OIL & GAS

The Independent Third Party Process for HPHT Material Characterization, Equipment Design Verification and Validation

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Disclaimer,
The information provided in this presentation are based on interpretation of the current guidelines/requirements and may be subject to change.

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Objective

- To present DNV GL interpretation of BSEE TAS Guidelines for independent 3rd party verification of subsea HPHT systems.
- This presentation will focus on DNV GL i3p verification content, boundaries, and expectations.

Definition of HPHT

As stated in 30 CFR 250.807(b):

HPHT environment means when one or more of the following well conditions exist:

(1) The completion of the well requires completion equipment or well control equipment assigned a pressure rating greater than 15,000 psig or a temperature rating greater than 350 degrees Fahrenheit (°F);

(2) The maximum anticipated surface pressure or shut-in tubing pressure is greater than 15,000 psig on the seafloor for a well with a subsea wellhead or at the surface for a well with a surface wellhead; or

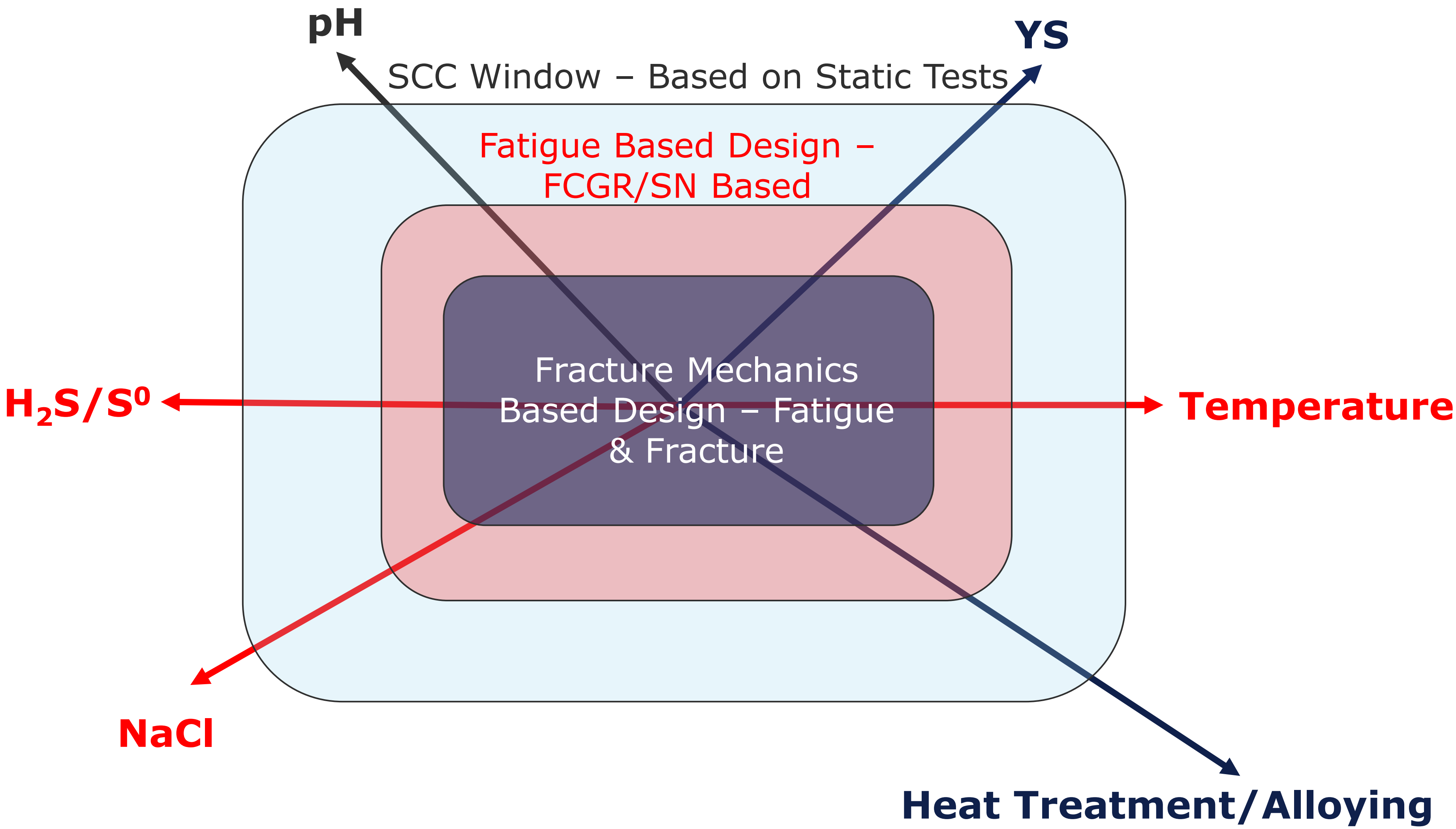
(3) The flowing temperature is equal to or greater than 350 degrees Fahrenheit (°F) on the seafloor for a well with a subsea wellhead or at the surface for a well with a surface wellhead.

HPHT Applications

- HP/HT Challenges involve T>350°F, P>15ksi.
- Environmental Conditions
  - Sour Production
    - High H_2S/Elemental S
    - High Cl^-
  - Seawater with CP
    - Low T (40°F)
    - Elevated T?
- Challenges involve
  - Design
  - Installation
  - Materials
  - Operation

- Typical subsea materials used are high strength steels, however the elevated T and P generally requires the use of high strength nickel based alloys and/or cladded construction.
- Modification of design philosophy (Fracture & Fatigue vs Stress Based)
  - Environmentally Assisted Fatigue and Fracture become critical in design

Implications of Design Philosophy – Stress Based vs Fracture Mechanics Based



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Proposed Design Approach in API 17TR8

- Proposed design philosophy is divided into the following regimes for HP/HT:
  - >350°F – Defines HP/HT
  - >15ksi, >350°F –ASME Div.2
    - Linear Elastic Analysis
    - Global Plastic Collapse
    - If application is fatigue sensitive – Use SN approach
  - >20ksi – ASME Div.3
    - Elastic Plastic Analysis
    - Global Plastic Collapse
    - If application is fatigue sensitive – Use life cycle requirements?
- Fatigue sensitive applications can be designed either via the SN or FCGR approach.
- However, in both approaches the need to characterize toughness in for the final analysis is critical.

Materials Challenges for Subsea HP/HT Applications

Nickel Based Alloys/CRA's

HP/HT Sour Environments

- **Low pH/High H_2S/High Cl^-**
- **High T**
- **SCC and Corrosion Fatigue**

Fabrication Challenges

- **Welds/Clad layers (625)**
- **Alloy Selection (718/945/625+)**
- **Cu Plating issues – leading to low T H embrittlement**

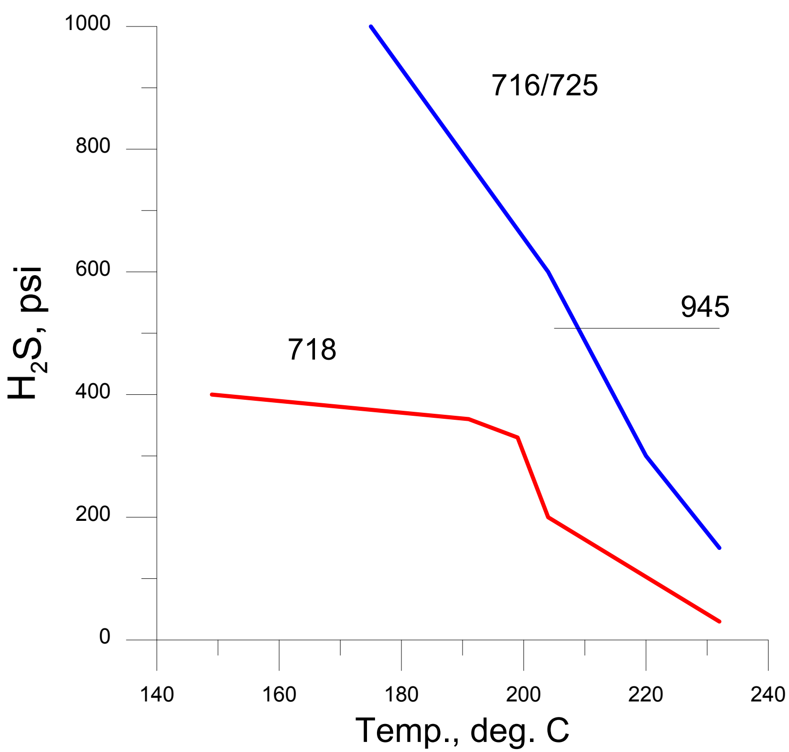
Low T Shut in Conditions

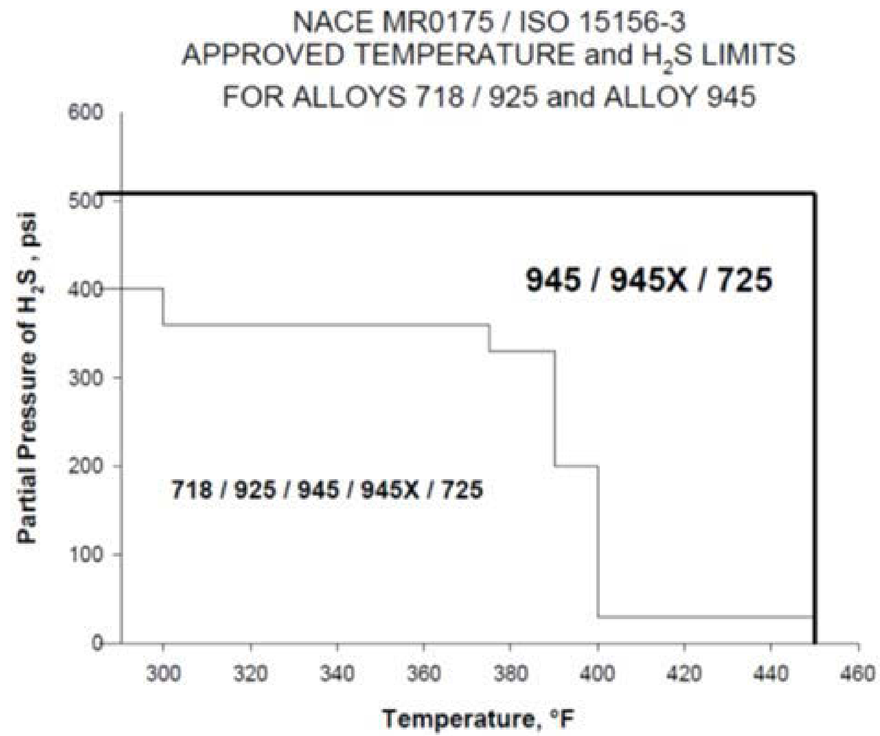
- **High H_2S/Low pH**
- **Lower T (~40F)**
- **Fracture Issues**

Low T CP Issues

- **Lower T (~40F)**
- **Cathodic Protection**
- **Fatigue & Fracture Issues**

Current acceptance limits in ISO 15156





- SCC behavior of precipitation hardened alloys has been evaluated in various environments using C-rings/SSR tests.

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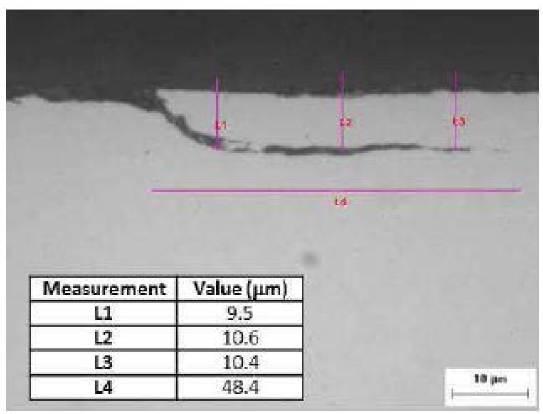
Recent work on PH Nickel Alloys to Develop a Robust Test Method

Table 4
Summary of the test results. All the failures were found on one specimen out of the two tested for each condition.

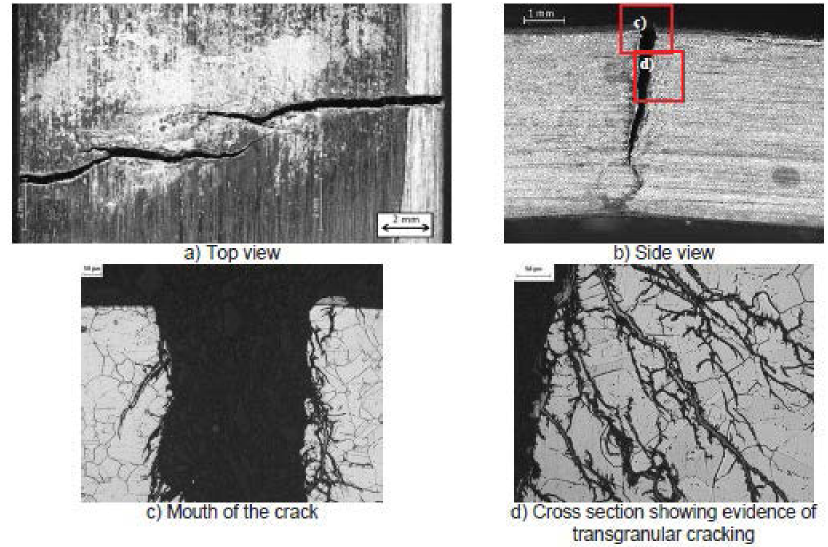
Alloy	NACE MR0175/ISO 15156 severity level	Testing Method	Test Duration, days			
			30	90	183	365
UNS N07718	VI	Conventional FPB	P	P	NT	NT
		Creviced FPB	F	P	NT	NT
UNS N07716	VI	Conventional FPB	P	NT	NT	NT
		Creviced FPB	P	NT	NT	NT
UNS N09945	VI	Conventional FPB	P	P	NT	NT
		Creviced FPB	P	P	NT	NT
	VII	Conventional FPB	NT	NT	NT	P
		Creviced FPB	NT	NT	NT	F
UNS N09925	VII	Conventional FPB	P	P	NT	NT
		Creviced FPB	P	P	NT	NT
UNS N09935	VII	Conventional FPB	P	P	P	P
		Creviced FPB	P	F	P	NT
UNS N07725	VII	Conventional FPB	P	P	P	P
		Creviced FPB	P	P	P	P

Notes:
NT = Not Tested
P Pass
F Fail



Measurement	Value (µm)
L1	9.5
L2	10.6
L3	10.4
L4	48.4

Figure 3 – Cross section analysis of UNS N07718 tested as FPB in presence of a crevice former after 30 days at conditions corresponding to NACE MR0175/ISO 15156 level VI



a) Top view
b) Side view
c) Mouth of the crack
d) Cross section showing evidence of transgranular cracking

Figure 4 - UNS N09935 tested as FPB in presence of a crevice former after 90 days at conditions corresponding to NACE MR0175/ISO 15156 level VII.[8]

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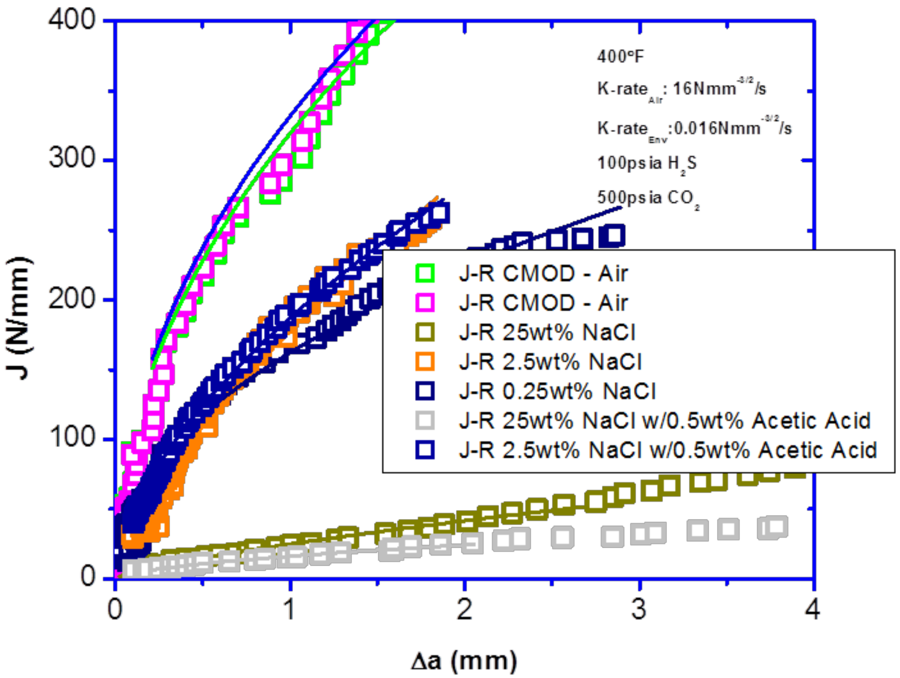
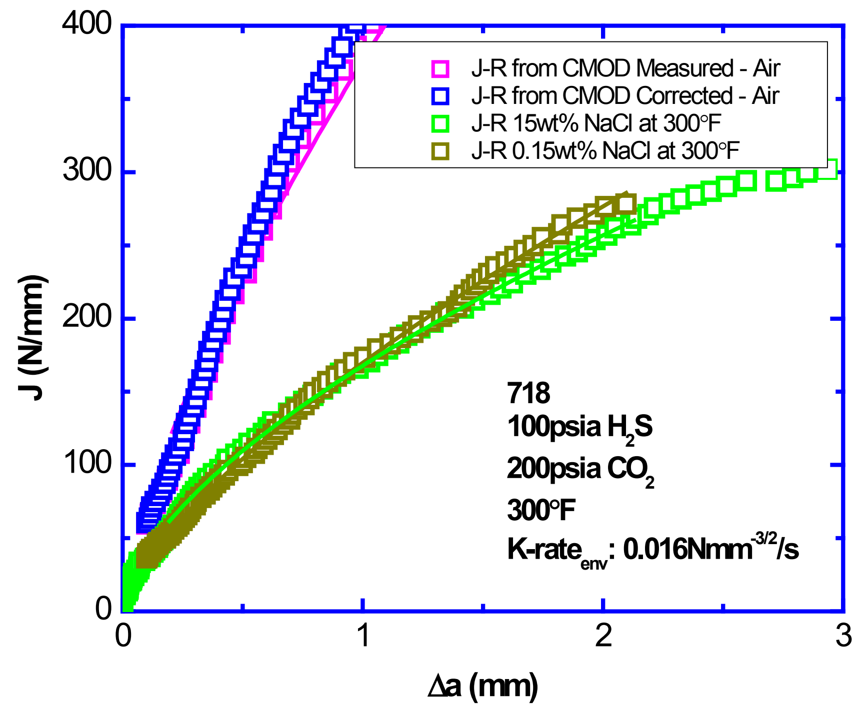
Effect of Temperature on J-R curves





- At lower temperature (300°F) no significant effect of varying chloride concentration.
- Substantial effect of temperature on J-R curves – increasing temperature leads to lower J-R curves.

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Expectations from HPHT third party review

DNV GL Interpretation of BSEE TAS Expectations:

- A review of the planned design analysis methodology and engineering standard(s) that will apply to the design verification.
- Verify that the planned design analysis methods and engineering standard(s) are appropriate for the design temperature(s), pressure(s), and environment to be encountered.
- The independent third-party should confirm the acceptance of the design analysis or verification testing methods or any other procedures the applicant proposes to use.
- An analysis of the actual design verification calculations.
- A review of the design validation testing methods proposed.
- An analysis of the actual design validation test.

Expectations from HPHT third party review

DNV GL:

- To demonstrate the added value of third party verification by DNV GL.
- Global impact for a safe and sustainable future.
- DNV GL third party review is evidence based:
  - Define "WHAT": A well defined Functional Design Specification (Operator)
  - Describe "HOW": Methodology used in delivering the "WHAT" (Technology Owner)
  - Provide "WHY": Evidence in the form of codes, methods, calculations, analysis, testing demonstrating the methodology (HOW) has delivered the intended end product (WHAT). (Operator and Technology Owner).

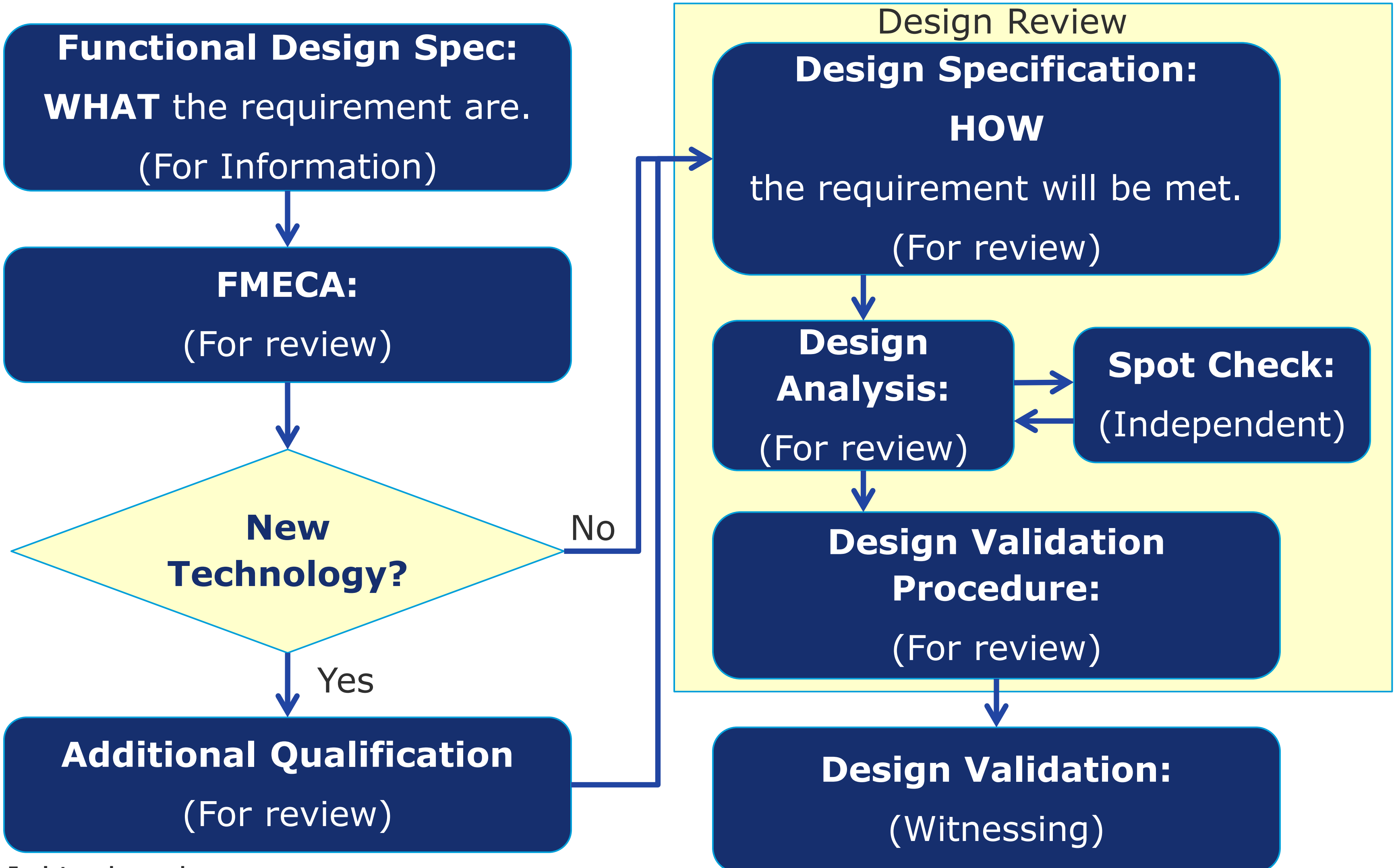
Basis of Verification Approach

- DNV GL verification will follow BSEE Technical Assessment Session (TAS) equipment categorization:
  - “Category 1:Primary Pressure Containing and Pressure Controlling equipment. This equipment design verification and validation must be reviewed and accepted by an independent 3rd party.
  - Category 2: Secondary Barrier equipment providing protection that is not critical to well control.

    This equipment must undergo an additional internal design verification and validation review by the operating company or an independent 3rd party.
  - Category 3: Non-critical equipment and/or equipment not permanently installed in the well; but used in an HPHT environment.

    Any equipment that may be used as a barrier cannot be considered Category 3.”

Third party review process



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Verification Approach

Kick-off Workshop
Alignment with Operator and Technology Owner

Verification Plan
Scope of Work for i3p

Definition and planning of activities

FMECA reviews
Review of results, action items and risk categorization

Performance Assessment
Review evidence addressing FMECA risks identified

Design Verification
Review of design documents

Independent Analysis/Spot Check
Confirmation by separate independent calculation

Design Validation
Witnessing of critical qualification /validation testing

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Qualification, Validation and Verification (Third party review boundaries)

- Qualification ≡ FMECA + Design Verification + Validation Testing

- Design Verification:

  Examination by design analysis to determine conformity with specified requirements.

- Validation Testing:

  Confirmation by testing to demonstrate conformity of the product to design requirements

- Qualification:

  Mitigation of risks identified through FMECA by additional design verification and validation testing to ensure fitness for service.

Design Verification

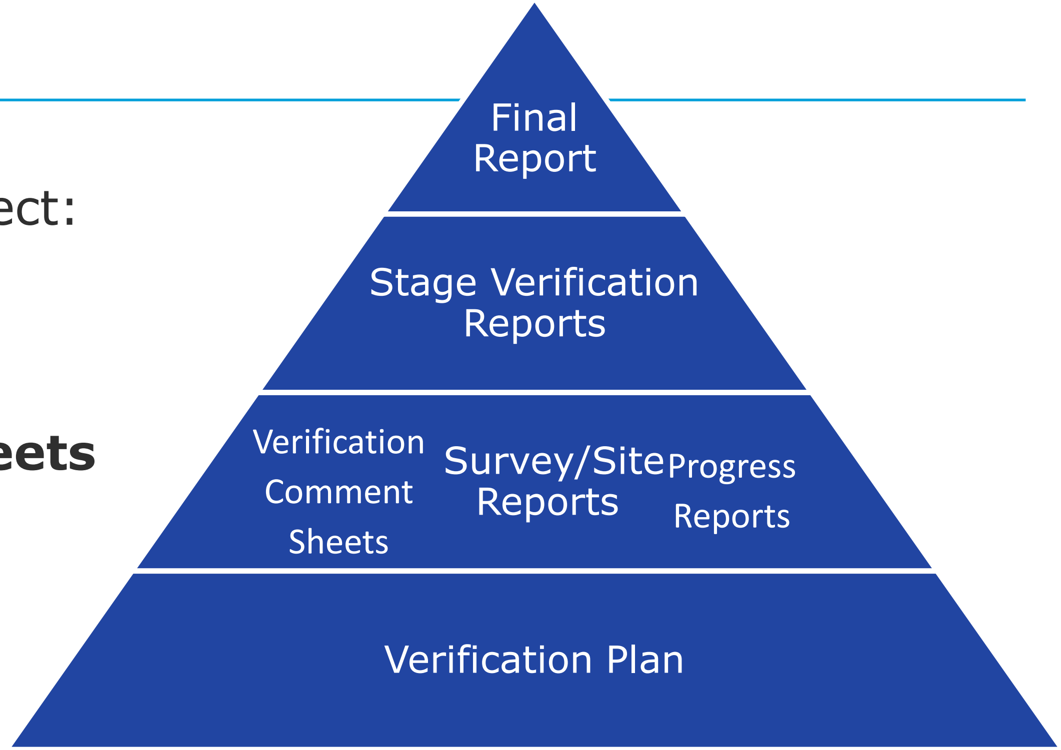
- Review of Engineering Standards and Industry Codes used (including regulatory requirements),
- Design approach and analysis methodology,
- Due consideration to the environmental conditions including loads, temperature(s), and pressure(s),
- Material selection review,
- Welding and Cladding review,
- Review of FMECA reports and action items to ensure the gaps in industry codes are identified and properly addressed.

Design Validation

- Review of evidences that FMECA action items have been addressed (Performance assessment),
- Review of the qualification test procedures,
- Independent evaluation of validation testing,
- Mapping validation testing onto potential failure modes, ensuring that all failure modes, particularly in regards to HPHT, have been covered adequately,
- Fabrication quality assurance audit.
- Load monitoring methods (where fatigue is identified as a mode of failure)

Deliverables

DNV GL will issue the following deliverables throughout the project:



- **Verification Plan**
- **Verification Comments Sheets** (VerCom) for each document reviewed
- **Design Verification Report (DVR)**
- **Site Report** (Test and inspection)
- **Final Report:** All design verification and design validation activities (including onsite test reports) will be captured in the final independent third party review report. Also The equipment not covered by third party design verification (and the reason) will be included.

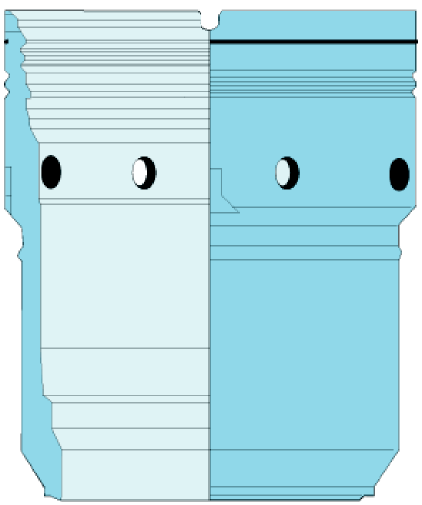
Final Report to BSEE

BSEE expects a report directly from the independent third party, addressing:

- Basis of Design,
- Material Selection and Qualification,
- Design Verification,
- Design Validation Measures,
- Welding and cladding,
- Fabrication process,
- Load monitoring (Fatigue life),
- List of reviewed documents,
- List of documents not reviewed (and the reason),
- List of identified deficiencies.

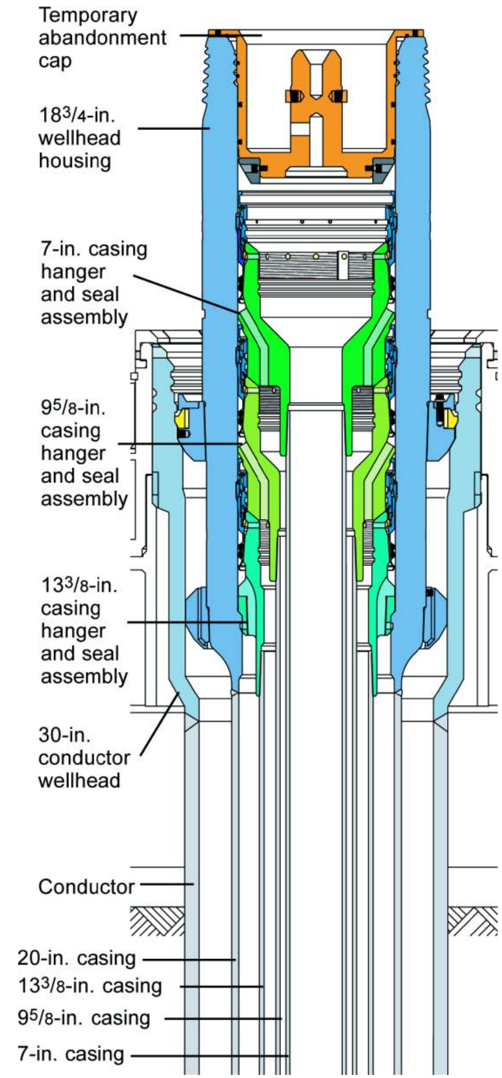
Third party review logistics (Package breakdown)

Design Verification will be performed at **System Level** rather than Component Level.



30-in. low-pressure wellhead housing

Source: petrowiki



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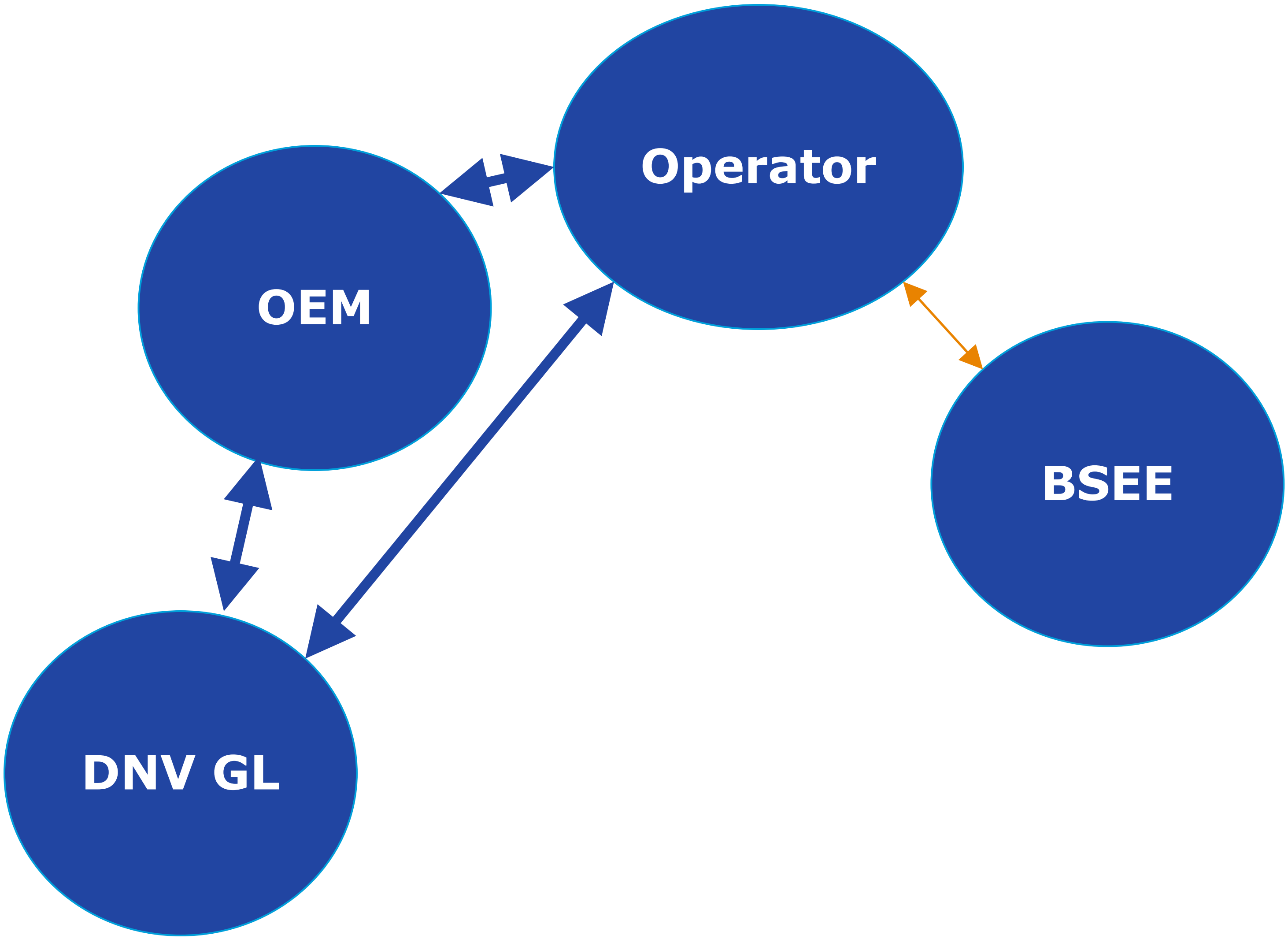
Third party review
Communication Structure



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