I MPD….do you?

Blaine Dow
Schlumberger

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I MPD….do you?

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Poll Question

Where is everyone joining from?

Poll Question

What is your experience level?

Poll Question

What part of industry are you from?

Poll Question

What brings you here today?

Poll Question

Do you have experience with MPD on previous projects?

Managed Pressure Drilling

1. Annular Friction
2. Surface Pressure
3. Delta Energy
4. Hydrostatic Pressure
5. Pressurized Mud Cap

Managed Pressure Drilling

1. Annular Friction
2. Surface Pressure
3. Delta Energy
4. Hydrostatic Pressure
5. Pressurized Mud Cap

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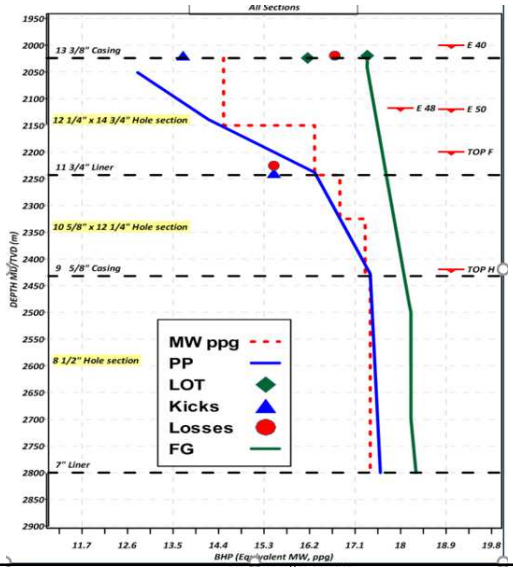
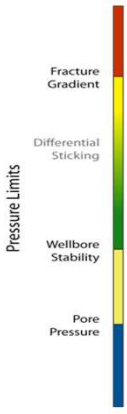
Typical Pore Pressure / Fracture Gradient Plot



Drilling Pressure Limits



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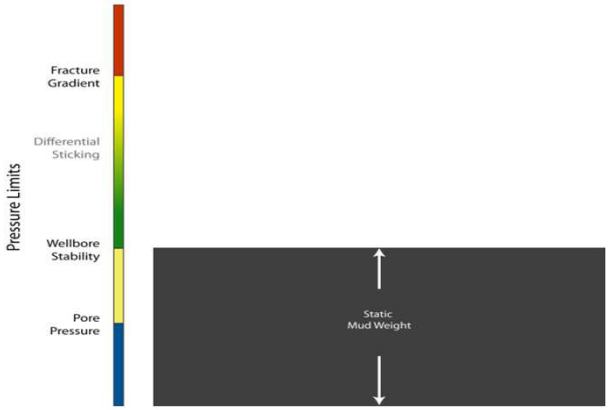

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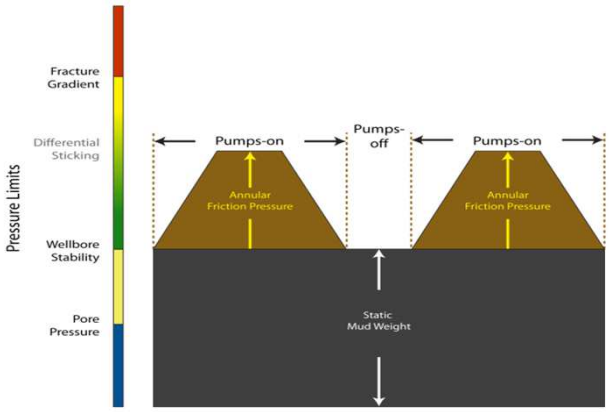
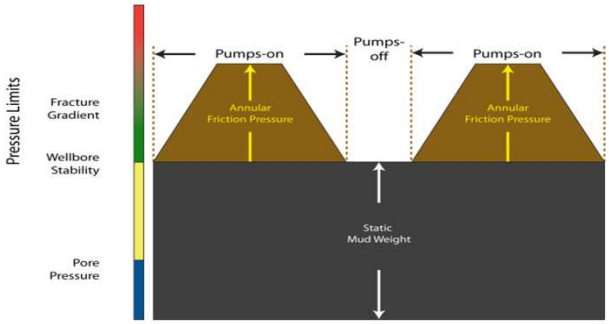


Tight Window PP-Stability/FG



Depletion / High ECD / Narrow Margin – MPD Solution

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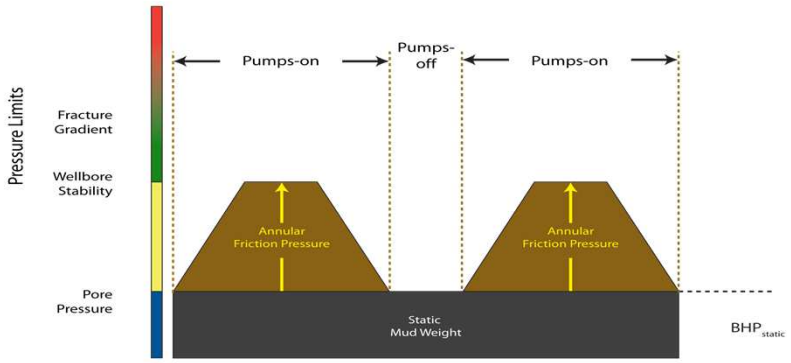
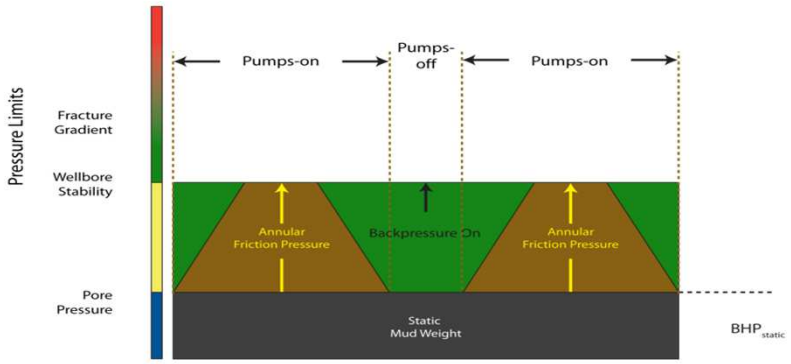


Depletion / High ECD / Narrow Margin – MPD Solution



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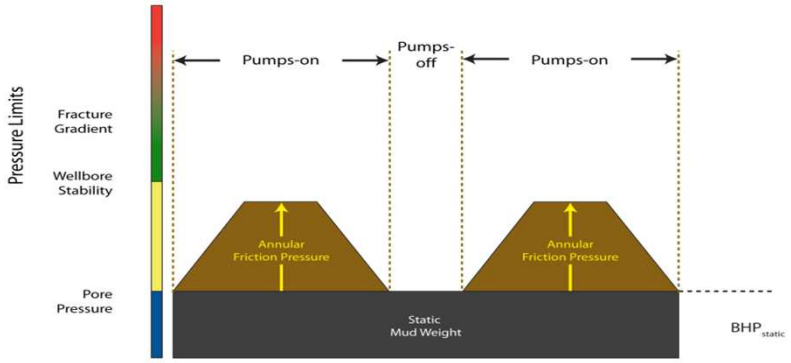
Depletion / High ECD / Narrow Margin – MPD Solution



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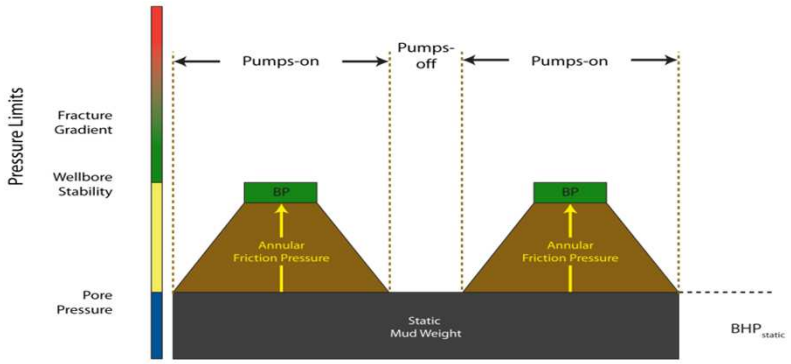

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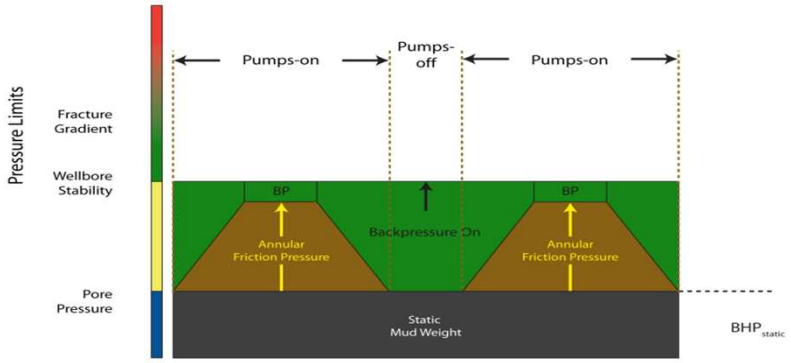
Depletion / High ECD / Narrow Margin – MPD Solution



Why We Do it

- Safety:
  - Kick detection, faster well control response, pore pressure fingerprinting, environmental barrier
- Eliminate non-productive time:
  - Kicks, losses, stuck pipe, borehole collapse, ballooning
- Improve Efficiency:
  - Eliminate casing strings, reduce formation damage, better ROP

How We Do it

– Close the system:
  - Rotary control device

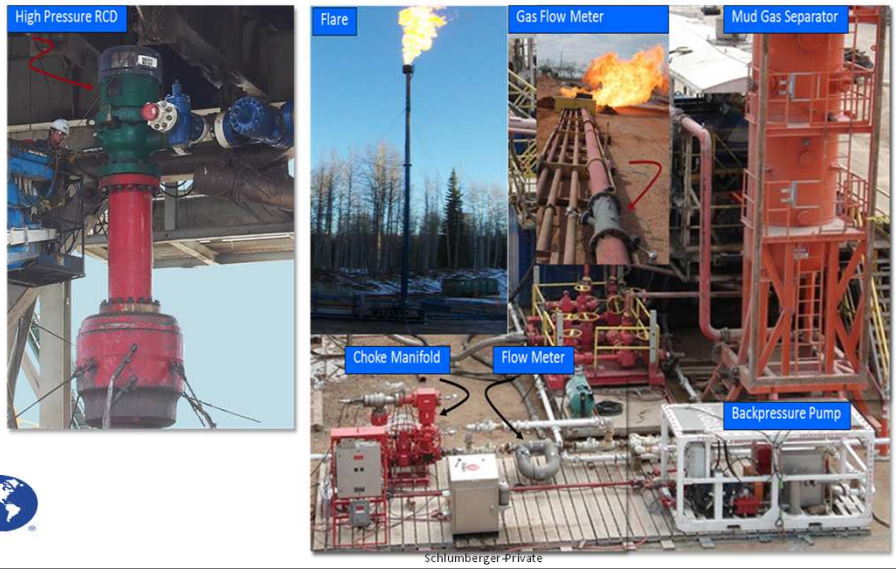
– Trap pressure:
  - Choke manifold, back pressure pump

– Anticipate and respond to the well:
  - Hydraulics modeling, manual or automated control system

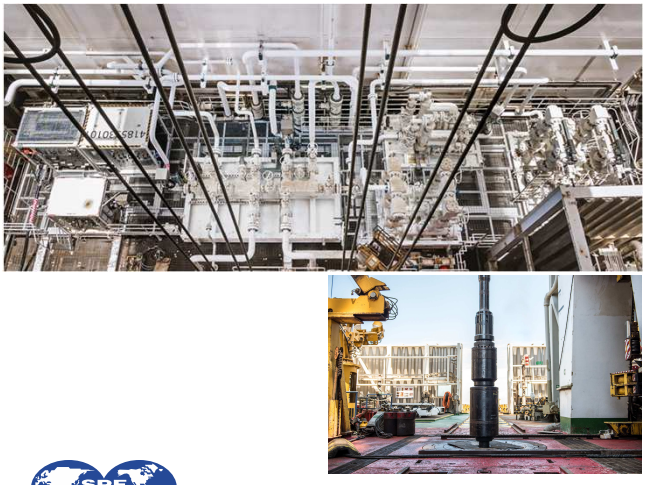
MPD Applications for Extreme Environments

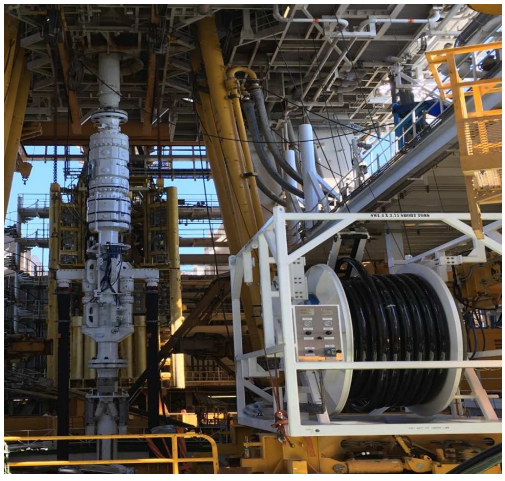
Deep Water	ERD Horizontal	Mature Depleted On & Off Shore	HPHT	Fractured Reservoirs
• Kick detection • Narrow margin • ECD reduction • Loss avoidance • Wellbore stability	• ECD reduction • Loss avoidance • Stuck pipe avoidance • Hole cleaning • Drilling optimization	• Narrow margin • ECD reduction • Loss avoidance • Wellbore stability • Kick detection • Drilling optimization • Reservoir damage	• Wellbore breathing avoidance • Kick detection • Narrow margin • Wellbore stability • Loss avoidance • Pressure environment detection (Dynamic Flow-in/Leak-Off)	• Kick detection • Controlled losses • Reservoir damage

Land Installation

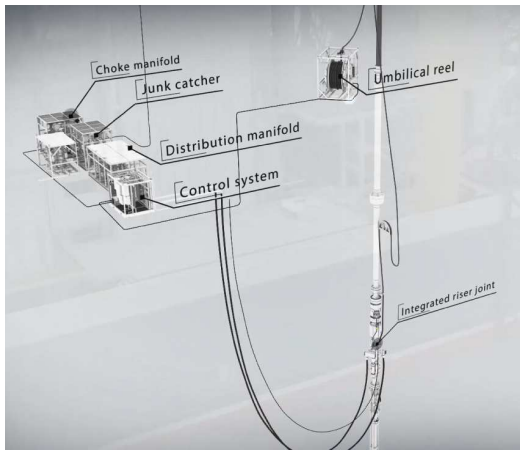


Deepwater Installation





Deepwater Installation



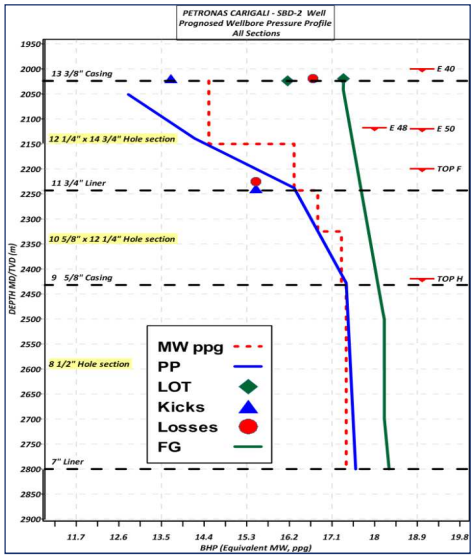
MPD Solutions for 4 Unique Drilling Challenges

- HPHT Exploration
- Wellbore Stability
- Drilling Performance in Unconventional Projects
- Drilling Faster

HPHT Exploration: Offshore Malaysia

(SPE151518)

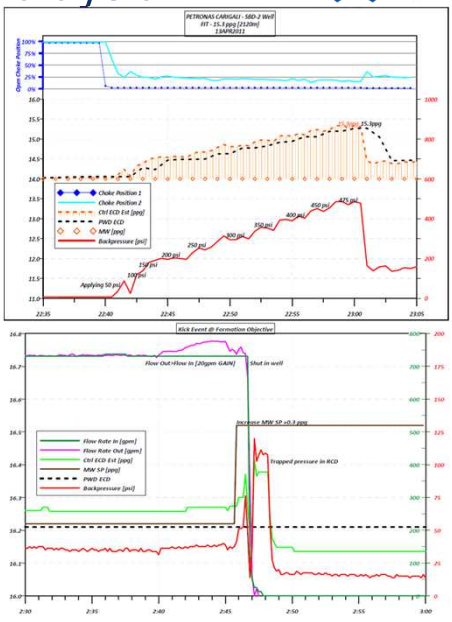
- Challenge
  - Offset exploration attempt failed to reach target
  - Shallow pressure ramp – 2000m TVD
  - Temperature exceeding 150C
  - Well control event led to loss of well
  - Second attempt required advanced MPD service



HPHT Exploration: Offshore Malaysia

(SPE151518)

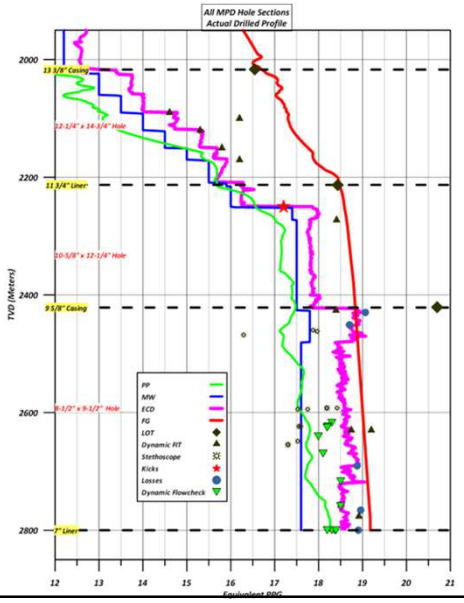
- Execution
  - Dynamic flow checks and dynamic LOT required to walk PP curve
  - Early influx detection enabled quick well control response
  - Intense hydraulic analysis required for tripping



HPHT Exploration: Offshore Malaysia

(SPE151518)

- Results
  - Successfully managed complex PP/FG curve
  - 3 hole sections, 780m, drilled with MPD
  - 560m deeper than offset
  - Successfully reached TD with no drilling margin
  - Reservoir was exploration success



MPD Solutions for 4 Unique Drilling Challenges

- HPHT Exploration
- Wellbore Stability
- Drilling Performance in Unconventional Projects
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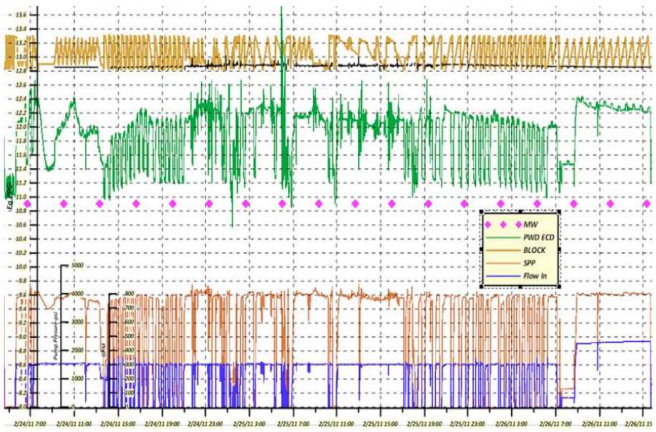
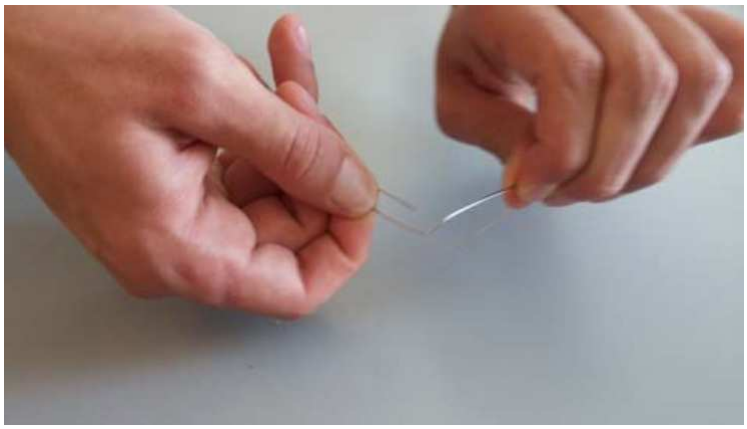
Example of a Stability Failure

- 10.9ppg Static mud weight
- Cycling during backreaming reached +/- 2.7ppg
- Particularly during pack-off





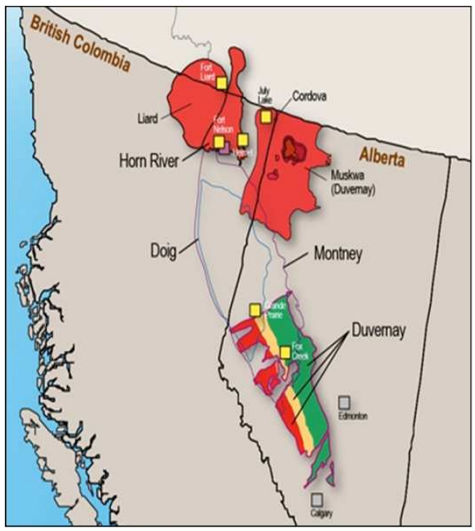
MPD Solutions for 4 Unique Drilling Challenges

- HPHT Exploration
- Wellbore Stability
- Drilling Performance in Unconventional Projects
- Drilling Faster

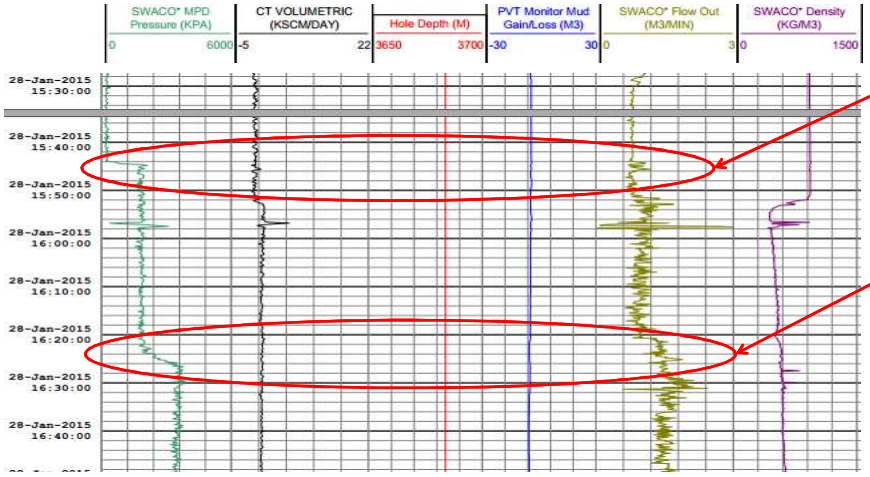
Drilling performance in unconventional projects:

(SPE168017)

- Challenge
  - Mature field with tight gas, loss circulation, natural fractures, wellbore breathing
  - 5 7/8” hole, 5000 ft lateral @ 10000 ft TVD
  - 0.33ppg drilling window
  - Offset wells could not drill more than 1800 ft lateral due to unmanageable influx and losses

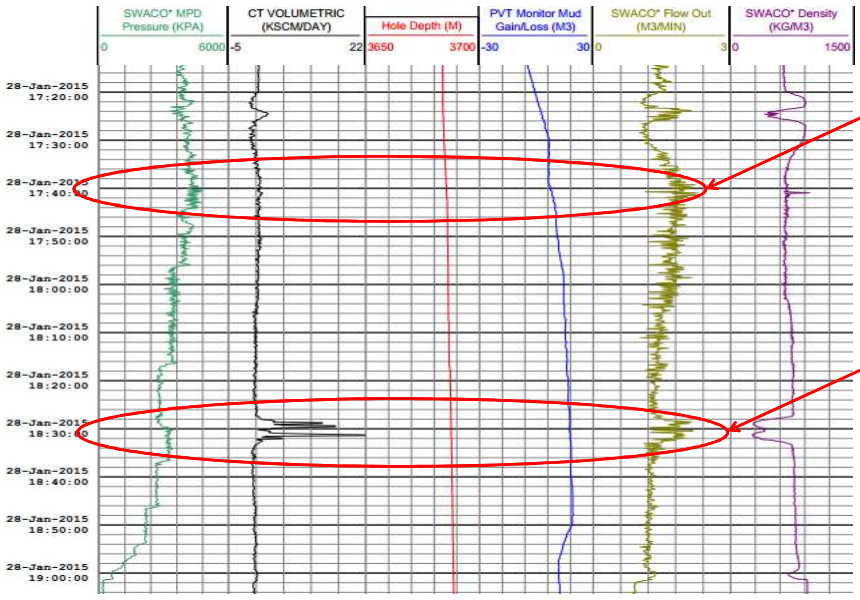


Influx Management on the Fly



Influx detected, backpressure applied

Influx growing, more backpressure applied



Heavy weight rollover initiated while drilling resumes

Last bit of gas passes at surface, Influx managed

Drilling Performance in Unconventional Projects:

(SPE168017)

- Results
  - 4 successful wells
  - Lateral length achieved
  - Significant days saved versus offsets
  - Significant reduction in mud losses

Well ID	Lateral Length, ft	Days Saved on Lateral Section	Reduction in Mud Losses (Saved), bbl
Well A	5000+	baseline	baseline
Well B	5900+	21	2200
Well C	5250+	20	2500
Well D	5250+	28	3000

MPD Solutions for 4 Unique Drilling Challenges

– HPHT Exploration

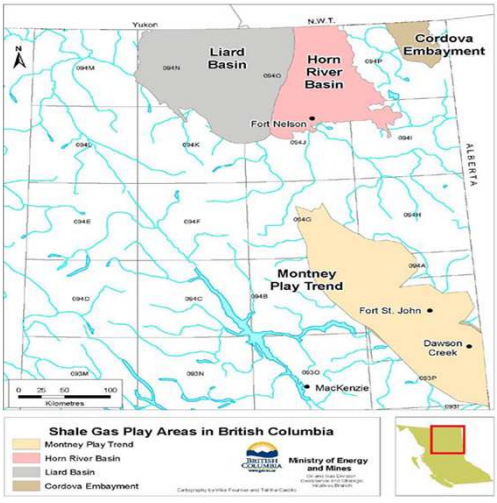
– Wellbore Stability

– Drilling Performance in Unconventional Projects

– Drilling Faster

Montney Formation – Western Canada

- Problem:
  - High mud weight to control background & connection gas
  - ECD-Induced losses
- Challenge:
  - Manage mud weights vs Minimum and Maximum PP/FG
  - Improve ROP and NPT for both sections
- Solution:
  - Reduce MW:
    - 11.2 ppg to 7.5 ppg for intermediate hole
    - 13.7 ppg to 10.4 ppg for main hole
  - Drill with statically underbalanced mud, maintain near balanced state with applied surface pressure



Montney Formation – Drilling Performance

– Intermediate Hole:
- 3011 ft Drilled Vs. 2886 ft (best Conventional Well)
- 41 hrs of drill time vs 77.5 hrs for the best Conventional Well
- 87 ft/hr Avg ROP vs. 38 ft/hr best Conventional Well

– Main Hole:
- 3 Bit Runs vs. 8 Bit Runs in the best Conventional Well
- 10102 ft drilled vs. 7767 ft for the best Conventional Well
- 243.75 hrs of drill time vs. 290.3 for the best Conventional Well
- 37 ft/hr Avg ROP vs. 26.3 ft/hr for the best Conventional Well

Poll Question

Those who have used MPD, what was your driver?

Poll Question

What type of Drilling Projects are you working on?

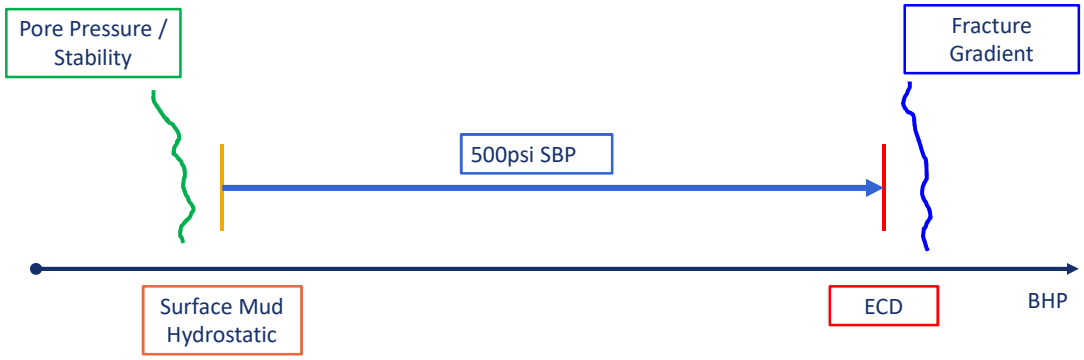
Drilling Engineering Considerations for MPD

MPD Constant Bottom Hole Pressure

- **Conventional Drilling**
  - Circulating
    $BHP_{Dynamic} = P_{hyd} + P_{Friction}$
  - Static
    $BHP_{Static} = P_{hyd}$
- **MPD Surface Pressure Application**
  - Circulating
    $BHP_{Dynamic} = P_{hyd} + P_{friction} + P_{surface}$
  - Static
    $BHP_{Static} = P_{hyd} + P'_{surface}$

$BHP_{Dynamic} = BHP_{Static}$

MPD Design – Drilling and Connections



MPD Design – Drilling and Connections

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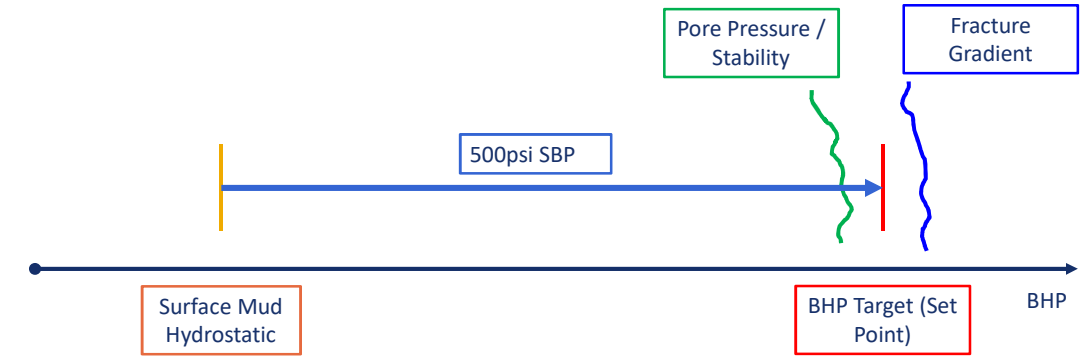
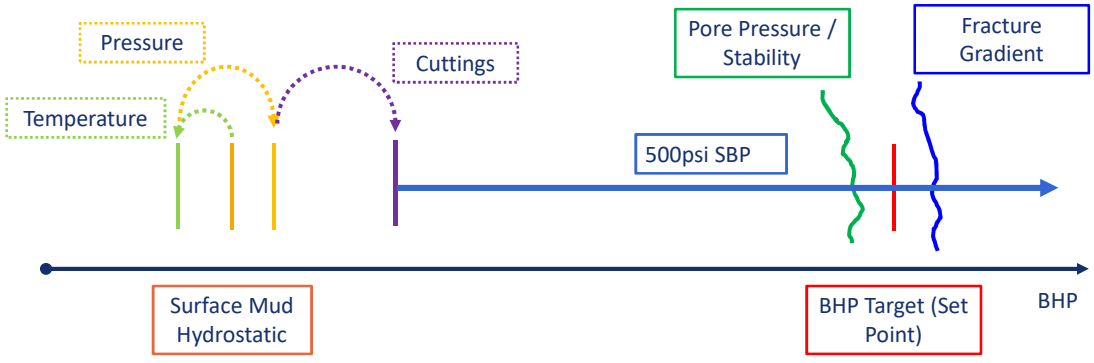


Factors Affecting Hydrostatic Pressure

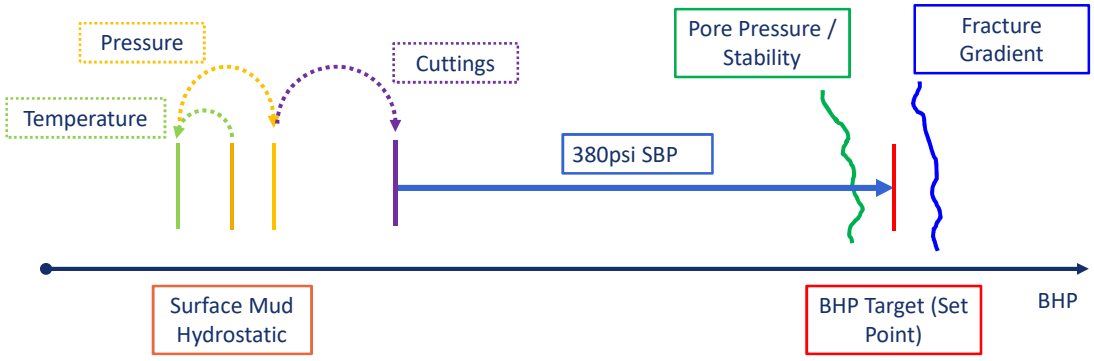
– Pressure-Temperature effect

– Drilling cuttings in the mud

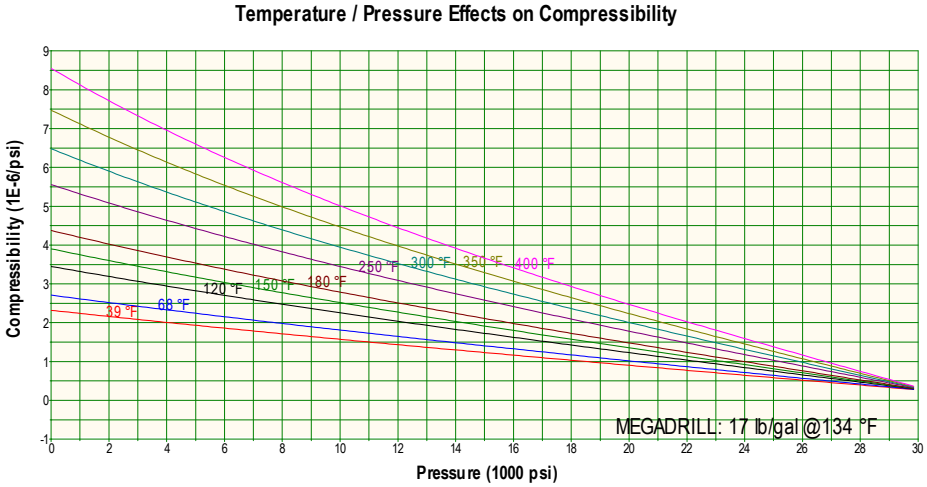
MPD Design – Drilling and Connections



MPD Design – Drilling and Connections



Compressibility



Annular Friction Losses

- **MPD Surface Pressure Application**
  - Circulating
    $BHP_{Dynamic} = P_{hyd} + P_{friction} + P_{surface}$
  - Static
    $BHP_{Static} = P_{hyd} + P'_{surface}$

$=$

$BHP_{Dynamic} = BHP_{Static}$

Annular Friction Losses

- **MPD Surface Pressure Application**
  - Circulating
    $BHP_{Dynamic} = P_{hyd} + P_{friction} + P_{surface}$
  - Static
    $BHP_{Static} = P_{hyd} + P'_{surface}$

$=$

$BHP_{Dynamic} = BHP_{Static}$

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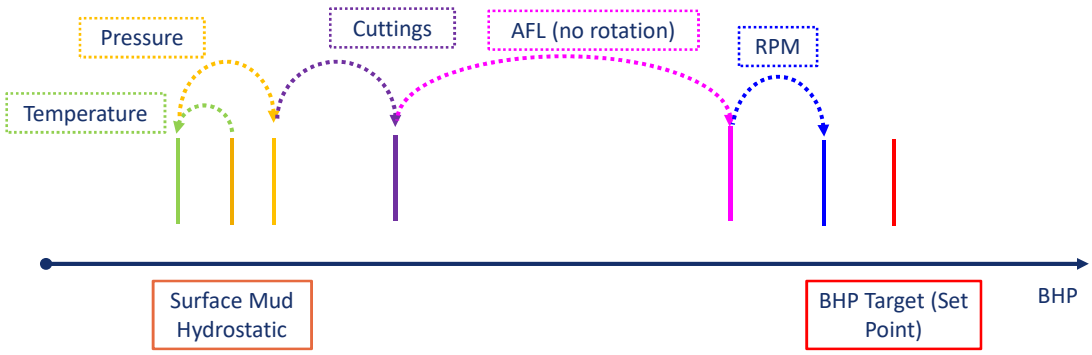
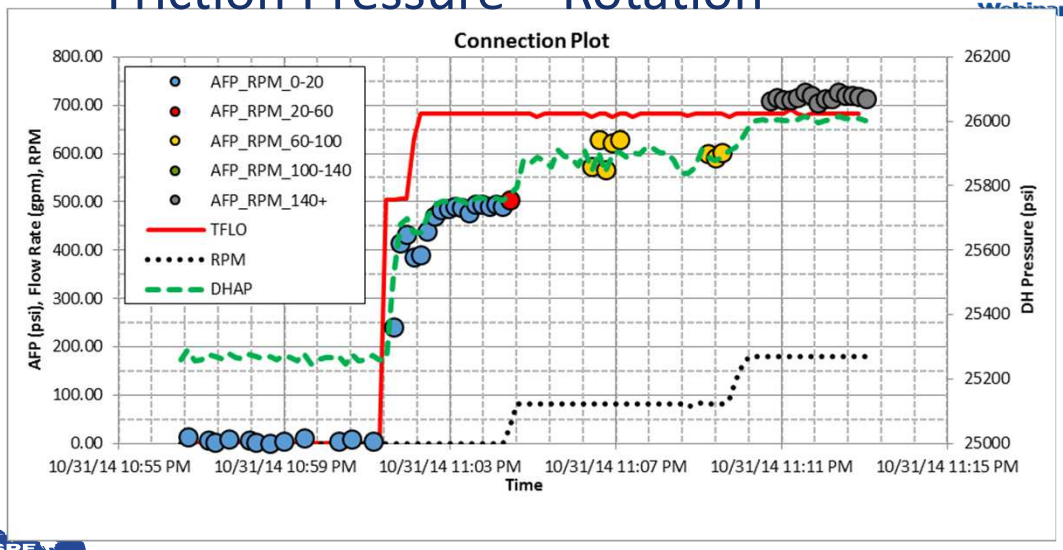
Factors Affecting Annular Friction Losses

- Mud rheology
- Hole depth
- Annular cross section
  - Hole size
  - Drill pipe size
  - BHA
- RPM

MPD Design – Drilling and Connections



Friction Pressure – Rotation



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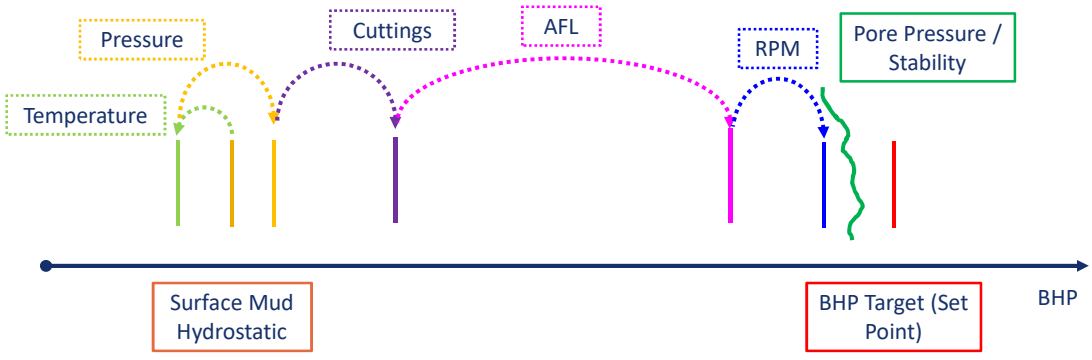

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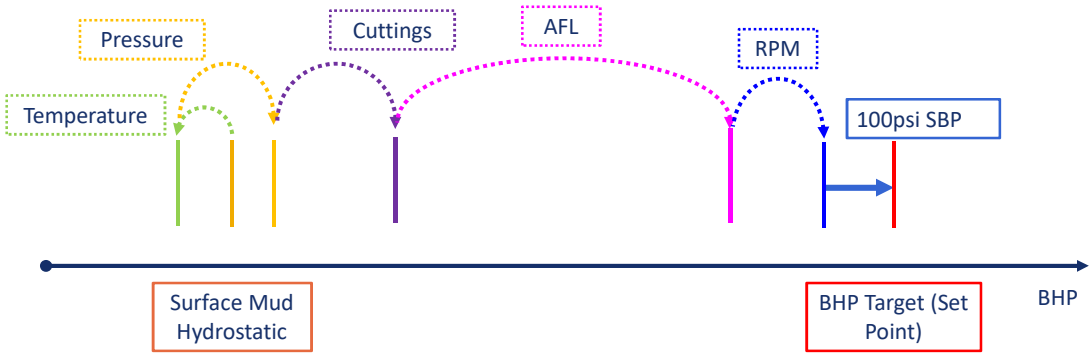


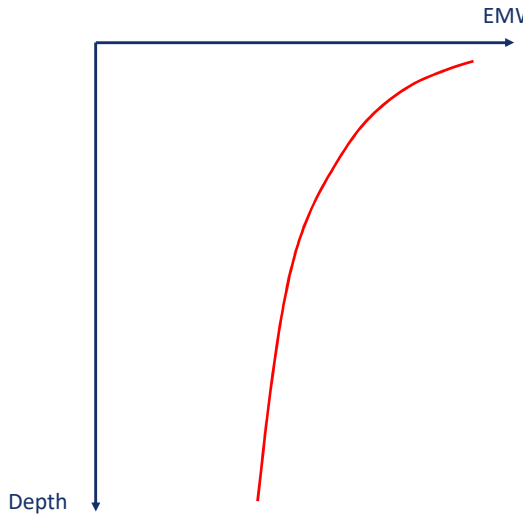
Questions?

MPD Techniques

Anchor Point – Equivalent Mud Weight Plot

– During a connection:

$$\text{EMW} = ESD + \frac{SBP}{0.052\,TVD}$$



Anchor Point – Annular Friction Losses

– Factors affecting the AFL

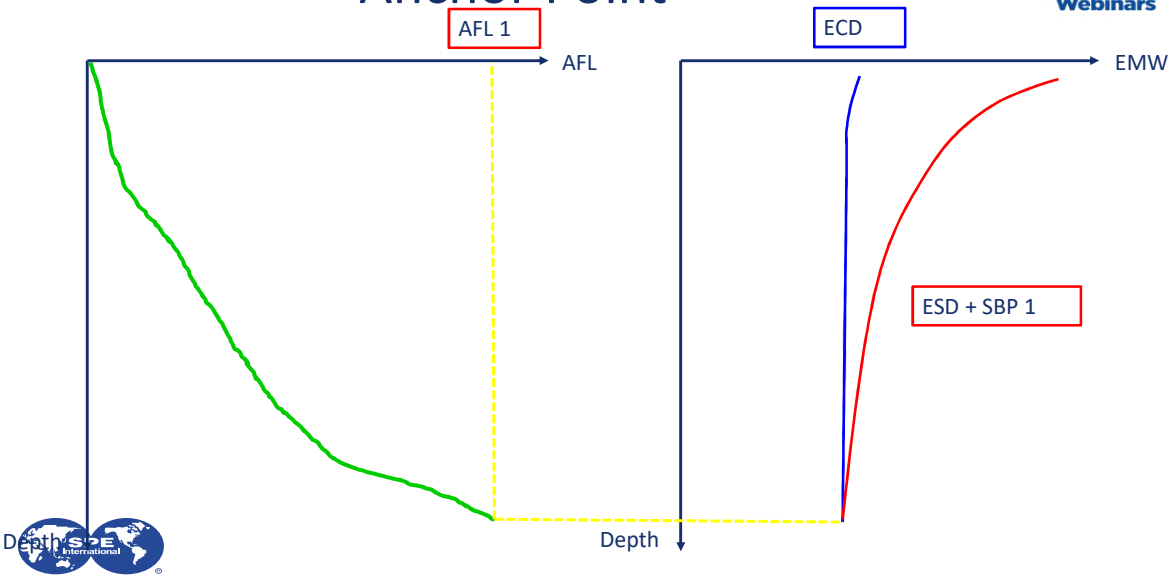
- ….
- Hole depth
- ….

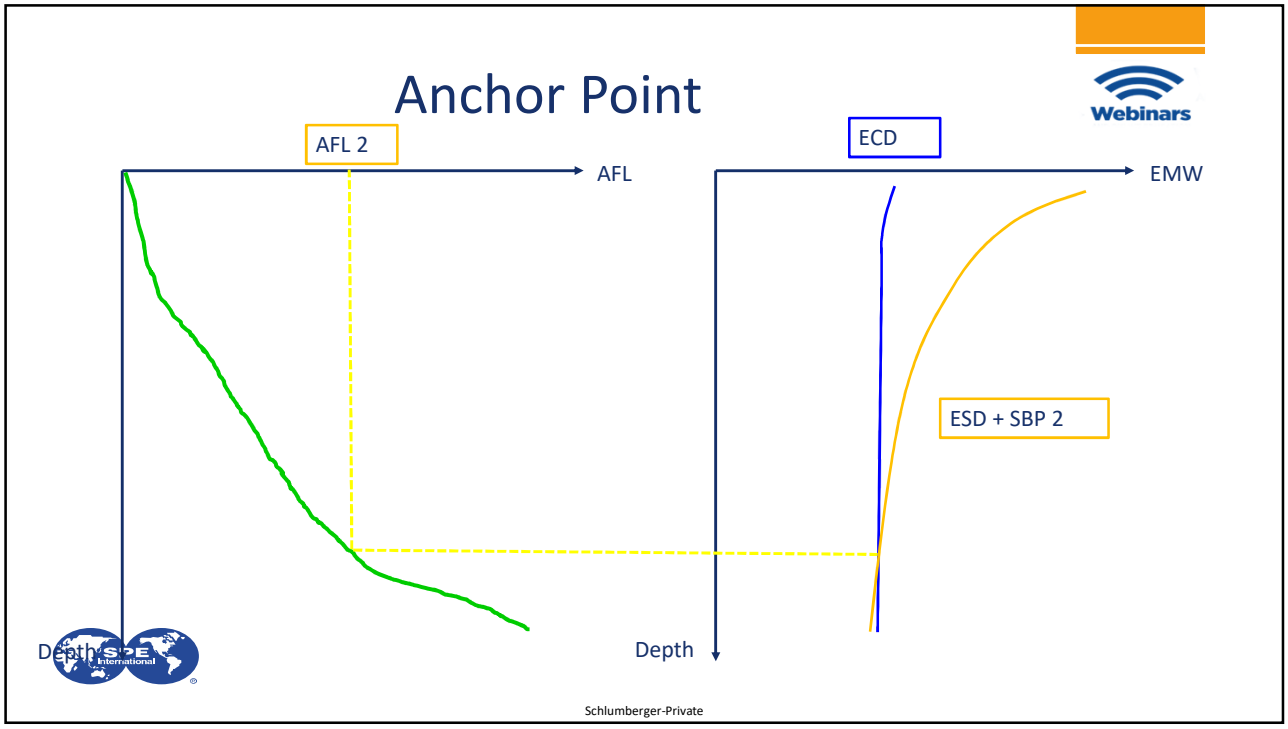
- **MPD Surface Pressure Application**
  - Circulating
    $BHP_{Dynamic} = P_{hyd} + P_{friction} + P_{surface}$
  - Static
    $BHP_{Static} = P_{hyd} + P'_{surface}$

$P_{friction} + P_{surface} = P'_{surface}$

$BHP_{Dynamic} = BHP_{Static}$

Anchor Point




Anchor Point
Webinars
AFL 2
AFL
ECD
EMW
ESD + SBP 2
Depth
Depth
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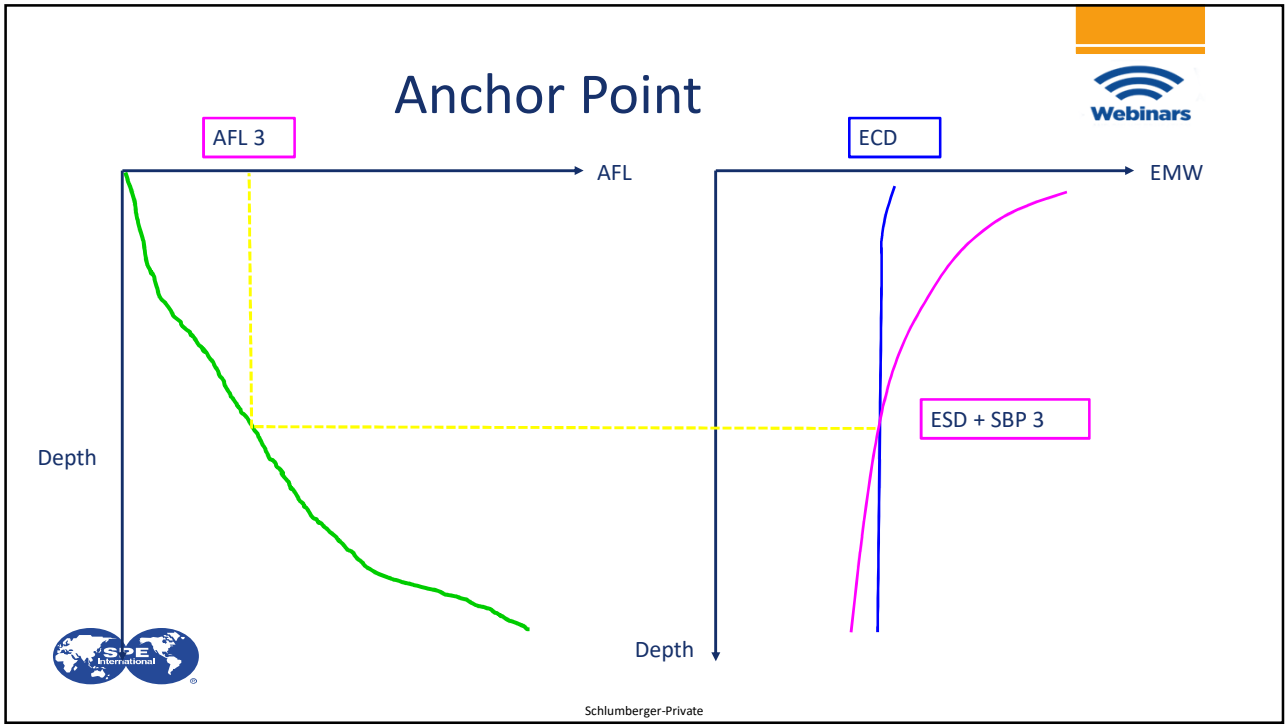
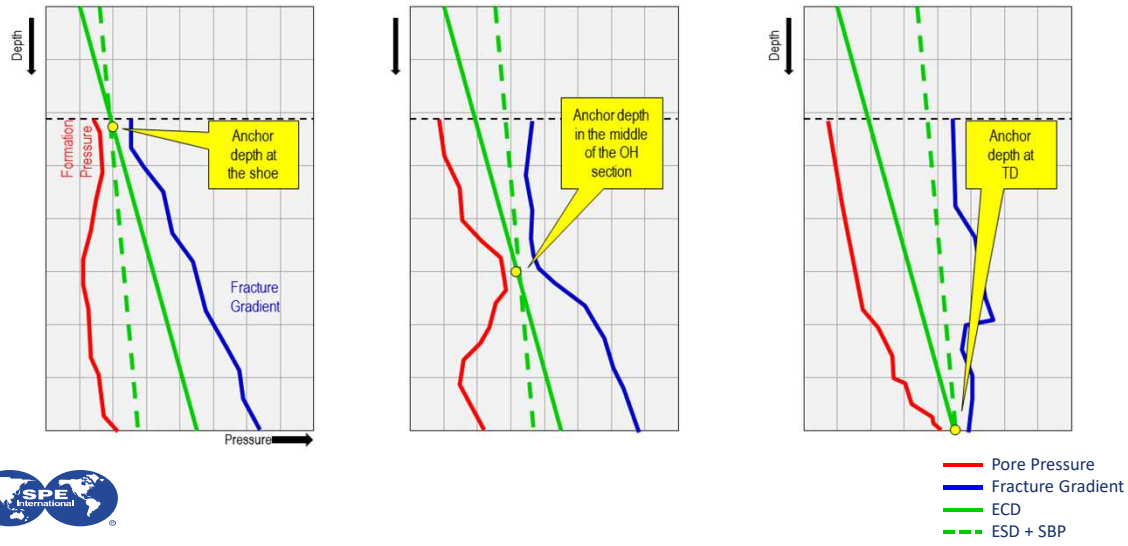
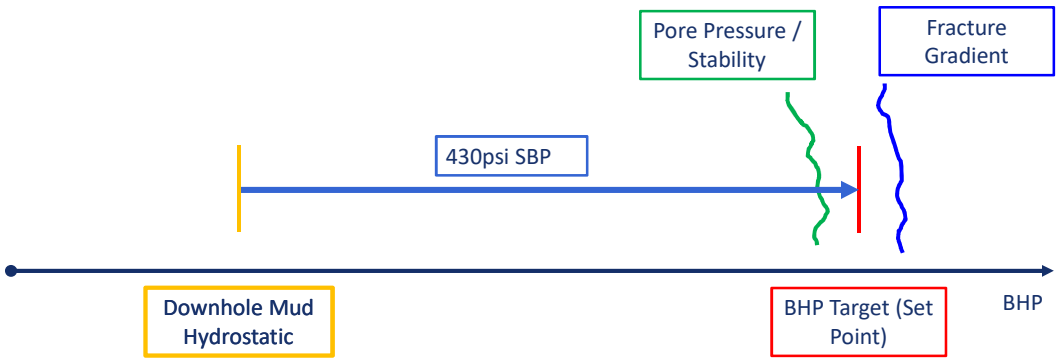

Anchor Point
Webinars
AFL 3
AFL
ECD
EMW
ESD + SBP 3
Depth
Depth
Schlumberger-Private

Anchor Point Selection

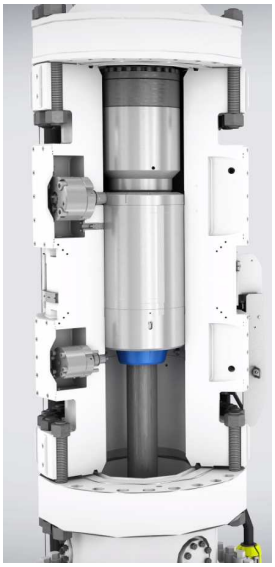


Tripping out of Hole



Tripping out of Hole

- BHA Components do not fit through the RCD sealing elements
- The Sealing Elements / Bearing Assembly will be removed
- No possibility to apply surface pressure



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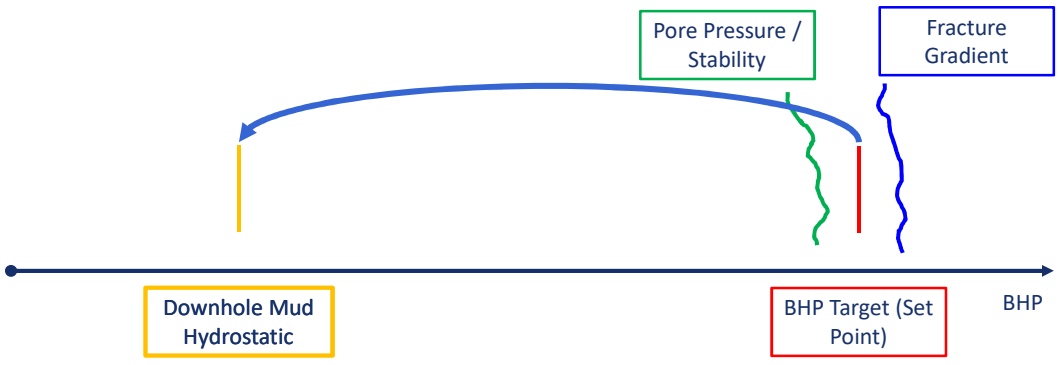
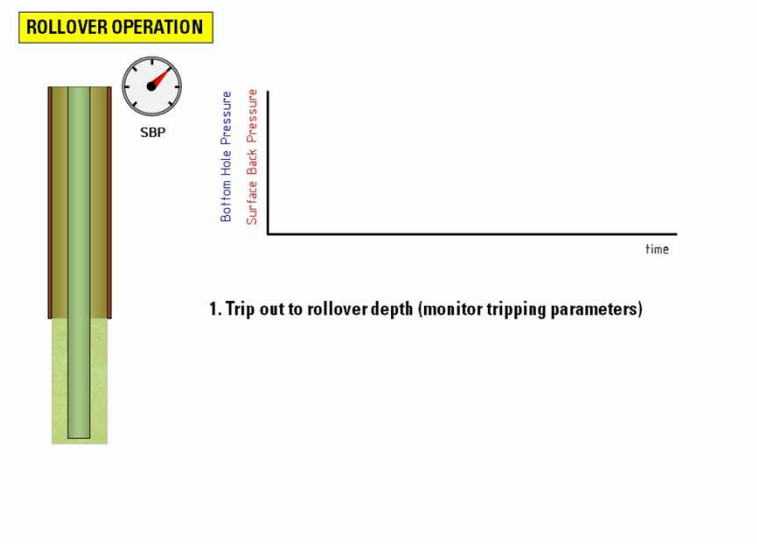


Tripping out of Hole

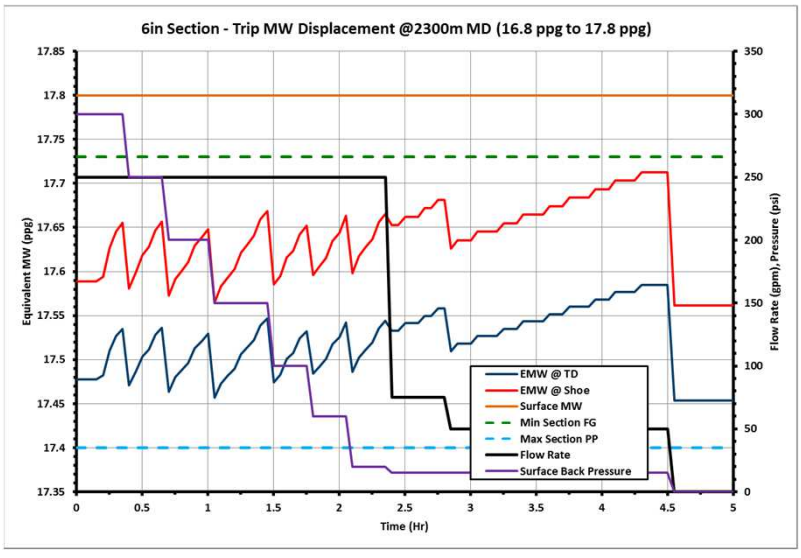
Mud Displacement

- Trip mud density
- Wellbore trajectory → Mud in the vertical section
- Annular friction losses → Displacing at TD vs Higher in the wellbore
- Volume constraints
- Density differential
- Next activity: Continue drilling / Running casing

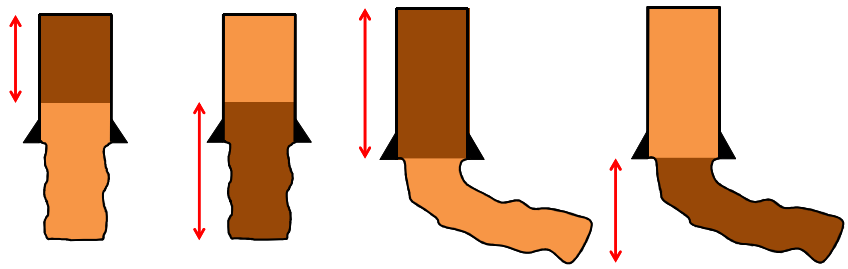
Mud Displacement



Mud Displacement



Heavy Mud Sinking to the Bottom



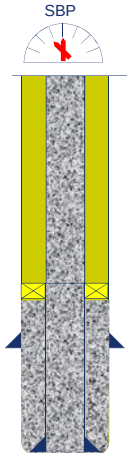
Tripping out of Hole

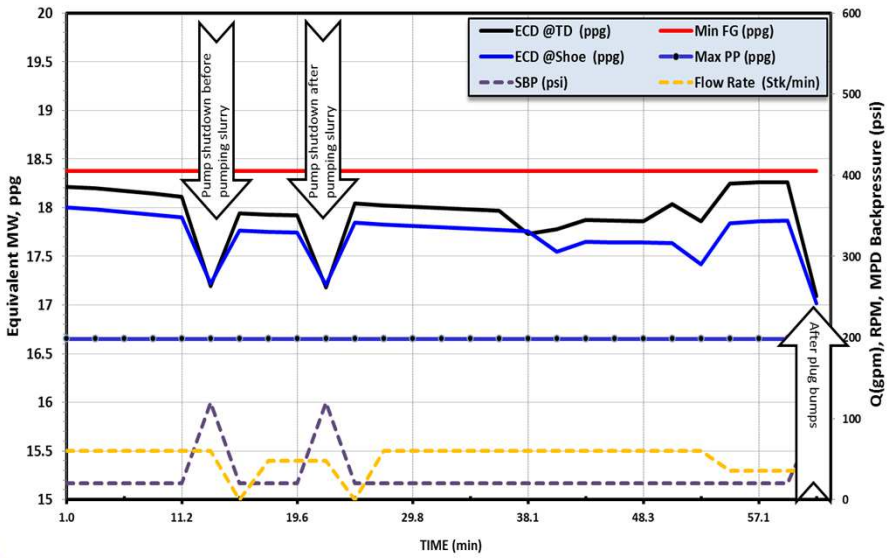
- Possibility to apply surface pressure while tripping out of hole
- Offset the swab effect
- A tripping schedule is provided including
  - Tripping speed
  - Surface back pressure

Casing / Liner Tripping and Cementing

– Casing / liner can be stripped to the bottom

– Managed pressure cementing





Questions?

What about when MPD fails???

What is MPD failure?

- Defining failure first requires a definition for success:

MPD Success = **Drilling** + **Tripping** + **Casing/Liner Running** + **Cementing**

- "Success," therefore, is full delivery of a hole section…..
- Consequently, MPD failure means the well section was not delivered

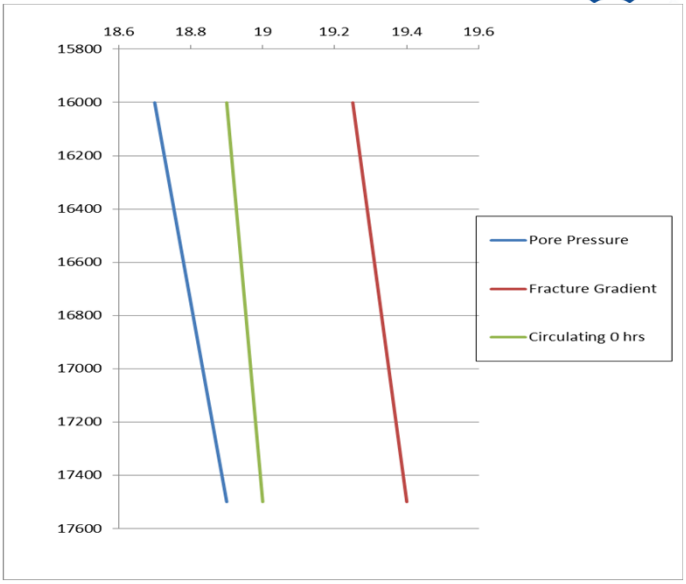
Case 1: Modeling temperature effect

Well Backdrop:

- HPHT exploration well
- Narrow PP/FG margin
- Ran out of drilling window 5000' shy of TD

Compelling question – is the well drillable with MPD?

- At TD of section, window estimated to be 0.4 ppg
- Applying constant bottom hole pressure MPD technique, **well is drillable**



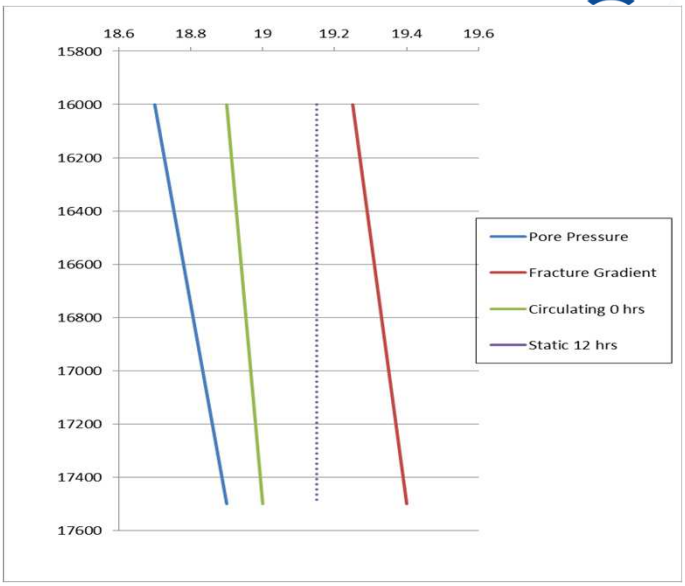
Case 1: Modeling temperature effect

However…

- Once reaching TD, now what?

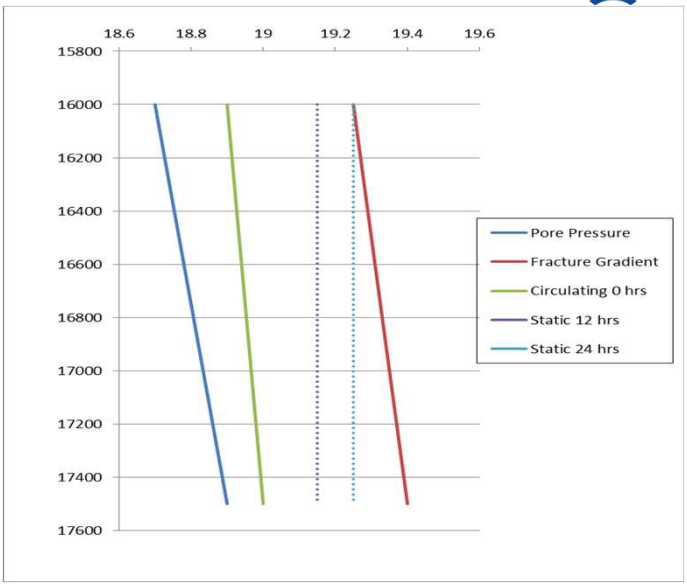
- Characteristics of the well design, fluid properties and thermal gradient indicate further analysis required

- After 12 hours, static temperature and compressibility begin to raise effective mud weight more than 0.2 ppg above ECD at TD



Case 1: Modeling temperature effect

- After 24 hours, static mud weight reaches FG at shoe

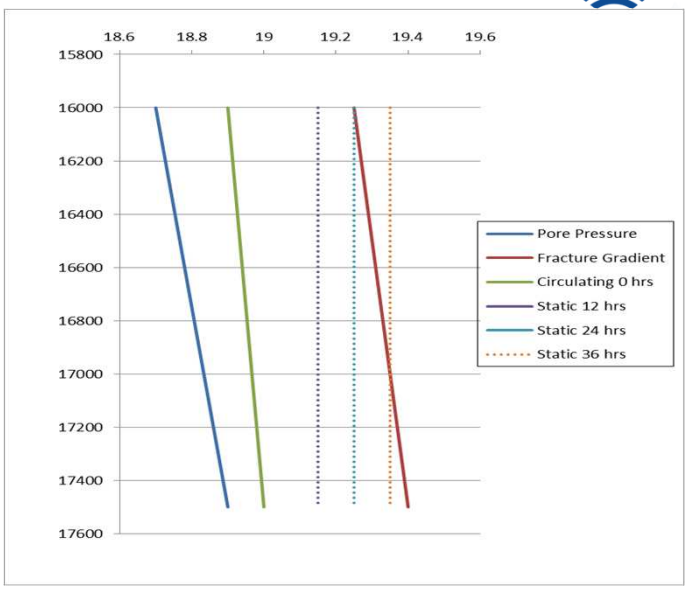


Case 1: Modeling temperature effect

- After 36 hours, static mud is beyond FG for almost all of the hole section

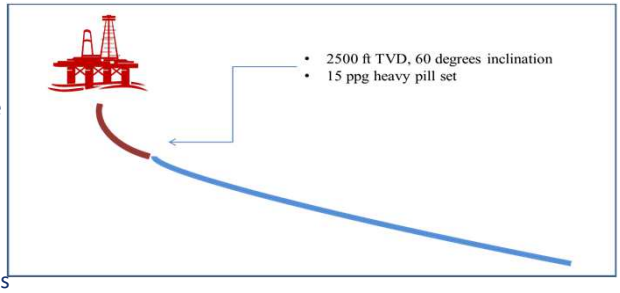
Therefore:

Success requires:
- A complex rollover schedule requiring multiple density pills that accommodate thermal effect
- Time-sensitive planning of activities – wireline, liner running, etc.



Case 2: Isolating a heavy pill

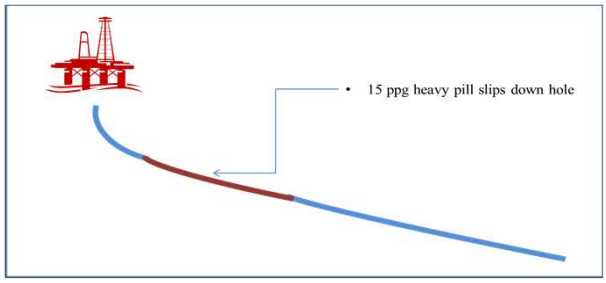
Well Backdrop:
- 8 ½" hole section build from 50–70˚
- 10000' MD, 7500' TVD
- Narrow window: 12.0 ppg stability and 12.5 ppg FG, sensitive to cycling
- Static MW of 10.8 ppg water-base mud
- Goal: Constant bottom hole pressure
- Logistics and climate limit multiple large-volume mud systems
- Tripping plan: Spot 15 ppg heavy pill at 2500 ft TVD



Case 2: Isolating a heavy pill

What happened:

- 15 ppg heavy pill failed to remain in place
- Cleanout trip with pressure while drilling confirmed pill had fallen
- hole section collapsed as pill slid down the well, reducing effective bottom hole pressure



Lesson Learned:

- Alternative displacement strategy
  - Full displacement from bottom
    - More time spent, but worth it
  - Smaller differential pill weight
  - Temperature stable spacer

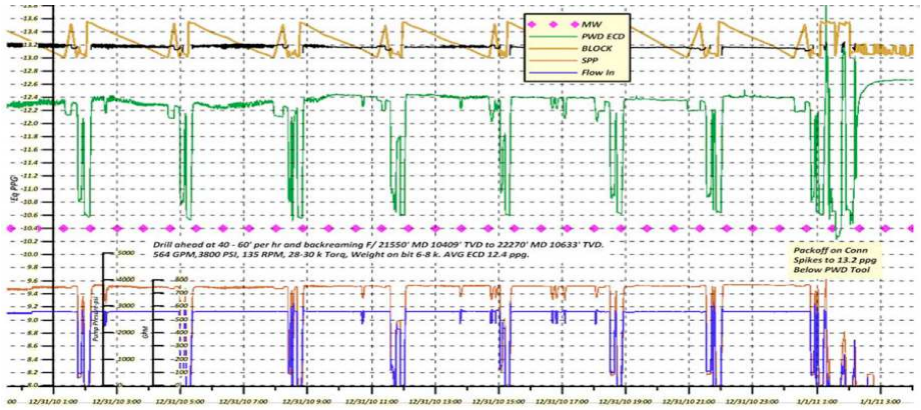
Case 3: MPD and extended reach drilling

Well Backdrop:

- 8 ½" x 9 ¼" re-entry hole section targeting two depleted sands (3 ppg drawdown and 5.5ppg drawdown respectively)
- Narrow window: 11.4 ppg stability and 13 ppg FG
- 4,000' section beginning at 10,000' TVD and 70˚ inclination
- MPD driver: Offset well section lost due to borehole collapse

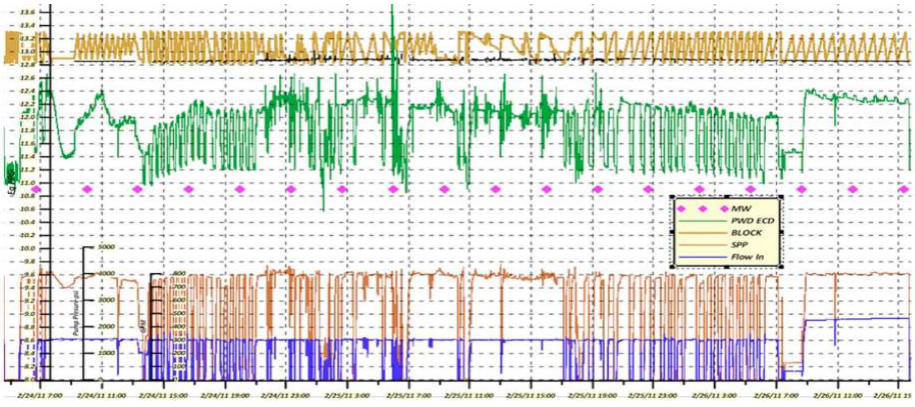
Case 3: Recorded PWD from offset

- Borehole sensitive to cycling
- 1.6 ppg cycle on connections with 10.4 ppg static mud weight



Case 3: Recorded PWD from offset

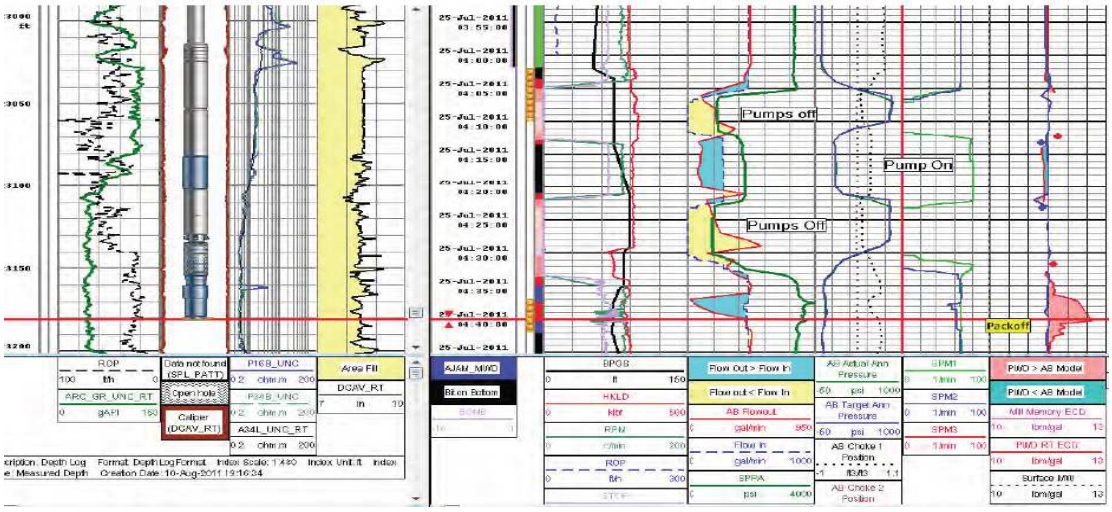
- 10.9 ppg static mud weight
- Cycling during backreaming reached +/- 2.7 ppg
  - Particularly during packoff



Case 3: Planning

- MPD Objective: constant bottom hole pressure to eliminate cycling effect
- Static MW of 10.2 ppg with flat rheology synthetic-base mud
- Constant bottom hole pressure application targeting 11.6 ppg EMW

Case 3: As Drilled



Case 3: Outcome

- Reached TD maintaining constant bottomhole pressure through >95% of section
- Minor packoff events crossing depleted unconsolidated sands
- Following bottoms up circulations, trip out encountered tight spots at sands
- Conventional “clean up” program compounded packoffs and losses
- Aggressive LCM program “cleaned” hole, inducing further packoff and lost section

Learning:

- Marriage between ERD and MPD is a fine balance
- Clean hole is essential prior to trip out – BUT, RCD will limit RPM

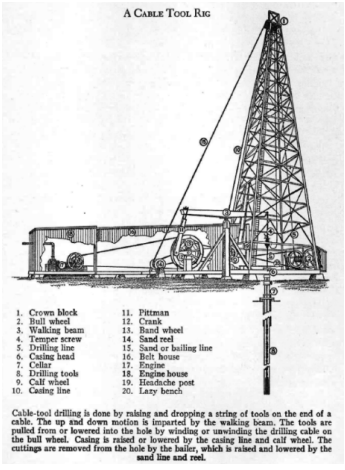
Conclusions

- Each case represented less than ideal outcome for the operator
- In each case, MPD equipment performance was not an issue
- MPD success was hindered by responding to events with “conventional” drilling response plans
- Successful MPD requires re-think of the entire drilling process and more thorough appreciation of consequences of events
- Shared lessons learned will help overall success of MPD applications

Webinars

Sustainability of MPD???

Webinars



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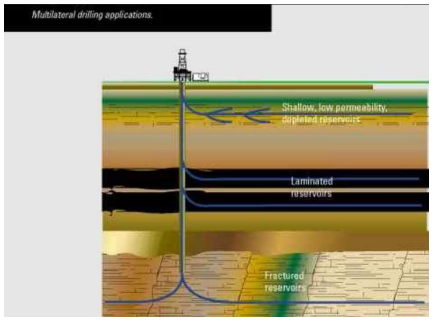
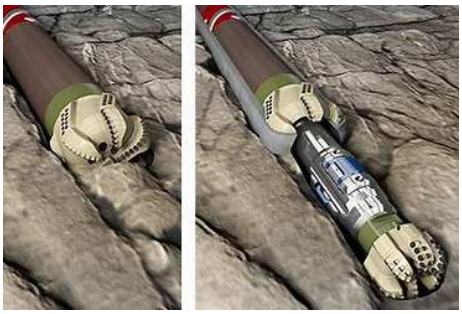
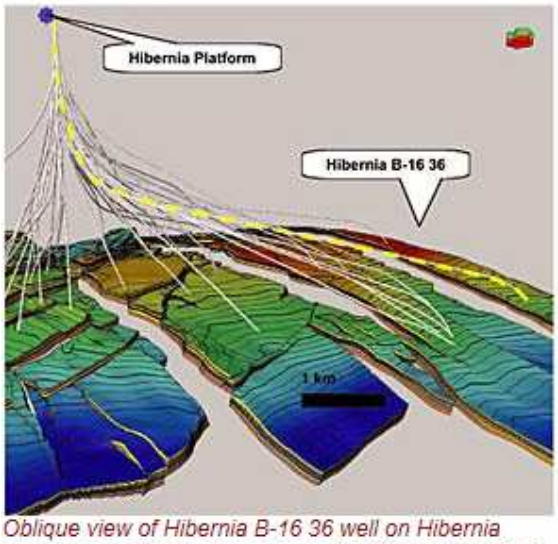


Multi-lateral systems

Coiled Tubing Drilling

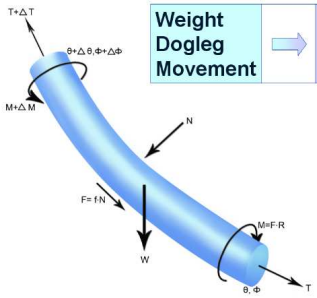


Casing Drilling



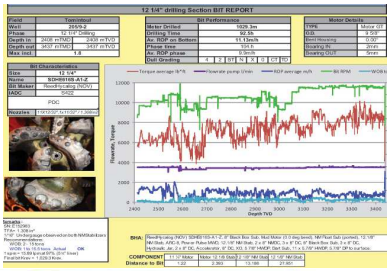
Oblique view of Hibernia B-16 36 well on Hibernia formation depth structure shows the OPA1 well (photo courtesy of ExxonMobil Canada Ltd.).

Click here to enlarge image



Weight
Dogleg
Movement

Drag
Torque
Side force



US005706905A

United States Patent [19]

Barr

[11] Patent Number: 5,706,905

[45] Date of Patent: Jan. 13, 1998

[54] STEERABLE ROTARY DRILLING SYSTEMS

[75] Inventor: John D. Barr, Cheltenham, England

[73] Assignee: Camco Drilling Group Limited, of Hycalog, Stonehouse, England

[21] Appl. No.: 604,324

[22] Filed: Feb. 21, 1996

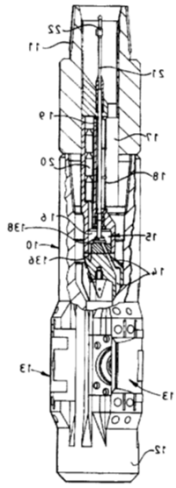
[30] Foreign Application Priority Data

2259316 3/1993 United Kingdom .
2298217 8/1996 United Kingdom .

Primary Examiner—Hoang C. Dang

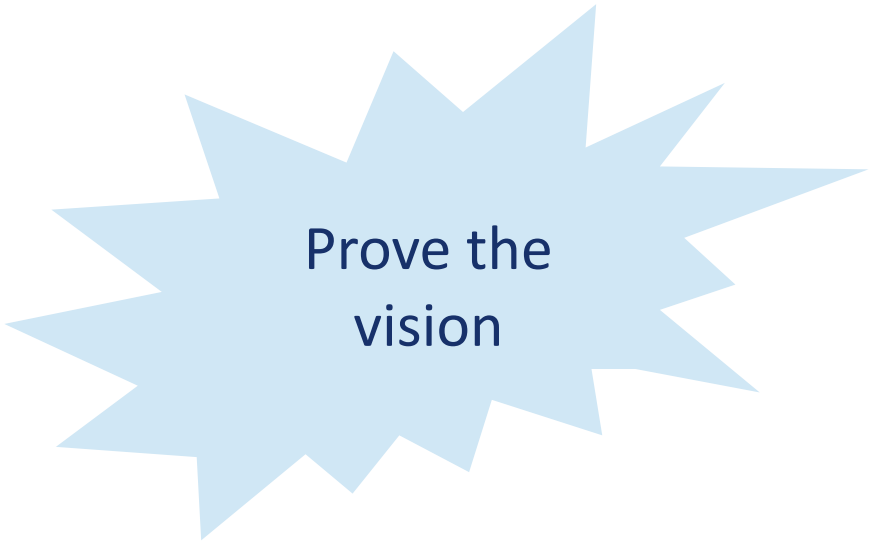
[57] ABSTRACT

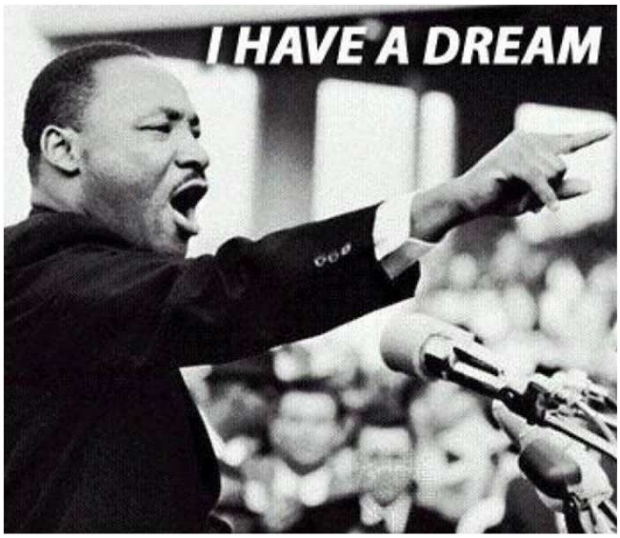
A modulated bias unit, for use in a steerable rotary drilling system, comprises a number of hydraulic actuators spaced apart around the periphery of the unit, each having a movable thrust member which is hydraulically displaceable



Operator's Business Model?

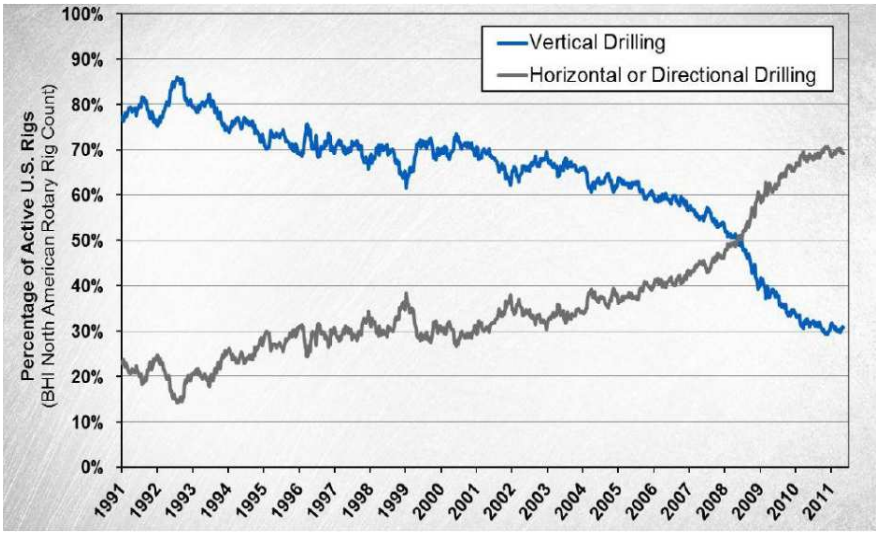
Provider's Business Model?





AND IT WORKED!!!!

Was it Expandable?



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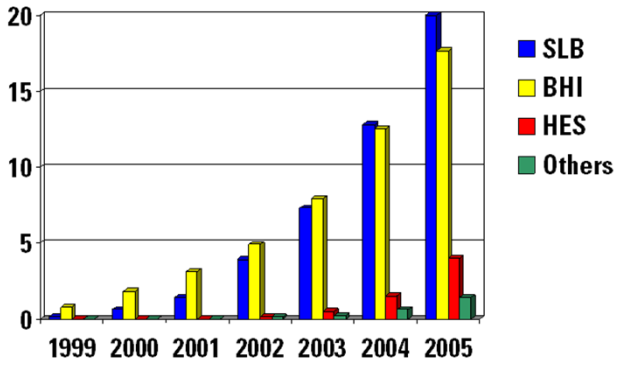
Cumulative Footage for RSS by Year



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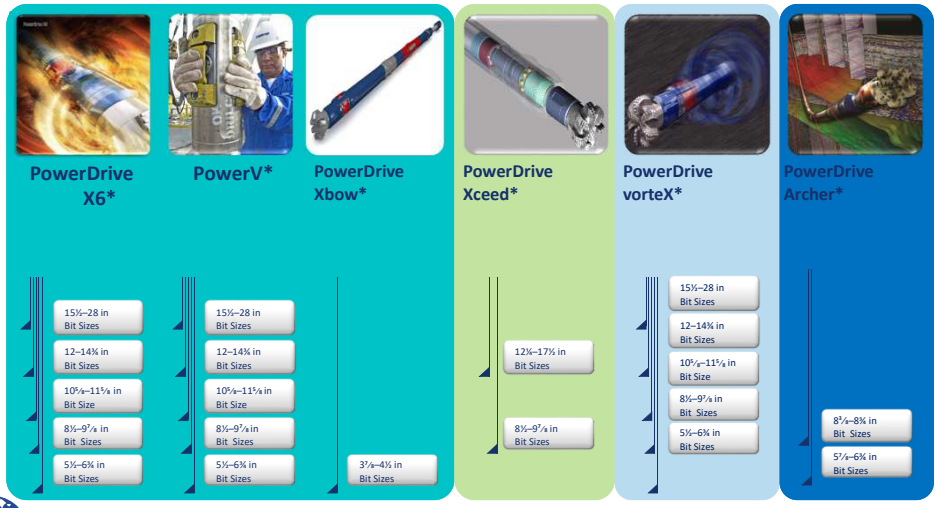
Rotary Steerable Systems



Operator's Business Model?

Provider's Business Model?

Operating Margins

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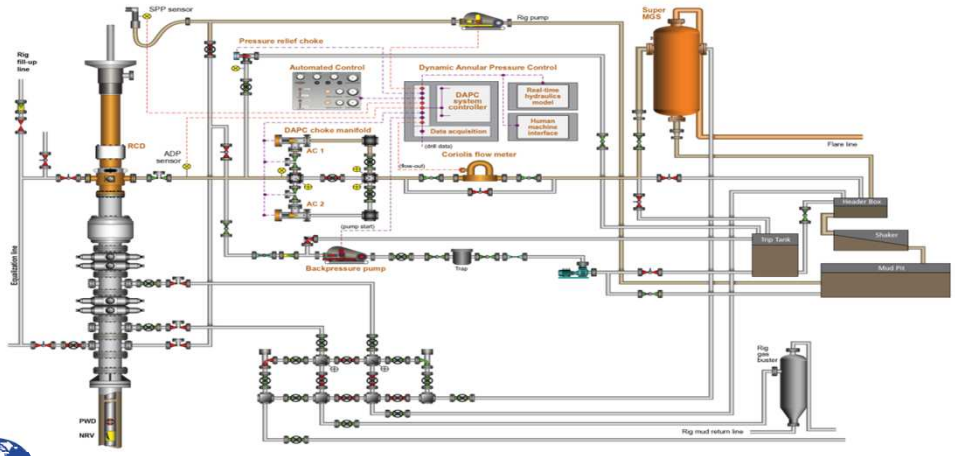
Automated Managed Pressure Drilling



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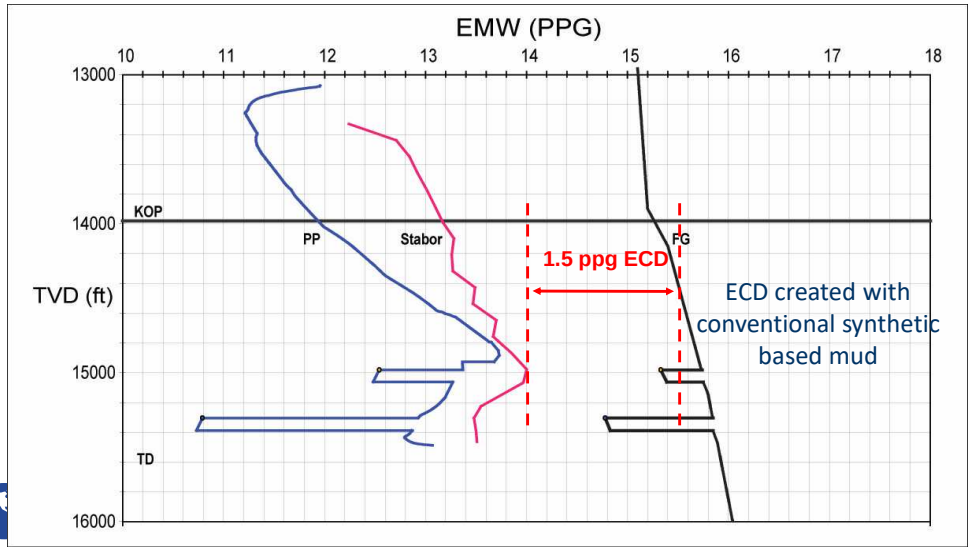
Narrow Drilling Windows



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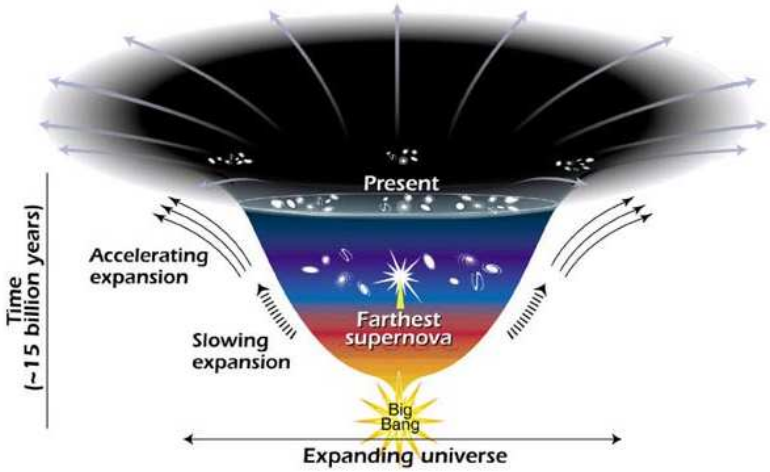
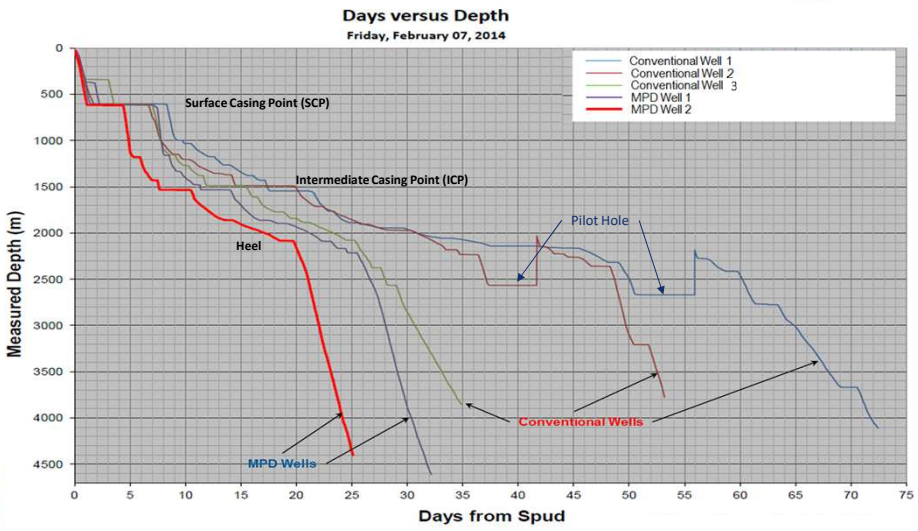
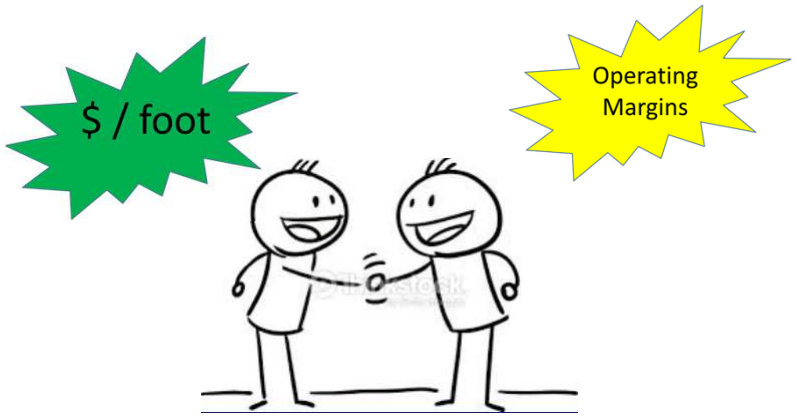
Operator's Business Model?

Provider's Business Model?



Efficiency Focus





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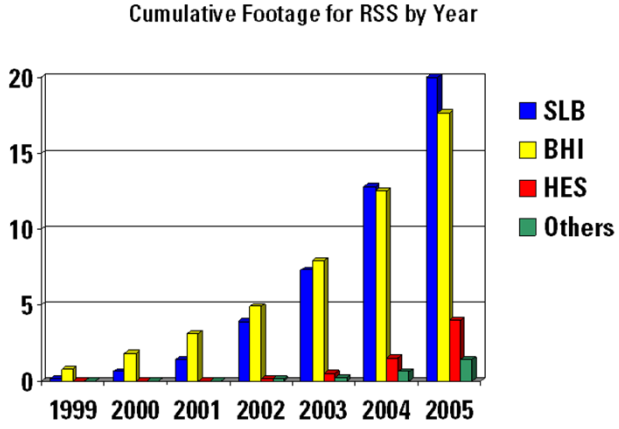

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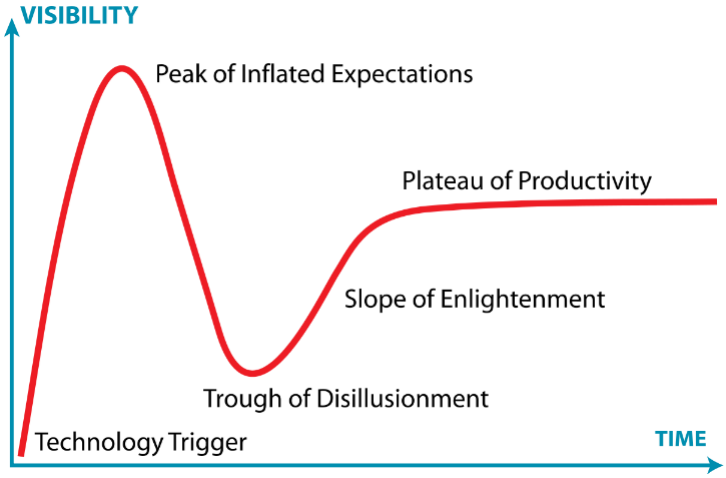

The Gartner Hype cycle

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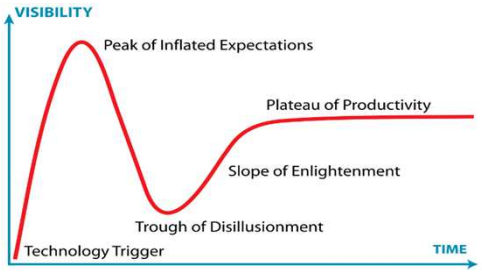
Poll Question

For MPD, where on the Gartner Hype Cycle do you think industry?



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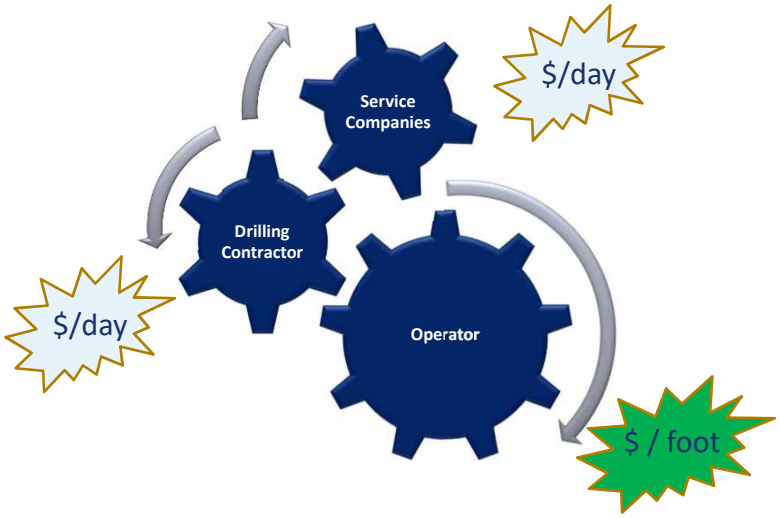
MPD Deployment Lead Actors



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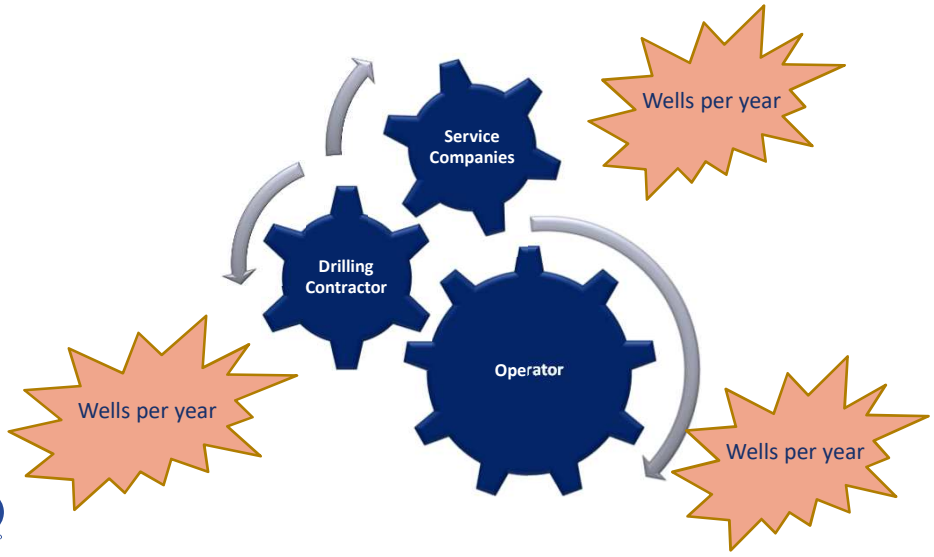
Alignment is Critical



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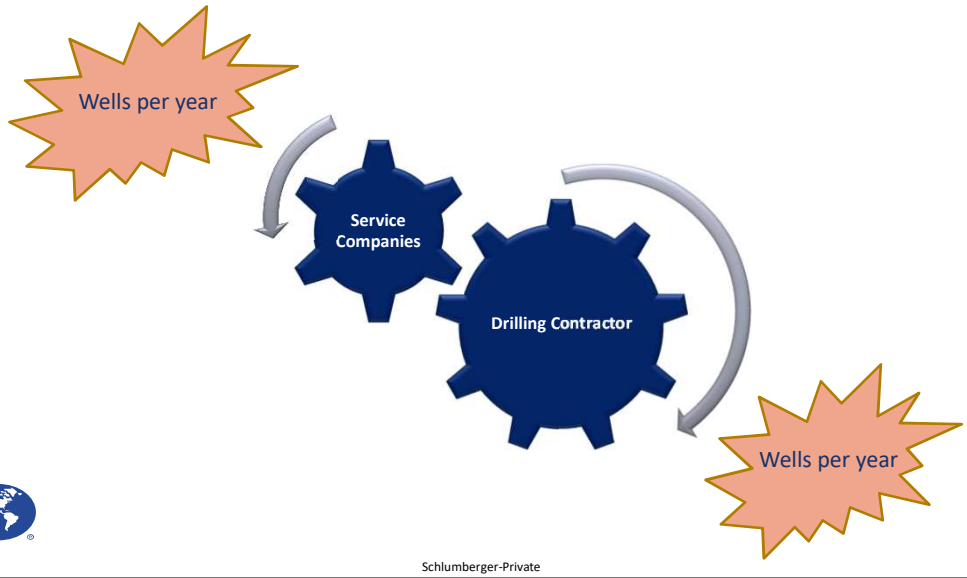
Or Change the Delivery Model



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Or Change the Delivery Model

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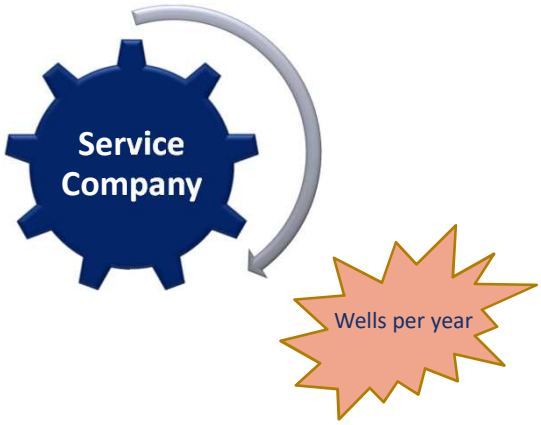
Or Change the Delivery Model



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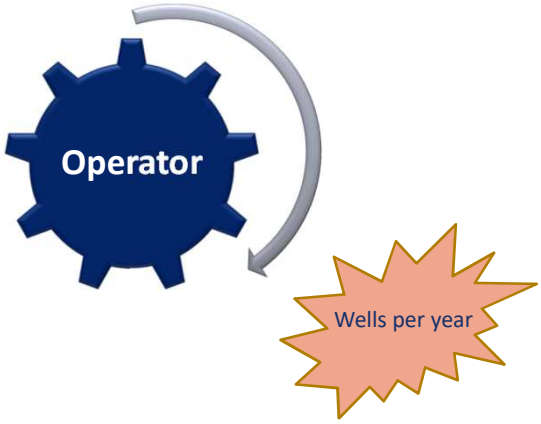
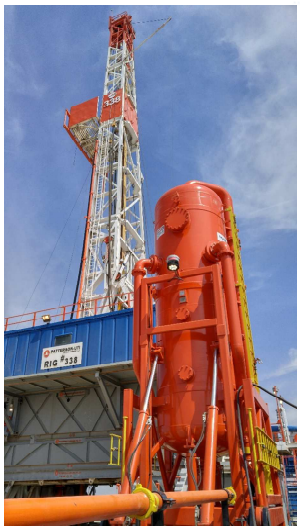


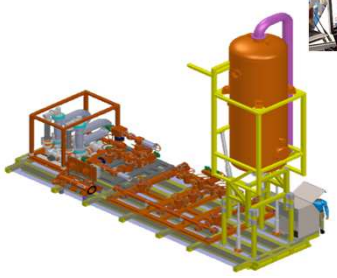
Mobile MPD

- High-efficiency mobile MPD
- Reduced Crew, Improved Asset Utilization
- Rapid Install time - 40 minutes at wellsite



MPD Enabled Rig

- Rig equipped with the necessary pressure control assets required to execute MPD
- Packages customized based on rig contractor requirements and tiered to expand as well complexity grows
- Operational service support through experts sent to rig



Webinars

Thank You for Your Attention!

Are There Any Questions?