Protocols for Equipment Rated Greater Than 15,000 PSI

PER15K - HPHT Equipment Development Process

PER15K TASK GROUP

API HPHT Task Group Deliverables

For the Development of Safe, Reliable, Fit-for-Use Products Outside of the Scope of Existing International E&P Standards Outline a Detailed Methodology for the:

Establishment of Product Essential Design Inputs (Basis of Design)

Identification of:

- **Pressure, Temperature, & Applied Loads From Systems Analysis**
- **Product Life Cycle Requirements**
- **Product Reliability Requirements & Potential Failure Modes**
- **Material Data for Exposed Environments**

Appropriate Product Design and Life Cycle Analysis Techniques

Establishment of Product Design Validation Protocols and Qualification Criteria

Identification of Essential:

- **Manufacturing Process Control**
- **Inspection Requirements**

Establishment of the Essential Storage, Handling and Use Parameters

Identification of Ongoing Data Collection and Product Performance Feedback

Drivers for API to Perform this Work

New product technology without significant industry experience

High Pressure thick wall forged bodies have a different failure mode which results in Fast Fracture as opposed to "Leak Before Burst" and requires different analysis techniques.

Challenging physical and environmental conditions of new E&P developments, beyond the limits of traditional industry standards.

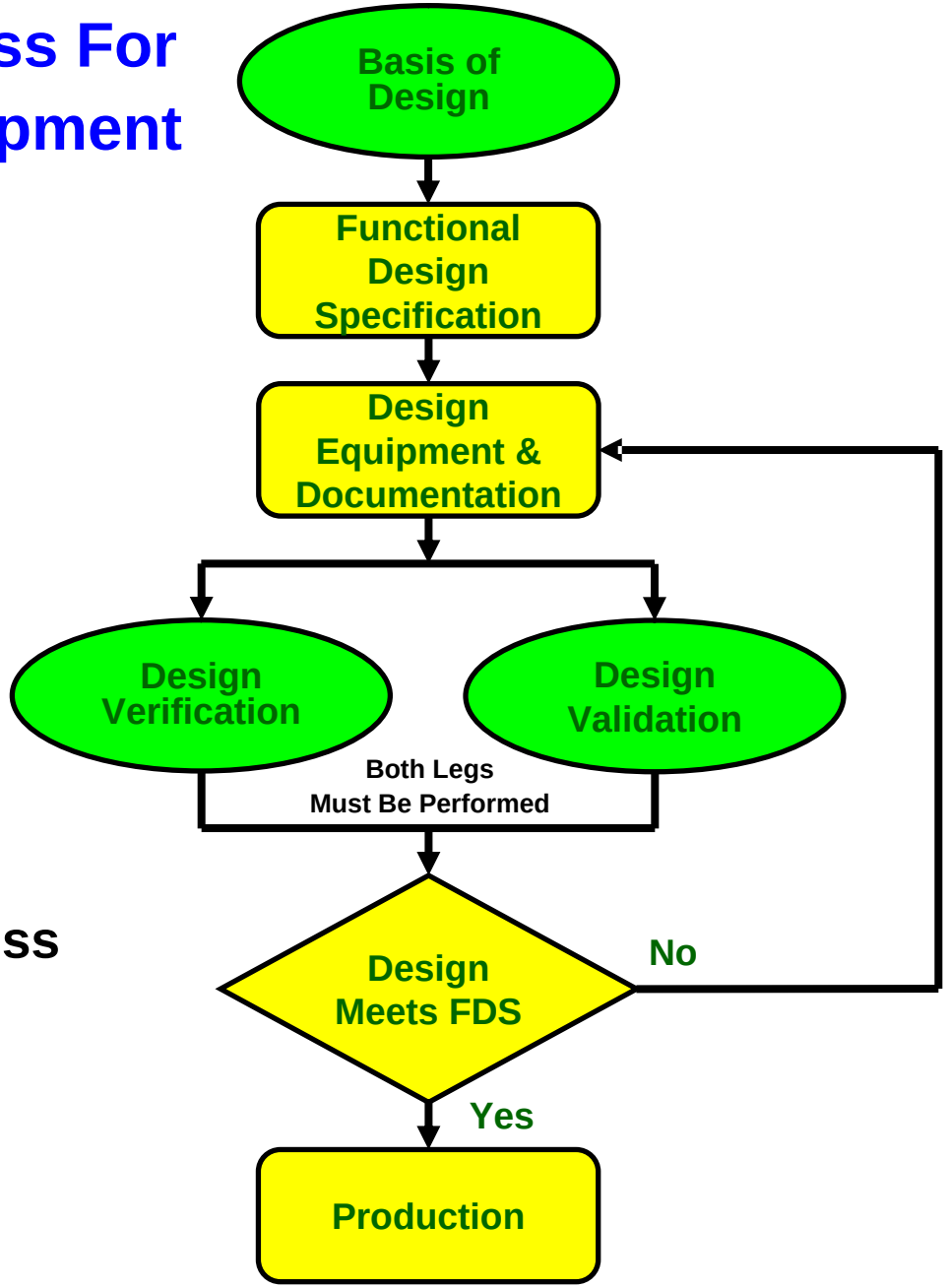
Advanced design and analysis capabilities.

Industry commitment to the technical integrity and HSE associated with industry challenges.

Availability of significant historical experience and lessons-learned:

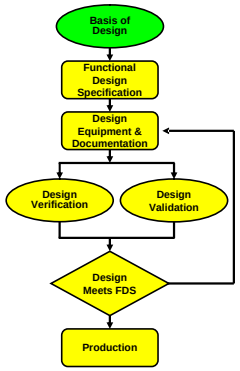
- **1980's: 30,000 psi wellhead and Xmas tree equipment**
- **1990's: 300+ deg. F wellhead and Xmas tree equipment**
- **2000's: Advanced design analysis capabilities and design codes**

Product Development Process For Existing or New Design Equipment



Fit for Purpose Qualification Process

Development Process



API Design Verification

7.3.5 Design and development verification

ISO 9001:2000, Quality management systems—Requirements

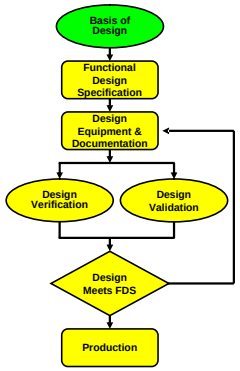
7.3.5 Design and development verification

Verification shall be performed in accordance with planned arrangements (see 7.3.1) to ensure that the design and development outputs have met the design and development input requirements. Records of the results of the verification and any necessary actions shall be maintained (see 4.2.4).

Note: Design verification activities can include one or more of the following:

a. Confirming the accuracy of design results through the performance of alternative calculations.
b. Review of design output documents independent of activities of 7.3.4.
c. Comparing new designs to similar proven designs.

Development Process



API Design Validation

7.3.6 Design and development validation

ISO 9001:2000, Quality management systems —Requirements

7.3.6 Design and development validation

Design and development validation shall be performed in accordance with planned arrangements (see 7.3.1) to ensure that the resulting product is capable of meeting the requirements for the specified application or intended use, where known. Wherever practicable, validation shall be completed prior to the delivery or implementation of the product. Records of the results of validation and any necessary actions shall be maintained (see 4.2.4).

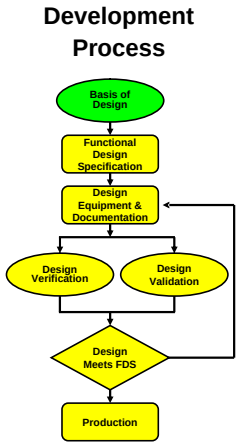
Note: Design validation can include one or more of the following:

a. Prototype tests.

b. Functional and/or operational tests of production products.

c. Tests specified by industry standards and/or regulatory requirements.

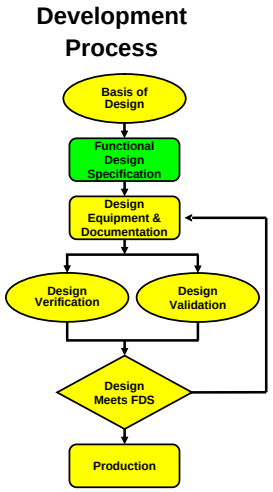
d. Field performance tests and reviews.



Project Basis of Design

Operational Specific Basis of Design

- Equipment Location – Surface or Subsea
- Location Environment – Max / Min
- Pressure – Inside / Outside
  - Maximum / Minimum / Transient / Steady State
  - Various Flow Rates
- Temperature – Inside / Outside
  - Maximum / Minimum / Transient / Steady State
  - Various Flow Rates
- Environmental Exposure
  - Outside (seawater, drilling and completion fluids, etc)
  - Inside (seawater, drilling and completion fluids, etc)
  - Reservoir Surfaces Contact
  - Reservoir Chemistry
- Anticipated Life Cycle Operating Requirements
  - Interventions, Work Over, Shutdowns, etc.

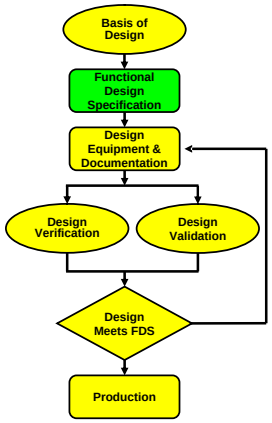


Functional Design Specification

Operational Statement of Requirements

- System Description
- Operating Conditions based on Basis of Design
- Known Applied Loads
- System Analysis to Obtain all Component Loads
  - Include all Pertinent Equipment Interfaces
  - Study Installation and Removal Loads
  - Study Start-up, Steady State, Shut-down
- Failure Modes & Effect Analysis of Components
- Life Cycle Operations for System/Components
- Environments in Contact w/ Wetted Surfaces

Development Process

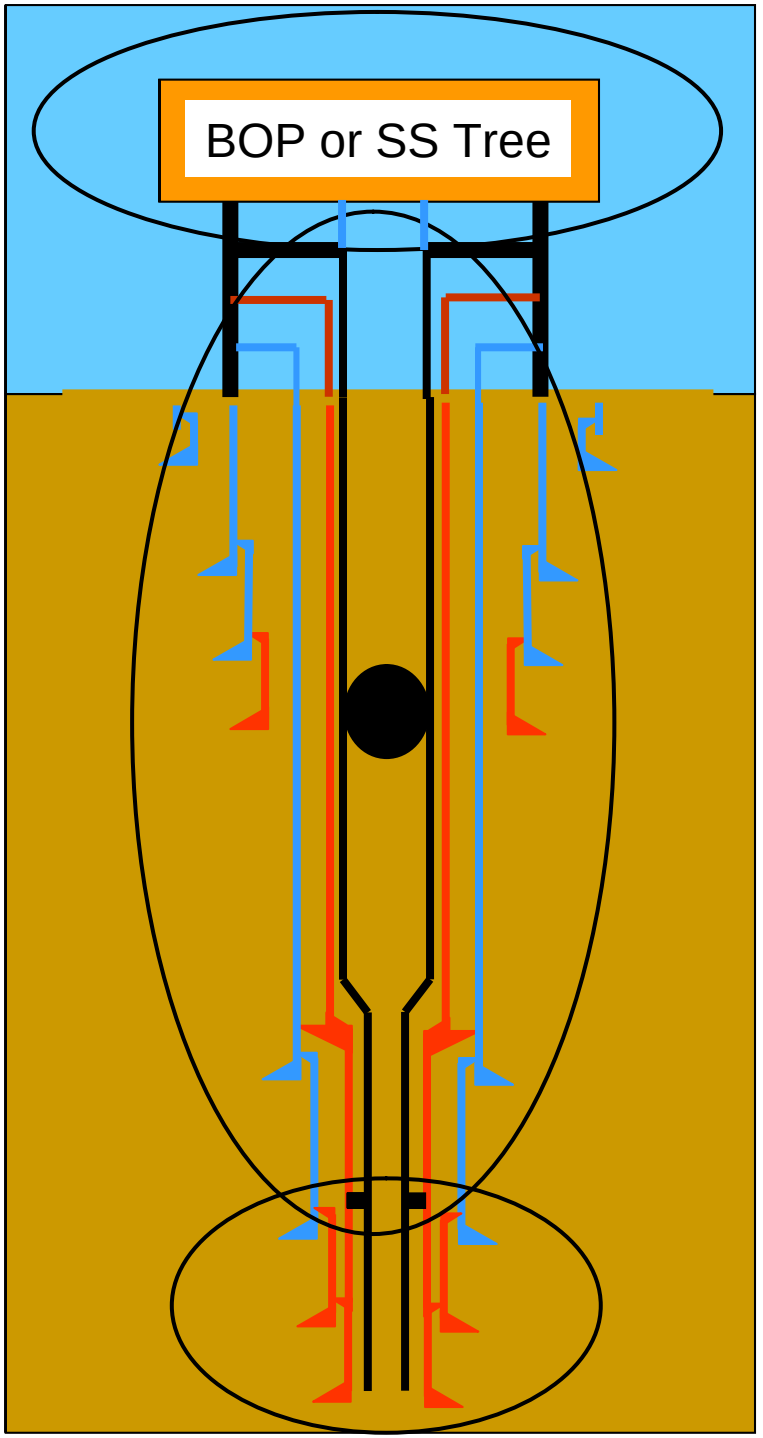


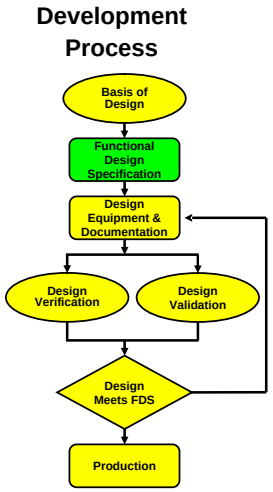
System Analysis Specification Breaks

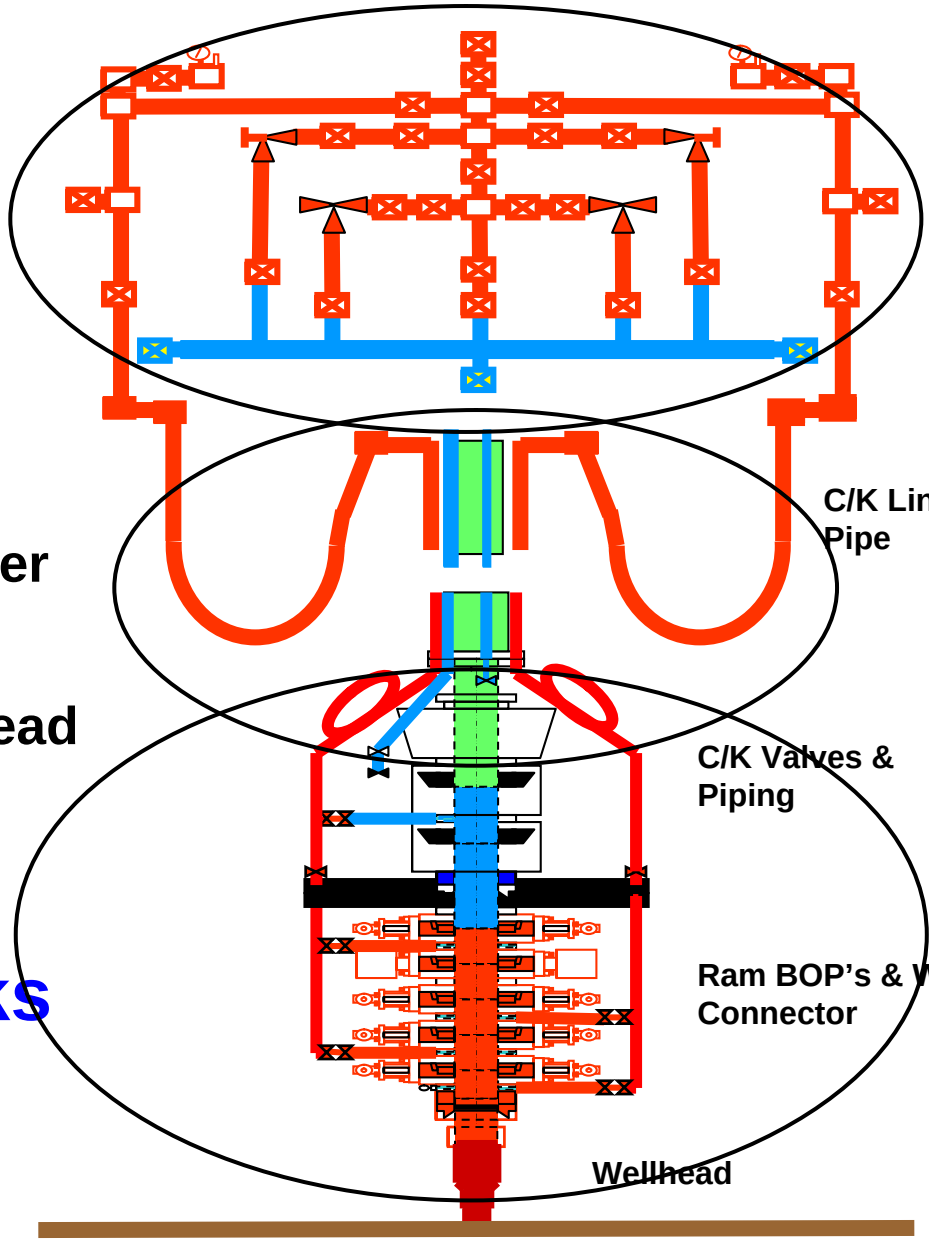
Above Wellhead

Wellhead
Casing
Tubing

Completion Equipment

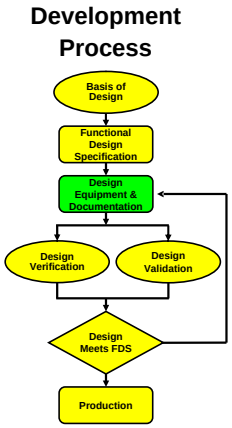






System Analysis
Specification Breaks

Well Construction
Well Completion
Well Intervention



Design & Documentation

Design Specifications and Practices

- **Applicable Industry Standards**
- **Customer Specifications**
- **Company Proprietary IP**

Determine Design Envelope & Interface Dimensions

Determine Physical Operating Envelope

Functional Issues (outlets, door openings, etc.)

Material / Welding Specifications

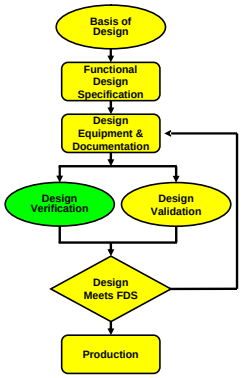
NDE Criteria

Specify Design Verification Analysis Requirements

Specify Design Validation Testing Requirements

Write Design Verification & Validation Quality Plans

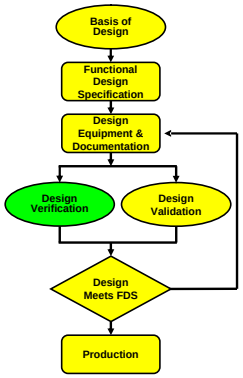
Development Process



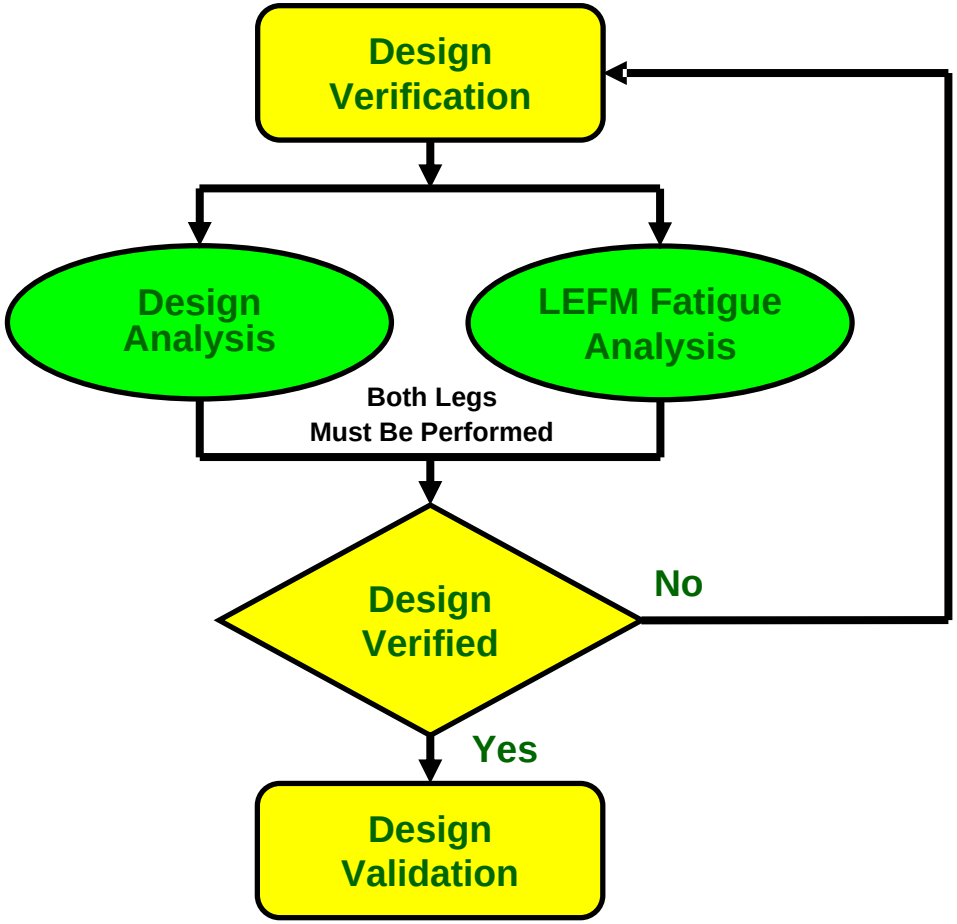
Design Verification

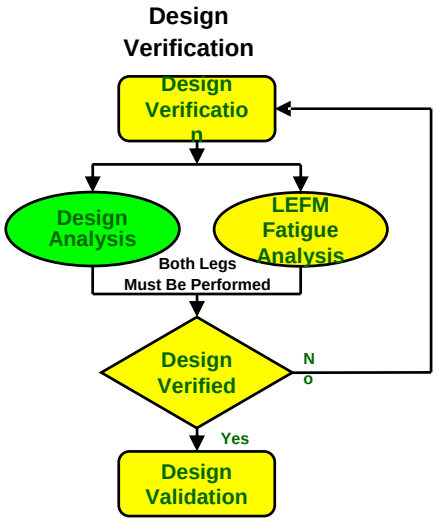
- Uses Functional Specification as Inputs
- Design Material Properties
  - Material Properties At Design Temperature (Inside & Out)
  - Material Properties In Service Environment (Inside & Out)
  - Determine Minimum Detectable Flaw Size (inspection)
- Comprehensive Design Conditions Analyses
  - Static, Dynamic, & Transient
  - Pressure (Inside and Out)
  - Thermal (Inside and Out)
  - Loads (Tension, Bending, & Torsion)
- Stress Analysis Using FEA
  - Comprehensive Design Conditions (Operating)
  - Hydrostatic Proof Test
- Life Cycle Fatigue Analysis
  - Fracture Mechanics/S-N Curves
  - Cycles to Failure

Development Process



Design Verification Analysis

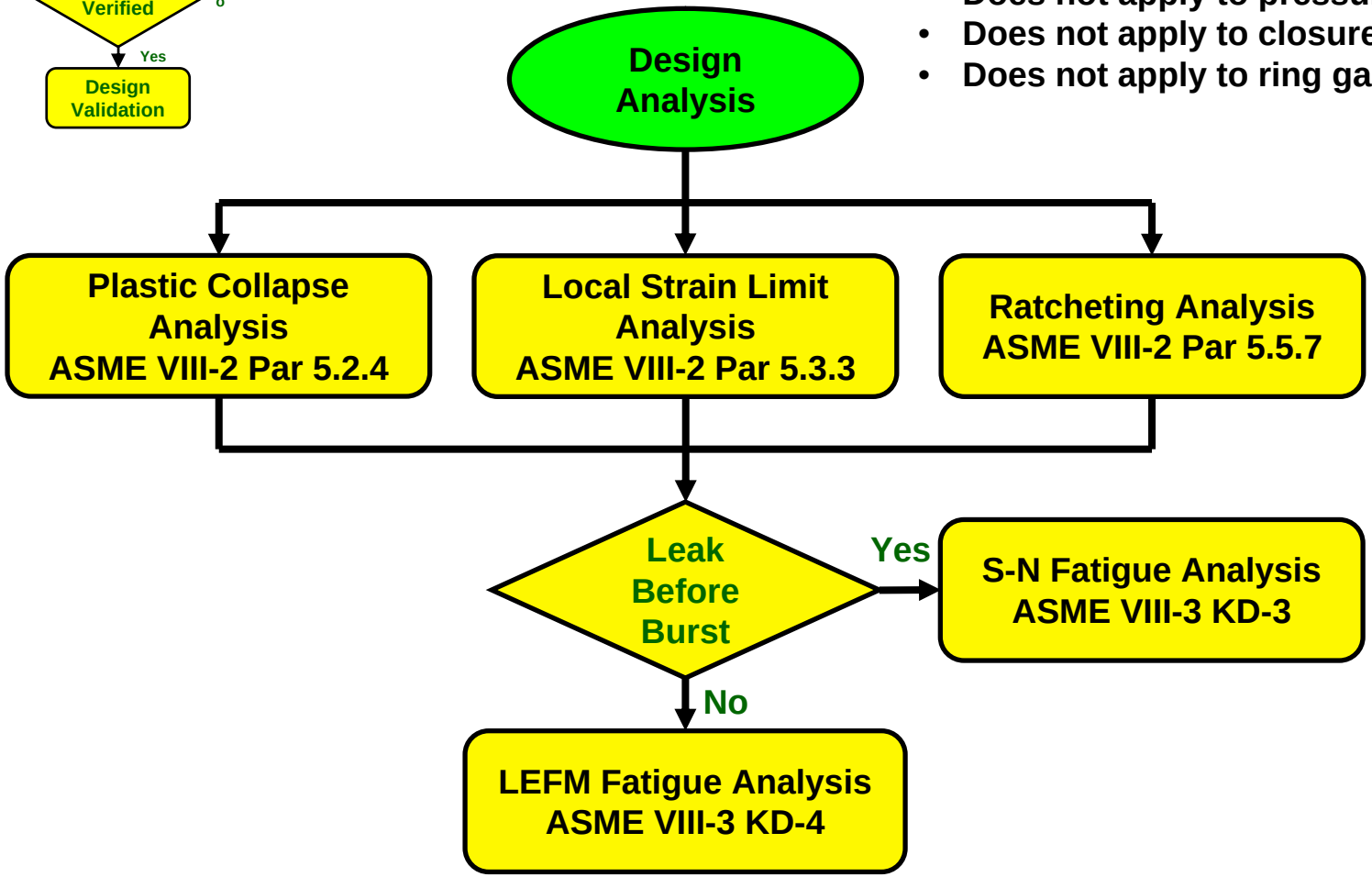




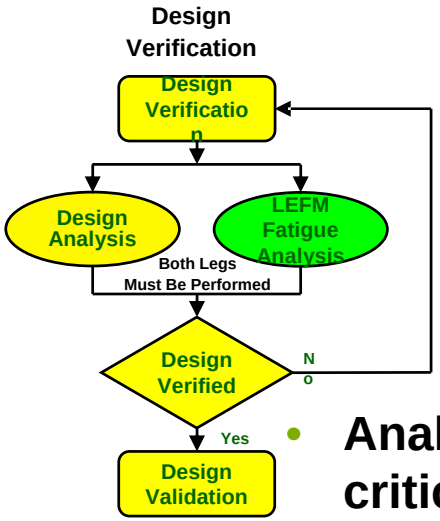
Design Analysis

Design Verification Analysis

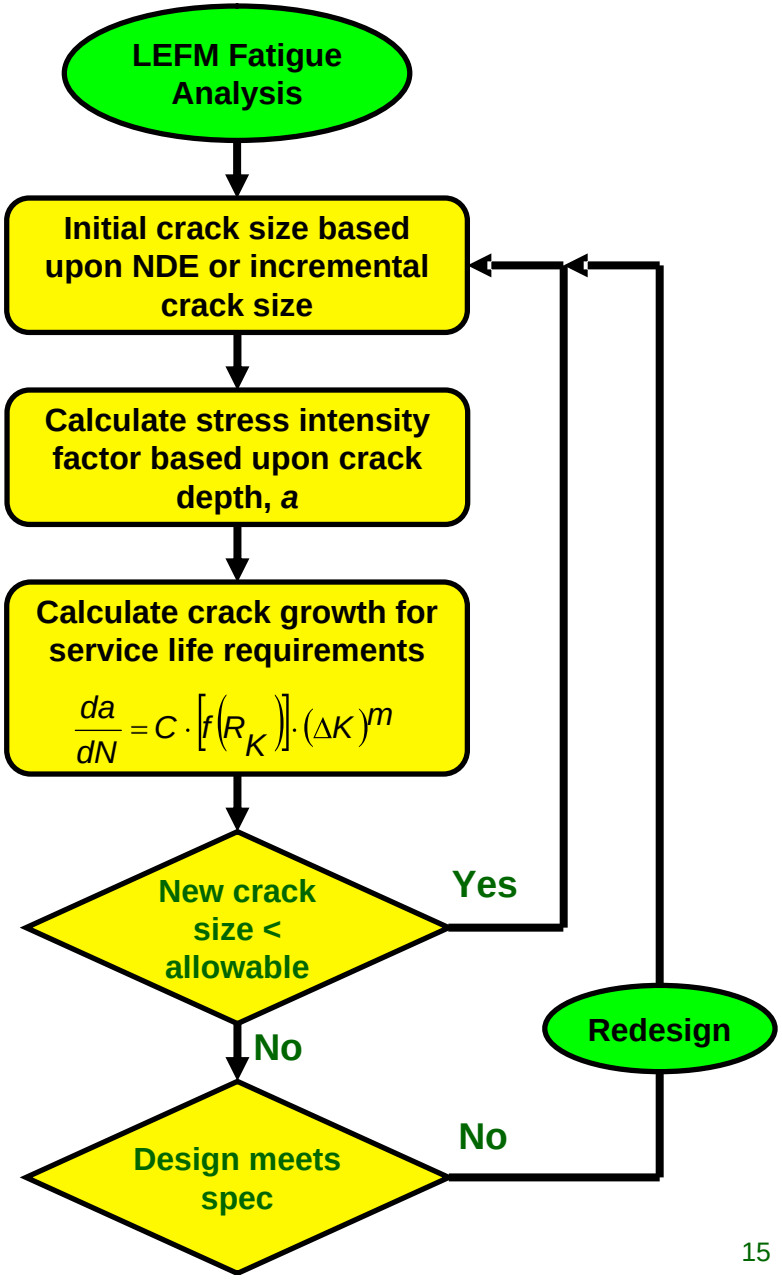
- **Applies to pressure containing parts**
- **Does not apply to pressure retaining parts**
- **Does not apply to closure bolting**
- **Does not apply to ring gaskets**

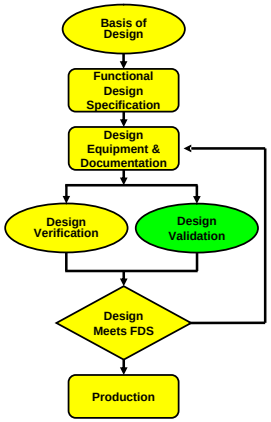


LEFM Fatigue Analysis



- Analysis required for each critical section
- Assume initial crack size based upon NDE capability
- Crack aspect ratio should be updated as crack grows
- Use appropriate material crack growth rate data for environment and loading
- Allowable crack size based upon ASME Div 3 KD-412 or Other Acceptable Criteria





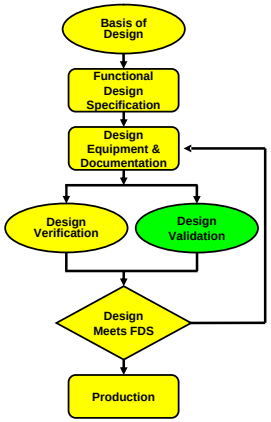
Design Validation

Design Test Program

- Use Functional Design Specifications
- Validate Design Verification
- Insitu Temperature Requirements
  - Inside and Outside
  - Dynamic, Transient, and Steady-State
- In-Service Load Conditions
  - Pressure & All Applied Loads (Tension, Bending, Etc)
  - Inside and Outside
  - Dynamic, Transient, and Steady-State
- Measure and Monitor Peak Stresses
- Establish Reliability Goals and Testing Methodology

If Physical Tests are Impractical

- Analytical Simulations
- Scale Model Tests
- Tests of Less Magnitude - Scale

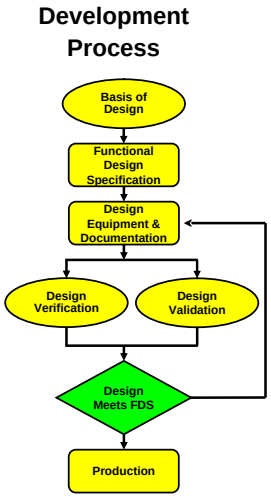


Design Validation protocol development Using FMEA (Failure Mode and Effects Analysis)

- **FMEA, Failure Mode and Effects Analysis is a bottoms up approach to analyzing system design and performance. FMEAs employ probability of failure categories based on probability ranges.**

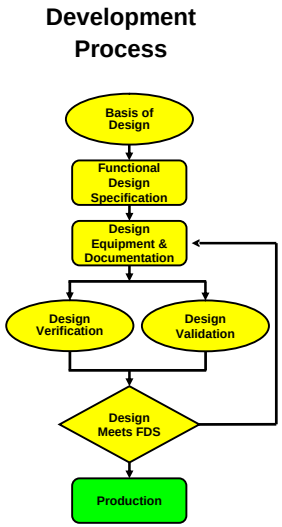
- **FMECA, Failure Mode, Effects and Criticality Analysis is based on MIL-STD-1629, "Procedures for Performing a Failure Mode, Effects and Criticality Analysis". In a FMECA, the probability of a specific failure occurring is given as a numerical prediction.**

- **A FMEA is qualitative, whereas a FMECA is a quantitative analysis. The proper category is determined by the experience and expertise of the analyst, instead of a mathematical probability calculation involving actual component failure rates.**

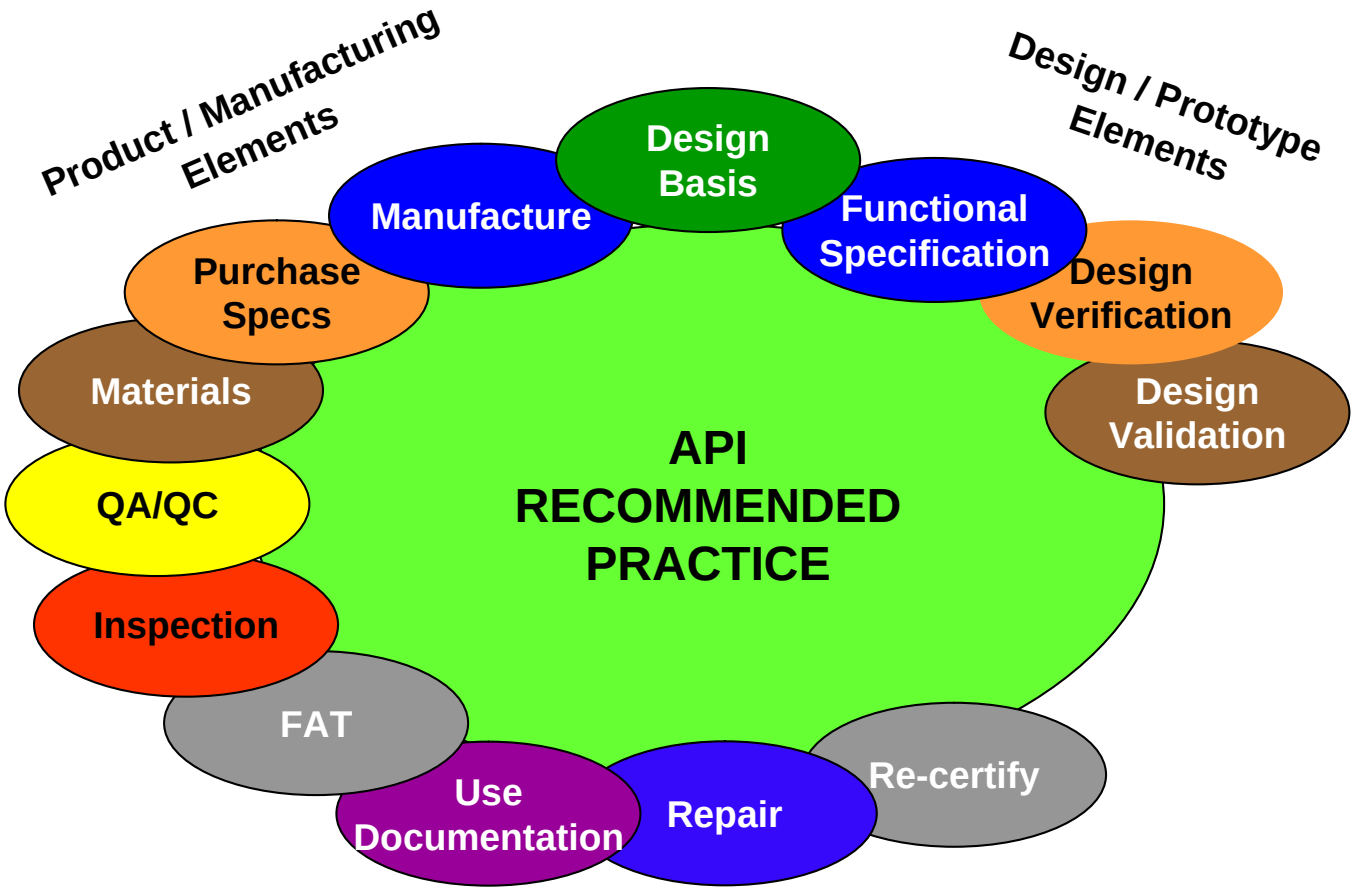


Design Meets Functional Design Specification (FDS)

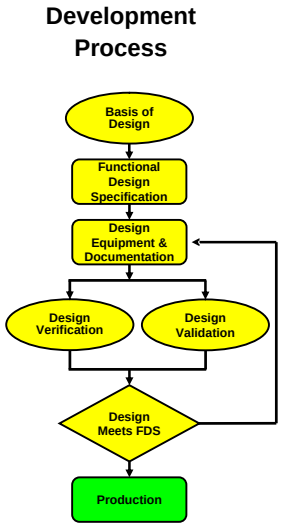
- **Both Legs of Process Flowchart Must be Satisfied**
  - **The Design Validation Process Confirms the Design Verification Results**
- **Document All Design, Verification & Validation Data**
- **Design Specifications and Practices**
  - **Applicable Industry Standards**
  - **Customer Specifications**
  - **Company Proprietary IP**
- **Material / Welding Specifications**
- **NDE Criteria**
- **Design Verification Analysis**
- **Design Validation Testing**
- **Quality Plans**

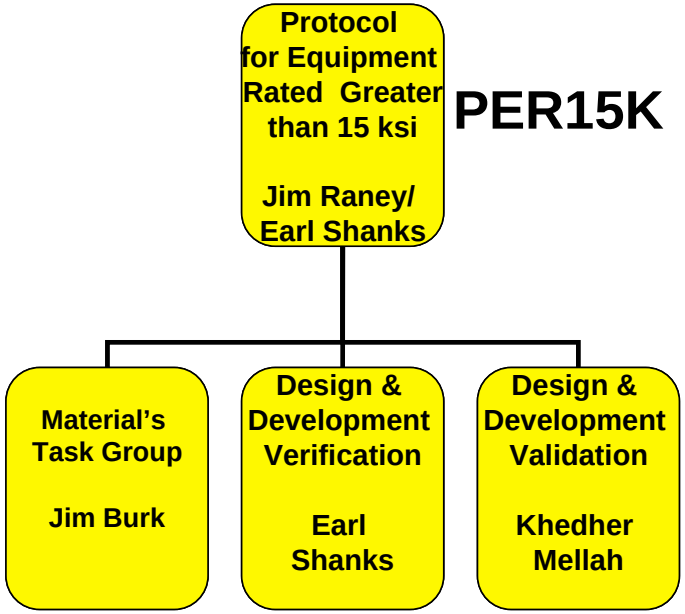


Elements Required to Complete The Manufacturing Process



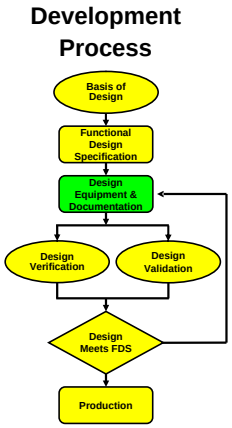
Proposed Timeline for PER15K





PER15K form as a task group under the ESC.

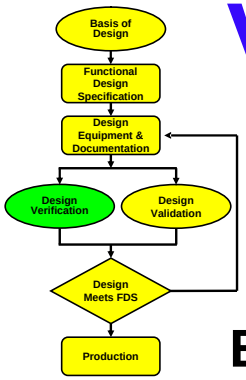
Proposed Time Line for PER15K														
Task	**Dates**	**Jan '09**	**Feb '09**	**Mar '09**	**Apr '09**	**May '09**	**Jun '09**	**Jul '09**	**Aug '09**	**Sept '09**	**Oct '09**	**Nov '09**	**Dec '09**	**Jan '10**
Presentation at the API Winter Meeting	Jan '09.													
Set meeting with vendors and operators	Jan-June '09													
Hold quarterly meeting to generate a draft document	Jan-Sept '09.													
1st Draft, Review draft.	Oct '09.													
2nd Draft, Present at Winter API Meeting	Jan'10.													



Materials Deliverables and Timeline

- Re-initiate Materials Task Group monthly meetings ***February 2009***
- Establish lists of Materials and Property Requirements-***June 2009***
  - Elastic properties-Modulus & Poisson's ratio with temperature
  - Mechanical strength –yield and ultimate with temperature
  - Fracture Toughness – CVN, KIC/JIC with temperature
  - Fatigue – S/N and crack Growth rate
  - Environments – Air & Seawater
- Populate materials property tables – ***October 2009***
- Establish additional data requirements – ***December 2009***
- Propose testing (MMS F22 effort) – ***2010 API Winter Meeting***

Development Process



Verification Development & Timeline

Example Analysis Required by ECS Complete

Recommendations Have Been Received to Modify Doc

Formed a Design Analysis Team

- **Review Recommended Changes**
- **Make Recommendations to Verification Work Group - March**

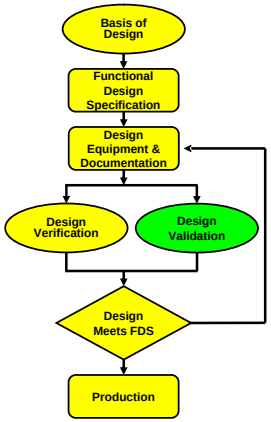
Verification Work Group Will Act on Recommendations - April

Revise Verification Document - June

Establish Review Groups to Wordsmith Document - August

Merge Work Efforts into New Revision - Oct

Submit to PER15K Task Group - Nov



Validation Development Process

- Develop the test development protocol and use the 6HP example to demonstrate it. Develop the process.
- Perform the FMEA to come up with the test protocol for the completion equipment in question. Update the process.
- Produce a document with proposed test protocol list and test steps.
- Collect feedback and update the document
- 2009: Perform FMEA for:
  - Ask participant to share FMEA and test example.
  - SCSSV
  - If time allows: Gauges or Packer

Proposed 2009 timeline