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Development of a 20,000 psi and 350˚F Rated Subsea Wellhead System

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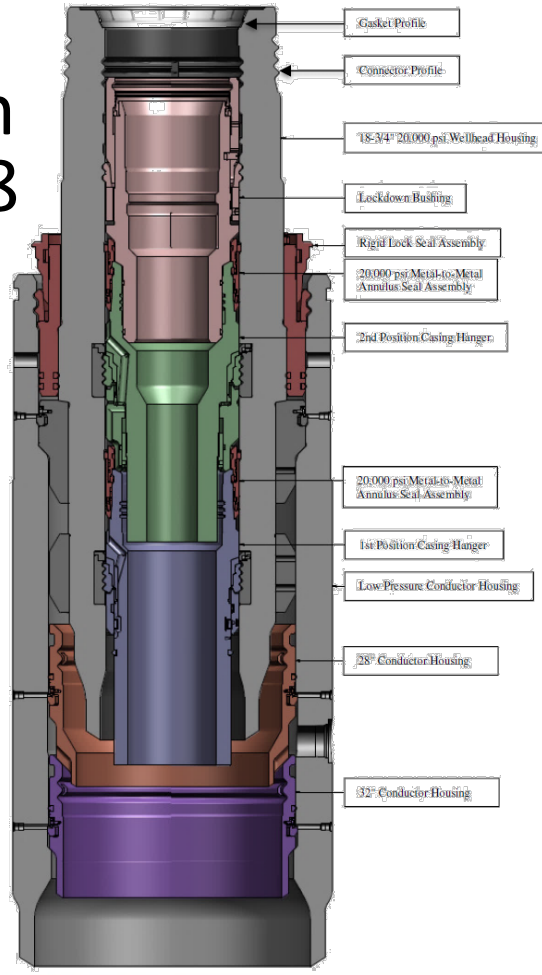
Lead Engineer

TechnipFMC

INTRODUCTION

- HPHT 18 ¾” Subsea Wellhead System designed and qualified per API 17TR8 (HPHT Design Guidelines)
  - ➢ Design Approach
  - ➢ Challenges and lessons learned
  - ➢ Independent Third Party (I3P) Review Process



SYSTEM RATINGS

- 20,000 psi
- 0˚F - 350˚F
- 8,900,000 lb total casing weight
- 2,700,000 lbf rated casing hanger running tool
- Up to 3,300,000 lbf rated casing hanger upthrust
- 20,000 psi BOP testing
- 10,000,000 ft-lbf bending
- Over 4,000,000 lbf tension
- 10,000,000 lb compression

DESIGN PHILOSOPHY

- Design flowchart from API 17TR8
- Detailed product specifications
- Failure Modes, Effects, and Criticality Analyses (FMECA's)
- Increased level of analysis and testing

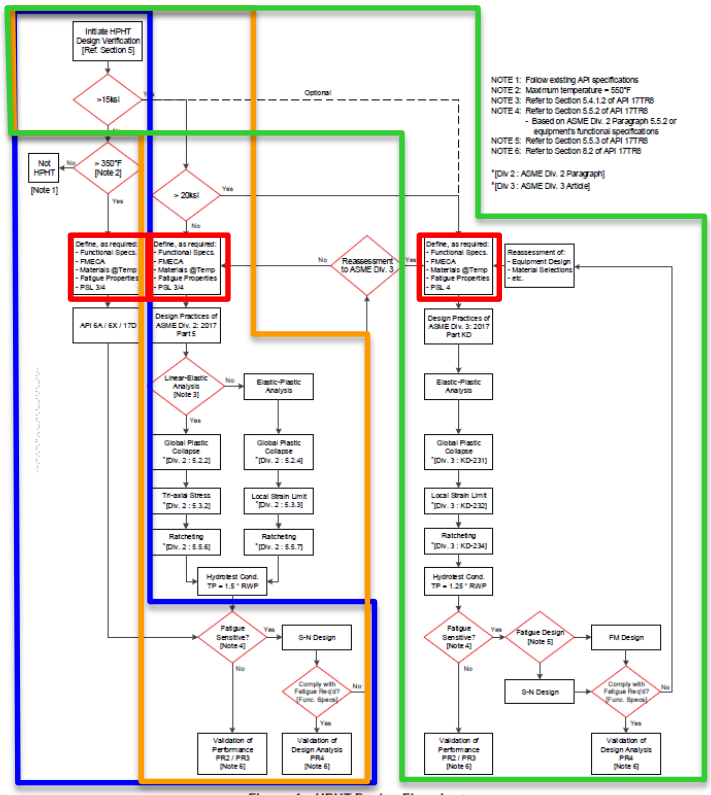


Figure 1—HPHT Design Flowchart

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Line #	Applicable Operating Modes	Function/ Component	Failure Mode	Failure Cause	Failure Effect (Semi-Local and Global effect)	s, SNs, LL and RC		Severity	Probability	Risk Category	Verification Assessment			Validation Test												Severity	Probability	Risk Category
											Industry Design Code	Analysis	Materials Analysis	PR2/ Code Standard	Level 2	Level 3	Process/Production Control Measure (i.e. Engineering Safeguard/ Preventive Detection)	Safeguard Code	Comments	Recommendations	Responsibility	Expected Date of Completion	Status Open/Closed	Actions Taken				
23	Production	M2M seal element	Loss of Functionality - loss of containment	Thermal cycles can cause the seal to move axially inside the wellhead and this cyclical movement could lead to galling	Loss of containment between annular cavity and well bore.			5	2	10	API 17D, section 8.7.2.1		Material is 8630, coated with PTFE coating (C81000) , 85k yield, NACE rated (M20409)	M2M ASA: Legacy PR2 report RPT10008228, 20k top, 15k bottom, 0-350F. PR2 Report RPT10111598 documents PR2 to 15k top, 11k bottom, 35-350F. PR2 Report RPT10146930 documents PR2 to 20k top, 11k bottom, 0-350F PR2 Report RPT10146929 documents PR2 to 20k top, 15k bottom, 0-350F	Legacy Report 90-41 shows results for the lockdown capacity of a similar geometry (basis for this design) M2M ASA: Legacy Report 91-66 shows results for scrub testing, lockdown capacity (basis for this design) The ASA is qualified to the requirements in the product specifications to meet the requirements of the project. SPC10119990 - M2M ASA SPC10107364 - Elastomer ASA		LDB installed on the hanger will prevent axial movement of the seal element. PTFE coating (C81000) is applied to part in an effort to ensure the assembly and interfacing parts can move freely, thus minimizing galling concerns. Several different tests with same geometry and similar geometry have been tested and there was no galling detected between Seal Element and mating interfaces.	QT			ENGR		CLOSED	RPT10146930 & RPT10146929 released on ECN 1292280.		5	1	5
24	Production	Seal Element	Loss of Functionality - loss of containment	Thermal cycles leading to loss of contact pressure	Loss of containment between annular cavity and well bore.			5	2	10	API 17D, section 8.7.2.1			M2M ASA: Legacy PR2 report RPT10008228, 20k top, 15k bottom, 0-350F. PR2 Report RPT10111598 documents PR2 to 15k top, 11k bottom, 35-350F. PR2 Report RPT10146930 documents PR2 to 20k top, 11k bottom, 0-350F PR2 Report RPT10146929 documents PR2 to 20k top, 15k bottom, 0-350F Elastomer ASA: PR2 report RPT10049658, 15k top, 10k bottom, 35-250F (HNBR) PR2 Report RPT10073025, 20k top, 12.5k bottom, 35-250F (HNBR) PR2 Report RPT10076154, 20k top, 12.5k bottom, 35-300F (FKM) PR2 Report RPT10146926, 20k top, 12.5k bottom, 35-250F (FKM)	M2M ASA: PR2 Report RPT10111598 documents Extended Cycle Testing and Worst Case Discharge Simulation. M2M ASA PR2 Reports RPT10146929 & RPT10146930 document Extended Cycle Testing.		The ASA is qualified to the requirements in the product specifications to meet the requirements of the project. SPC10119990 - M2M ASA SPC10107364 - Elastomer ASA	QT			ENGR		CLOSED	RPT10146930 & RPT10146929 released on ECN 1292280.		5	1	5
25	Production	Seal Element	Loss of Functionality - loss of containment	Excessive pressure cycles above & below the seal (cyclic loading) (galling on the M2M seal element could lead to failure)	Loss of containment between annular cavity and well bore.			5	2	10	API 17D, section 8.7.2.1			M2M ASA: Legacy PR2 report RPT10008228, 20k top, 15k bottom, 0-350F. PR2 Report RPT10111598 documents PR2 to 15k top, 11k bottom, 35-350F. PR2 Report RPT10146930 documents PR2 to 20k top, 11k bottom, 0-350F PR2 Report RPT10146929 documents PR2 to 20k top, 15k bottom, 0-350F Elastomer ASA: PR2 report RPT10049658, 15k top, 10k bottom, 35-250F (HNBR) PR2 Report RPT10073025, 20k top, 12.5k bottom, 35-250F (HNBR) PR2 Report RPT10076154, 20k top, 12.5k bottom, 35-300F (FKM) PR2 Report RPT10146926, 20k top, 12.5k bottom, 35-250F (FKM)	M2M ASA: PR2 Report RPT10111598 documents Extended Cycle Testing and Worst Case Discharge Simulation. M2M ASA PR2 Reports RPT10146929 & RPT10146930 document Extended Cycle Testing.		The ASA is qualified to the requirements in the product specifications to meet the requirements of the project. SPC10119990 - M2M ASA SPC10107364 - Elastomer ASA	QT			ENGR		CLOSED	RPT10146930 & RPT10146929 released on ECN 1292280.		5	1	5
26	Production	Seal Assembly	Loss of functionality, individual components shift/move relative to each other away from a fully locked position	Ratcheting due to cyclic thermal and pressure loads	Cracks form and propagate through the ASA leading to loss of containment			4	3	12	API 17D, section 8.7.2.1			M2M ASA: Legacy PR2 report RPT10008228, 20k top, 15k bottom, 0-350F. PR2 Report RPT10111598 documents PR2 to 15k top, 11k bottom, 35-350F. PR2 Report RPT10146930 documents PR2 to 20k top, 11k bottom, 0-350F PR2 Report RPT10146929 documents PR2 to 20k top, 15k bottom, 0-350F Elastomer ASA: PR2 report RPT10049658, 15k top, 10k bottom, 35-250F (HNBR) PR2 Report RPT10073025, 20k top, 12.5k bottom, 35-250F (HNBR) PR2 Report RPT10076154, 20k top, 12.5k bottom, 35-300F (FKM) PR2 Report RPT10146926, 20k top, 12.5k bottom, 35-250F (FKM)	M2M ASA: PR2 Report RPT10111598 documents Extended Cycle Testing and Worst Case Discharge Simulation. M2M ASA PR2 Reports RPT10146929 & RPT10146930 document Extended Cycle Testing.		The ASA is qualified to the requirements in the product specifications to meet the requirements of the project. SPC10119990 - M2M ASA SPC10107364 - Elastomer ASA	QT			ENGR		CLOSED	RPT10146930 & RPT10146929 released on ECN 1292280.		4	1	4
27	POOH, Retrieval and Mistrips	Wellhead Lockring	Dropped Object downhole	Wellhead Lockring snags on BOP annular ram	Lockring strips off seal assembly and drops downhole			2	2	4	*	N/A					Operator must ensure annular ram is fully opened in order to drift the SLT-retrieved seal assembly without snags. Another option is to use the dog & window packoff design which replaces the lockring with encapsulated dogs. The lockdown capacity for this design is lower but this would be ok if the LDB is used for the lockdown requirement. ICP for SLT Retrieval is ICP100002857; section 3.0, #9 lists expected retrieval load and instructs techs to contact base if overpull is not achieved.	FIELD, ENGR		Add note to ICPs to ensure Annular ram is completely open prior to POOH	ENGR		N/A			2	2	4

FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Line #	Applicable Operating Modes	Function/ Component	Failure Mode	Failure Cause	Failure Effect (Semi-Local and Global effect)	GNs, SNs, LL and RCA		Severity	Probability	Risk Category	
25	Production	Seal Element	Loss of Functionality - loss of containment	Excessive pressure cycles above & below the seal (cyclic loading) (galling on the M2M seal element could lead to failure)	Loss of containment between annular cavity and well bore.			5	2	10	

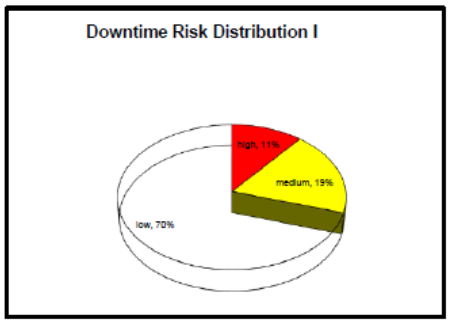
FAILURE MODES, EFFECTS, AND CRITICALITY ANALYSIS (FMECA)

Risk Evaluation Summary 1

Downtime (Effect Severity)	1	2	3	4	5
5	18	10	3	1	0
4	4	13	0	3	0
3	5	0	2	0	0
2	1	3	1	0	0
1	0	0	0	0	0

Cause Probability

high	7	11%
medium	12	19%
low	45	70%
Total Causes	64	

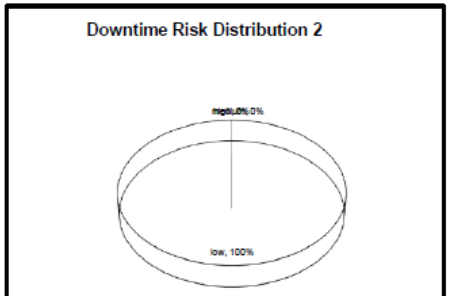


Risk Evaluation Summary 2

Downtime (Effect Severity)	1	2	3	4	5
5	32	0	0	0	0
4	17	3	0	0	0
3	7	0	0	0	0
2	4	1	0	0	0
1	0	0	0	0	0

Cause Probability

high	0	0%
medium	0	0%
low	64	100%
Total Causes	64	



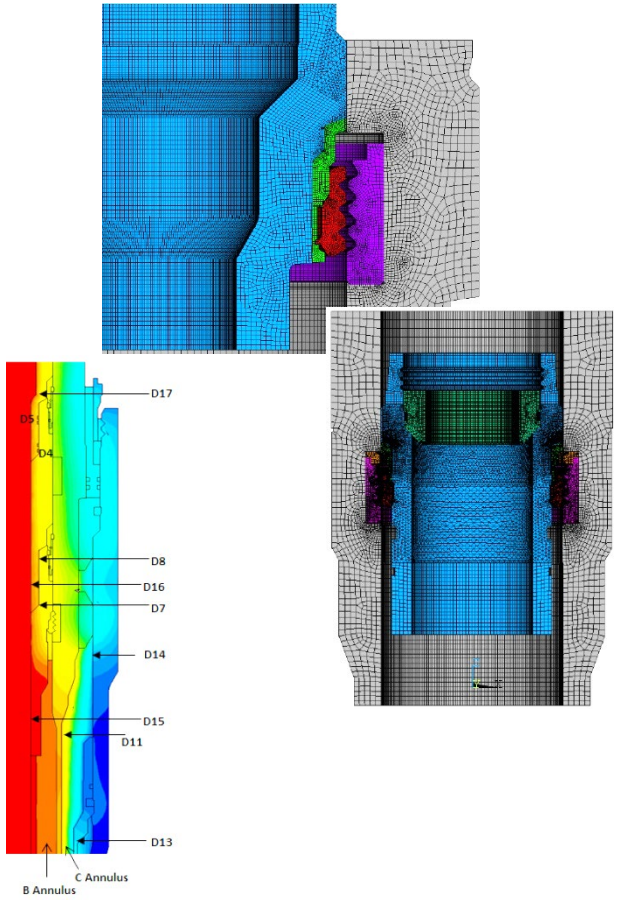
COMPONENT DESIGN

Classical Engineering Calculations

$$S_T = \frac{5}{6} S_Y \qquad S_m = \frac{2}{3} S_Y$$

Finite Element Analysis (FEA)

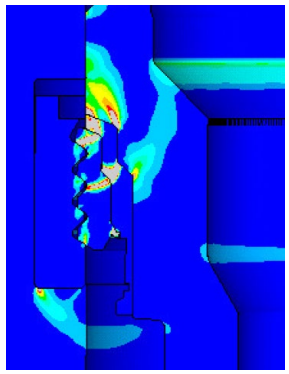
- Extensive elastic-plastic analysis per ASME:BPVC Sec VIII, Div. 3
  - ✓ Global Plastic Collapse
  - ✓ Local Strain Limits
  - ✓ Ratcheting
- Fatigue Analysis
  - ✓ System
  - ✓ Components
- Thermal Analysis

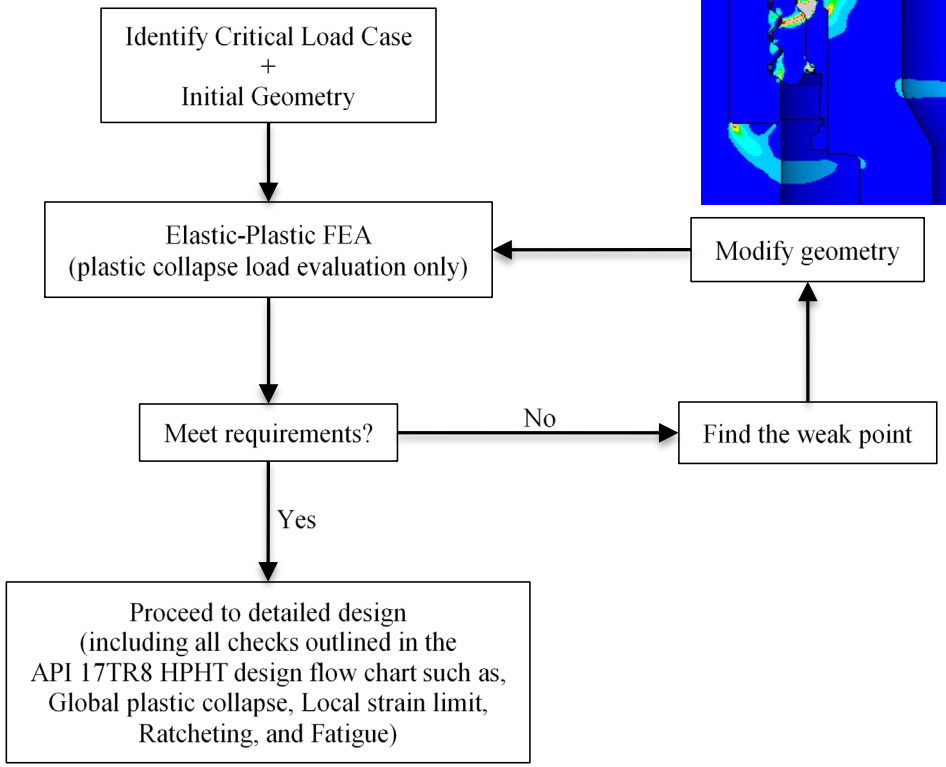


COMPONENT DESIGN

Example Load Cases

- Installation:
  - Casing Weight
  - BOP Test Loads (multiple tools)
- Operation:
  - Internal Pressure
  - Casing Weight
  - External Pressure
  - Upthrust
  - Combined Loads



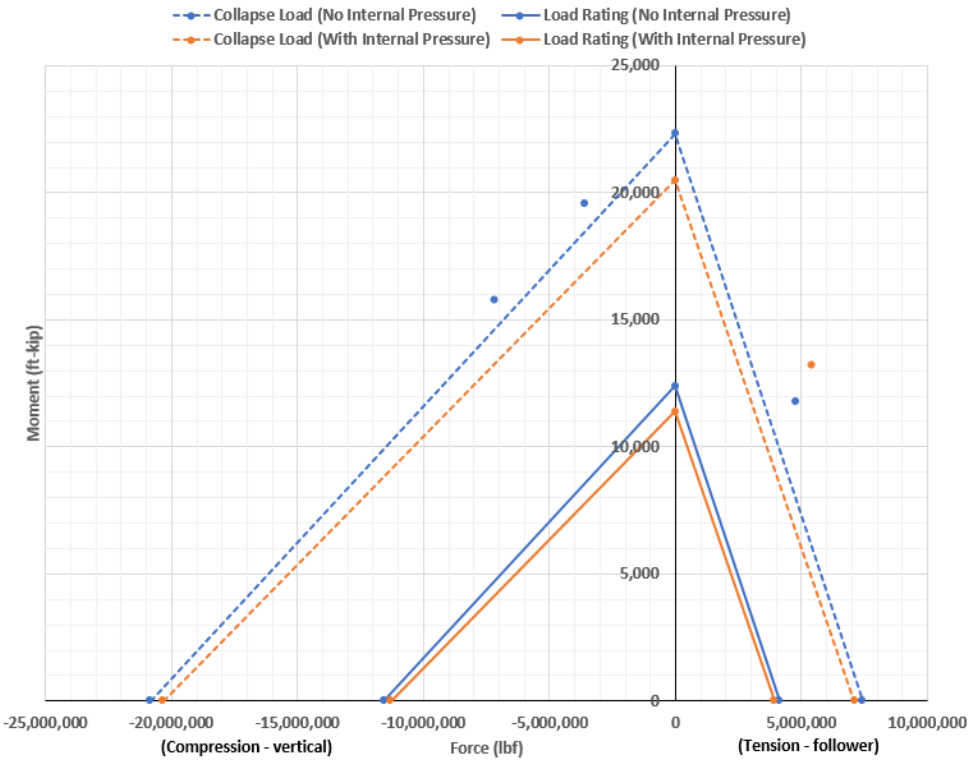


SYSTEM DESIGN

Structural Analysis Objectives	Fatigue Analysis Objectives
Document Capacities ➢ Bending Moment ➢ Tension ➢ Compression	Establish a baseline fatigue performance ➢ Example set of loads ➢ Example set of soil conditions ➢ Minimize risk during project specific analysis
Evaluate variables such as: ➢ Combined Loading ➢ Internal Pressure ➢ Wellhead System Preload ➢ Rigidity (cement level, casing program)	Evaluate variables such as: ➢ Casing Weight ➢ Wellhead System Preload ➢ Rigidity (cement level, casing program)

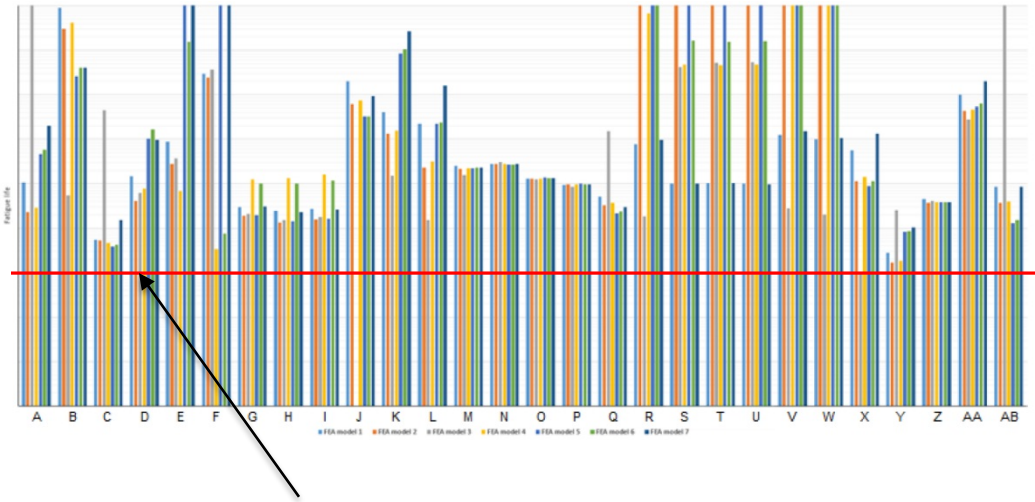
SYSTEM DESIGN: STRUCTURAL

- Generated from 15 different FEA models/load cases
- Little impact to capacity
  - Cement Level
  - System Preload
- Internal pressure slightly reduced capacity



SYSTEM DESIGN: FATIGUE

- Generated from 7 different FEA models/load cases
- Evaluated all hot spot locations for each load case
- Generated comparison graphs
  - Free-Corrosion S-N Curve
  - Cathodic Protection S-N Curve
  - C1 S-N Curve for Welds



QUALIFICATION TESTING

- API 17D Qualification Testing
  - ✓ Seal Assemblies Qualified per API 6A, Annex F (PR2)
  - ✓ API 17D Pressure & Load
  - ✓ Function Tests

- Additional API 17TR8 Requirements
  - FMECA Driven Test Examples
    - Seal Assembly Testing:
      - ✓ Extended Cycle
      - ✓ Worst Case Discharge Simulation
    - System Testing:
      - ✓ Structural Bend Test
      - ✓ Preload Loss

SYSTEM LEVEL TESTING

- 18,000,000 ft*lbf bending moment
- Preload loss curve established up to 12,000,000 ft*lbf
- >100 DAQ channels used for instrumentation
  - Strain Gages
  - LVDT's
  - Inclinometers

ANNULUS SEAL ASSEMBLY (ASA) TESTING

- 20,000 psi Bore x 15,000 psi Annulus, 0˚F-350˚F
  - ✓ API 6A, Annex F, Section F.2.23 (PR2)
  - ✓ 200+ Hydrostatic Bore Extended Cycles
  - ✓ 200+ Hydrostatic Annulus Extended Cycles

- 20,000 psi Bore x 11,000 psi Annulus, 0˚F-350˚F
  - ✓ API 6A, Annex F, Section F.2.23 (PR2)
  - ✓ 200+ Hydrostatic Bore Extended Cycles
  - ✓ 200+ Hydrostatic Annulus Extended Cycles
  - ✓ **Worst Case Discharge Simulation**

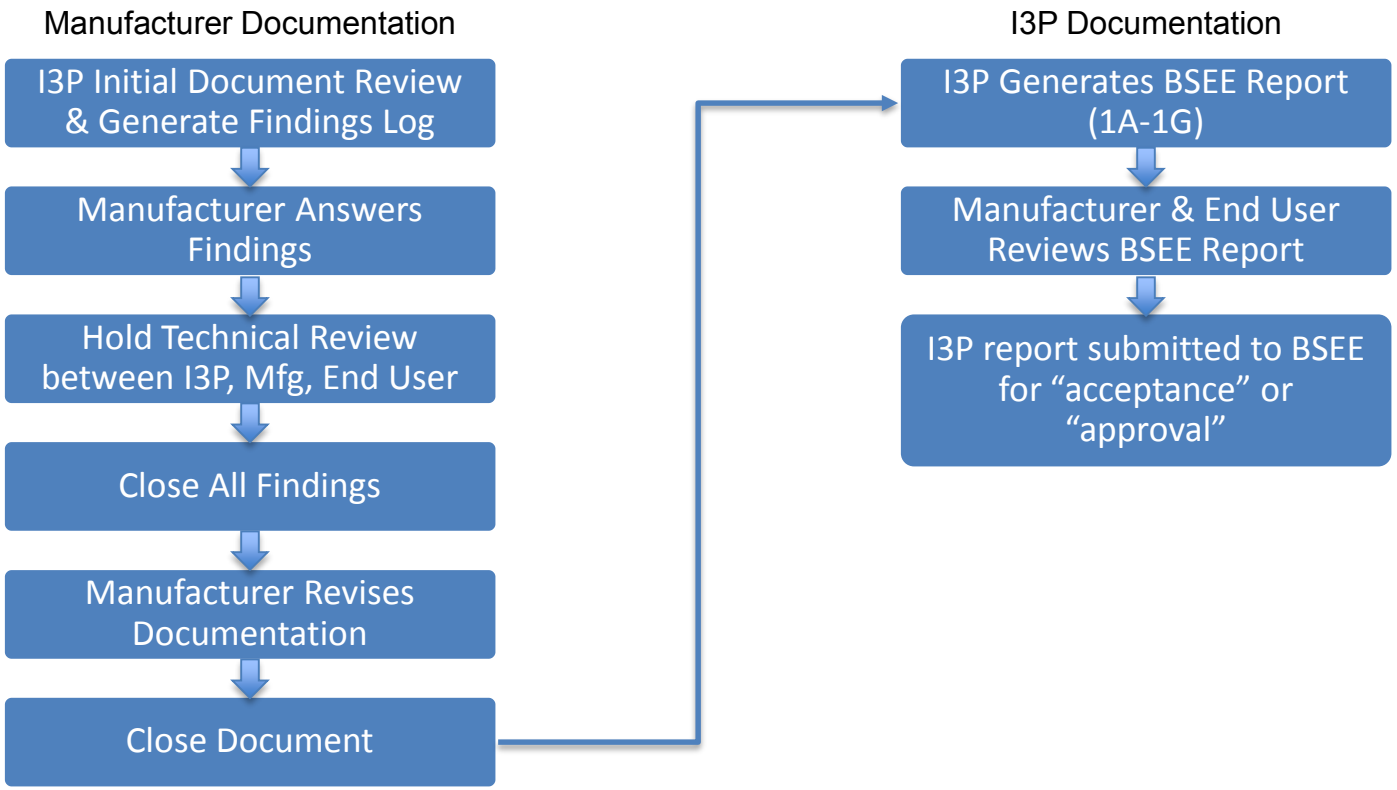
- Zero Leakage Criteria

- Two independent articles tested for repeatability

INDEPENDENT THIRD PARTY (I3P) REVIEW

- Required by BSEE for HPHT equipment
- Identify I3P company early
- Hold information sessions early
- Understand scope of review
- Schedule/Budget appropriately

INDEPENDENT THIRD PARTY (I3P) REVIEW



CONCLUSIONS

- The 20,000 psi 350˚F HPHT Wellhead System is fully compliant to API 17TR8
- Design method included extensive elastic-plastic finite element analysis in accordance with ASME:BPVC Sec VIII, Div 3
- Failure Modes, Effects, and Criticality Analysis (FMECA) was a critical tool used in the development process
- Independent third party (I3P) review process was a substantial effort during the development that must be accounted for during the planning phase

Acknowledgements / Thank You / Questions

Thank You:

Development partners

For more information please contact:

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