

HOUSTON CHAPTER

*"The Industry forum for  
Drilling practices and technology"*



# Settable Fluids Work!

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# Agenda

1. Introduction
  2. Theory
  3. Components
  4. Design Criteria & Mechanical Properties
  5. Limitations
  6. Lab Testing
  7. Field Considerations
  8. Applications
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- A faint, dark blue background image of an offshore oil rig is visible behind the text. The rig is a complex structure with multiple towers and platforms, situated in the middle of the ocean. The overall color scheme of the slide is a gradient of dark blue.

# History

- **Cement**
  - Similar to Drilling Fluids in properties and additives, however, it sets by hydration and the reaction is controlled by retarders and accelerators
- **Gunk (and Reverse Gunk)**
  - Blends of clay and NAF (or organo clay and water) which, when mixed with WBM in the thief zone (or NAF), forms an impermeable plug which seals off the borehole

**Tires, Pharmaceuticals (drug coatings, acid soluble), etc...**

# Concept

- Generally, cationic (+ve charged) cross-linkers bridge or cross-link anionic (-ve charged) polymers
- Other chemistries exist (Borates, -ve charged cross-linker)
- Different polymers have different cross-linking sites
- Retarders slow the rate of cross-linking, while accelerators alter the environment (pH, temperature, salinity) to promote cross-linking



Linear

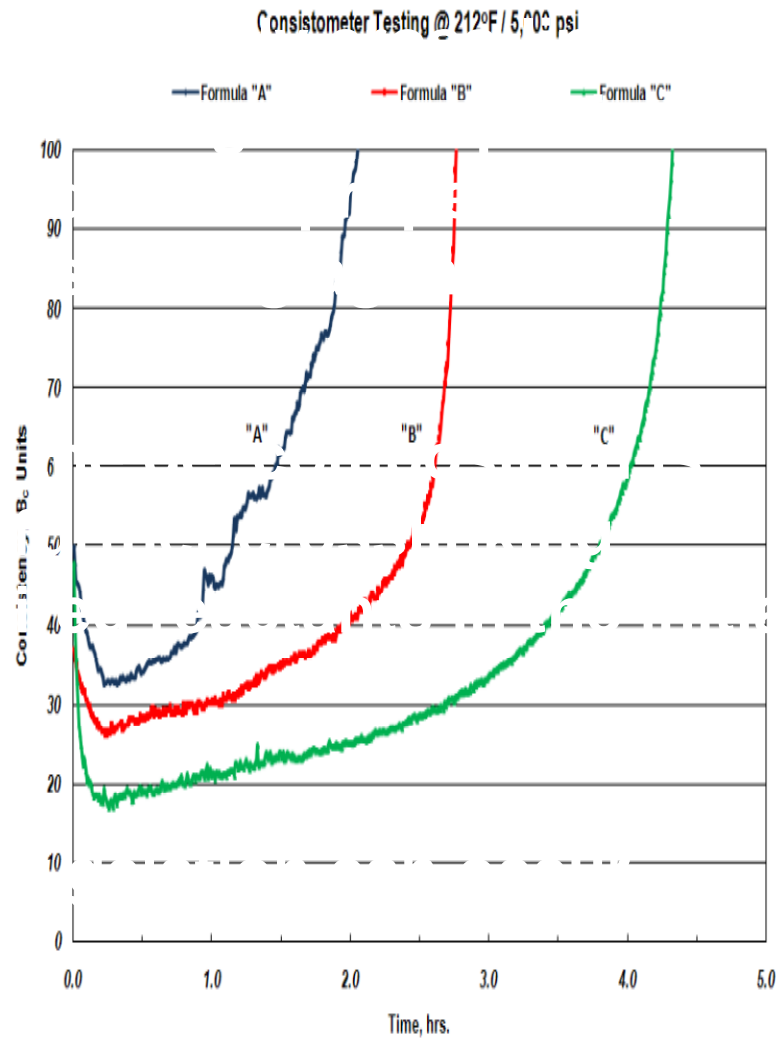
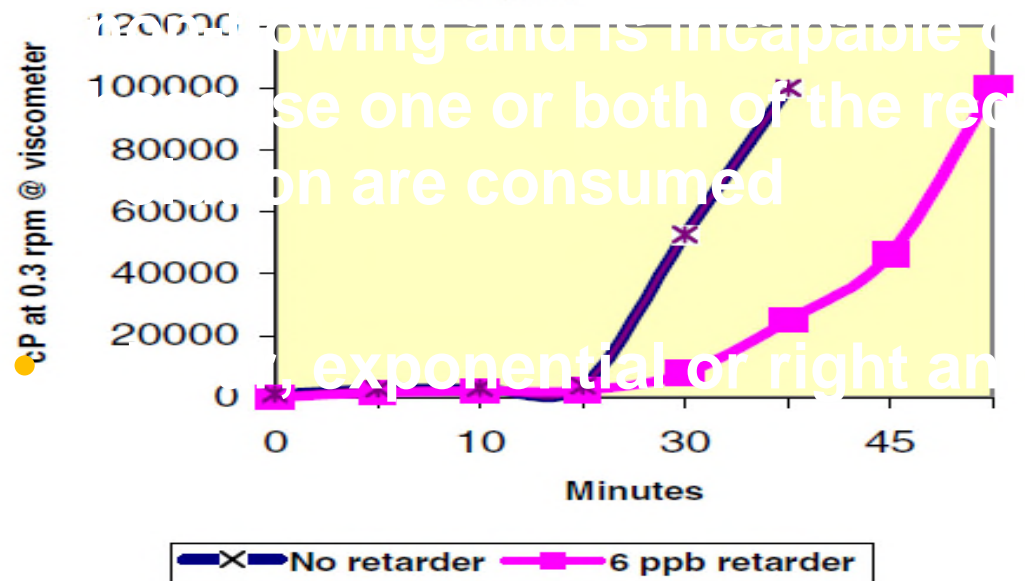
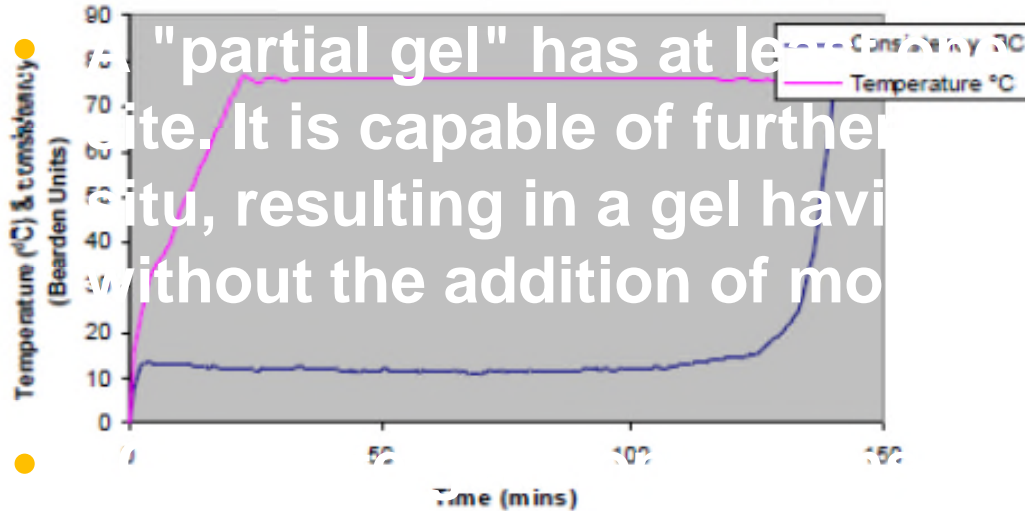


Branched



Crosslinked

# Gelation Stages



"partial gel" has at least 70 Bearden units. It is capable of further gelation, resulting in a gel having 90 Bearden units without the addition of more material.

Following and is incapable of further gelation. In this case one or both of the reactants are consumed.

exponential or right angle

# Polymers

- **Natural Polymers :**
  - Xanthan Gum, Guar Gum, Starch
- **Modified Natural Polymers :**
  - Carboxymethyl Cellulose (CMC), Polyanionic Cellulose (PAC), Hydroxyethyl Cellulose (HEC)
- **Synthetic Polymers :**
  - Polyacrylamides, Polyacrylates

**We're looking for high molecular weight and highly branched polymers. The more the cross-links, the more rigid the pill is.**

# Cross-Linkers

- A compound, which when mixed with a certain polymer fluid – guar, polyacrylamide, etc – creates a viscous gel
- Multivalent Metal Ions
  - Chromium (III)
  - Titanium (IV)
  - Zirconium (IV)
  - Aluminum (III)
- Miscellaneous
  - Borate salts
  - Aldehydes

# Retarders & Accelerators

## Retarders:

Work by one of the following mechanisms:

- Tying up the cross-linker
- Weakly binding to the cross-link sites on polymer chains
- Buffering the reaction conditions (pH)

## Accelerators:

- Usually used in low temperature applications where the cross-linking process is slow.
- Typical applications are below 60 °F

# Other Components

- **Settable Fluids may contain other LCM to slow down the loss rate while they set (synergistic effect).**
- **These LCM may be:**
  - **Fibrous: Reduce Loss rates in highly fractured zones**
  - **Granular: Mainly Calcium carbonate to increase acid solubility**

# Design Criteria

- 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.**

# Mechanical Properties

- **What?**
  - Compressive Strength: a material's external resistance to compressive force
  - Shear Strength: a material's internal resistance to that force
- **Why?**
  - Tolerate down-hole harsh conditions, especially the amount of overbalance: the greater the shear strength, the greater  $\Delta P$  it will tolerate
  - Identify the Top of the Plug

# Settable Fluids vs Cement

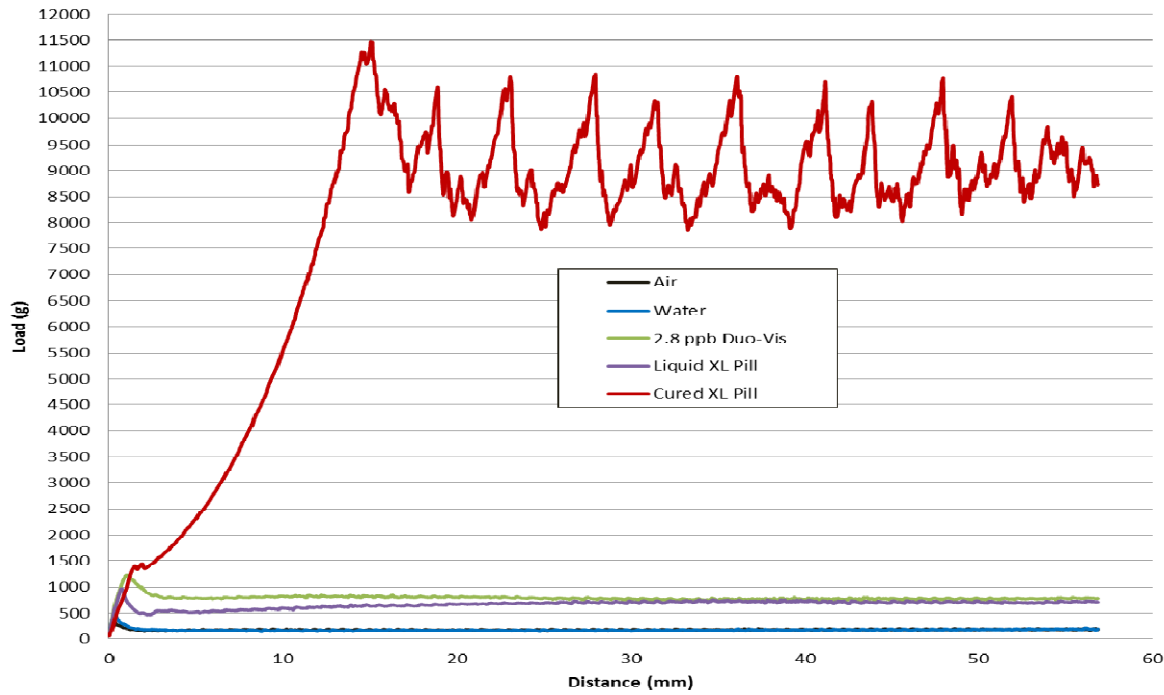
Point of Comparison	Settable Fluids	Cement
No exothermic reaction	√	X
Wide Density Range	√	X
Minimal Shrinkage (Micro-Annulus)	Dependent on pill type	Dependent on Job Design and Execution
Removable	Dependent on pill type	X
Resistant to common contaminants	√	X
Deformable under Stress	Dependent on pill type	X
Minimal Leakage (Gas Permeability)	√	Dependent on Job Design and Execution
Compatible with Drilling Fluids	√	X

# Limitations

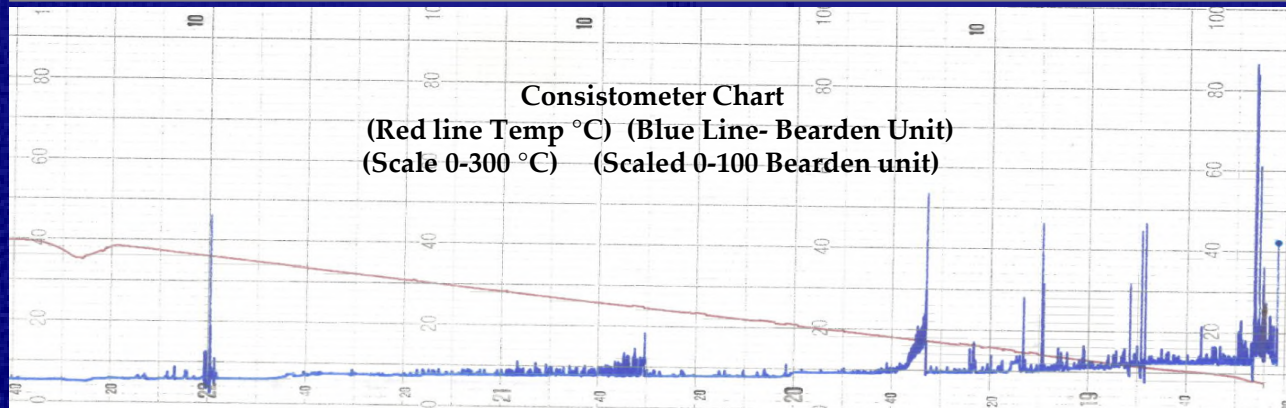
- Pills can't always be stored on location without biocides: require some precautions
- Require long periods of time to mix, spot and set
- Less effective for high static loss rates, and a pill may be washed away before it sets
- Retarders and accelerators may affect the consistency of the final product

# Lab Testing

Load vs. Distance (10 mm/min, 1" dia. syringe, 0.0725" dia. orifice)



Consistometer Chart  
(Red line Temp °C) (Blue Line- Bearden Unit)  
(Scale 0-300 °C) (Scaled 0-100 Bearden unit)



# Removal Techniques

- Acid (7.5 to 15% HCl)
- Oxidation ( $\text{H}_2\text{O}_2$ ,  $\text{MgO}_2$ )
- Proprietary solvents and breakers
- No treatment: self-degrading with time and/or temperature



# Field Considerations

- Always mix in fresh water unless otherwise noted
- Avoid flushing lines with acid or caustic
- Use biocides if pill is stored for extended period of time (some biocides interfere with the reaction)
- Only add the cross-linker or accelerator Immediately before pumping
- Make sure the pill is pumpable (viscosity)
- Slightly over-displace out of the drill string to avoid plugging it

# Applications (Candidate Selection)

- **Water Shut-off**
- **Shallow Losses (No BOP, Low Squeeze Pressure)**
- **Dynamic Losses up to Total losses**
- **Fractured Carbonates**
- **Short-term Zonal Isolation**
- **Long-term Zonal Isolation**
- **Sand Consolidation**

# Field Applications

WELL	DEPTH	VOLUME	LOSS RATE	LOSS RATE	BHT	PILL
Application	Lost Circulation		PRE-PILL	POST-PILL	(design)	DENSITY
	ft	bbbl	bph	bph	deg F	ppg
1	6,548	220	1500	0	85	11
2	13,920	200	1150	0	141	14.4
3	12,655	80	960	0	125	14.6

WELL	DEPTH	VOLUME	Mud weight	Mud weight	BHT	PILL
Application	Water Shutoff		PRE-PILL	POST-PILL	(design)	DENSITY
	ft	bbbl	ppg	ppg	deg F	ppg
4	5,220	18	11.1	10.1	170	10
5	5,324	19	11.6	10.6	170	9.93
6	5,380	19	11.6	10.4	170	9.95

## QUESTIONS?

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