HIGH PRESSURE HIGH TEMPERATURE (HPHT) WORKSHOP OUTPUT DOCUMENT

V1 (January 5, 2018)

Disclaimer

The information contained within this document was captured from the OOC HPHT Workshop held on November 28th, 2017. The opinions and information expressed within do not represent any one organization's position, rather the results of open dialogue on the topic. This information should not be utilized out of context or without a clear understanding of the event and topics covered.

OFFSHORE OPERATORS COMMITTEE
staff@theooc.us

1 Executive Summary

Offshore Operators Committee (OOC), National Oceans Industries Association (NOIA), American Petroleum Institute (API), and the Bureau of Safety and Environmental Enforcement (BSEE) joined several operating companies (Anadarko, BP, Chevron and ExxonMobil) in planning and executing a High Pressure High Temperature (HPHT) Workshop. This workshop was developed to capture the work that has been performed to date, summarize the efforts underway currently and highlight the optimization efforts planned for the near future around HPHT technology. The workshop was attended by over 70 representatives from BSEE (headquarters, ETAC and GOMR) and a broad spectrum of industry (Operators, OEMs, Engineering Companies, Consultants and Independent Third Party (I3P) providers), several key points were captured during the workshop presentations and discussion:

1. BSEE has an existing process (many years in development) to approve HPHT projects. Based on the progression of available industry standards, the process can be updated and streamlined.

2. BSEE's vision for the HPHT equipment approval process includes transitioning the process from the detailed BSEE-approval to compliance with Industry Standards and a simplified acceptance by BSEE, (supported by future standards, certification or compliance verification processes, etc.). The current process is established and defined within BSEE regulations, processes and HPHT CDWOP guideline documents to support HPHT technology acceptance and HPHT project approval. BSEE will continue to use current process for issuing approval for OCS projects.

3. The objective of the BSEE approval process is to review whether the equipment is fit for purpose and has associated documentation on record. Reuse of equipment within the equipment design envelope (Technical Specifications) should not require redundant (certification) documentation or BSEE review.

4. Industry has extensive experience successfully operating HPHT project onshore and offshore dating back to the 1970's. The maturity of HPHT technology presents an opportunity for all stakeholders to streamline and stabilize the review process. Industry and HPHT Workshop participants recommend that BSEE leverage industry standards that cover HPHT equipment, and design methods, to limit the scope of I3P and BSEE reviews.

5. Clarity of expectations for I3P verification is integral to the review process. It is recommended by Industry, that BSEE clearly defines that the I3P verification scope is limited to review and documentation that project requirements have been met. The specific project requirements and acceptance criteria are defined up front in the level of detail selected by the operator. Applicable standards and load cases should be outlined within this process. This I3P definition and level of verification detail is included in the plan BSEE approves. The primary responsibility of project's fitness-for-purpose assessment remains with the operator and the operator owns the responsibility for risk management. The operator defines and provides to the I3P the functional requirements (load cases) of the project.

6. Once standards that can be verified and documented are established, the review process can be simplified, with the reporting requirements limited to one document stating that equipment, with the specified technical specifications, meets the functional design requirements. The current process requires over 20,000 pages of documentation for HPHT equipment alone; a significant regulatory burden that impacts project schedule.

7. The Argonne National Labs (ANL) data points do not require any updates to API or American Society of Mechanical Engineers (ASME) standards (API reviewed the report and agrees no changes are required to API standards). During this Workshop, the ANL lead author confirmed that ANL did not intend to suggest that a higher ASME margin factor is appropriate. ANL authors stress the importance of understanding the loads, which operator-workshop participants also presented and stressed. Conclusion: If service loads are well defined, and material properties are well understood (as required by exiting standards and methods) then the standards as written are adequate.

8. Workshop committee and API agreed that API 17TR8 should continue to be applied as written to the design of high-pressure, high-temperature subsea equipment including the use of ASME standard LRFD margins of 2.4 for ASME Section VIII, Division 2 and 1.8 for ASME Section VIII, Division 3.

9. ASME codes (DIV 2 & 3) have been applied to a significant number of complex applications with associated successful fit-for-purpose service history in high-pressure, high-temperature environments. (including oil and gas subsea applications, reference presentation appendix)

10. NTTAA (National Technology Transfer & Advancement Act) outlines that the US Government shall use, as appropriate, applicable API and ASME standards which have been developed through an ANSI accredited process. Industry recommends that BSEE leverage existing HPHT equipment standards and remove the burdensome review process for equipment currently covered by HPHT standards.

2 History

Charlie Williams of the Marine Board within the National Academies of Engineering and Sciences gave an overview of the industry's history with HPHT technology and fields. The slides from this presentation can be found in Appendix B.

This history began in the 1970's with both onshore and offshore projects. Through the historical review, a significant history of industry accomplishment in delivering fit-for-purpose equipment for HPHT projects was highlighted. The past projects have ranged in pressures up to 30,000-psi. Throughout four decades of projects, including with high H_2S applications, the industry has demonstrated a proven track record of safely developing and implementing HPHT equipment on oil and gas projects. The industry has also been able to adapt relevant standards to the changing project requirements for more than 30-years.

There are currently HPHT projects in the execution phase offshore with 25,000-psi equipment. Four offshore HPHT projects are currently in the review and approval process in the Gulf of Mexico. BSEE's Gulf of Mexico region has the authority to approve these projects utilizing its existing process as it has demonstrated in the past.

It is well understood by industry and BSEE that standards come after the first implementation of technology because technology development precedes standards development.

BSEE staff acknowledges that industry is well ahead of the curve on HPHT standards development in comparison to the past progress of standard development for 10 ksi or 15 ksi equipment. These standards are based on proven technical advances in HPHT designs. The current level of HPHT standards development has been a 12-year collaborative process within industry and is based on proven technical advance in HPHT design.

3 HPHT Standards and Industry Guidance

API presented an overview of its standards development efforts including highlights of its American National Standards Institute (ANSI) accredited process. The slides from this presentation can be found in Appendix C. As with all standards, HPHT standards will continue to be updated and have been keeping pace with technology development. There are several key standards and guidance documents for HPHT, such as API 17TR8, which provide significant implications around industry consistency in design, manufacture and application of HPHT equipment. Additionally, Industry and BSEE both agree to follow API 6X for application of stress criteria (TRESCA, von Mises).

API highlighted 38 standards and guidance documents that apply to HPHT equipment. These documents are summarized below:

1. API TR 1PER15K-1 - Protocol for Verification and Validation of High-pressure High-temperature Equipment
2. API STD 2RD – Dynamic Risers for Floating Production Systems
3. API TR5C3 - Technical Report on Equations and Calculations for Casing, Tubing, and Line Pipe Used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing
4. API RP 5C5 Recommended Practice on Procedures for Testing Casing and Tubing Connections
5. API Spec 6A - Specification for Wellhead and Christmas Tree Equipment
6. API Std 6X - Design Calculations for Pressure-containing Equipment
7. API TR 6AF - Technical Report on Capabilities of API Flanges Under Combinations of Load
8. API TR 6AF1 - Technical Report on Temperature Derating on API Flanges Under Combination of Loading
9. API TR 6AF2 - Technical Report on Capabilities of API Integral Flanges Under Combination of Loading—Phase II
10. API TR 6F1 - Technical Report on Performance of API and ANSI End Connections in a Fire Test According to API Specification 6FA
11. API TR 6MET - Metallic Material Limits for Wellhead Equipment Used in High Temperature for API 6A and 17D Applications
12. API Spec 6FA - Specification for Fire Test for Valves
13. API Spec 6FB - Specification for Fire Test for End Connections
14. API Spec 6FD - Specification for Fire Test for Check Valves
15. API RP7G - Recommended Practice for Drill Stem Design and Operating Limits
16. API Spec 7K - Drilling and Well Servicing Equipment
17. API Spec 7HU2 – Hammer Unions
18. API RP10B-2 – Recommended Practice for Testing Well Cements
19. API Std 65-2 - Isolating Potential Flow Zones During Well Construction
20. API RP10F - Recommended Practice for Performance Testing of Cementing Float Equipment
21. API Spec 11D1 – Packers and Bridge Plugs
22. API RP 13D - Rheology and Hydraulics of Oil-well Fluids
23. API RP13B-2 Recommended Practice for Field Testing Oil-based Drilling Fluids
24. API RP 13I - Recommended Practice for Laboratory Testing of Drilling Fluids
25. API Spec 14A – Specification for subsurface safety valve equipment
26. API Spec 16A - Specification for Drill-through Equipment
27. API Spec 16C - Choke and Kill Equipment
28. API Std 53 - Blowout Prevention Equipment Systems for Drilling Wells
29. API TR 17TR8 - High-pressure High-temperature Design Guidelines

30. API Spec 17D - Design and Operation of Subsea Production Systems - Subsea Wellhead and Tree Equipment
31. API RP17G - Recommended Practice for Completion/Workover Risers
    - API SC19 revising spec 14L, 19AC, and 19G1 to add HPHT annexes
32. API TR 19TR1 – HPHT Guidelines
33. API Spec 20A - Carbon Steel, Alloy Steel, Stainless Steel, and Nickel Base Alloy Castings for Use in the Petroleum and Natural Gas Industry
34. API Spec 20B - Open Die Shaped Forgings for Use in the Petroleum and Natural Gas Industry
35. API Spec 20C - Closed Die Forgings for Use in the Petroleum and Natural Gas Industry
36. API Spec 20E - Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries
37. API Spec 20F - Corrosion Resistant Bolting for Use in the Petroleum and Natural Gas Industries
38. API Std 20D - Nondestructive Examination Services for Equipment Used in the Petroleum and Natural Gas Industry

4 HPHT Validation Testing

Three presentations were presented and discussed around HPHT equipment testing. These included a summary of industry comments to the ANL draft report, an overview of ASME Section VIII DIV2 and DIV3's history and application record, and an overview of sample to full-scale testing of subsea HPHT equipment. The slides from these presentations can be found in Appendix D.

4.1 Industry Review of ANL Draft Report

The summary presentation given on the API response to the draft ANL report touched on several key points including the main conclusion that the ANL report data points do not require any changes to API or ASME standards. The ANL data points fit within the Terada data points used to validate the standards. In addition, the ANL study did not account for anisotropic material properties that resulted in variation of correlation from material properties to performance. API review validated that utilization of materials that meet or exceed minimum design properties are sufficient for HPHT equipment.

4.2 ASME DIV 2 and DIV 3

The summary presentation gave an overview of the significant amount of testing data used to validate the ASME standards. The Terada test data includes 145 multi-source data points across a wide range of materials that support the ASME Section VIII DIV 3 design margins. ASME Section VIII is a recognized design standard that is utilized across multiple industries for high pressure applications. Additional research to validate the ASME design margin is not needed based on the already completed extensive test data utilized to establish the design standard. No new information from the ANL draft report that requires modifications to the existing standard.

4.3 Dril-Quip Test Data

An example of several sample and full-scale test results for subsea HPHT equipment were shared. As expected, the data exhibited some scatter in the ultimate strength data points, but verified sufficient safety factors for all normal, extreme, and survival loads. The full-scale equipment testing data clearly illustrated that actual failure points were far beyond all operating envelops.

5 BSEE Review Process

BSEE presented its HPHT equipment and OCS-project review process. The slides from this presentation can be found in Appendix E. The key point covered in this presentation was that a review process has already been established, and covers the following topical sections:

1. What needs to be included in the Conceptual Plan to request approval to build HPHT Well Equipment

2. I3P reports for HPHT equipment design and construction

3. What needs to be included in the Conceptual Plan to request approval to Drill and Complete a HPHT well

4. I3P reports for HPHT well completions

5. Considerations for using External Hydrostatic Pressure in your HPHT Equipment Design (API 17 TR12)

6. Guidance on writing an I3P report

There are existing projects that have gone through this established process and others that are currently progressing utilizing this regulatory framework. The BSEE process will continue to evolve leveraging industry advancements as appropriate. For example, steps 1 and 2 in the current review process may be replaced by industry standards or compliance processes. Consistent with the Executive Order on an America First Offshore Industry Strategy, there are opportunities to optimize the already established process by using industry standard-based equipment compliance to replace the current burdensome documentation requirements (thousands of pages).

There is uncertainty in engagement with the regulator and industry desires more transparency and clarity in approvals. **Industry recommends that the standard, proven practice of utilization of the minimum specified material properties in the design and production of components and equipment is continued with no change. Such components and equipment shall be considered "fit-for-service" as long as their properties meet or exceed the minimum material requirements specified in the applicable standards.**

6 HPHT Project Application Examples

Two examples on how operators apply industry design guidelines and engage in the regulatory review process were presented. The slides from these presentations can be found in Appendix F. Overall industry has invested in excess of several billion dollars in HPHT projects in the GOM, including leases, exploration, development and equipment costs. It is common that operator investments exceed $1 billion before final project approval by BSEE. Regulatory uncertainty presents a significant investment risk to operators. Until revisions are made to the HPHT project approval process, BSEE should commit additional resources to the BSEE Gulf of Mexico Region to better manage the required engineering review process. Schedule pressure and the volume of required documentation review create a bottleneck with existing BSEE staff levels on current projects.

6.1 Anadarko Example

Anadarko launched a HPHT equipment development program in 2014. The program covers design, verification, and validation testing for (190) HPHT assemblies and components. The program addresses all HPHT equipment from the rig floor down to the reservoir perforations. Including all seafloor production equipment. Final validation testing is expected to conclude within the next 6 months, around June of 2018. An investment of over $100 million has been made to date and over $500 million on equipment development program for one project.

The development program is based on the current BSEE TAS HPHT Draft Guidance. A system engineering approach has been used to identify all primary and secondary barrier equipment during the well's life cycle; drilling, completions, production, and intervention operations. Surface and subsurface loads have been developed for all operating, extreme, and survival operations. A governing failure mode has been identified for each assembly and component. "Serviceability" and "Sealability" are the leading failure modes in 55% of the assemblies and components. Global Plastic Collapse on pressure as identified within the ANL report affected only 8% of the assemblies and components. Industry standards cover 55% of the identified failure modes and Supplier / Operator standards cover 45%.

Anadarko has developed a certified design review process to coordinate the review process between the operator, Supplier, and I3P. Regulatory approval is identified as a major risk for the HPHT development program.

6.2 Chevron Example

HPHT Projects require effective collaboration between Operator and OEMs to assure fit-for-purpose design. Current design methods enable equipment development for HPHT projects. The design methods and practices are defined and supported by Qualification (Verification and Validation), with additional I3P Verification that supports regulatory CDWOP and SCDWOP filings with BSEE.

Operator Verification and Validation Process includes the following steps.

1. Function Design Specifications (Pressure, Temperature, Environmental Loads, External Loads, etc.),

2. Failure Mode Identification (Plastic Collapse, Brittle Fracture, Fatigue Cracking, Ratcheting, Serviceability- maintain seal & component functionality, etc.),

3. Verification (FEA, Calculations), and

4. Validation (Material Characterization Testing (SLD), Material Fatigue Testing in Environment, Component/Assembly Qualification Testing, Strain Gauging for Validation of FEA Model, Serviceability Validation).

At this point the question is asked: Are All Failure Modes Mitigated? If no, the process is recycled. If yes, the Design is Verified and Validated to be Fit-For-Service as defined by the Functional Specifications.

Chevron reiterated that an effective collaboration between Operator and OEM enables HPHT development.

Current I3P Process.
The role of the I3P at the component / assembly level is to verify the capacity in expected service environments and that the equipment has the technical specifications listed. This is accomplished by verification that the requirements specified were met. At the project level; The role of the I3P is to verify that the project stated loads are within the bounds of the previously verified component/assembly capacity.

Overall the role of I3P is to verify that the **Outputs/Results** of processes, methods, and designs **meet or exceed** the **specified targets.** It was clearly outlined and confirmed by BSEE that the role of the I3P is not to redo any analysis. Operators are responsible for defining the well conditions and equipment requirements. OEMs with collaborative feedback from operators develop equipment with defined capability as characterized by equipment's technical specifications. The role of I3P is twofold:

1. To verify the Technical Specifications of equipment by verification that all defined requirements, such as standards compliance, were met.

2. Verify that at the component through system level, the equipment Technical Specifications meet all of the Operator Specified Project Functional Specifications.

It is important to optimize and focus the role of I3P on verification. This I3P optimization will make the role more effective yet robust.

Some detailed examples of the role of I3Ps were provided in the context of the current BSEE guidance.

These examples are provided to better define the adequate level of verification from I3P, and to assure that the role of I3P is not extended into the roles of the Operator and OEMs. It is recognized that different levels of verification (especially beyond what is required) could result in dramatically different levels of effort.

1. **Report (1A) – Basis of Design/Functional Specifications & Failure Mode Analysis**

    a. Operator defines all relevant loads.
    b. For information only, I3P reviews Operator prescribed loads, I3P then verifies that the operational capacity of equipment (Technical Specifications) meet and exceed the specified Operator-prescribed loads.
    c. Operator-OEM identifies all relevant failure modes.
    d. I3P verifies that (Operator-OEM)-identified failure modes were mitigated.

2. **Report (1B) – Material Selection, Qualification, Testing**

    a. Operator-OEM prescribes material manufacture process, utilizes minimum material properties in design, and develops material test plan in environment in accordance with the FMECA.
    b. I3P verifies that minimum material properties are utilized in the design process and that necessary compatibility/fatigue testing has been performed in environment.

3. **Report (1C) – Design Verification Analysis**

    a. Operator-OEM develop verification plan and perform all necessary FEA and calculations.
    b. I3P verifies that FEA is performed per code requirements, ensures the designer has correctly incorporated relevant loads, and verifies the correct material properties were utilized.

4. **Report (1D) – Design Validation Analysis**

    a. Operator-OEM develop validation plan that is in accordance with existing API standards and mitigate all identified failure modes.
    b. I3P reviews test procedures and reports to verify compliance with existing codes and standards, ensure testing has validated the FEA model, and ensures testing is representative of expected service.

7 DeepStar Update

OOC DeepStar presented an overview of their current plans concerning HPHT. The planned efforts under DeepStar will be to support future needs and to optimize HPHT technology, not enable any HPHT methods. Industry and DeepStar will continue to conduct research and development in support of offshore safety and efficiency. The DeepStar presentation can be found in Appendix G.

8 Summary

Industry has had a successful history with HPHT projects, onshore and offshore, since the 1970's. These projects were developed utilizing and adapting relevant engineering standards and practices for oil and gas applications. Industry has also traditionally applied engineering practices of the ASME Codes (Div. 2 and Div. 3) with adaptive applications for oil and gas industry. Industry's initial effort to codify engineering practices for HPHT application into an API standard begin with the development of API 1PER15K-1 - *Protocol for Verification and Validation of High-pressure High-temperature Equipment*. The continually evolving standard development process resulted in the publication of over 38 API HPHT standards, across various API Subcommittees that ensure safe HPHT equipment designs. Additionally, compliance with BSEE TAS HPHT Guidance requires three separate entities (Operators, Suppliers and I3P) to assure HPHT equipment is fit-for-service in the applicable HPHT environment.

Operators agree that BSEE HPHT Guidelines are a useful process that could be formalized for ongoing and future use. Operators agree that Div 2 and Div 3 load factors of 2.4 and 1.8 are satisfactory for HPHT designs.

Operators heard BSEE's desire to move the HPHT Guidance process to an industry-owned process for equipment acceptance with BSEE having final approval of HPHT CDWOPs for OCS-projects

Operators acknowledge it will take years for all relevant standards to have HPHT annexes. In the interim the HPHT Guidance process can be followed for HPHT equipment qualification. OCS-Project CDWOP/DDWOP are approved by BSEE and the same practice will be followed for OCS-Projects in HPHT conditions.

A list of the Planning Committee Members, agenda and the attendees of the HPHT workshop can be found in Appendix A.

APPENDIX A: PLANNING COMMITTEE, AGENDA, ATTENDEES

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TABLE OF CONTENTS

OFFSHORE OPERATORS COMMITTEE

staff@theooc.us

PLANNING COMMITTEE

Name	Company
Kusinski, Greg (HPHT WG Chair)	Chevron
Flores, Rafael	BP
Mitchell, Nicholas	ExxonMobil
Raney, Jim (Walz, Gregg)	Anadarko
Hopkins, Holly	API
Luthi, Randall	NOIA
Zimmerman, Evan	OOC
Pittman, Michael	BSEE
Hoshman, Russell	BSEE

AGENDA

HPHT: Experience & Reinforcing the Progress of Industry

DoubleTree – Downtown Houston
Dezavala Room
400 Dallas Street, Houston, Texas 77002
November 28, 2017 8:00 am – 5:00 pm

8:00-8:30	Registration
8:30-8:45	Welcome & Workshop Objectives (*Greg Kusinski*, Chevron & *Evan Zimmerman*, OOC)

Industry HPHT efforts

8:45-9:15	History of HPHT (*Charlie Williams*, NAS Marine Board)
9:15-10:00	API Overview of HPHT Applicable Standards (*David Miller*, API)
10:00-10:30	ASME DIV 3, (*Dan Peters*, Structural Integrity Associates)

Closing the gap in the uncertainties in design methodologies

10:30-10:50	Context of Argonne Report's data points (*Man Pham*, Anadarko)
10:50-11:20	Industry Testing (*Jim Kaculi*, Dril-Quip)
11:20-12:30	Lunch

BSEE progress internally on a process

12:30-1:15	BSEE Review Process (*Russell Hoshman*, BSEE)
1:15-1:45	Industry Response (all – open discussion)
1:45-2:00	Break

Best practices (operator processes)

2:00-3:30	Operator HPHT Processes (Anadarko & Chevron)

Path forward

3:30-3:45	Deepstar Scope Discussion (*Joe Gomes*, OOC Deepstar)
3:45-4:30	Summarize the Information Captured (All - discussion)
4:30-4:45	Workshop Output Document Process & Adjourn

ATTENDEES

Last Name	First Name	Title/Position	Company / Organization:
Aiken	Bill		Aiken Engineering
Ajak	John	Petroleum Engineer	BSEE
Allen	Eric	Senior Engineer	DNVGL
Anish	Simon	Technology Manager US Offshore	Statoil
Antony	Shaji	Project Manager	American Bureau of Shipping
Apiecionek	Matthew	Sr. Program Manager	Halliburton
Baker	David	Research Engineer	ExxonMobil Upstream Research
Bartlett	Tim	HPHT Systems Technical Manager	TechnipFMC
Bowie	Mike	Director, Oilfield Equipment-North America	Baker Hughes, a GE company
Cole	Stuart	Snr Technical Manager	Vallourec
Cromer	Lauren	Project Manager	ABS
Douglas	Scherie	20A Regulatory Advisor	Anadarko
Feijo	Luiz	Director global offshore	ABS
Flores	Rafael	Drilling Specialist	BP
Frazer	Ross	Technical Director	HWCG LLC
Fury	Sandi	Mgr, Regulatory Affairs	Chevron GOM BU
Gallander	Frank	Industry Interface Consultant	Chevron
Garcia	Sharon	Project Manager	ABS
Goggans	Tim	Subsea Engineer	Cobalt International Energy
Gomes	Joseph	Project Manager	DeepStar
Gordon	Joe	Regulatory Advisor	Chevron
Han	Young-Hoon	Sr. Engineer	Cameron A Schlumberger Company
Hansen	Paul	HPHT Regulatory	Chevron
Hariharan	Peringandoor	Senior Wells Engineer (WE)	Shell International Exploration and Production Inc
Harish	Patel	Senior Technical Advisor	ABS
He	Alan Xiaojun	Engineering manager	Statoil
Herrington	Larr		LLOG
Holt	Calvin	Snr. Drilling Advisor	Chevron
Hopkins	Holly	Sr. Policy Advisor, Upstream	API
Hoshman	Russell	Technical Advisor	BSEE
Hughes	William	HPHT Technology Project Manager	Chevron
James	Richard	Petroleum Engineer	BSEE
Ji	Jing	Principal Engineer	American Bureau of Shipping
Jones	Jeff	Senior Subsea Systems Advisor	ExxonMobil Upstream

Jones	Jason	GOM HCT Project Manager	Halliburton
Jung	Gonghyun	Senior Mechanical Engineer	Shell
Kaculi	Jim	Vice President - Engineering	Dril-Quip, Inc.
Kaminski	Dennis	Senior Completions Advisor	Anadarko
Kusinski	Greg	Program Committee	Chevron
Lan	Christy	Petroleum Engineer	BSEE
Larson	Eric	Consulting Engineer, Mechanical Equipment	Baker Hughes, a GE Company
Lehr	Doug	Sr. Mgr. Design for Reliability	Baker Hughes, a GE Company
Lindley	Roy		Argonne
Miglin	Bruce		Argonne
Miller	David		API
Miller	James	20M Wellehads	Chevron
Mitchell	Nick	IMT Manager	ExxonMobil
Myers	Greg		Baker Hughes / General Electric
Oliver	John	Technical Service Advisor	Halliburton
Parker	Wanda	Regulatory Consultant	WJPEnterprises
Payne	Alton	Chief, Standards Development	BSEE
Peters	Daniel	Associate	Structural Integrity Associates, Inc.
Pham	Man	20A Technical Advisor - Codes and Standards	Anadarko Petroleum Corporation
Pham	Julian	Petroleum Engineer	BSEE
Pittman	William	Chief, Risk Assessment and Analysis	BSEE/OORP
Ramzi	Hassan		Wild Well Control
Raney	James	Director, Engineering & Technology	Anadarko
Roberts	Nolan	Director Global Business-Surface	Cameron A Schlumberger Co
Ronan	Steven	Chief Engineer	Offshore Technical Compliance, LLC
Rumney	Andrew	Senior Engineer	Schlumberger
San Pedro	Ramón	Principal	Stress Engineering Services, Inc.
Seaman	Richard	D&C Manager HPHT Projects	Chevron
Shamshy	Shak	DeepStar Director	Chevron
Shanks	Earl	Petroleum Engineer	BSEE
Shavandi	Mohsen	Principal Engineer	DNV GL
Shull	Charles	Sr. Offshore Regulatory Policy Advisor	Shell Oil Company
Skeels	Brian		TechnipFMC
Sorem	William	Sr. Subsurface Consultant	ExxonMobil
Strait	Dave		Chevron

Sutton	Mark	Lead Drilling Engineer	Statoil
Turner	Russell	Regulatory Quality Mgr.	Baker Hughes, a GE Company
Tyler	Ken	Well Engineering Team Lead	Shell
Vaclavik	Matthew	Subsea Hardware Engineer	Chevron
Wade	Foster	Manager - Public & Regulatory Affairs	Statoil
Walz	Gregory	20A Project Coordinator	Anadarko
Wiegand	Sandra	Petroleum Engineer	BSEE
Williams	Charlie		NAS
Zimaro	Tony	Drilling & Well Manager	Statoil

APPENDIX B: HISTORY

V1 (January 5, 2018)

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OOC HPHT Workshop
Nov 28, 2017
Houston, Texas

Charlie Williams

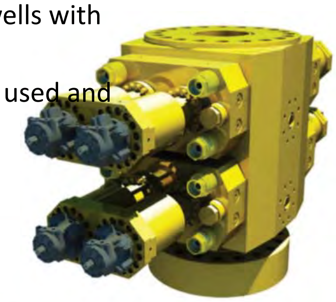
High Pressure / High Temperature

A History of delivering on the

Technical Challenges

Examples from HPHT history

- HPHT is not new to the industry
  - 1974: Bertha Rogers 1 in Oklahoma encountered 24,850 psi and 475°F at 31,432 ft
  - 1979: Exxon Mongure in Mississippi used equipment rated at 30K psi and 350°F.
  - 1984-85: Both Shell and Arco drilled onshore wells with equipment rated at 30K psi and 350°F.
  - Last decade: Numerous sets of 20K equipment used and installed



World Oil HPHT
DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

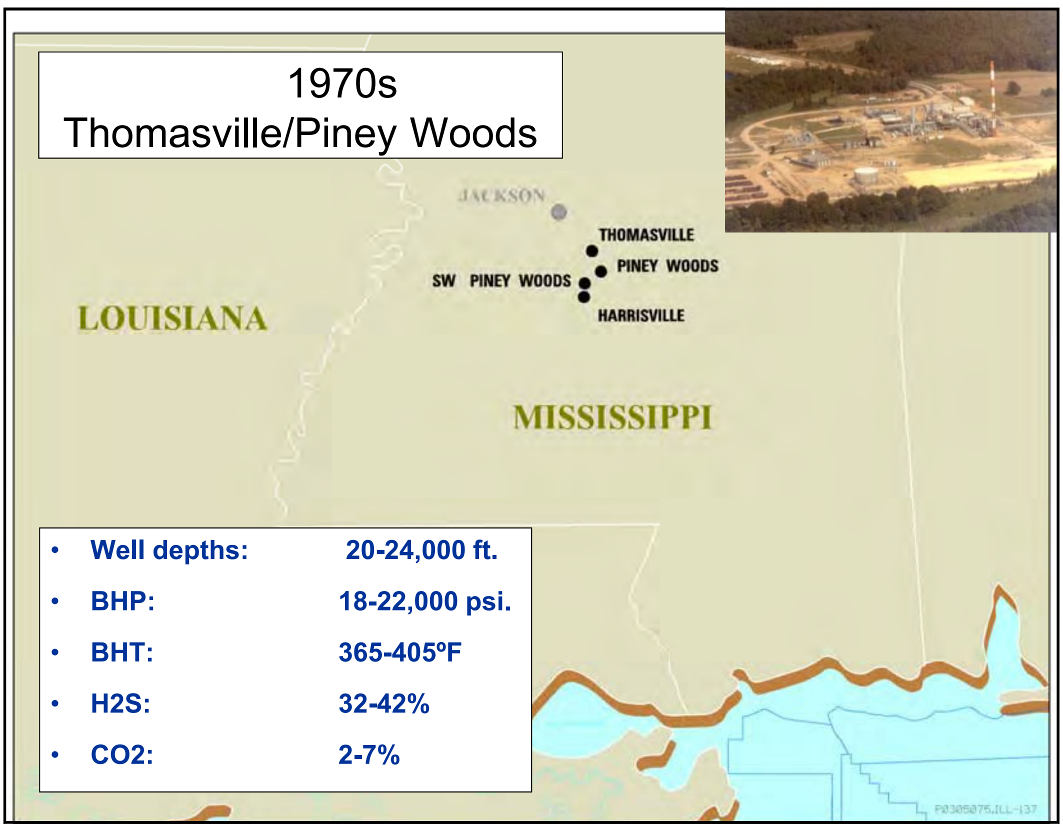
	Field	Depth, ft	BHP, psi	BHT, ºF	CO_2, %	H_2S, ppm
Onshore						
•	Thomasville	24,000	23,000	410	8	460,000
•	Jackson Dome		16,000	11,000	350	99
Offshore						
•	Mobile Bay	23,000	13,450	410	3.5	16,000
•	Eugene Island		18,800	15,700	330	2
•	Picaroon	17,000	15,000	360	4.5	11

NACE CRACKING CRITERIA

Total Pressure, ksi	1	5	10	15	20	25
H_2S, ppm at 0.05 psia partial pressure	50	10	5	3.3	2.5	2

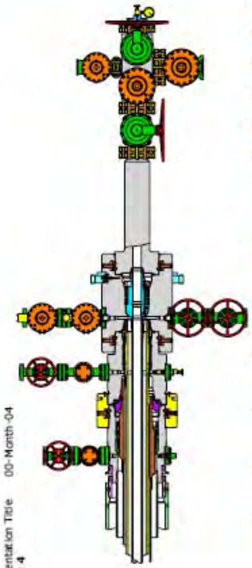
In fact, for HPHT applications, any detective H_2S concentration poses risk of environmental cracking in susceptive steels.

1970s Thomasville/Piney Woods



- **Well depths: 20-24,000 ft.**
- **BHP: 18-22,000 psi.**
- **BHT: 365-405ºF**
- **H2S: 32-42%**
- **CO2: 2-7%**

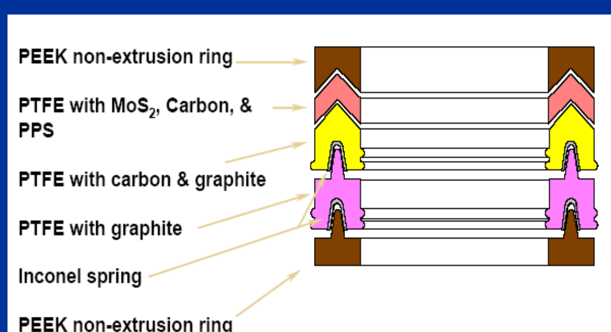
HP/HT Surface Equipment Experience



HPHT Field Experience

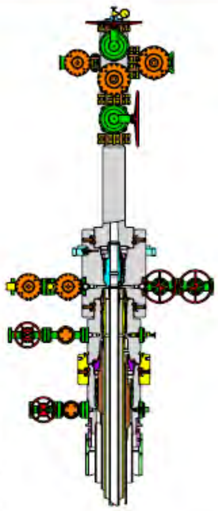
- 20 ksi wellhead & tree - Shell Oil, Mississippi, 1972
- 30 ksi wellhead & tree - Shell Oil, Mississippi, 1974
- 10 ksi wellhead & tree 400ºF - Mobil Indonesia, 1976
- 30 ksi wellhead & Tree – Exxon, Mississippi 1980
- API 6F "Improved" fire resistant wellhead & tree Elf (Heimdal) Norway, 1981
- 20 ksi wellhead & clad tree - Shell Oil, GOM, 1984
- 15 ksi 350ºF Integrated Jackup System - Chevron Destin Dome - 1988
- 20 ksi wellhead & clad tree 350ºF – Chevron Mobile Bay 1988
- 20 ksi (18 ksi rated at 450ºF) integrated mudline, wellhead & test tree - Ranger Oil, Central Graben - 1992
- 15 ksi wellhead & tree 350ºF - Texaco (Erskine), Central Graben - 1998
- 15 ksi wellhead & tree 400ºF - Elf Elgin/ Franklin, Central Graben – 1998
- Vetco Gray has made 10 of 12 30 ksi systems worldwide

Presentation Title 00-Month-04
Page 4



Pressure & Temperature De-rating vs. Material & Seal Selection & Issues

6σ



Utilization of Auto-Frettage to qualify 75 ksi material when pressure tested to 37,500 PSI or 45,000 PSI hydro

- **API Spec 6A PSL 3 requirements today for <or = 20,000PSI**
  - UT
  - MAG or LP
  - Machine components
  - Hydrotest assembly at 1.5 x Working Pressure
  - Gas Test at Working Pressure
- **What was done in the 1970's for 30,000 PSI equipment**
  - UT
  - MAG or LP
  - Machine Components
  - Assemble major pressure vessel components (ie. Valve body and Bonnet c/w flanges and bonnet bolting) with plug or fixtures in Bonnet bore
  - Hydrotest
    - (Obsolete) API Spec 6AB- 37,500 PSI
    - Customer specific- 45,000 PSI
  - Dis-assemble and MAG or LP
  - Re-Assemble total product
  - Gas Test at Working Pressure

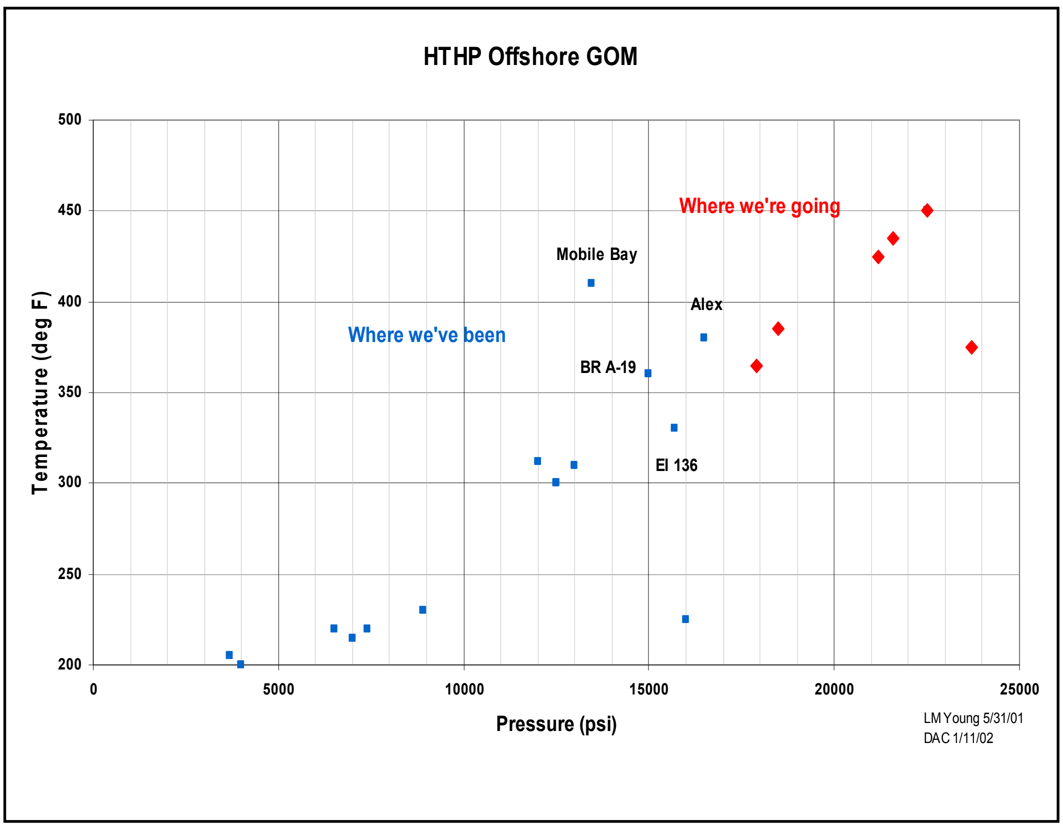
Presentation Title 00-Month-04
Page 41

vetco™

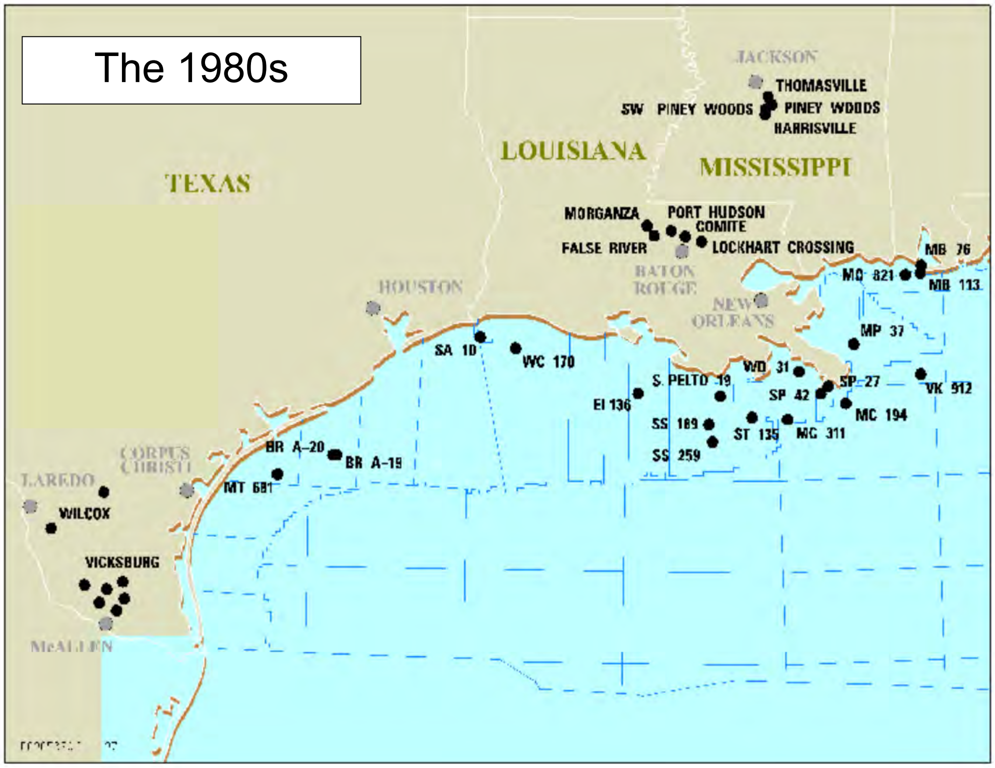
Key Elements – HP/HT plus Sour & Acidic Gas

- specific HSE & emergency procedures & systems
- Technical Standards for Design, Manufacture, Materials, & installation
- Extensive & meticulous Materials testing leading to Specs
- QA/QC – staff & procedures
- All metal seals where possible
- tubular connection designs – most with back-up elastomers
- New elastomer materials & containment procedures
- corrosion inhibition & de-scaling/de-salting systems
- Attention to technical detail in design, installation, & operation

Field	Depth, ft	BHP, psi	BHT, ºF	CO_2, %	H_2S, ppm
Onshore					
• Thomasville	24,000	23,000	410	8	460,000
• Jackson Dome		16,000	11,000	350	99
Offshore					
• Mobile Bay	23,000	13,450	410	3.5	16,000
• Eugene Island		18,800	15,700	330	2
• Picaroon	17,000	15,000	360	4.5	11



The 1980s



THANK YOU

Questions

Charlie Williams

APPENDIX C: HISTORY

V1 (January 5, 2018)

Disclaimer

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OFFSHORE OPERATORS COMMITTEE

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Overview of API Standards activity on HPHT

David Miller, P.E., F. ASCE
Director, Standards Development
miller@api.org

HPHT: Experience & Reinforcing the Progress of Industry Workshop

November 28, 2017

API Overview

API formed in 1919 as national trade association to support the U.S. oil and natural gas industry

API Standards Department published first standard in 1924 covering pipe sizes, threads, and couplings

Today, API maintains nearly 700 standards with 260+ on E&P activities

API Standards in regulation

- 96 standards referenced by BSEE in CFR
- 130 standards referenced by Federal Government with 430 citations
- 240 standards referenced by state governments with 4130 citations
- 225 standards referenced globally

API Overview

Standards Development Committees:

Upstream:
- Committee on Standardization of Oilfield Equipment & Materials
- Drilling and Production Operations

Downstream:
- Committee on Refinery Equipment
- Process Safety
- Safety and Fire Protection Committee

Midstream:
- Committee on Petroleum Measurement
- Pipeline Standards Committee

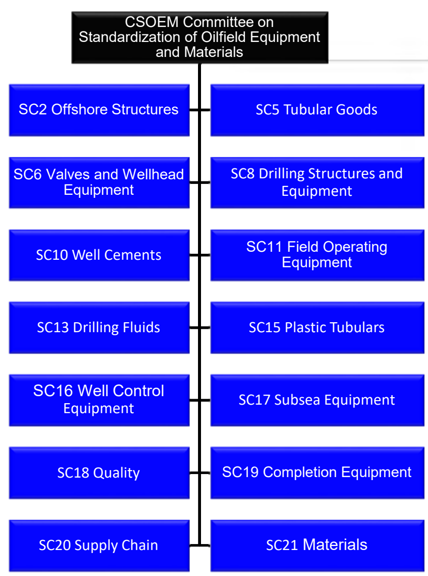
300+ Task & Work Groups

API CSOEM Organization

Has 240+ standards under it's purview.

Roughly ½ of the standards are in development/revision.

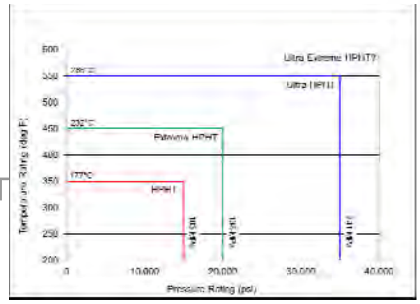
Each subcommittee develops and maintains standards through task/work groups according to established policies and procedures using volunteers.



HPHT Definition

Various definitions in industry

- Tier I, Tier II, Ultra-HPHT etc.



30CFR250.804 also defines HPHT

- >15,000 psi or >350°F
- Used for today's activity

Activity Scope Limit

Scope limit: Equipment typically used in well construction and production

- does not include platforms, processing equipment, fire control systems, etc.
- does not include documents which defer to normative references (e.g. API RP17W *Capping Stacks* defers to API 17G *Completion/Workover Risers* for pressure ratings)
- Does not include other language versions of API publications
- Does not include documents which could used for HPHT conditions but contain no special requirements (e.g. RP19B *Evaluation of Well Perforators* or API 19G2 *Flow Control Devices*)

CSOEM Standards Activity

API TR 1PER15K-1 published 2013
- Originally began under SC6 as RP6HP in 2005
- Industry action to go back and clarify/re-codify the overarching principles to be used in developing HPHT equipment.
- Early discussions about writing one document containing requirements for all products was abandoned.
  - Too many differences between downhole products and surface products (geometrical constraints)
- Agreed path was Technical Report followed by product-specific requirements in product specifications

HPHT in SC2

STD 2RD – Dynamic Risers for Floating Production Systems
- Does not list HPHT equipment.
- Does not preclude HPHT equipment.
- Defers to API 5CT and 5L for pipe requirements
- Contains extensive stress calculation requirements
- Contains fatigue assessment requirements

energy API

HPHT in SC5

API TR5C3 - Technical Report on Equations and Calculations for Casing, Tubing, and Line Pipe Used as Casing or Tubing; and Performance Properties Tables for Casing and Tubing

- Provides technical guidance for the determination pipe performance properties for all casing/tubing size, weight, and grade combinations
  - Axial Strength
  - Internal Pressure Resistance
  - Collapse Resistance
  - Ductile Rupture
- Lists 51 pipe size/wall/grade combinations with pressure ratings >15K psi

API RP 5C5 Recommended Practice on Procedures for Testing Casing and Tubing Connections

- Exposes the connections to both ambient and elevated temperature in all four quadrants on varying geometries and make up conditions.
- Includes elevated temperature (356°F) testing for both CAL III and CAL IV

energy API

HPHT in SC5

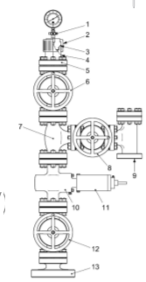
API RP7G - Recommended Practice for Drill Stem Design and Operating Limits

- Lists 37 drill pipe size/wall/grade combinations with pressure ratings >15K psi

HPHT in SC6

History of requirements in standards

- AWHEM published the first draft of 15,000 psi flange dimensions in 1957.
- 20K wellhead equipment first appeared in API Spec 6A in the 9th edition which was published in 1972.
- API Spec 6AB covering 30,000 psi flanged wellhead equipment was published in 1983.



API Spec 6A - Specification for Wellhead and Christmas Tree Equipment

- 21st edition in draft
- Adding boarding shutdown valves with minimum PSL 3
- Clarifying requirements for “safety valves” (SSV, USV, BSDV) making PR2F testing and 6AV1 validation normative
- Changing PSL 4 to be more aligned with HPHT material and NDE requirements for CRA materials

HPHT in SC6

API Std 6X - Design Calculations for Pressure-containing Equipment

- Introduction gives a good history of pressure containing equipment calculations for both API SC6 and ASME BPVC

API TR 6AF - Technical Report on Capabilities of API Flanges Under Combinations of Load

- Includes 69 rating charts for Type 6BX flanges with pressure vs. bending moment with tension (including 20K and 30K flanges) but no temperature

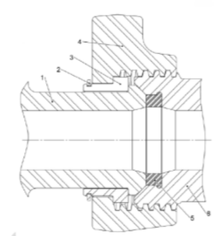
API TR 6AF1 - Technical Report on Temperature Derating on API Flanges Under Combination of Loading

- Similar work to TR 6AF but with ratings at 350°F and 650°F for 4 grades of materials. Does not include 30K flanges.

HPHT in SC6

- API TR 6AF2 - Technical Report on Capabilities of API Integral Flanges Under Combination of Loading—Phase II
  - Similar work to TR 6AF but with ratings at 250°F internal and 30°F external. Does not include 30K flanges.
- API TR 6MET - Metallic Material Limits for Wellhead Equipment Used in High Temperature for API 6A and 17D Applications
  - Yield strength degradation charts for 11 common alloys from 300°F to 450°F
- API TR 6F1 - Technical Report on Performance of API and ANSI End Connections in a Fire Test According to API Specification 6FA
  - Includes both predicted results and actual results
- API Spec 6FA - Specification for Fire Test for Valves
- API Spec 6FB - Specification for Fire Test for End Connections
- API Spec 6FD - Specification for Fire Test for Check Valves

HPHT in SC8



- API Spec 7K - Drilling and Well Servicing Equipment
  - WI 3201 to add 20K cement hoses in process
- API Spec 7HU2 – Hammer Unions
  - Document in process
  - Contains complete dimensional and material requirements for hammer unions
  - Includes 20K rated products for standard service
  - Refers to API Spec 6A and ASME BPVC Section VIII, Div 2, Part 5 for design

energy API

HPHT in SC10

API RP10B-2 – Recommended Practice for Testing Well Cement
- Includes high temperature tests based on well depths and temperature gradients

API Std 65-2 - Isolating Potential Flow Zones During Well Construction
- Includes guidelines and requirements for <u>all</u> cementing operations

API RP10F - Recommended Practice for Performance Testing of Cementing Float Equipment
- Includes testing requirements at 400°F and 5,000 psi
- In revision to move to specification for equipment

energy API

HTHP in SC13

API RP 13D - Rheology and Hydraulics of Oil-well Fluids
- Contains basis understanding and guidance about drilling fluid rheology and hydraulics
- Gives equations and methods for estimating fluid density for HTHP wells
- Describes use of HTHP viscometer (40K psi, 600°F) for measuring fluid properties

API RP13B-2 Recommended Practice for Field Testing Oil-based Drilling Fluids and API RP 13I - Recommended Practice for Laboratory Testing of Drilling Fluids
- HTHP testing of filtrate properties to 500°F

HPHT in SC16

API Spec 16A - Specification for Drill-through Equipment

- 20K drill-through equipment first appeared in API 6A 9th edition in 1972. 16A 1st edition was published in 1982.
- 4th edition published
  - Contains 7 sizes with 20K pressure ratings and temps up to 350°F
  - Includes extensive testing and fatigue testing requirements
- 20K, 25K, and 30K BOPs have been produced and installed

HPHT workgroup in process to write HPHT requirements for BOPs as annex to API 16A, 4th Edition

- Initial ballot out for comment.
- Projected completion in late 2017

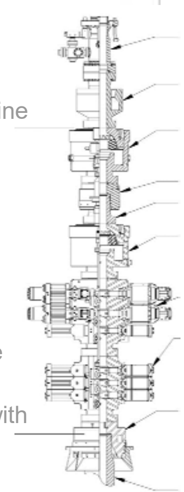
HPHT in SC16

API Spec 16C - Choke and Kill Equipment

- Includes 5 sizes of equipment to 20K; 3 sizes of union/articulated line sizes to 20k; and 4 sizes of flexible line sizes to 20k
- Defers to API 6X, API 6A, and API 16A for many items
- Requires hydrostatic testing to 1.5x RWP

API Std 53 - Blowout Prevention Equipment Systems for Drilling Wells

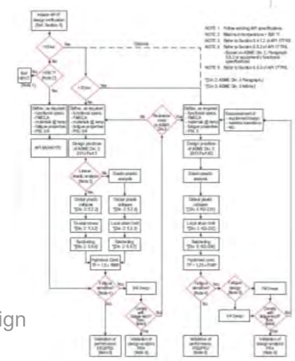
- Includes 20K, 25K, and 30K equipment ratings for surface and subsea BOPs
- Requires consideration of elastomeric seal compatibility with high-pressure, high-temperature conditions.



HPHT in SC17

API TR 17TR8 - High-pressure High-temperature Design Guidelines

- Design guidelines for oil and gas subsea equipment
- Limits temperature considerations to 550°F
- 3 verification methods provided
- 2 fatigue assessment methods
- Material selection and property testing listed
- Seals and bolting
- Design validation recommendations
- Hydrostatic testing multiplier tied to verification methods
- Revision in process to:
  - Standardizing material testing protocols used in design verifications
  - Identifying design margins for Extreme and Survival conditions
  - Develop annex for fatigue analysis input parameters.



HPHT in SC17

API Spec 17D - Design and Operation of Subsea Production Systems - Subsea Wellhead and Tree Equipment

- 20K wellheads are available from at least 3 suppliers with at least 12 installed.
- Revision of 17D planned to address specific requirements for HPHT

API RP17G - Recommended Practice for Completion/Workover Risers

- Includes 20K psi ratings and up to 650°F temperature ratings
- Contains extensive stress calculation and fatigue assessment requirements
- Currently in revision

HPHT in SC19

- API Spec 14A – Specification for subsurface safety valve equipment
  - Includes HPHT annex with additional requirements for
    - Materials (both metal and non-metal)
    - Design Verification including fatigue screening
    - Extensive design validation
    - Limits of design scaling
    - Quality plan for manufacture
    - Final design review
- API Spec 11D1 – Packers and Bridge Plugs
  - Includes HPHT annex with requirements similar to API Spec 14A
  - Includes annex with requirements for HPHT operating tools
- Others in revision to add HPHT annex
  - API Spec 14L – Specification for Lock Mandrels and Landing Nipples
  - API Spec 19AC – Completion accessories
  - API Spec 19G1 – Side-pocket mandrels

NE™ Tubing Retrievable Safety Valve (TRSV)

HPHT in SC19

- API TR 19TR1 – HPHT Guidelines
  - Document in process to standardize the approach to writing HPHT requirements for SC19 equipment. All requirements are additional to "front matter".
  - Includes:
    - More elaborate functional specifications (e.g. environment details)
    - More stringent technical specifications (e.g. elastomer compound assessments)
    - Enhance design verification analyses (FEA to ASME codes)
    - Enhanced design validation tests (no specifics, each product spec writes this section)
    - More stringent manufacturing requirements (NDE, welding, etc.)

HPHT in SC20

Documents set qualification levels for sub-suppliers and extend requirements into supply chain for base products and processes.

- API Spec 20A - Carbon Steel, Alloy Steel, Stainless Steel, and Nickel Base Alloy Castings for Use in the Petroleum and Natural Gas Industry
- API Spec 20B - Open Die Shaped Forgings for Use in the Petroleum and Natural Gas Industry
- API Spec 20C - Closed Die Forgings for Use in the Petroleum and Natural Gas Industry
- API Spec 20E - Alloy and Carbon Steel Bolting for Use in the Petroleum and Natural Gas Industries
- API Spec 20F - Corrosion Resistant Bolting for Use in the Petroleum and Natural Gas Industries
- API Std 20D - Nondestructive Examination Services for Equipment Used in the Petroleum and Natural Gas Industry
- Many others in process

HPHT Research in API

Conducted as part of normal standards development

SC5 – Tubular Goods

- Investigating temperature effects on modulus of elasticity
- Investigating collapse of 9-7/8 and 11-7/8 sizes at elevated temperature
- Investigating alternative calculation methods for high-collapse pipe

SC8 – Drilling Structures and Equipment

- Verification FEA analysis for hammer union designs

SC10 – Well Cements

- Investigating measurement methods on static gel strength development to reduce variation.

SC21 – Materials subcommittee

- Temperature de-rating of material yield strength
- Grade 660 bolting elevated temperature testing
- Near-yield cycle testing

Closing remarks

- API standards represent industry's collective wisdom on equipment and operational practice, developed and refined over many years:
  - The industry has a wealth of historical use information; including on HPHT
  - Standards follow innovations and learnings and present proven engineering practices – and changes to standards are normal and to be expected
    - 38 standards reviewed containing HPHT requirements
  - Participation in standards development is welcomed and necessary.
- API standards are widely cited by Federal, State, and International Regulators
- The next API meeting is in San Antonio – Jan 22-26, 2018

Thank you for your attention!

Overview of API Standards activity on HPHT

David Miller, P.E., F. ASCE
Director, Standards Development
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HPHT: Experience & Reinforcing the Progress of Industry

November 28, 2017

APPENDIX E: BSEE REVIEW PROCESS

V1 (January 5, 2018)

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OFFSHORE OPERATORS COMMITTEE
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Bureau of Safety and Environmental Enforcement

BSEE Approval Process for HPHT Projects in the Gulf of Mexico

Russell Hoshman

OOC HPHT Workshop

Nov 28, 2017

"To promote safety, protect the environment and conserve resources offshore through vigorous regulatory oversight and enforcement."

Code of Federal Regulations 30 CFR 250.286 to 250.295

- All projects on the OCS using non-conventional production or completion technology will require a Deepwater Operations Plan (DWOP)
- All DWOP approvals will provide **conditions of approval** to address using technologies that are not addressed in the regulations.

1

BSEE ORDER OF OPERATIONS

1. **Drilling Application for Permit to Drill (APD)**
   - BSEE District Office and District Operations Support (DOS)
   - HPHT casing design, containment / capping stack and blowout intervention
2. **HPHT Conceptual Plan (CDWOP)**
   - BSEE Technical Assessment Section (TAS)
   - TAS to provide specific HPHT guidance in response
   - APD or APM for a well completions can not be approved until Conceptual Plan is approved
3. **HPHT Well Completion under APD or APM**
   - BSEE District Office and District Operations Support (DOS)
4. **HPHT Deepwater Operations Plan (DWOP)**
   - TAS project approval required before well can be placed on production
5. **HPHT Well Intervention - APM**
   - BSEE District Office and District Operations Support (DOS)

2

Code of Federal Regulations for HPHT Projects

- **30 CFR 250.804 - Additional requirements for subsurface safety valves and related equipment installed in high pressure high temperature (HPHT) environments**
- **(a)(1) Design Verification Analysis**
- **(a)(2) Design Validation Testing**
- **(b) HPHT is greater than 15,000 psia or 350°F**

3

Code of Federal Regulations for HPHT Projects

30 CFR 250.731 What information must I submit for BOP system components?

(c) Certification by a BAVO (I3P)

- **(1) Shear Ram capability per 250.732**
- **(2) BOP Designed, Tested and Maintained**
- **(3) Accumulator System Capability**

(d) Additional Certification by a BAVO (I3P), if you use a subsea BOP, a BOP in HPHT environment as defined in 250.804 or a surface BOP on a floating facility.

- **(1) BOP stack suitable for the rig and well design**
- **(2) BOP stack not damaged from previous use**
- **(3) BOP stack will operate in the conditions**

<4>

BSEE HPHT Project Approval Guidance Document 6 Parts

1. What needs to be included in the Conceptual Plan to request approval to build HPHT Well Equipment
2. I3P reports for HPHT equipment design and construction
3. What needs to be included in the Conceptual Plan to request approval to Drill and Complete a HPHT well
4. I3P reports for HPHT well completions
5. Considerations for using External Hydrostatic Pressure in your HPHT Equipment Design (API 17 TR12)
6. Guidance on writing an I3P report

Conceptual Plan for HPHT EQUIPMENT

Your Conceptual Plan should address:

- Equipment and Assembly List and Diagrams
- Equipment Categorization
- Basis of Design
- Hazards & Failure Mode Analysis
- Material Selection and Qualification
- Design Verification Analysis
- Design Validation Testing
- Equipment Quality Assurance and Inspection Plan
- I3P Nominations

6

Conceptual Plan for HPHT EQUIPMENT

Your Conceptual Plan should include:

- Equipment Categorization
  - Category 1 – Primary Barrier for Protecting People and the Environment
  - Category 2 – Secondary Barrier
  - Category 3 – Non critical equipment
- Equipment Subcategory
  - Subcategory A – Alternate Design Analysis Methods
  - Subcategory S – Standard Design Analysis Methods
- Any Equipment rated at greater than 15,000 psia or 350 °F and categorized as 1A or 1S or 2A requires an I3P

7

Conceptual Plan for HPHT EQUIPMENT

The following equipment will be Category 1 for the purpose of I3P reporting:

- Wellhead System
- Tubing Head
- Tubing Hanger
- Tree
- Production Casing
- Production Liner
- Production Liner Hanger / Packer
- SCSSV
- Production Casing and Liner Cement
- Capping Stack
- BOP
- CWOR
- Subsea Test Tree
- Production Tubing
- Wellhead Connectors
- Landing Nipples and Tubing Plugs
- BSDV
- Flowline Risers (CVA)
- HP Workover Riser
- HIPPS System

<8>

Conceptual Plan for HPHT EQUIPMENT

Your Conceptual Plan should include plans for:

- **Summary of the Proposed Basis of Design**
  - **Identify mechanical loads such as internal pressure, external pressure, tension, compression, bending, internal temperature, external temperature, cyclic loading, etc.**
  - **Identify environmental exposure such as H_2S, CO_2, Cl, Hg, etc.**
- **HAZID/HAZOP and/or FMEA/FMECA**
  - **All potential modes of failure must be identified.**
  - **All potential load cases must be identified.**
  - **Consequences of failure must be understood**

9

Conceptual Plan for HPHT EQUIPMENT

Your Conceptual Plan should include plans for:

- **Material Selection and Qualification**
  - **Material Properties needed for design analysis to address identified failure modes**
  - **Material Tests to be conducted for material characterization**
- **Proposed Design Verification Analysis to be conducted for each component and assembly such as strength and fatigue analysis**
- **Proposed Design Validation Tests such as prototype tests, initial pressure test, nondestructive examination, destructive examination, life cycle test, etc**

10

Conceptual Plan for HPHT EQUIPMENT

Your Conceptual Plan should include plans for:

- **Summary of Proposed Load Monitoring for components where fatigue has been identified as a potential mode of failure**
- **Proposed Independent Third Parties (I3P)**
- **Plans for I3P Analysis for Basis of Design, Material Selection and Characterization, Design Verification, Validation Testing, and Fabrication**

11

Conceptual Plan for HPHT WELL DESIGN

Your Conceptual Plan should include plans for:

- Typical Well Schematic
- Well Control, Completion Intervention Procedures and Equipment
- Tubing and Casing Force Analysis
- Threaded Connection Qualifications
- Cementing Materials and Procedures
- Packer Qualification
- Plans for Trapped Annular Pressure
- Relief Wells and HPHT Capping Stack
- Maximum Anticipated Surface Pressure (MASP), Expected Surface Pressure (ESP) and Estimated SITP
- Environmental Conditions and Material Requirements
- I3P Nominations

<12>

Conceptual Plan for HPHT WELL DESIGN

Your Conceptual Plan should address:

- The completion of a HPHT well requires that the following equipment be built, and readily available in the Gulf of Mexico:
  - **Well Control Equipment – BOPs, Riser, Choke Lines, Kill Lines, and a Rated Well Capping Stack**
  - **Well Completion and Intervention Equipment – Completion Workover Riser Package, Subsea Test Trees, Riser Systems, Running Tools**
  - **Coiled Tubing BOP Equipment, Wireline Equipment, Tubing Plugs**
  - **Kill Pumps, Manifolds**
  - **All Well Completion Equipment and Tubulars**

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Conceptual Plan for <u>HPHT WELL DESIGN</u>

Your Conceptual Plan should address:

- Analysis of the production tubing, production casing and production liner for the site specific well for tri-axial forces, burst, collapse, compression, and tension for all possible load cases
- Analysis of the cementing materials and procedures for the production casing and production liner
- Qualification of casing and tubing threaded connectors
- Trapped annular pressure and production casing pressure monitoring (A & B annulus) and management

14

Conceptual Plan for <u>HPHT WELL DESIGN</u>

You Conceptual Plan should address:

- <u>Relief Well Capabilities</u> and <u>HPHT Capping Stack:</u> 30 CFR 250.462(c) "What are the source control and containment, and collocated equipment Requirements?" The "Containment Plan Report" describes your source control and containment capacity to the Regional Supervisor
- Packer and Bridge Plug analysis and qualification
- Well Completion Procedures, Well Control Procedures, and Well Intervention Procedures for more than one method of Well Intervention with and without the tree in place

15

Independent Third (I3P) Review

- **Why does BSEE request I3P reviews?**
  - Whenever a New Technology Application is deemed technically complex and requires a high degree of specialized knowledge, BSEE may seek an I3P review to facilitate the approval process
  - An I3P may not be involved directly in the project. The I3P is only verifying the work of the manufacturer or the operator

16

Independent Third (I3P) Review

- **The Conceptual Plan provides a proposed plan for the design and construction of HPHT equipment and the completion of the HPHT wells**
- **The Conceptual Plan also provides an outline and specific expectations for the I3P**

17

I3P Reports for HPHT Equipment Design

1). ***I3P Report (1A)*** Basis of Design and Functional Specifications (Requirements) The report must also include hazard and failure analysis including HAZID/HAZOP and/or FMEA/FMECA for the loads and environment identified in the basis of design

2). ***I3P Report (1B)*** Material Selection, Qualification, and Testing

3). ***I3P Report (1C)*** Design Verification Analysis

4). ***I3P Report (1D)*** Design Validation Analysis. The report should include a summary of tests and test results.

5). ***I3P Report (1E)*** Load Monitoring (required if fatigue is a potential failure mode) Provide a detailed description of how loads on fatigue sensitive equipment will be monitored.

6). ***I3P Report (1F)*** Fabrication, Quality Management System, and Inspection and Test Plan (ITP) that identifies the Quality Control/Quality Assurance process, and Inspections of the final products.

7). ***I3P Report (1G)*** Final Report that ties Reports 1A through 1F together

<18>

I3P Reports for HPHT Well Completions

1). ***I3P Report (2A)*** Completion, intervention, and kill procedures.
The report must identify all the necessary equipment to do this work and verify the equipment is readily available and accessible and will remain so for the life of the well

2). ***I3P Report (2B)*** Force analysis for the production tubing, production casing, and production liner for each possible load case identified per Appendix B.

3). ***I3P Report (2C)*** Design verification and validation analysis for cementing materials used in the production casing and liner and associated cementing procedures

4). ***I3P Report (2D)*** Packer qualification analysis

5). ***I3P Report (2E)*** Qualification analysis for threaded connectors for the production tubing, production casing, and production liner.

6). ***I3P Report (2F)*** Trapped annular pressure and production casing pressure management plans

7). ***I3P Report (2G)*** Relief well capacity and HPHT capping stack analysis.

8). ***I3P Report (2H)*** Justification for the estimated SITP and MASP

9). ***I3P Report (2I)*** Discussion of environmental conditions and material requirements

10). ***I3P Report (2J)*** Final Report that ties Reports 2A through 2I together

<19>

Independent Third (I3P) Review

- The final Conceptual Plan (CDWOP) is not approved until all the I3P reports are received, reviewed and accepted by BSEE
- No HPHT well may be completed until the Conceptual Plan (CDWOP) is approved

20

Independent Third (I3P) Reports

The I3P is responsible for two things:

1. Reviewing the various engineering analysis performed by the operator or the equipment manufacturer and verifying the outcome of the analysis
2. Capturing the results of their review into a report that is clear, concise and complete. This will become a permanent BSEE record and an integral part of the approval process

21

Independent Third (I3P) Reports

- **Clear:** BSEE would like to see a consistent format for I3P reporting
- **Concise:** BSEE is asking the I3P to reduce the original engineering analysis by the operator or the manufacturer
- **Complete:** BSEE would like for the I3P report to be a standalone document. That is BSEE should not have to review any other document to understand what has been reviewed, designed, built, tested and the final results of the analysis

22

Independent Third (I3P) Reports

- The reports should be written as a clear summary. Anyone should be able to read the report and clearly understand what component was reviewed, what the variables were, loads and factors in the review, what analysis methods were used, what standards were used, what test were performed, and what the results of the review were, without having to link the report to any other document
- The report should contain quantitative information not just qualitative statements of acceptability without stating the factors being considered and the end results of the analysis

23

Independent Third (I3P) Reports

- Documents that were reviewed during the I3P review must be clearly referenced but not attached to the report
- Provide a detailed list of all documents and test records reviewed, including author, document name/title, revision number, and author's or operator's document number. Include a summary of the document, the conclusions, and the title of the document in your description

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Independent Third (I3P) Reports

- A common Engineering Technical Report's format includes:
  - Transmittal Letter
  - Title Page
  - Executive Summary
  - Table of Contents
  - List of Figures and Tables
  - Report Body
  - Conclusion
  - References

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Bureau of Safety and Environmental Enforcement

Argonne National Lab Report and Path Forward

Russell Hoshman

OOC HPHT Workshop

Nov 28, 2017

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Argonne National Laboratory Report

- Evaluation of Pressure Rating Methods Recommended by API 17TR8 (Dec 2016)
- ANL's Conclusions:
  - The ASME Section VIII, Division 3, elastic-plastic method is not recommended for HPHT subsea equipment, as published with a 1.8 load factor (for plastic collapse)
  - Pressure rating HPHT subsea equipment based on the Division 3 elastic-plastic methods is acceptable if a design load factor of 2.1 or greater is used.
  - When evaluating for Combined Stress, Stress Intensity (Tresca Maximum Distortion Energy Theory) should be used and not von Mises Equivalent Stress.

1

TAS and HETAC Conclusions from the ANL Report

(1). Using the minimum material properties, the calculated plastic collapse was lower than the actual burst pressure by about 7%

(2). Using the actual material properties, the calculated plastic collapse was higher than the actual burst pressure by about 7%

(3). As the actual material properties approach the minimum material properties, the calculated plastic collapse could be greater than the actual burst pressure as demonstrated by this experiment. This could result in a less conservative determination of the rated working pressure

(4). When using ASME Section VIII Div 3, increased conservatism can be obtained by increasing the plastic collapse load factor from 1.8 to 2.1

(5). Increased conservatism can be obtained by using Stress Intensity instead of Von Mises

<2>

Proposed Path Forward Based on ANL Report

- The pressure rating of equipment is designed using minimum material properties
- The actual tested material properties must exceed the minimum material properties
- If the actual material properties as determined by test(s) are near or equal to the minimum specified values, additional information may be requested by BSEE. BSEE will exercise caution and may request an analysis with load factors greater than those proposed in API or ASME under this condition

- When evaluating combined stresses, follow the guidance in API Standard 6X

3

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Certified Design Review

Russell Hoshman

OOC HPHT Workshop

Nov 28, 2017

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API Standard for I3P

- BSEE created the I3P process for HPHT Equipment Design because API SPECIFICATION STANDARD did not exist for HPHT Equipment design

- In about 2 years most API SPECIFICATION STANDARD for HPHT equipment will be in place

<1>

How Do We Handle HPHT Equipment Approvals After the API Specification Standard are updated for HPHT?

- Historically, BSEE accepts 15,000 psi well equipment designed and built to API Standards without question
- When the API Specification Standards are all updated for HPHT, BSEE should: (Options)

1. Continue the existing BSEE I3P review process for 20,000 psi rated well equipment (30 CFR 250.804)
2. Have API write a standard for HPHT I3P process. (call it API Certified Design Review)
   a) Option A
   b) Option B

<2>

Option A
API Certified Design Review

- API writes a Standard for HPHT equipment I3P Design Review (API Certified Design Review)
- This process is managed by API and the manufacturers not BSEE
- HPHT equipment will come with API documentation that it has undergone an API Certified Design Review
- BSEE accepts this equipment without being involved in the equipment design review

<3>

Option B
API Certified Design Review

- API writes a Standard for HPHT equipment I3P Design Review (API Certified Design Review)
- This process identified what is required for a proper I3P design review
- BSEE will continue receiving I3P reports for the approval of HPHT Equipment Conceptual Plans

<4>

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HPHT Standards

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OOC HPHT Workshop

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API HPHT Standards

- **API TR PER 15K-1**, Protocol for Verification and Validation of HPHT Equipment, 1st edition, March 2013
- **API 17TR8**, High-Pressure High-Temperature Design Guidelines, 1st edition, Feb 2015
- **API 17TR8**, High-Pressure High-Temperature Design Guidelines, 2nd edition, (Passed Ballot to be published in a few months)
- **API 17TR12**, Considerations of External Pressure in the Design and Pressure Rating of Subsea Equipment, 1st edition, March 2015
- **API Spec 11D1**, Packers and Bridge Plugs, 3rd edition, April 2015, Annex B for HPHT

<1
>

API HPHT Standards

- **API Spec 14A**, Specifications of Subsurface Safety Valve Equipment, 12th edition, Jan 2016 (HPHT)
- **API SPEC 6A**, Specifications for (Surface) Wellheads and Christmas Trees, 20th edition, Oct 2010 with revisions through March 2016
- **API Standard 6X**, Design Calculations for Pressure Containing Equipment, 1st edition, March 2014
- **API Standard 2RD**, Dynamic Risers for Floating Production Systems, 2nd edition, Sept 2013.
- **API RP 5C5**, Procedures for Testing Casing and Tubing Connectors, 4th edition, Jan 2017

2

API HPHT Standards

- **API Spec 16A**, 4th editions, Annex H, Drill-Through Equipment High-Pressure High-Temperature Application. Final Comment Review.
- **API Spec 17D**, Design and Operation of Subsea Production Systems – Subsea Wellhead and Tree Equipment, 3rd edition. Work just starting and it will address API 17TR8.
- **API Standard 17G**, 3rd edition, Design and Manufacture of Subsea Well Intervention Equipment, Failed in Ballot
- **API Standard 17G1**, 1st edition. System Configuration and Operation for Subsea Well Intervention Systems, Failed in Ballot

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APPENDIX F: HPHT PROJECT APPLICATION EXAMPLES

V1 (January 5, 2018)

Disclaimer

The information contained within this document was captured from the OOC HPHT Workshop held on November 28, 2017. The opinions and information expressed within do not represent any one organization's position, rather the results of open dialogue on the topic. This information should not be utilized out of context or without a clear understanding of the event and topics covered.

TABLE OF CONTENTS

OFFSHORE OPERATORS COMMITTEE
staff@theooc.us

System Engineering Results to Date

Gregg Walz
Anadarko Petroleum Corporation

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20A Project – System Engineering

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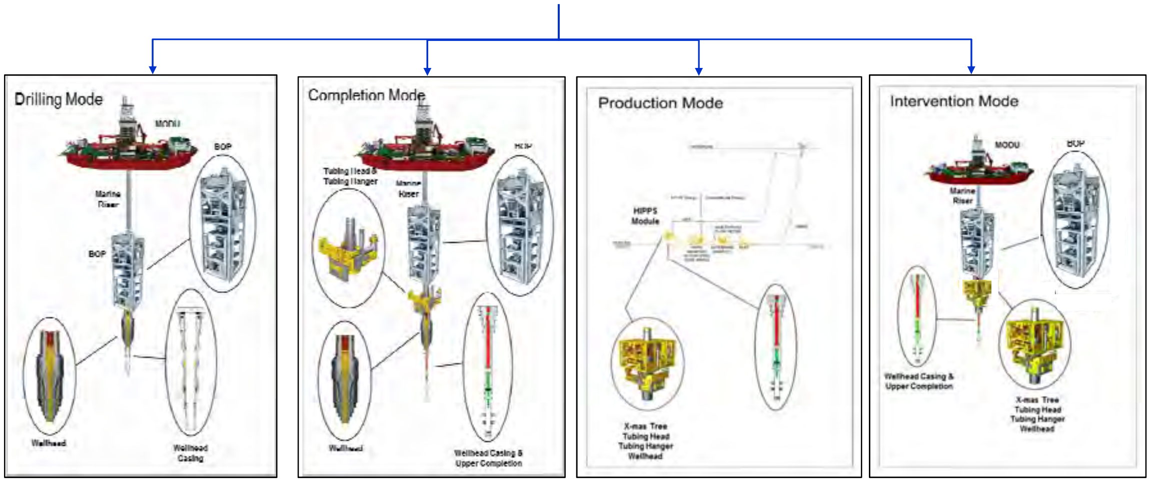
"Whole Life Cycle"



Load Identification & Bracketing

Confidential

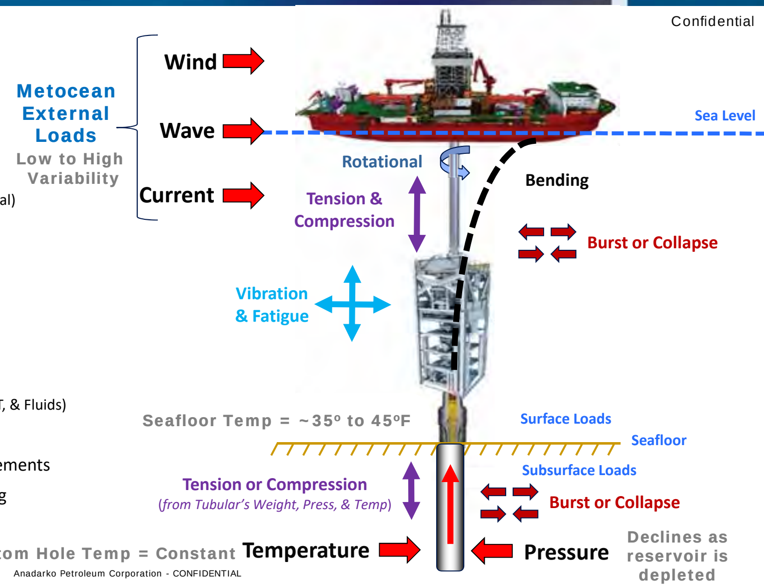
Surface Loads Derived From:

- Direct Metocean Measurements
- Statistical Metocean Data
- Vessel Motions & Stability Measurements
- Equipment Designs Analysis & Testing
- Soils Data Measurements (Site Specific or Regional)
- Global Riser Analysis
- Direct Motion Measurements @ BOP

Sea Floor is the interface point

Subsurface Loads Derived From:

- Direct Downhole Reservoir Measurements (P, T, & Fluids)
- Direct Seafloor Measurements (P & T)
- Production Rate Modeling and Direct Measurements
- Tubular & Equipment Design Analysis & Testing



System to Component Design (Big & Small)

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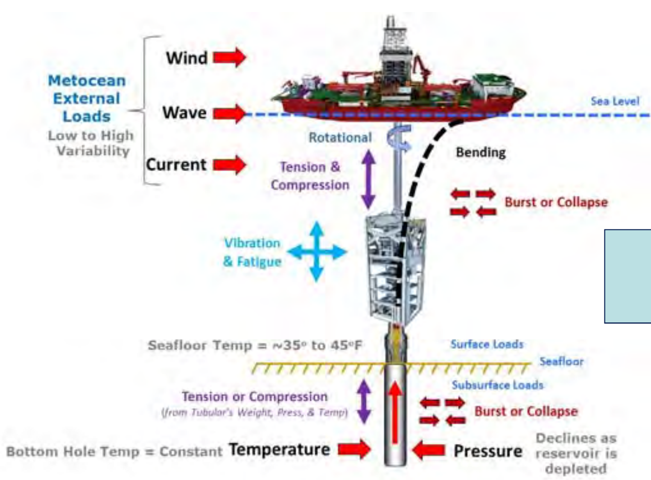

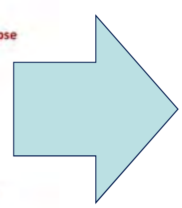

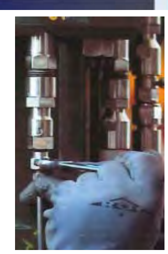

20A Project: Demonstrate Fit-for-Service

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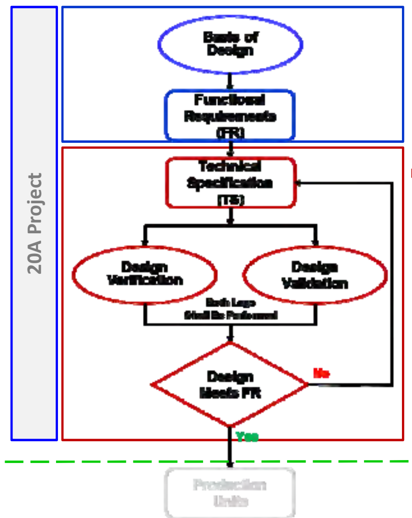

- **APC**
  - Basis of Design & Loads
  - Functional Requirements (FR)
  - Risk Analysis/HAZID (System, Subsystem-Level)
  - Fluids List for Materials Testing
- **Supplier's Technical Specification (TS)**
  - Design Basis (Assembly/Component)
  - FMEAs / FMECAs
  - Material Selection/ Qualification
  - Design Verification
    - Mechanical Integrity/Fatigue
  - Validation Testing: Procedures/Results
  - Quality Plan/ ITPs for Production Unit

Independent Third-Party (I3P) Verification of:

A. Basis of Design, Functional Requirements Risk Assessment, etc.
B. Material Selection & Qualification
C. Design Verification
D. Validation Testing
E. Load Monitoring (as required)
F. Quality Plan, ITPs
G. Summary of 1A-1G for well-specific data

Demonstrate Fit-for-Service

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Design Verification (Simple to Complex)

Confidential

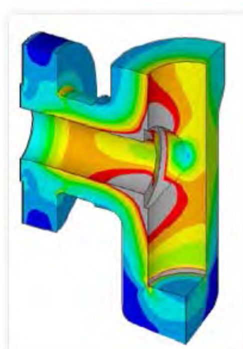
Simple Hand Calculations

$$P = \frac{2Y_P t}{D}$$

Burst Strength of the Pipe Body

P = Minimum internal yield pressure
Y_p = Minimum yield strength
t = Nominal wall thickness
D = Nominal outside diameter

Complex 3D FEA Models



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Material Qualification Examples

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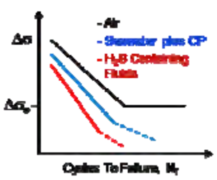
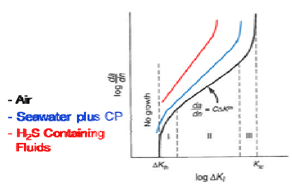
- **Industry standards**
  - API 20B: Open Die Shaped Forgings for Use in the Petroleum and Natural Gas Industry
  - API 20C: Close Die Shaped Forgings for Use in the Petroleum and Natural Gas Industry
  - DNVGL-RP-0034: Steel Forgings for Subsea Applications
- **Environmental Effects for Material Testing**
  - Elevated Temperatures
  - Fluids: Production, Drilling, Completion
  - Seawater and Cathodic Protection

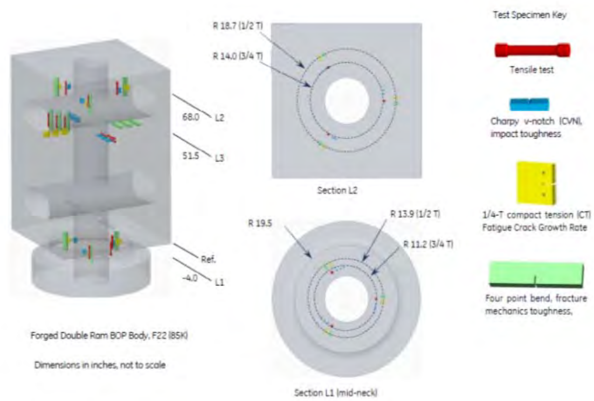
Example of Environmental Effects of Material Properties



S-N Fatigue Curve



Fatigue Crack Growth Rate (FCGR)



Example of 20A Project Material Qualification

Validation Testing Examples

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18-3/4" Shear Testing

Connector Testing
(Combined Loading: Pressure, Tension, and Bending)

Hose Cycle Testing

Control Line Connector Testing

20A Project Workstreams

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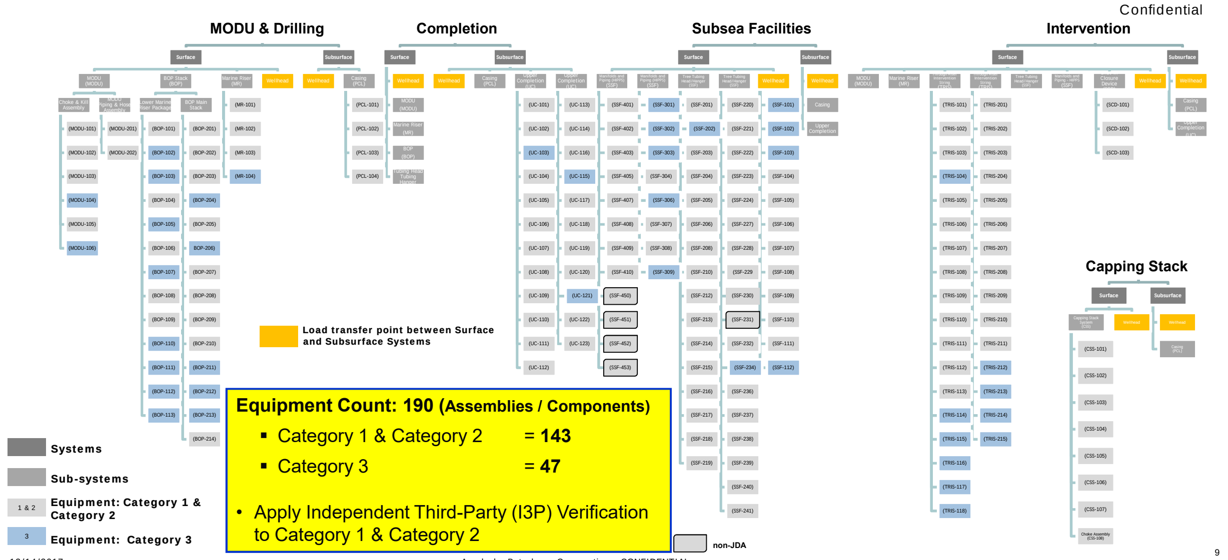

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Design Verification – Failure Modes

Confidential

- Failure modes **covered by Industry** design standards / codes:
  1. **Fatigue:** Cyclic loads, i.e., pressure, temperature, external loads, etc.
  2. **Material:** Corrosion, environmental cracking, bolting material, etc.
  3. **Strain Limit:** Inelastic / permanent deformation begins
  4. **Plastic Collapse:** Load that causes overall structural instability, i.e. pressure, structural (axial, compression, torsional), etc.
  5. **Hydraulic Control:** Loss of hydraulic control function / hydraulic fluids
- Failure modes **covered by Operator / Supplier** design standards:
  6. **Seal / Sealability:** Inability to seal between mating components; elastomers, bolts, ring gaskets, etc.
  7. **Serviceability:** Inability to function/perform as intended, i.e. leaks, seizure between mating components, etc.

Component Governing Failure Mode

- Fatigue
- Hydraulic Control
- Material
- Plastic Collapse: Pressure
- Plastic Collapse: Structural
- Seal / Sealability
- Serviceability
- Strain Limit

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20A System – Governing Failure Modes

20A PROJECT

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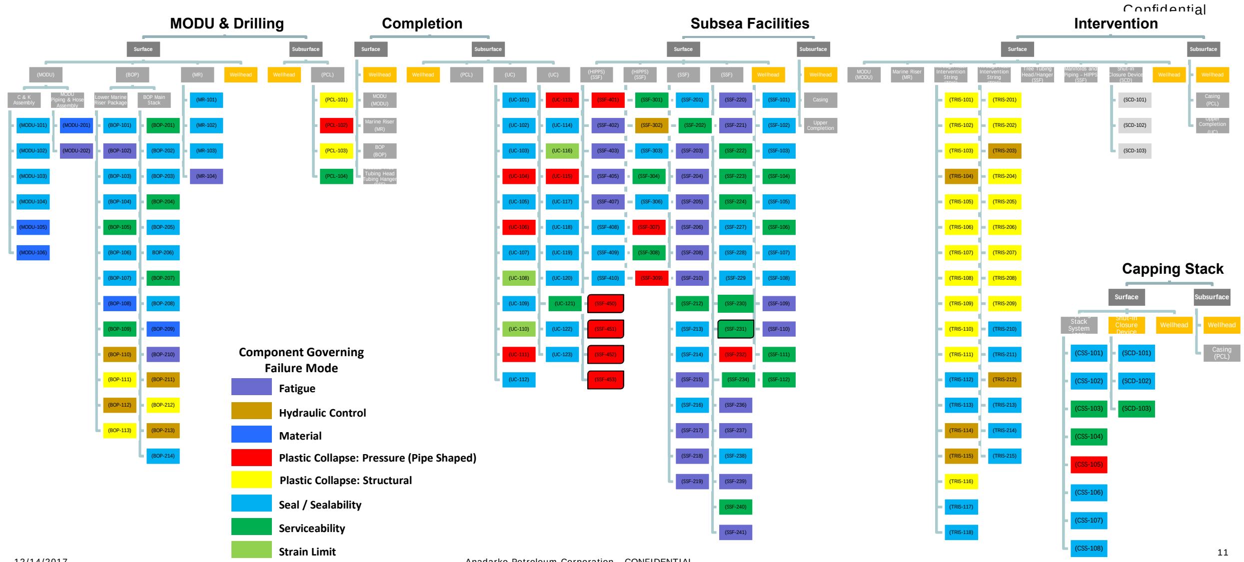

20A System - Governing Failure Modes

20A PROJECT

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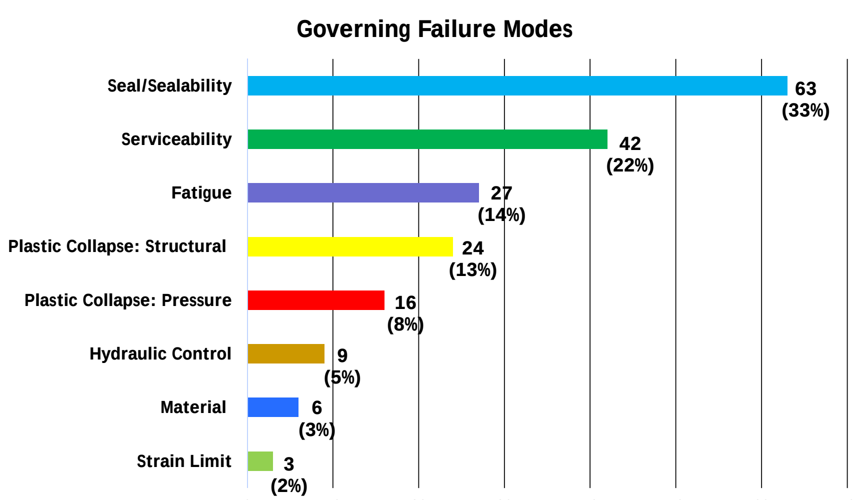

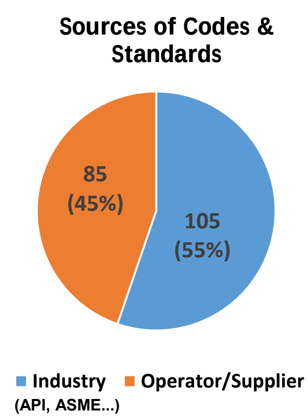

APC's Certified Design Review: Certification of Fit-for-Service

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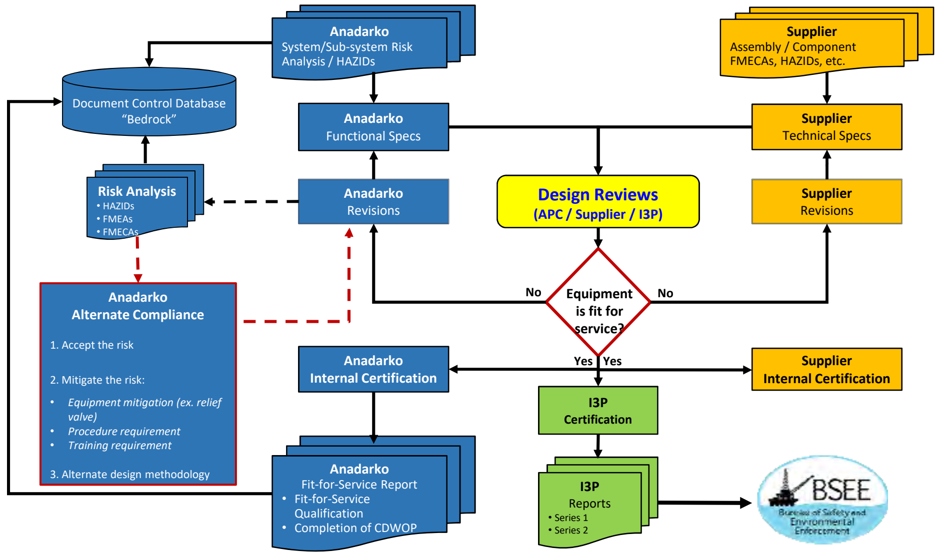


20A Project – Guiding Principles

Confidential

- **Apply Engineering First Principle**
- **Apply Industry Codes / Standards as Acceptance Criteria**
- **Holistic and Integrated Approached to Engineering Application**

Chevron
human energy

Chevron Approach for HPHT Equipment and Projects

Matt Vaclavik
Greg Kusinski
November 28th, 2017
HPHT Workshop

Chevron Approach

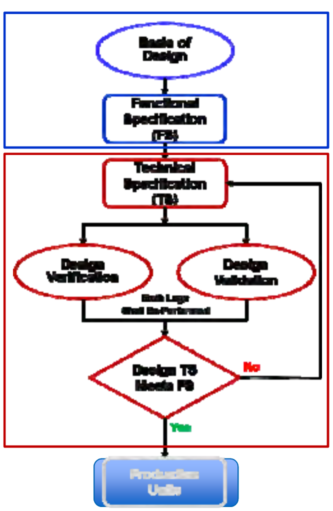
1. Equipment Level
   Roles & Responsibilities During Design, V&V, and I3P verification

2. Project Level
   Fitness-for-Project assessment
   Equipment Technical Specifications vs. Project Functional Specifications

1. Chevron & OEMs - Roles & Responsibilities during Equipment Design, V&V and I3P verification

Roles, Responsibility and Deliverables

BSEE Technical Assessment Section HPHT Guidance, 2012 – Present



- **Operator**
  - Basis of Design
  - Functional Specifications (FS)
    - Operational Loads
  - Risk Analysis / HAZID
  - Fluids List for Design
- **Supplier's Technical Specification (TS)**
  - Design Basis
  - FMEAs / FMECAs
  - Material Selection/ Qualification
  - Design Verification
  - Design Validation
  - Quality Plan for Production Unit

Independent Third-Party (I3P) Verification of:

A. Basis of Design, Functional Specifications, Risk Assessment
   - Report 1A

B. Material Selection & Qualification
   - Report 1B

C. Design Verification
   - Report 1C

D. Design Validation
   - Report 1D

E. Load Monitoring Plan (as required)
   - Report 1E

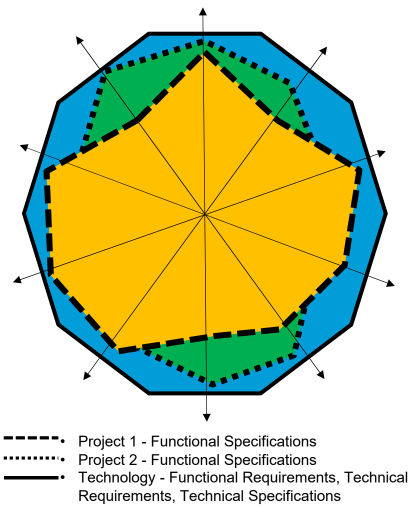
F. Quality Plan
   - Report 1F

G. Summary of 1A-1G for well-specific data
   - Report 1G

Equipment is Fit-for-Service

Establishing Equipment Technical Specifications Based on the Requirements of Multiple Projects

- Understand Project 1 Requirements
- Understand Project 2 Requirements
- Frame Technical Requirements
- Develop V&V Plan and Execute
- I3P Verification



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Design Verification & Validation Process

Function Design Specs
- Pressure
- Temperature
- Environmental Loads
- External Loads

→

Failure Mode Identification
- Plastic Collapse
- Brittle Fracture
- Fatigue Cracking
- Ratcheting
- Serviceability (maintain seal & component functionality)
- Etc.

↓

Verification
- FEA
- Calculations

←

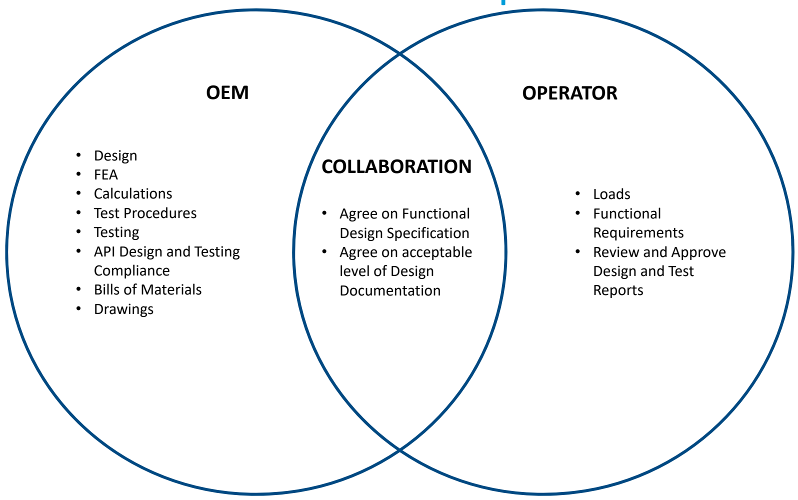
Validation
- Material Characterization Testing (SLD)
- Material Fatigue Testing in Environment
- Component/Assembly Qualification Testing
- Strain Gauging for Validation of FEA Model
- Serviceability Validation

↓

All Failure Modes Mitigated? → **Design Verified and Validated – Fit For Service**

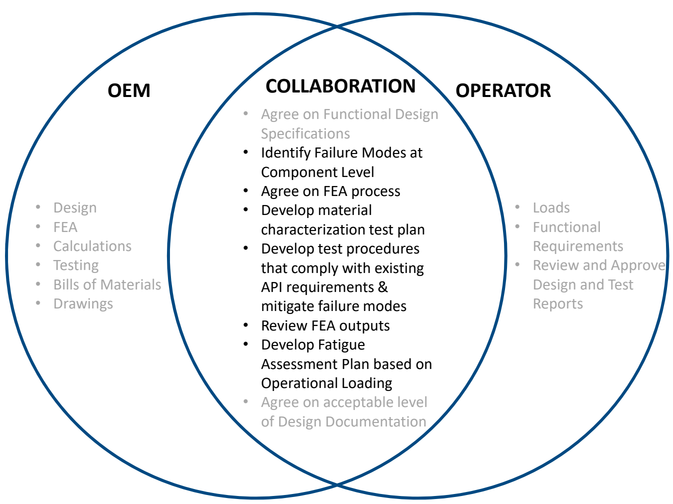
6

Conventional Deepwater



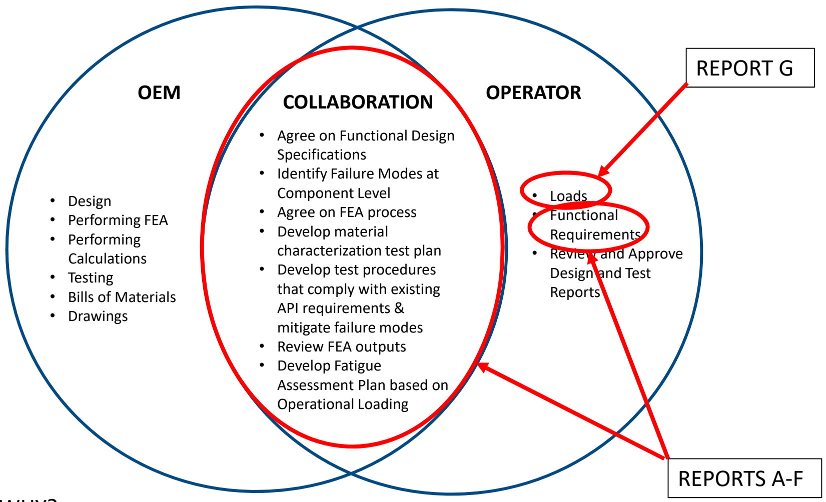
- ❑ WHY?
  - Existing equipment design based on safe operating history and API 17D & API 6A compliance.
  - Operator's role was to provide loads/functional requirements and ensure API compliance.

New Horizons - HPHT



- ❑ WHY?
  - Operator knows how the equipment will be used and should be an integral part of the failure mode identification process.
  - Operator and OEM should collaborate throughout the verification and validation process.

WHERE DOES I3P FIT IN?



- WHY?
  - Per BSEE guidance on gaining CDWOP approval for HPHT Project, these areas are necessary for I3P involvement and review to verify the design.

WHAT LEVEL OF DETAIL IS NECESSARY FOR I3P TO VERIFY A DESIGN?

- Does I3P get to review the loads prescribed in the FDS for information or do they get to question how the load histograms were developed and how the Operator generated those loads?
- Does I3P review the failure modes or do they get to comment/approve whether the list is sufficient?
- Does I3P get to review material specifications for information as the basis of design or do they get to comment on specific parts of the forging process, material testing details, etc.?

CVX PERSPECTIVE

- **Report (1A) – Basis of Design/Functional Specifications & Failure Mode Analysis**
  - Operator defines all relevant loads.
  - I3P reviews Operator prescribed loads and verifies they are within operational capacity of equipment.
  - Operator-OEM identifies all relevant failure modes.
  - I3P verifies that (Operator-OEM)-identified failure modes were mitigated.
- **Report (1B) – Material Selection, Qualification, Testing**
  - Operator-OEM prescribes material manufacture process, utilizes minimum material properties in design, and develops material test plan in environment in accordance with the FMECA.
  - I3P verifies that minimum material properties are utilized in the design process and that necessary compatibility/fatigue testing has been performed in environment.
- **Report (1C) – Design Verification Analysis**
  - Operator-OEM develop verification plan and perform all necessary FEA and calculations.
  - I3P verifies that FEA is performed per code requirements, ensures the designer has correctly incorporated relevant loads, and verifies the correct material properties were utilized.
- **Report (1D) – Design Validation Analysis**
  - Operator-OEM develop validation plan that is in accordance with existing API standards and mitigate all identified failure modes.
  - I3P reviews test procedures and reports to verify compliance with existing codes and standards, ensure testing has validated the FEA model, and ensures testing is replicative of expected service.

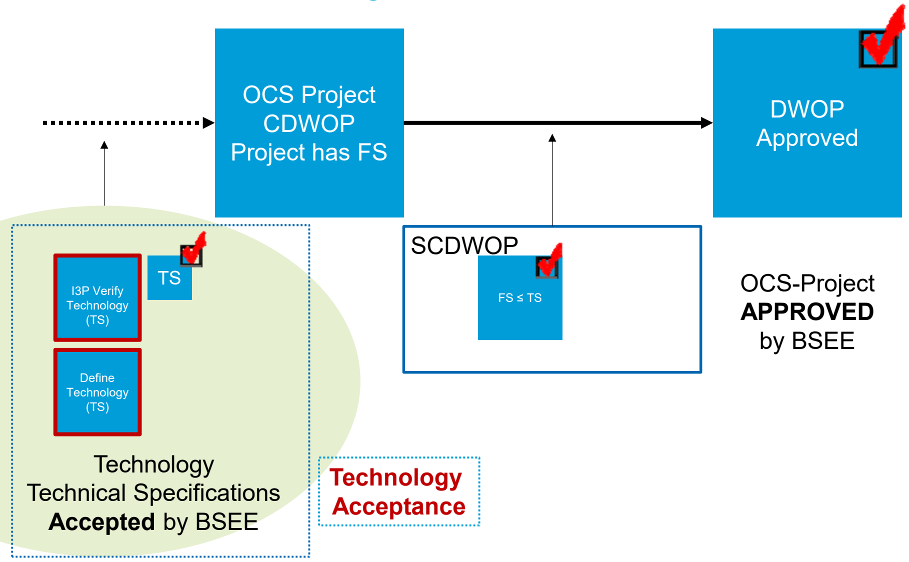
CONCLUSIONS

- The role of the I3P at the component/assembly level is to verify the capacity in expected service environments.

- **KEY CHALLENGE:**
  HOW MUCH VERIFICATION IS SUFFICIENT?

2. Equipment Technical Specifications vs. Project Functional Specifications

Project CDWOP



Technical Specifications Developed Deploy on a Project

Technical Specifications Verified

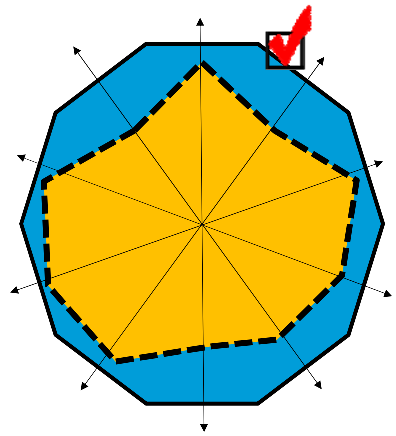
Project level Verification

Project

1. List Functional Specifications of Project

Equipment and Project

2. Verify: Technical Specifications ≥ Functional Specifications



- - - - - Project 1 - Functional Specifications

——— Technology - Functional Requirements, Technical Requirements, Technical Specifications

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Roles of Parties

BSEE Approves

Operator
- Defines BoD and Conditions of Use
- Defines Qualification Targets
- Claims Fitness for Purpose

OEM/Vendor
- Designs Equipment
- Qualifies with Operator
- Supports Fitness For Purpose
- Supports I3P

I3P
- Verifies Fitness for Purpose through review or RESULTS
- Prepares reports for Operator to be filed with BSEE

At the project level; The role of the I3P is to verify that the project stated loads are within the bounds of the previously verified component/assembly capacity.

Overall
THE ROLE of I3P is to verify that the **Outputs/Results** of processes, methods, designs **meet or exceed** the **Specified targets**

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Closing Thoughts:
All this complexity requires simplicity
Chevron
• HPHT Projects require effective collaboration between Operator and OEMs to assure fit-for-purpose design
• Current methods enable HPHT projects
• Design
• Qualification (Verification and Validation)
• I3P Verification
• Role of I3P could be Optimized, yet Robust and Effective
Greg Kusinski,
gkusinski@chevron.com
Greg Kusinski, © 2017 Chevron Corporation
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APPENDIX G: DEEPSTAR HPHT EFFORTS

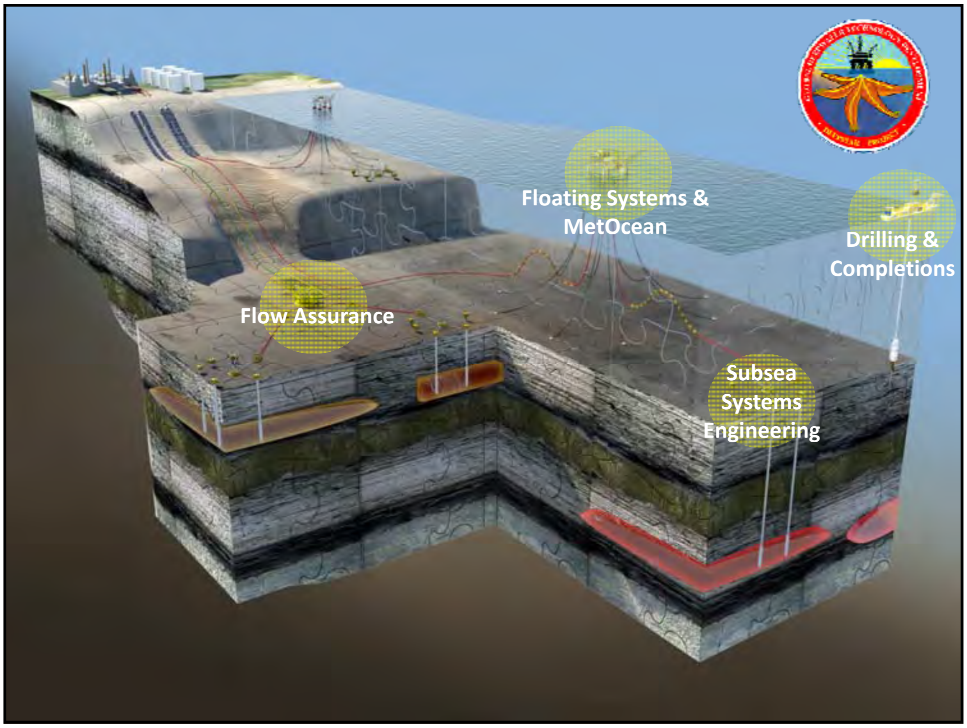
V1 (January 5, 2018)

Disclaimer

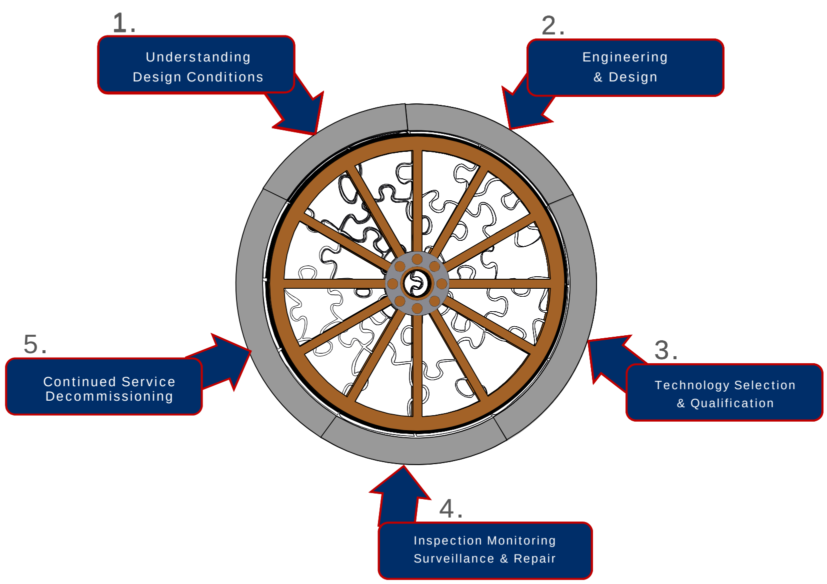
The information contained within this document was captured from the OOC HPHT Workshop held on November 28, 2017. The opinions and information expressed within do not represent any one organization's position, rather the results of open dialogue on the topic. This information should not be utilized out of context or without a clear understanding of the event and topics covered.

OFFSHORE OPERATORS COMMITTEE
staff@theooc.us

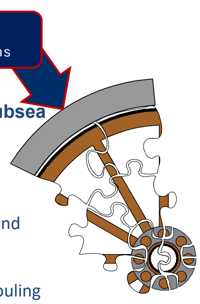

DeepStar ®
A Global Offshore Technology Development Consortium
Joseph Gomes– DeepStar Project Manager
HPHT: Experience & Reinforcing the Progress of Industry


Floating Systems &
MetOcean
Drilling &
Completions
Flow Assurance
Subsea
Systems
Engineering

DeepStar systematic approach to technology development



Understanding the Design Conditions



Reservoir and Fluid Properties & Subsea System Integration

Flow Assurance

- 12202 - Gas hydrate formation under extreme conditions of high pressure and high salinity
- 12201 - Asphaltene Deposition and Fouling in Reservoirs
- 5204 - Methanol and Ethylene Glycol Mixtures Solubility at High Pressure

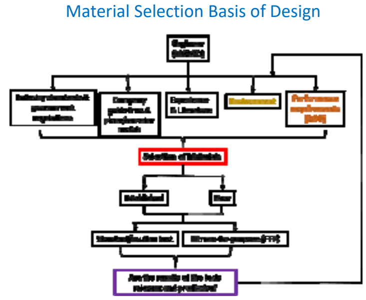
Drilling Systems:

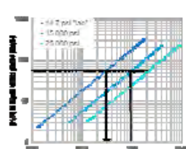
- **12503 - Standardized Materials Selection Basis of Design and Equipment Testing Criteria**

Subsea Systems:

- 7302 - Extreme HPHT Subsea System Study

Material Selection Basis of Design





DeepStar® methodology for materials selection basis of design and equipment testing criteria

a) Objective

HPHT Materials selection

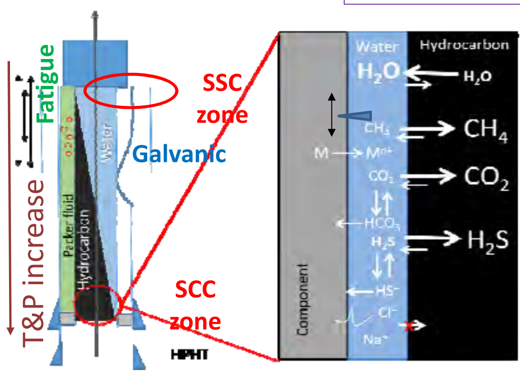
b) Methodology

Definition of the Environment

Interaction of the material/microstructure and environment

c) Goal

Material qualified for HPHT application



Environments to Consider and Evaluate:

- Production, injection, drilling, and completion fluids

Thermodynamics and Effects of the Environment

- Model the environment: *in-situ* pH, H_2S/CO_2 partial pressure, [Cl⁻], inorganic/organic scaling
- Flow assurance, well intervention, and reservoir souring
- Well failures and case histories

Translate conditions from field to laboratory

- Ideal gas law, Henry's law, and/or fugacity (real gas)
- Dynamic and static well conditions

Define Qualification test Protocols for Failure Modes & Time Dependent Effects:

- Corrosion, SSC/SCC, fatigue, and fracture toughness

Engineering & Design

Drilling & Completions, Flow Assurance & Subsea System Integration

Flow Assurance

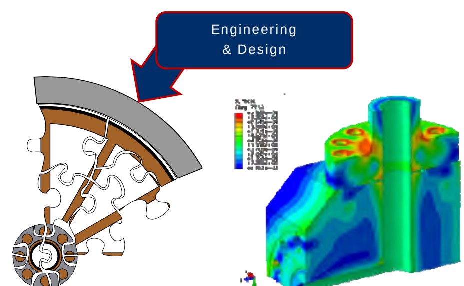
- 11206 – Transient Simulation for HIPPS System Design,

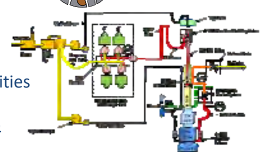
Subsea

- 10304 - All Electric Subsea Autonomous HIPPS Architecture Feasibility Study
- **12302 - 20Ksi Systems**

Drilling, Completions & Intervention

- 12501 - 20Ksi Well Drilling System MODU Upgrade
- 12502 - Completion design consideration and well access system that enable HPHT well intervention
- 12505 - Analysis of current technology and capabilities for shearing
- 8503 - Annular Pressure Buildup Analysis, Model & Mitigation for HPHT Wells
- 7501 - D&C Gaps for HPHT in Deepwater

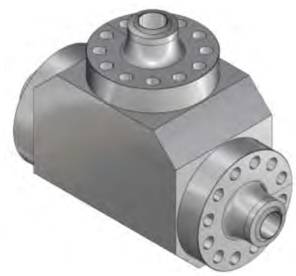


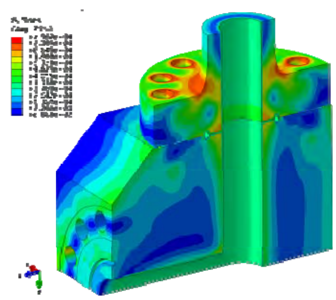


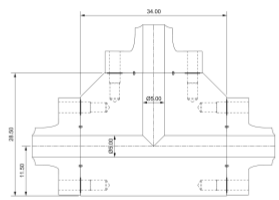
DeepStar® 12302 20 ksi Systems verification of design methodologies for HPHT

Verification of Standard Design for 20 ksi Systems

– The objective of this project a case study on the application of design verification methodologies as outlined in API 17TR8 on a 5” 20 ksi tee assembly.







7

Technology Selection & Qualification

Methodologies

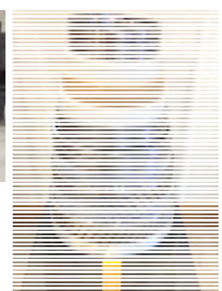
DeepStar 11904 – Subsea Integrity Assurance

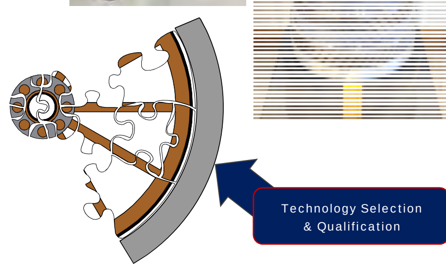
Technologies - Riser

DeepStar 12403 - Ultra Deepwater 20 Ksi Composite Tubular

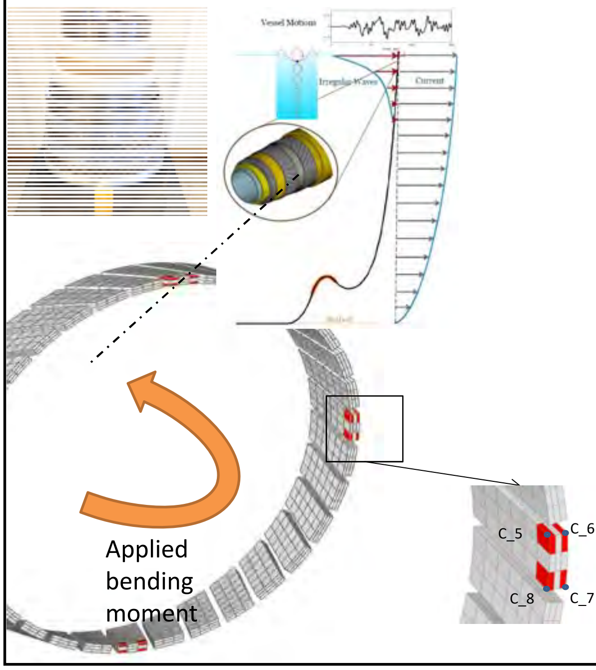
DeepStar 12407 - Testing of High Strength Connected Steel Riser

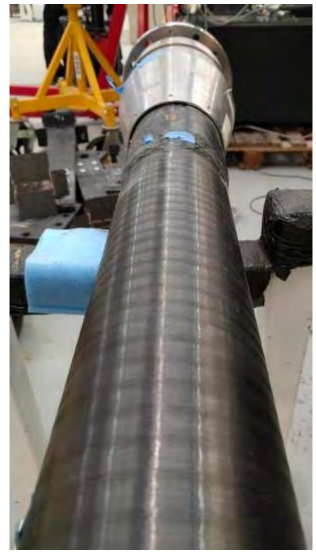
DeepStar 11401 - HP Flexible Flowline and Riser for Ultra-Deepwater Project – Full Scale Qualification





Flexible Ultra Deepwater 20 KSI Composite Tubular





DeepStar Collaborative Effort

DeepStar Satellite Project:

20 ksi Systems Validation of Analysis by Testing

PETROBRAS
MAERSK OIL
woodside
Statoil

- Demonstrate the application of API 17TR8 for HP/HT subsea equipment design
- Assurance API 17TR8 provides:
  - fit-for-service for HP/HT equipment design and
  - adequacy of HP/HT design methodologies
  - opportunities for optimization of **subsea designs**
- 20ksi Technology Qualification = Verification + Validation

DeepStar 20 ksi Systems Project Structure

20 ksi Systems Validation;

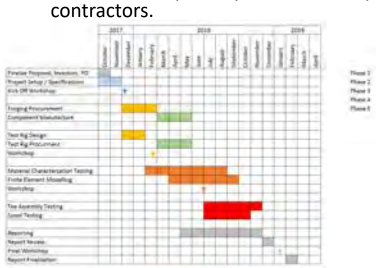
Save the Date: December 13th 2017

Timeline: 18 months.

DeepStar expected start December 2017

Letter of intent sent to interested parties

DeepStar under contract review with members and primary and secondary contractors.

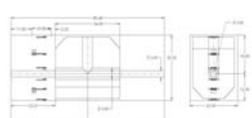


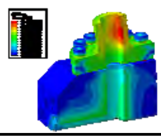
Project Objectives

- 20ksi Technology Qualification = Verification + Validation

Project Deliverables

- Complete material specifications for all materials used.
- PQR and NDE procedures / results.
- Mechanical properties.
- Complete material testing plan.
- Report of complete testing and validation evaluations, including test data such as strain gauge results, NDE, PQR and destructive metallurgical testing.
- Update design analysis, as necessary.
- Industry peer review of results and conclusions.





DeepStar®

Global Offshore Technology Development Consortium

26 Years of Industry Excellence

DeepStar Recruiting Members for DeepStar 2017 .....

DeepStar is the industry's longest running and most successful offshore technology development consortium and it has generated significant value by providing technology transfer to its members and the industry. There is an increased need in the industry for an operator-driven, collaborative technology development program.

DeepStar® CORE + Satellite Model

(Focused CORE R&D Program + Satellite Projects Model)

CORE R&D Program

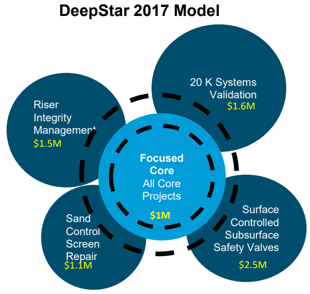
DeepStar CORE Program focuses on all members' common collaborative technology needs; discusses industry technology issues and develops ideas for larger, elective satellite projects.

Satellite Projects

Focuses on elective Satellite Projects in which the technology advancement is aided by collaborative among interested parties.

Satellite Participants:
BP
ExxonMobil
PEMEX
Repsol
Shell
Total

DeepStar 2017 Model



DeepStar® Technical Subcommittees:

- **Drilling, Completion and Intervention**
  - Drilling Operations
  - Drilling Intervention & Repair
  - Plug & Abandonment
- **Flow Assurance**
  - Hydrates
  - Insulated Pipelines & Equipment
- **Subsea Systems Engineering**
  - 20 K Systems Review & Validation
  - Long Distance Tieback
  - Subsea Chemical Storage & Injection
- **Floating Systems & Met-Ocean**
  - Integrity Management
  - Localization for UAVs
  - Low Cost FPSO Alternative
  - Marine Growth Models
  - Mooring Reliability
  - Riser Continued Service
  - Robotic Inspection

Potential Technical Subcommittee

- **Operations**
- **Subsurface (Geosciences + Reservoir)**

DeepStar Membership Fee

- **Member ($80,000 - annual)**
- **Associate Member ($15,000 - annual)**

Visit www.thedeepstar.com Contact DeepStar Director Shak Shamshy shakir@chevron.com or DeepStar Program Manager Joe Gomes joe@theooc.us