SPE 119900

Critical Evaluations of Additives Used in Shale Slickwater Fracs

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Outline

- Introduction
- Additives
  - Friction Reducers
  - Biocides
  - Reuse Water
  - Scale Inhibitors
  - Proppants
  - Clay Stabilizers
  - Surfactants/ Micro-emulsions
  - Conclusions

Summary

1. Friction Reduction (FR) need to be selected based on and compatible with:
   a. the high salt concentrations,
   b. biocide and
   c. breaker.
2. A properly tailored FR can outperform conventional FR systems 2 to 1.
3. Produced and flowback water can be returned to usable quality with oxidation, Floc and drop and filtering through 25 micron filters.

Summary

4. KCl inhibits clay swelling in shales, but the major influence is likely fines migration which is limited by applying polymeric clay stabilizers
5. The formulation of the surfactants into a microemulsion (ME) allows the surfactant to travel further into the matrix allowing the surfactant to remain with the leading edge of the penetrating fluid.
6. Fluid recoveries are greater and production is increased when ME formulated surfactants are compared to conventional surfactants in shale.

Consider these when choosing Fluid Additive(s):

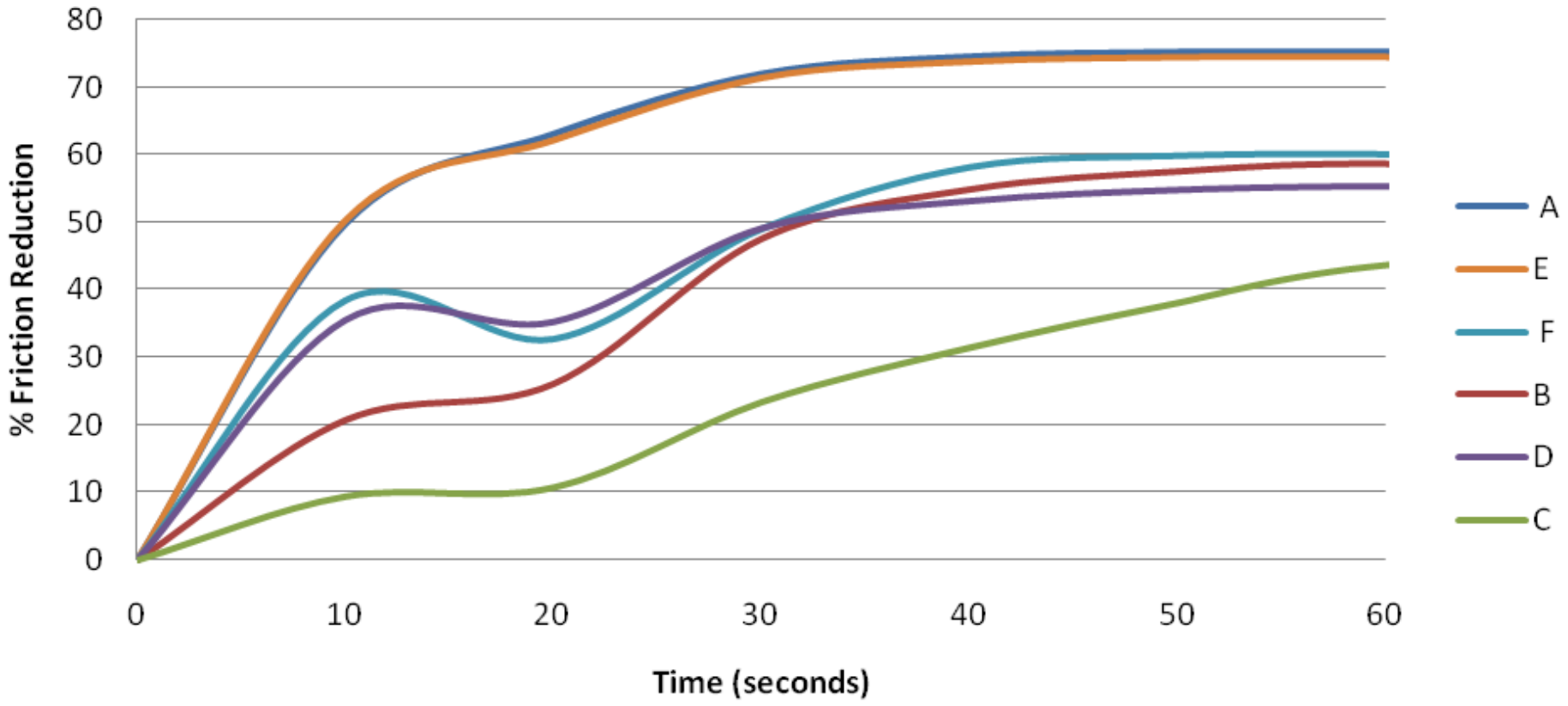
- Tubulars and pumping rate and pressures
- High percentage of clays
- Potential generation of fines, both siliceous and organic
- Acid solubility
- Microbiological activity
- Potential for scale generation
- Problems with recovering injected fluids

Friction Reducers

- Introduction (purpose, use, etc)
- Comparison various commercially-available friction reducers used in slick water fracs today in various waters with various amounts of salt
- Impact of various biocides on the FR performance

Friction Flow Loop to Measure Friction Reducers

Friction Flow Loop Data
Comparison Between Friction Reducers at Concentration of 0.25gpt in 2% (wt) KCl tap water
Pipe dimension - 1/2" OD - 0.402" ID



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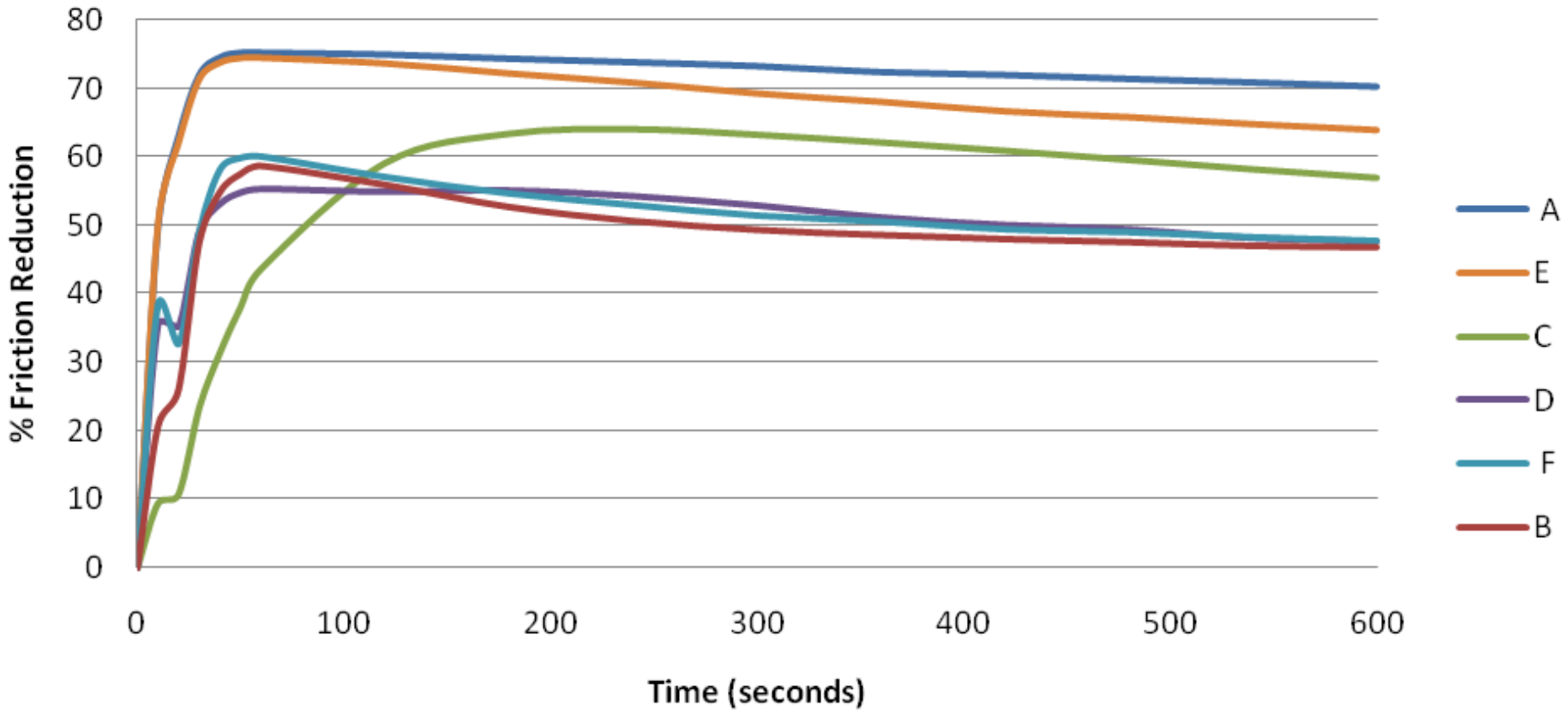
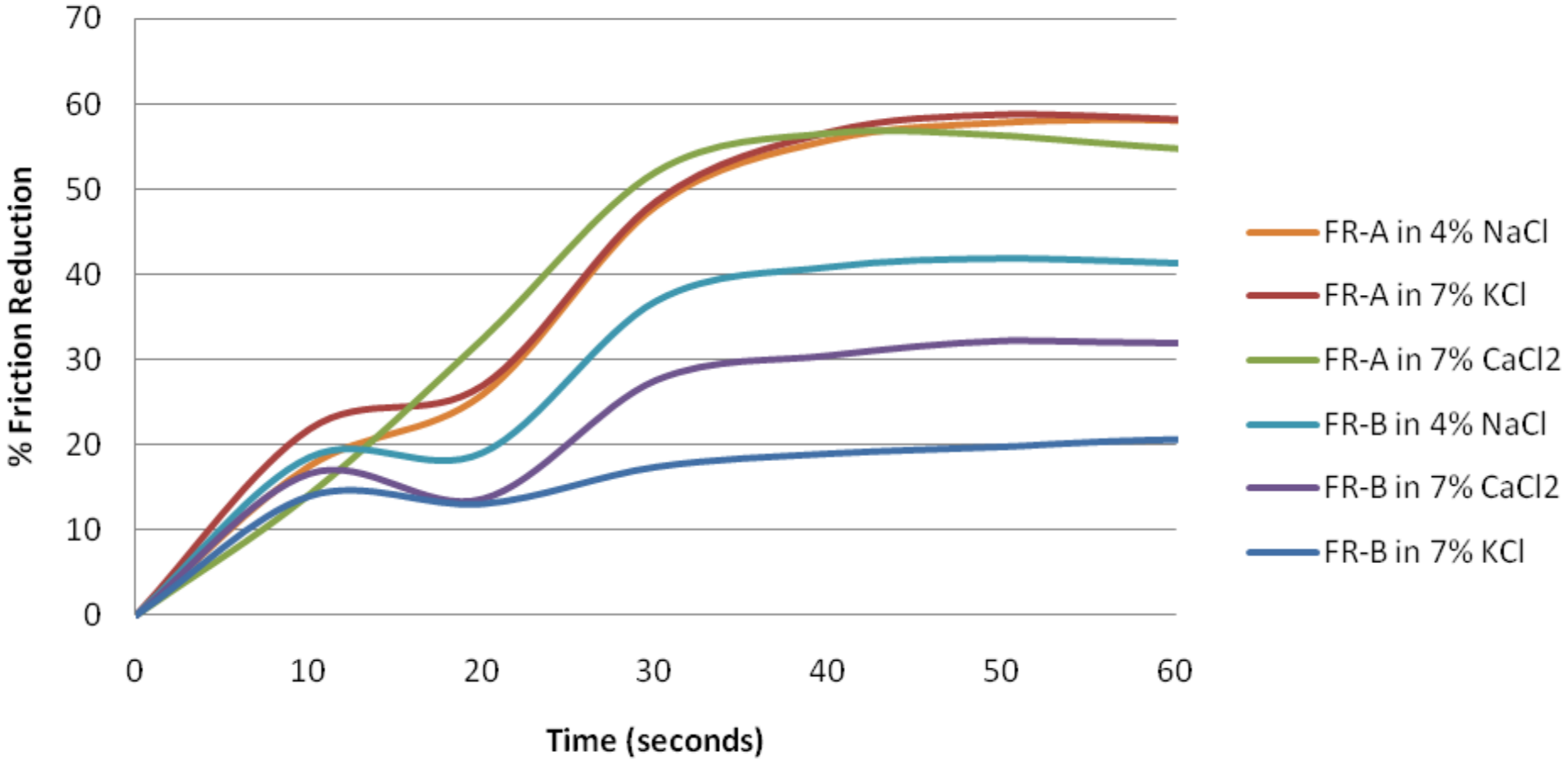
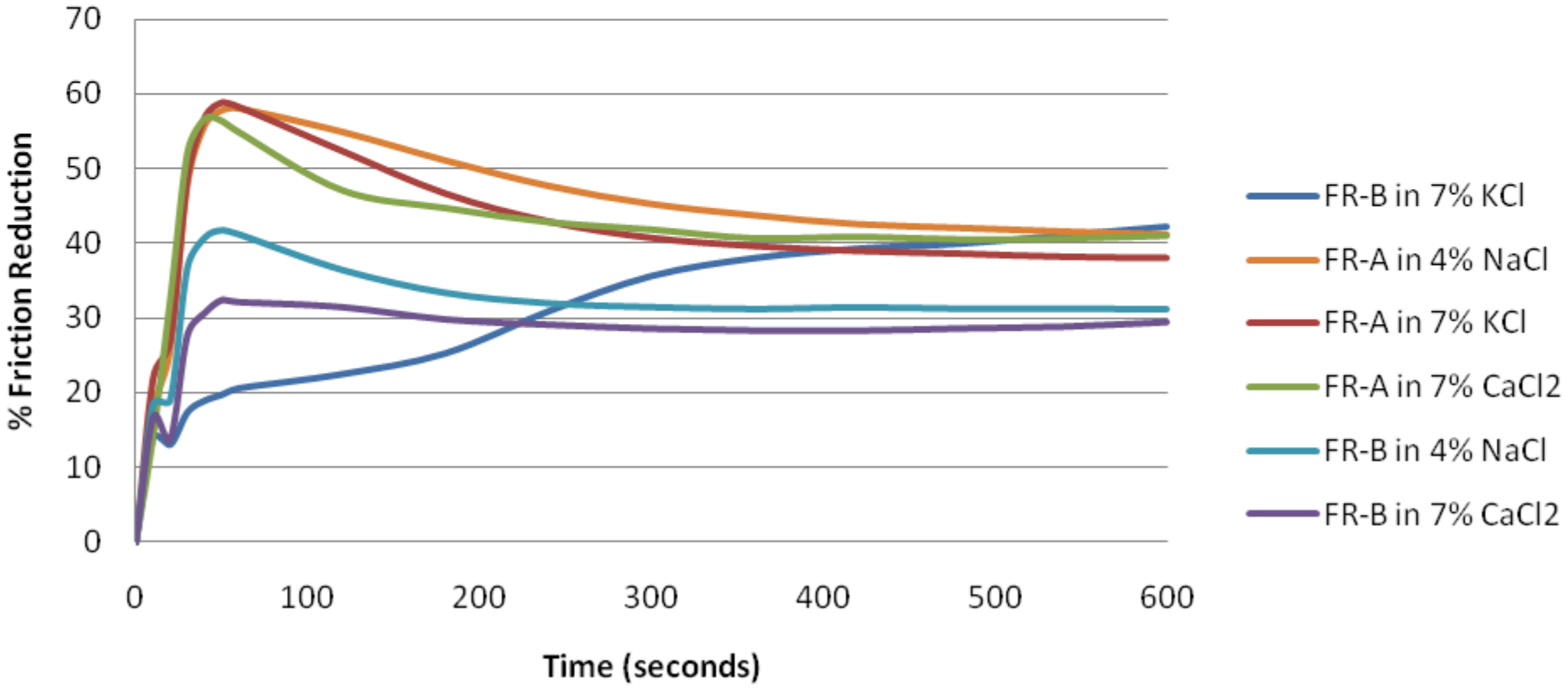
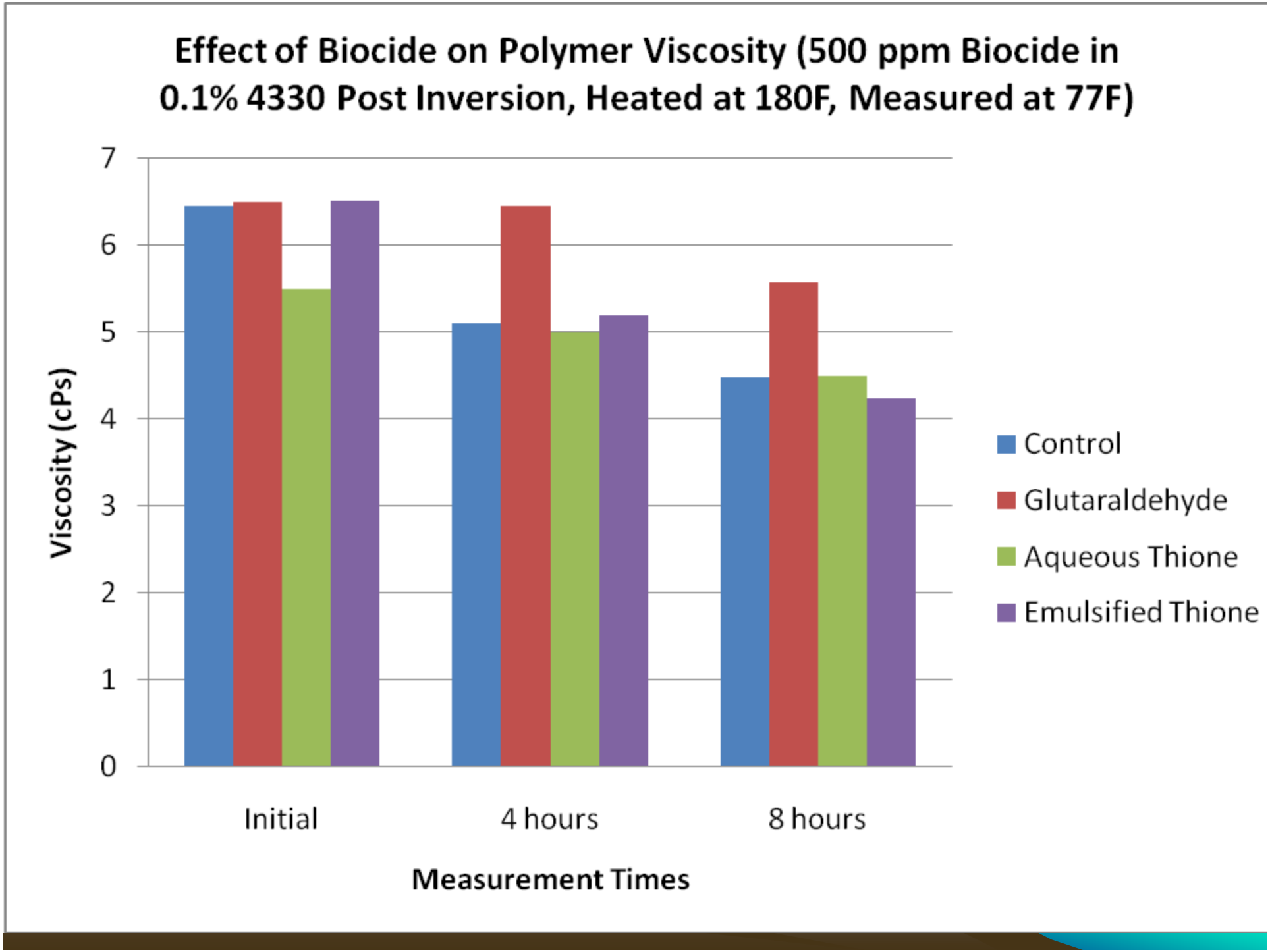


Friction Flow Loop Data
Comparison of 1.0 gpt of Cationic Friction Reducers
4% NaCl, 7% KCl, or 7% (wt) $CaCl_2$
Tubing dimension - 1/2" OD - 0.402" ID
Flow Rate: 5 gpm



Friction Flow Loop Data
Comparasion of Cationic Friction Reducers
1.0 gpt of FR-A compared to FR-B in
4% NaCl, 7% KCl, or 7% (wt) $CaCl_2$
Tubing dimension - 1/2" OD - 0.402" ID
Flow Rate: 5 gpm




Effect of Biocide on Polymer Viscosity (500 ppm Biocide in 0.1% 4330 Post Inversion, Heated at 180F, Measured at 77F)
Viscosity (cPs)
0
1
2
3
4
5
6
7
Initial
4 hours
8 hours
Measurement Times
Control
Glutaraldehyde
Aqueous Thione
Emulsified Thione

Produced water and reused frac waters can have contamination consisting of:

- Iron
- Calcium
- Barium
- Strontium
- Sulfate
- Oily Solids
- Soluble Hydrocarbon
- Polymer & Gel
- Solids, Clays, Sand, Silt
- Salts, Monovalent and Divalent Metals
- Scale & Corrosion Inhibitors
- Bacteria

The following procedure is currently being adopted to treat produced water in the Haynesville Shale wells:

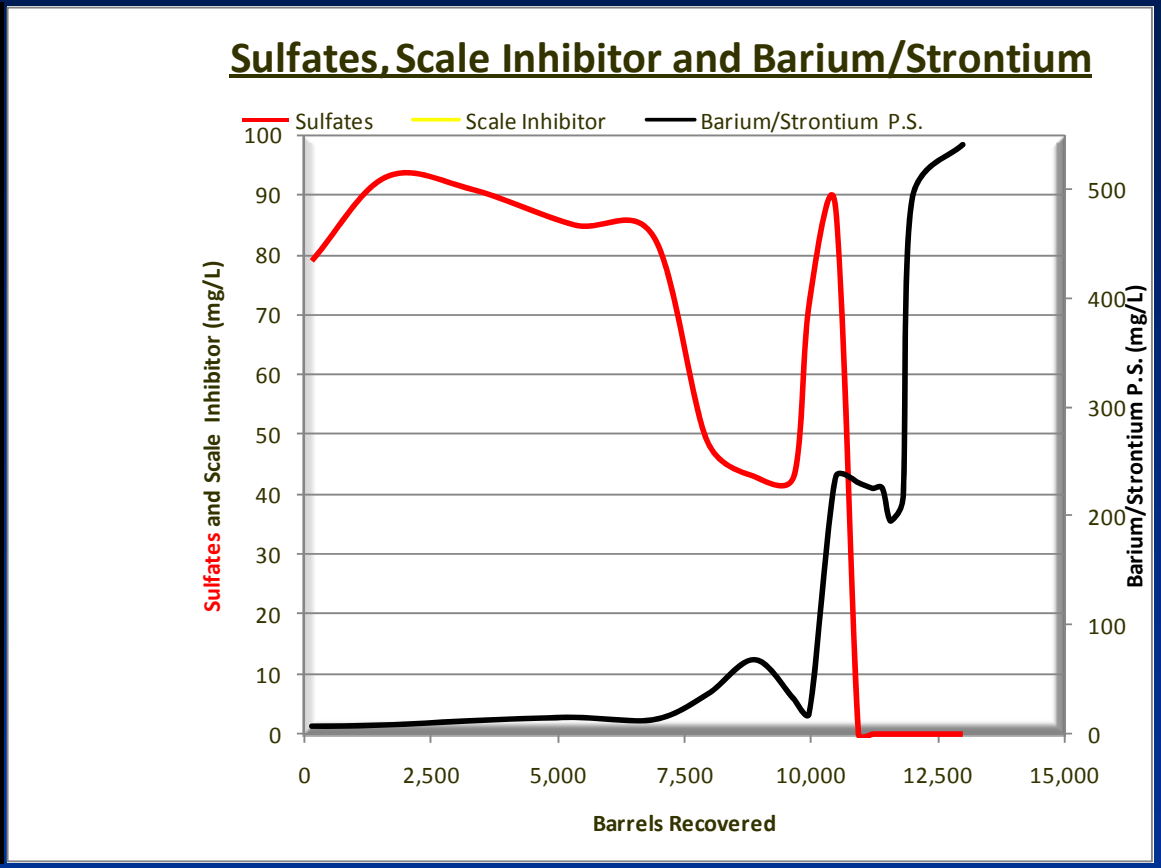
- Step1:Oxidation to remove iron, kill bacteria and break polymers. Oxidizers such as hydrogen peroxide or hypochlorite can be used.
- Step 2: Flocculate solids. Use classic water treatment chemistry to remove suspended solids and scale by precipitation –FLOC & DROP or Pellets.
- Step 3: Filter to 25 micron.
- Optional: Add scale inhibitor to maintain water compatibility.

On the left 25 micron filters used to filter the precipitated iron and bacteria from the water. On the right, the iron and bacteria are oxidized, then flocced and dropped, and finally filtered (provided by Kevin Smith of TSS).

Frac water analysis

pH	6.7
Temperature (°F)	72.4
Specific Gravity	1.002
Fluid Density (lb/gal)	8.36
Titrated Chlorides (mg/L)	100
TDS (mg/L)	2,900
Salt %	0.3
Total Hardness (mg/L)	201
Ca as $CaCO_3$ (mg/L)	109
Ca^{2+} (mg/L)	44
Mg as $CaCO_3$ (mg/L)	92
Mg^{2+} (mg/L)	22
Total Iron (mg/L)	< 3
Sulfates (mg/L)	53
Carbonate Alkalinity (mg/L)	0
Bicarbonate Alkalinity (mg/L)	146
Total Alkalinity (mg/L)	146
Scale Inhibitor (mg/L)	0
Barium Strontium P.S. (mg/L)	0

Flowback analysis of water



Proppant Selection and Placement

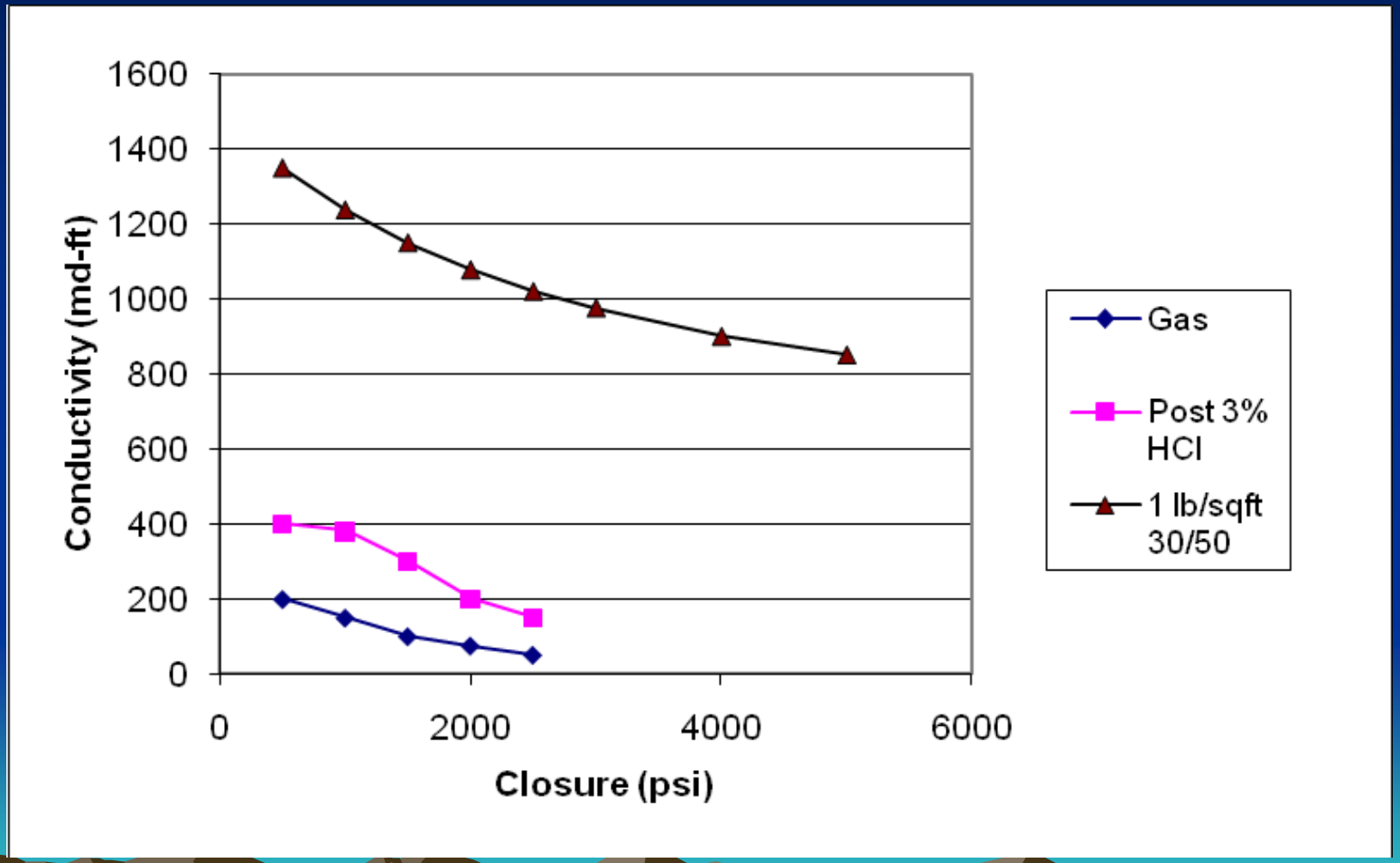
- Selection:
  - Size Matters
  - Strength
  - Quantity
  - Specific Gravity
  - New Generation of Proppant
  - New Proppant- The Smart Proppant?

Placement:

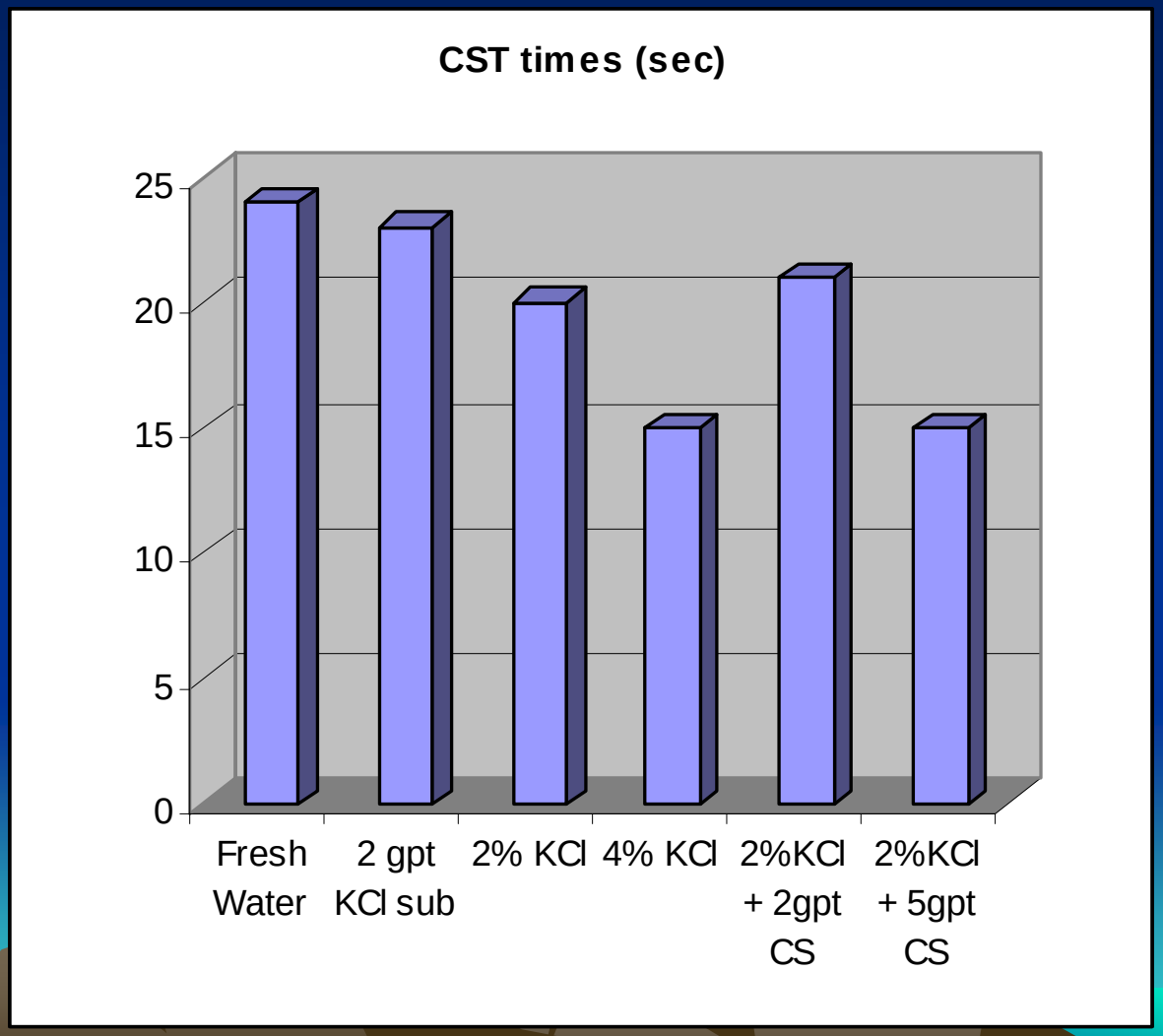
- Partial monolayer
- 1#/ft2?
- Don’t need no stinkin’ proppant?

- Various stimulation techniques are compared to show the difference between acidizing fracturing without proppant and the addition of 40/60 sand
- The impact of clay stabilizers is analyzed
- The impact of surfactant selection on water recovery and relative permeability is evaluated

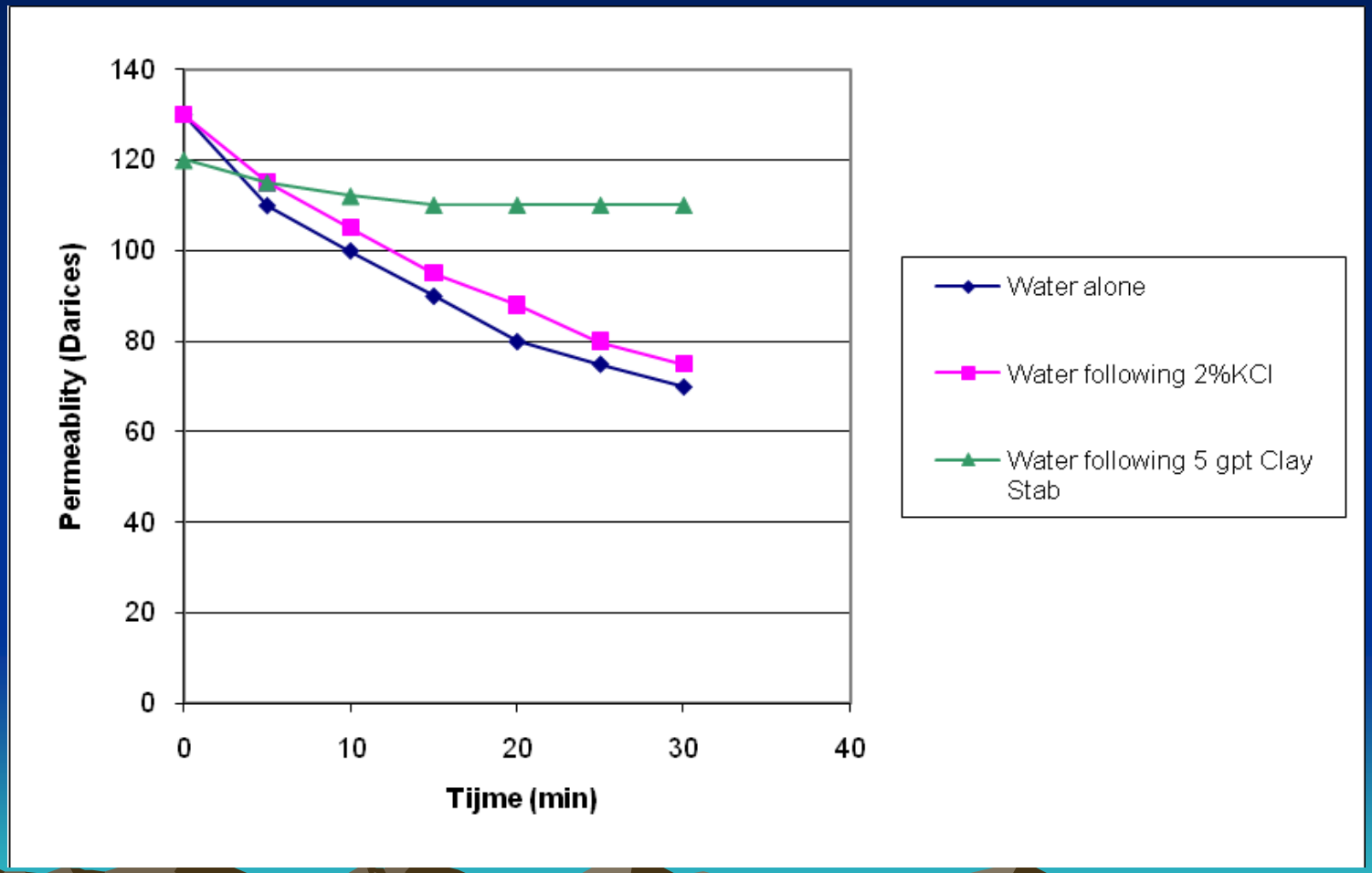
Conductivity of split shale cores with no proppant or acid, with acid and with 1 lb/sq ft 30/50 mesh sand.



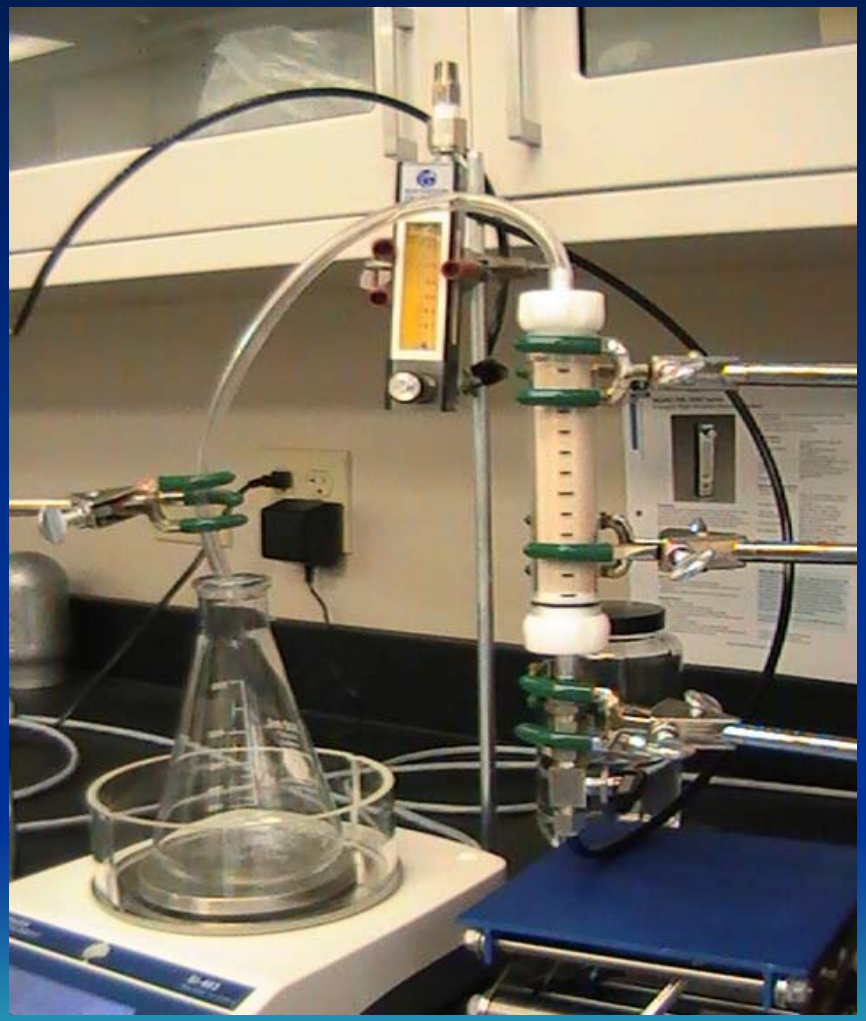
Capillary Suction Times for the Utica Shale with various clay stabilizer (CS) techniques.

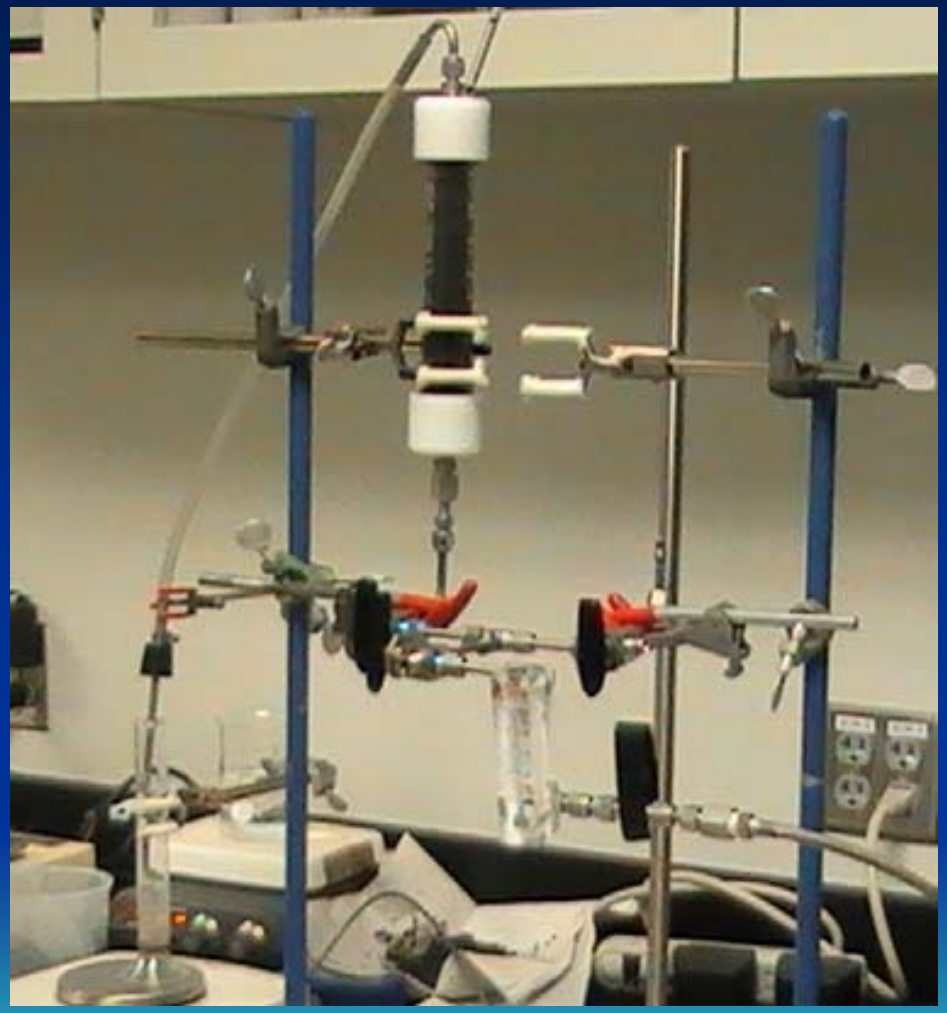


Shale column flow tests showing effectiveness of KCl and polymeric clay stabilizers



Sand and Shale Columns





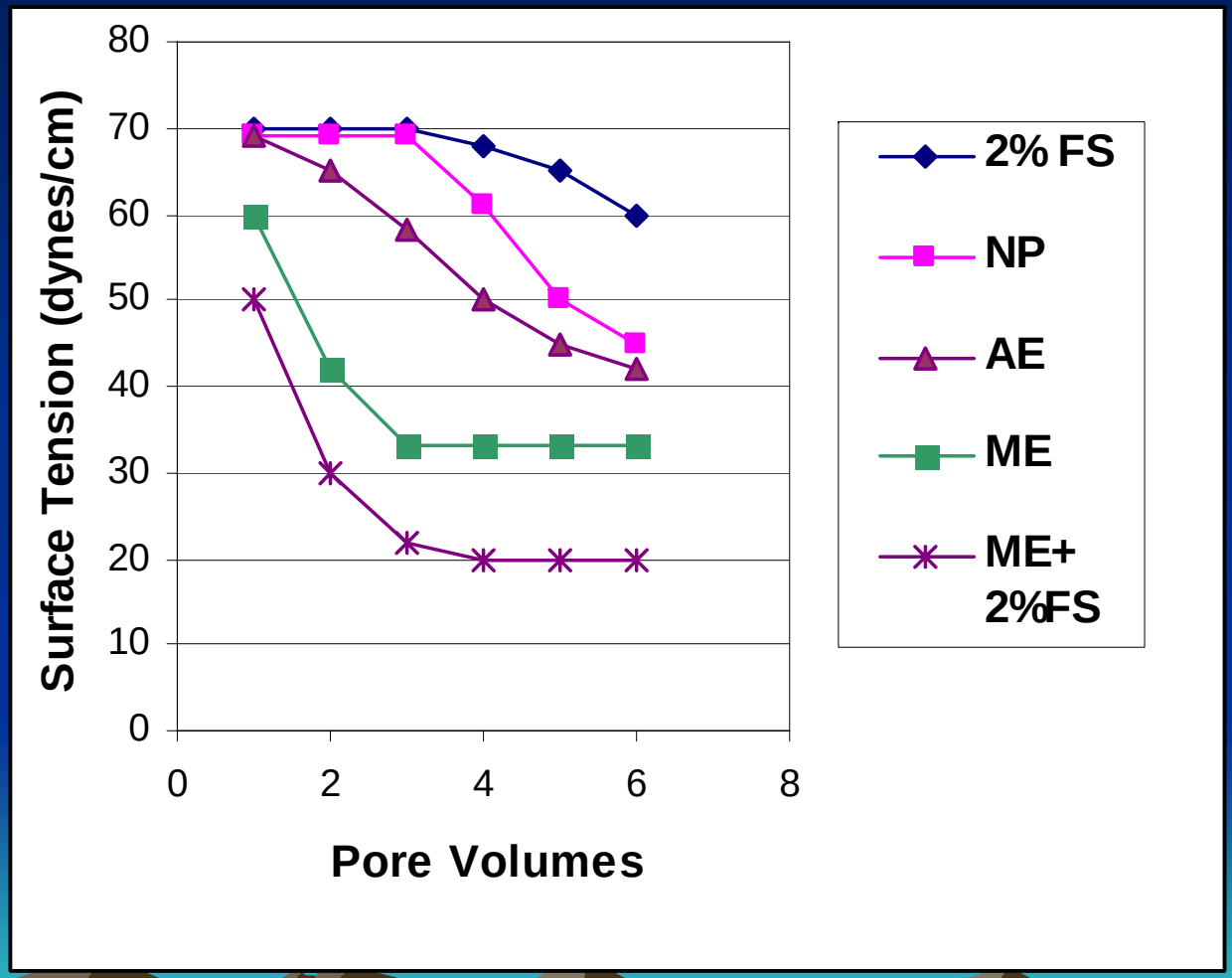
Micro-emulsion (ME)

Definition: thermodynamically stable dispersion of two immiscible liquids, stabilized by surfactants; it is typically clear because the dispersed droplets are less than 100 nanometers in diameter.

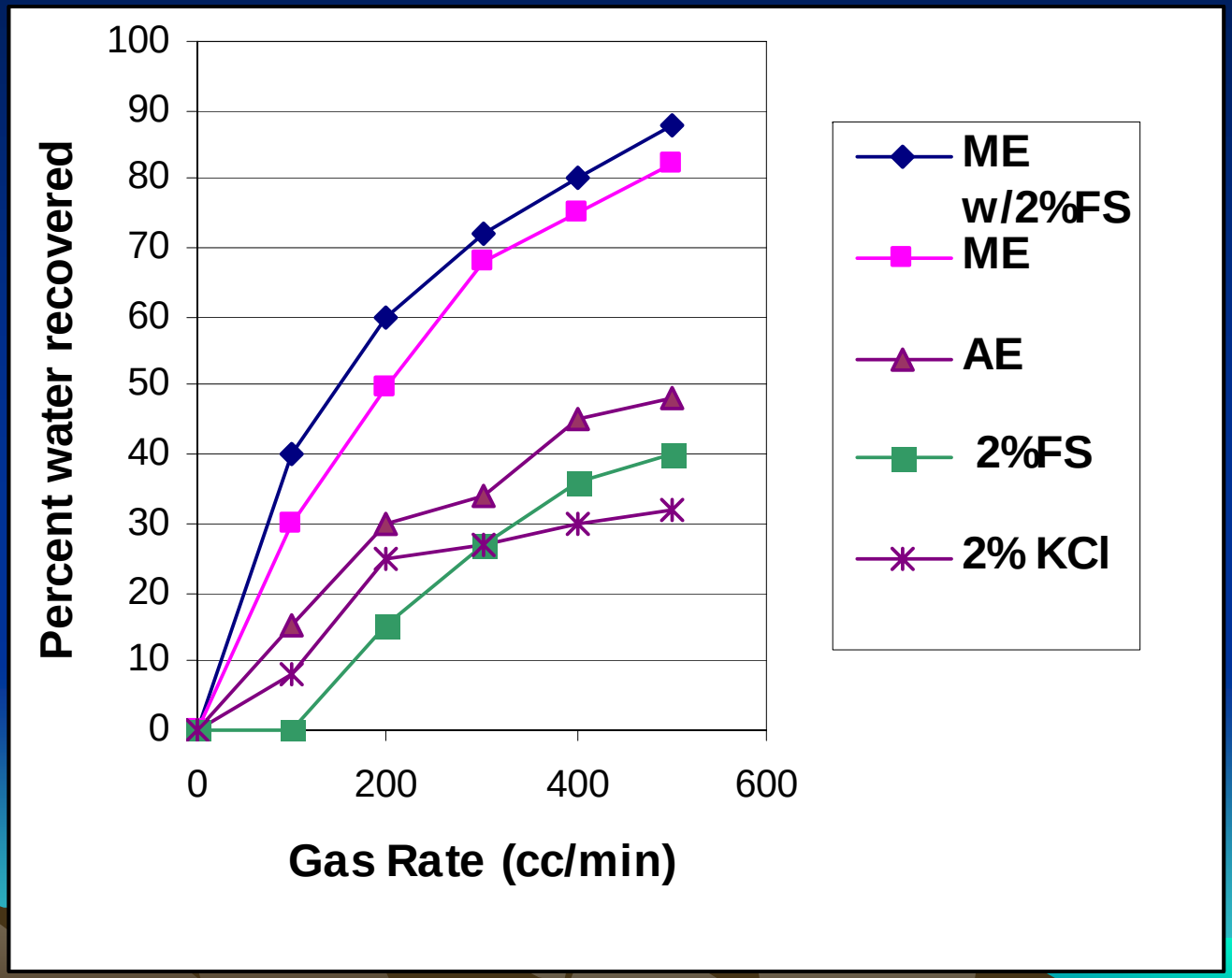
Surfactant, solvent, co-surfactant work together

Broad oilfield application: drilling, hydraulic fracturing, cleaning, EOR, etc.

Shale column surfactant adsorption tests. Surface tension measured vs pore volumes of 2% KCl containing 2 gpt of the indicated surfactant at the 1 ft port



Sand column water recovery tests with various surfactants. The percent water recovered from the column is measured vs gas rate



Conclusions

1. Produced and flowback water can be returned to usable quality with oxidation, Floc and drop and filtering through 25 micron filters.
2. Friction Reduction (FR) additives need to be selected to be compatible with the high salt concentrations, biocide and breaker.
3. The properly tailored FR can outperform conventional FR systems 2 to 1.
4. The biocide needs to be selected to be compatible with the FR and breaker system. A system that has both short term and long term kill is recommended for shales to avoid future production problem

Conclusions (cont'd)

5. KCl inhibits clay swelling in shales, but the major influence is likely fines migration which is limited by applying polymeric clay stabilizers
6. Common surfactants are adsorbed rapidly onto the shale matrix. The formulation of the surfactants into a microemulsion (ME) allows the surfactant to travel further into the matrix allowing the surfactant to remain with the leading edge of the penetrating fluid.
7. Fluid recoveries are greater and production is increased when ME formulated surfactants are compared to conventional surfactants in shale.

Thank you!

Questions?