# A Four Step Approach to Verify Delivered Proppant

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Since the late 1940s, proppants have been the primary construction material for a conductive hydraulic fracture. However, it was not until the late 1970s that critical properties were identified and proppant performance examined under guidance from the American Petroleum Institute (API). By the early 1980s API recommended practices (RP 56, 58, & 60) to be applied at the wellsite were scribed and introduced. Yet, employment of these American standard practices at the wellsite became cursory as the rig count collapsed and time passed. This subsequently left the industry with inconsistent data, lack of accountability, poor record keeping, and little information for assessment of delivered proppant. These API standards have since transitioned to one, RP 19C, which globally is represented as ISO 13503-2.

It was in 1947 that the first well was hydraulically fractured with Arkansas River sand to increase well productivity in the Hugoton Field of southwest Kansas. From that point forward the proppant and hydraulic fracturing industry began to develop, but it was not until some 20 to 25 years later that companies were becoming committed to supplying the petroleum industry with proppant. So, by the mid-1970s there were three (3) sand mining companies, one (1) ceramic manufacturer in its infancy, and two (2) fledgling resin coated proppant companies serving the industry. API proppant testing standards formulated in the late 1970s and driven by operating companies were being introduced to help the end user (e.g. the operator) reconcile the properties and performance of delivered proppant with materials that were bargained. Market demand in recent years, though, has magnified the need to apply these testing standards correctly, and not in a cursory or casual manner. By year ending 2013, there were some 80 sand mining companies, 47 ceramic proppant manufacturers, and 18 resin coated proppant companies supplying proppant to the global fracturing industry. Thus, the proppant market is more complex than ever, and it may be helpful to ask a few questions.

## CRITICAL PROPPANT QUESTIONS:

1) What proppant performance will meet my reservoir requirements?
2) What proppant properties and performance did I bargain?
3) What proppant properties and performance are delivered to the wellsite?

Critical proppant questions are important to obtaining unrestricted flow capacity from the reservoir. Answering the first question requires communication with Mother Nature. In other words what due diligence have I engaged to understand reservoir properties (e.g. permeability, pressure, elasticity, etc.)? Understanding the reservoir is primary to knowing what proppant requirements are suited for a successful stimulation. Then one simply has to find that proppant description and bargain it within their supply chain. Thus, we identify two performance thresholds against which delivered proppant can be measured, namely the reservoir and bargained proppant. Remaining is the need to determine what proppant performance arrives at the wellsite. Since material delivered is never going to be the exact same material selected for design or pre-frac tests, it is important to have a process for verification.

## A FOUR STEP APPROACH TO VERIFY DELIVERED PROPPANT:

1) Test
2) Reference
3) Track
4) Review

1) Test: This step is essential to understand the properties and performance of delivered proppant. However, to be meaningful one must apply the API RP 19C standard practices as intended. These standards rely on the following four essential tenets:
    - representative sampling from a flowing stream
    - reliable testing with calibrated equipment

- reproducible testing following standardized procedures
- retention of samples for a least 6 months

These tenets or principles have implications.

It means that sampling statically from the top of field bins, off a belt, or from a pile is not a method that will facilitate representative or reliable samples for testing. Samples must be obtained with recommended tools from a flowing stream for the mass to be examined. A flowing stream can be found when loading pneumatic trailers, when unloading into a field bin, when moving proppant from field bin conveyor to blender hopper, etc.

Similarly, reliable testing with calibrated equipment must be as outlined in the standards. For instance, if one is implementing proppant sieve analysis then a master sieve stack is required for periodically calibrating the working sieve stack, whether in the lab or field. Without reference to a master stack one is not practicing proppant quality control. The proppant sample size must also be balanced with the surface area of the sieve stack. Thus, a correctly split 100 gram proppant sample is designed for 8 inch diameter sieves, not 3 inch or 5 inch diameter sieves.

Correctly splitting a proppant sample is the first step in implementing reproducible testing with standardized procedures. API RP 19C describes tools for splitting and outlines the following tests:

- Turbidity
- Apparent density
- Bulk density
- Krumbein shape factors
    - Roundness
    - Sphericity
- Sieve analysis
- Acid solubility
- Crush resistance
- Loss-on-ignition

Retention of representative samples is important for repeat, follow-up, or additional evaluation. API requires that delivered proppant samples be retained for a minimum of six months.

2) Reference: The second step in verifying wellsite delivered proppant is to compare proppant test results with empirical or public data. If a practical approach to proppant selection was employed then there should be pre-frac properties and performance test data available on currently manufactured material; otherwise public data on laboratory prepped proppant samples in supplier literature, websites, or computer models must be referenced. That comparison produces certain options as follows:

- Delivered proppant matches empirical or public data of bargained proppant.
  Action: Pump delivered proppant according to design schedule.

- Delivered proppant matches reservoir needs but not empirical or public data as bargained.
  Action: Pump delivered proppant as is or make some design change to accommodate reservoir.

- Delivered proppant does not match bargained proppant or reservoir requirements.
  Action: Alter frac design to maximize delivered proppant performance, pump proppant according to original frac schedule, or reject proppant and possibly postpone job.

Note: Understanding proppant performance can only occur when industry testing standards (API or ISO) are applied to produce representative and reliable data which permits an operating engineer to then make informed decisions. Options b) and c) require conversations with proppant supply chains. Delivering proppant that is less than bargained is more likely when the operator or consumer does not apply proppant testing standards. Delivering proppant that is less than “fit for purpose” does not serve reservoir needs, operator needs, or sustain the supply chain. That was best illustrated recently in SPE 168641 where it was concluded that "Productivity impacts were observed for using sub-standard product that impacted well performance by ~ 15%".

3) Track: Every pound of delivered proppant travels from a source to the point of application, the wellsite. However, the more removed that source is from the original mining / manufacturing facility the more likely it is to be subjected to pneumatic damage, particle segregation, and contamination, Those most common sources from origin to wellsite are as follows:
    - Mining / Manufacturing facility
    - Mining / Manufacturing trans-load
    - Trucking company trans-load
    - Service company trans-load or district storage
    - Offset well from an incomplete job with another operator
    - Your offset well with an incomplete frac job

   The information for tracking the delivered proppant supply is found on pumping service company weight tickets and bills-of-lading. The documents should be complete and legible. If they are not so, then the pumping service company upon request should be willing to address that. The following information is easily extracted from these documents:
    - Source
    - Shipping Point
    - Transport Company
        - Tractor #
        - Trailer #
        - Driver # or name
    - Mass / Mesh Size / Proppant Name
    - Delivered Date & Time
    - Arrival & Departure Time

   Some pumping service companies have centralized proppant shipments and returns at their own trans-load or storage to make tracking a source more cumbersome. That practice in fact simply makes the material more suspect and begs more frequent inspection.

4) Review: Examination of supply chains is all about consistency. If one compiles and monitors (e.g. monthly, quarterly, annually) proppant shipping and testing records then one has the information required to judge the consistency of each supply chain. Those supply chains that are least consistent in supplying bargained proppant require more quality control. Those supply chains that meet operator requirements more frequently are more consistent and require less inspection.

So, how does one budget for real proppant quality control? For that we need to know our proppant investment. What did we spend in the previous year on proppants? Knowing that investment, we can appropriate some percentage as our budget.

Once we have a budget what is the best way to allocate those funds? Again, we look at the consistency of our supply chains. Also, we look at objectives. If we are drilling wildcats then we would want to look at every well completion to give the reservoir the best opportunity to respond. Then when we transitioned into development, the frequency could be adjusted to accommodate quality control needs. If we are a small operator drilling only one or a few wells per year, then it would make sense that understanding delivered proppant performance might be critical to our success on each well. Otherwise, inspection frequency of delivered proppant is dependent on supply chain consistency.

If one is continuing to inspect proppant in a cursory or casual manner, then one is not following standard practices for quality control set in motion by operating companies and their supply chains some thirty (30) years ago. Those practices are critical to representative and reliable information; failure to apply them is reflected in case histories.

<u>CASE HISTORY # 1</u>

Reeves County, Texas

Operator received 11 truckloads (500,000 lb) Ceramic proppant.
The delivered proppant was described as follows:

- Sieve Analysis: 20/40 mesh (bills-of-lading and weight tickets)
- Specific Gravity: 3.2 (public data)

Ceramic proppant was rejected by operator based on the following tests (static sample collection):

- Sieve Analysis: 30/50 mesh
- Specific Gravity: 2.81

An independent quality control company was engaged by the trucking company to perform the following tasks:

- intercept the trucks upon return to trans-load
- collect flowing stream samples when unloading trucks
- complete the same tests performed at the wellsite using API RP 19C standard practices

Results from independent quality control company were as follows:

- Sieve Analysis: 20/40 mesh (each of 11 truck-loads)
- Specific Gravity: 3.13 (average of 11 truck-loads)

Comments:
Proppant test results following API procedures were found to be as represented by the proppant company.
Wellsite delivered proppant was rejected by inexperienced quality control personnel applying cursory methods.
Failure to apply API proppant testing standards with experienced personnel resulted in the following:

- Rejected proppant
- Job delay
- Unnecessary costs

<u>CASE HISTORY # 2</u>

Irion County, Texas
Wolfcamp horizontal completion
21 fracs over 5 days

Designed proppant: 130 truckloads (6,000,000 lb) sand, both 40/70 and 20/40 meshes

Transportation record compiled by the pumping service company only included as follows:

- bill-of-lading #
- proppant mass = 6,000,319 lb

Transportation record compiled by an independent quality control company was more detailed and scrutinized.

Comments:
Careful review of bills-of-lading and weight tickets found that four (4) records were duplicated totaling 187,750 lb.
The pumping service company could not produce records for the four (4) missing loads of sand.
The operator was therefore invoiced for 6,000,319 lb – 187,750 lb = 5,812,569 lb

<u>COMMON WELLSITE PROPPANT ISSUES</u>:

1) Application of procedures that do not resemble API standard practices, such as the following:
    - static sampling by hand
    - splitting with paper cups
    - using small diameter sieves with too large a test sample
    - agitation of sieves by hand or with a single motion shaker
2) Contamination of proppant due to dirty field bin compartments
3) Unloading pneumatically into field bin compartments at higher pressure than recommended by supplier
4) Skipping inspection of field bins post-job to ensure that all proppant has been pumped
5) Failing to scrutinize bills-of-lading or weight tickets at job end to avoid duplications

## CONCLUSIONS:

1) Applying a four (4) step approach (test, reference, track, review) to verify delivered proppant helps to promote chain of custody and supply chain consistency.

2) Tabulating proppant investment to establish a budget permits the best use of quality control resources.

3) Contracting well trained quality control personnel can prevent job delays and added expense.

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Figure 1 – Proppant sampling point from conveyor to blender hopper


Figure 2 – Proppant sampling between pneumatic trailer and field bin compartment
(US Patent # 7,121,156 B2)

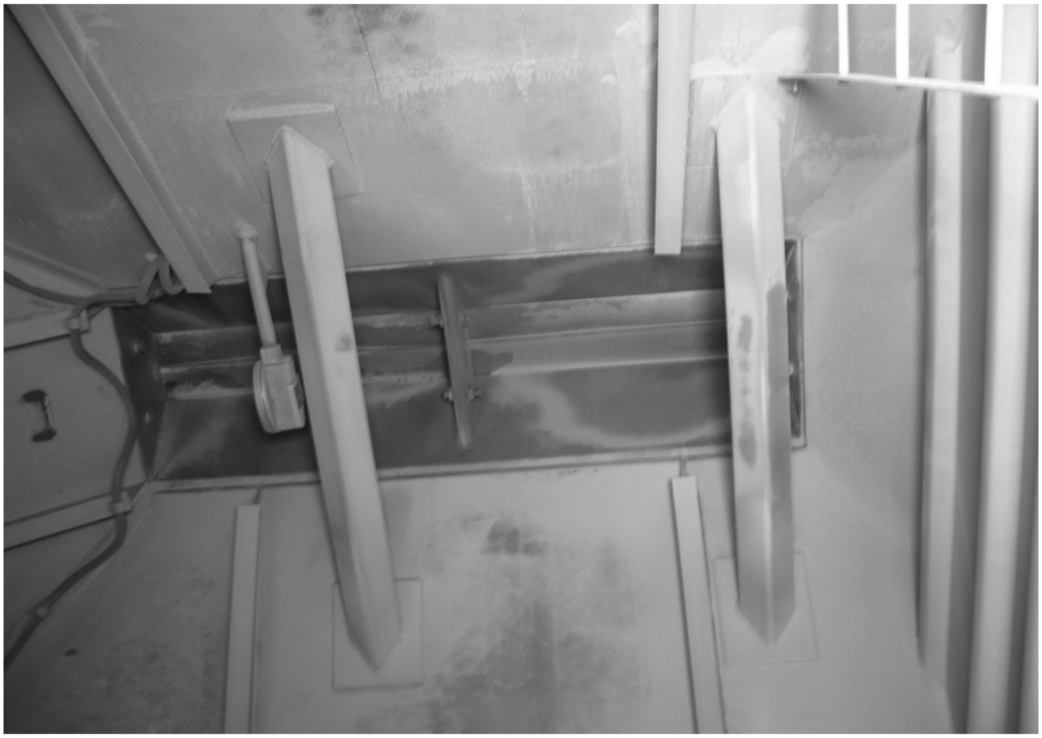

Figure 3 – Clean field bin compartment


Figure 4 – Trailer Gauges for pneumatic pressure