QUALIFYING FLUID & PROPPANT PERFORMANCE®

Southern Ohio Sand

40/70 Sand

ISO 13503-2 Proppant Quality Analysis

Mr. Dave English

RFA #100-12-02-22-36-C

February 21, 2012

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Information:

Sample Origin:	**Fed Ex**
Technician:	**Patrick Randel**
Sales Contact:	**Brandon White**
Report Generated by:	**Kirk Decker**

Background:

February 6, 2012 one sand sample is received from John, **Southern Ohio Sand**. John requests **ISO Standard 13503-2 Particle Size Distribution** and **Crush** analysis on the "**40/70 Sand**". Request communications were confirmed by Brandon White, PropTester.

Color Analysis – Proppant Test Data:

Proppant test results are referenced against ISO 13503-2 standards and available public data. Classification by color or numerical variance does not imply a level of performance. However, coloring of standard and public data does indicate a specific range of variance of sample test results. The numerical ranges are typical of data variance between laboratories that participate in ISO round robin or performance (e.g. conductivity) evaluation. When limits (e.g. > or <) are used, then only green or red will apply.

Conclusions / Comments:

- This **Southern Ohio Sand 40/70 Sand** is 98.6% in size, with a **Median Particle Diameter** of 0.319 mm which ***meets*** the **ISO Standard** requirement of $\geq$ 90% material falling between the 40 and 70 mesh screens. This sample sieve distribution is similar to that of 40/70 frac sand public data. **Figures 1 & 2**

- The **ISO Crush** requires that crush properties of a proppant are evaluated at incremental pressures until fines generated are $\leq$ 10% by weight. For the **Southern Ohio Sand 40/70 Sand** the crush test was halted @ 6,000 psi with the sample producing an average of 9.5% fines. According to ISO 13503-2, this sample would be classified as *6k proppant*. **Figure 1**

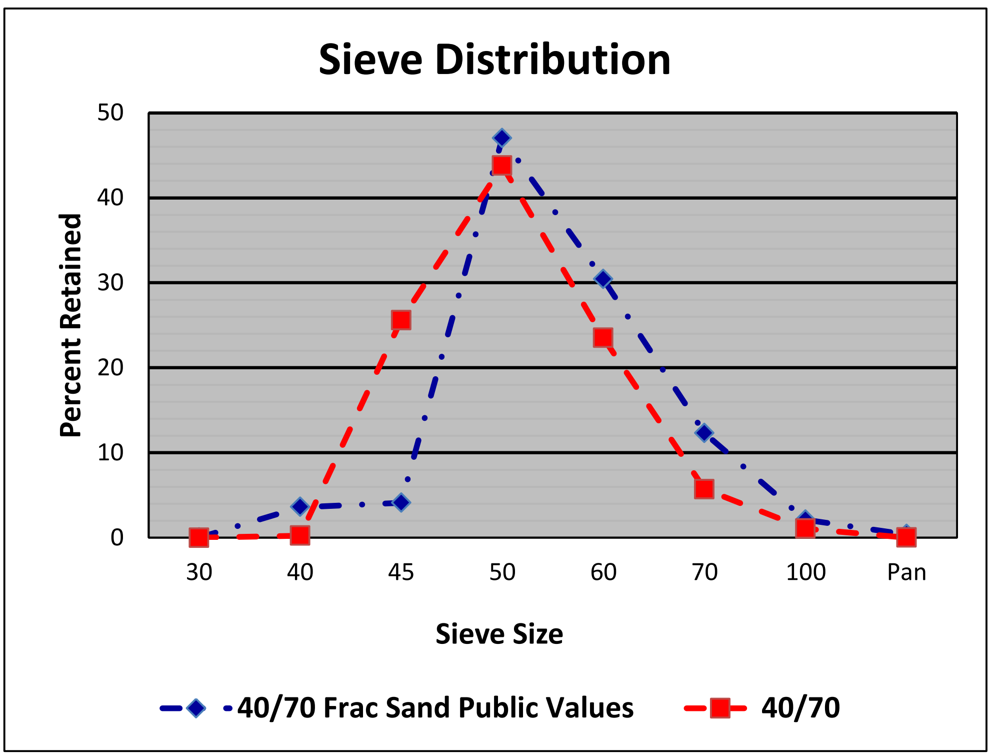
Figure 1 – Proppant Test Data:
Southern Ohio Sand 40/70 Sand

Quick Chek ✓			*ISO 13503-2*	40/70 Frac Sand Public Values	40/70
Particle Size Distribution, mm		Mesh size			
	0.600	30	$\leq$ 0.1	0	0.0
	0.425	40		3.6	0.2
	0.355	45		4.1	25.6
	0.300	50		47.0	43.8
	0.250	60		30.4	23.5
	0.212	70		12.3	5.7
	0.150	100		2.1	1.1
	<0.150	Pan	$\leq$ 1.0	0.4	0.0
	Total			100	100.0
	% In Size		$\geq$ 90	93.8	98.6
Mean Particle Diameter, mm					0.324
Median Particle Diameter (MPD), mm					0.319
Crush Chek✓					
ISO Crush Analysis (% Fines) 4lb/ft2@ 6,000 psi			$\leq$ 10		9.5
ISO Crush Analysis (% Fines) 4lb/ft2@ 7,000 psi			$\leq$ 10		15.2

Sample Correlation 0 to +/- 8.999% Variance From ISO or Published Data	Sample Correlation +/- 9 to 25% Variance From ISO or Published Data	Sample Correlation -25> X > +25% Variance From ISO or Published Data

Figure 2 - Sieve Distribution: Southern Ohio Sand 40/70 Sand

Sieve Size	40/70 Frac Sand Public Values	40/70
30	0	0.0
40	3.6	0.2
45	4.1	25.6
50	47	43.8
60	30.4	23.5
70	12.3	5.7
100	2.1	1.1
Pan	0.4	0.0



Testing Definitions & Descriptions

Turbidity – A measure to determine the levels of dust, silt, suspended clay, or finely divided inorganic matter levels in fracturing proppants. High turbidity reflects improper proppant manufacturing and/or handling practices. The more often and more aggressively a proppant is handled, the higher the turbidity. Offloading pressures exceeding manufacturer guidelines can have a detrimental effect on the proppant performance. Produced dust can consume oxidative breakers, alter fracturing fluid pH, and/or interfere with crosslinker mechanisms. As a result, higher chemical loadings may be required to control fracturing fluid rheological properties and performance. If fluid rheology is altered, then designed or modeled fracture geometry and conductivity will be altered. A change in conductivity directly correlates to reservoir flow rate.

Krumbein Shape Factors – determines proppant roundness and sphericity. Grain roundness is a measure of the relative sharpness of grain corners, or of grain curvature. Particle sphericity is a measure of how closely a proppant particle approaches the shape of a sphere. Charts developed by Krumbein and Sloss in 1963 are the most widely used method of determining shape factors.

Clusters – Proppant grains should consist of single, well-rounded particles. During the mining and manufacturing process of proppants, grains can attach to one another causing a cluster. It is recommended by ISO 13503-2 that clusters be limited to less than 1% to be considered suitable for fracturing proppants.

Bulk Density – A dry test to gain an estimation of the weight of proppant that will fill a unit volume, and includes both proppant and porosity void volume. This is used to determine the weight of a proppant needed to fill a fracture or a storage tank.

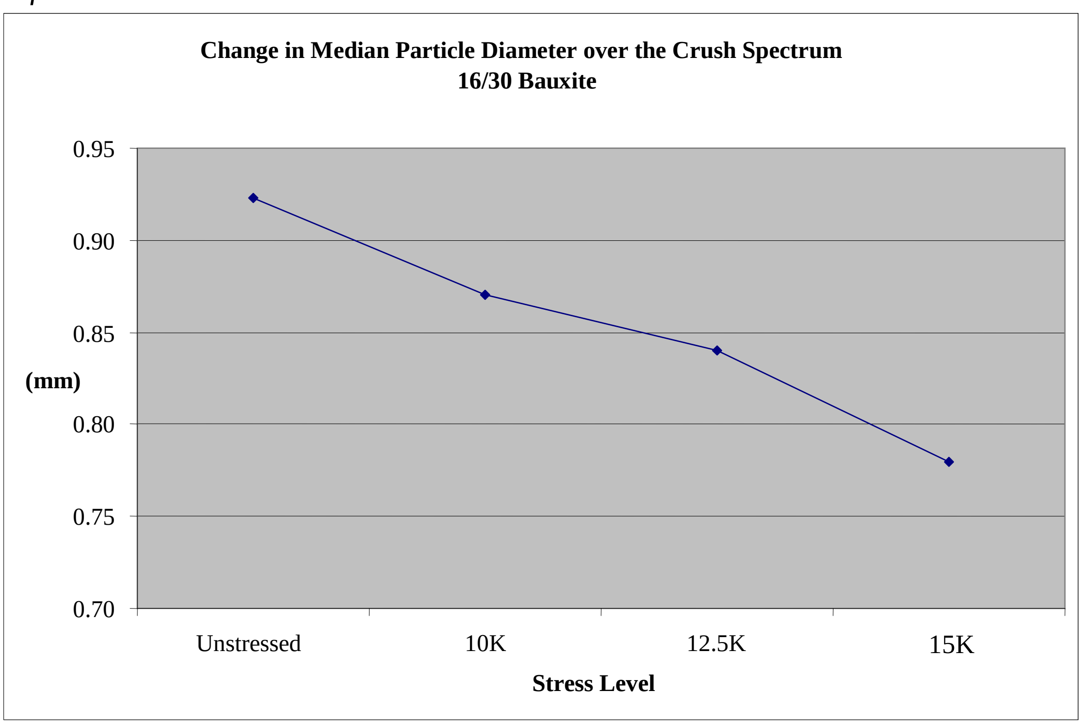
Specific Gravity – Also called Apparent Density, it includes internal porosity of a particle as part of its volume. It is measured with a low viscosity fluid that wets the particle surface.

Sieve Analysis: Particle Size Distribution & Median Particle Diameter – Also called a sieve analysis, this test determines the particle size distribution of a proppant sample. Calibrated sieves are stacked according to ISO 13503-2 recommended practices and loaded with a pre-measured amount of proppant. The stack is placed in a Ro-Tap sieve shaker for 10 minutes and then the amount on each sieve is measured and a percent by weight is calculated on each sieve. A minimum of 90 % of the tested proppant sample should fall between the designated sieve sizes. Not over 0.1% of the total tested sample should be larger than the first sieve size and not over 1.0% should fall on the pan. The in-size percent, mean particle diameter, and median particle diameter are calculated which relates directly to propped fracture flow capacity and reservoir productivity.

Testing Definitions & Descriptions

API / ISO Crush Test – The **API** test is useful for comparing proppant crush resistance and overall strength under varying stresses. A proppant is exposed to varying stress levels and the amount of fines is calculated and compared to manufacturer specifications. Studies by Coulter & Wells (e.g. SPE JPT, June 1972, pp. 643-650) have demonstrated that as little as 5% added fines can reduce propped fracture conductivity by 50%. The **ISO** test classifies a proppant according to the stress at which $\leq$ 10% fines are generated; for example an ISO 7k proppant would produce $\leq$ 10% fines at 7000 psi.

A **PT Crush Profile** (see example below) can show graphically how median particle diameter (MPD) can vary with changes in closure stress. Unlike the ISO crush test, the PT Crush Profile uses the entire proppant sample for crushing at each stress, the sample is then sieved to determine particle distribution, and MPD is then calculated. A change in MPD directly correlates to flow capacity and reservoir productivity. *This test, ordered separately, provides a more realistic view of initial proppant flow capacity at reservoir specific stresses.*



Testing Definitions & Descriptions

Acid Solubility – The solubility of a proppant in 12-3 hydrochloric-hydrofluoric acid (HCL-HF) is an indication of the amount of undesirable contaminates. Exposing a proppant (specifically gravel pack/frac pack materials) may result in dissolution of part of the proppant, deterioration in propping capabilities, and a reduction in fracture conductivity in the zone contacted by such acid. The loss of fracture conductivity near the wellbore may cause a dramatic reduction in well productivity, as has been demonstrated by Raymond and Binder (JPT, January 1967, Pgs. 120-130).

Resin Content/Loss on Ignition (LOI) – This test determines the resin content remaining on the proppant. Resin content is a direct function of the proppants strength and its ability to encapsulate the substrate when exposed to high stress levels. By reducing fines generation and migration, the proppant pack remains clean, allowing maximum well production.

Resin Coating Efficiency – Used to determine the percent of uncoated grains in a resin coated proppant sample.

Unconfined Compressive Strength (UCS) – Grain-to-grain bonding at specific temperatures over time will develop bond strength that can be measured by using a UCS test. This test directly reflects the proppants ability to bond downhole in order to reduce embedment and control proppant flowback. By reducing embedment and keeping the available proppant in place, fracture width can be maximized.

pH of Water Extract – This test reflects the potential chemical impact of a proppant on fracturing fluid pH. Processing or manufacturing of a proppant can leave residues, or ‘free phenol’ in the case of resin coated proppants, which can interfere with polymer hydration rates, cross-linking mechanisms, etc. These effects if detected can usually be remedied by increasing buffering capacity, but if undetected can alter fracturing fluid rheology, change fracture geometry, and impact propped fracture conductivity. A change in conductivity directly correlates to reservoir production rate.

TEST PROCEDURES

PropTester® & **ISO** test procedures were applied in this Request for Analysis (**RFA**)

Quick Chek	**Procedures**
Turbidity	***ISO 13503-2***
Microscopic Exam	***ISO 13503-2***
Krumbein Shape Factors	
Clusters	
Photomicrographs	
Bulk Density	***ISO 13503-2***
Specific Gravity	***ISO 13503-2***
Sieve Analysis	***ISO 13503-2***
Particle Size Distribution	***ISO 13503-2***
Mean Particle Diameter	***ISO 13503-2***
Median Particle Diameter (MPD)	***PropTester***®

Crush Chek	**Procedures**
API Crush Test	**API RP 56/58/60**
ISO Crush Test	***ISO 13503-2***
PT Crush Profile	***PropTester***®

Res Chek	**Procedures**
% Resin Content, LOI	***PropTester***®
Coating Efficiency %	***PropTester***®
Unconfined Compressive Strength (UCS)	***PropTester***®
pH of Water Extract	***PropTester***®

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