Verification and Validation Challenges of HP/HT BOP and Well Control Equipment

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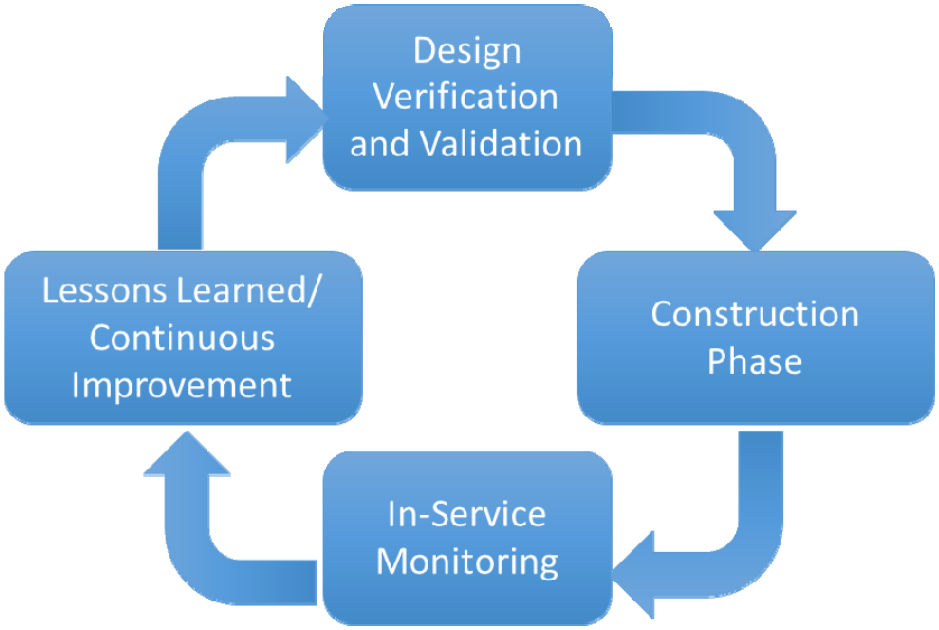
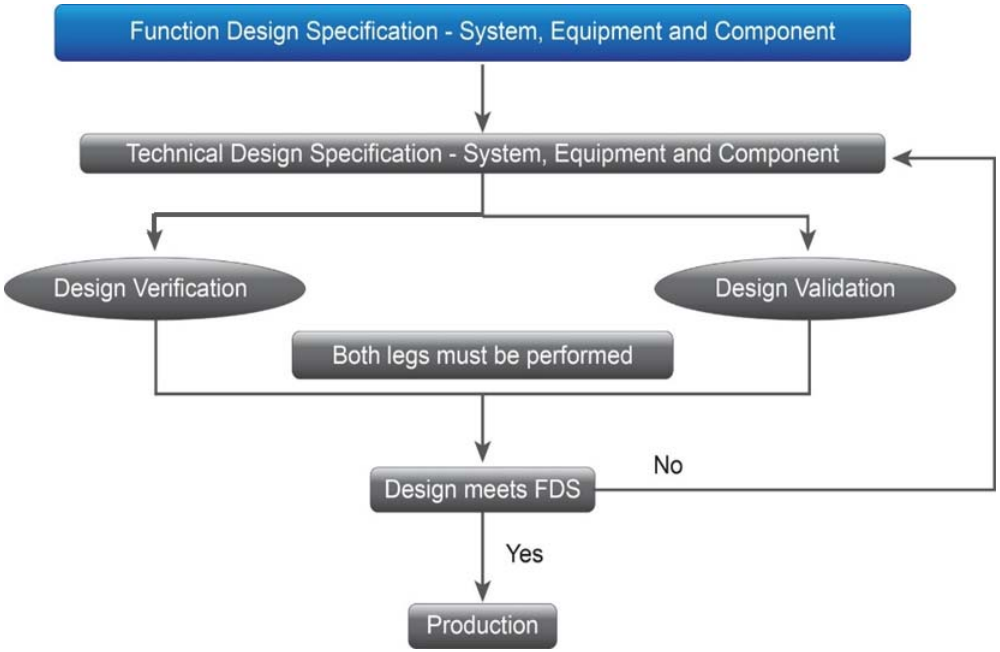


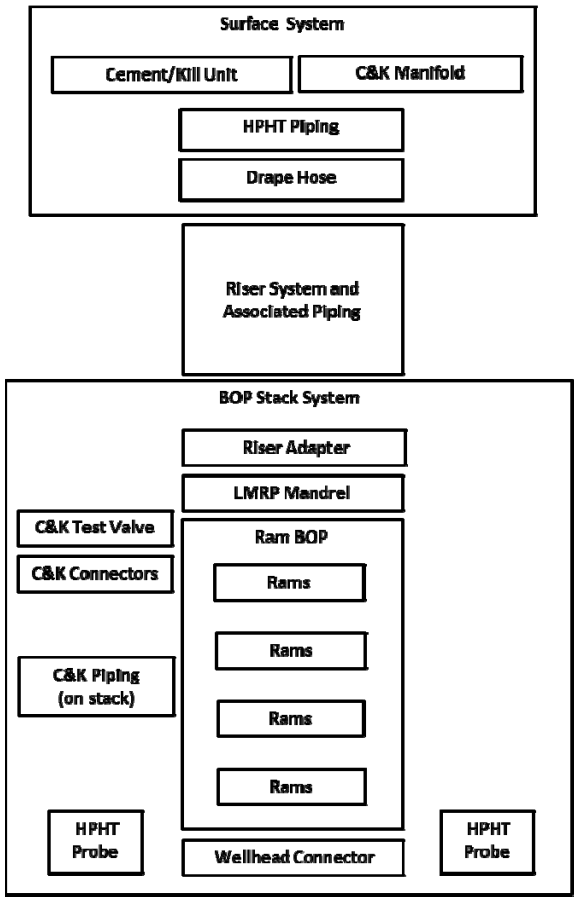
Introduction

- Definition of HPHT
  - HPHT is greater than 15,000 psi and/or greater than 350°F/177°C
- Code and standards for Well Control Equipment
  - API Std. 53
  - API Spec. 6A, 16A – 4th Edition Draft
  - API Std. 16AR – First Edition Draft
  - API Spec. 16C – Second Edition
  - API Spec. 16D – Third Edition Draft
  - API RP 16Q – Second Edition Draft
  - API RP 17TR8
  - ASME BPVC Section VIII, Div. 2 and 3
- HPHT equipment design process



HPHT Well Control Equipment Diagram

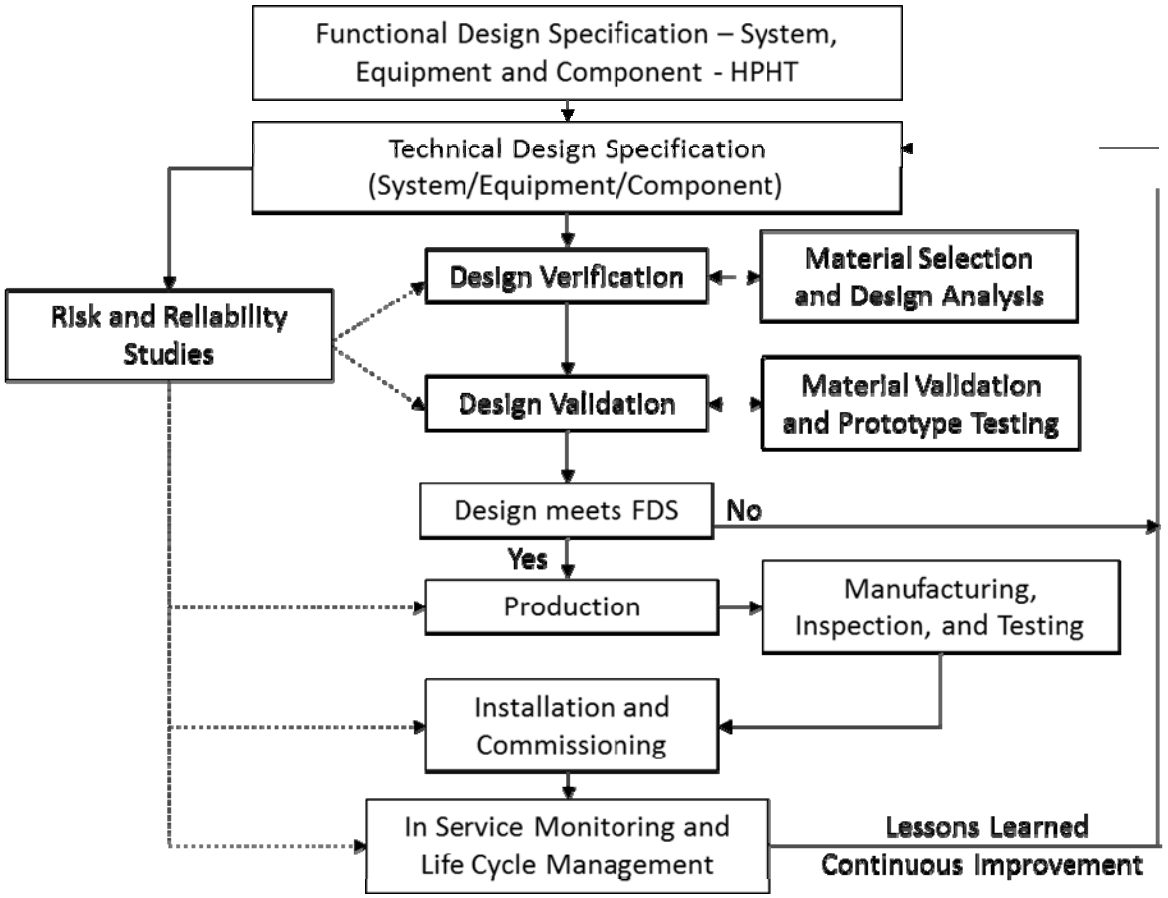
- BOP Stack System
  - Wellhead connector
  - Ram BOP/ram blocks
  - C&K connectors, valves, lines
  - HPHT probes
  - LMRP mandrel
  - Gas bleed valves
- Riser System
- Surface Equipment/Piping
- Annular Preventer not HPHT



ABS Technology Qualification (TQ)

- Per API TR 17TR8 and API TR 1PER15K-1
  - **Qualification:** process of validation and verification of the technology against certain offshore and marine industry standards and practices
    - Qualification = Risk reduction through risk study:
    - HAZID/HAZOP/FMECA + Design Verification + Validation Testing
  - **Verification:** to confirm that HPHT equipment design or development activity is in compliance with its functional specifications and there is adequate protection against failure modes identified
  - **Validation:** to demonstrate that the equipment meets the mechanical integrity and functionality/operability requirements as per the functional/design specifications

Overall TQ Flow Process



Overall Challenges

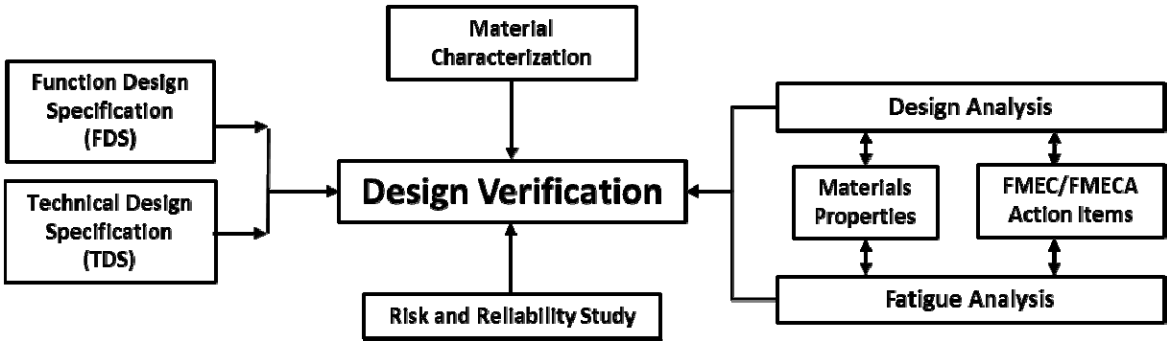
- HPHT conditions exceed capabilities of current drilling equipment
  - 15,000 psi and 250°F are current limitations
- Lack of codes, standards and/or regulations specific to HPHT system/equipment design and manufacturing
  - API 17TR8 Guidelines for production systems
  - API 16A – Annex for HPHT
- Unknown risk associated with equipment design and operations
- Regulatory uncertainty and newly proposed regulations
- Lack of field data and industry experience

Design Verification Challenges

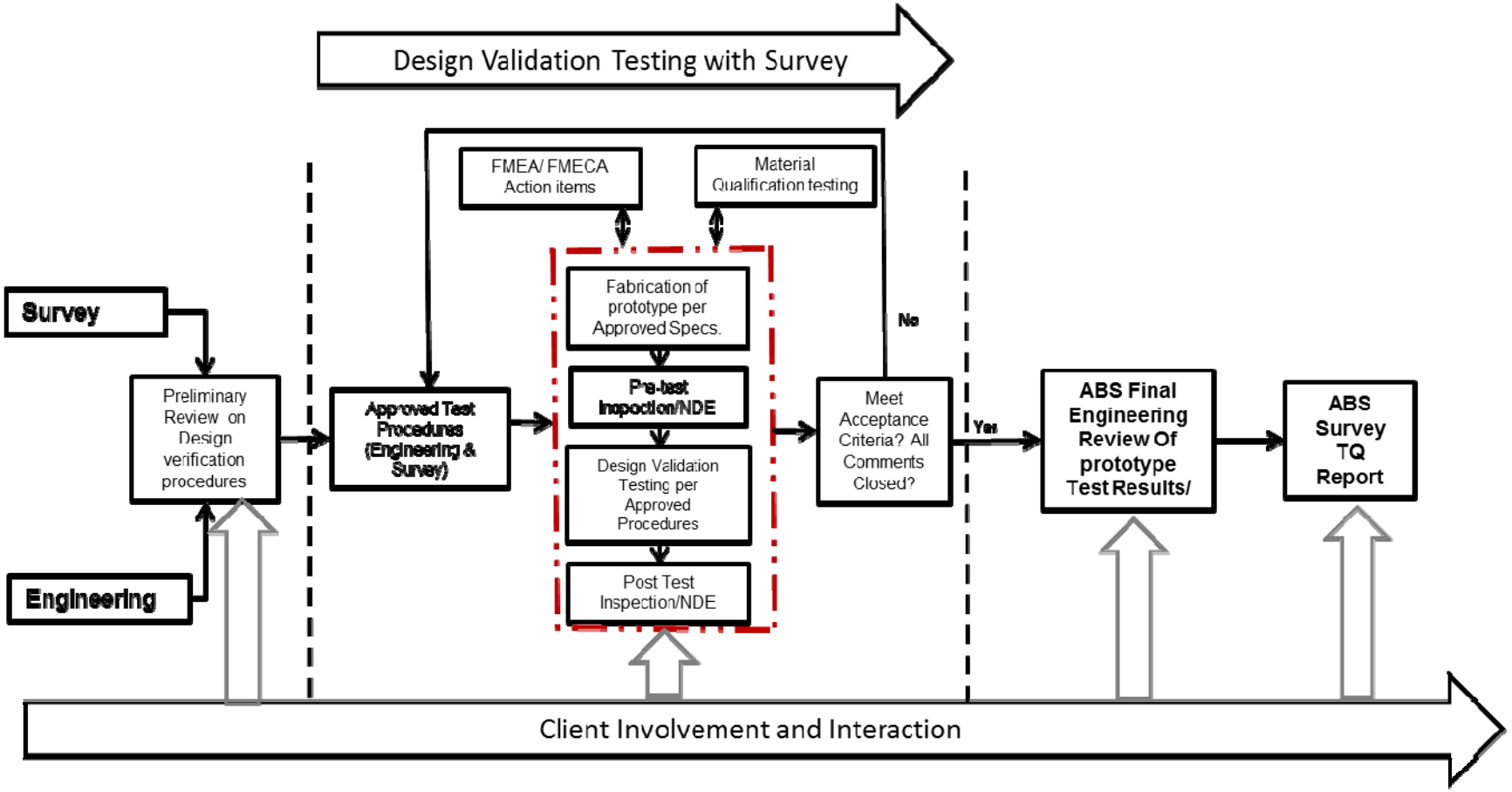
- Design standards used and types of analysis chosen
- Design exceeds or deviates from existing engineering standards
- FEA verification and calibration with test result
- Design analysis methods for welding and cladding planned for any equipment or components
- Calibration with test results

Design Verification Challenges

- Appropriately defined functional design specification/ technical design specification
- Load cases in the analysis and sequence of applied loads
- Thermal load analysis and effects
- Fatigue analysis
- Verification of sealing components (elastomeric sealing materials)



Design Validation and Prototype Production



Design Validation Challenges

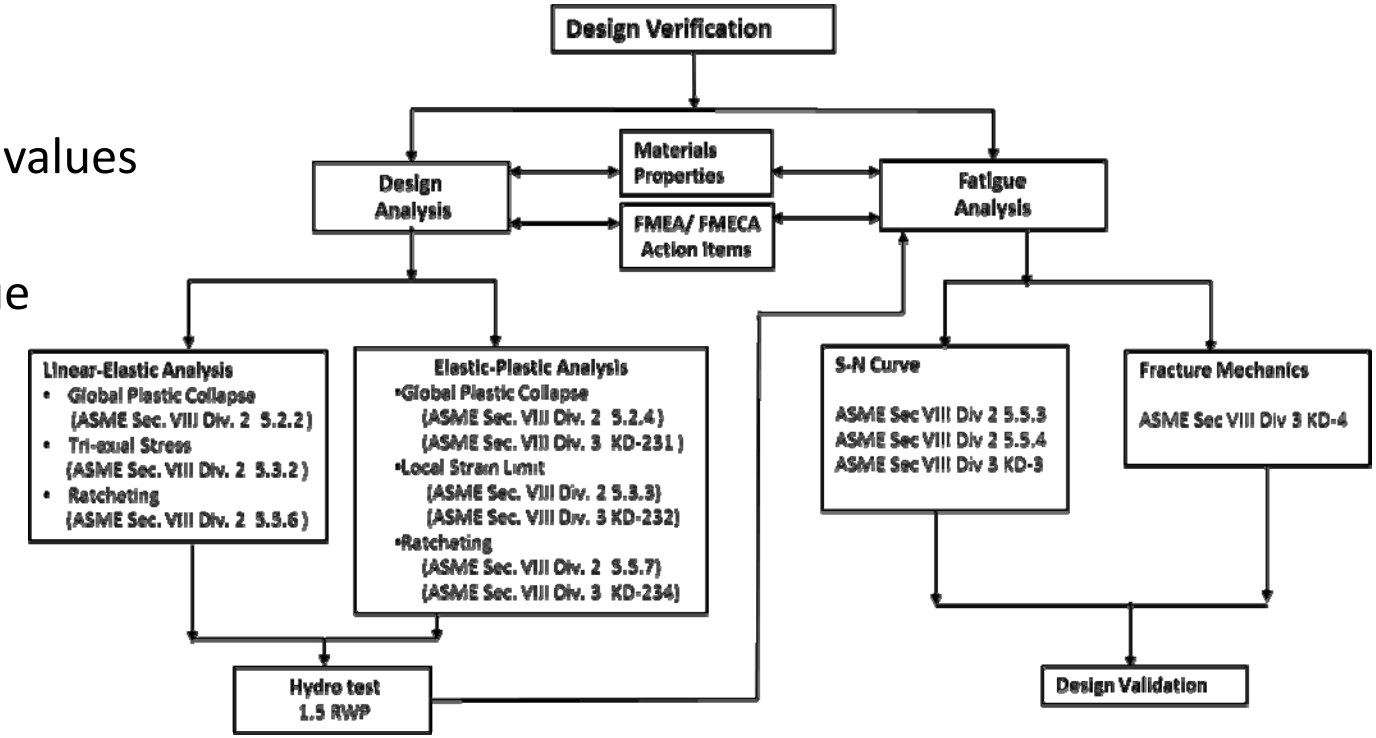
- Test equipment, cost and time
- Test equipment calibration prior to test/recalibration after test
- Testing fluids – stability and suitability at high temps
- Application of strain gauges in test – use of and placement
- High temperature testing – testing to simulate environmental temps
- Bolting validation test requirements
- Failure of associated equipment during testing
- Load sequencing
- Detailed procedures and recording required for testing
- Testing facilities for prototypes

Material Selection Challenges

- Temperature
- Chemistry
- Manufacturing procedure
- Material properties
- Exposure to environment: seawater, wellbore, drilling and completion fluids
- General and localized corrosion
- Erosion
- Elastomers
- Design life
- Creep at high temperatures
- Material interactions

Design Verification and Material Selection

- Material properties
  - True stress
  - Strain curves
  - Fracture toughness values
  - Fatigue properties
  - De-rating factors due to HT exposure
- Loading histogram



Material Design Validation

- Test conditions during test (temperature, loading conditions, strain rates, etc.)
- Test coupon sampling
- Welding procedure concerns
- Heat treatment sensitivity studies – if new alloys are developed
- NDE acceptance criteria
  - Probability of detection
  - Agreement on all parties on technique
- Qualification of manufacturers

Summary

- Guidance for HPHT equipment is increasingly necessary in the oil and gas industry
- Current standards, codes, and regulations provide a high level overview for environments above 15,000psi and/or 350°F; however, further detailed descriptions and guidance are in need
- The Technology Qualification process provides confidence and guidance for the owner, operator, and manufacturer to safely and systematically utilize their equipment
- Questions