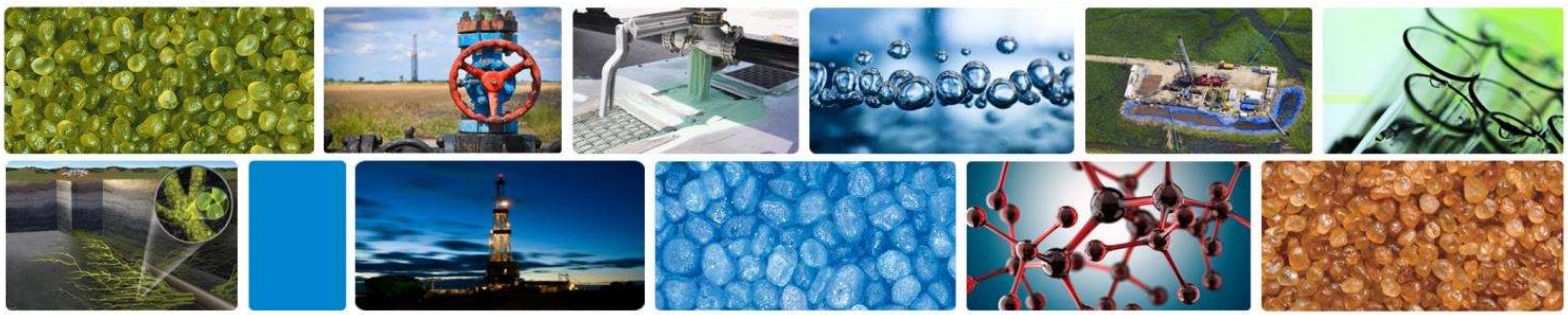

On-the-Fly Resin Coating Controls Proppant Flowback and Enhances Conductivity

Logan Cabori, Hexion Inc.

Agenda

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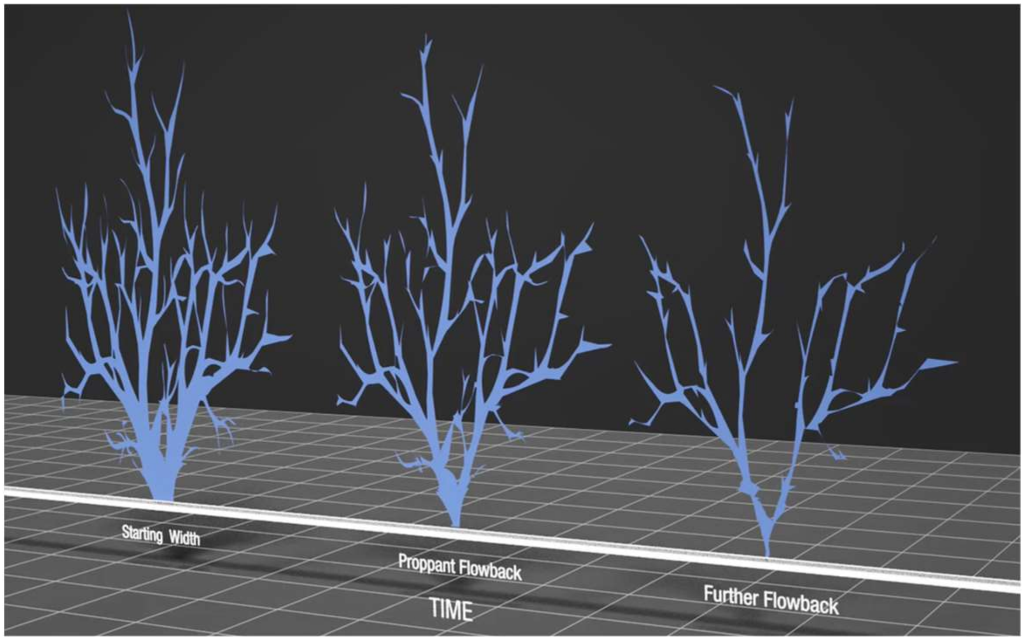
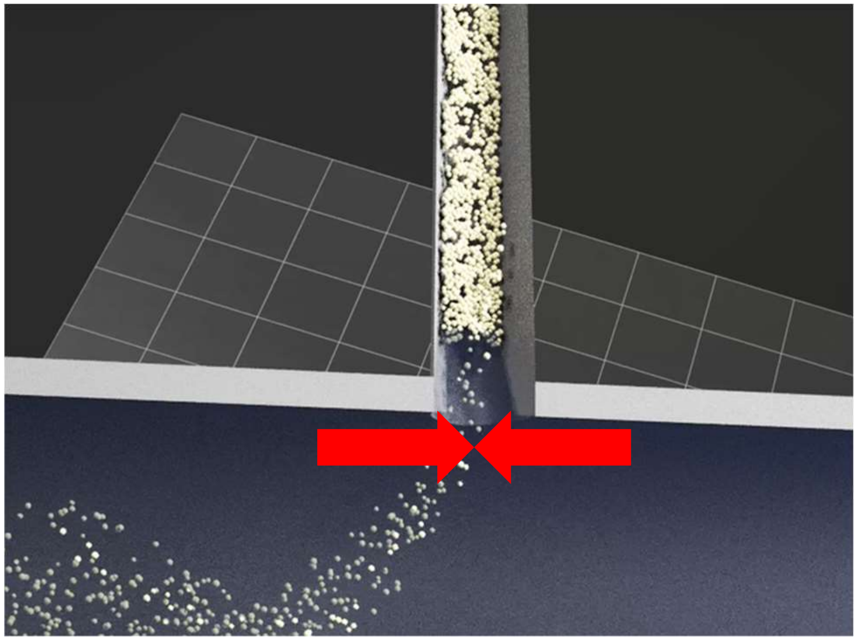
- Proppant Flowback Effects
- Existing Mitigation Techniques/Technology
- Theory: Requirements of a New Additive
- Laboratory Testing
- Field Studies
- Next Generation Development
- Conclusion

Effects of Proppant Flowback





Fractures can close or be significantly reduced in size as proppant flows back.

Proppant flowback near wellbore can result in loss of connectivity between the fracture and wellbore.

Effects of Proppant Flowback

Effects of proppant flowback are not limited to reduced hydrocarbon production. Additional costs related to proppant flowback are:

- Damage to surface equipment
- Hauling and disposal of proppants that reach the surface
- Damage to artificial lift systems
- Additional days for flowback crews to be on site, and
- Lost production time for well remediation including additional cleanouts for displaced proppants that do not return to the surface and deposit in the lateral.

Existing Mitigation Techniques/Technology

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Physical Solutions
- Forced Closure
- Fibers
- Shaped (interlocking) Proppants
- Choke management

Chemical Solutions
- Curable resin coated proppants
- On-the-fly resin coating
- Proppant surface treatments

No physical or chemical proppant flowback control strategy is perfect for all wells.

Technical shortcomings, application inflexibility, and cost of the existing techniques/technologies led to the development of PFCA.

Theory: Requirements of a New Additive

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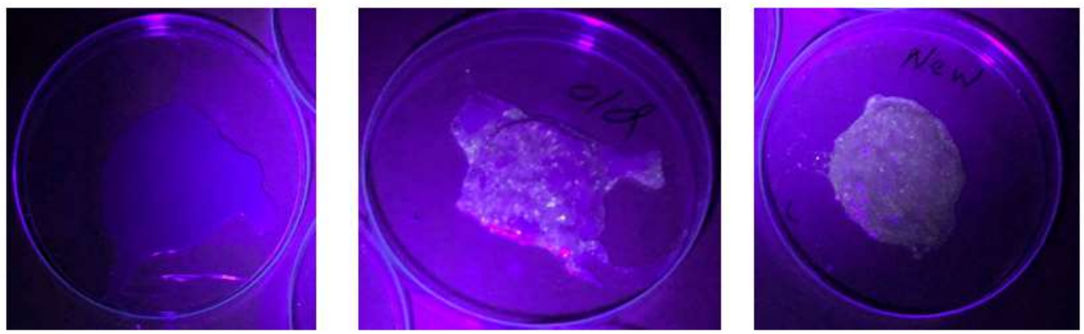
- Liquid additive that can be added on-the-fly
- Ability to coat substrate in an aqueous medium (frac fluid)
- Adhesive properties that facilitate coating of the proppant surface and subsequently bonding the particles together
- Insolubility in water as well as oil
- Thermal stability in order to survive normal well temperatures
- Easy equipment clean-up
- No special equipment required
- Cost effective

Laboratory Testing: Coating Efficiency- Fluorescence is used to ensure uniform coating

- **Efficient coating for PFCA was observed in the laboratory as well as in field samples taken directly from the blender tub.**



Untreated Frac Sand | Treated Sand With Inefficient Coating | Treated Sand With Efficient Coating

An even coating is critical for the mechanical strength of the consolidated proppant pack.

Laboratory Testing: Unconfined Compressive Strength

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- UCS testing indicates that sand treated with PFCA has adequate bond strength to control proppant flowback.

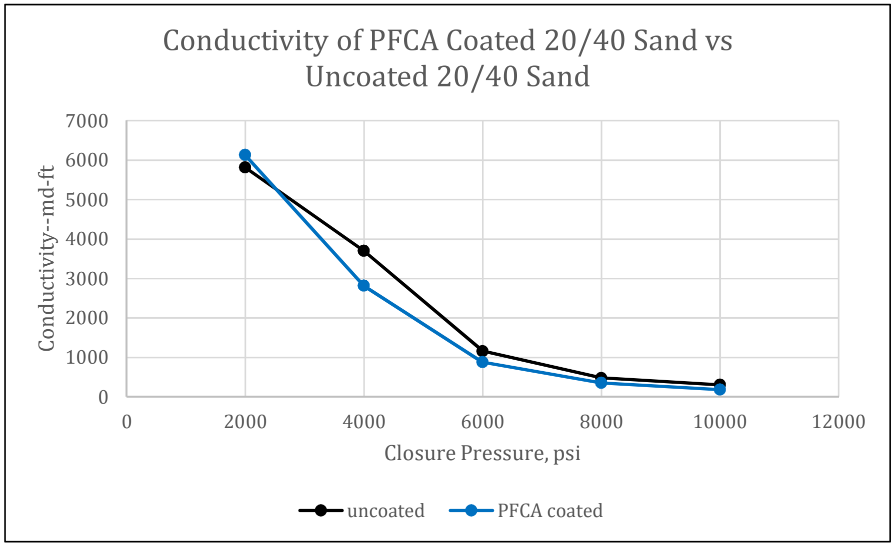
Table 1. Effect of PFCA loading level on UCS value of Permian regional 40/70 sand cores

Entry	Proppant	Loading, %	Aging Temperature, °F	UCS, psi
1	40/70	1.00	200	77
2	40/70	1.25	200	113
3	40/70	1.50	200	144

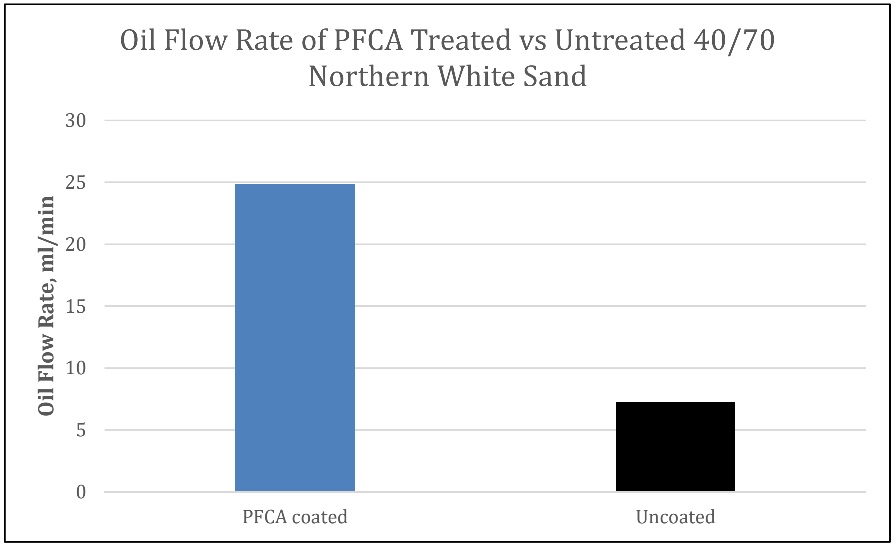
Table 2. Effect of PFCA loading level on UCS value of Permian regional 100-mesh sand cores

Entry	Proppant	Loading, %	Aging Temperature, °F	UCS, psi
1	100 mesh	1.00	200	101
2	100 mesh	1.20	200	140
3	100 mesh	1.30	200	154
4	100 mesh	1.50	200	187

Laboratory Testing: Oil flow rate and Conductivity



The PFCA coating has no significant effect on conductivity



PFCA-coated sand has three times higher oil flow rate compared to uncoated sand pack

Gravity flow rate testing showed improved oil flow rate for PFCA. Standard baseline conductivity (2% KCl solution) indicated no significant impact on conductivity.

Laboratory Testing: Critical Flow Rate – Third Party Laboratory

- Critical flow rate is a key parameter that is widely used to characterize the ability of a control measure to limit proppant flowback.

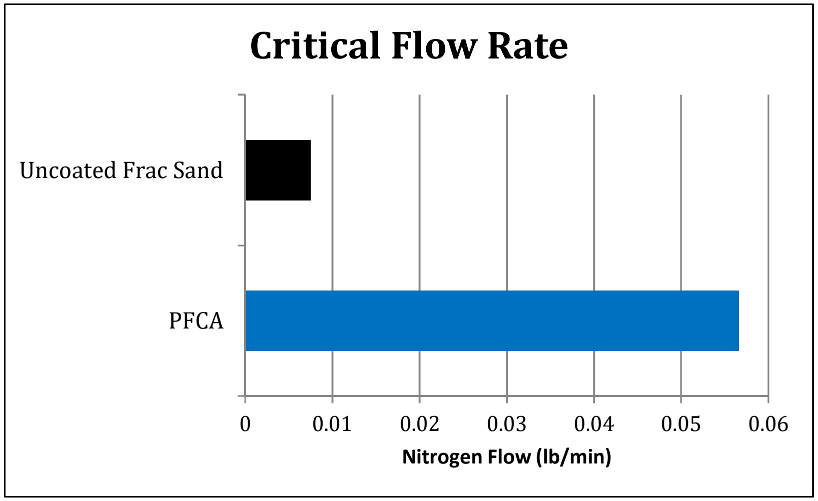
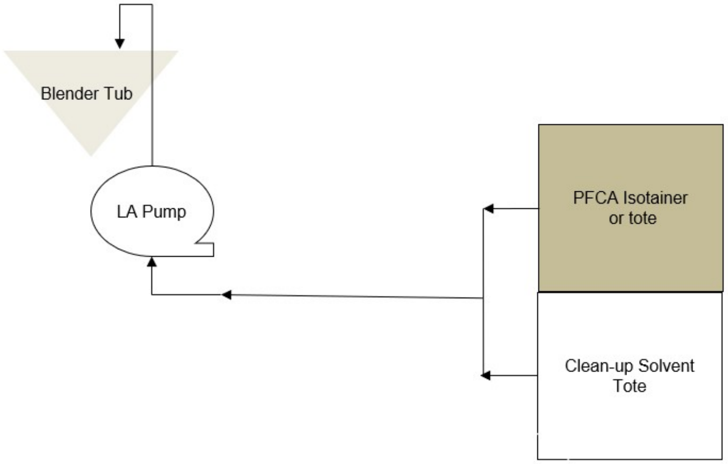
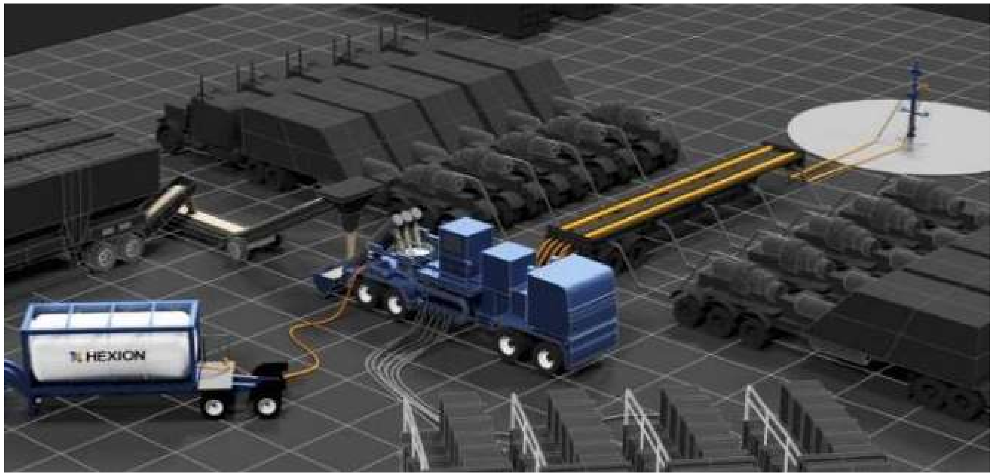


Figure 8. PFCA-coated sand has seven times higher critical flow rate than the uncoated sand

Field Studies: PFCA Application

- The setup for pumping PFCA is similar to other liquid chemicals
  - Typical application rates vary from 1.0-1.5% BWOS (by weight of sand)
  - Samples are taken from a sample port off the blender or missile
  - The samples are visually inspected on site and analyzed by fluorescence method in the laboratory





Field Studies: Case Study 1
Wolfcamp A in Reeves County, Texas

- Initial Head-to-Head Trial:
  - 10% tail-in of 100 mesh RCP vs. 10% tail-in of 100 mesh treated with PFCA

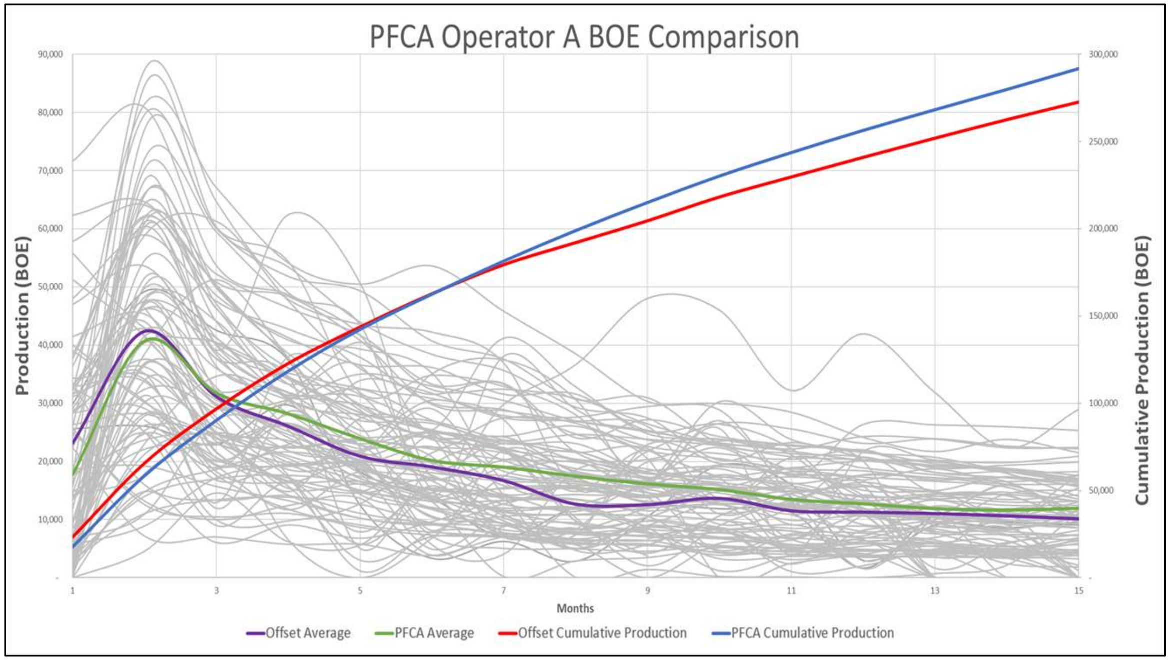
Stage #	Description	Fluid Type	Rate (bpm)	Clean Vol (gals)	Prop Con (PPA)	Prop Type	Stage Prop (lbs)
1	Breakdown	Slickwater	15	1,050			
2	Spreadhead Acid	15% Acid	15	1,000			
3	Flush	Slickwater	95	18,473			
4	Pad	Slickwater	95	4,200			
5	100 Mesh 0.5 PPA	Slickwater	95	95,000	0.5	100 Mesh	47,500
6	100 Mesh 1 PPA	Slickwater	95	142,500	1	100 Mesh	142,500
7	100 Mesh 1.5 PPA	Slickwater	95	110,833	1.5	100 Mesh	166,250
8	100 Mesh 2 PPA	Slickwater	95	71,250	2	100 Mesh	142,500
9	100 Mesh 2 PPA + PFCA	Slickwater	95	47,500	2	100 Mesh +PFCA	95,000
10	Flush	Slickwater	95	18,473			

The PFCA well produced 50% less proppant during drill-out. An 80% reduction of proppant flowback was observed during flowback.

Field Studies: Case Study 1
Wolfcamp A in Reeves County, Texas

- Next phase: Operator A completed 61 PFCA wells and compared them to 31 wells that used the traditional resin coated proppant design. Production was observed for 15 months.

Operator A was able to reduce overall CAPEX by nearly $7.6mm while increasing BOE production.



Field Studies: Case Study 2
3rd Bone Spring in Lea County, New Mexico

- Operator B was using a 25% RCP tail-in and still experiencing flowback that was damaging ESPs.
- Switching to PFCA, Operator B was able to coat a 50% tail-in while remaining cost neutral.

Stage #	Stage Type	Fluid Type	Clean Vol (gals)	Prop Con (ppa)	Stage Prop (lbs)	Prop Type	Avg Rate (bpm)
1	Pad	Slickwater	20,000				80.0
2	Prop	Slickwater	30,000	0.50	15,000	40/70 Regional	80.0
3	Prop	Slickwater	40,000	0.75	30,000	40/70 Regional	80.0
4	Prop	Slickwater	45,000	1.00	45,000	40/70 Regional	80.0
5	Prop	Slickwater	56,000	1.25	70,000	40/70 Regional	80.0
6	Prop	Slickwater	60,000	1.50	90,000	40/70 Regional	80.0
7	Prop	Slickwater	68,000	1.75	119,000	40/70 Regional + PFCA	80.0
8	Prop	Slickwater	65,500	2.00	131,000	40/70 Regional + PFCA	80.0
9	Flush	Slickwater	18,354				80.0

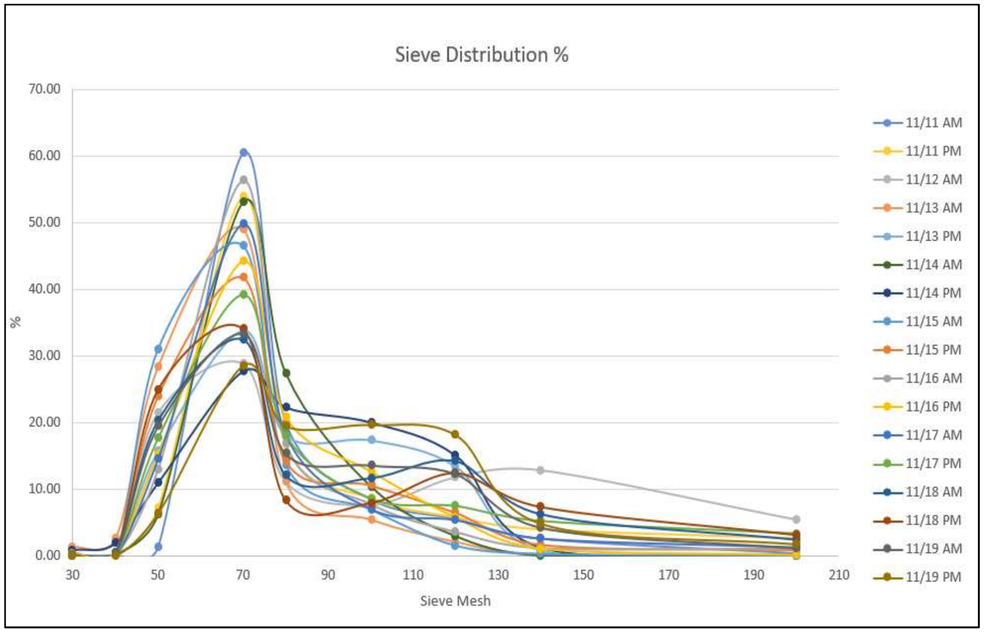
Field Studies: Case Study 2
3rd Bone Spring in Lea County, New Mexico

- During the first month of initial flowback, the PFCA well produced only 30 lb of proppant to the surface
- With success of the initial trial, subsequent trials have been conducted to optimize their usage of PFCA in order to reduce CAPEX spend
- Additional trials were conducted with a 40% and 35% tail-in design. Only trace amounts of proppant flowback were observed in these trials

Field Studies: Case Study 3
2nd & 3rd Bone Spring in Lea Co., NM and Ward Co., TX

- In order to develop a job design for PFCA, a proppant flowback study was performed on a comparable nearby well targeting the same formation.
- Samples were taken every twelve hours to compare the flowback samples to the initial mesh size distribution of the 40/70 and 100 mesh sand.
- The study concluded that the 40/70 tail-in was flowing back to the surface.
- Based on the results, a trial was designed to utilize a 40% tail-in of PFCA on two wells in a four-well pad.

Field Studies: Case Study 3
2nd & 3rd Bone Spring in Lea Co., NM and Ward Co., TX



Stage #	Stage Name	Fluid Type	Prop Con (ppa)	Prop Type	Clean Vol (Gal)	Stage Prop (lbs)	PFCA Vol (Gal)	Avg Rate (bpm)
1	Breakdown	Slickwater			1,000			10
2	15% HCl	Acid			2,000			10
3	Pad	Slickwater			15,000			90
4	.50 PPA	Slickwater	0.5	100 Mesh	100,000	50,000		90
5	.75 PPA	Slickwater	0.75	100 Mesh	80,000	60,000		90
6	1.00 PPA	Slickwater	1	100 Mesh	90,000	90,000		90
7	1.50 PPA	Slickwater	1.5	100 Mesh	60,000	90,000		90
8	2.00 PPA	Slickwater	2	100 Mesh	50,000	100,000	116	90
9	1.00 PPA	Slickwater	1	40/70 White + PFCA	60,000	60,000	69	90
10	1.50 PPA	Slickwater	1.5	40/70 White + PFCA	60,000	90,000	104	90
11	2.00 PPA	10# Linear Gel	2	40/70 White + PFCA	30,000	60,000	69	90
12	Flush	Slickwater			21,000			90

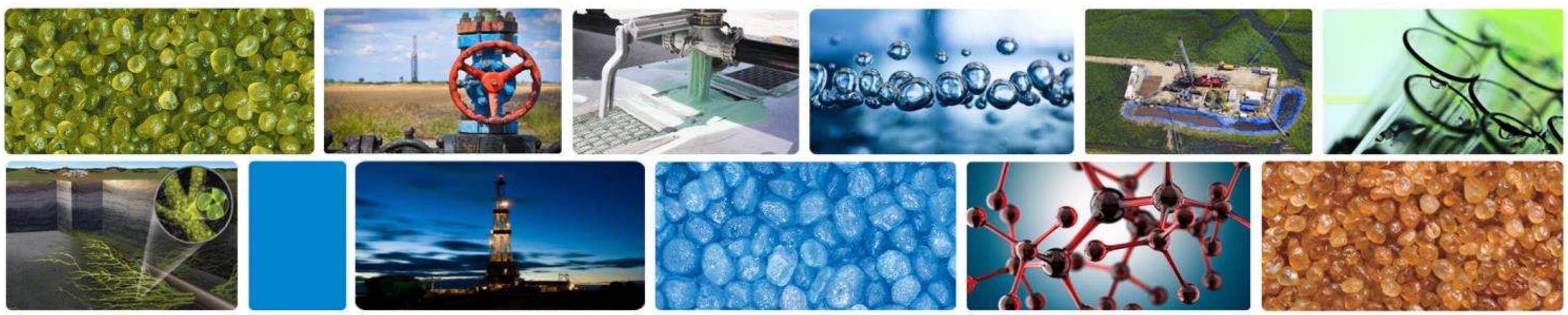
Field Studies: Case Study 3
2nd & 3rd Bone Spring in Lea Co., NM and Ward Co., TX

- Initial flowback results showed PFCA-completed wells had over 75% less proppant flowing back than wells completed without PFCA.

- This led Operator C to continue optimizing the percentage of proppant treated with PFCA to reduce CAPEX while minimizing proppant flowback.

Conclusion

- Proppant flowback continues to have a significant impact on well profitability.
- PFCA was developed as a more economical proppant flowback control system that is added directly to the blender tub.
- This paper presents extensive laboratory testing and field results that demonstrate the fitness of PFCA at stopping or reducing proppant flowback while improving hydrocarbon production in treated wells.



Next Generation Development

PropCure™
On-the-Fly Curable Resin Coating

- Two part system that is mixed at the wellsite in an in-line static mixer that feeds directly into the blender tub
- The two components of the coating layer will crosslink to form a chemical bond between sand grains to provide a strongly consolidated proppant pack which reduces sand flowback
- Is effective over a wide temperature range: 105˚F - 350˚F
- High critical flow rate for improved proppant flowback control in high rate wells
- Can be applied to any type and mesh size proppant

Technical Advantages and Benefits

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PropCure coating provides savings by:

- Mitigating proppant flowback
- Reducing time for flowback services to be onsite
- Extending life of artificial lift systems and other equipment
- Reducing the need for additional surfactants

PropCure coating improves production and revenue by:

- Keeping proppant in the fractures and maintaining pathways for oil and gas to flow
- Improving conductivity of the proppant pack compared to uncoated frac sand
- Encapsulating proppant fines, which can otherwise move and plug off the permeability of the proppant pack
- Altering the relative permeability of the proppant pack

Unconfined Compressive Strength Testing

Sand Type	Temperature, °F	Shut-in Time, h	Dosage, % BWOS	UCS, psi
40/70	200	16	1	>250
40/70	325	16	1	>250
100 Mesh	240	16	1.5	>400

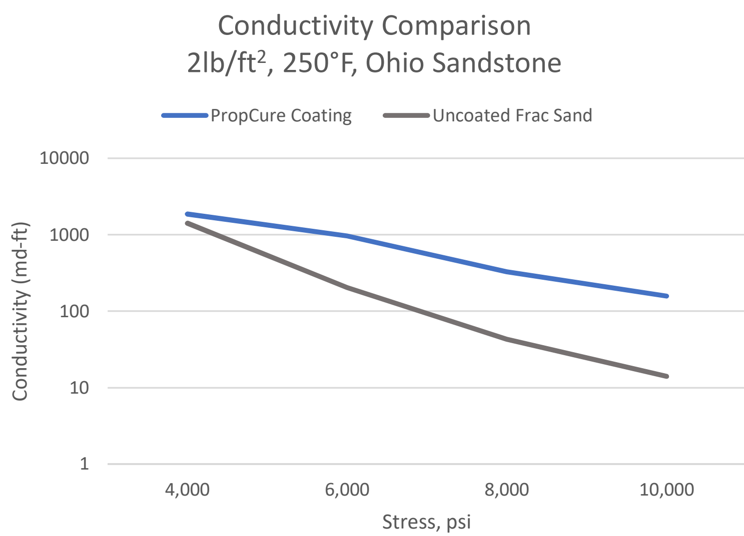
**Testing done at 1000 psi with a one-inch diameter cell.*

PropCure coating provides significant bond strength to control proppant flowback. The coating is effective at a wide range of bottomhole temperatures.

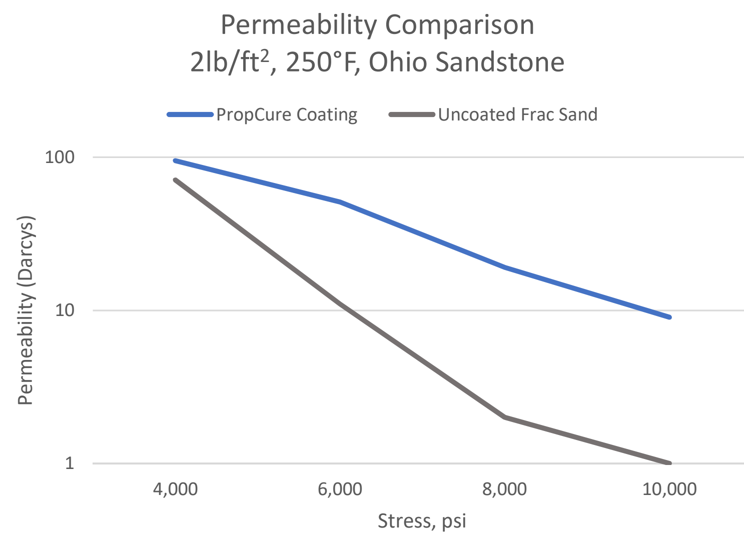
Sand treated with PropCure Coating forms a consolidated core

Conductivity and Permeability

**Testing done using customer provided +30-70 northern white sand*



Closure Stress, psi	4,000	6,000	8,000	10,000
	Conductivity (md-ft)			
PropCure Coating	1860	962	328	157
Uncoated Frac Sand	1411	202	43	14



Closure Stress, psi	4,000	6,000	8,000	10,000
	Permeability (Darcys)			
PropCure Coating	95	51	19	9
Uncoated Frac Sand	71	11	2	1

PropCure coating has improved conductivity and permeability compared to the control of uncoated frac sand. This improvement can be attributed to fines encapsulation and reduced fines migration.

Flowrate Test on VFC-2000 Coated and Raw Sand Pack

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Column preparation for VFC-2000 coated sand pack

- 1. coated 100 g NMS 100 mesh with 0.5% VFC-2000, following standard procedure
- 2. pack UCS cell. Applied 1000 psi pressure with bottom valve closed
- 3. cure at 250 F for 24 h
- 4. cell taken out and cooled to RT
- 5. pack the raw sand column following step 1-4.

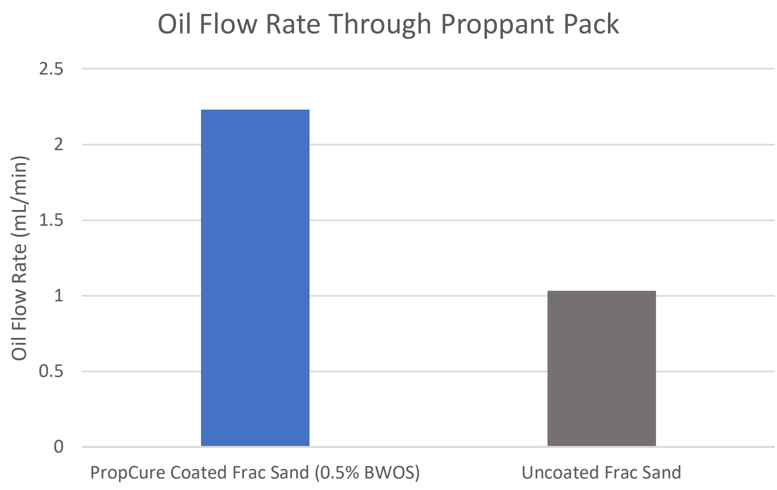
Flow rate measurement

- Open the cell. Replace the bottom valve with an adapter (picture on next page)
- Added water to the cell top to the full level. Record the time from the first drop to the last drop of water
- Repeat once
- Dry column with nitrogen overnight
- Isopar L measurement follows same procedure

Surface Activity Data

By altering the relative permeability, PropCure coating provides more that two times higher flow rate compared to uncoated frac sand.

Running this technology, even at low concentrations, can reduce or eliminate the need for additional surfactants.



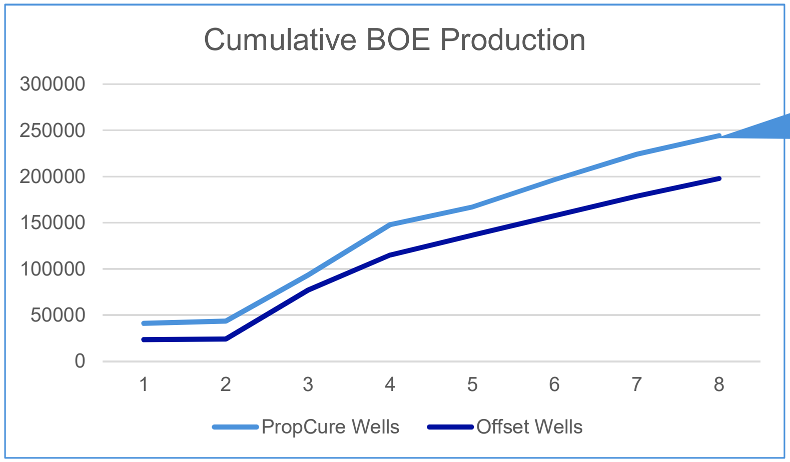
PropCure Field Study in the Bakken

- Bakken 7 Well Pad
  - 5 Bakken Wells / 2 Three Forks Wells
- 40 Stages per well
- 8M lb of 40/70 White Sand
  - 200K/stage
- Lateral ~10K ft.
- Slickwater Fluid System
- PropCure 7% Lead-in / 18% Tail-in
- 1% BWOS Concentration

- 3 Wells PropCure (2 Bak / 1 TF)
- 4 Wells Raw Sand (3 Bak / 1 TF)

- Wells were taken off production for a period of time due to the price volatility in Q2 of 2020

Stage #	Description	Fluid Type	Rate (bpm)	Clean Vol (gals)	Prop Con (PPA)	Prop Type	Stage Prop (lbs)
1	Spreadhead Acid	Acid	15	750			
2	TP Water	TPW	70	24,000			
3	TW Water - Pad	Slickwater	70	8,000			
4	40/70 Mesh (0.5 ppg) - PropCure	Slickwater	70	30,000	0.5	40/70 Mesh + PropCure	15,000
5	40/70 Mesh (1.0 ppg)	Slickwater	70	23,000	1	40/70 Mesh	23,000
6	40/70 Mesh (1.5 ppg)	Slickwater	70	30,000	1.5	40/70 Mesh	45,000
7	40/70 Mesh (2.0 ppg)	Slickwater	70	26,000	2	40/70 Mesh	52,000
8	40/70 Mesh (2.5 ppg)	Slickwater	70	12,000	2.5	40/70 Mesh	30,000
9	40/70 Mesh (2.5 ppg) - PropCure	Slickwater	70	14,000	2.5	40/70 Mesh + PropCure	35,000
10	Flush	TPW	70	19,216			
11	Pumpdown	TPWPD	10	20,216			



PropCure Wells increased production by 24%

VFC-2000 and PropShield comparison

	PropShield	VFC-2000
Ease of Pumping	On Demand, can be pumped at any time during job as long as PPA is >.5 PPA Requires 1 LA pumps Minimum	On Demand, can be pumped at any time during job as long as PPA is >.5 PPA Requires 2 LA pumps Minimum
System Component	Single component	2 part system crosslinks to form a chemical bond between sand grains 1:1 ratio of XA and XB
Proppant Applications	Works on Raw Silica sand and ceramics. Any mesh size can be coated. %BWOS will change depending on type and size	
Critical Flow Rate	8X higher than Raw sand	19X Higher than Raw sand
Special Equipment	None- uses standard LA pumps on Service company equipment	Inline Static Mixer to blend 2 part system-Hexion Provides
BHT Range	68˚F - 215˚F	105˚F - 350˚F

Conclusion

- Proppant flowback continues to have a significant impact on well profitability

- Hexion's Liquid Additive Technologies were developed as more economical proppant flowback control systems that are added directly to the blender tub
- SPE-201372-MS presents extensive laboratory testing and field results that demonstrate the fitness of PFCA at stopping or reducing proppant flowback while improving hydrocarbon production in treated wells
- Based on field data and laboratory testing, lower concentrations of PFCA are being evaluated as replacements for surfactants typically used for production enhancement
- Next-generation developments are being designed to meet demands for higher temperature wells and wells with higher flow rates. Initial Results are very promising.

Even at reduced coating levels PropCure and PropShield have surfactant like qualities that help increase production. This is seen in the field and quantified in the lab with flow tests.

Acknowledgements / Thank You / Questions

Co-Authors

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- Benjamin Abrams
- Dr. John Green
- Kevin Hamori
- Adam Harper

- Questions
  - Please Contact
    - Logan.Cabori@Hexion.com
    - Kevin.Hamori@Hexion.com

  - Based on SPE-201372

Laboratory Testing: Oilflow Rate Test

- The oil flow rate test is conducted to understand if the coating improves or impedes oil flow compared to a control.
- Testing is done by using the setup shown in **Figure 4**.
- The proppant is dry coated with PFCA in a separate container. The coated proppant is then packed into the glass column.
- **Isopar™ L (API gravity of 53.2°),** a laboratory oil, is added to the column. The bottom valve is then opened until the proppant pack is fully saturated.
- After full saturation, the rate of flow is calculated. Untreated proppant is used as a control for comparison.