PRODUCED WATER SOCIETY
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A Mechanism to Fight Against Formation Damage for Saltwater Disposal

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Primary Issue:

- Varieties of salts, fines and residual chemicals with compositions vary daily

Secondary Issue:

- Untamed Turbulence resistance when pumping saltwater

Consequences:

- Wells being damaged 24/7;
- Pressure escalates rapidly during operation.

Saltwater Composition:

Iron, a most troublesome ion, along with gel, friction reducer, crude oil and other unknown species

Metal Ion	Average (mg/L)
Calcium	16,558
Magnesium	2,137
Sodium	60,423
Potassium	1,497
Aluminum	0.5
Barium	2.8
Strontium	791
Iron	**32.6**
Manganese	4.7

Total dissolved solids (TDS) frequently exceed 200,000 ppm (or 20%)!

Proposed Solution:

- ✓ Turbulence Minimization
- ✓ Formation Damage Mitigation

Simultaneous Turbulence Suppression and Formation Stimulation

Turbulence & Typical Saltwater:

Critical Re#: 2,900

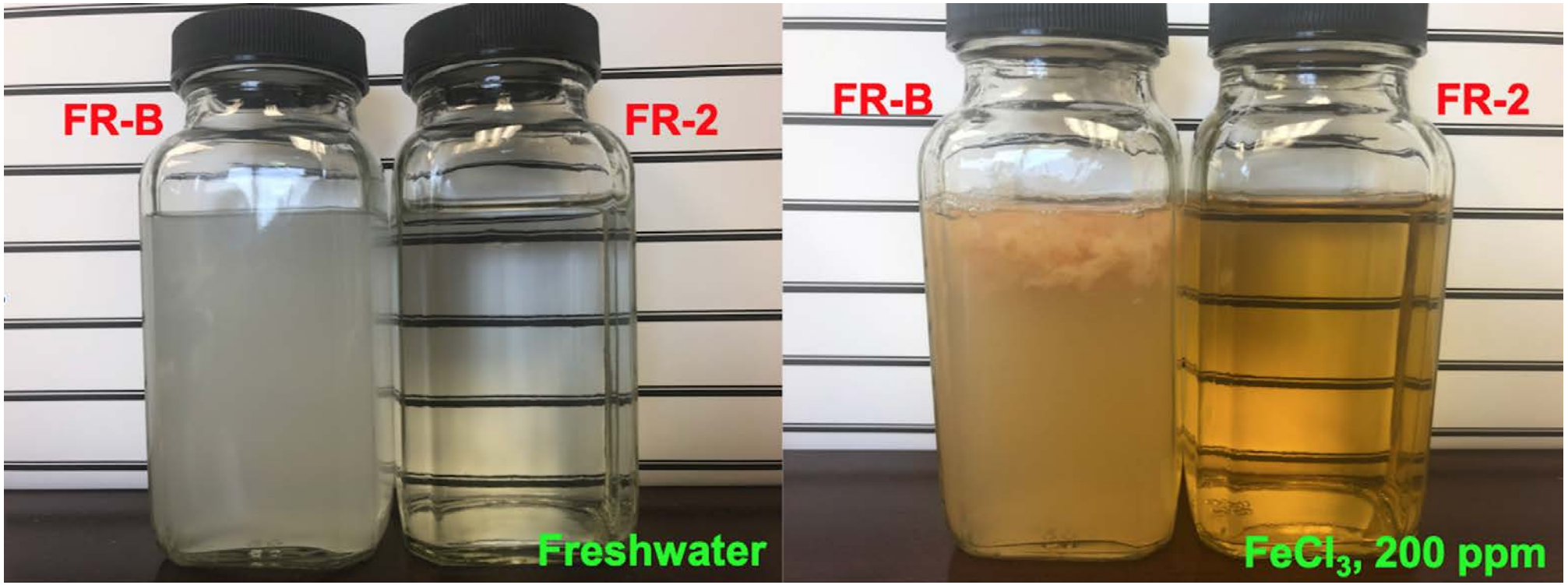
❖ Turbulence Flow in Pipe:

$$Re\# = \frac{4Q}{\pi DV}$$

V - kinematic viscosity: 1.0701mm²/s for FR-2 @ 1.0 GPT

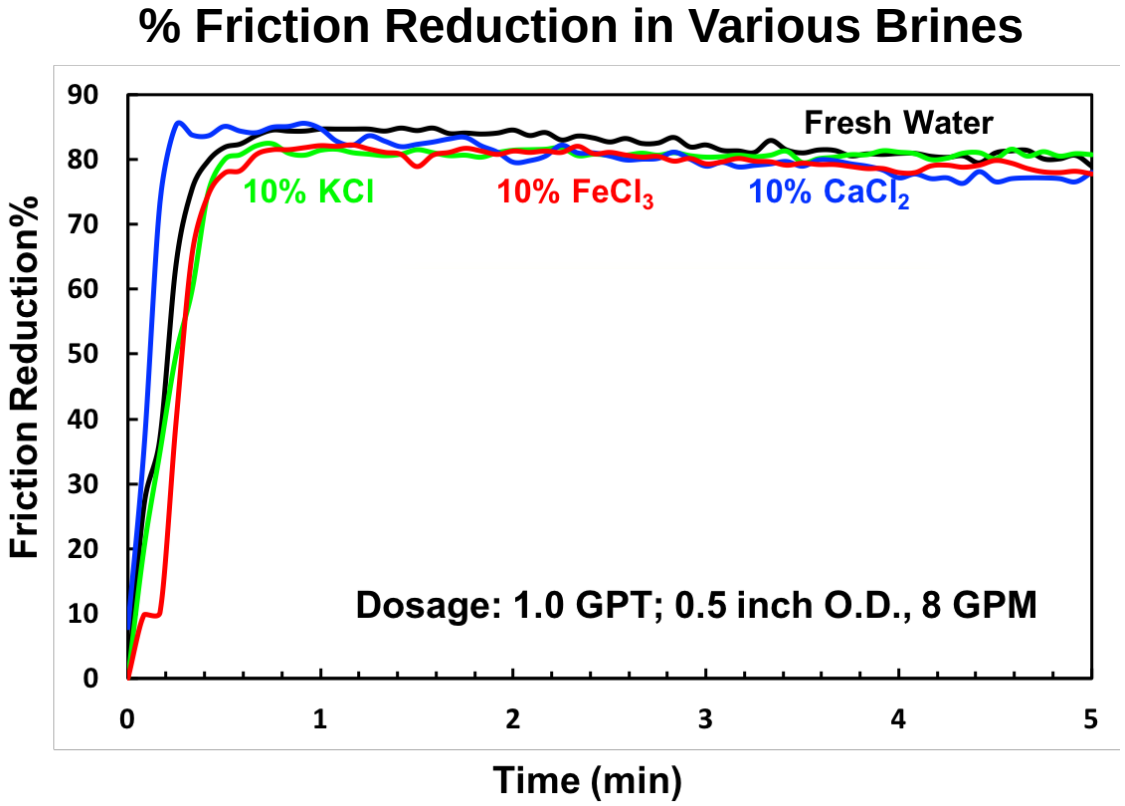
- **4.65-in (118 mm) pipe @ 88 bbl./min, Re# 2,353,969.**
- **2.325-in (59 mm) pipe @ 2.2 bbl./min, Re# 117,698**

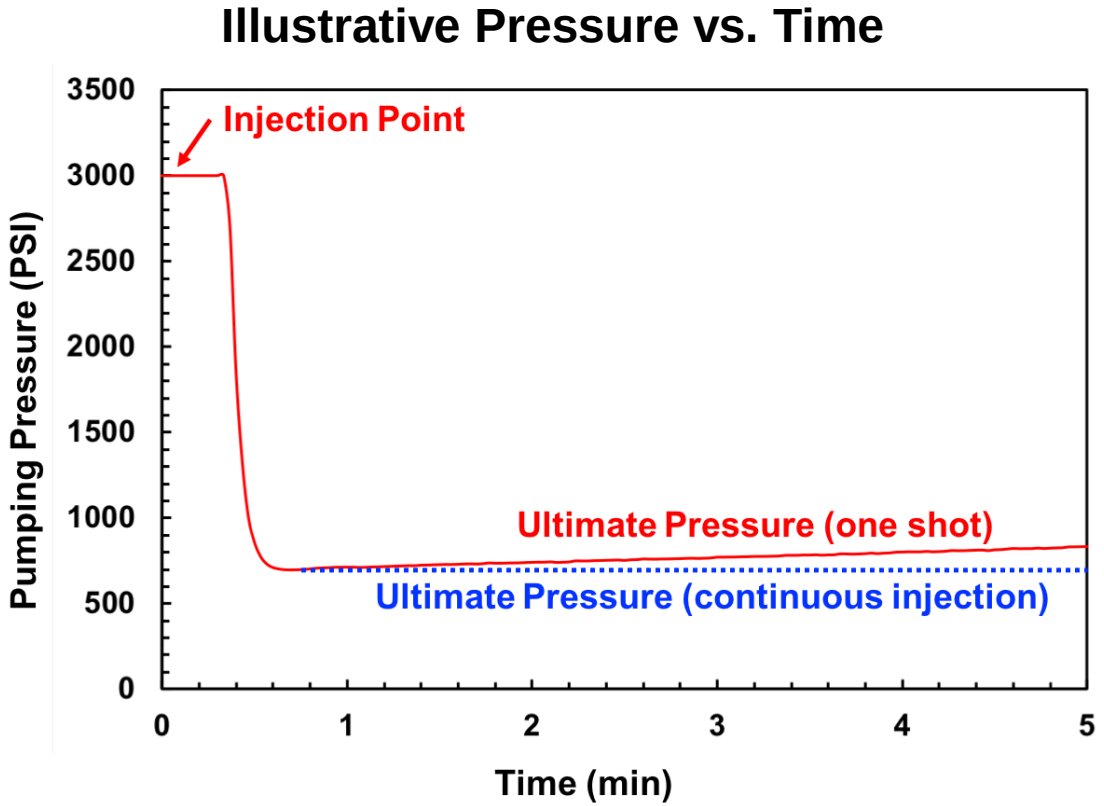
FR-2 Compatibility:



Dosage: 1.0 GPT/1000 ppm, 25 ℃

FR-2 All-Brine Applicability:





Dosage: 1.0 GPT/1000 ppm

FR-2 Non-Damaging:

Friction Reducer	Original Perm K_1 (mD)	Final Perm K_2 (mD)	Regained Perm
FR-B	166.3	0.5	0.3%
FR-2	147.7	146.5	99.2%

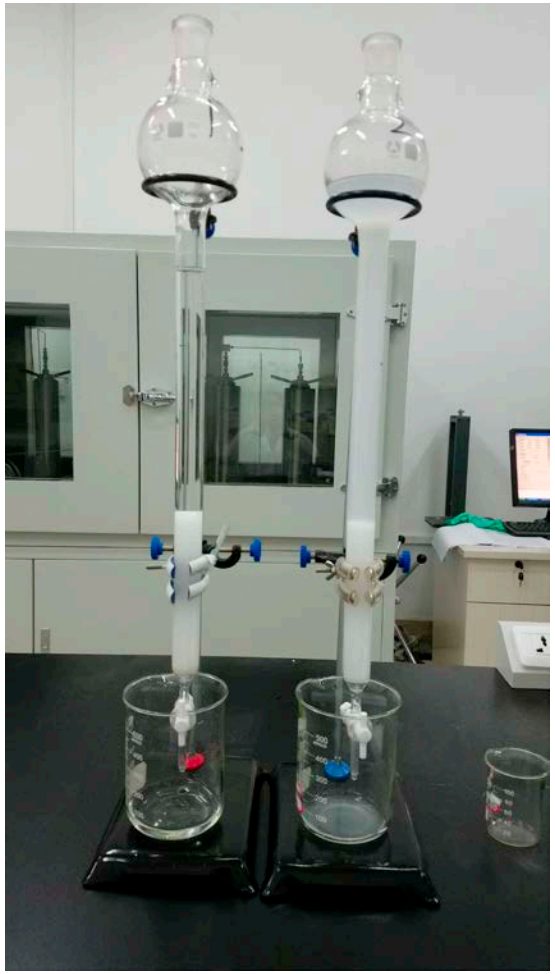
$$Regained\ Perm = \frac{K_2}{K_1} \times 100\%$$

Dosage: 1.0 GPT/1000 ppm

FR-2 Fluidity:

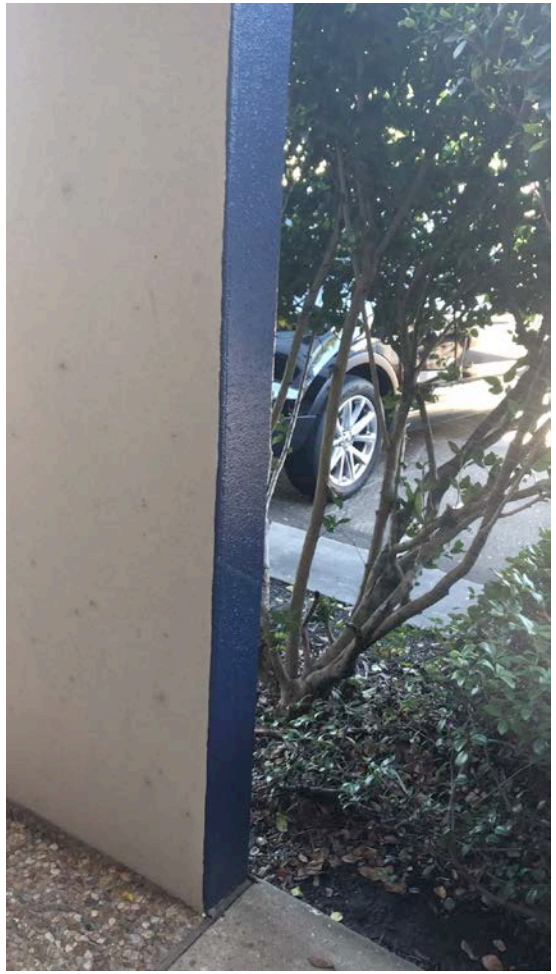
Dosage:

1.0 GPT/1000 ppm

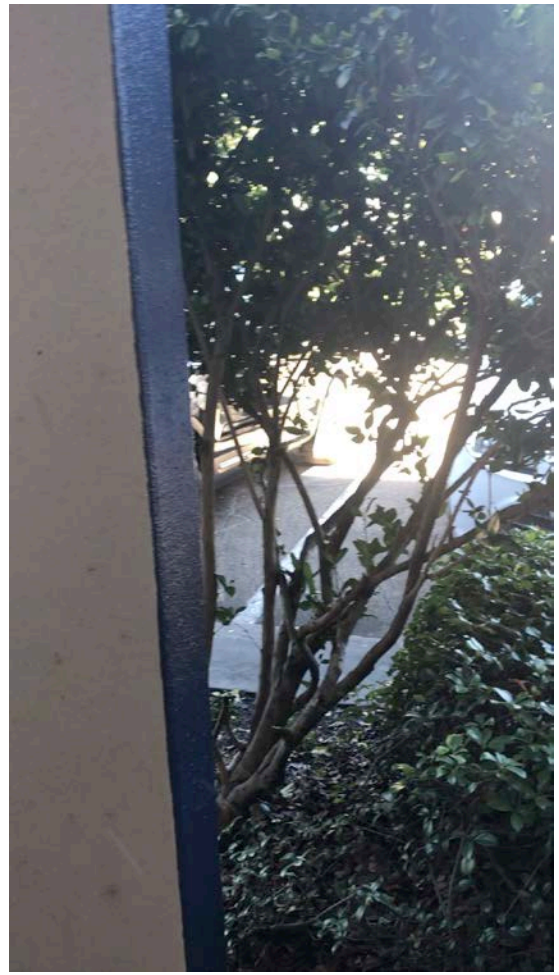


Freshwater: FR-2 vs. FR-B

Saltwater without FR-2



Saltwater with FR-2



FR-2 Field Trials:

Case 1: Richland, TX

Results

1). Tamed pumping pressure;

2). Enhanced injection rate;

3). Quicker pressure drop when stopping pumping.

FR-2: ca. 1.0 GPT; Flow: ca. 2 bbl./min.

FR-2 Field Trials:

Case 2: Jal, NM

1) Pressure increased quickly (e.g. 2 h) to trigger shutdown at 2,400 psi;

2) Well had to remain shut down for days before retaking water.

Results

1) With FR-2 (35 gallons), pumping time elongated 4 times;
2) Before FR-2, pressure ramped at 7 psi/min; with FR-2: 0.4 psi/min;
3) Well pumped ca. 900 bbl. first run; 1,200 bbl., second run same night.

Economics of Field Implementation:

Recommendation:

1). “Shock” treatment:

Treating damaged well with FR-2 at 1.0 GPT for one day or until see major improvements

2). Maintenance: Keep a constant FR-2 at e.g. 100 ppm level

3). Repeat “shock” whenever there is pressure hiking

4). Subject to optimization depending upon expected outcome

Cost estimate: as low as 5 cents/bbl.

ROI: up to $10MMM per year per well!

Summary

- **FR-2 was all-brine applicable and shown to reduce turbulence resistance and wellhead pressure.**
- **FR-2 stimulates the well and enhance water injectivity.**
- **This is a unique mechanism fighting against formation damage with high ROI**