Summary

Proceedings and Minutes of the Hydraulic Fracturing Expert Panel XTO Facilities, Fort Worth September 26, 2007

Hard Copy for Distribution to the ASWCMC
July 30, 2008

Prepared by
Tom Hayes, GTI

Proceedings and Minutes of the Hydraulic Fracturing Expert Panel XTO Facilities, Fort Worth September 26, 2007

Meeting Opening

The Barnett Shale Water Conservation and Management Committee Meeting that hosted the Hydraulic Fracturing Expert Panel was called to order by Tom Hayes. The meeting facilities and lunch were provided by XTO Energy; the meeting was opened with a few words of welcome from Doug Agee of XTO.

Panel Members

Tom Hayes introduced the Panel Members to the meeting attendees. Members of the Expert Panel are described in Table 1; this table was used for the introduction section of the meeting.

Table 1. Members of the Expert Panel

Name	Affiliation	Area of Expertise
Dusty Weatherly	ConocoPhillips	Petroleum Engineering - Completions
Chuck Kelly	Consultant	Field Completions Supervisor
Gary Schein	BJ Services	Hydraulic Fracturing Fluids Expertise Provider
Von Parkey	Halliburton	Hydraulic Fracturing Expertise Provider
Rusty Werline	Devon Energy	Field Completions Supervisor
Mike Murphy	Champion Technologies	Chemicals Applications for Well Completions
John Whittington	EOG Resources	Petroleum Engineering - Completions

Overview

Tom described the background, rationale and approach for conducting the Expert Panel. The goal of the panel was stated as follows: "Determine the minimum water quality requirements for reliable and effective hydraulic fracturing of the Barnett Shale for natural gas production." The central questions to be addressed by the Panel were presented. These are shown in Table 2. Five of the questions (Foundational Questions) were addressed by the Panel before the meeting; five of the questions (Discussion Questions) were to be covered during the Expert Panel meeting. Overview slides are contained in the Slide Presentation of the Appendix.

Table 2. Critical Questions to be Addressed by the BSWCMC Hydrofracturing Expert Panel on Water Quality.

Type	Panel Questions
Foundational Questions	1. What key frac fluid properties are we trying to create with freshwater as an ingredient in the slickwater fracing process?
	2. What are the identified water impurities of concern in the Barnett Shale flowback / produced water?
	3. Which of the impurities affect the desired frac fluid properties noted in Question 1?
	4. What levels of impurities can be tolerated and continue to maintain efficient frac placement?
	5. What are additional safety considerations when pumping Barnett Shale flowback / produced water?
Discussion Questions	6. Are there incompatibility issues when fracing with mixed waters from different sources?
	7. Will the use of flowback / produced water affect the plug / perforating procedure in between frac stages?
	8. Are there frac equipment or downhole tubular reliability/function issues when comparing freshwater to flowback / produced water fracing?
	9. Are fluid dynamics such as leak-off and viscosity affected positively by flowback / produced water? Or is there a difference compared to freshwater?
	10. In your professional opinion, what is the maximum level of impurities that can be practically used to hydraulically fracture the Barnett Shale and avoid reservoir damage? ➢ Oil and Grease ➢ Soluble Organics ➢ Chlorides ➢ Bicarbonates/Carbonates ➢ Ca / Mg / Mn / Fe / Ba / etc. ➢ Scale Index Limits ➢ Suspended Solids ➢ Total Dissolved Solids ➢ Bacterial Counts ➢ pH / Eh Limits

Conclusions

The conclusive responses from the Frac Job Expert Panel are summarized in Table 3. Within the table, the responses are identified with each of the questions posed to the panel. Overall, a fairly high level of agreement was found among responses to a majority of the questions; where differences of opinion existed, common-ground compatible statements could be found and stated as shown in the table.

Table 3. Conclusive Responses from the Frac Job Expert Panel

Question		Conclusions
Summary of Written Responses to Foundational Questions Obtained from Panel Members Prior to the Panel Discussion		
1. What key frac fluid properties are we trying to create with freshwater as an ingredient in the slickwater fracing process?		Key frac fluid properties include: ▪ Low Viscosity ▪ Non-reactive ▪ Non-Flammatory ▪ Minimal residuals ▪ Minimal potential for scale & corrosion. ▪ Low entrained solids ▪ Around Neutral pH (pH 6.5 – 7.5)
2. What are the identified water impurities of concern in the Barnett Shale flowback / produced water?		Impurities of concern include: ▪ Scale Forming Constituents ▪ High Dissolved Solids (Chlorides, Sulfates, & Calcium) ▪ Bacteria: Acid Producing Bacteria (APB) & Sulfate Reducing Bacteria (SRB) ▪ Suspended Solids ▪ Hydrocarbons ▪ Acid Gases (CO_2 & H_2S) ▪ Friction Reducers
3. Which of the impurities affect the desired frac fluid properties noted in Question 1?		The impurities that affect the desired frac fluid properties (as per Question 1) include: ▪ Chlorides increase demand for friction reducers and scale inhibitors ▪ Scale potential [f(Ca, Mg, Ba, SO_4, CO_3…)] ▪ Suspended solids (> 25 microns) ▪ Bacterial growth (SRB and APB) ▪ Crude oil effects on friction reducer ▪ Scale & corrosive materials affect downhole and surface production facilities ▪ Adding inhibitors affects friction reducers
4. What levels of impurities can be tolerated and continue		The levels of impurities that can be tolerated in terms of performing an efficient frac placement are as follows:

Question		Conclusions
to maintain efficient frac placement?		▪ Chlorides: Panel responses ranged from 3,000 to 90,000 mg/l; however, 6 out of 7 Panel Members thought that 10,000 mg/l Cl was acceptable. ▪ Ca^{++}: Panel responses ranged from 350 to 1,000 mg/l; however, all panel members agreed that a calcium level over 350 mg/l begins to increase friction reducer demand. ▪ Suspended Solids < 50 mg/l ▪ Entrained oil & soluble organics < 25 mg/l ▪ Bacteria, cells/100 ml < 100 ▪ Soluble gas removal - To non-problem levels as defined by safety requirements and corrosion specifications. ▪ Low levels of Ba^{++} - To non-problem levels as defined by scale forming potential.
5. What are additional safety considerations when pumping Barnett Shale flowback / produced water?		The main safety considerations include: ▪ Spillage potential ▪ Moderate flammability hazard ▪ Scale forming potential ▪ Moderate H_2S content and potential health risk ▪ Equipment plugging ▪ Salt corrosion causing metal failure
Responses to <u>Discussion Questions</u> Addressed During the Expert Panel Meeting		
6. Are there incompatibility issues when fracing with mixed waters from different sources?		There are no apparent incompatibility issues associated with introducing mixed waters in the Barnett Shale formation. Precautions, however include the following: ▪ Scaling tendencies may arise, even during a frac job and during the release of flowback water. Most concern over $BaSO_4$ and $CaSO_4$ precipitates. ▪ Need to watch pH resulting from the mixing of water streams. The pH can affect the formation of carbonate based scale. ▪ Presence of iron resulting from water blending can cause problems. High iron concentrations can cause problems with plugging. ▪ When planning which water streams to blend, it is good to implement scale inhibition programs, like the Oddo-Thompson Model. ▪ Scale formation incompatibility may occur in the mixing of flowback water with Ellenburger water; however, this can be mitigated through the use of computer models for scale formation prediction (such as the Oddo-Thompson Model) and through the informed use of scale inhibitors. ▪ The mixing of flowback waters from wells located in diverse places on the Barnett is not expected to present problems. ▪ Care should be taken over what types of industrial waters are

Question		Conclusions
		used for performing frac jobs (e.g. flu gas desulfurization impoundments, high iron industrial waters, etc.)
7. Will the use of flowback / produced water affect the plug / perforating procedure in between frac stages?		No. The consensus of the Panel was that in principle the use of recycled flowback (FB) or produced water (PW) in place of 100 percent freshwater should not make a difference in the placement of the hydraulic fractures or in well production performance. The reason is that it's a pretty dirty downhole environment anyway, and that with the use of appropriate precautions, introduction of reused flowback or produced water is not likely to present problems in terms of overall well performance. Sand, friction reducers and other chemicals that are added on purpose comprise a fairly dirty environment. Furthermore, there are no intrinsic show stoppers in the actual use of saline waters for performing frac jobs in terms of the effective placement of hydraulic fractures and in terms of stimulation of gas production performance.
8. Are there frac equipment or downhole tubular reliability function issues when comparing freshwater to flowback / produced water fracing?		No. In terms of the effects on frac equipment that is used transitionally to complete a well, we don't see much of an effect on well performance due to water quality.
9. Are fluid dynamics such as leak-off and viscosity affected positively by flowback / produced water? Or is there a difference compared to freshwater?		Minimally, yes. Salt water has better leakoff and viscosity properties, but only to a slight extent. This category of water properties is not likely to be a controlling factor in water reuse and management.
10. In your professional opinion, what is the maximum level of impurities that can be practically used to hydraulically fracture the Barnett Shale and avoid reservoir damage?		Oil and grease. No problem at levels up to 200 ppm (by unanimous agreement). Soluble organics. Through a show of hands, the Panel responded that soluble organics are not a problem with water pumped downhole. Chloride. In the final deliberation, seven out of seven panel members thought that 10,000 mg/l chlorides would be acceptable for use downhole to achieve effective hydraulic fractures. Calcium, Magnesium, Carbonate. These parameters can be managed collectively through the use of scale control models (e.g. Oddo-Thompson Model).

Question		Conclusions
		Ba, SO_4. Simple solubility calculations are often sufficient to predict problematic levels of these constituents. However, the scale formation computer models are also useful for this. Iron. The panel agreed that levels of iron under 20 ppm are not a problem. Soluble Calcium. Most of the Panel believes that over 350 mg/l of soluble calcium triggers greater demand for friction reducer during the frac job procedure. Suspended Solids. Up to 100 mg/l of TSS are not a problem. Even higher concentrations would probably have no effect on frac job quality. Eh. All of the Panel indicated that this parameter is not likely to be problematic in the reuse of FB or PW in frac jobs. pH. Biocide effectiveness is the main concern with this parameter. Most biocides work best below pH 7, though many biocides will still work between pH 7 and 8. Highly alkaline frac waters (above pH 8) should be avoided. Total Dissolved Solids (TDS). The Panel agreed that this parameter is covered through the guidelines on chlorides (conversion to NaCl from chloride is fairly straight forward). Bacteria. This parameter is usually handled indirectly through guidelines on biocide residuals and the use of field-related test cultures where applicable.

Close of Expert Panel Meeting

Tom Hayes thanked the Panel and the Attendees for making the Expert Panel Meeting a success.

A special thanks was extended to XTO Energy and to XTO staff (Kathy Dolff and Doug Agee) for providing the meeting facilities and food in support of this event.

Proceedings Prepared by Tom Hayes, GTI