Rheology : A Key Parameter for Plug Milling Efficiency

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Agenda

- Completion Practices in North America
- Coiled Tubing Milling & Cleanouts
  - Challenges
  - Current Practices
- Role of Fluid Rheology
- Case Histories
- Conclusions
- Questions

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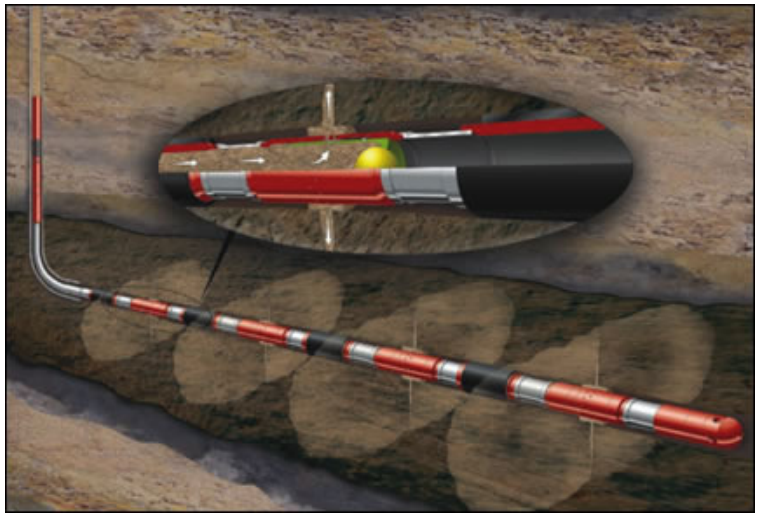
Completion Practices

- ***Composite Bridge Plugs***
  - Completion and stimulation flexibility
  - Cemented casing/liner
  - Verified method
  - Perforating and milling cost
  - Longer stimulation time

- ***Multistage Fracture Sleeve***
  - Multiple stages
  - Continuous stimulation
  - No cemented liner required
  - Restricted wellbore access for re-frac
  - Completion intervals pre-planned



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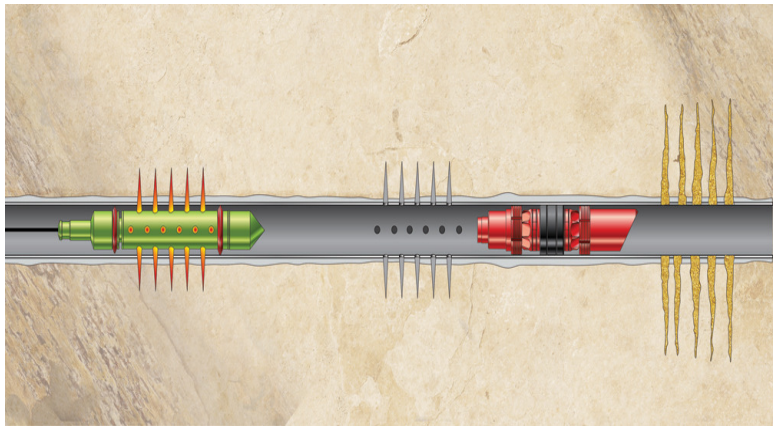
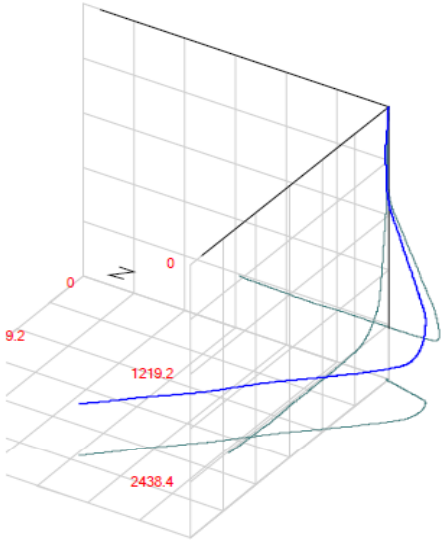
The Need To Mill

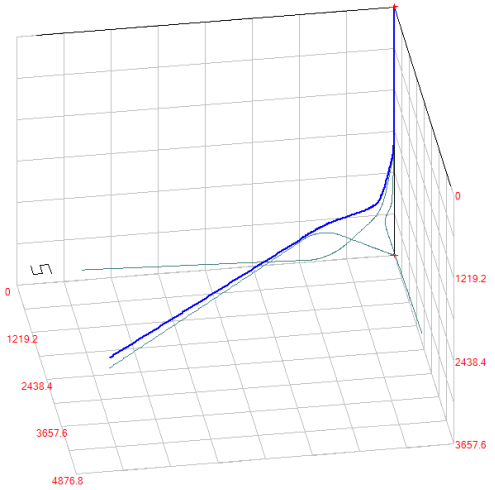
- Bridge plugs MUST be removed to start production
- Frac Sleeves may stay in hole but balls must flow back
- Frac balls wedge into seats – can take as much as 1000 psi differential to remove
- Each seat acts as a down hole choke – not significant if only 3-5 stages…
- … but what if there are 40 stages?
- Can cause significant production impairment (SPE 138322)



Intervention Challenges

- Long Laterals with TD exceeding 5000m.
- Complex well trajectories.
- Sour environment.
- HPHT.
- Ever increasing number of stages.
- Plug / seat / ball materials.





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Coiled Tubing Milling

Objectives

- Reach the desired depth
- Mill all plugs
- Circulate out all cuttings to surface
- Leave a clean hole

Challenges

- Lock up
- Insufficient WOB
- Variable cuttings size
- Sand, Metal, rubber etc.
- Higher Pump Rates
- Higher HP requirement
- Coiled Tubing Size
- Coiled Tubing Fatigue…

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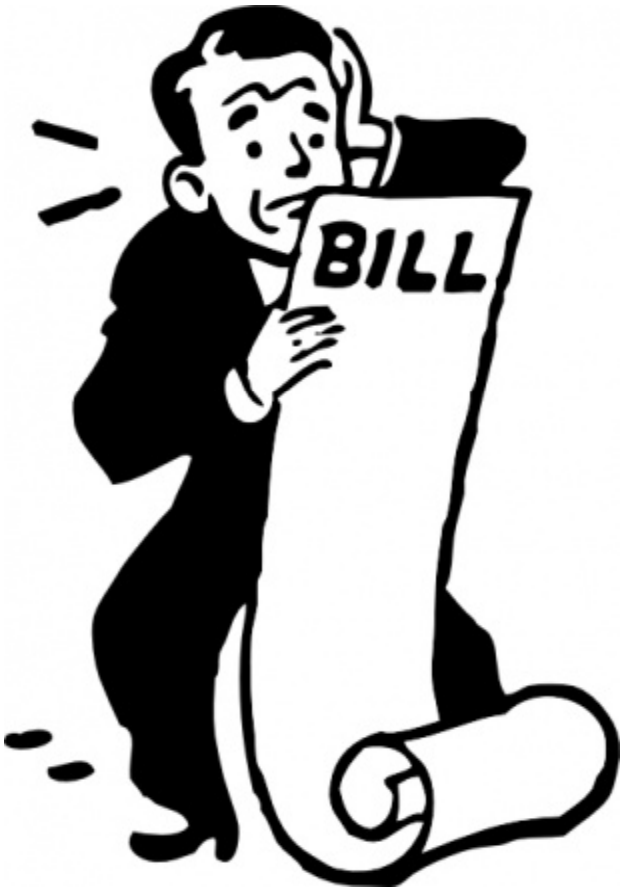
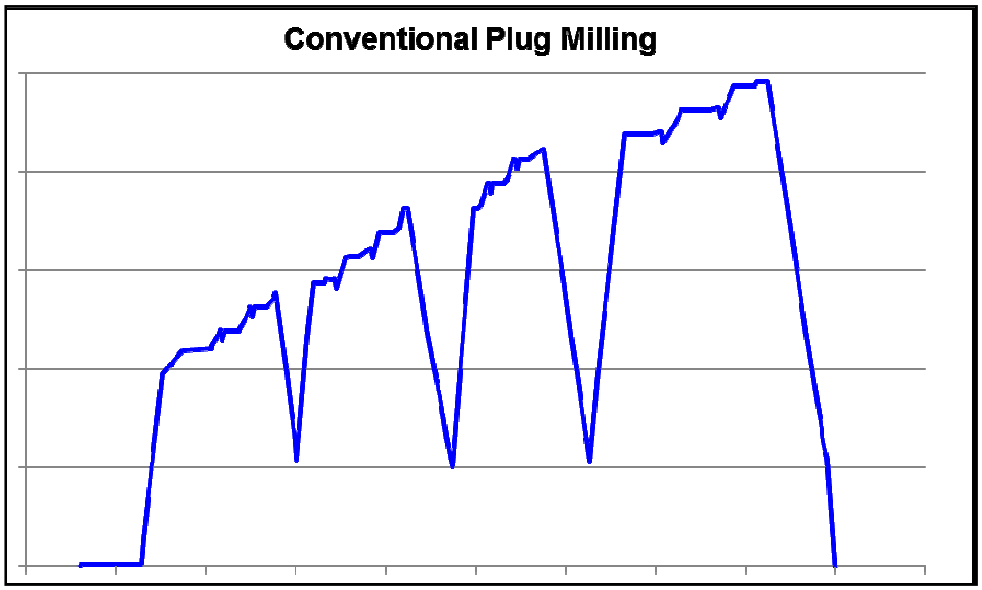
Project Economics



- TIME
- Fluids
- Tools
- Coil Size
- Coil Life
- HP

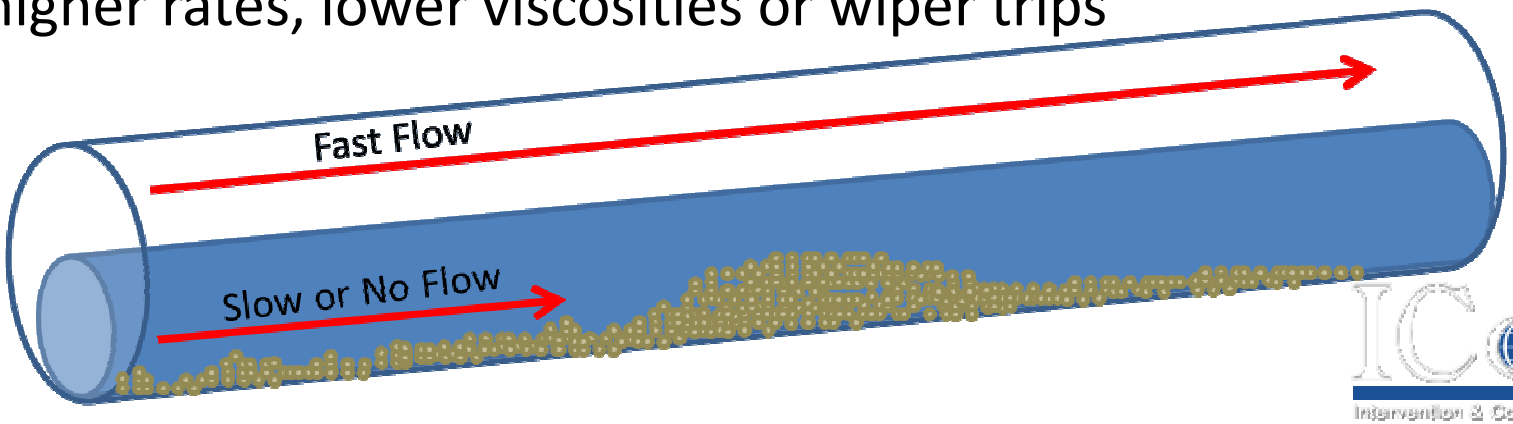
Current Practices

- Pump FR to reduce friction pressure.
- Pump gel sweeps to carry cuttings.
- Perform wiper trips every 2-4 plugs milled to transport solids to vertical
- Stuck Pipes
- Insufficient hole cleaning.
- Subsequent venturi runs.



Are we REALLY doing it right?

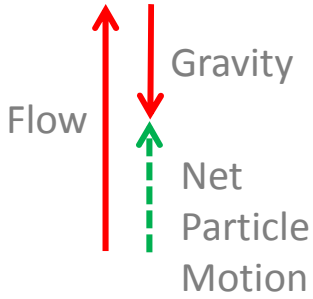
- Current practices came from vertical wells and drilling rig techniques
- In horizontals, solids settle out no matter WHAT is pumped
- Higher pump rates and pipe rotation allow rigs to re-entrain solids
- CT does not rotate, need turbulence to re-entrain solids: higher rates, lower viscosities or wiper trips



Understanding Solids Transportation

Vertical Section

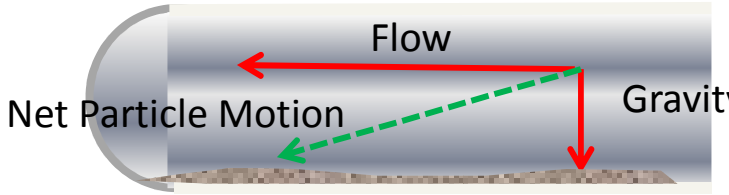
- Increased viscosity helps
- Laminar flow acceptable



In the vertical, flow is parallel to gravity so particles are continuously re-entrained.

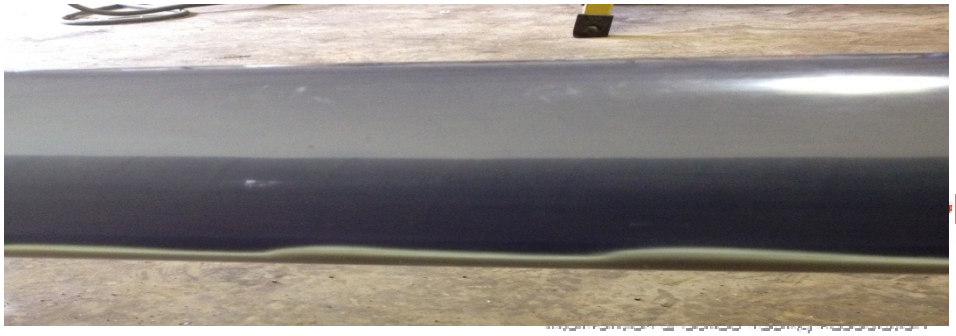
Horizontal Section

- Increased <u>viscosity hurts</u>
- Laminar flow drops solids to low side of liner
- High velocity and low viscosity allows turbulence
  Particles settle out quickly without turbulence



Dunes are created by improper fluid rheology

Water at 500 lpm erodes the dune at 2 m/min.
Gel does NOTHING!



Optimizing Rheology

Water

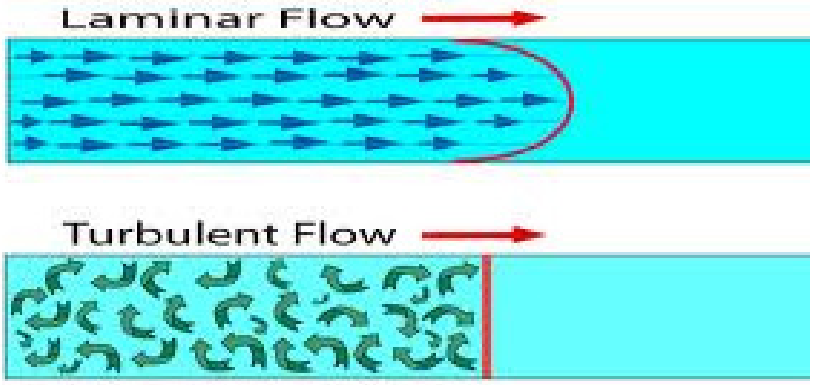
- Low viscosity fluid (~1 cP)

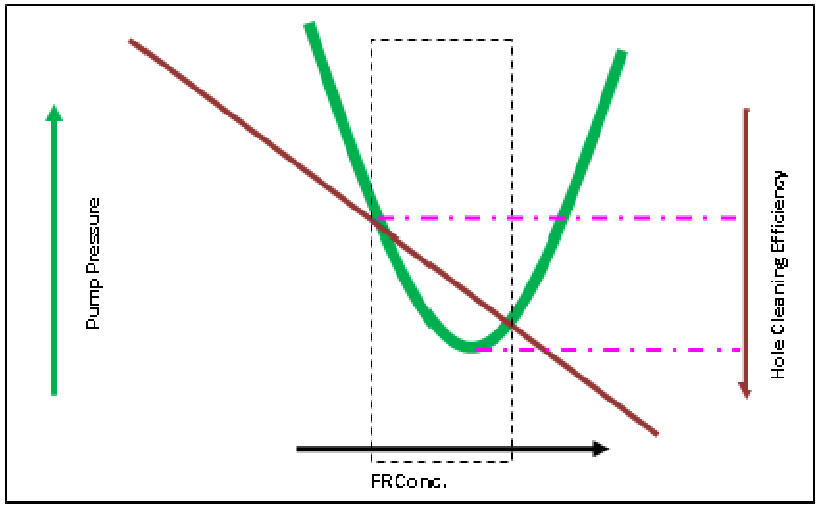
Friction Reducers

- Long chain polymers
- Low viscosity (~2-5 cP)
- Designed to suppress turbulence at the tubing wall only

Gels

- Guar based polymer linear gel
- High viscosity (~20-60 cP)
- Designed to keep solids entrained, difficult to pump into the turbulent flow regime
- Degrades with temperature





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Rheology Control System

- Proprietary System comprising of:
  - Patented Inline Mixers
  - Patented Dual Flow Loops
  - Chemicals
  - Real time monitoring and optimization of fluid rheology.

Rheology Control System

- Addresses major concerns about coiled tubing operations
- Consistency in pressure control
- Optimization of chemical usage
- Optimization of Rheological metrics for debris removal
- Adaptability and Flexibility without compromising accuracy
- Trained Fluid Engineers on site.

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NO GEL USED

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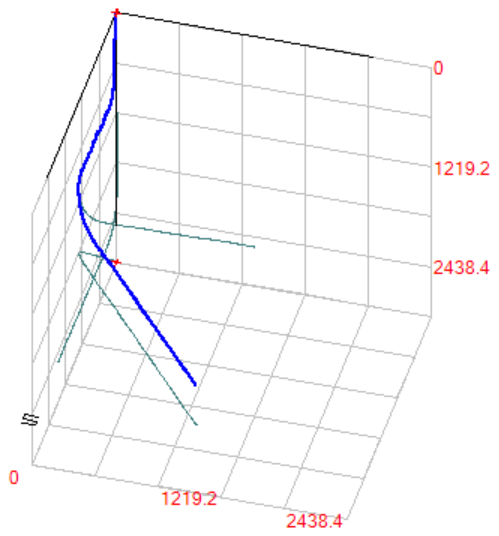
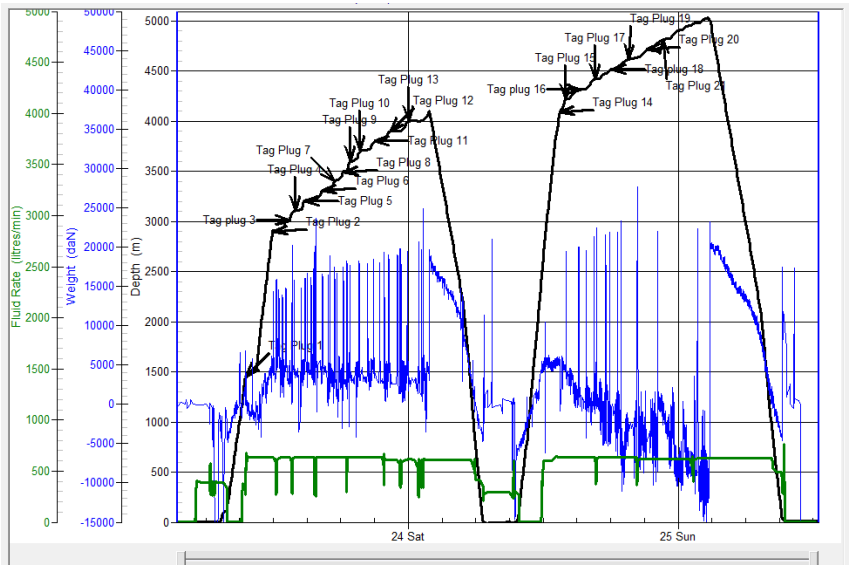
Case History 1

- TD>5200mKB; TD/TVD>2
- 139.7mm Casing w/20 Plugs
- 60.3mm CT
- 73mm BHA
- 2 Runs
- As little as 29mins spent per plug





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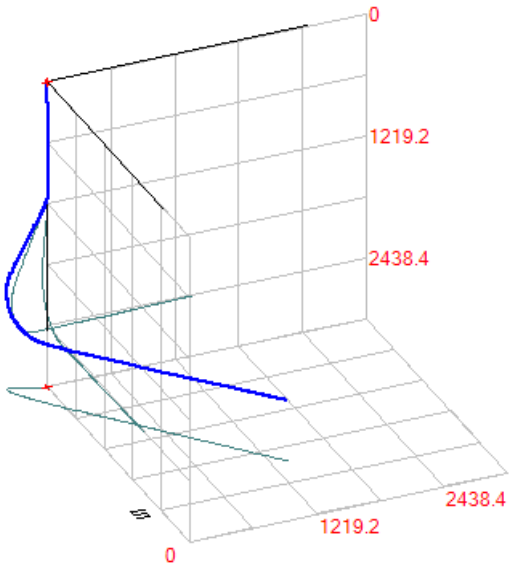
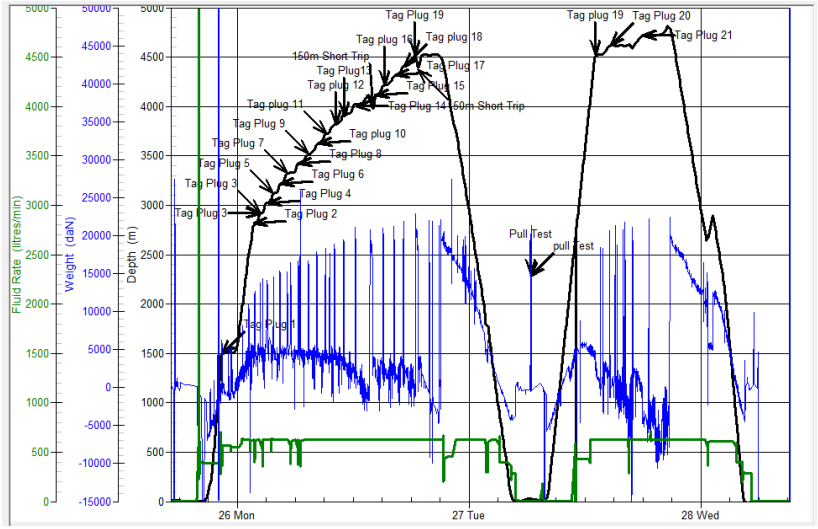
Case History 2



- TD>5100mKB; TD/TVD>2
- 139.7mm Casing w/21 Plugs
- 60.3mm CT
- 73mm BHA
- 2 Runs
- As little as 31mins per plug
- Motor failure after Plug 18



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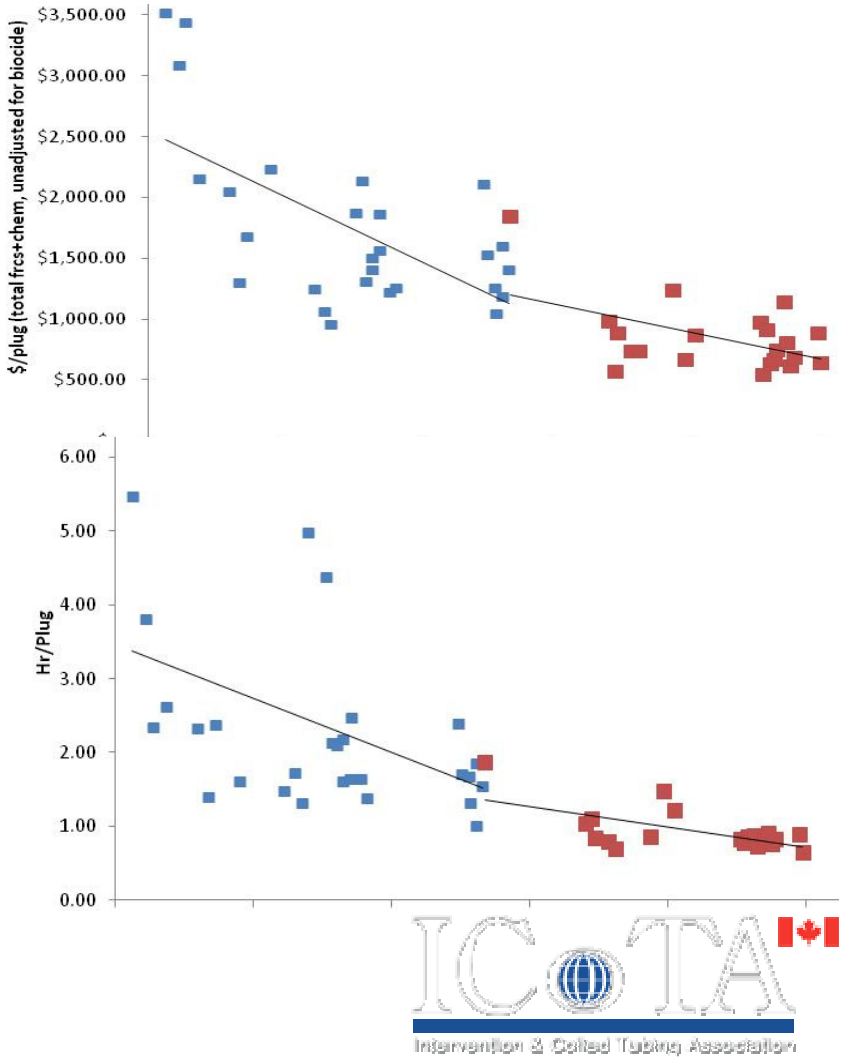
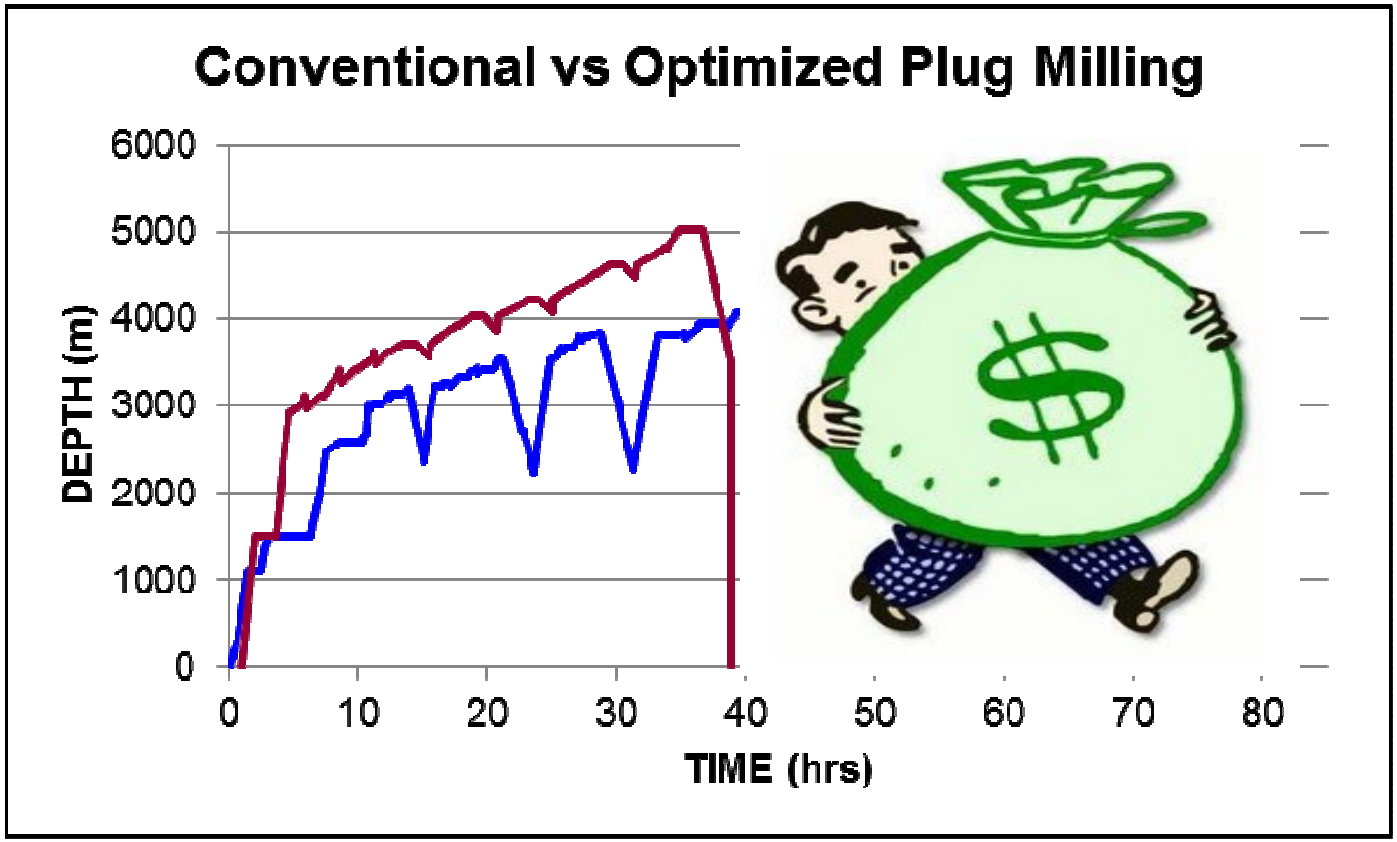
And More…

- >60% reduction in cost per plug
- 50-70% reduction in drill time per plug
- 50-70% reduction in chemical usage
- Improved solids transportation



Conclusion



Summary

OPTIMIZE **Rheology**

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THANK YOU

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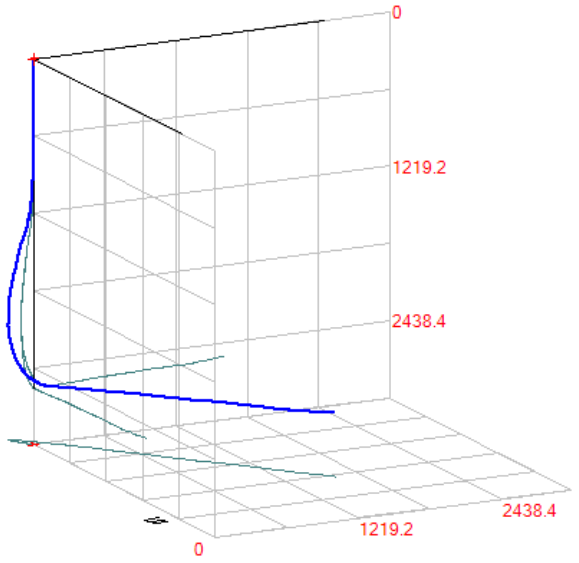
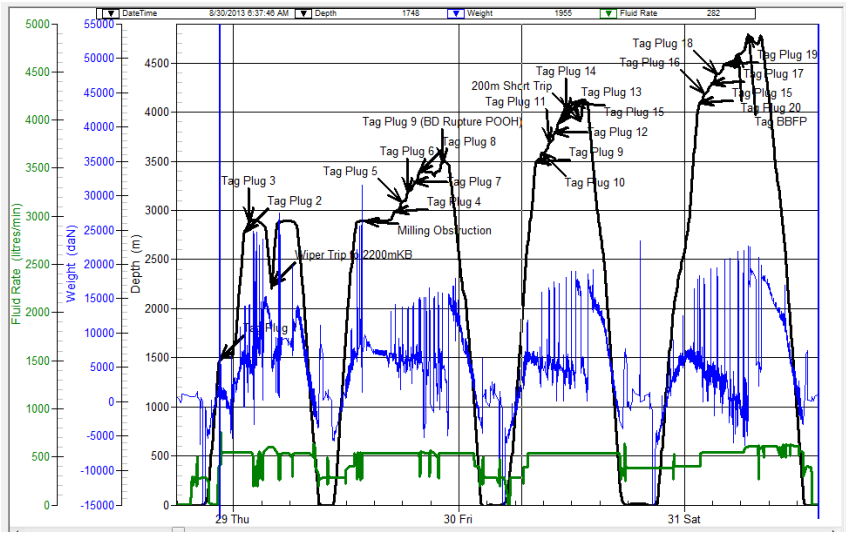
Case History



- TD>5100mKB; TD/TVD>2
- 139.7mm Casing w/20 Plugs
- 60.3mm CT
- 88.9mm BHA
- 4 Runs
- Avg. 63mins spent per plug
- BD vs. Ported Sub.



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