Lost Circulation – Toolbox for Systematic NPT Reduction

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Agenda

- Background
- Solutions Toolbox
  - Selection Criteria
  - Lost Circulation Scenarios
  - Modes of Operation
  - Well Design
  - Managed Pressure Drilling
  - Casing Drilling
  - Specialty Drilling Fluids
  - Wellbore Strengthening
  - Conventional LCM Treatments
  - Novel LCM Treatments
  - Data Science Tools
- Conclusions

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Current Industry Trends?

Cost Discipline

- Drill "Advantaged Oil" Fields
- Leverage Commodity Market
- Reduce R&D Spending

Data Science

- Transform Operations
- Drive Efficiencies
- Minimize Risk
- Optimize Production & Reserves

ESG Awareness

- Geo-thermal
- Department of Energy
- More Regulations
- Sustainable Products

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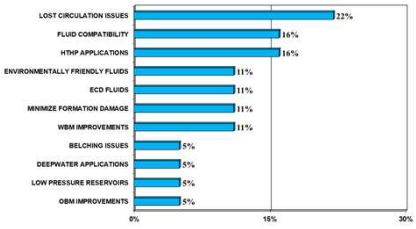
Background

- **Lost Circulation: the loss of whole fluid into a subterranean rock while drilling, cementing, completing or running tubulars in a well**
- **Lost Circulation Materials (LCM) are not covered under API 13A standards**
- **LCMs have different HSE profiles**



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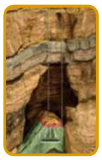
Lost Circulation Scenarios


Matrix Permeability


Natural Fractures


Induced Fractures


Faults


Vugs & Caverns

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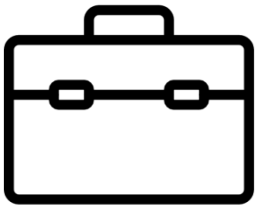
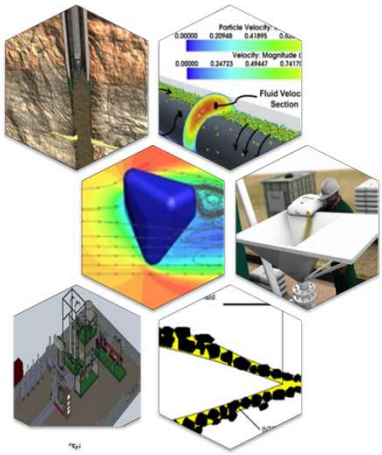
Lost Circulation Solutions Toolbox





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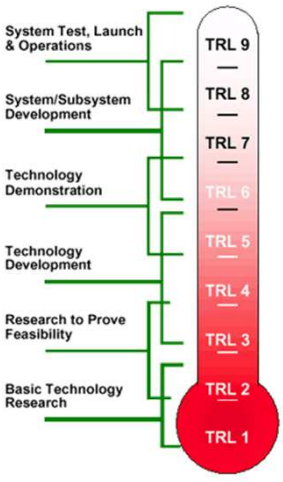
Tool Selection Criteria

Successful technology implementation requires an understanding of:

- Lost Circulation Scenario Identification
  - Depth
  - Scenario
- Mode of operation (Maximize)
- Advantages (Exploit)
- Limitations (Minimize)

Fit for Service ≠ Fit for Use



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Complexity Matrix

Zone	Complexity	Impact On cost	Impact on time	Use of High Fluid loss pills	Environmental Considerations	Temperature limitations of reactive pills
Shallow	Low	Low	Low	Unlikely (no BOP)	High	Low temp considerations, need catalysts
Medium	Medium	Medium	Medium	Likely , limited squeeze pressures	Medium	No special considerations
Deep	Medium-high	Medium-high	Medium-high	Likely	Medium	No special considerations
Ultra Deep	high	high	High	Likely	Low-Medium	Need of retarders

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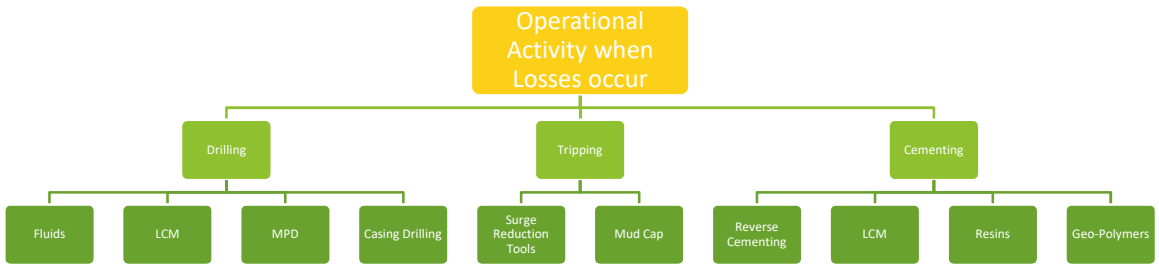
Mode of Operation



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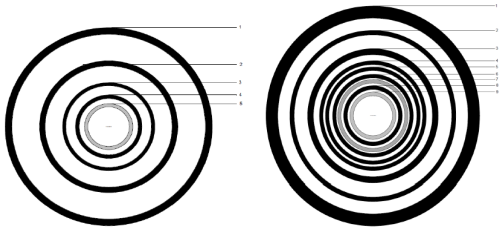
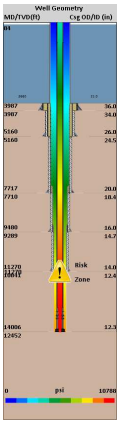
Well Design

Well Design

Comparison of 1990s casing design to current deep well design



Digital Twin



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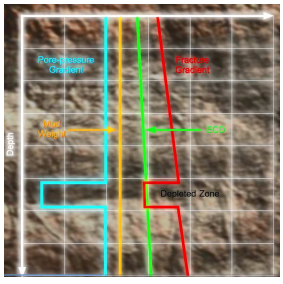
Managed Pressure Drilling

Advantages

- Stuck pipe reduction
- Minimal changes to fluid properties (density mainly)
- Constant BHP
- Multiple techniques by multiple service companies



Limitations

- Short life of Rotating Control Device seals
- The need for conventional methods for tripping and cementing (few wells trip or cement using MPD)
- Not all Lost Circulation prone wells are MPD candidates
- Needs a Mud Weight Window to operate within (not the case if FG is exceeded)
- Multiple techniques by multiple service companies

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Casing/Liner Drilling

Advantages

- Time savings
- Minimizing losses
- Similar technique across the industry
- Less cuttings amount

Limitations

- Total RPM count
- Limited BHA options
- "Smear" effect doesn't always happen.
- Premature set of Liner Hanger (rare)
- Limited annular clearances
- Potential for sag (low AV above liner)
- Fine LGS buildup

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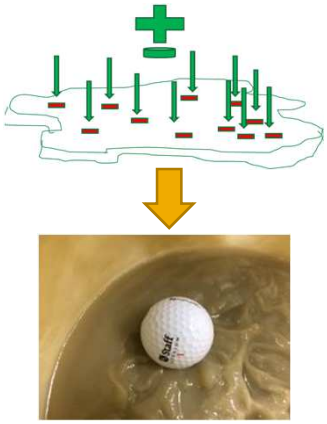
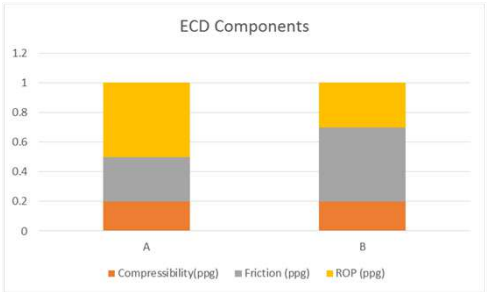
Specialty Drilling Fluids

Water-Based MMO



Non Aqueous Low ECD



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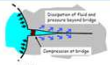
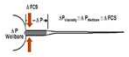
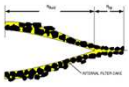
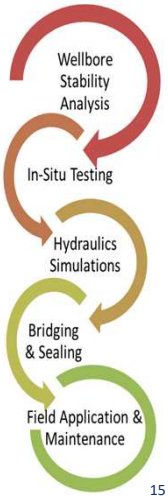
Wellbore Strengthening

Method	Material Type Important?	Material Size Important?	Rock Stress	Location of Seal
Stress Cage (2004)	Yes	Yes	Increases	
Fracture Closure Stress (2005)	No	No	Increases	
Fracture Propagation Resistance (2009)	Yes	Yes	Not Changing	



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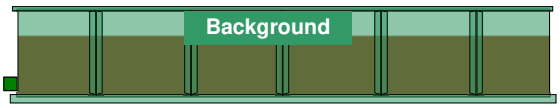
Wellbore Strengthening Material Application

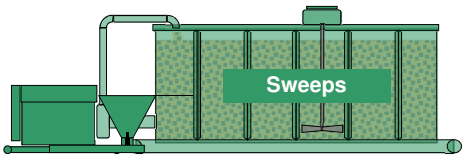
Background

- If particles are relatively small
- Save Rig Time



Sweeps

- If particles are relatively large
- More Rig Time



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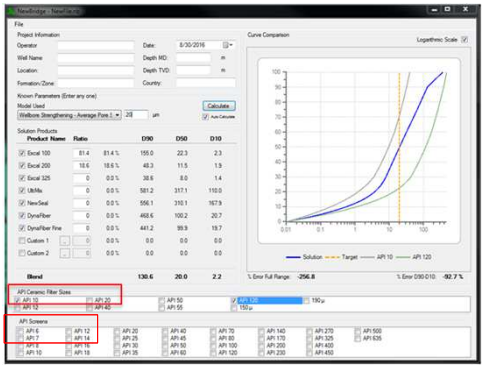
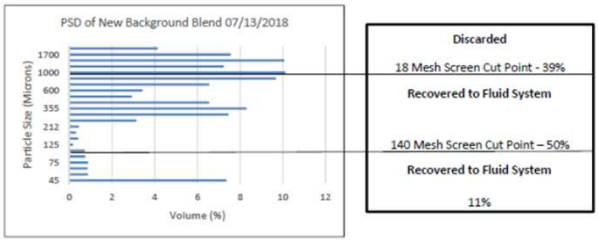
Conventional LCM Treatments





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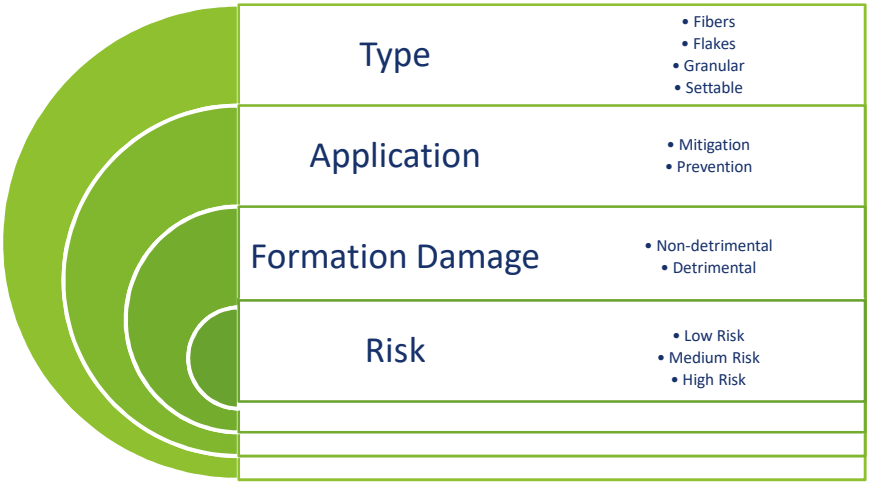
Lost Circulation Material Classification



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Deployment Constraints

On Surface

- Pump Suction and Discharge Screens
- Surface Drill Pipe Filtering Screen

Down-hole

- Downhole Filter Screens
- Under-reamer Screens
- MWD/LWD Screens
- Mud Motor/Rotary Steerable
- Bit Nozzles

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WBS Application – Decision Matrix

Loss Zone Characterization	Loss Rate	50-100 bbl/hr			
	Loss Mechanism	Dynamic		Static	
	Loss Zone	Known	Unknown	Known	Unknown
Application Best Practices	Carrier Fluids	Base Oil/Water/Drilling Fluid		Base Oil/Water/Drilling Fluid	
	Bypass Sub / Through Bit	Through Bit (verify with downhole tools provider)		Bypass Sub (verify with downhole tools provider)	
	Product Treatment Level (lb/bbl)	Product A Product B Product C	14 ppb 16 ppb 20 ppb	Product A Product B Product C Product D	14 ppb 16 ppb 20 ppb 20 ppb
	Application Method	Spot Pill	Sweep	Spot Pill	Sweep
	Placement Method	Pump then pull		Pump then pull	

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Novel LCM Treatments

- Settable Water-Based Fluids
  - Polysaccharides
  - Di-valent Mixed Metal Oxide
- Settable Non-Aqueous Fluids
  - Expandable Silicates
  - Geo-Polymers
- Novel Solutions
  - Resins
  - Synthetic Fibers
  - Eutectic Metals
  - Shape Memory Polymers
  - Nano-technology based additives

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Settable Fluids Typical Design Criteria

- **Gelation Progression**
- **Time (mixing, pumping, spotting and curing)**
- **Density (pill, base fluid, pill components)**
- **Temperature (BHCT, BHST)**
- **Volume (Dead Volume, Loss Zone, Loss rate)**
- **These criteria will affect the amount of polymer, retarder and cross-linker to mix.**

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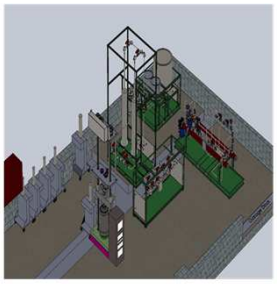
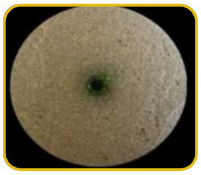
Lab Testing

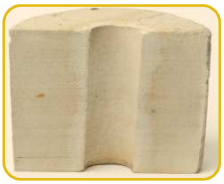


Unidirectional flow

Radial flow

Radial flow/Tri-axial stress





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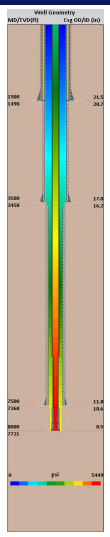
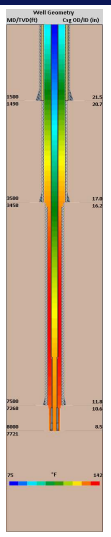
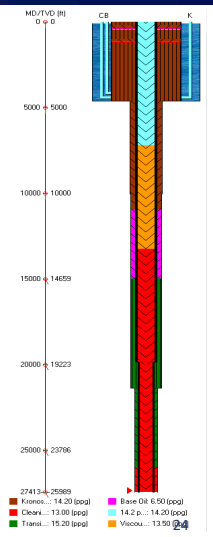
The Role of Software Modeling

- Pressure Prediction
  - U-Tube effect
  - Proper Placement
- Temperature Prediction
  - Set Time
- Pill Displacement
  - Contamination concerns







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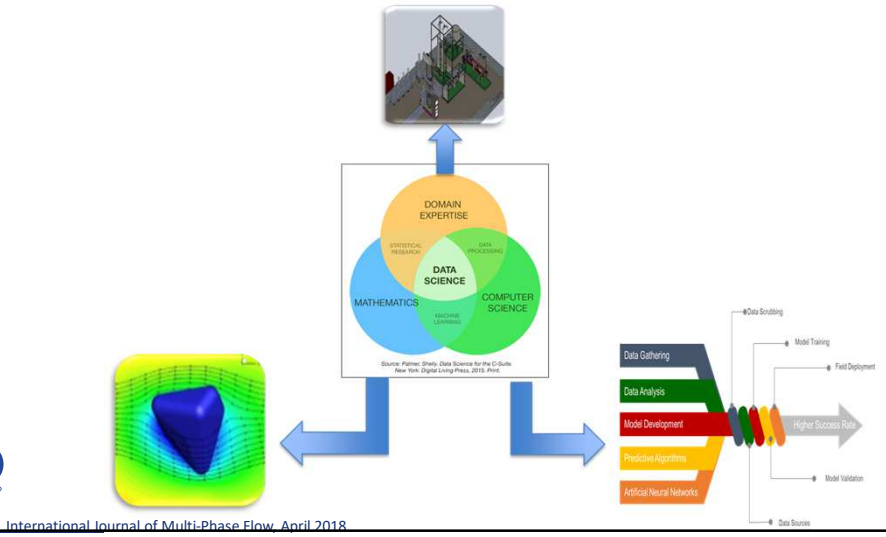
Data Science Tools



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Technology Deployment via Field Trials

- Define IP
- Define What Success looks like
- Define what is being tested
- Define Reporting Format, Authority, etc.
- Vendor and operator need to have the same technical objectives
- Field trials involve multiple disciplines which may not have been involved in development.
- Well objectives and operational constraints conflict with field testing.

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Conclusion

- There are many “Tools” at the drillers disposal to use to manage lost circulation instances.
- Most Lost Circulation instances require more than one “Tool”
- Data Science can help detect, notify and select appropriate solutions

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Q&A

Thank You!

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