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Future Considerations for HPHT Equipment and Systems

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Abstract

With the growing number of subsea wells being completed at pressure up to 15,000 psi, consideration is now being given to developing the 'next generation' of subsea equipment with ratings to 20,000 psi.

This paper discusses a number of design considerations and challenges which need to be overcome in order to reach these goals, whilst maintaining a balance between personnel safety, product reliability and equipment size and weight, in order to achieve cost-effective designs.

Background

While the development work involved in achieving subsea HPHT equipment (rated for over 10,000 psi and 250^{o}F) has been significant, it has been piecemeal, project requirement driven, and highly proprietary in nature. Now offshore exploration efforts are turning to even deeper reservoir pockets and the industry recognizes a need for the next step (to 20,000 psi working pressure systems and likely over 350^{o}F). Several questions are being raised over how to define appropriate temperature ratings and introduce additional service life requirements, such as fatigue and cyclic loading. Every combination of design pressure, temperature rating and cycle life involves significant product development. Furthermore, HPHT narrows the number of available materials because of the extremely high partial pressures of H_2S and corrosive byproducts combined with the temperature de-rating of material strength for temperature (both metallic and non-metallic). Fracture mechanics and associated fatigue design analysis is a science being used to more rigorously design pressure containing equipment at ambient temperatures. However fracture mechanic theory is totally unknown at elevated temperatures. Therefore expanded understanding of material performance at higher temperatures is needed along with a wider search for new ferrous, non-ferrous and composite materials.

In preparation for this next move, several design requirements need discussion and agreement within the Industry before development work begins. Further, Industry wide agreement on Design Codes is also needed. Significant materials development and testing work is anticipated for high temperature sealing elements which work at both HPHT conditions and cold hyperbaric sea floor conditions when the equipment is dormant. In deepwater these higher HPHT requirements may also require the creation of a whole new wellhead, BOP, and marine riser system to meet both HPHT and current handling capacities of rigs and derricks.

This position paper outlines suggested design guidelines and areas of basic research that the Industry needs to address within standards committees and Industry sponsored research programs to establish and focus the direction for HPHT.

Design for Structural Integrity

There is a need for more thorough qualification test guidelines, especially for subsea equipment. Do we still maintain the conventional 1.5 x working pressure for 20,000 psi equipment or something less; depending on the accuracy of newly proposed design methods and qualification tests? Here, there needs to be a balance between personnel safety, and containment of equipment size and weight. The Industry may need to re-evaluate the trend mandating tests for every size/pressure/temperature combination, i.e. go back toward revised version of “API scaling” to bring equipment qualification down to reasonable cost and duration.

Division 2 vs. Division 3

The foundation for accepted design practice behind current API standards and recommended practices use classical thin and thick walled pressure vessel theory, governed by ASME’s Section 8, Division 2 Pressure Vessel Code. This pressure vessel theory, as adopted by API, assumes:

1. Linear-elastic stress analysis
2. The general primary membrane stress at test pressure should be less than 83 % of the vessel’s material yield strength
3. The primary failure mode to be elastic or plastic deformation resulting in “leakage before fracture”
4. Material creep at elevated temperatures is offset by derating the material yield strength (also used in API Specification 6A, Appendix G)
5. No consideration, nor requirement for fatigue analysis

General engineering practice has accepted 1.5 x working pressure as the accepted “safety factor” to assure that pressure containing and pressure controlling components will withstand working pressure requirements.

However, this conventional wisdom has come under scrutiny