Reconcile ASME and NACE
  - Refine cyclic and fatigue analysis
  - Add Sensors and Monitoring for cycle life
  - Systems engineering of spec breaks and interfaces
  - Work with ASME Div 3 to submit a “code case”

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Questions?

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