Planning of High Pressure And High Temperature Well of Western Offshore

Authors:
Atanu Bhattacharjee,K.Krishna Pratap, Javed Ahmad,S.B.Uniyal
Institute of Drilling Technology, ONGC, Dehradun

Planning of HPHT Well

- Drilling of high pressure high temperature wells has always been a challenging job worldwide as these wells are high risk high cost .

- Success in drilling of these wells require special considerations, not only in well bore equipment and design, but also in project execution and a lot of precautions have to be taken while drilling these wells

HPHT well planning require very high emphasis on following factors, for better and more realistic planning

- Due consideration and Analysis of geo prognosticated data.
- Proper computation of anticipated load to be encountered.

(HPHT) well is defined as :

Undisturbed BHT at the prospective reservoir depth is greater than 300 deg F (149 deg C)and either the maximum anticipated pore pressure exceeds 0.8 psi/ft or pressure control equipment with a rated working pressure in excess of 10,000 psi is required

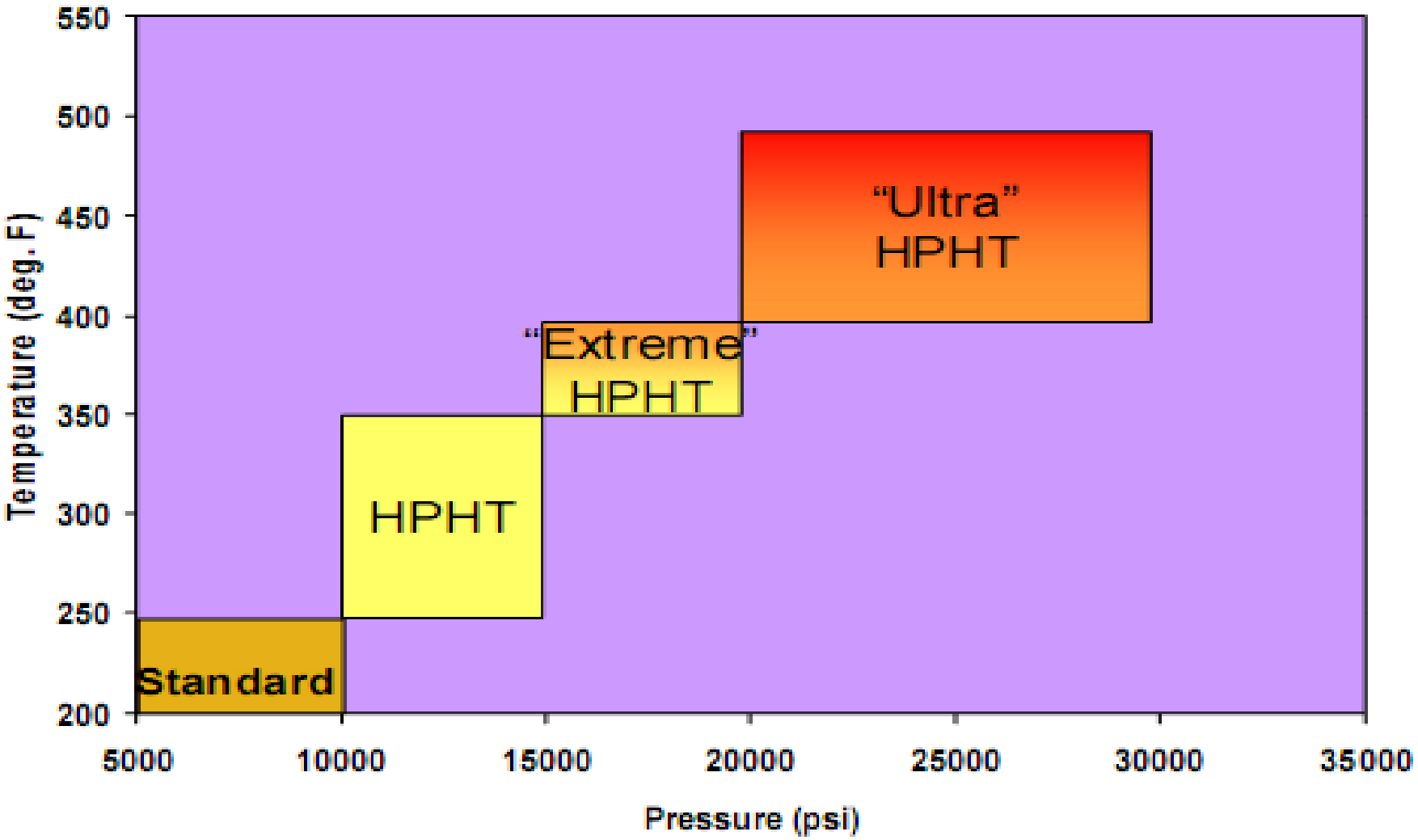
Two very important points to be considered before designing HPHT well:

1. The margin between the fracture gradient and pore pressure is usually small. The difference is critical in the design of the well.
2. HPHT wells usually have high ECD's (Effective Circulating Density) leading to lost circulation problems followed by a loss/ gain cycle that becomes difficult to control

HPHT Classifications

Standard service is considered as pressures up to 10,000psi and temperatures to 250^{0}F Thereafter a three tier approach to HPHT classifications exists

Tier 1: HPHT
Pressure 10K to 15K
Temperature up to 350 ^{0}F
Tier 2: Extreme HPHT
Pressure over 15K to 20K
Temperature over 350^0 F to 400^{0}F
Tier 3: Ultra HPHT
Pressure over 20K,
Temperature over 400^{0}F



Source: OTC 17927, "Ultradeep HP/HT Completions: Classification, Design Methodologies, and Technical Challenges"

Areas to be emphasized for Planning of HPHT Well

- Casing Seat Selection
- Casing Design
- Hydraulics
- Selection of Wellhead
- Mud Policy
- Cementation Policy

Planning Of HPHT Well Of Western offshore Basin

- **Well under consideration belongs to Western offshore of India in which anticipated pore pressure is 12250 psi at TD (4400m) and temperature around 372^0 F (189^0 C) .**

- **Objective of the well is to explore the hydrocarbon potential of Daman, Mahuva and Panna formation..**

The well design is limited to

- **Casing Seat Selection**
- **Casing Design**
- **Hydraulics**
- **Selection of Wellhead**
- **Drilling fluid**
- **Cementation aspect**

The salient features considered for designing the HPHT well

- Analysis of geo prognosticated data and study of offset wells data for any complications which are taken into consideration for well planning.

- Formulation of technical designs keeping in view the offset well histories and geological information.

Outcome resulted into:

- **Selection of casing seat as per prognosticated formation pressure and tentative LOT values of offset wells**
- **Designing of casing based on effect of high bottom hole temperatures and pressures.**
- **Optimum Hydraulics based on Mud rheology and proper hole cleaning.**
- **Selection of proper wellhead to suit the HPHT conditions.**
- **Mud policy compatible and stable for HPHT.**
- **Selection of logging tools for high temperature application.**
- **Cementing policy with respect to high temperature.**

Geological Input Data

Expected Formation Pressure regime

Depth	Pore Pressure	Mud weight (MWE)
Sea bed-1770	Hydrostatic	8.6
1770-2720	Hyd + 20-30%	8.6-11.18
2720-3380	Hyd + 30-70%	11.18-14.62
3380-4400	Hyd + 70-90%	14.62-16.34

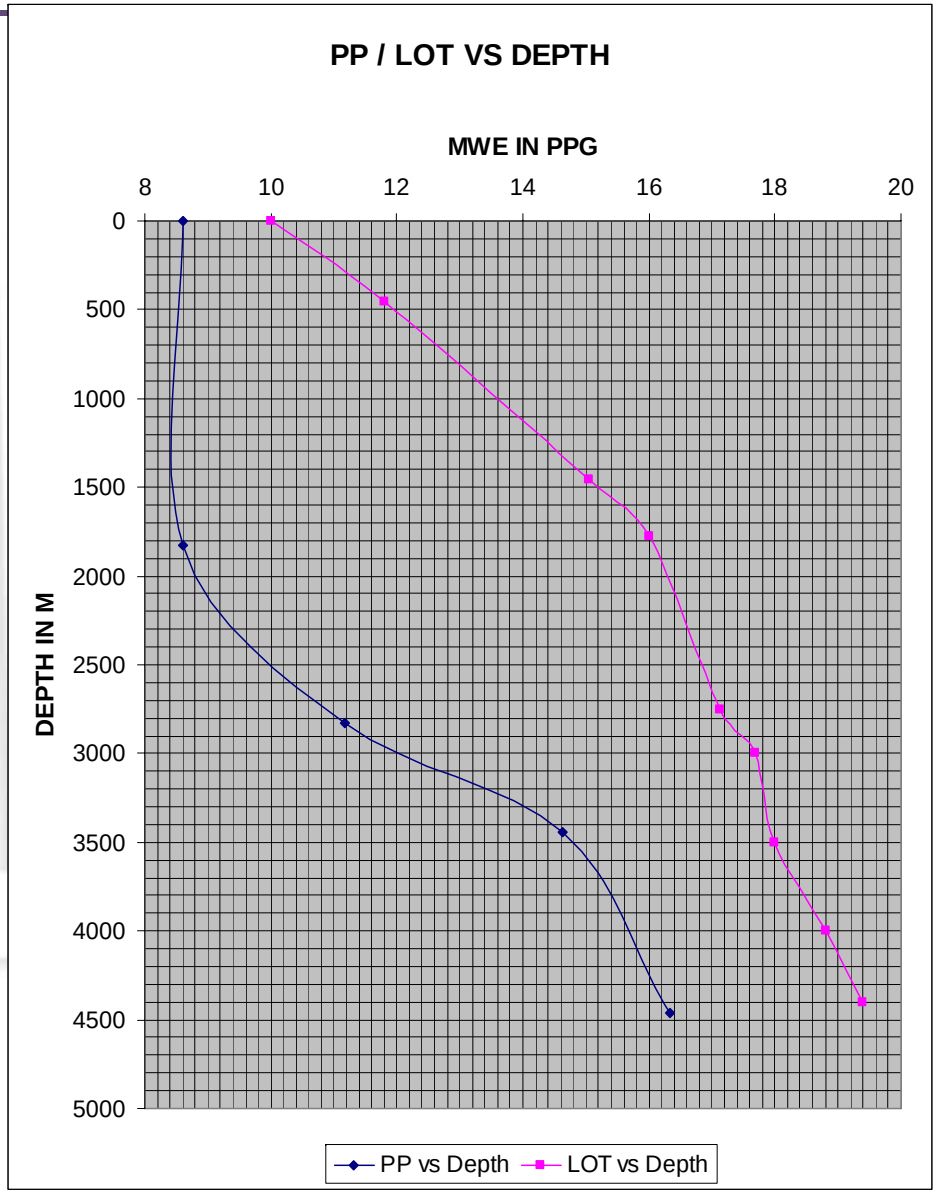
Expected Oil/Gas Shows

Formation	*Depth (m)*
Daman	2430-2770
Mahuva, Diu and Belapur	2770 – 3380
Panna	3380 - 4400

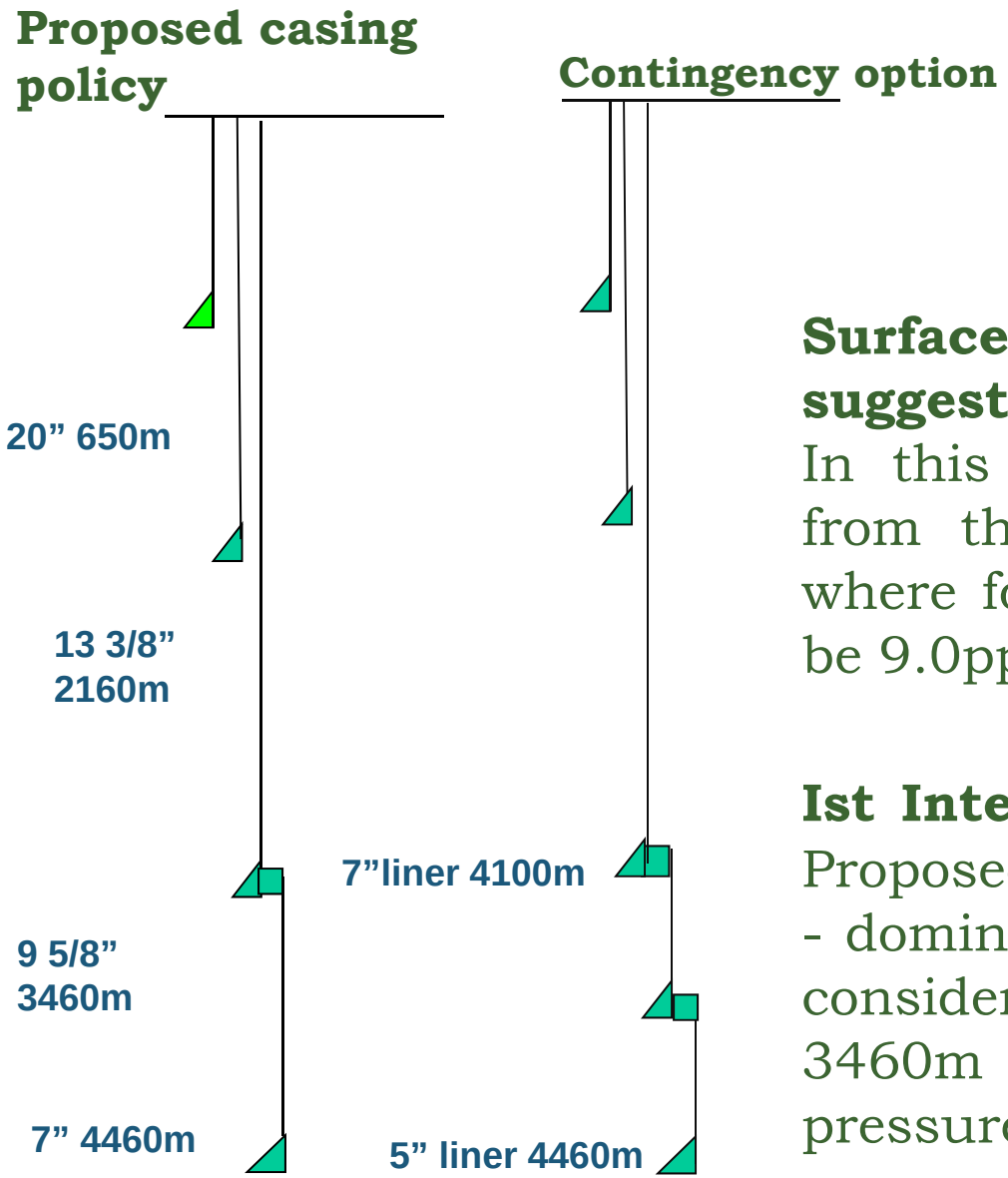
Expected Bottom Hole Temperature

Depth in m	*Temperature in (^0C)*
1500	85
2600	123
3100	140
4000	174
4400	189

Formation	Depth (m)	Lithology
Chinchini	Seabed – 1425	Clay, claystone
Bandra & Tapti	1425 – 1770	Predominantly shale with some limestone
Mahim & Bombay	1770 – 2430	Dominantly shale with few Limestone bands
Daman	2430 – 2770	Predominantly shale with sandstone Siltstone and limestone
Mahuva, Diu and Belapur	2770 - 3380	Shale and Limestone
Panna	3380 – 4400	Shale, sandstone, siltstone with minor Limestone



Selection of Casing Seats



Surface Casing 20”(650m) : - shoe suggested at 650 M.

In this case, 0.5ppg kick considered from the next casing shoe - 2160m where formation pressure expected to be 9.0ppg MWE .

Ist Intermediate Csg 13 ⅜”(2160m) - Proposed at 2160m in Mahim formation - dominantly shale. A kick 0.5ppg MWE considered from the next casing shoe - 3460m where expected formation pressure is 14.8ppg MWE.

2nd Intermediate Casing 9- 5/8”(3460m) : Suggested at 3460m in Panna formation (shale sand stone, Sst ,minor lime stone). A kick of 0.5ppg MWE is considered from the next casing shoe - 4460m. Expected formation pressure is 16.34ppg MWE.

7” liner (3360-4460m): Suggested with shoe at 4460m which is permitted by LOT value below tentative 9-5/8” shoe at 3460m. The expected formation pressure at 4460m is 16.34ppg MWE

Contingency Plan

If 7”liner is to be lowered to around 4100m due to any downhole complication in 81/2” section then the expected LOT value below 4100m will be at least 18.9ppg which will permit the well to be drilled to T.D 4460m and subsequently completed with 5” liner.

Contingency option	
7” liner interval	**3360m -- 4100m**
5” liner interval	**4000m -- 4460m**

Note: Considering hull + air gap - 30 m
Water depth - 30 m . all depths are from RKB

Consideration of Effect of Temperature in Casing Design

- One of the major risks occur in high temperature wells where the intermediate casing or upper production casing is set above the transition zone containing the high temperature.
- During production, these casings are heated up as a result of the hot produced fluids and their properties may alter as a result of the high temperatures.
- Burst strength is directly proportional to yield strength and a reduction in the later causes a reduction in burst strength as given by:

Burst strength (B) = 0.875 x 2 x yield strength(psi) x wall thickness(in)/ OD(in)

Note:

The deration due to temperature reduces the Minimum Yield Strength by 0.03 percent per degree Fahrenheit above the assumed temperature for which the nominal value is stated (68° F) ambient temperature.

The Following Table Shows The Effects Of Temperature On The Yield Strength Of Casing.

Grade	Yield Strength(PSI)	Ambient Temperature		
		212 ^{0}F (100 °C)	392^0 F (200 °C)	482^0 F (250 °C)
L-80	80000	76500	72000	69000
C-90	90000	86000	81000	78000
C-95	95000	90880	85500	82000

Proposed Casing Design

String	OD/Weight /Grade	Conn.	MD Interval (m)	Drift Dia. (in)
Surface Casing	20", 106.5 ppf ,J-55	Quick connection type	0-350	18.813
	20", 133 ppf , J-55	Quick connection type	350-650	18.543
Intermediate Casing	13- 3/8", 68 ppf, P-110	BTC	0-2160	12.259
Intermediate Casing	9 -5/8", 53.5ppf, Q-125	Premium	0-3460	8.50**
Production liner	7", 32 ppf, P-110	Premium	3360-3800	6.0
	7", 32 ppf, Q-125	Premium	3800-4460	6.0

- ** to be specially drifted to 8.5”

Contingency option in 8 ½” phase

String	OD/Weight /Grade	Conn.	MD Interval (m)	Drift Dia. (in)
Surface Casing	20", 106.5 ppf ,J-55	Quick connection type	0-350	18.813
	20", 133 ppf ,J-55	Quick connection type	350-650	18.543
Intermediate Casing	13- 3/8", 68 ppf, P-110	BTC	0-2160	12.259
Intermediate Casing	9 -5/8", 53.5ppf, Q-125	Premium	0-3460	8.50**
Production liner	7", 32 ppf, P-110	Premium	3360-3800	6.0
	7", 32 ppf, Q-125	Premium	3800-4100	6.0
Production liner	5", 18 ppf, P-110	XL	4000-4460	4.151

** to be specially drifted to specified size

In case of 7” liner completion 9 -5/8” casing connection must be premium

Selection Of Well Head For HPHT Applications

API Defines High Pressure / High Temperature as

–Any Application where pressure exceeds 10,000 psi

–Any Application where the temperature exceeds 350 ^{0} F (177 ^{0} C)

Extreme High Pressure / High Temperature is

–Any Application where pressure exceeds 15,000 psi

–Any Application where the temperature exceeds 400 ^{0} F (205 ^{0} C)

Selection Of Well Head For HPHT Applications

. On HPHT well heads

"U" class well heads are capable of handling surface temperatures ratings only up to 250 ° F. Beyond that up to 350 ° F and shut in pressure of 11000 – 12000 PSI "X" rated Well Head is recommended by API. Material strengths have been de-rated due to high temperature application by about 80%

Selection of Well Head

Considering the pressure & temperature data given; only in last two well head sections (i.e. C & D section) need to be of "X" class specification and remaining A & B wellhead sections can be "U" class

Drilling fluid policy for the HPHT.

Sl no	Depth Interval (Mts.)	SpGr	API Funnel Vis. (Sec)	API Fluid Loss (ml.)	pH	PV cps	YP Lbs/100 ft2	Gel_0 Lbs/100 ft2	Mud System
1.	0-650	1.05-1.10	45-60	N/C	9-9.5	-	-	-	Fresh-Water Bentonite-Gel System
2.	650-2160	1.10-1.25	45-55	14.0 - 8.0	9-9.5	10-15	20-25	4-5	KCl-PHPA-XCP-Polyol mud system
3.	2160-3460	1.25-1.83	40-50	6.0-5.0	9.5-10	15-25	15-20	4-5	KCl-K-Lignite mud system
4.	3460-4460	1.83-2.05	55-60	5.0 – 4.0	9-9.5	25-35	18-25	5-8	Synthetic Polymer mud system

Cementing Policy

Casing size	Shoe Depth(m)	Cement rise (m)	Cement column (m)	Slurry wt. inMWE (sg)
20”	650	Surface	650	
13 3/8”	2160	1660	500	1.90
9 5/8”	3460	2960	500	2.00
7” liner	4400	3360	1100	2.2
7”liner(contingency)	4100	3360	740	2.2
5” liner (contingency)	4400	4000	400	2.2

Conclusion & Recommendation

- Casing seats are selected tentatively on the basis of provided geological data. For the well, 4 Casing Policy is suggested, however a contingency provision is proposed for drilling 8 ½" phase, where high pressure and temperature are anticipated.

- High temperature suite of wire line logging tools capable of taking logs upto temperature 375^0 F are needed.

- LWD is suggested to be used during drilling for formation evaluation and knowledge on well bore geometry etc.

- PWD can be added to know ECD, Pore Pressure, Swab & Surge.

- Due care should be taken for mud loss specially in the depth range 2720-3380m
- BOP, Choke and kill manifold of 15M rating to be used for drilling 8 ½" hole.
- Mud Coolers are recommended to be used to reduce the flow line temperature as well as BHCT.
- The Rig should have advanced and sophisticated equipments like Top Drive, LMSS, Mud Cleaner etc.
- Considering the well data given, only the C & D sections of well head (for strings 9-5/8" & 7") need to be "X" class specification and remaining A & B sections can be "U" class

- As the well is supposed to be completed with 7” liner , in view of HPHT nature of the well 9 ⅝” casing connection is proposed to be premium (gas tight), which is required as in case of 7” liner, 9⅝” casing will be acting as production casing.

- It is suggested to use 7” / 5” (if contingency plan is followed) liner hanger with pack off provision so as to obtain better annular sealing.

- There is a considerable temperature difference between the liner hanger top (BHST 140 ^{0} C approx) and the liner shoe (expected BHST 189 ^{0} C @ 4400m). Hence Selection & doses of additives will be a challenge to get desired parameters for good cementation both at the bottom and upper section of the liner.

•Sensitivity test, Stability test and simulation of cement job should always be performed before cementing in a high temperature well.

•ECD calculations on the basis of actual Mud weight and rheology must be done to determine the best possible displacement rate which keeps the ECD below Fracture Pressure / LOT value.

•For minimizing gas migration, Gas tight cement slurry or right angle set cement slurry is recommended

Thank you