NEW TECHNOLOGY QUALIFIES PROPPANT PERFORMANCE BEFORE THE FRAC

Earl R. Freeman, Don A. Anschutz, Jason J. Renkes and Allan R. Rickards
PropTester, Inc.

ABSTRACT
This paper offers a new approach to qualify proppant before fracture stimulation. Automated and patented flowing stream sampling technology, only recently available, is easily positioned between a pneumatic trailer and field bin. Mobile labs are used to measure proppant sample physical properties and correlate public domain or job design data. Differences, which provide the basis for performance and engineering decisions, relate to mining anomalies, manufacturing defects, transportation abuse, and contamination. This is critical, as proppant is the primary construction material for a conductive fracture. To evaluate these supply chain issues API quality practices include long standing principles: 1) representative sampling from a flowing stream, 2) standardized testing with calibrated equipment, and 3) sample retention for follow-up evaluation. Since proppants are chosen to improve reservoir response, sampling proppant before the frac and evaluating its quality can identify supply chain deficiencies, assess proppant performance, and facilitate an opportunity to improve stimulation design.

INTRODUCTION

In the 1970s the proppant supply chain began formulating practices to standardize the quality control of proppants delivered to the well-site under the guidance of the American Petroleum Institute (API). The supply chain participants consisted of mining, manufacturing, pumping service, and operating companies. These practices were respectively introduced in the 1980s as API Recommended Practices 56, 58, and 60. These documents contained key principles for quality control as follows:

1. Each sample is to be collected from a flowing stream with a minimum number of samples in order to be representative of the mass.

2. Standardized testing procedures must be applied with calibrated equipment in order for quality data to be reliable and reproducible.

3. Samples are to be retained for a minimum time period in order to facilitate any additive, repetitive, or follow-up evaluation.

These principles have stood the test of time, and API practices are now being transitioned into the International Organization for Standardization (ISO) world wide.

This paper addresses the importance of sampling proppant according to those standards established by API / ISO in order to have proppant data that can be evaluated for performance. Automated and patented technology now permits an engineer to sample pneumatic trailers before the frac to facilitate a valid (e.g. representative, reliable, and reproducible) quality control record for the evaluation of delivered proppant performance.

MANUAL AND AUTOMATED SAMPLING

API / ISO require flowing stream sampling of a proppant mass moving from point A to point B. Manual sampling (Figure 1) at the well-site can only occur during the frac from conveyor to hopper. The minimum number of samples (e.g. 5 samples per 100,000 lbs) and manner of sampling is outlined in API / ISO documents. However, an automated sampling tool (Figure 2) enables one to retrieve a greater frequency of flowing stream samples from individual trailers as they discharge pneumatically into a field bin. In both cases samples can then be combined as a composite for representative testing of the proppant mass. But, unlike manual sampling, with the automated sampling device each truck can be isolated and tested if discrepancies are seen in a composite sample.

SUPPLY CHAIN ISSUES

Mining anomalies are usually presented as particle size variation or mineralogical differences. This can occur when different mineral sources or supply points are accessed. For example some mines can predominately produce sands with smaller median particle diameters for a given mesh range. So, if sand is being purchased to provide a given flow capacity, it would be important to know the source and particle distribution delivered to the well-site. That can only be confirmed if the sand is properly sampled at the well-site and evaluated. Otherwise, we are only assuming that the right product has been delivered.

Manufacturing defects are a part of the industrial process, and therefore, it is a primary driver of the need for quality control. This supply chain component applies to any man-made proppant formulated from bauxite deposits, resin coatings (sand or ceramic), composites, etc. In proppant manufacturing there are a number of variables (e.g. substrate composition, particle size, starting temperature, kiln temperature, time at temperature, resin content, adequate cooling, sieve maintenance, upper & lower control limits, storage conditions, personnel experience, etc.). However, the delivered condition of the proppant at the well-site will determine its performance at reservoir conditions. This can only be obtained from a representative proppant sample, not a cursory one.

Transportation abuse occurs when proppant is moved an excessive number of times (e.g. proppant returns) or in an abusive manner (e.g. high pneumatic discharge pressures). This is usually due to available trucking shortages, DOT requirements, driver inexperience, conflicting goals, lack of supervision, etc. The net effect can only be determined by examining a representative flowing stream sample of the delivered proppant supply.

Contamination can take place anywhere along the supply chain. It occurs when grain storage sites are used to house proppant, when proppant is transferred from the ground, when storage bins are not properly cleaned, etc. Examining delivered proppant in a representative way provides the basis for judging impact on performance.

PERFORMANCE CHARACTERISTICS

Qualifying proppant performance differs from the typical API RP 56/58/60 minimum test recommendations and from simply verifying proppant type. API RP 56/58/60 has set up fairly broad minimum test parameters to compare products in the same class. For example, sieve distribution on a typical 20-40 mesh proppant simply states 90% between the designated screens with no more than 0.1% larger than the 20 mesh and no more than 1.0% on the Pan. However, these parameters offer little insight into the actual performance of the proppant*.

Service companies routinely verify proppant type on location. A static sample is taken and some modified form of the API RP 56/58/60 sieve distribution check is conducted. This is a superficial evaluation to ascertain that the right proppant is on location, and that in a broad sense it meets the API criteria. However, this does little to give the operator insight into the performance of the product.

Proppant performance is directly tied to the product specification for manufacturing when its conductivity/permeability tests were performed. Any variation from this specification will alter the performance of the product, either positively or negatively.

These parameters may include some or all of the following:

- Chemistry
- Crush Strength
- Sieve Distribution
- Acid Solubility
- Specific Gravity
- Bulk Density
- Turbidity

CASE HISTORIES

Onshore Case History: Refer to Figures 1 - 4

An operator historically only had access to service company support for proppant quality control at the well-site. However, the proppant sampling was typically static, non-API, and therefore non-representative of the proppant mass. The testing that followed never included more than a non-API sieve analysis that always reflected a proppant that was 90% by weight in size. The operator expressed frustration in not being able to confirm the delivered quality of the proppant that was being designed and purchased. Although only cursory data was available, requests to compile even those proppant QA/QC records for previous years were not fulfilled by the alliance service company. The fact is that maintaining meaningful proppant quality control records has not been a core business, nor a responsibility for anyone in the proppant supply chain.

This changed in 2005 when a new company entered the market to service the proppant supply chain with patented automated sampling technology. This service enabled the operator to do the following:

a. inspect and photograph field bin compartments before proppant delivery
b. retrieve representative pneumatic flowing stream samples " before the frac"
c. isolate each pneumatic trailer with a split sample before composite testing
d. monitor /document pneumatic discharge pressures and total time to unload each trailer
e. secure transportation details (tractor #, trailer #, driver name, carrier, proppant source, etc)
f. have the option to obtain test data "after the frac" or "before the frac" using a mobile lab
g. build an accessible, centralized database for the delivered proppant
h. set aside proppant split samples for 1 year to permit follow-up testing
i. assign responsibility for supply chain issues
j. provide a basis for improving the quality of delivered proppant

Over a period of twelve months the operator had delivered proppant sampled with an automated tool on twenty-two different wells in the same field. Each well was to be fracture treated with about 50,000 pounds 16/30 mesh brown sand. Proppant delivery was coordinated with the pumping service company, and the steps outlined above were followed. Proppant delivery was usually the day prior to the frac, but the operator chose not to use a mobile lab. So, data was compiled and used constructively to improve and maintain the ongoing quality of the delivered proppant.

The first 2 wells revealed that the delivered 16/30 mesh brown sand, upon sieve analysis, had a large excess % fines retained on the PAN. The transportation records revealed that the proppant had been stored in service company facilities. The proppant condition and records provided evidence that the material that had been moved several times. As a result the median particle diameter (MPD) was reduced by an average of 12% compared to public domain. As noted in previous literature, just a 10% loss in MPD can result in a 20% loss in propped fracture conductivity.

The operator was able to address this example of transportation abuse constructively with the service company to ensure that returned proppant was not delivered to future wells. Future deliveries came directly from mining company trans-loads. Automated technology was used for sample collection to confirm quality and performance.

Offshore Case History: Refer to Figures 5 - 11

When dealing with mistakes that can cost hundreds of thousands of dollars a day, knowing the performance characteristics of critical products before a frac becomes an integral part of any QA/QC program. Many operators offshore spend thousands of dollars prior to a FracPac or Gravel Pack in an effort to ensure product performance and specifications. Proppant, although a critical component of the treatment, has typically been evaluated using manufacturer "typical" data, due to the logistics of collecting and testing a representative sample prior to the frac.

In 2005 a new patented technology was introduced that made it possible to collect a representative sample of the proppant as it was loaded on a stimulation vessel. But a sample without a way to test it presented yet another problem, so Mobile Laboratories were built and an array of tests (including API RP 56, 58 & 60) were implemented that allowed for quick and accurate evaluation of critical performance characteristics of the proppants on-site.

In order to understand the importance of pre-job testing, two deep water Gulf of Mexico jobs were selected that utilized the same product. The wells are from the same operator in the same field located approximately 140 miles off the coast of Louisiana. The first job was completed in August 2006 and the second job was completed in March

2007. The first job utilized the on-site collection tool, and the product was evaluated prior to the job. Because of multiple job delays and timing the sample on the second job was collected during the treatment and evaluated after the frac. Procedures outlined in API RP 56/58/60 were strictly followed to ensure representative sampling and testing.

Proppant performance is a direct relationship of how well the product matches a specific set of measurable specifications. These specifications define the conductivity/permeability of the product and in the case of sand control the particle size that will flow through the pack.

The key critical parameters associated with proppants that help define performance are as follows:

a. The sieve distribution and the associated median particle diameter
b. The resistance to crushing at specified closure pressures
c. The Krumbein roundness and sphericity
d. Acid Solubility

The key critical proppant parameters associated with job design are:

a. Conductivity/Permeability
b. Specific Gravity
c. Bulk Density
d. Turbidity

Understanding how a product will perform prior to the job allows an engineer to make adjustments to the design to optimize the effectiveness of the completion and ultimately the performance of the well.

Listed below is a summary of some of the findings from the study:

Job 1: 16-30 mesh Intermediate Ceramic Sample collected with Automatic Sampling Tool

- Automated sampling tool is used to collect a sample prior to the frac and an on-site mobile laboratory is used to run test prior to frac.
- Field Bins are inspected and found free of contaminates.
- Transportation records confirming product type, weight, offloading pressures, trucking company and driver are compiled.
- Specific Gravity was 3.32 g/cc vs. a published value of 3.27 g/cc. The new number was available prior to the frac.
- Bulk Density was 1.93 g/cm (121 lb/cu ft) vs. a published value of 1.88 g/cc (117 lb/cu ft). The new number was available prior to the frac.
- Turbidity measurements were marginally high at 270 NTU; engineer and service contractor was notified of possible interaction of dust particles with the fracturing fluid.
- Sieve mesh distribution and resulting median particle diameter were slightly larger than the manufacturer specifications but were determined to be within the desirable limits for the D-50.
- Crush resistance at the higher stress ranges was higher than expected. However, by utilizing a crush profile across the stress range that the product would most likely be exposed, it was determined that the product would meet performance requirements.

Job 2: 16-30 mesh Intermediate Ceramic Sample collected during FracPac and Gravel Pack Stages using an API Manual Sampling Tool with test results available after the frac:

- Transportation records are not compiled and field bins were not inspected prior to loading.
- Specific Gravity for the FracPac Stage was 3.35 g/cc and the Gravel Pack Stage was 3.36 g/cc vs. a published value of 3.27 g/cc. No adjustment could be made prior to the frac.
- Bulk Density for the FracPac Stage was 1.95 g/cm (122 lb/cu ft) and the Gravel Pack Stage was 1.92 g/cm (120 lb/cu ft) vs. a published value of 1.88 g/cc (117 lb/cu ft). No pre-frac adjustment could be made.

- Turbidity measurements were 161 NTU for the FracPac Stage & 141 NTU for the Gravel Pack Stage.
- The Sieve Mesh Distribution and resulting median particle diameter for the FracPac Stage was slightly larger than the manufacturer specifications but slightly smaller for the Gravel Pack Stage. Although both were determined to be within the desirable limits for the D-50 some concern was noted about the varying size.
- The Crush Resistance at the higher stress ranges was more elevated than expected and was a cause for concern. Future testing will be conducted on retain samples prior to shipment and followed up with on-site sampling and testing.

CONCLUSIONS

1. Representative sampling from a flowing stream is the first step for ensuring proppant quality control.

2. Quality control when conducted per API/ISO enables one to assess delivered proppant performance.

3. The ability to sample dynamically before the frac provides the opportunity for pre-frac proppant analysis.

4. Pre-frac proppant analysis provides data that can be used to improve stimulation design / implementation.

5. Automated sampling technology can be applied for both onshore and offshore applications.

REFERENCES

1. "Recommended Practices for Testing Sand Used in Hydraulic Fracturing Operations", American Petroleum Institute, Exploration and Production Department, Washington, D.C., API Recommended Practice 56 (RP 56), 2nd Edition, 1995.

2. "Recommended Practices for Testing Sand Used in Gravel Packing Operations", American Petroleum Institute, Exploration and Production Department, Washington, D.C., API Recommended Practice 58 (RP 58), 2nd Edition, 1995.

3. "Recommended Practices for Testing Hi-Strength Proppants Used in Hydraulic Fracturing Operations", American Petroleum Institute, Exploration and Production Department, Washington, D.C., API Recommended Practice 60 (RP 60), 2nd Edition, 1995.

4. Anschutz, Don A and Wick, John G.: "Proppant Sampling", United States Patent number 7,121,156, issued October 17, 2006.

5. Penny, G. S.: "Guest Editorial: New International Standards for Proppant Testing" Journal of Petroleum Technology, December, 2005.

6. Freeman, E. R., Anschutz, D. A., Renkes, J. J, and Milton-Tayler D.: "Qualifying Proppant Performance", paper SPE 103623 presented at the SPE ATCE, San Antonio, TX, September 24-27, 2006.

ACKNOWLEDGEMENTS

The authors would like to thank BP America and PropTester, Inc for the opportunity to publish this paper.

Figure 1 – Field Bin Compartment

Figure 2 – Automated Sampling From a Flowing Stream

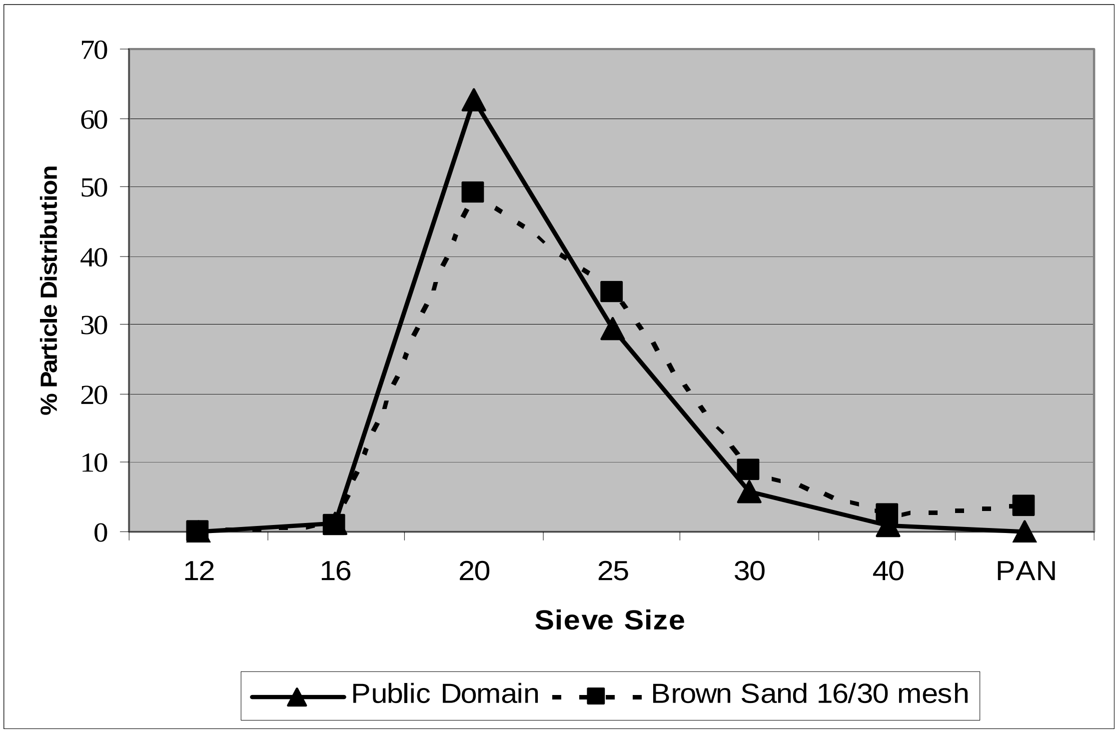

Figure 3 –Proppant Delivery on Initial 2 Wells

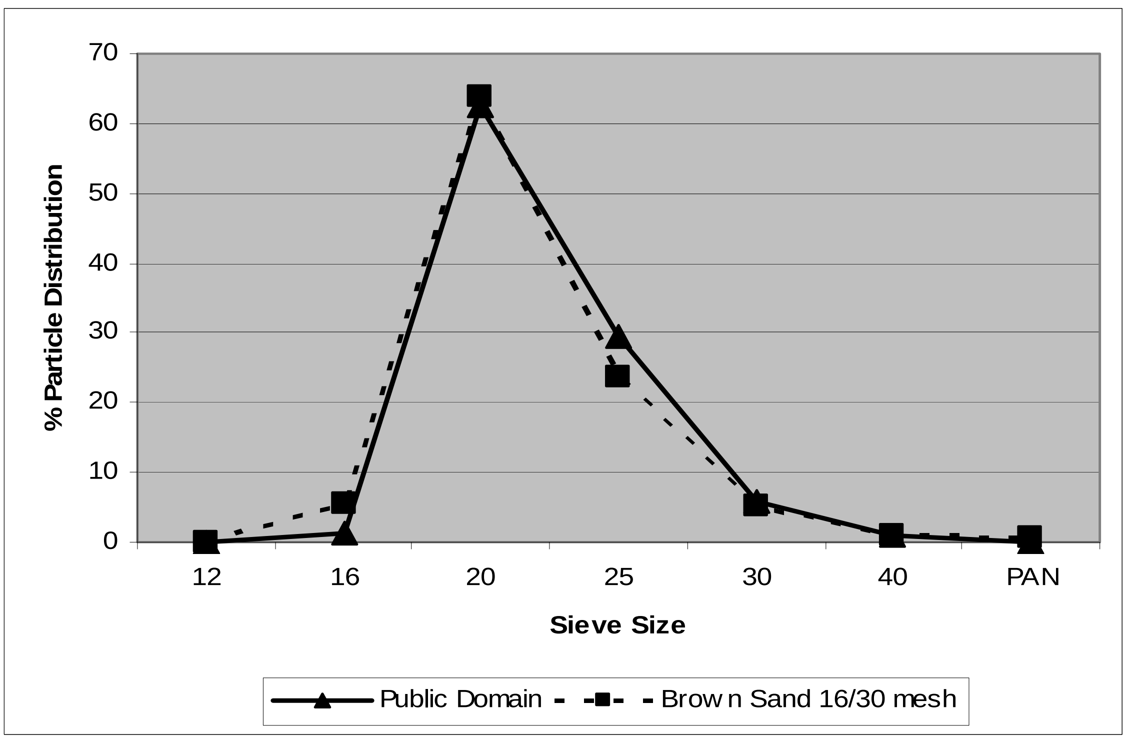

Figure 4 – Proppant Delivery on Remaining 20 Wells

Figure 5 – Automated Sampling Between Pneumatic Trailer and Frac Boat

Figure 6 – API / ISO Manual Sampling Tool


Figure 7 – Mobile Laboratory


Figure 8 – Frac Boat Field Bin

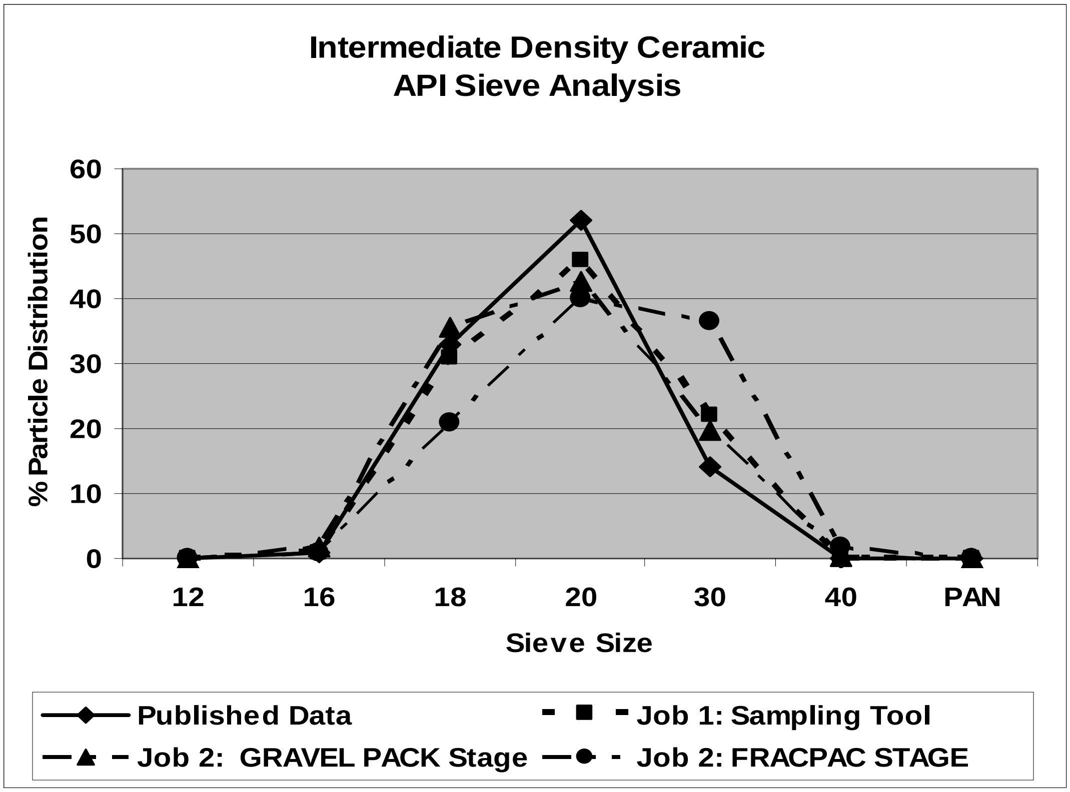

Figure 9 – API Sieve Analysis

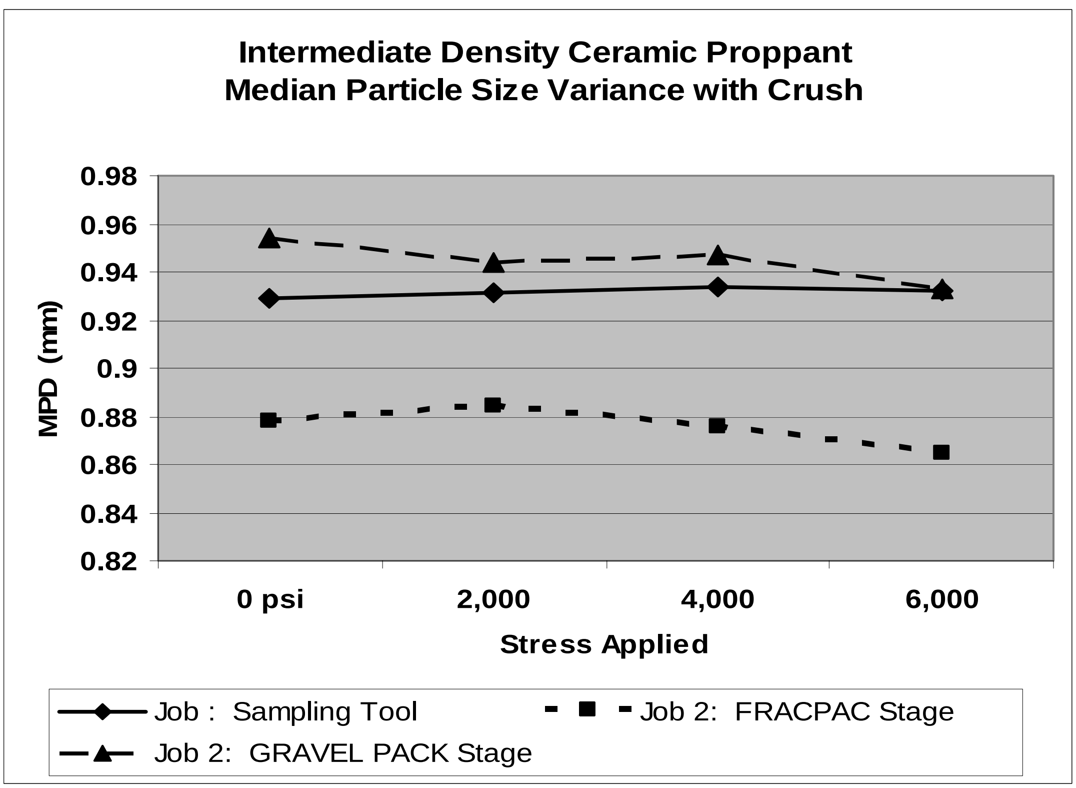

Figure 10 – Median Particle Diameter with Crush

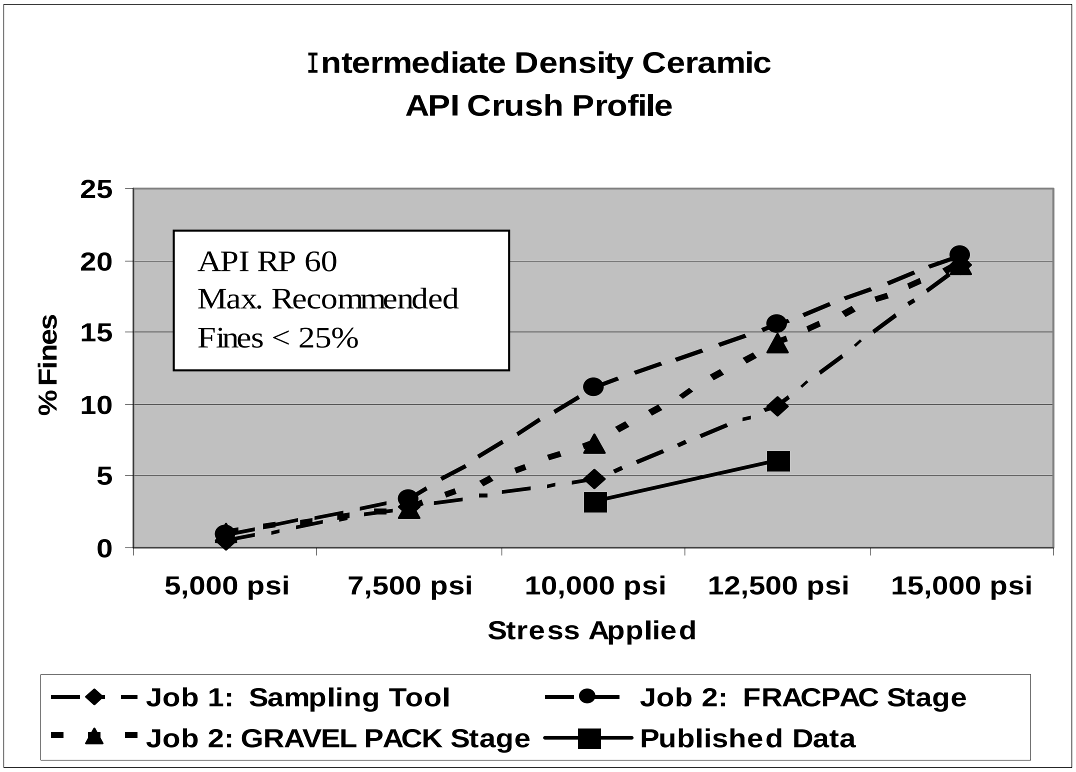

Figure 11 – API Crush Profile