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EXTENDED ABSTRACT

Mitigating Challenges in Drilling and Completion of HPHT Wells

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Abstract

Drilling and testing of HPHT wells are always a global challenge – both from the perspective of High Pressure and High Temperature conditions vis-à-vis availability of suitable tools/equipment and technology to overcome these challenges. From the experience gained through thorough analysis of various complications encountered in many drilled HPHT wells during drilling or testing which led to premature termination or abandonment or unsuccessful/inconclusive testing and from recent drilling of two HPHT wells in Bantumilli South Field of ONGC, specific hurdles for drilling and completion have been identified and analysed. Accordingly, for the next well, suitable and meticulous well plans were made and all the required resources mobilised, which could ultimately see a successfully drilled and tested HPHT well. This milestone achievement, which had eluded success in HPHT exploitation since long, has given confidence to undertake more such endeavours to enable a giant leap towards probing the huge reserve potential locked within HPHT and its monetisation through appropriate planning and suitable technology.

1. Introduction

HPHT well is classified as a well having an undisturbed bottom hole temperature of greater than 300°F (149°C) and a pore pressure of minimum 0.8 psi/ft (~15.3 lbm/gal) or requiring a BOP with a rating in excess of 10,000 psi (68.95 MPa). In the subsurface, High Pressure (HP) and High Temperature (HT) may coexist (i.e. HPHT) or occur individually (i.e. HP or HT). In either case, overcoming the HPHT/HP/HT situation is a major challenge for successful completion of wells.

HPHT fields occur globally and pressure and temperature vary widely. Distribution of global HPHT fields is depicted in **Fig 1**.

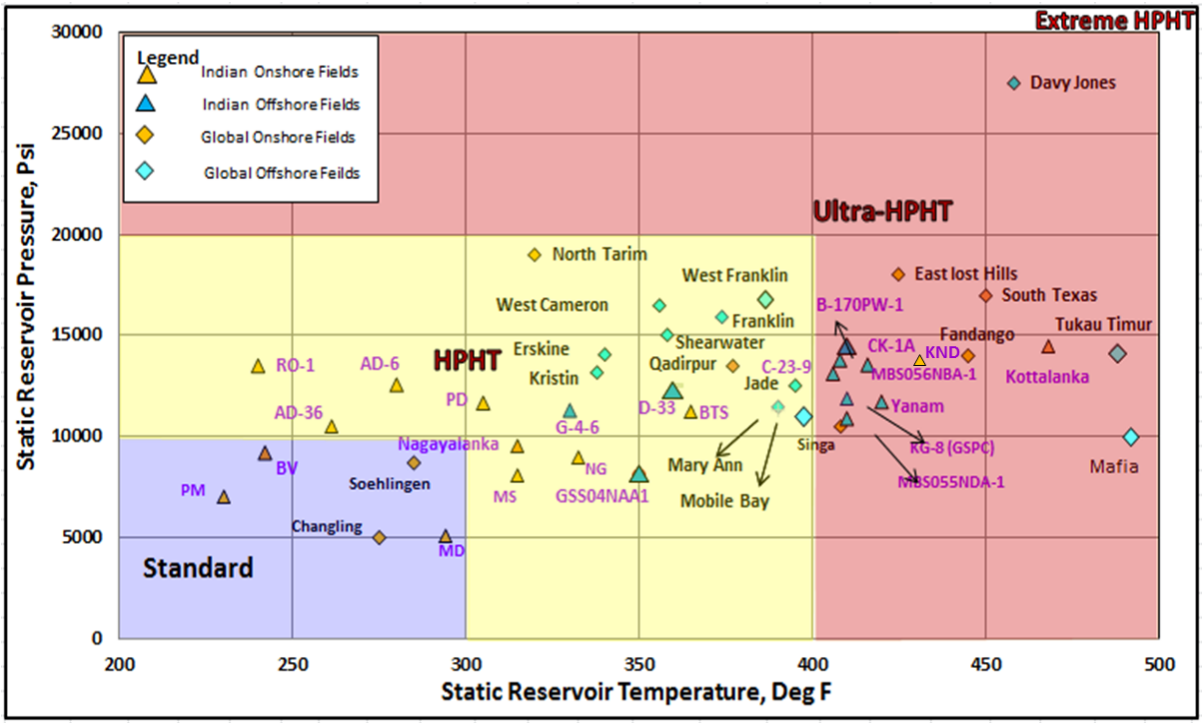

Fig 1: Global HPHT fields

In Indian basins, HPHT fields are mostly present in KG-PG basin (YS-5, YS-6, YS-7, YS-8, GS-71 and Deen Dayal in offshore and Bantumilli South in onland), Mumbai offfshore (D-33, B-41, C-23-9, GS-OSN-2004/1) and Cauvery Basin (Periyakudi). Many other fields such as Nagayalanka and Nandigama in KG basin have recorded temperatures above 300°F. In the Northeast, High pressure wells are known in Agartala Dome and Khubal fields.

Ultra HPHT condition (around 468°F and 14,000 psi BHP) is known to occur in Kottalanka field of KG onland.

The HPHT/HP/HT fields of ONGC are shown under **Fig. 2**.

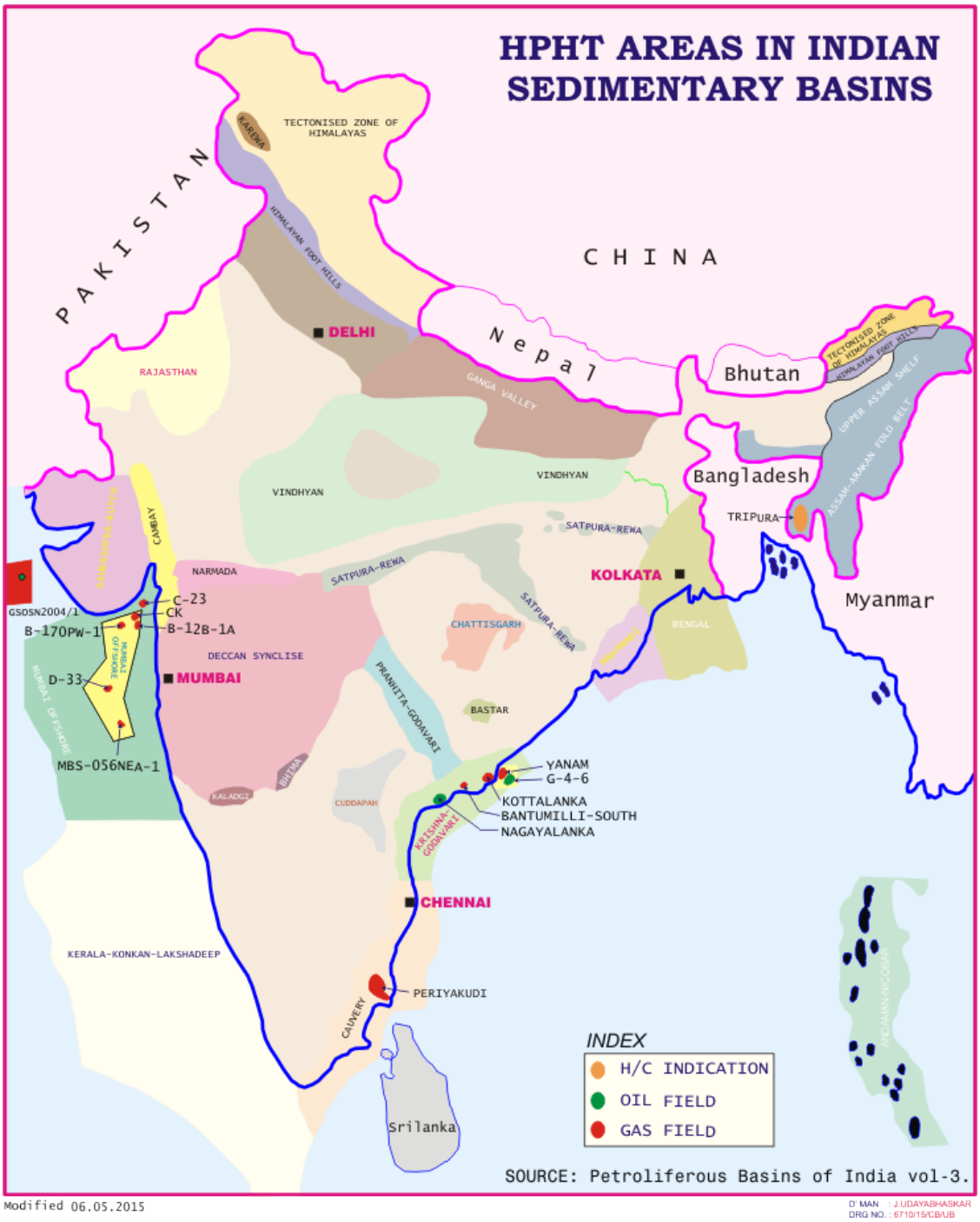

Fig 2: HPHT/HP/HT Fields of ONGC

2. Specific Focus Areas for Successful Drilling and Completion of HPHT Wells

In order to drill and complete a HPHT well successfully, following are the specific focus areas which are to be addressed effectively right from design stage of the well.

A. Well Planning

For successful planning of HPHT wells, accurate pore pressure and temperature predictions are very essential. During well planning, well test design and completion engineering should be considered as the basis in order that production objectives are achieved. Impact of cyclic loading resulting from both

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temperature and pressure cycles during production operations including probable stimulation operations is be taken into consideration. The size of production casing should depend on the anticipated production profile, well stimulation such as hydraulic fracturing etc. Detailed contingency planning is crucial for situations that require lead times for alternate equipment or services.

Selection of tubular should consider aspects like requirement of high yield-strength grade to handle excessive burst and collapse pressures, expandable liner hangers, premium metal-to-metal gas tight connections for tubular to avoid leak during production, Corrosion-resistant alloys (CRAs) to protect from wellbore fluids that can corrode, high-yield steel and tubing stresses due to thermal cycling.

B. Casing and Tubing Design

HPHT casing design software is essential for designing HPHT wells. This software critically examines drilling load cases as well as the production load case based on the predicted pore pressure, fracture pressure and temperature profiles. All casings are also modelled and in particular the production casing/liner for stress analysis.

The pressure and temperature profiles for the well are key inputs that impact the entire casing and tubing design. The temperature prediction will affect tubing loads, stresses and forces, hydrate predictions, equipment temperature specification like BOP, elastomers used in surface test equipment, Co-flexip hoses etc, annulus pressure management and control line fluid selection.

In addition to the temperatures, the tubing design should include a thorough assessment on tubing forces due to load cases like burst, collapse and axial.

Design Limit plot for 7”production liner for a typical HPHT well is shown in **Fig.2**.

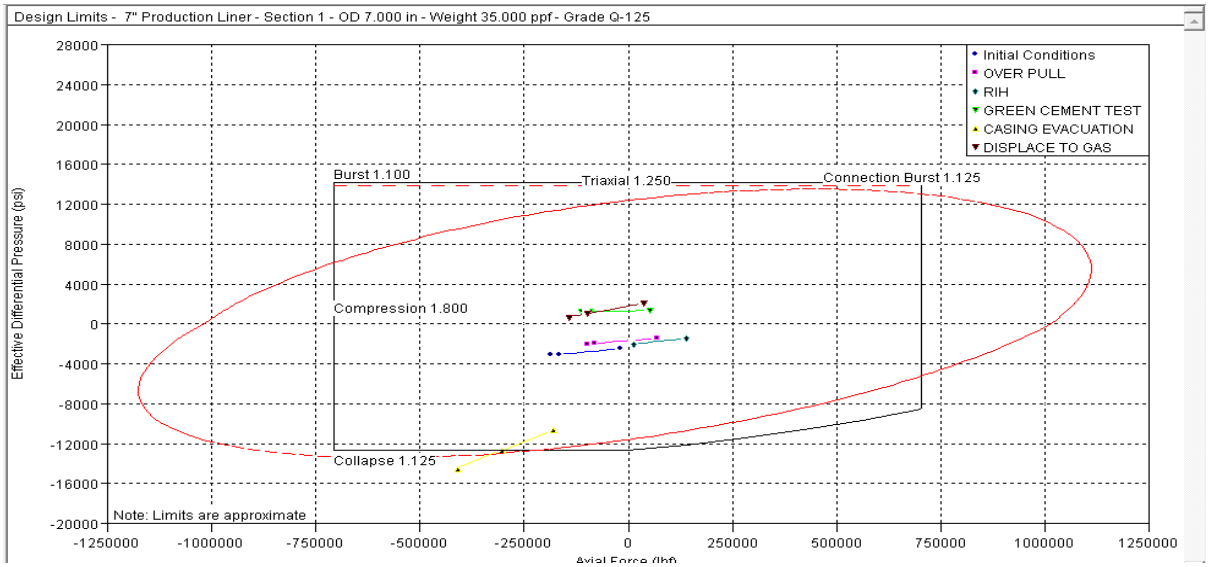

Fig.2: Design Limit plot for production liner of a typical HPHT well

Design Limit plot for 7”production tubing for a typical HPHT well is shown in **Fig.3**.

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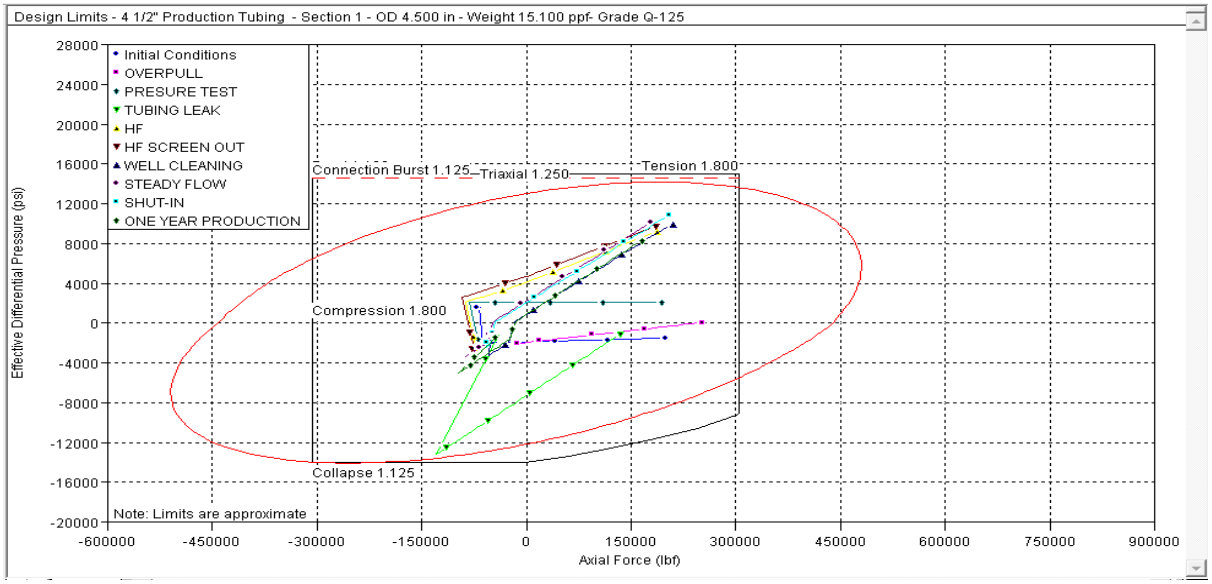

Fig.3: Design Limit plot for production tubing for a typical HPHT well

C. Drilling Fluid Selection

Water based PHPA-Polymer based drilling fluids can be used in top sections of the well. But a robust drilling fluid system is required in intermediate and final phases, to mitigate the well stability problems and achieve better rheology. In the final phase, due to high temperature (more than 300°F), it is difficult to control rheological properties of water based drilling fluid, leading to hole instability. Hence, Synthetic Oil Based drilling fluid (SOBM) is well suited for drilling deeper HPHT wells. SOBM is environmentally safe, can be weighted up for HP requirements, imparts better hole stability, very stable at High temperatures and gives good hole conditions for logging, casing etc.

D. Completion Fluid Selection for Testing

Clear completions are required as testing & completion fluids because they allow down hole valves and gauges to function properly. They efficiently transmit hydraulic force down the hole, leading to smooth operations of downhole equipment. Clear brine of Cesium Formate is well-suited as testing & completion fluid. Use of Alternate HPHT Completion Fluids based on micronized barytes and Micromax are also under active consideration.

E. Cementing

HPHT cementing operations are difficult as the temperature effects are the main considerations. Pumping rates during cementation job needs careful consideration as narrow margin between pore and fracture pressure may result in loss situation.

3. Case Histories

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Case Histories of the three drilled wells (Well#1, Well#2 & Well#3) in the Bantumilli South Field are mentioned hereunder to bring out the difficulties faced in the first two wells and its mitigation in the third after detailed planning of inputs, resource mobilisation and close monitoring during drilling and testing phase.

~~A.~~ HPHT Well #1

The well was released with a target Depth of 4500m and targeted to explore the Mesozoic synrift sequence.

a) Problems faced during Drilling:

i) Well activity at ~4200m, Pressure exceeded the LOT value (1.88 MWE) and burst pressure rating of 9 5/8" casing. Hence drilling was prematurely terminated at 4223 (Target Depth was 4500m)

b) Problems faced during Testing:

i) Multi-cycle DST valve failed in heavy water base mud (2.0 SG). Drilling Fluid was used as testing fluid;
ii) DST string got snapped;
iii) Detailed testing for Reservoir studies of Objects could not be carried out due to limitations in well head rating (10,000 psi instead of 15,000 psi);
iv) Non-availability of suitable HT packers

B. HPHT Well #2

The well was released with a target Depth of 4600m and targeted to explore the Mesozoic synrift sequence.

a) Problems faced during Drilling:

i) Short landing of $9^5/_8$" casing by 117m due to poor ROP and mud loss during cementation;
ii) Well could not be drilled to Target Depth (4600m) and terminated at 4373m due to loss & activity (absence of kick tolerance);
iii) Loss of hermeticity and difficulty in regaining hermeticity;
iv) Water based drilling fluid was used.

b) Resource constraints:

i) Non availability of Clear fluid, SOBM & 15K units;
ii) Non availability of HT packers

C. HPHT Well #3

Based on the analysis of the problems faced during drilling and completion of HPHT Well#1 and HPHT Well#2, the HPHT Well#3 was successfully drilled to target depth (4600m) and tested by adopting the following measures –

i) $9^5/_8$" casing depth was revised at 4100m so as to get a high LOT value to drill further to 4600m, covering high pressure sections;
ii) SOBM was used for drilling the 12¼" and 8½" phases. The drilling fluid was loaded to required weights and ensured well stability even in HPHT conditions;
iii) Wellhead and Testing equipment rated to 15K were used;
iv) 7" Expandable Liner hanger and premium gas tight connections for production casing were used;
v) Cesium Formate brine (2.02 SG) was used as testing fluid, leading to successful testing of multiple HPHT objects for first time;
vi) HT packers were used

The above measures have helped in successful drilling and testing of the HPHT Well #3. This well has proved to be a Gas Producer, leading to further plans to quickly monetize this HPHT field.

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4. Conclusion

Subsurface HPHT conditions are always challenging for successful drilling, completion and testing of a well. Proper understanding of field-specific HPHT challenges is a key factor towards adopting the right approach in HPHT venture. Accurate pore pressure prediction is vital for planning the casing seats and well/tubular designing through robust well engineering studies using state-of-art software. Planning should commence at the proposal stage itself as all the equipment should be of proper rating and are generally long lead items. Compromising on the specifications due time constraint can be suicidal. Following all the requisites meticulously, an HPHT well can be drilled, completed and tested successfully as explained in this paper.

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