World Oil® HPHT

DRILLING, COMPLETIONS & PRODUCTION CONFERENCE

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Introduction and Case History of an HPHT High-performance Water-based Fluid in Texas

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Introduction

- Conventional HPHT
- Development of a high-performance, HPHT water-based fluid
- Introduction and case history of a newly developed HPHT water-based fluid

Conventional HPHT Fluids Options

Mud System	Stability	Characteristics
Chrome-Lig	176°C	• Solids tolerant • Highly stable
KCl-K-Lignite	170°C	• Shale inhibition • Solids tolerant • Stable
Polymer Systems	To individual polymer limitation	• Encapsulation or coating inhibition • Low wash out • Generally clay-free
Polyol Systems		• Cloud Point manipulation at BHT with salts
Invert Emulsion Systems	Greater than 260°C	• Similar characteristics to non-HPHT NAF systems

Properties HPHT Fluids

Drilling Fluid Properties	Required Performance in HPHT Wells
Plastic viscosity (PV)	As low as reasonably possible to minimize ECD effects
Yield stress and gel	Sufficient to prevent sag, but low enough to reduce gelation or high surge and swab pressure
HPHT fluid loss	Low to prevent formation damage and risk for differential sticking
HPHT rheology	Stable and predictable
Compressibility	Known to estimate downhole pressure and ECD
Contaminate Resistance	Stable in presence of gas, brine, and cement
Gas solubility	Needed for accurate kick detection
Stability of degradation or aging	Properties that do not fluctuate under static and dynamic conditions but reality drop after dynamic and increase after static
Solids tolerant	Properties that are unresponsive to drill solids
Weighting	Ability to increase fluid density at kick recognition

Original High-performance HPHT Formulation

- Robust product line
- Performance was impeccable
- Very cost-focused

Downfall

- Viscosifier would not tolerate divalent

Customer-driven Expectations

A Water-based Alternative to Diesel Oil-based Mud
for Horizontal Production Intervals

Requirements for success:

- Match ROP, wellbore management, days on well, logging, and casing operations
- Withstand operational conditions
- Improve wellsite cuttings and waste management options
- Minimize liquid mud/transportation
- Improve HSE factors
- Address environmental responsibility and liability

HPHT Fluid Considerations

- Project-specific fluid design
  - Water
  - Non-aqueous
  - Air/Foam
- Temperature and time stability modeling
  - Density
  - Viscosity
- Cost-effective design
- Solids and hydraulics
- Contaminants
- Downhole tools
- Formation
- Compression and expansion characteristics
- Flowline temperatures

Designed From the Ground Up

Intense, in-depth R&D program and strict adherence to scientific method

- Characterize the shale
- Identify operational criteria
- Conceptualize design
- Identify components
- Examine and validate formulations for application
- Rheological & contaminant testing
- Stress system: design for most hostile conditions
- Validation: DSC testing

Conceived for Demanding Shale Applications

Application-specific design and formulation

- Non-relevant criteria received secondary focus

Contains no clays

- Temperature
- Contaminants, specifically divalent brines

Extreme HPHT tolerance

- WBM polymer and lubricant stable to 425°F (218°C)

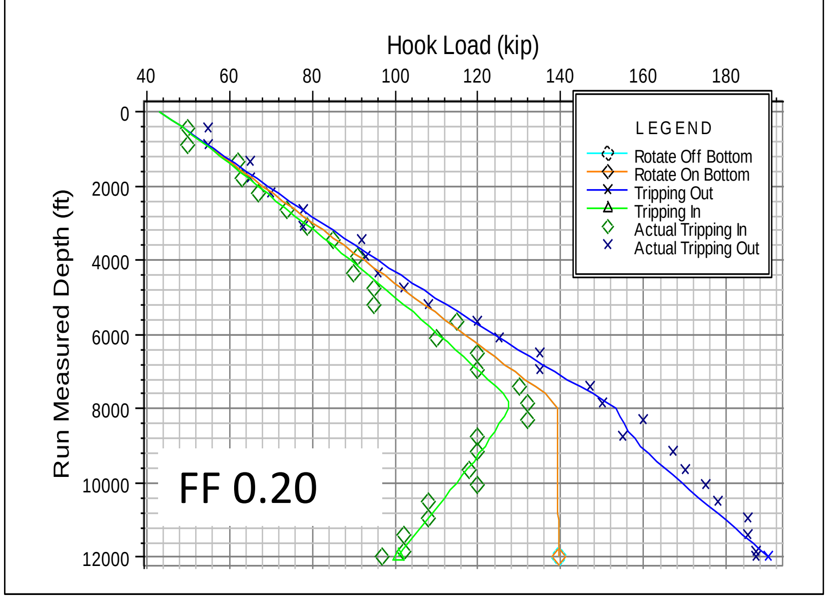
OBM-like lubricity

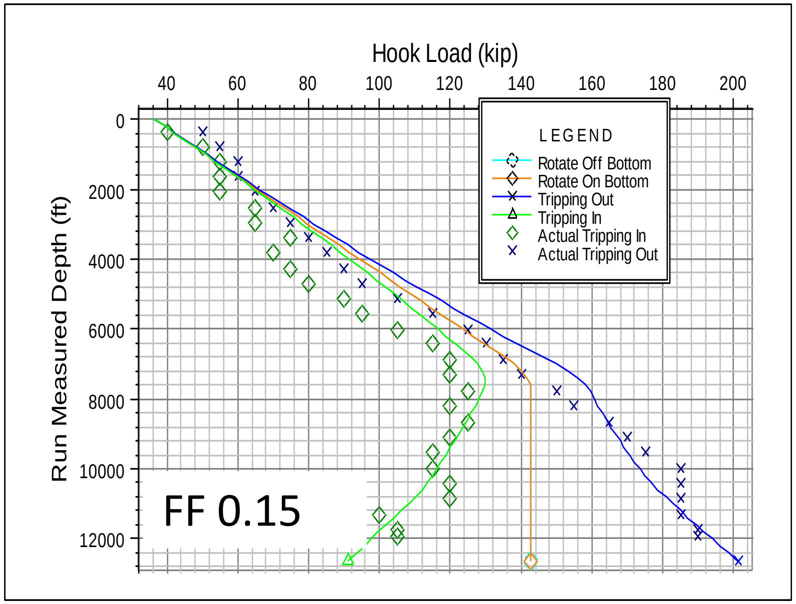
- Lubricant performance achieved with 2-4% by volume

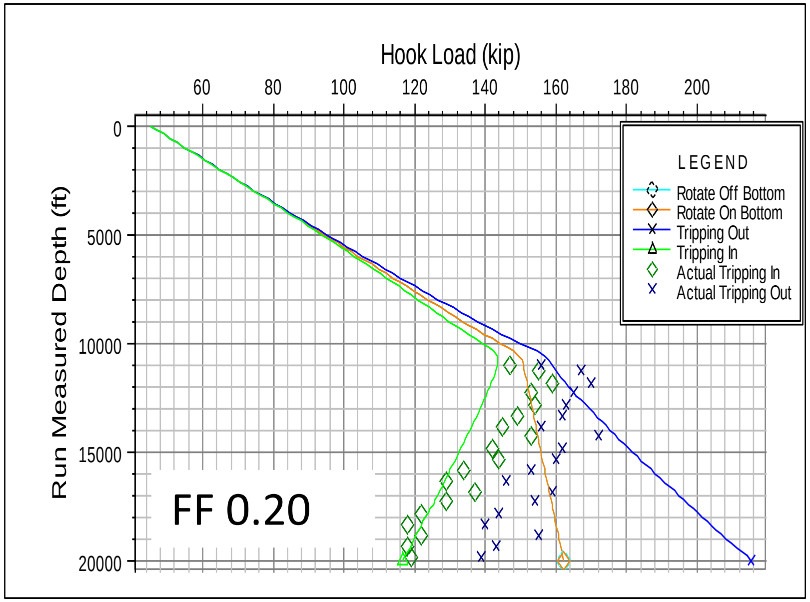
Lubricity Tester

- Block on ring test
- Simulate contact force between drill string and wellbore
- On-site measurements conducted for lubricity (CoF)
- Conventionally only used for fluid design

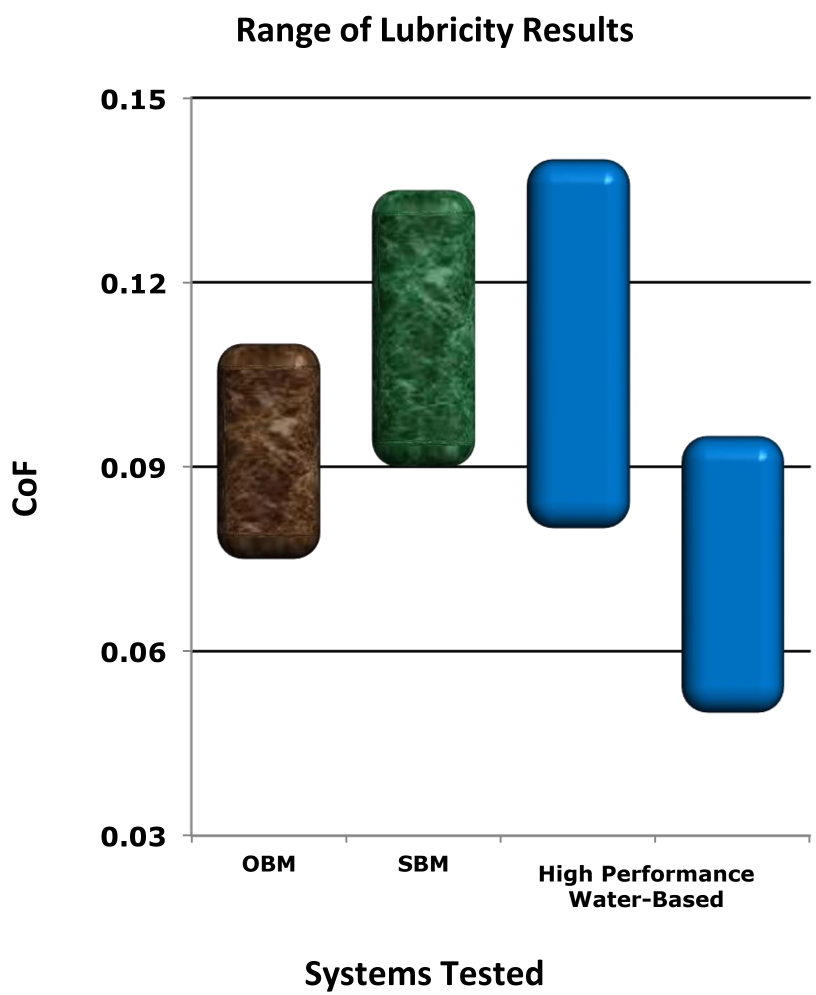
Software Generated Friction Factors







Reducing Friction



Drilling Fluid	Open Hole Friction Factor	Steel-on-steel Coefficient of Friction (CoF)
Air	0.40-0.60	
Foam water-based	0.35-0.55	
Lignosulfonate water-based	0.20-0.30	0.20-0.28
Polymer water-based	0.20-0.30	0.20-0.28
NAFs	0.15-0.20	0.07-0.13
High-performance water-based	0.10-0.30	0.04-0.10

Benefits of Using a Field Device

- Having a lubricity meter on-site allows for the ever-changing environment
- Studying the correlation and variability in torque and drag associated with casing runs allows for improved performance
- Sustained torque reduction while drilling
- Use of a high-performance, water-based drilling fluid can compare and improve results formally seen with NAFs

Design Components for an HPHT Viscosifier

Develop HPHT Polymer

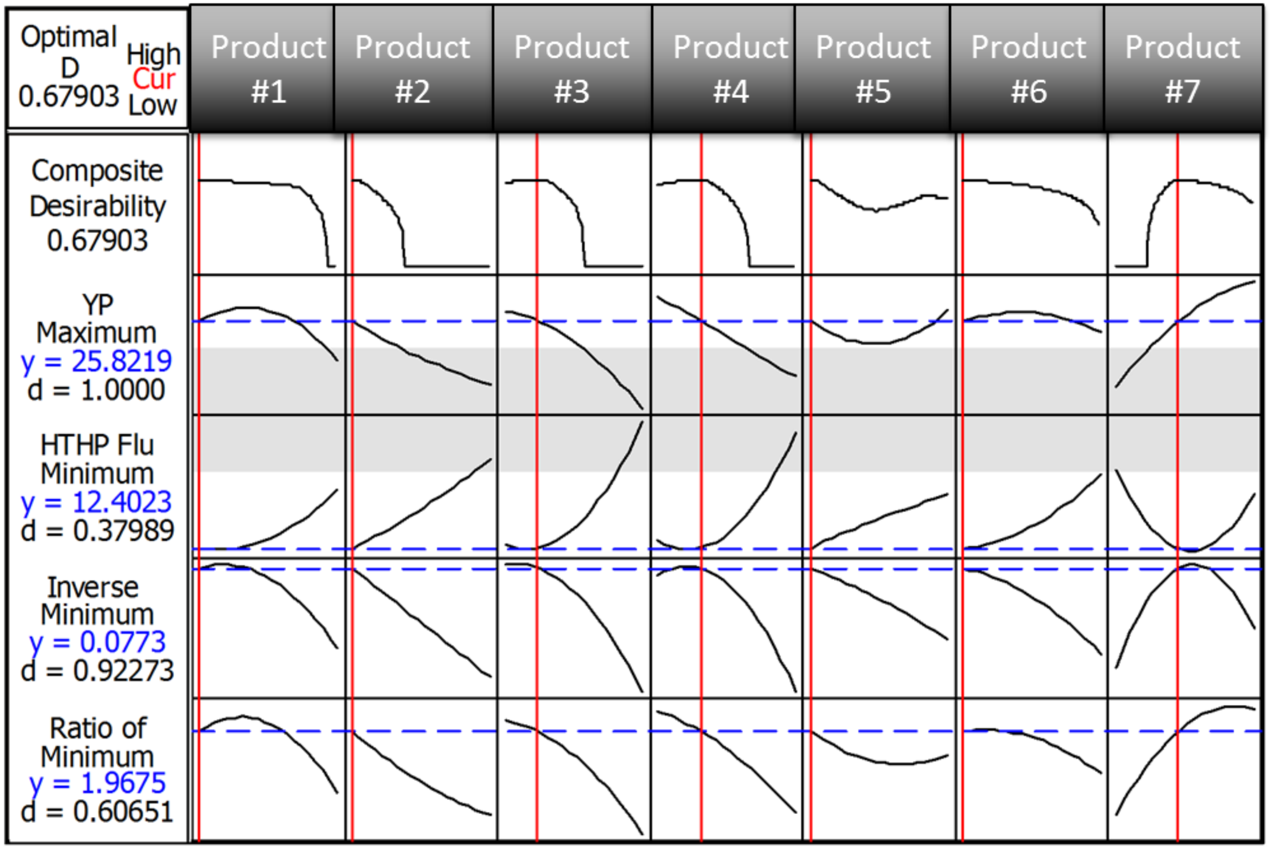
- Tolerant to brines
- Tolerant to divalent ions
- Capable of over 425°F (218°C)
- Capable of densities exceeding 18.4 ppg
- Compatible with hematite
- Match performance as seen with prior HPHT viscosifier for fresh water

Six Sigma

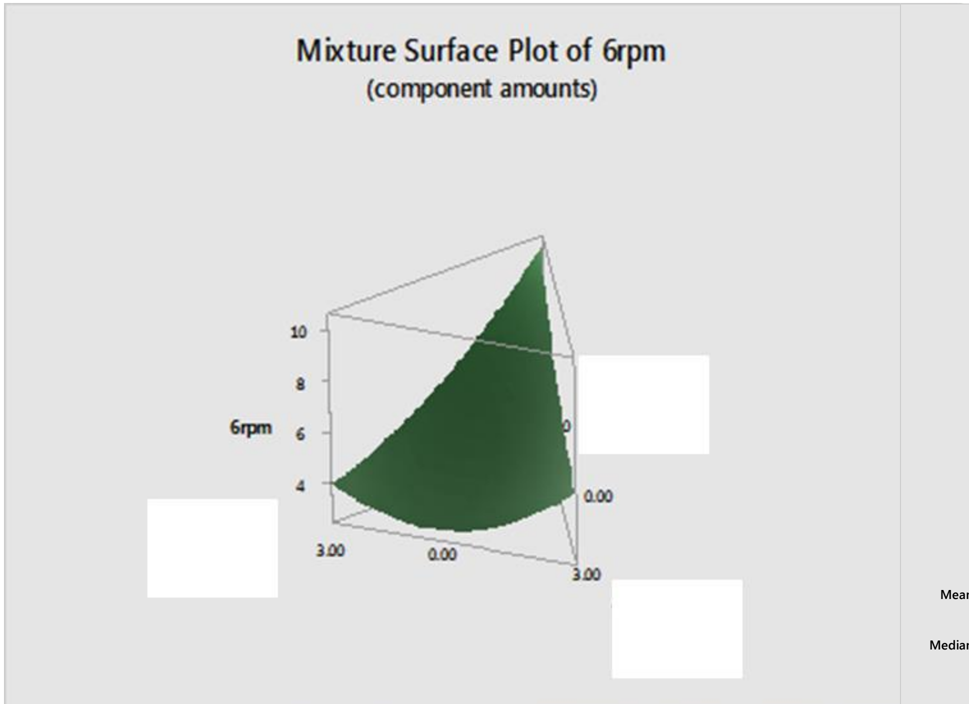
Developed using mixture study analysis

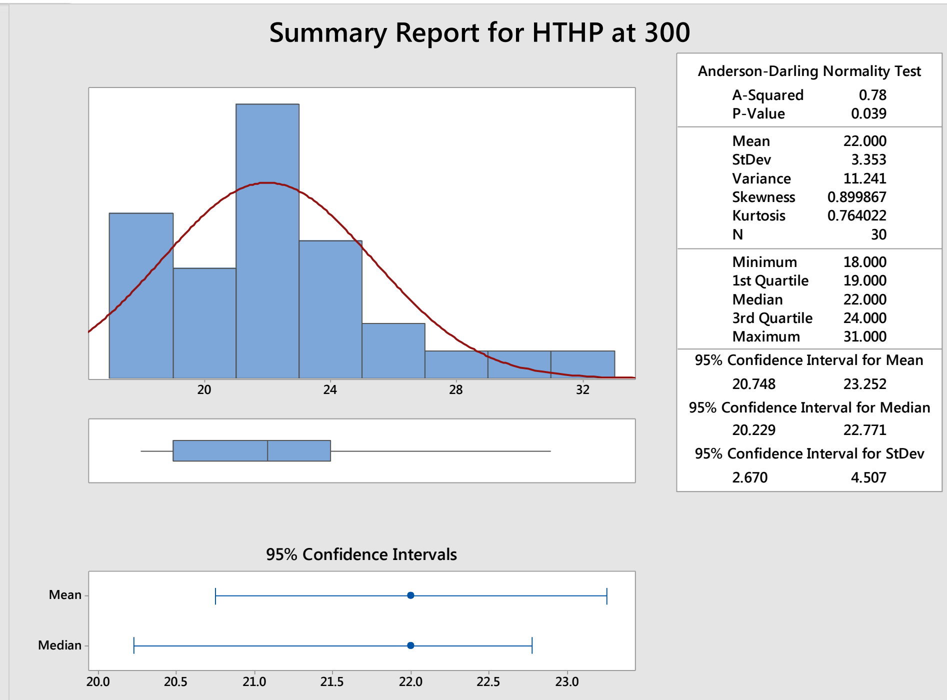
- Yield point
- Low shear rheology
- HPHT fluid loss

Design Components for an HPHT Viscosifier



Design Components for an HPHT Viscosifier





System Development

Fluids	Br 1	Br 2	FW 1	FW 2
Potassium / Sodium Chloride Brine, ml	241	-	-	-
Sodium Chloride Brine, ml	-	241	-	-
Fresh water, ml	-	-	225	218
NDFX 259, g	2.0	2.0	0.75	0.75
NDFX 258, g	2.0	2.0	0.75	0.75
EvoVis, g	-	-	1.0	1.0
EvoCon II, g	4.0	4.0	4.0	4.0
EvoLube DPE, ml	14.0	14.0	10.5	10.5
NewStabil, g	2.0	2.0	-	-
Hi-Perm, ml	-	-	7.0	-
Deep Drill, ml	-	-	-	14.0
Caustic soda, g	0.5	0.5	0.6	0.75
Barite, g	400	400	452	454
Hot Rolled 150 °F, hours	16	16	16	16
Properties at 120 °F				
600 rpm	127	136	72	147
300 rpm	80	82	42	93
200 rpm	58	60	29	67
100 rpm	35	38	16	40
6 rpm	7	8	3	6
3 rpm	5	7	2	4
10 sec gel, lb/100 ft^2	6	7	3	5
10 min gel, lb/100 ft^2	7	8	4	5
Plastic viscosity @120°F, cP	47	54	30	54
Yield point, lb/100 ft^2	33	28	12	39
API filtrate loss, ml/30 min	2.8	1.5	1.8	2.0
pH (Meter) @ 80 °F	9.7	9.6	7.9	8.9
Hot Rolled Shale Dispersion Test				
Shale Retention, percent	98.0 – 99.0	98.0 – 99.0	98.0 – 99.0	98.0 – 99.0
Shale Retention on Fresh Water, NewZan D fluid for comparison = 7.0				

Fluids Modeling

- ECD management
- Surge/Swab
- Hydraulics
- Fluid Compressibility
- PVT testing

Initial Project Summary

- Jasper County, TX
- Several into the Woodbine and Buda formations
- Mud weights were as high as 17.3 ppg
- Temperatures in excess of 400°F(204°C)

Mud Wt. Initial	**15.5 ppg**
Mud Wt. Max	17.3 ppg
Viscosity Avg.	55 sec./qt.
PV/YP Avg.	56/30
6/3 rpm Avg.	8/6
API FIL Avg.	2.5 mL/30 min
HPHT FIL Avg.	28 mL/30 min
pH	9.5 – 10.0
EvoLube®%	1.0 – 2.0
Coefficient of Friction Avg.	.14
BHT Max	306°F

Project Summary (Wildcat)

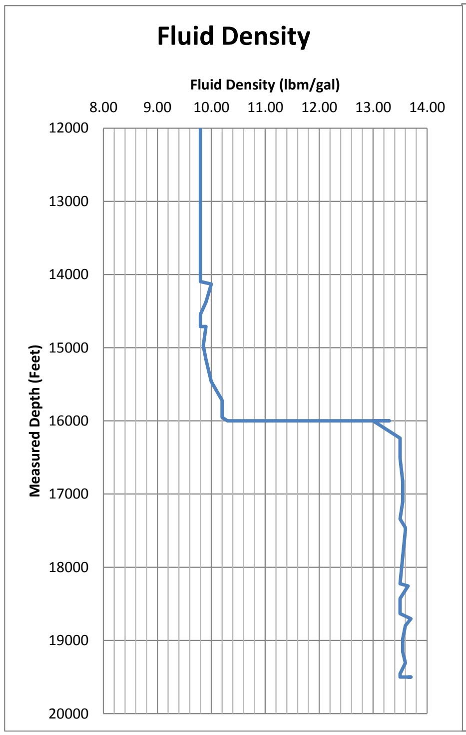
- Angelina County, TX
- Exploratory into the Cotton Valley group
- Mud weights were expected to be high
- Temperatures could be in excess of 450°F
- Prior offsets allowed for displacement of OBM to HPHT water-based formulation

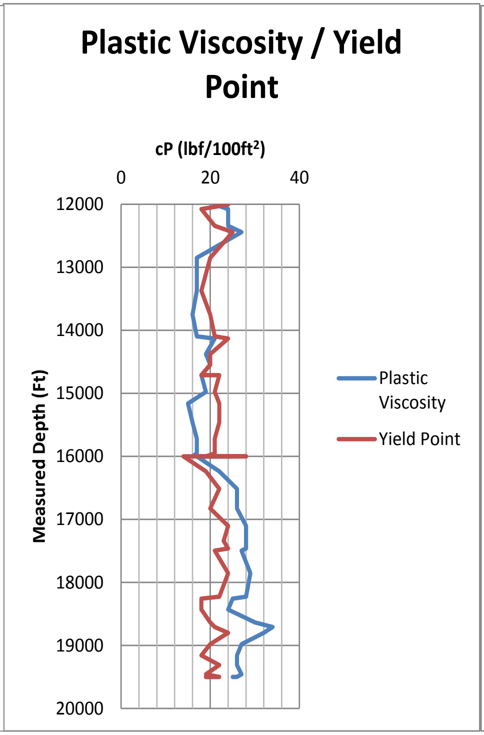
Project Summary (Wildcat)

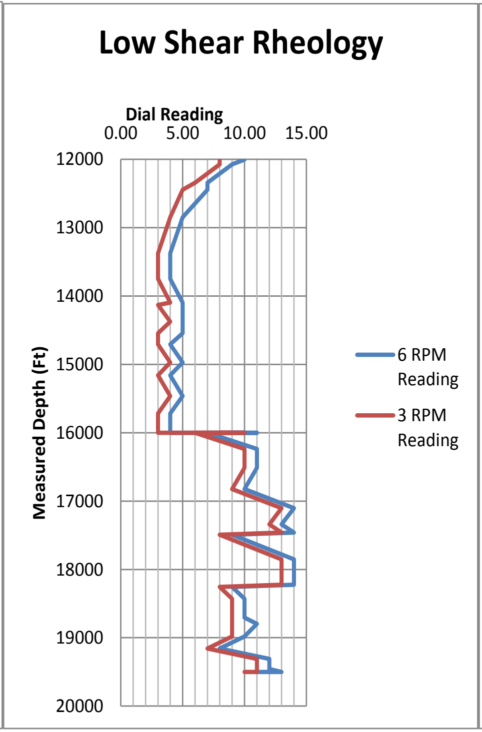
- Intermediate fluid would be similar to prior wells in Jasper County
  - This consisted of the original high-performance water-based fluid products
- Production fluid would use the new formulated system
  - The prior system would be converted using the newly formulated polymers

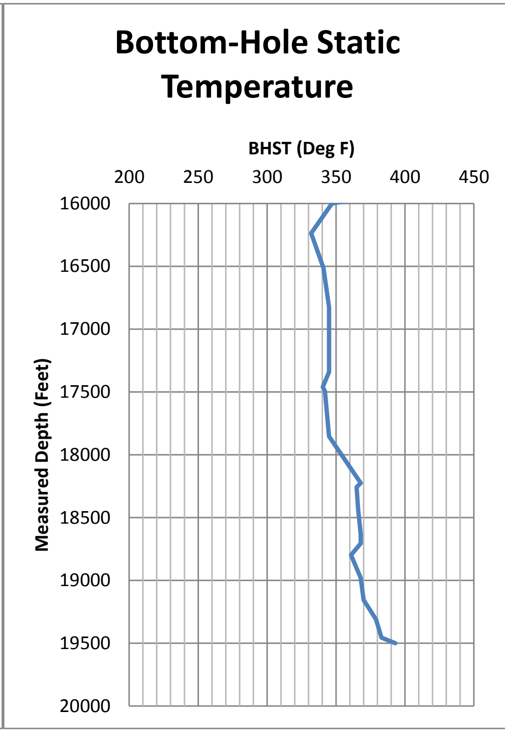
Project Summary (Wildcat)

Average Mud Properties		
Property	Intermediate	Production
Mud Weight (ppg)	9.9	13.6
PV (cp)	19	27
YP (lbf/100 ft^2)	21	21
API Fluid Loss (ml)	5.3	4.5
HPHT Fluid Loss (ml)	34.2	28.6
3/6 RPM	4/5	10/11
10 sec Gels	4	12
pH	9.8	9.7
MBT (ppbe)	5.7	8
Mud Lubricity	N/A	0.16


Fluid Density
Fluid Density (lbm/gal)
8.00 9.00 10.00 11.00 12.00 13.00 14.00
Measured Depth (Feet)
12000 13000 14000 15000 16000 17000 18000 19000 20000


Plastic Viscosity / Yield Point
cP (lbf/100ft^2)
0 20 40
Measured Depth (Ft)
12000 13000 14000 15000 16000 17000 18000 19000 20000
Plastic Viscosity
Yield Point


Low Shear Rheology
Dial Reading
0.00 5.00 10.00 15.00
Measured Depth (Ft)
12000 13000 14000 15000 16000 17000 18000 19000 20000
6 RPM Reading
3 RPM Reading


Bottom-Hole Static Temperature
BHST (Deg F)
200 250 300 350 400 450
Measured Depth (Feet)
16000 16500 17000 17500 18000 18500 19000 19500 20000

Conclusion

- Implementing lessons learned from a successful HPHT water-based fluid into a new system to handle wellbore contaminants
- Six Sigma evaluations of new products
- Successful case history in Angelina County, TX