1st Under Balance Drilling Project in India

ONGC-Mumbai Region

31st March 2016
UBD Project Overview

- UBD Drivers
- Project Details
- Project Engineering
- Project Execution and Lesson Learnt

Injected Fluid/Gas
Produced Fluid

World’s Number 3 Exploration & Production Company: Platts
General Comparison of drilling methods

- Pore Pressure
- MPD
- Conventional Drilling
- Collapse Pressure
- UBD
- Frac Pressure

Depth vs Pressure graph
Definition of Under Balance Drilling

**UBD is:**

“When hydrostatic head of drilling fluid is **Intentionally** designed to be lower than the pressure in the formation being drilled, the operation is being considered as Under Balance Drilling. Hydrostatic Pr. may be naturally less than formation Pr or it can be induced.”

Result: natural or induced flow of formation fluids into the wellbore.
Primary Drivers for UBD Technology

To improve the effective penetration rate NPT has to be reduced.

ONGC being a major national oil company has taken many steps of reducing losses from its matured field in drain hole.

- System LCM & NDDF for minimizing reservoir damage.
- LCM form various vendors.
- Using of low specific gravity material.
  - Hollow gas sphere
  - Micro bubble technology.

Mud Loss Impact over Total NPT quite considerable
Primary Drivers for UBD Technology

- Solution to Mud Loss Prevention.
- Drilling without damaging formation
- Immediate production benefits
- Enhanced Productivity
- Cost save on Mud, Logging, Well Bore Cleanup and Stimulation
- Superior **real time** Reservoir management.
Objectives for UBD Technology

Drilling Objective
- Safely Drilling in UBD conditions with MPD
- Drill DH without effecting environment
- Drill DH without Formation Damage & Mud loss
- Evaluate the suitability and economic feasibility of UBDT
- Assessment of reservoir while drilling.

Reservoir Objective
- Evaluate long term potential through reservoir characterization.
- Obtain reservoir flow data from flow test
- Based on field trial results define the steps for increasing recovery factor of filed by UBDT.
Project Details
Initially Based on Cost Benefit Analysis 3 Wells of Neelam and 3 wells of MH asset was identified.

Identified Wells:
- 3 Wells of HK #2H, #6H, #9H
- 3 wells of N-22#8H, #4H, #2H

• Rig Identification
  – Victory Driller
Project Details

- M/s Blade was hired for Technical assistance, Hiring of UBD service provider, Engineering & Execution, prepared the Basis of Design (BOD) for both the field.
- Based on BOD, Technical scope prepared and contract in place for UBD service provider.
- UBD Service provider M/s Halliburton was hired, Prepared Front End Engineering Design (FEED) study of 3 wells each of N&H and MH asset for UBD implementation.

Based on BOD and available services with ONGC, Concentric Casing Gas Injection model is acceptable.
Project Details

To Drill 6 Nos. Of 6” Drain-holes With Application Of UBD Technology

• Fields/Wells: Heera HK Platform - 3 Wells,
  : Mumbai High N-22 Platform - 3 Wells
• Target Layers:
  – H3B Layer (Bassein Limestone)
  – L-III Reservoir (A1 Layer)
• Basis Of Design: Technical Feasibility & FEED
  – Well/Platform Selection, Rig Selection And Rig Survey
• Detailed Engineering of Equipment, Requisite Chemicals
• Manpower Planning
• Base Oil As Primary Drilling Fluid (Through Drill String)
• Concentric Casing Gas Injection (N2) Method - 7” Tieback To Surface
Project Stake Holders and Responsibility

- Stake holders
  - Project Owner – M/s ONGC LTD.
    - Project Scheduling and Monitoring
    - Rig Selection
    - Rig Modification and Its Scheduling
    - Project Coordination
    - Material Input
    - Safety Regulatory Body Clearance
    - Placement of Selected Company-man
Project Stake Holders and Responsibility

• Stake holders
  – Project Owner – M/s ONGC LTD.
    • Detailed Safety Audit
    • UBD specific Training of Rig and ONGC Supervisors
    • Supply of Base oil.
    • Logistic Support
    • Real time well placement with reservoir assessment
    • UBD specific Lower and Upper completions
  – Technical Advisor - M/s Blade Energy
  – Service Provider – M/s Halliburton
Project Details

Project Activities

<table>
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<tr>
<th>Project Scoping (FEED)</th>
<th>Detailed Design</th>
<th>Implementation</th>
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<tr>
<td>Candidate Selection</td>
<td>Project Approval</td>
<td>Tools Mobilized</td>
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<td>Rig Mods &amp; Fabrication</td>
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<tr>
<td>Detailed Design</td>
<td>HAZID, HAZOP</td>
<td>OISD Approval</td>
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<td>Obtain March 2016</td>
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<td>HAZOP Closeout</td>
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<td>UBD</td>
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<td>Produce</td>
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<td>Evaluate Results</td>
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</table>

- **Phase-1**: 3 HK Wells is Completed in June 2016
- **Phase-2**: 3 N-22 Wells is Completed in Dec 2016

- **FEED**: Completed in April 2015
  - Rig VD 1st – Mar’2016
  - 2nd – Oct 2016
- **HAZID, HAZOP and DWOP**: Feb/Sept 2016
- **Trg. of Super Comp.**: March 2016
Project Engineering
Underbalanced Conditions

- **Degree of underbalance**
  - Maintain plan BHCP conditions within UBD operating window.
  - Goals to achieve stable BHCP throughout the UBD

- **Allows for better BHCP and influx control**

- **Hole cleaning**
  - Ensure adequate liquid velocity

- **BHA performance**
  - Bit cooling,
  - BHA elastomer compatibility,
  - Data transmission,
  - Directional tool
Multiphase system

- Fluid made up of gas and liquid
- Pressure Terminology
- Flow Terminology
- Multiphase Hydraulics
- Fluid properties vary with pressure and temperature
  - Gas/Liquid Ratio
  - Density
  - Viscosity
  - Surface pressure
  - Frictional pressure drop
## Application Techniques

<table>
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<tr>
<th>Well Geometry</th>
<th>Fluid Design</th>
<th>Environmental</th>
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<tbody>
<tr>
<td><strong>Conveyance Method</strong></td>
<td><strong>Injection Method</strong></td>
<td><strong>Liquid-Gas Ratio</strong></td>
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<tr>
<td>Jointed Pipe &amp; Rig</td>
<td>Drill pipe Injection</td>
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<tr>
<td>Jointed Pipe &amp; HWU</td>
<td>Parasite String</td>
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<tr>
<td>Coiled Tubing</td>
<td>Concentric Drilling pipe</td>
<td>Foam</td>
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<tr>
<td></td>
<td>Concentric Casing</td>
<td>Single Phase</td>
</tr>
</tbody>
</table>

Reservoir Pressure in HK wells of 1250 psi or EMW 4.8
Project Engineering

Wells Profiles are Engineered
- Hydraulics
- Torque and Drag
Well Engineering

- BHP = \( P_{\text{hydro}} + P_{\text{fric}} + P_{\text{surface}} \)

Frictional Plays important role in deciding the DH length

Graph showing the relationship between pressure (psi) and gas rate (MMscf/day) with different flow regimes: hydrostatically dominated, friction dominated, increased formation flow, and reduced gas injection.
Well Engineering

Well Control

- Conventional well
  - Primary Barrier – Hydrostatic Head of Liquid
  - Secondary Barrier – BOP and Rig Choke.

- UBD wells
  - Primary Barrier – RCD (Rotating Circulating Device) Surface Back Pressure and Reduced Hydrostatic Column
  - Secondary Barrier – BOP and Rig Choke.

- Barriers are interdependent.
- Require pressure containment at surface.
- Share common wellbore elements below the BOP.
- Use of minimum three Floats
Well Engineering

Well Control

Detecting Kicks in UBD Operations

- Fundamentally Different From Conventional
- Primary Indicator - Increased Flow Rate

• Higher Permeability
• Higher Flow Rate

• Higher Res. Pressure
• Larger Drawdown
• Higher Flow Rate

• Poor Choke Control
• Lower BHP
• Larger Drawdown
• Higher Flow Rate

• Secondary Indicators
  - Increased Choke Pressure (with no choke setting change)
  - Higher ROP
  - Change in BHP (with no change in surface controls)

Killing of well by stop pumping UBD agent and well will be balance
Rig Selection and Modifications

• Rig Victory Driller Selected & Placed.

• Rig Modification
  – Technical Requirements
    • IADC well Classifications
    • Deluge and boundary cooling system
    • Reclassification of Hazardous zoning plan
    • Well control equipment interfacing with API UBD guidelines.
    • Electrical system interface.
Rig Selection and Modifications

– Technical Requirements
  • As per OISD Guidelines Specialist resources / document modification and preparation / UBD specific SIMOPS Matrix / UBO Training.
  • Visual inspection of DOGPL Equipment in conjunction with Halliburton

– Change in Scope – I/s P & C

– Rig Specific interface

– Induction of rig crew UBD Specific Training at all Level 1,2 and online Level 3 training before commencement
Well Engineering

- Detailed Drilling and Completion Programme with DWOP prepared.
- P & ID, VND and PFD prepared and approved
- Detailed layouts s prepared and consent with underwriters.
- Each UBD equipment's are Pressure tested and certified prior to mobilisation.
- Hazardous area are revised and approved.
- ERP and Risk matrix revised.
- Actions on HAZID and HAZOP Observation almost completed.
- Sign-off tri party bridging document
- Completed UBO course for supervisors.
- Rig crew trained at two level, and third online training at rig...
<table>
<thead>
<tr>
<th>UBD OPERATIONS</th>
<th>UBD SIMPOS Matrix</th>
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<td>Rig-up (Off line)</td>
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<td>RIH with Concentric Casing</td>
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<td>Critical Path Rig Up</td>
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<td>Pressure Test &amp; Commissioning</td>
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<tr>
<td>Displace Well to UBD Fluid</td>
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<tr>
<td>UBD Level 3 Training</td>
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<tr>
<td>UBD Drilling / Connection</td>
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<td>Tripping</td>
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<td>BOP Stack Testing</td>
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<td>Export to Production Platform</td>
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<td>Gas Flaring</td>
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<td>RCD Change Out</td>
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<td>Shut-in on UBD Surface Equipment</td>
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<td>UBD Well Control</td>
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<tr>
<td>MAINTENANCE AND REPAIRS</td>
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<td>Hot work (PTW)</td>
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<td>Working at height</td>
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<td>Confine Space Entry</td>
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<td>NON AVAILABILITY OF SAFETY SYSTEM</td>
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<tr>
<td>UBD Banners (RCD/Annular/Ram)</td>
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<td>Basic Fire Fighting</td>
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<td>UBD ESD System</td>
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<td>Kill Fluid (base oil)</td>
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<td>Radio Communications</td>
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<td>DAS System</td>
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<td>LIFTING OPERATIONS</td>
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<tr>
<td>Lifting / hoisting over pressurized equip.</td>
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<td>General Crane Operation</td>
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<td>TRANSPORTATION</td>
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<td>Helicopter Operations</td>
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| Y | if applicable: Allowed subject to individual activity permit restrictions and provided access to, and egress from, either operation is not affected by the other |
| R | Restricted: Risk Assessment is required prior to activities commencing, taking into account prevailing conditions. |
| N | Not Permitted |
| - | Not Applicable: Where no interaction can occur |
Well Engineering

Project prepared in compliance OISD RP 74 and API 92U for UBD operations
OISD has given consent to operate on 16th March 2016
UBD Equipment
• **Equipment:**
  - Rotating Control Device
  - Choke System
  - Sample Catchers
  - 4 Phase Separator
  - UBD Tank Farm
  - Surface Safety System
  - Chemical Injection Pumps
  - Pre-charge Pumps
  - Transfer Pumps
  - Piping 1 & 2
  - Snubbing Unit (3rd Party)

- Data Acquisition System
- Communication System
- UBD Control Cabin
- N2 Membrane System
- Float Valves
- LEL & H2S portable sensors
- Corrosion Management
- Echo meter
- Decanting Centrifuge (Callout)
- Fluid Loss Valve (sale item)
- Cuttings Disposal (3rd Party)
- Chemicals
Rotating Control Device

UBD Choke System
Injection and Bleed-off Manifold
Tank Farm and Separation System
$N_2$ Generation Unit
Project Execution
Well Profile of HK#2H

- Drain hole length  =  192 m
- Av. Oil Rate  =  652 BoPD
- Total Produced Gas  =  2.3 MMscf

Cased Hole:
- 20" Casing 392m Ang 9.5
- 13 3/8" Casing 910m Ang 53
- N2 Inj 1868m Ang 53
- 7" Casing 2342m Ang 85
- TD 2534m Ang 88.2

Drain Hole:
- Drain hole length  =  192 m
Bottom Hole Circulating Pressure

Drilled with Base Oil
Av ECD of 4.6

Drilled with Crude
Av ECD 4.1

Flowing the well lowers the ECD / increases drillability
Well Profile of HK#9H

Drain hole length – 238 m
Av. Oil Rate – 1683 BoPD
Total Produced Gas – 2.3 MMscf
Drilled with Base Oil
Av ECD of 4.4

Drilled with Crude
Av ECD 3.8
Well Profile of HK#6H

- **Drain hole length**: 171 m
- **Av. Oil Rate**: 1605 BoPD
- **Total Oil Exported**: 3804 bbls
ECD Well HK#6H

Drilled with Base Oil
Av ECD of 4.1

Drilled with Crude
Av ECD 3.8
Lesson Learned in First Phase – HK Wells

M/s Halliburton

• RCD bore – 11” RCD should be made available
• Fluid volume measuring and tracking system.
• Export line pressure display in DAS lab. Display and integration of Halliburton and Baker data
• Proper size of Export line to avoid excessive friction pressure
• Loss of suction in pumps and discharge measurement.
• Provision of bypass on pre-charge pump /export pump for online cleaning of strainers
• Modification of stripping stack.
Lesson Learned in First Phase – HK Wells

M/s Halliburton Contd.
- Installing a CCTV camera in the BOP area.
- Different type of NRV in BHA.
- Use of Hydraulic / Pneumatic wrench

M/s DOGPL (Rig)
- 500 tonne long bails.
- Longer 3 ½” IF circulating sub.
- Pneumatic Torque wrench
Lesson Learned in First Phase – HK Wells

M/s Baker Hughes

- Modification of tools to avoid repeated tool failures.
- Display and integration of Halliburton and Baker data.

ONGC

- Simplified BHA.
- Displacements with a spacer while changing over of fluid.
- Marine and air Logistics support.
- Birds View on Water cut by BS & W readings
- Reservior assessment while drilling
- Restict of DH length
# Platform HK Plan vs Actual

<table>
<thead>
<tr>
<th>Activity</th>
<th>HK # 2H Plan</th>
<th>HK # 2H Actual</th>
<th>HK # 9H Plan</th>
<th>HK # 9H Actual</th>
<th>HK # 6H Plan</th>
<th>HK # 6H Actual</th>
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</thead>
<tbody>
<tr>
<td>UBD Days</td>
<td>42</td>
<td>39.6</td>
<td>25</td>
<td>21.7</td>
<td>26</td>
<td>22.9</td>
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<tr>
<td><strong>Activity wise break-up</strong></td>
<td></td>
<td></td>
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<tr>
<td>Total Rig up days</td>
<td>17</td>
<td>34.8</td>
<td>8</td>
<td>5.5</td>
<td>7.5</td>
<td>3.9</td>
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<tr>
<td>Trans &amp; Offline R/Up</td>
<td></td>
<td>16.5</td>
<td></td>
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<tr>
<td>Online rig up</td>
<td>17</td>
<td>18.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UBD Drilling Days</td>
<td>4.5</td>
<td>12.1</td>
<td>5</td>
<td>8.6</td>
<td>5</td>
<td>10.7</td>
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<tr>
<td>Lower Completion</td>
<td>2.0</td>
<td>2.2</td>
<td>2.0</td>
<td>1.8</td>
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<td>1.9</td>
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<tr>
<td>Rig Down</td>
<td>3.5</td>
<td>3.0</td>
<td>3.0</td>
<td>2.2</td>
<td>3.5</td>
<td>2.6</td>
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<tr>
<td>Upper Completion</td>
<td>8</td>
<td>4.1</td>
<td>7</td>
<td>3.8</td>
<td>8</td>
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<tr>
<td>Final Rig down Days</td>
<td>7</td>
<td>0</td>
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</tbody>
</table>
Well Profile of N-22#4H

Drain hole length  –  251 m
Av. Oil Rate      –  135 BoPD
Gas               –  795 SCFM

20" Casing 324m Ang 14
13 3/8" Casing 1200m Ang 47
N2 Inj 1715m Ang 66
9 5/8" Casing 1976m Ang 88.5
7" Casing 1978m Ang 88.5
TD 2229m Ang 91
From 2111 m BS&W reflects Increase in water production
Well Profile of N-22#2H

Drain hole length – 209 m
Av. Oil Rate – 1552 BoPD
Gas – 378 SCFM

20" Casing 324m Ang 18
13 3/8" Casing 1149m Ang 38.31
N2 Inj 1685m Ang 71
9 5/8" Casing 1979m Ang 88.5
7" Casing 1982m Ang 88.5
TD 2191m Ang 90.5
N-22 #2H A well placement

Low Festivity reservoir producing oil with zero WC
From 2191 BS&W reflects 2% of water production
Hydrocarbon N-22#2H

Hydrocarbon export, cumulative export and BHCP vs Time

- **Drilling**
- Flow test #1
- Flow test #2
### Platform N-22 Plan vs Actual

<table>
<thead>
<tr>
<th>Activity</th>
<th>N22 # 8H*</th>
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<th>N22 # 4H</th>
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<th>N22# 2H</th>
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<tr>
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<td>24.2</td>
<td>19.0</td>
<td>30.6</td>
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#### Activity wise break-up

<table>
<thead>
<tr>
<th>Activity</th>
<th>N22 # 8H*</th>
<th></th>
<th>N22 # 4H</th>
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<th>N22# 2H</th>
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<td>Total Rig up days</td>
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<td>13.8</td>
<td>5.6</td>
<td>4.6</td>
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<td>4.1</td>
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<td>1.9</td>
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<tr>
<td>Upper Completion</td>
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<td>4.4</td>
<td>2.7</td>
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<td>Final Rig down Days</td>
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<td>7.0</td>
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N22#8H has been tried but unable to take up with UBD technology due to Shale at DH toe.
Lesson Learned in 2nd Phase – N-22 Wells

• Ensure the 7” casing shoe is set in competent limestone with any and all shale set behind it. Take losses in the 8 ½” section if necessary.

• Membrane nitrogen proved successful and probably cheaper than cryogenic.

• True Bore RCD and independent HT 400s both performed well.

• Require reliable, functioning and accurate calibration and control instrumentation to improve equipment functionality and production rate measurements.
• Worked out the economics while in planning stage where reservoir is water flooded.
• It is technically feasible, to drill water flood reservoir in underbalanced, but economically candidates is in Question.
• To break the emulsion in lines and separator demulsifier needs relooked in terms of dose and quality.
• MWD / RSS to resolve their problems with both RSS and Motor assemblies
Thank You