



QUALIFYING FLUID & PROPPANT PERFORMANCE™

Mississippi Sand

Mr. Curt Wilker

Fracture Conductivity Analysis

40/70 Mississippi Sand

RFA # 400-08-02-05-01

February 18, 2008



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Background:

Conductivity & Permeability tests were performed on a sample of proppant material provided by Mississippi Sand. Baseline Conductivity & Permeability tests were run at 150°F and 2,000, 4,000, 6,000, and 8,000 psi stress. International Standards, ISO procedures 13305-5 “Procedures for measuring the long term conductivity of proppants” are used.

Summary:

The following samples were received and tested according to the above procedures;

40/70 Mississippi Sand

Procedures

A closure stress is applied across a test unit for 50 hours to allow the proppant sample bed to reach a semi-steady state condition. As the fluid is forced through the proppant bed, the pack width, differential pressure, temperature and flow rates are measured at each stress. Proppant pack permeability and conductivity are then calculated.

Multiple flow rates are used to verify the performance of the transducers, and to determine Darcy flow regime at each stress; an average of the data at these flow rates is reported. The test fluid is 2% potassium chloride filtered to 3µm absolute. The initial conductivity, permeability and width is measured and compared to the final conductivity, permeability and width after each stress period. Stress is applied and maintained using an Isco 260D. Stress is applied at 100 psi/minute.

Width of the proppant pack is determined by assembling the conductivity cell with the Ohio sandstone wafers and shims without the sample proppants. The distance between the width bars that are attached to each end of the conductivity cells are measured at each of the four corners and recorded. The cells are then disassembled and reassembled with the proppant samples. The measurements are made again at the beginning and ending of each stress period. Width is determined by subtracting the average of the zero from the average of each of the stress width values. Conductivity is calculated using Darcy’s equation.

Sieve analysis is performed using the procedure found in ISO 13503-2 “Measurements of proppants used in hydraulic fracturing and gravel pack operations” Standard US mesh screens are used to separate the sample by size. Not more than 0.1% should be greater than the first specified sieve and not more than 1% should be retained in the pan. There should be at least 90% retained in the specified screens.



Calculations

Conductivity; $kW_f=26.78(\mu Q/\Delta P)^{-1}$

Permeability; $k=321.4\mu Q/(\Delta P)W_f^{-1}$

k is the proppant pack permeability, expressed in Darcy's;

kW_f is the proppant pack conductivity, expressed in millidarcy-feet

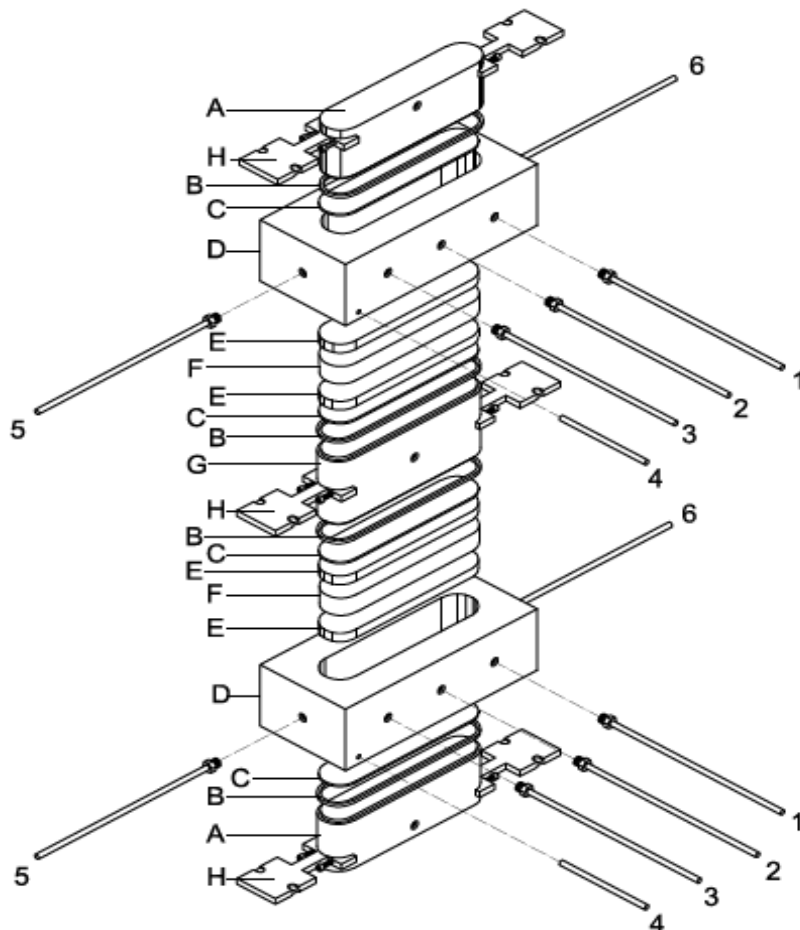
μ is the viscosity of the test liquid at test temperature, expressed in centipoises;

Q is the flowrate, expressed in cubic centimeters per minute;

ΔP is the differential pressure, expressed in psi;

W_f is proppant pack width, expressed in inches.

1-ISO 13503-5:2006(E) "Procedures for measuring the long term conductivity of proppants"



- 1. Low pressure port
- 2. Middle port
- 3. High pressure port
- 4. Thermocouple
- 5. Inlet
- 6. Outlet
- A. Upper and lower piston
- B. Tetralseal
- C. Metal shim
- D. Cell body
- E. Ohio sandstone
- F. Proppant
- G. Center piston
- H. Width slots
- I. Set screws



Table 1 – Test Data: 40/70 Mississippi Sand

(Baseline Conductivity & Permeability @ 2 lb/ft², 150°F, 2% KCL Water, Ohio Sandstone)

Stress (psi)	Conductivity (mDft)	Permeability (Darcy)	Width (in)
1000	1,536	74	0.243
2000	1,434	73	0.232
4000	1,150	61	0.221
6000	671	37	0.210
8000	250	15	0.198



Table 2 – Conductivity Data: 40/70 Mississippi Sand
(Baseline Conductivity @ 2 lb/ft², 150°F, 2% KCL Water, Ohio Sandstone)

Stress (psi)	Conductivity (mDft)
2000	1,434
4000	1,150
6000	671
8000	250

Figure 1 – Conductivity Chart: 40/70 Mississippi Sand

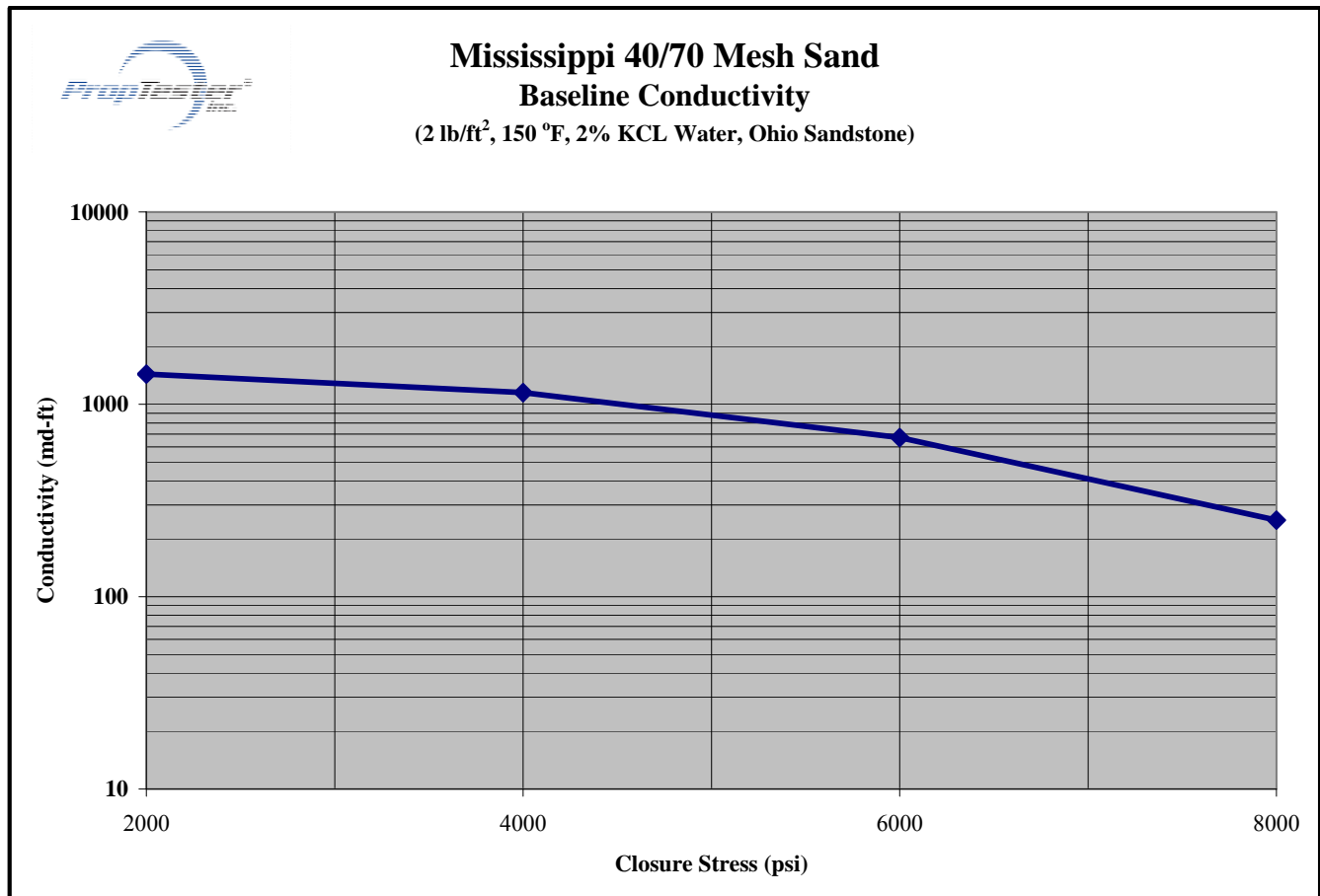
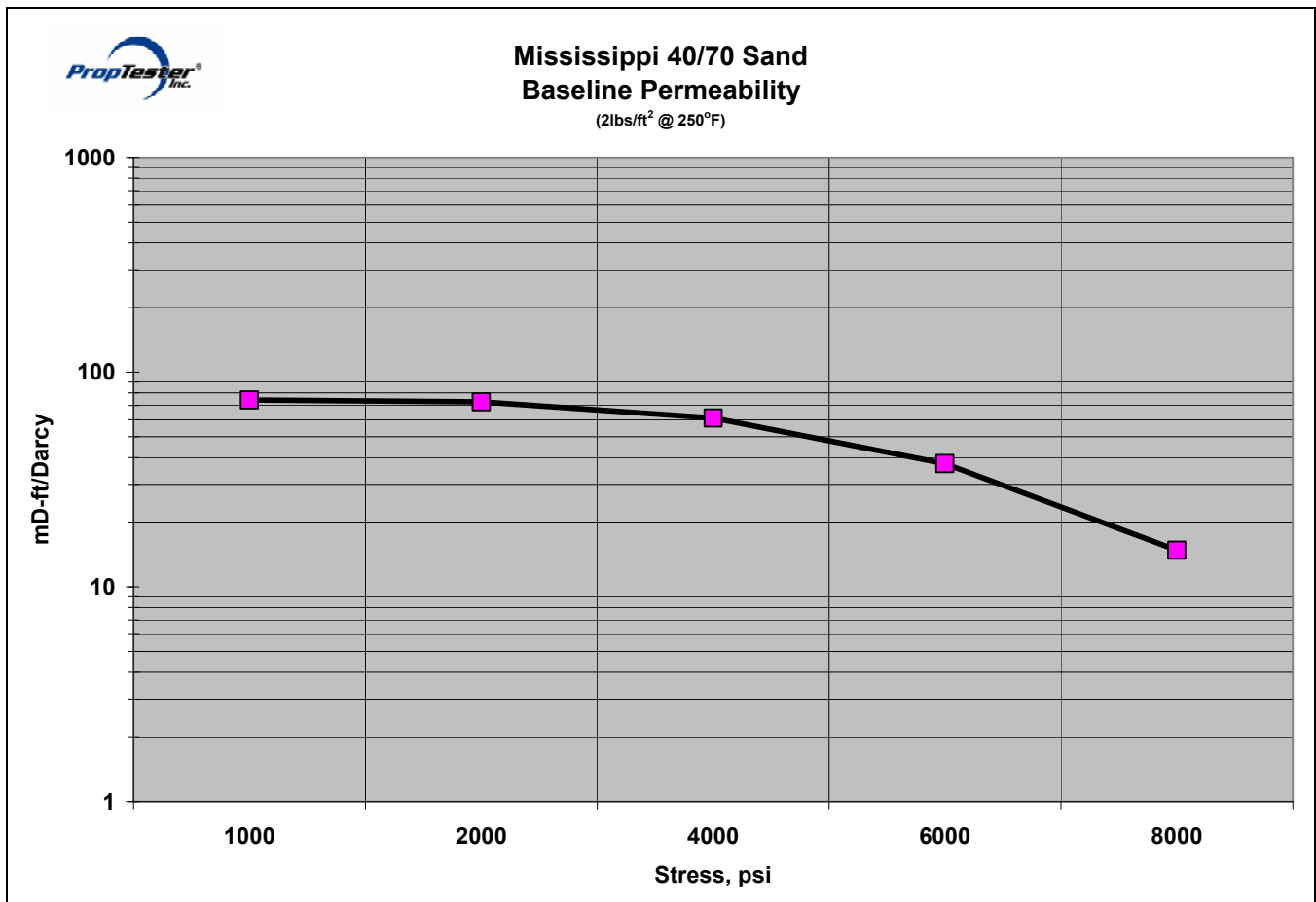




Table 3 – Permeability Data: 40/70 Mississippi Sand
(Baseline Permeability @ 2 lb/ft², 150°F, 2% KCL Water, Ohio Sandstone)

Stress (psi)	Permeability (Darcy)	Width (in)
2000	73	0.232
4000	61	0.221
6000	37	0.210
8000	15	0.198

Figure 2 – Permeability Chart: 40/70 Mississippi Sand





Mississippi Sand Conductivity

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Table 4 –Data Table: 40/70 Mississippi Sand

Sample:		Top	Mississippi 40/70 Sand												
Date:		1.25.08													
Sample	Stress,psi	Isco, psi	Date	Initial Conductivity md-ft	Final Conductivity md-ft	Initial Permeability Darcy's	Final Permeability Darcy's	DP Gauge psi	DP Gauge psi	Temp. °F	Rate mls/min	initial in H2O	Rate ml/min	final in H2O	Viscosity cps
1000	500		1.25.08-1.26.08	1536		74		0.070648		150	9	1.957			0.450
0.243															
2000	975		1.26.08-1.28.08	1473	1418	74	72	0.073644	0.076532	150	9	2.040	9	2.120	0.450
0.234				1543	1439	78	73	0.058121	0.05989	150	7.44	1.610	7.15	1.659	0.450
0.232				1563	1446	79	73	0.08664	0.089239	150	11.23	2.400	10.7	2.472	0.450
				1527	1434	77	73	0.07280	0.07522						
4000	1955		1.28.08-1.30.08	1252	1123	66	60	0.08664	0.101441	150	9	2.400	9.45	2.810	0.450
0.223				1256	1163	66	62	0.068626	0.072561	150	7.15	1.901	7	2.010	0.450
0.221				1258	1165	66	62	0.102524	0.112632	150	10.7	2.840	10.88	3.120	0.450
				1256	1150	66	61	0.08593	0.09554						
6000	2950		1.30.08-2.1.08	869	641	48	36	0.131043	0.171078	150	9.45	3.630	9.1	4.739	0.450
0.213				812	633	45	35	0.103968	0.136097	150	7	2.880	7.14	3.770	0.450
0.210				749	740	41	41	0.175085	0.087362	150	10.88	4.850	5.36	2.420	0.450
				810	671	45	37	0.13670	0.13151						
8000	3925		2.1.08-2.3.08	378	250	22	15	0.290605	0.443308	150	9.1	8.050	9.21	12.280	0.450
0.203				383	252	22	15	0.224542	0.372552	150	7.14	6.220	7.78	10.320	0.450
0.198				395	248	23	15	0.163533	0.27797	150	5.36	4.530	5.71	7.700	0.450
				385	250	22	15	0.22623	0.36461						



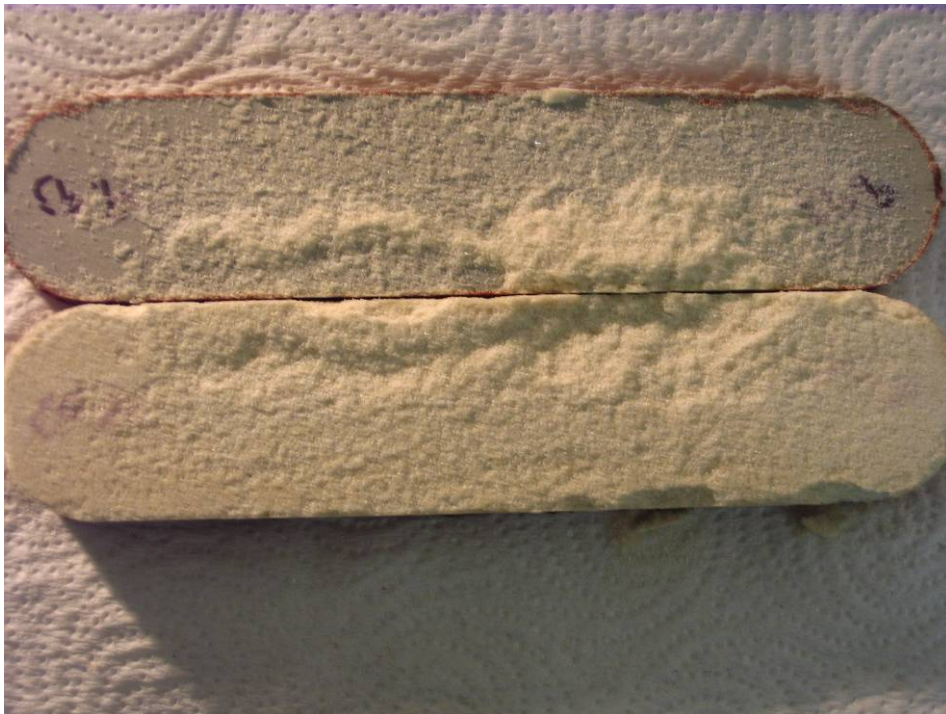
Table 5 - Proppant Test Data: 40/70 Mississippi Sand

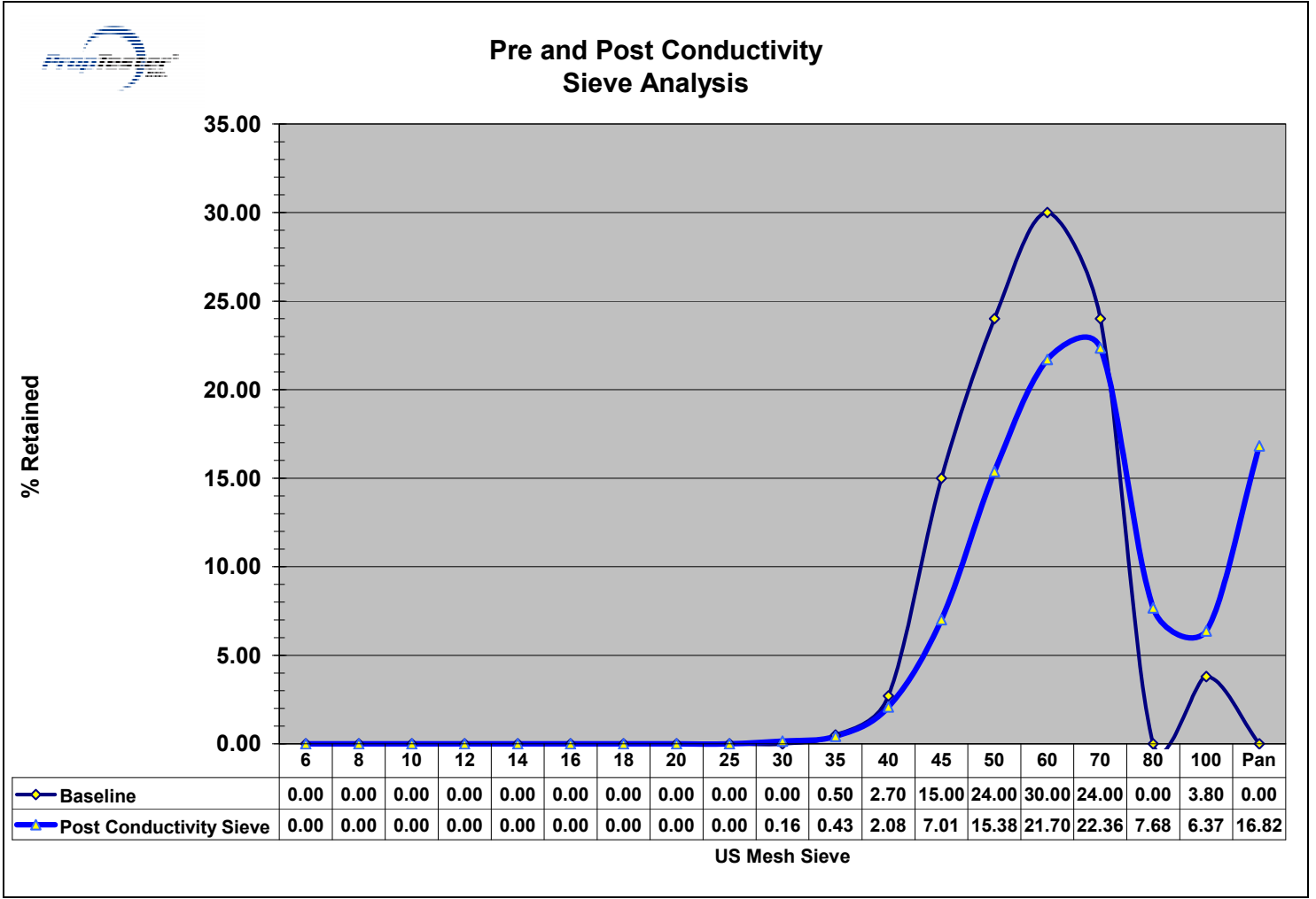
Quick Chek ✓		API Specs	Typical 40/70 White Frac Sand Specs	40/70 Mississippi Sand
Turbidity (NTU)		≤ 250	≤75	54
Krumbein Shape Factors				
Roundness		≥0.6	0.75	0.77
Sphericity		≥0.6	0.75	0.78
Clusters (%)		≤ 1.0	0.0	0.0
Bulk Density (g/cc)		n/a	1.60	1.50
Bulk Density (lbs/ft ³)		n/a	100.0	93.3
Specific Gravity (g/cm ³)		n/a	2.65	2.62
Particle Size Distribution	Mesh size			
	30	≤ 0.1	0.0	0.0
	40		0.2	3.2
	50		38.2	39.0
	60		29.8	30.1
	70		27.0	23.9
	100		4.8	3.8
	PAN	≤ 1.0	0.0	0.0
	Total		100	100
% In Size -40+70		≥ 90.0	92.0	93.0
Median Particle Diameter (MPD in mms)			0.282	0.289
Acid Solubility in 12/3 HCL/HF for 0.5 HR @ 150 °F (% Weight Loss)		≤ 3.0	<1.0	1.9
Crush Chek ✓				
API Crush Analysis (% fines) (PSI)				
40/70 @ 5000		≤8.0	3.3	5.3

Good Correlation
Marginal Correlation
Poor Correlation

Photographs

Sample between Ohio Sandstone Cores





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