BSEE Standards Workshop

API 17TR8: High-Pressure High-Temperature (HPHT) Design Guidelines

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Houston, Texas

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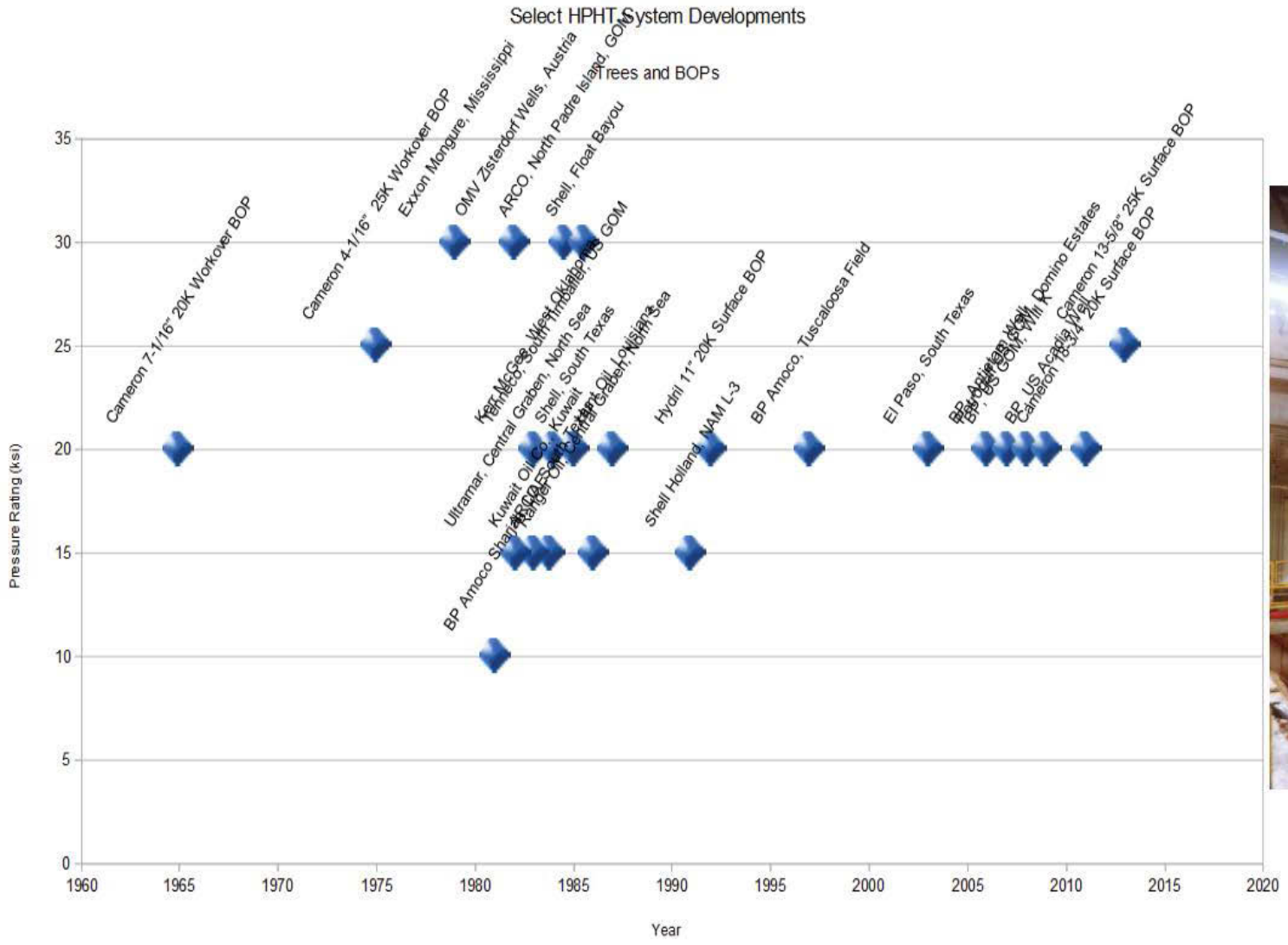
HPHT Design Guidelines

1. Evolution of HPHT
2. Previous HPHT Efforts
3. Present HPHT
4. Key Elements of API SC17 Technical Report 8 (17TR8)
5. API 17TR8 – Phase 2
6. Standardization Efforts
7. ASME Collaboration

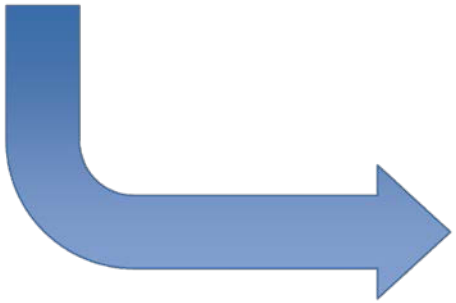
Evolution of HPHT

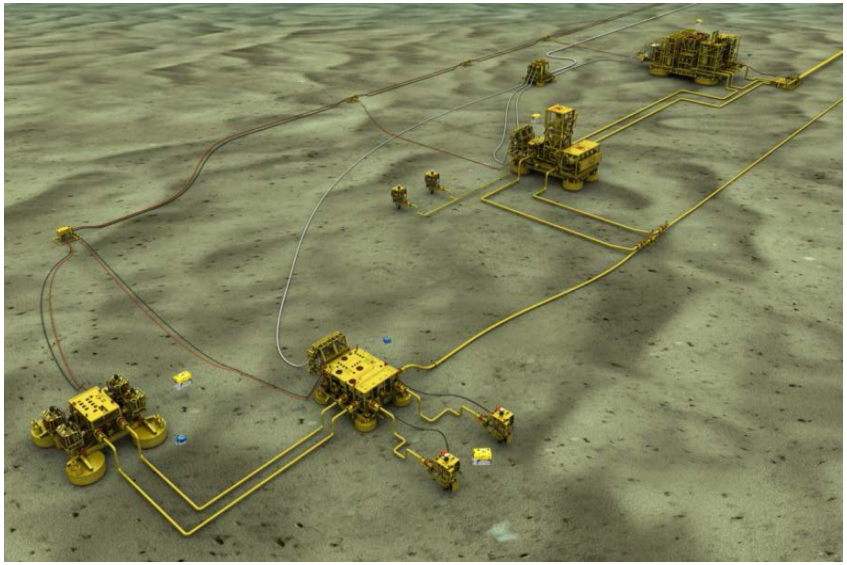


Previous HPHT

API 1PER15K-1: Protocol for Verification and Validation of High-pressure High-temperature Equipment

- Holistic approach in identifying wellbore issues and challenges associated with HPHT (> 15 ksi RWP):
  - 18-3/4” 20K surface stack
  - 13-5/8” 25K surface stack
  - 20K wellheads





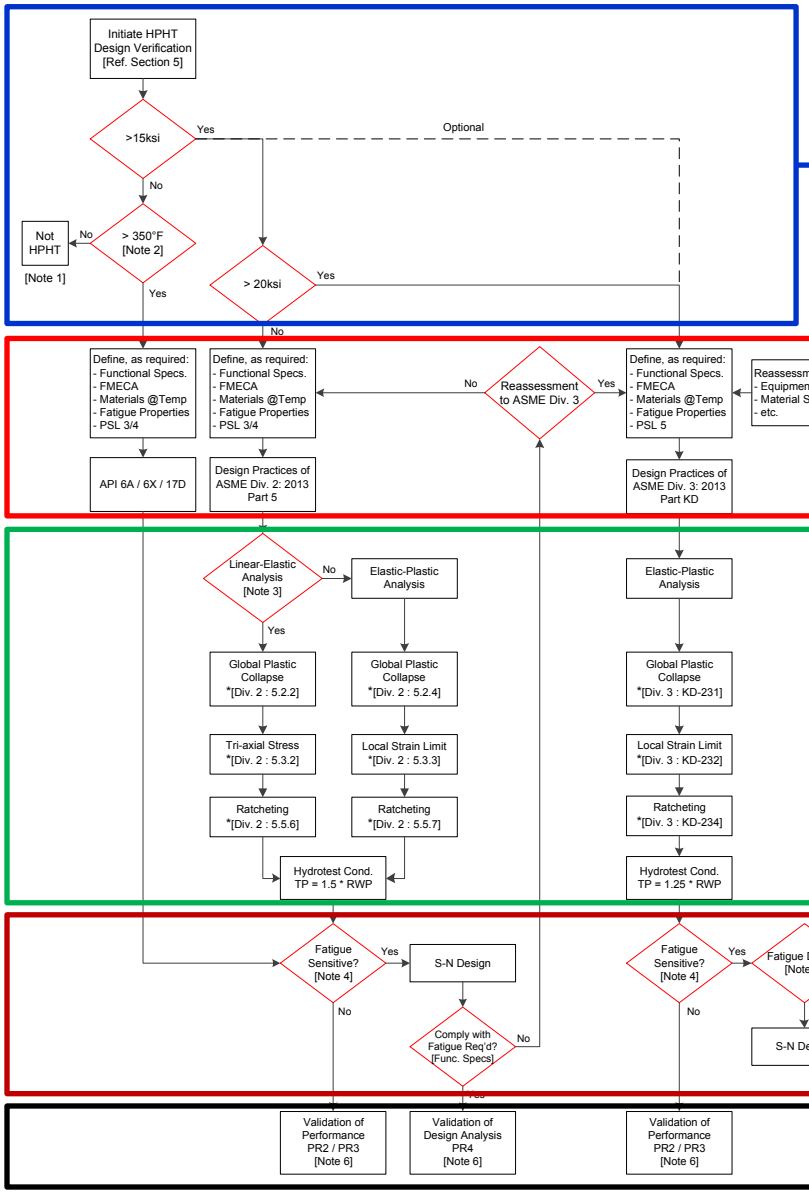
API 17TR8: High-pressure High-temperature (HPHT) Design Guidelines

- API 1PER15K-1 HPHT considerations are *assembled* into design flow chart – a “roadmap”
- Provides *a design guideline solution*

Present HPHT

- API 17TR8: High-Pressure High-Temperature (HPHT) Design Guidelines
  - Commenced: 2012
  - Published: February 2015
  - Industry Participations:
    - Oil & Gas: Operators, Manufacturers, Service Companies, Consultants
    - Industry Societies:
      - ASME - American Society of Mechanical Engineers
      - NACE – National Association of Corrosion Engineers
    - Regulatory Agency: DOI/BSEE: Active engagement

API 17TR8 : HPHT Design Flow Chart



Scope

Input

- **Functional Specifications**
- **Material Properties**
- **FMECA**

Design Verification

Fatigue Screening / Fatigue Assessment

Design Validation

API 17TR8 : Input

- Equipment Functional Specifications:
  - Design pressure (internal and external) & temperature
  - Production fluid chemistry and gas content:
    - H_2S, CO_2, etc.
  - Cyclic loading conditions
    - Pressure, temperature, external loads, etc.
  - Mechanical / Structural loads (external loads)
    - Drilling operation, workover operation, etc.
  - Corrosion, Corrosion/Erosion
  - Industry standards and regulatory requirements

API 17TR8 : Input

- Material properties for HPHT application:
  - Established list of mechanical and physical properties needed by equipment designers
  - Properties at various temperatures for environment / operating conditions
- Consideration to operating / environmental conditions, as applicable:
  - Produced Fluids (oil, gas)
  - H_2S, CO_2, etc.
  - Seawater + Cathodic Protection (CP)
  - Completion Fluids, Drilling Fluids
  - Chloride Corrosion, Hydrogen Embrittlement

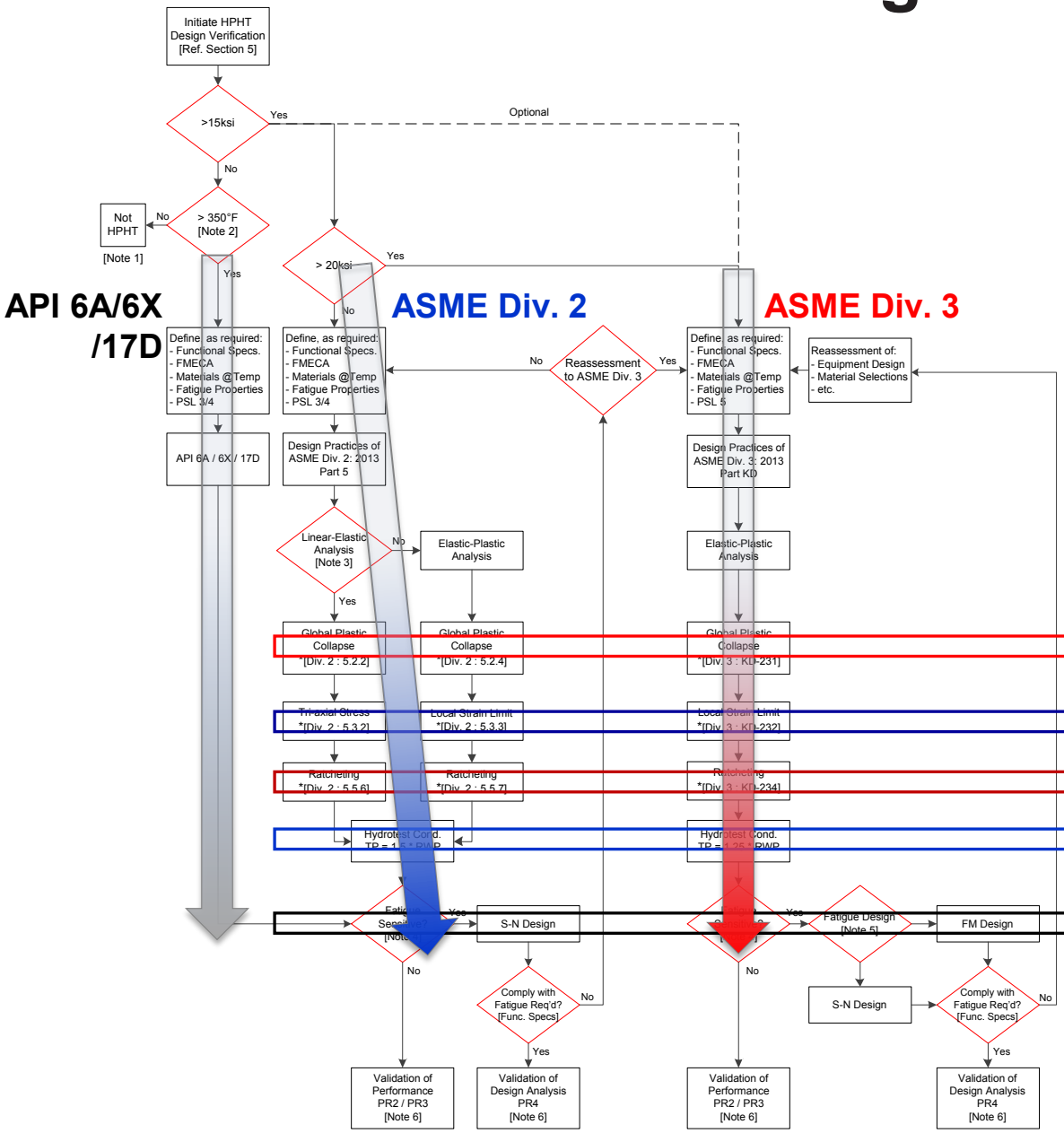
API 17TR8 : Input

- Failure Modes, Effects and Criticality Analysis (FMECA)
  - Identify applicable failure modes for design verification
  - Identify design validation testing requirements through FMECA: Equipment or Project-Specific
    - PR 3 / PR 4
  - API 17N provides guidance on FMECA procedures
    - API 17N: Recommended Practice for Subsea Production System Reliability and Technical Risk Management

API 17TR8 : Design Verification

- Design verification for protection against identified failure modes, for all design paths:
  - Global plastic collapse
  - Local strain limits
  - Ratcheting effects
  - Plastic collapse under hydrostatic test condition
  - Fatigue screening / Fatigue assessment
- Application of design codes:
  - API 6A / 6X / 17D (ASME BPVC Section VIII, Div. 2: 2004)
  - ASME BPVC Section VIII, Div. 2: 2013 Edition
  - ASME BPVC Section VIII, Div. 3: 2013 Edition

API 17TR8 : Design Verification



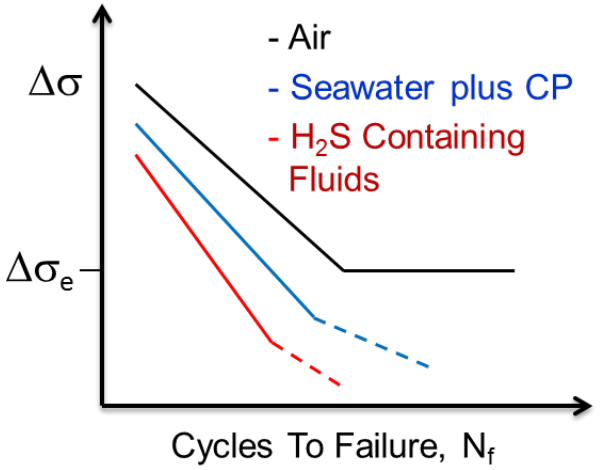
Design Margin

- API 6A / 6X / 17D
  - Linear-Elastic Analysis: $2/3S_y$
- ASME Div. 2
  - Elastic-Plastic Analysis: 2.4 on plastic collapse load
- ASME Div. 3
  - Elastic-Plastic Analysis: 1.8 on plastic collapse load

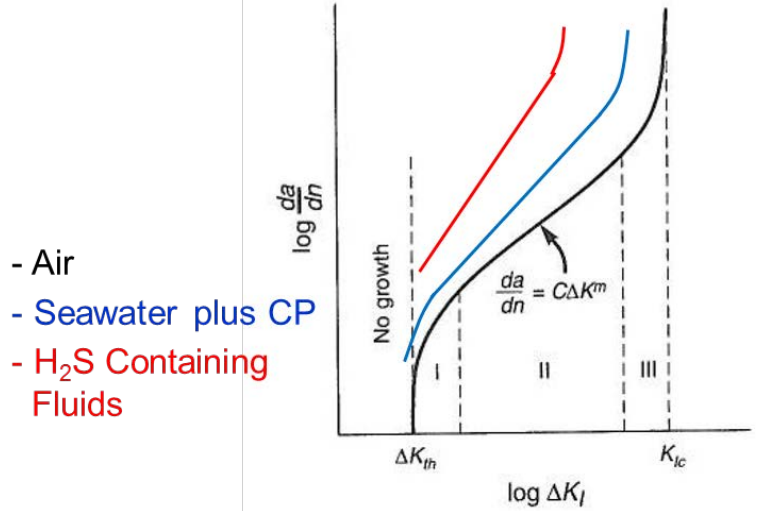
Failure Modes

API 17TR8 : Fatigue Assessment

- Fatigue Screening: To determine if equipment is fatigue sensitive or fatigue assessment is required
  - Experience with similar equipment operating under similar conditions can be basis for fatigue screening (ASME Div. 2 – Para 5.2.2)
- Environmental effects can have adverse impacts on fatigue properties
  - S-N Fatigue Curves
  - Fatigue Crack Growth Rate (da/dN versus ΔK)



S-N Fatigue Curves



Fatigue Crack Growth Rate (FCGR)

API 17TR8 : Design Validation

- PR: Performance Requirements
  - Extension on existing PR of API 6A/17D
  - Identify validation testing for designs and products
  - PR3: Performance-based
    - PR2 + additional identified from equipment-FMECA, e.g.:
      - Elevated operating temperature
      - Additional thermal cycles, endurance cycling
  - PR4: Design Analysis Validation
    - PR3 + additional identified from project-FMECA, e.g.:
      - Strain-gauging program and comparison to FEA results
      - Fatigue testing in accordance with recognized standards

API 17TR8 : Phase 2

- **No Change** to published 1st Edition: scope, design methodologies, materials requirements
- **Refinement** in the areas of:
  - Quantify the effects of hydrostatic pressure test through industry research studies
  - Standardization of material characterization testing procedures
  - Standardization of input parameters for fatigue assessment – regional
  - Definitions and allowable stresses for “Extreme” / “Survival” conditions

Hydrostatic Pressure Test

- Quantify the effects of hydrostatic pressure tests through research studies
  - Pressure Rating ≤ 20ksi (existing APIs or ASME Div. 2 path)
    - Hydrostatic Test Pressure = **1.5 x API RWP**
  - Pressure Rating > 20ksi (ASME Div. 3 path)
    - Hydrostatic Test Pressure = **1.25 x API RWP**
  - **No adjustment in test pressure for yield strength at test temperature versus design temperature**
  - High test pressure may result in excessive yielding/permanent strain damage that can affect component's functionality, sealing, fatigue life estimation, etc.

Standardization Efforts
Material Characterization Procedures

- Objectives:
  - Standardization of material characterization and testing procedures
- Equipment designer identifies required properties through material selection and qualification processes
- Parameters:
  - Fatigue S/N Curves
  - Fatigue Crack Growth Rate, FCGR
  - Fracture Toughness, in environment, K_{IEAC}
  - Strain Limit Damage

Standardization Efforts
Input Parameters for Fatigue Assessment

- Objectives:
  - Identify and standardize input parameters for fatigue assessment – regional

- Input Parameters:
  - Static loads: Pressure/Temp
  - External loads
  - Material Characterizations:
    - Fluids: Drilling, Completion
    - Environmental effects: H_2S, CO_2, seawater, CP, etc.
  - Water depth range
  - Metocean conditions
  - Soil model/data (P-y)
  - Rig type
  - Operations:
    - Drilling
    - Production

ASME Collaboration

- Initiate collaboration efforts at ASME Pressure Vessel and Piping (PVP) Conference – July 2014
  - Engagement with ASME community, raising awareness of API's development of API 17TR8 with application of ASME Div. 2 and ASME Div. 3
  - Identification of API & ASME collaborative efforts on relevant subsea topics
- ASME Task Group for Subsea Applications (SG-HPV)
  - 1st Meeting – January 28, 2015
  - ASME and API participants
- Ongoing Collaboration Efforts

Thank You