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Real-Time Casing Annulus Pressure Monitoring in a Subsea HPHT Exploration Well

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Abstract

With the present trend towards the exploration and development of deepwater HPHT fields, the associated subsea wellhead completion dictates finding solutions to control excessive pressure build-up in casing annuli. This is inherently difficult without a wellhead penetration, which would breach a primary well barrier, contrary to the requirement of API Specification 17D and ISO 13628-4. Today, existing mitigations (crushable foam, gas cap, etc.) are “blind” options relying solely upon modelling assumptions, and do not provide satisfactory and long term pressure management solutions.

Total E&P Norge recently drilled an HPHT subsea exploration well on the Norwegian Continental Shelf (875 bar, 180 °C). Due to the HPHT conditions, casing and tubing designs were subject to rigorous stress analysis. During well production modelling (well testing), Annulus Pressure Build-up due to thermally induced annular fluid expansion became a concern; in the event of a closed 13-3/8” annulus, the 20” burst and the 13-3/8” collapse design limits could have been exceeded.

As a consequence, Total E&P Norge decided to run acoustic wireless pressure and temperature gauges in the B and C annuli to monitor annulus conditions in real time in order to keep within well design envelope during well tests. This was the world-first deployment of its kind and it proved to work effectively. Post analysis of pressure and temperature logs confirmed that thermally induced Annulus Pressure Build-up can be a concern in subsea HPHT wells, and that deeper understanding of modelling performed in fundamental well design software is required.

Introduction

In a subsea well, it is technically challenging to monitor casing annulus pressure and to manage excessive Annulus Pressure Build-up (APB) due to thermally induced annular fluid expansion during well production. Moreover, in today’s industry drive towards the exploration and development of deepwater HPHT fields, the subsea completion of such wells requires long term and reliable pressure management solutions in the casing annuli.

Unlike traditional dry wellheads, where casing pressures can be monitored and managed from tappings or flanges installed directly into the wellhead (see Figure 1), current industry standards forbid any such porting in subsea wellheads (see Figure 2). Subsea well design, as such, relies only upon modelling assumptions and the design of a casing architecture strong enough to sustain the worst case APB scenario predicted.

For HPHT wells, using traditional design factors, this philosophy can result in an extremely heavy and expensive casing architecture. This is due to the high production temperatures inducing increased levels of annular fluid expansion, and hence higher APB.

In 2007, Total E&P Norge AS (TEPN) drilled a subsea exploration well on the Norwegian Continental Shelf. The well was HPHT with reservoir conditions of 875 bar and 180 °C. Thus, the casing and tubing designs were subject to rigorous stress analysis using proprietary casing design software. During well production modelling (well testing), APB due to thermally induced annular fluid expansion became a concern in the event of a closed annulus. Should the 9-7/8” casing annulus (B annulus) and/or 13-3/8” casing annulus (C annulus) be closed, the design limits of the well architecture could have been exceeded.

As such, the primary mitigation was the selection of a well architecture with a top of cement deeper than the previous casing shoe to allow any pressure build up to leak off into the formation (see Figure 3).