Fracturing with Light-Weight Proppants

RPSEA Sub-contract Number: 07122-38

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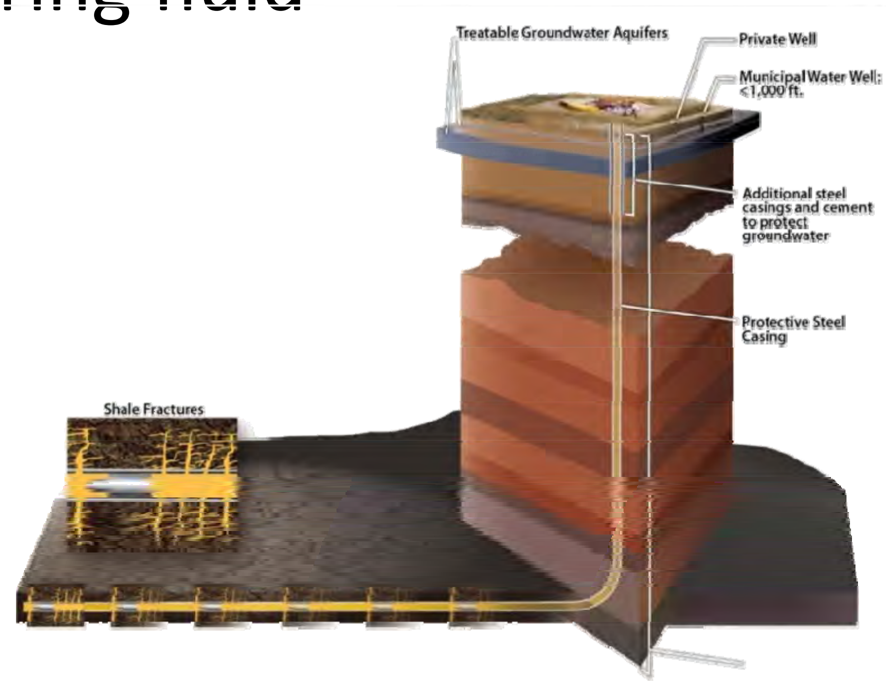
Outline

- Technical issues with fracturing shale gas
- Project objective
- Results
- Conclusions
- Future Directions

Key Issues with Shale Gas Production

- Low connectivity between pore space and well-bore: Multi-stage hydraulic fracturing
- Need long fractures; proppant settling
- Water needed for fracturing fluid
- Water disposal



(Cheasapeake Energy)

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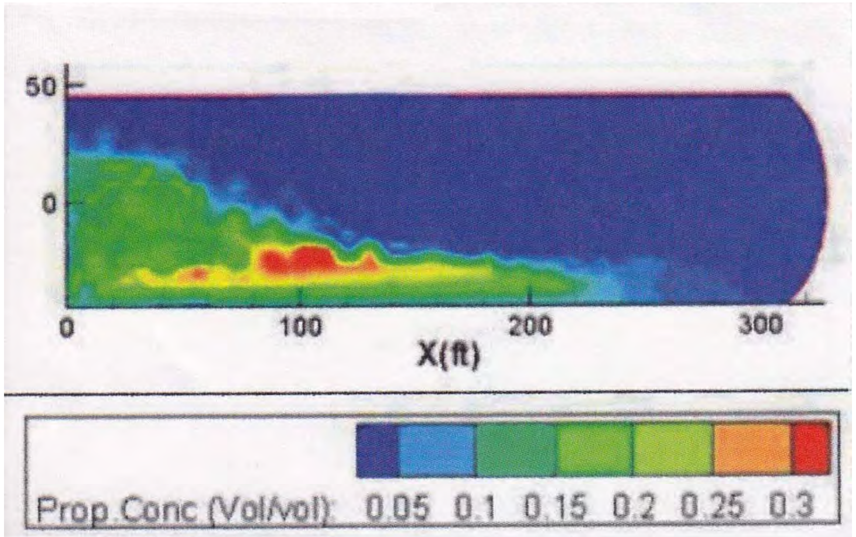


(Gadde et al., SPE 89875, 2004)

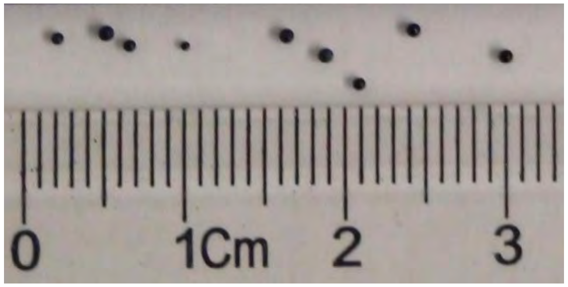
Project Objectives

- To develop non-damaging fracture fluids for long fractures in gas shale reservoirs
- Minimize water use
- Demonstrate their use by field tests

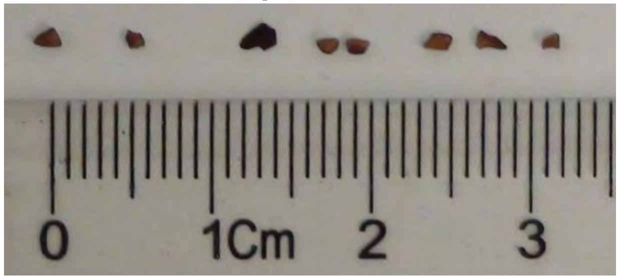
Strategy: Ultra-light-weight proppants & foam

Ultra Light Weight Proppants (ULW)

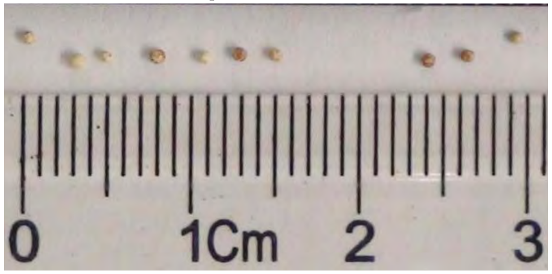
ULW1 (Polymeric)



ULW2 (Resin impregnated Walnut hull)

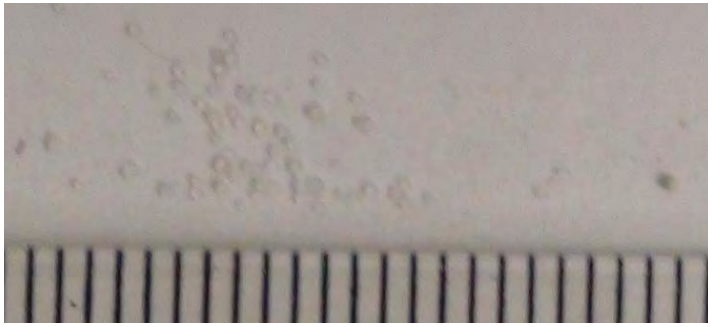


ULW3 (Resin coated Ceramic)



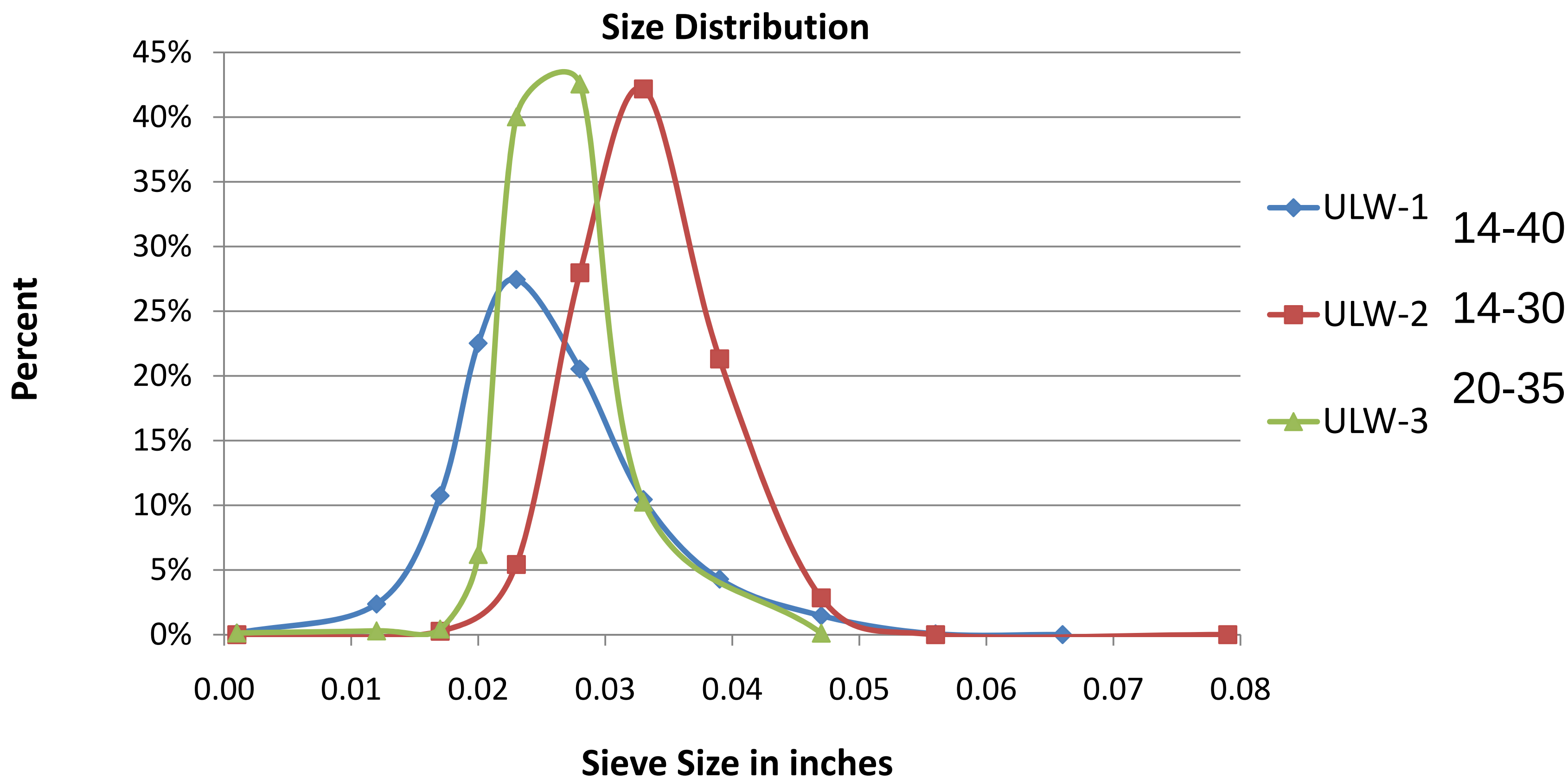
	ULW1	ULW2	ULW3
Density	1.08	1.25	1.75
Sphericity	1	0.62±0.07	0.78±0.01

(Supplied by BJ Services)



Reference: White Sand

Size Distribution



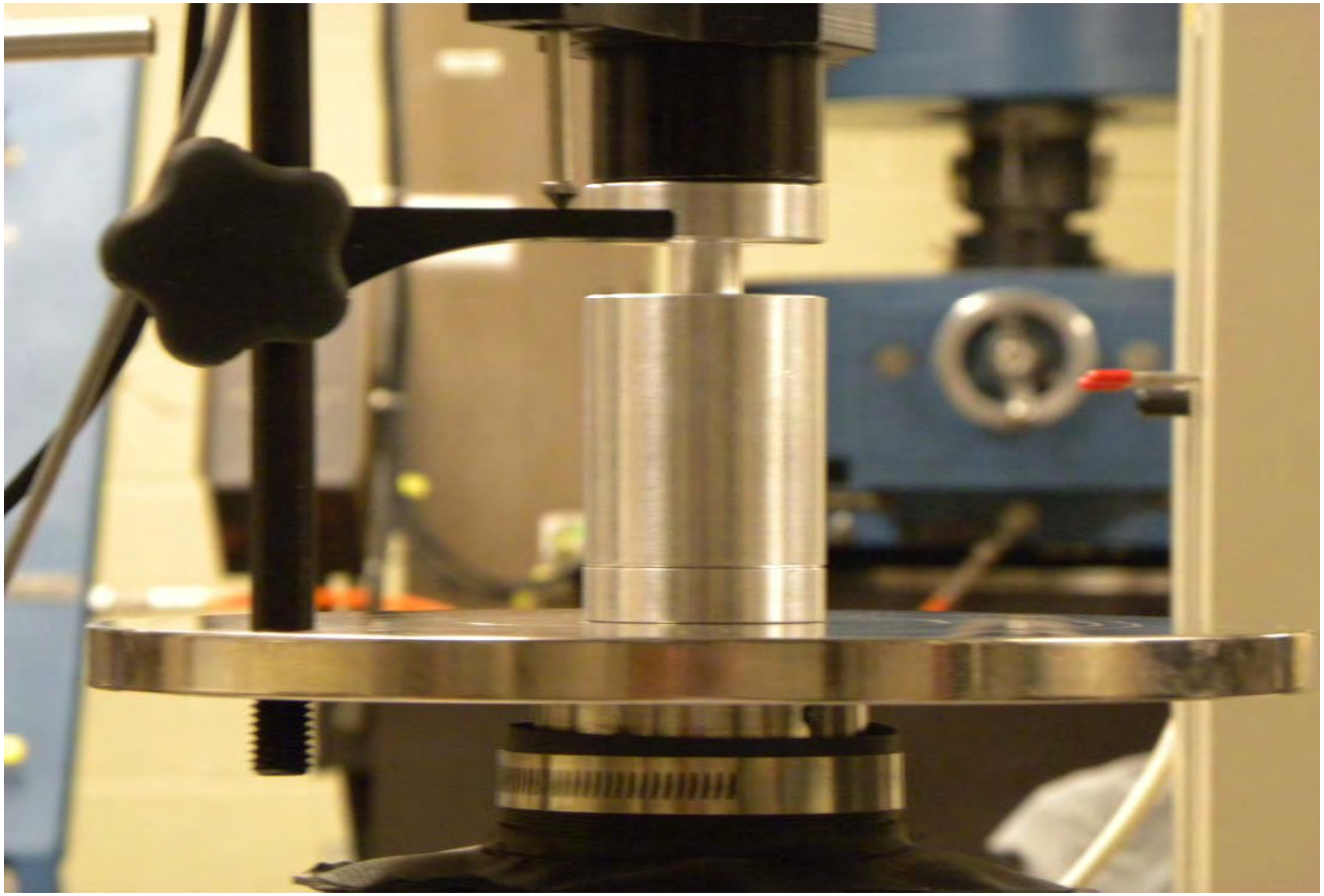
ULW1 is broadest; ULW2 is largest; ULW3 is narrowest.

courtesy: BJ Services

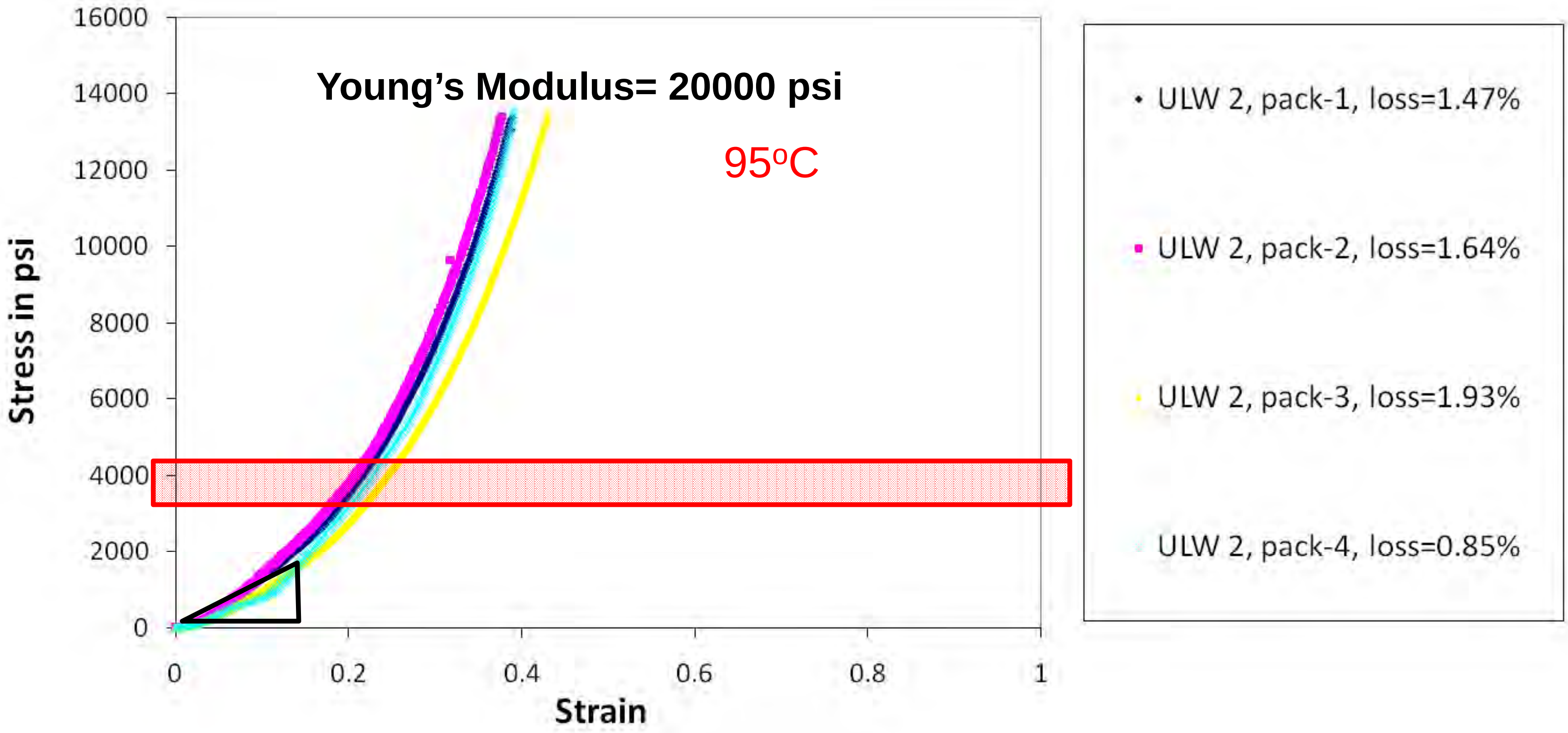
Results

- Strength
- Fracture conductivity
- Foam stability
- Proppant settling
- Foam rheology

Strength Test



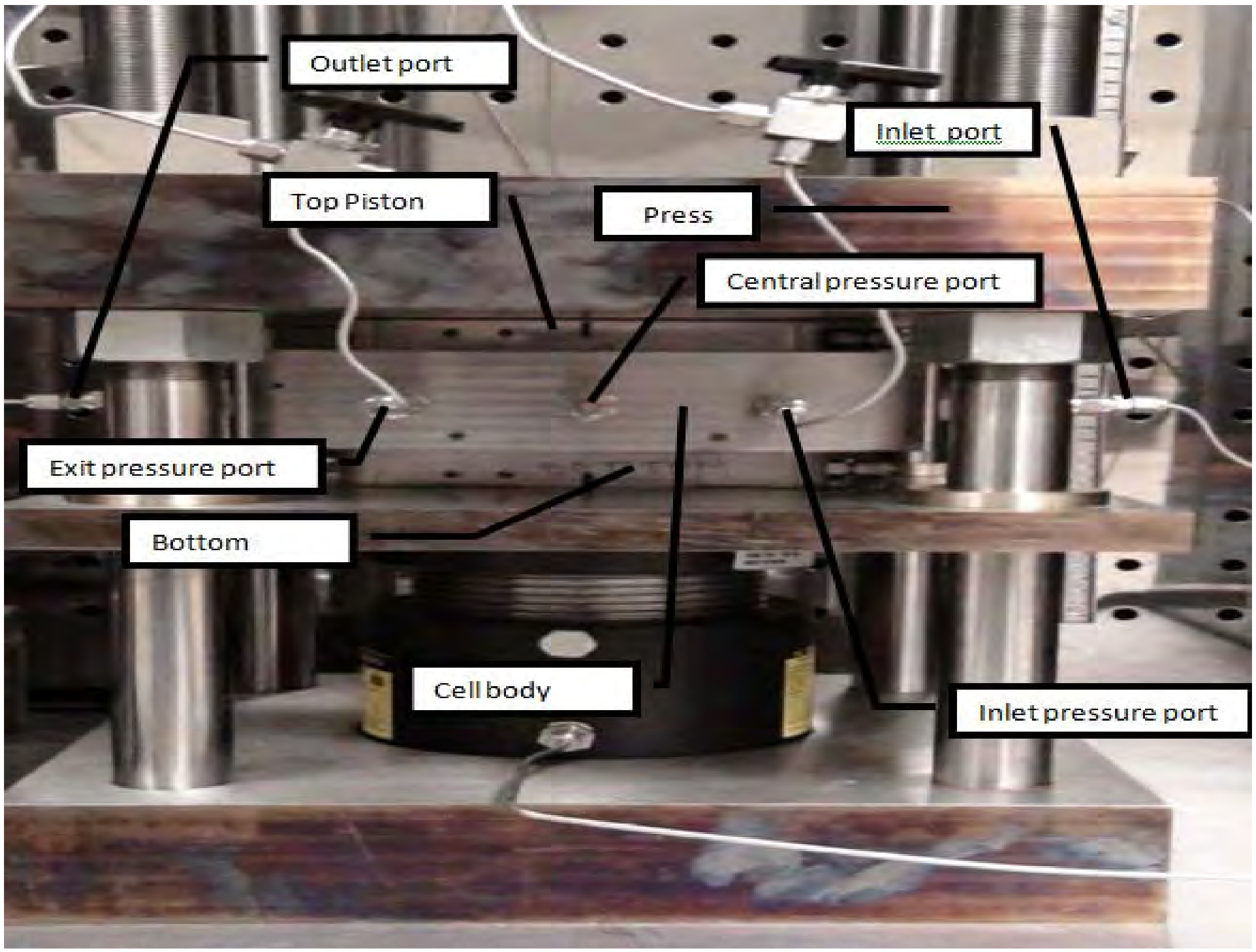
Crush Test ULW 2 Pack



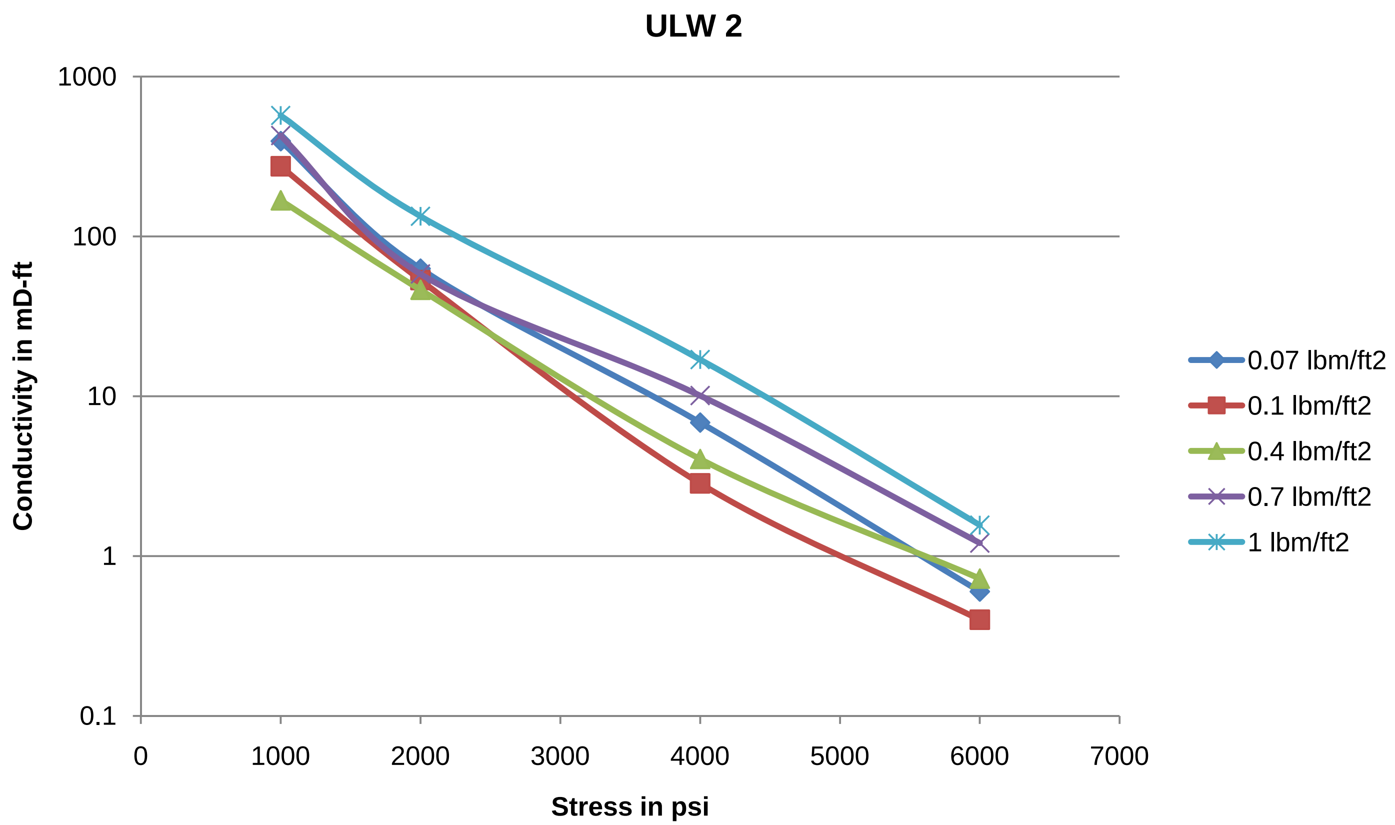
Crush Test

	Young's modulus(psi) @25°C	Young's modulus(psi) @95°C	% by avg wt fines formed @25°C	% by avg wt fines formed @95°C
ULW 1	25000	20000	4	0.4
ULW 2	25000	20000	2.5	1.5
ULW 3	45000	45000	14	30

Fracture Conductivity Test

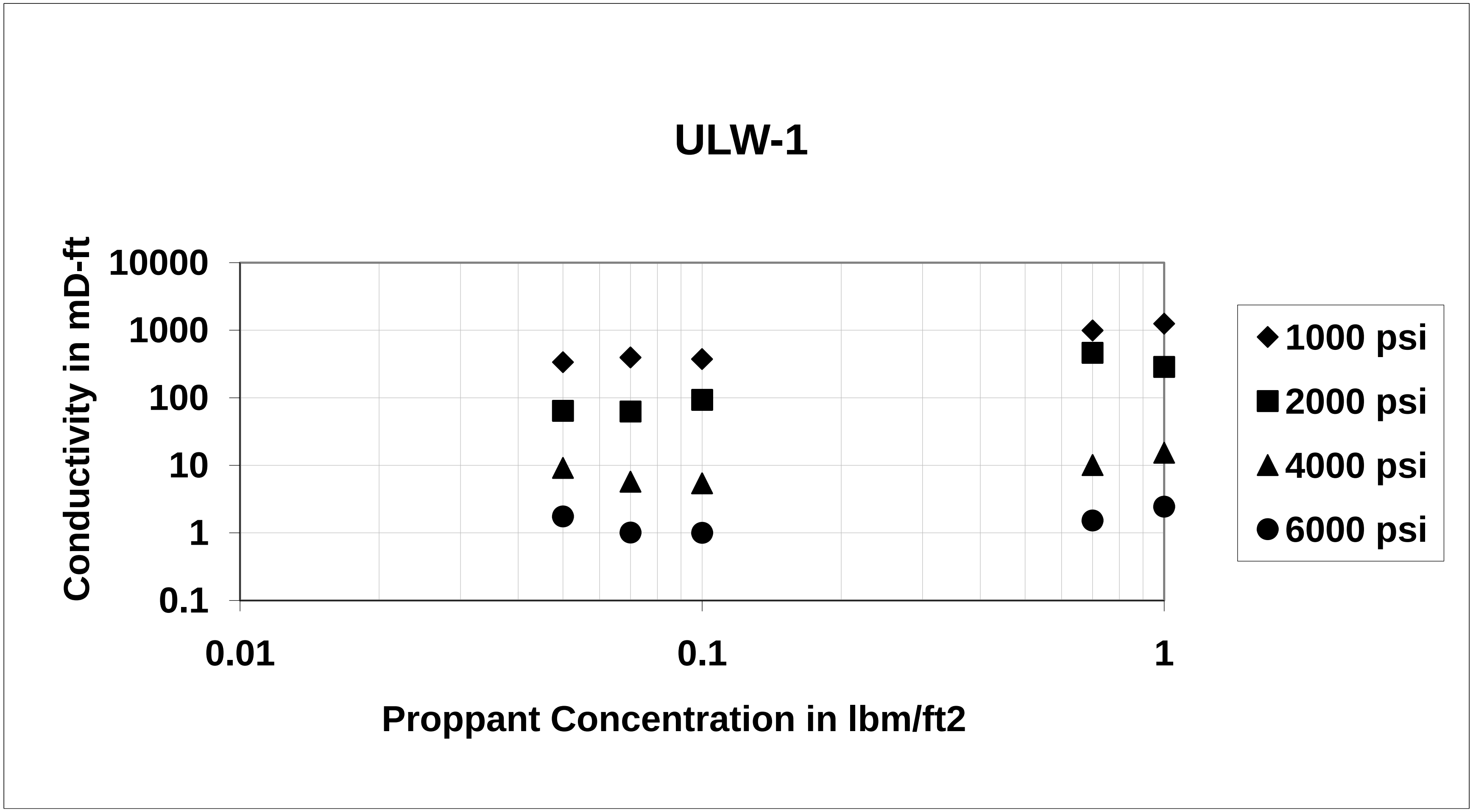


API Conductivity @ 95 C



- Fracture conductivity decreases with overburden stress, about 1 mD-ft at 6000 psi

API Conductivity @ 95 C



Sub-monolayer conductivity is comparable to multilayer conductivity

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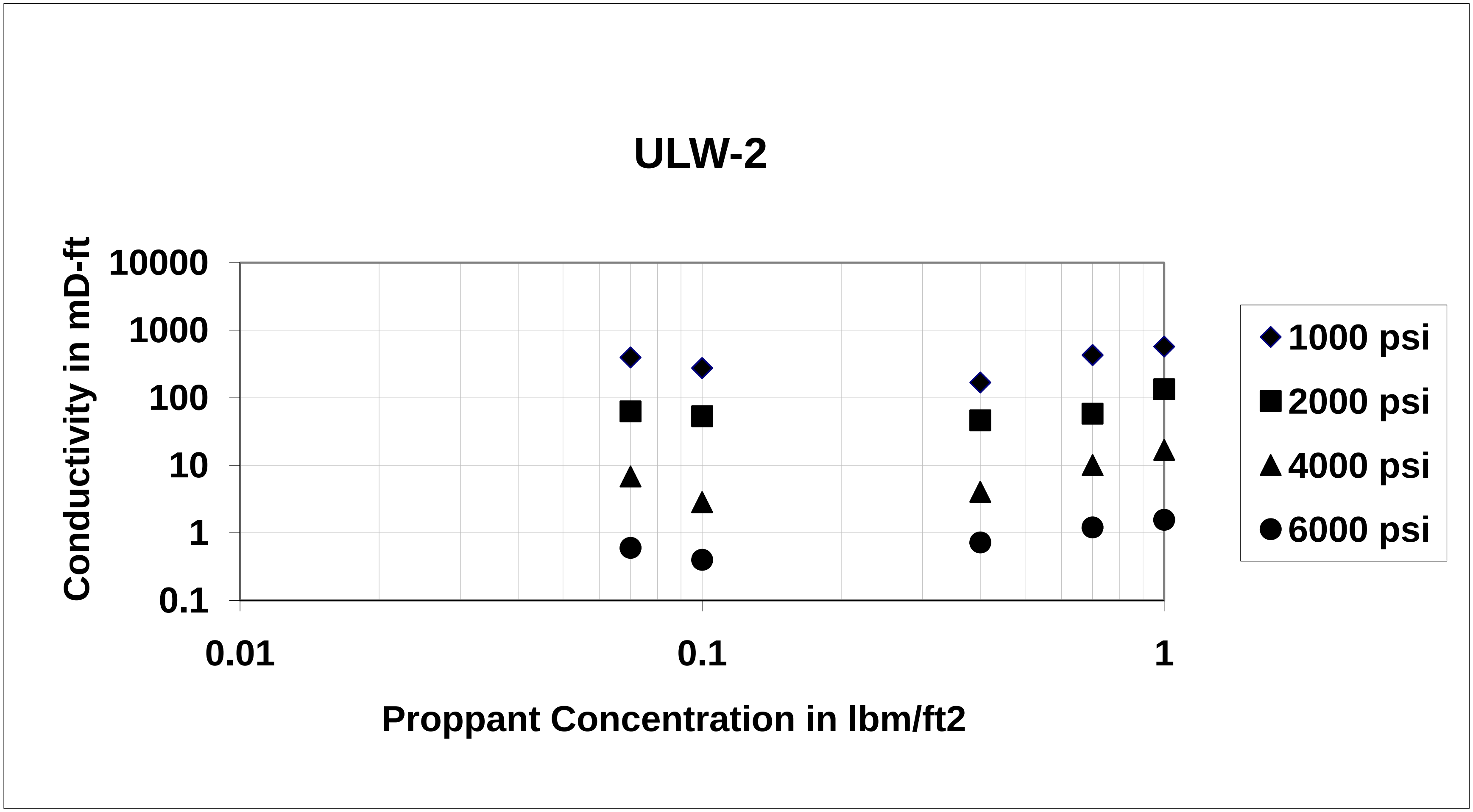

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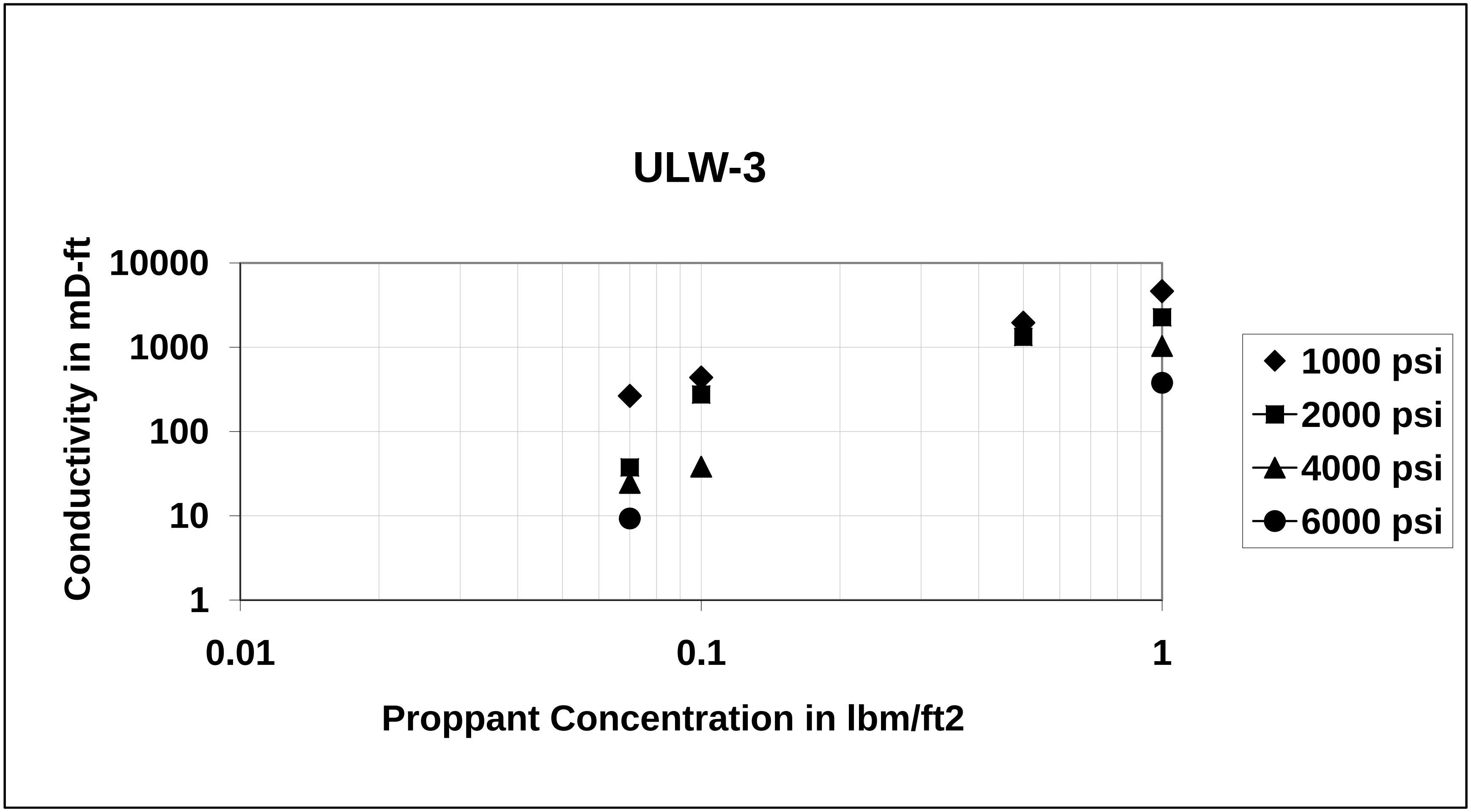
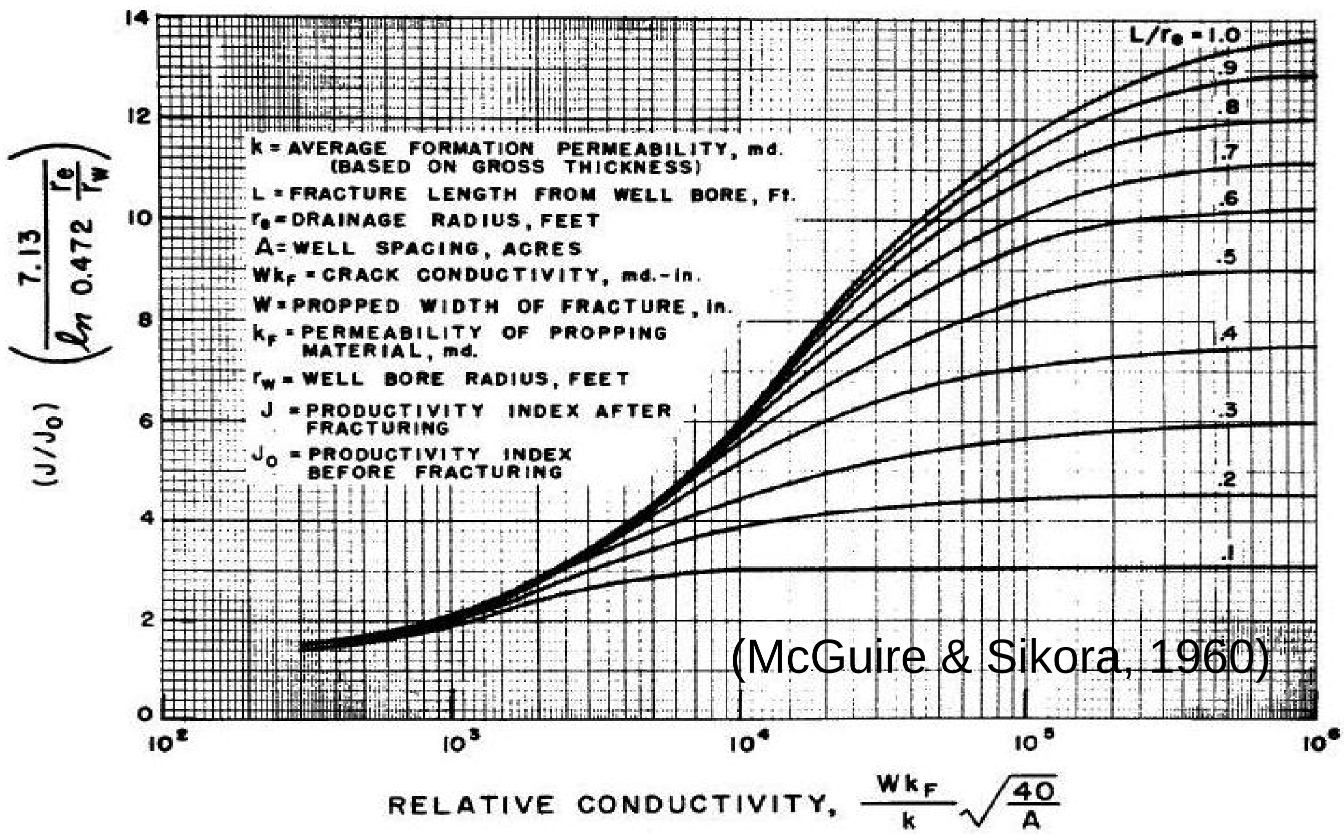


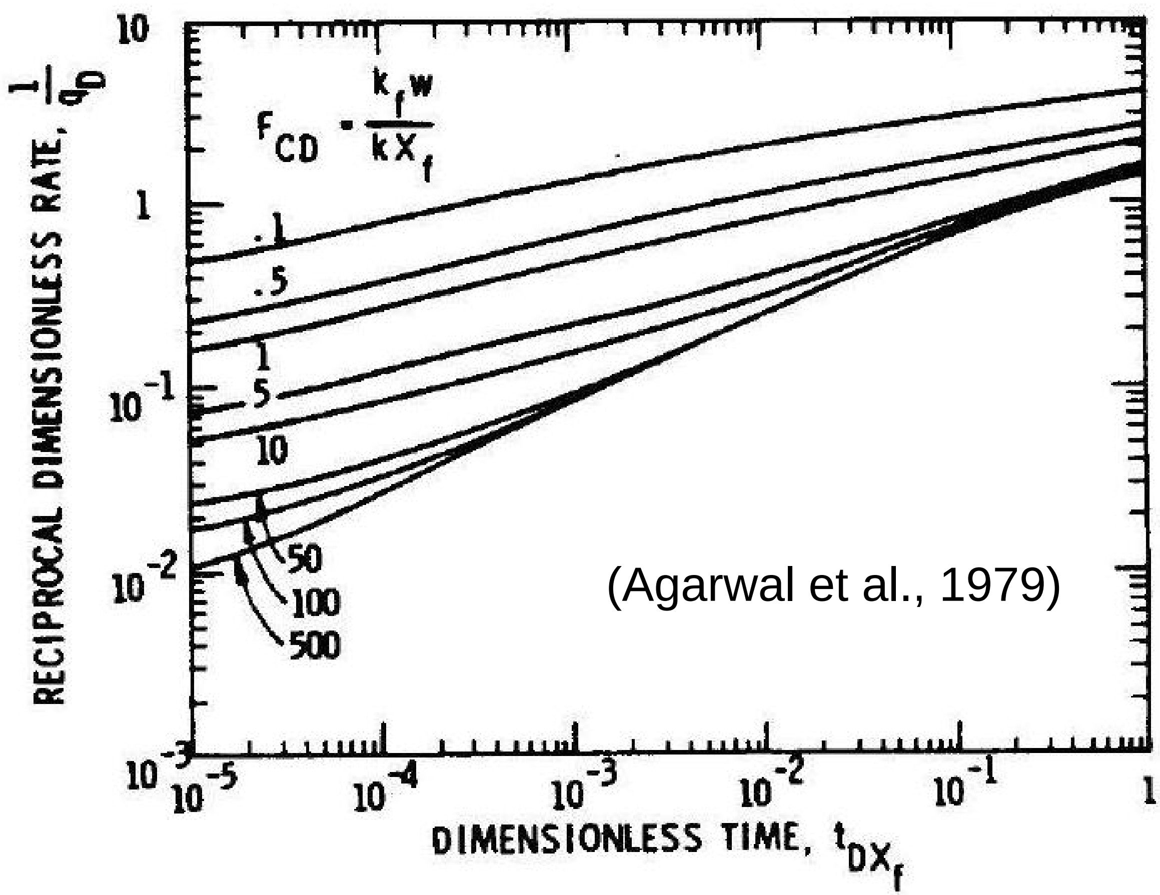
Conductivity increases with proppant concentration

How Much Conductivity is Needed?



- Relative conductivity = (1 md-ft/10^{-5} md)*1 = 10^5
- 1 md-ft is high enough for shales

How Much Conductivity is Needed?



- F_{CD} = 1 md-ft/(10^{-5} md x1000 ft) = 10^2
- 1 md-ft is high enough for shales

Foam Fracturing Fluid

1. Less water consumption

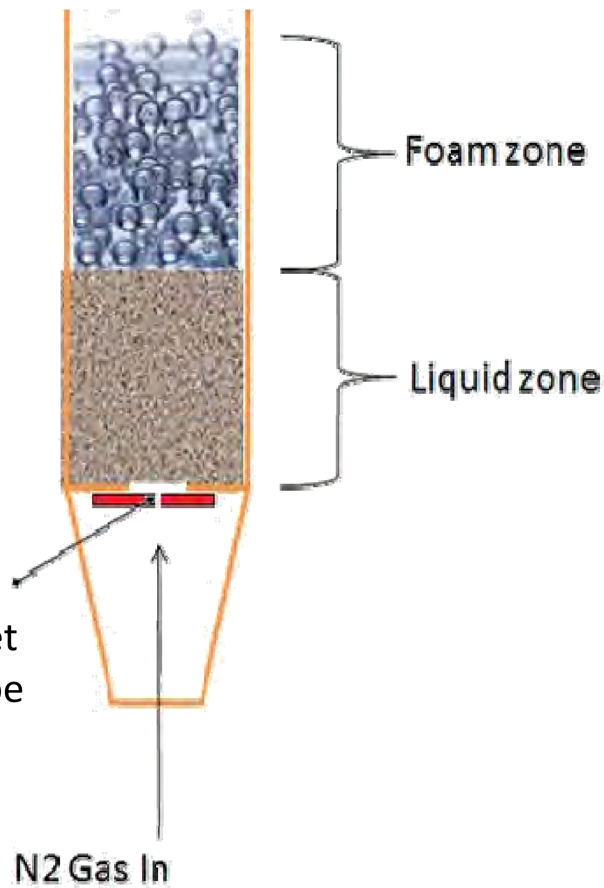
2. Gas expanding after the treatment to help recovery of the liquid phase

3. The two-phase structure has high viscosity

4. Gel filtercake deposited on the formation face is thinner (control the fluid loss)

5. Little proppant is produced if the flowback rate is kept low.

Experimental Setup for Stability Test



Needle-size inlet through the tape

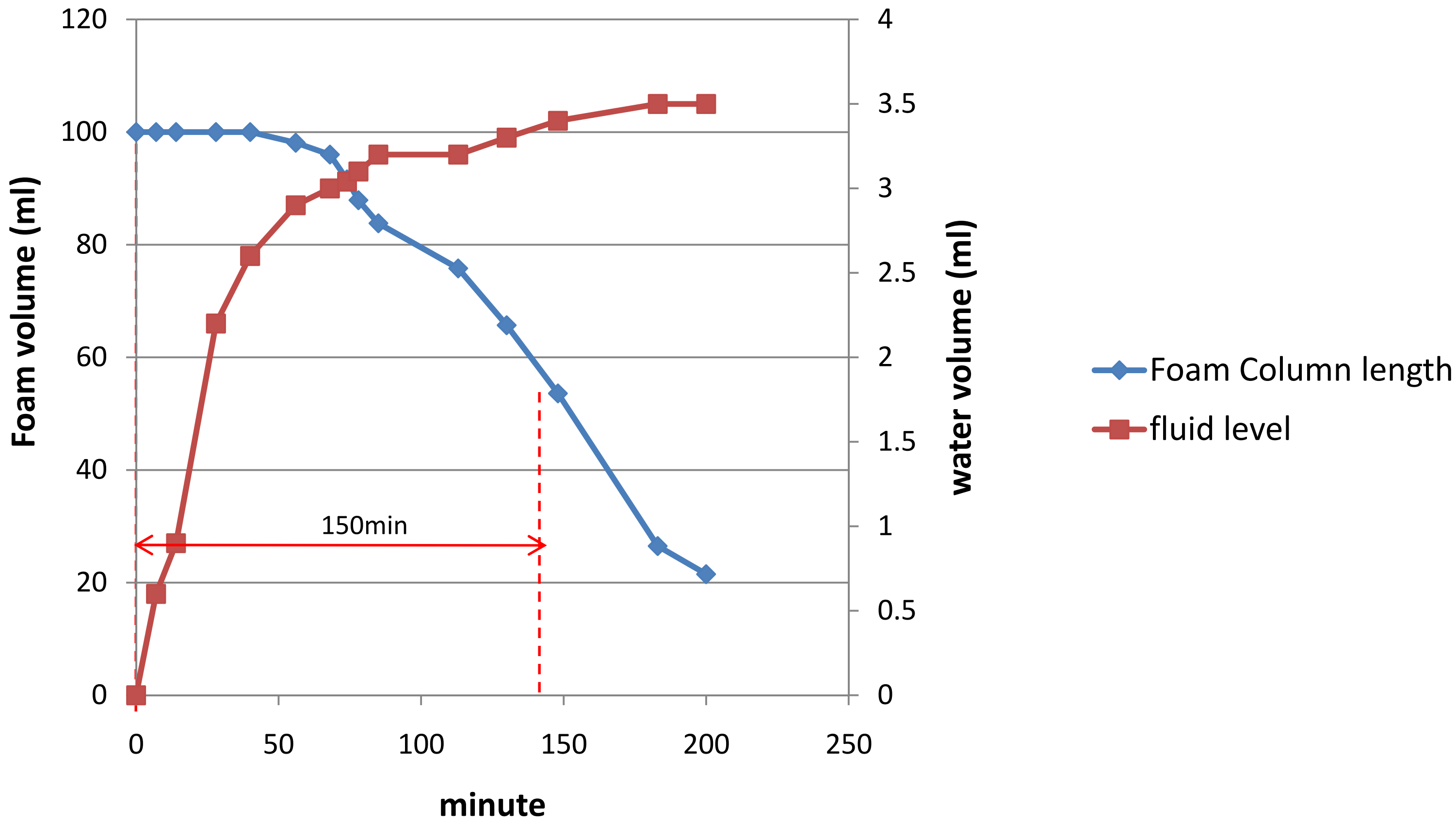
Schematic figure of the setup

Bubble size:1mm
(low flow rate)

Bubble size:2 mm
(high flow rate)

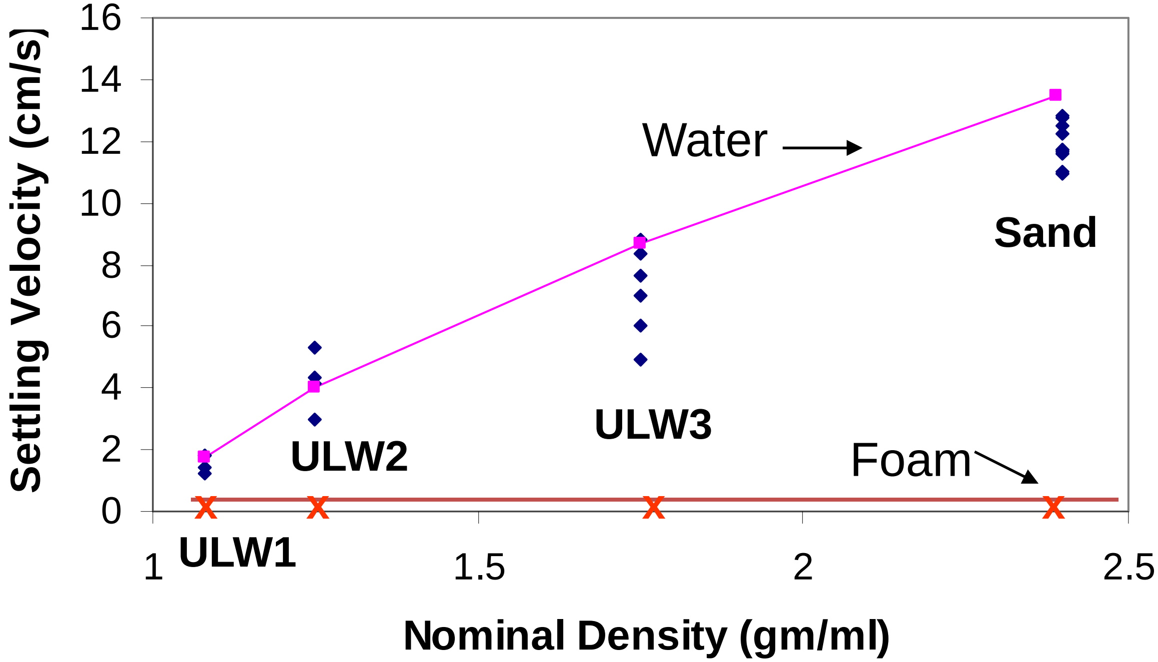
The bubble picture

Foam Stability



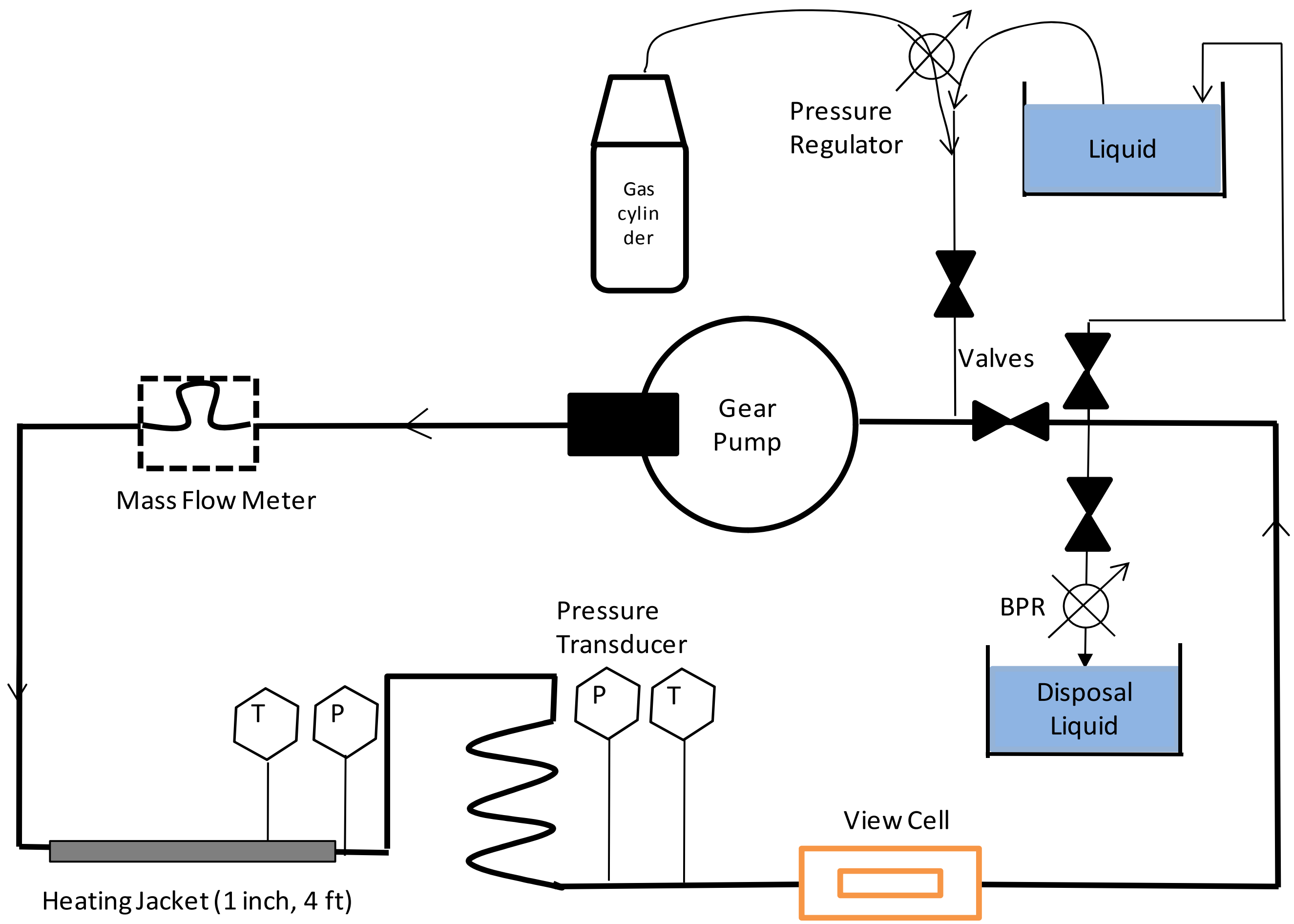
Foam half-life ~ 150 min

Proppant Settling Velocity (V_s)



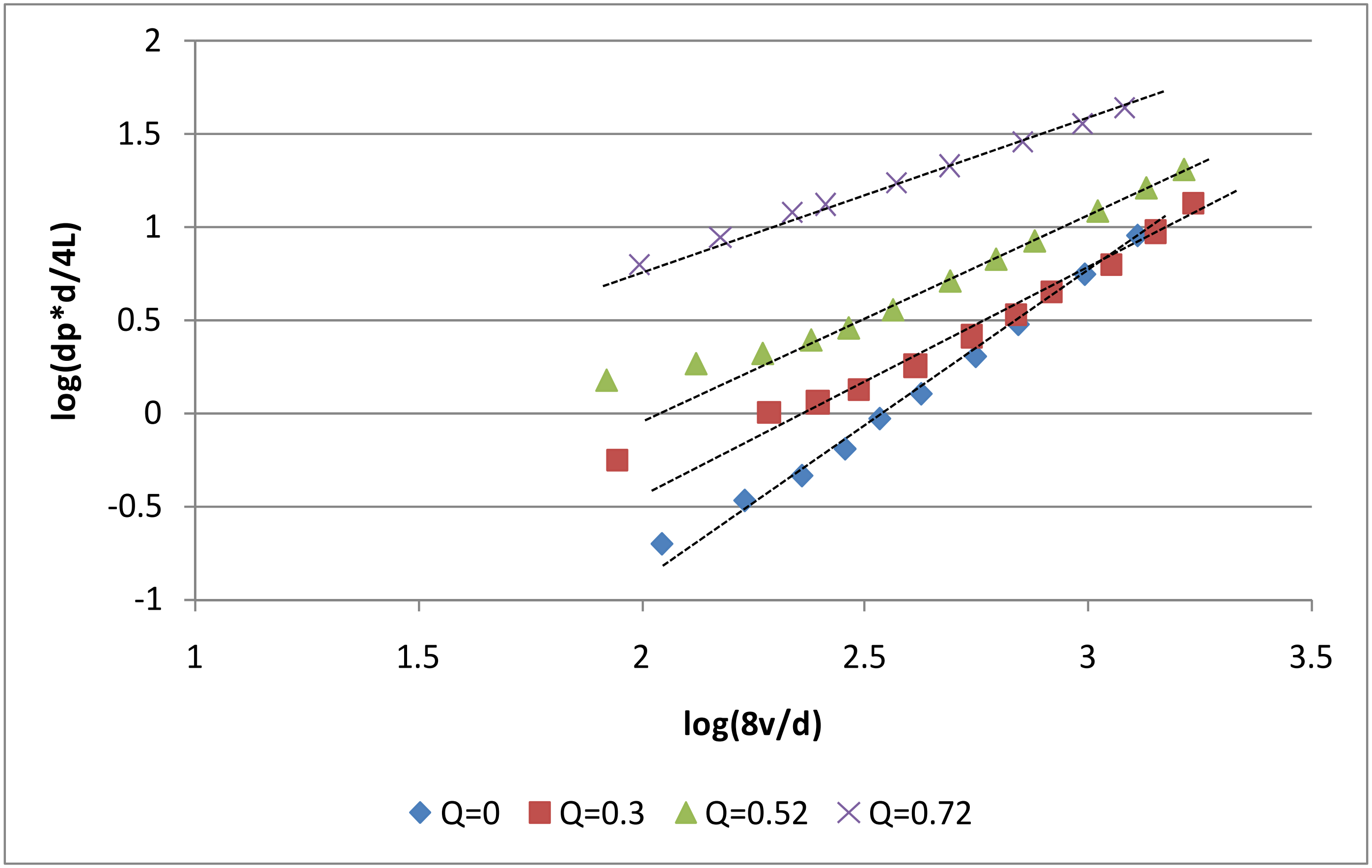
- $V_s = [0.072g(\rho_p - \rho_w)]^{0.71} d^{1.14} / \rho_w^{0.29} \mu^{0.43}$ for water
- $V_s = 0$ for all the proppants and the sand in foam

Foam Rheology Flow Loop



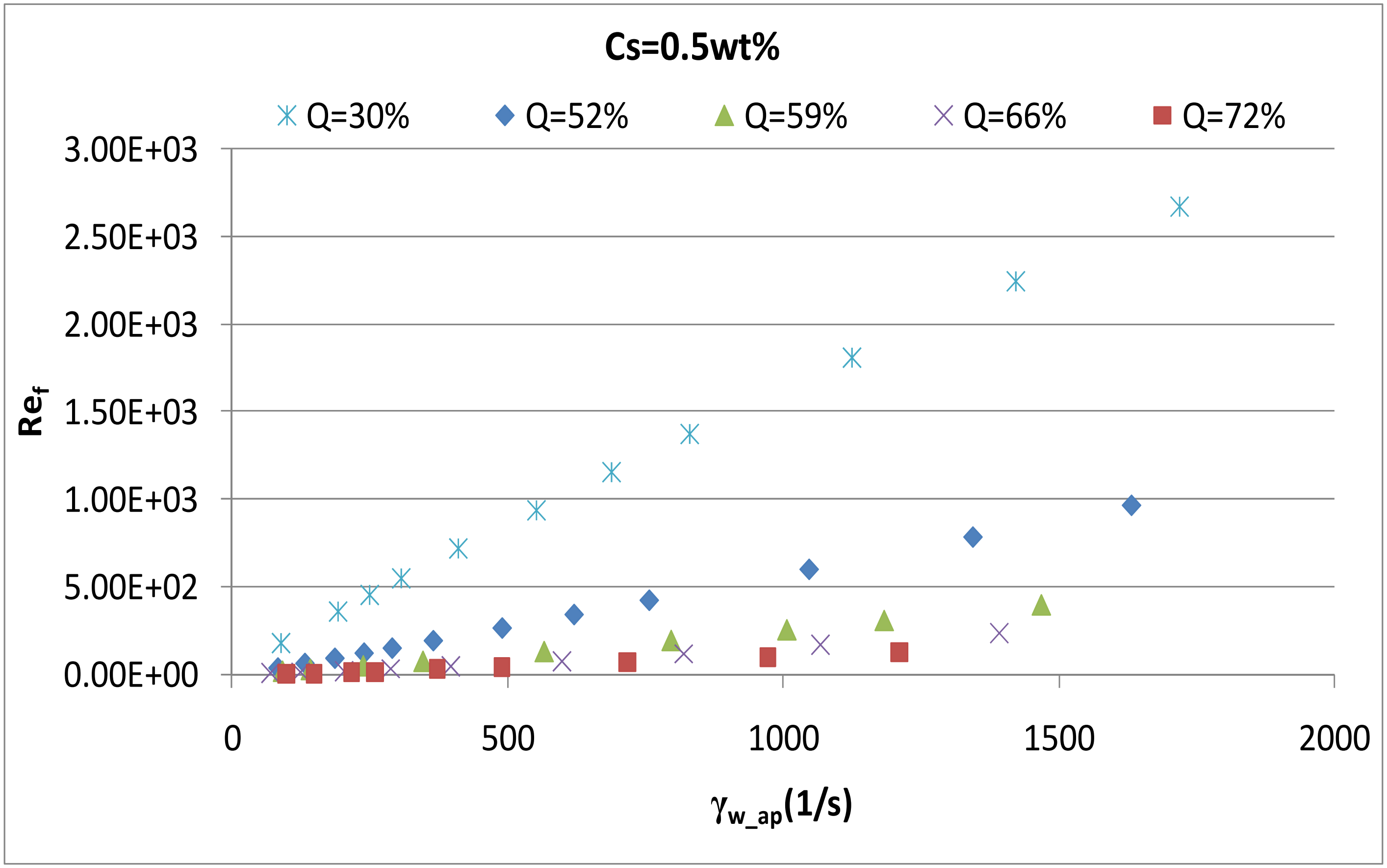
- Pressure tested up to 2000 psi

Foam Rheology



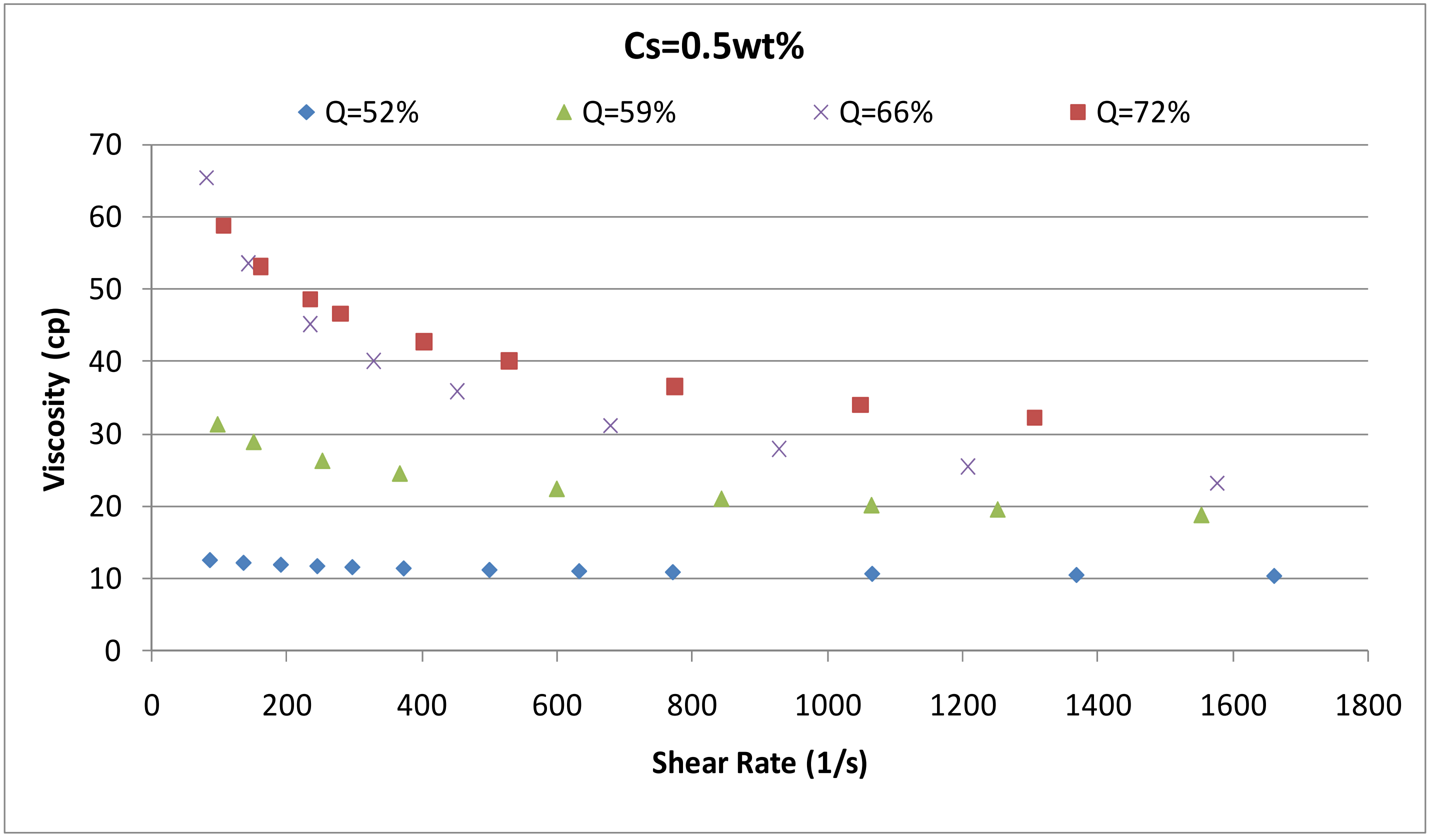
- Flow of water is turbulent
- Flow of foam is not turbulent

Foam Rheology



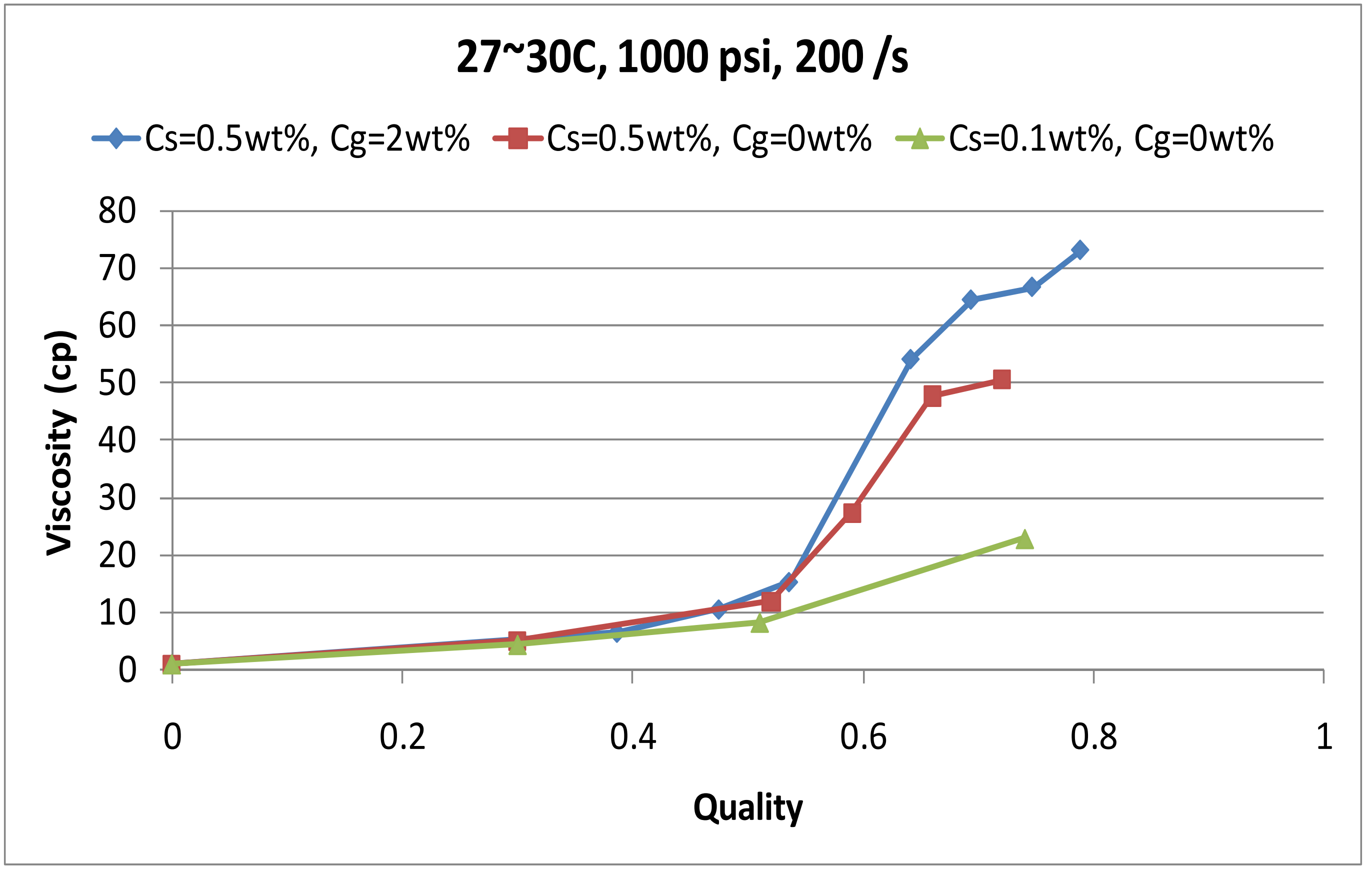
- Flow of foam is laminar

Foam Rheology: Shear Rate & Quality



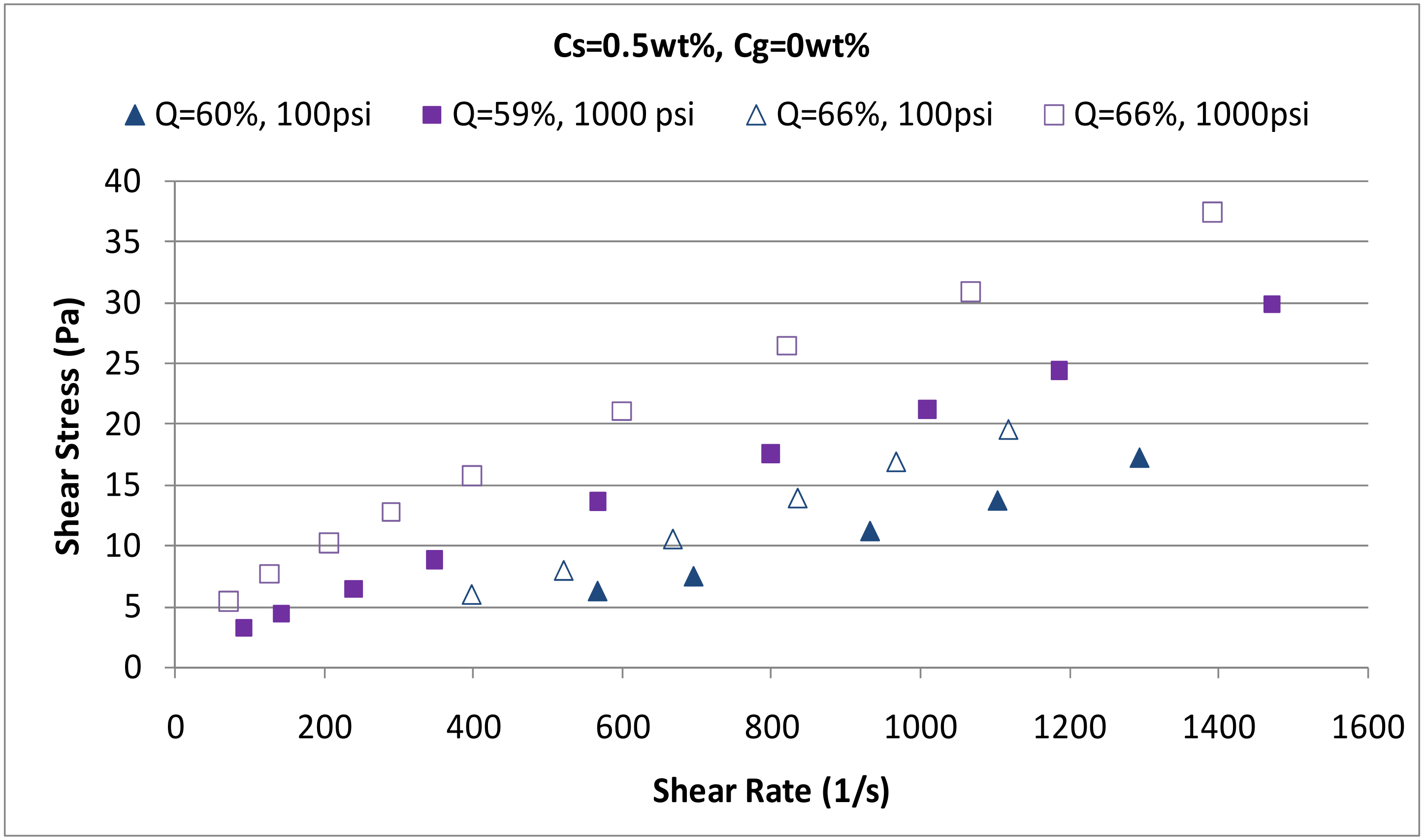
- Foam is shear thinning
- As quality increases, viscosity increases
- Viscosity is about 20-40 cp

Foam Rheology: Effect of Composition



- As the surfactant and stabilizer concentration increases, viscosity increases

Foam Rheology: Effect of Pressure



- As the back pressure increases, viscosity increases

Conclusions

- ULW proppant packs can endure stresses expected in Barnett shale (~4000 psi). ULW1 and ULW2 produce small amount of fines.
- Fracture conductivity is about 10 md-ft at 4000 psi; large enough for shale stimulation. Fracture conductivity of sub-monolayer is comparable to multilayer.
- Foams can be formulated that are stable during the fracturing process.
- The settling velocity increases with proppant density in water; settling is negligible in foams in static tests.
- Foam viscosity increases with quality & pressure and decreases with the shear rate.

Future Work

- Dynamic proppant settling
- Design of field test
  - Daneshy Consulting working with Devon & BJ
- Field test & evaluation
  - Working with Devon & BJ

Acknowledgements

- RPSEA
- Mr. Bill Wheaton, Devon
- Dr. Q. Qu, BJ Services
- Dr. A. Daneshy, Daneshy Consulting

Tasks

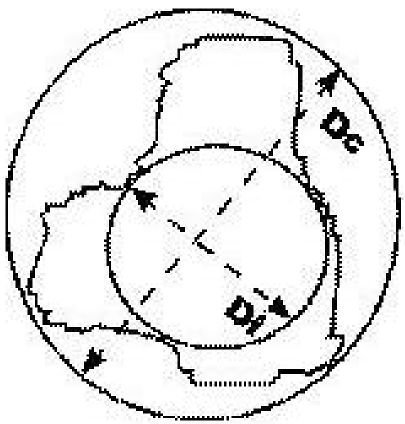
• Proppant properties	5/09-4/10
• Foam formulation	5/09-4/10
• Flow capacity	5/10-4/11
• Proppant transport	5/10-4/11
• Fracture design	5/11-10/11
• Field test & evaluation	5/11-4/12

Results

	ULW-1	ULW-2	ULW-3
Nominal density	1.08	1.25	1.75
Density of Pack (g/cc) (without closure stress)	0.6	0.8	1.2
Porosity of Pack (without closure stress)	44 %	36 %	31%
Sphericity	1	0.62±0.7	0.78±0.1

Riley Sphericity

$\Psi_R=(D_i/D_c)^{0.5}$



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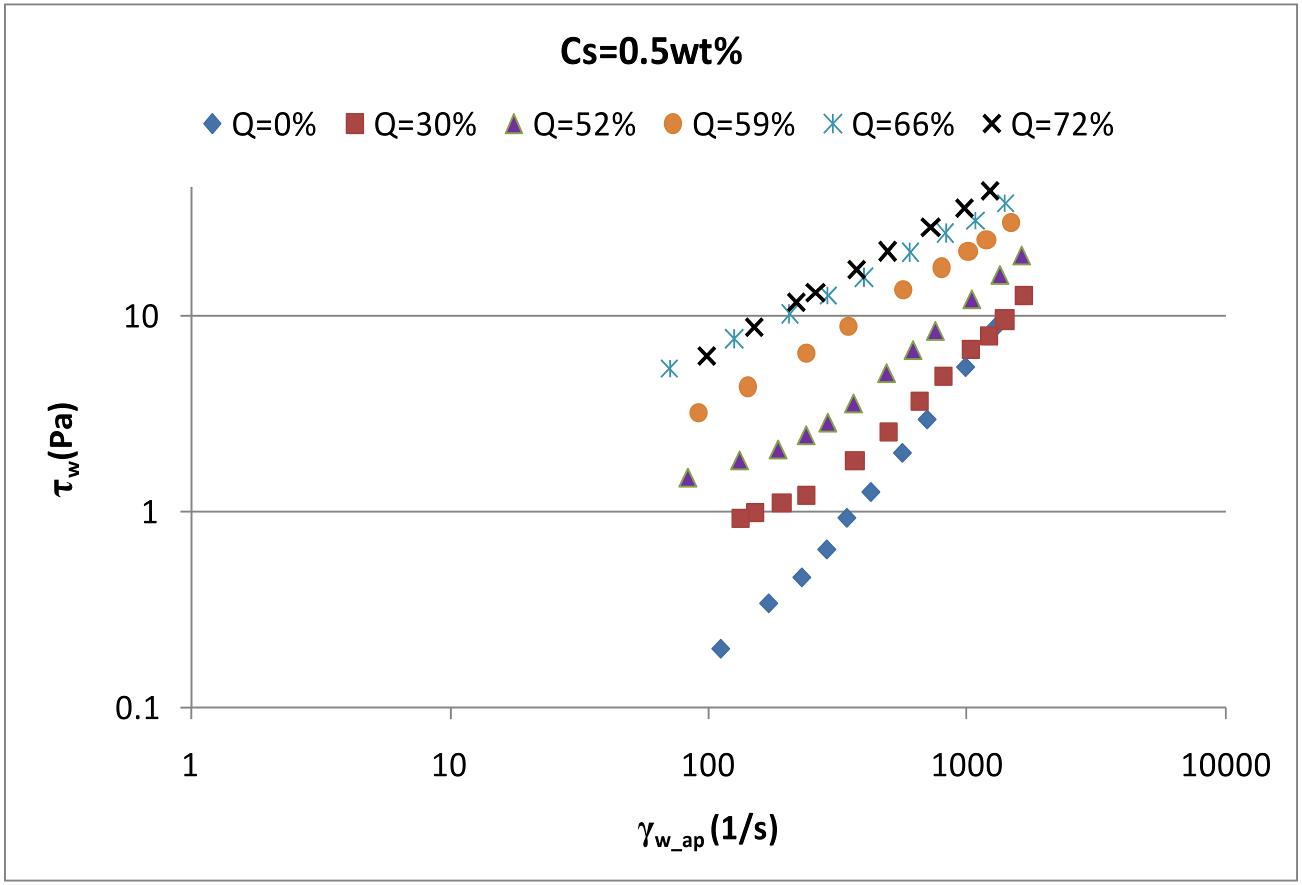

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