

Custody Transfer Crude Oil Sampling Systems

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INTRODUCTION

The sampling technique employed in extracting a representative sample for crude oil BS&W analysis has received a high level of scrutiny in the last twenty years from concerned oil companies around the world. The revenue implications are considerable, if the sample is not accurate. Whether it is pipeline custody transfer, tanker loading/unloading, or refinery input, a representative composite sample of the oil for laboratory analysis is critical. Plainly put, a 1% error is worth hundreds of thousands of dollars and frequently over a million dollars on one single shipload. That makes sampling a serious matter in the measurement world for crude oil sales.

The design of the equipment should be centered on the concept of extracting a sample from the pipeline, which is truly representative of the product. This is done by taking a sample in basically isokinetic conditions; actually and physically taking a sample from the flowing conditions or replicated flowing conditions. Sampling from dead legs, non-flowing streams, launch tubes, etc., will not provide a dependable quality sample.

Different sampling locations may present negative obstacles that must be designed around, or at least reduced as much as possible to preserve the integrity of the sample accuracy, but these obstacles must be considered and dealt with. The sampling of crude oil is decidedly more important now than it has been in past years and with the increased price of oil, the importance of proper sampling increases in kind.

The object of crude oil sampling is to determine the quality of the oil at the custody transfer point. The amount of basic sediment and water in the oil, a chemical analysis of the oil and shrinkage, and the API gravity should be determined. The process of accomplishing this task is not something to be left to convenience or ease of operations. The process must be accurate.

The purpose of a crude oil sampling system is to withdraw from a pipeline a small representative portion of the product that contains the water, oil, and contaminants in the same proportion as is flowing in the stream.

There are three well-known sampling standards that are used worldwide for automatic sampling of crude oil. Two of the standards are considered as identical and parallel – those are API Chapter 8.2 and ASTM D 4177. The third standard is ISO 3171. Also, there are well known alternate standards like EI Section 2 Part VI.

As an update at the time of this paper, API 8.2/ASTM D4177 is under revision. ISO 3171 will be shortly and the EI document is being used to help with both revisions. API Chapter 8 will be completely revised to not only update the crude oil section, but to separate and expand the chapter to look at not only crude oil, but also the other liquid products that have been overlooked for years. It is the desire of those who are working on this matter, to soon have a comprehensive document that will cover crude oil, refined products, feed stocks and other liquid products in a specific manner. Using the current 8.2 as a guide for refined products is not a proper use of the standard. Hopefully, this will be rectified within a few years.

For now, we look at the current task of sampling crude oil.

SAMPLE SYSTEMS

When sampling crude oil, three major items must be present:

1. The pipeline must be conditioned so that the point of sample is representative of the composition of the pipeline.

2. A sampling device must be able to sample the product under pipeline conditions (pressure, temperature, viscosity and contaminants) and also take a complete sample while not destroying the benefits of the conditioning system.

3. Properly designed sample receiver, capable of remixing the contents of the container and providing for an aliquot for the field or laboratory testing.

In addition to these fundamental components, there are additional aspects that are critical to the overall success of a quality system. They include:

- Proper sample handling of the sample
- Properly chosen analytical method and laboratory analysis
- Monitoring of the system performance
- Validation of the system installation

A Sampling System should be designed and developed on these three principles. A conditioning or mixing system should be designed for crude oil service. It must provide a mixture of the pipeline that is adequately dispersed and distributed across the pipeline diameter. A sampler then grabs a sample of this mixture with a collection device designed to allow the mixture to flow through the collection point under flowing conditions without distorting the sample due to creating a flow profile that would alter the mixed stream at the point of sample extraction. Then, this collected sample is directed to a sample receiver designed to maintain the integrity of the sample in all ambient conditions and re-mix the contents so that a small portion of the total sample volume can be removed from the whole and analyzed.

Sampling is not just 'another' function of measurement; it is the heart and soul of the profit figure. Crude oil sampling goes on past the pipeline, into the laboratory, analysis and accounting. It must start correctly if it is to end well! Companies have to seriously weigh the question of perceived convenience versus accuracy in analysis and the monetary savings.

The object of mixing in the line is to ensure the droplets of water are small enough to be sampled and the contaminants are uniformly distributed across the line. If a good mixture is not present, a good sample is not possible.

Piping configurations, pumps and other turbulence producing devices may provide mixing for good representative sampling. There are times when these conditions will allow for a good sample. However, while they do provide some mixing characteristics, they may not consistently provide distribution and dispersion of the pipeline contents adequate for proper sampling. That is a very critical decision that must be made – can we get lucky, or do we need to take a proactive approach to pipeline conditioning. Without adequate pipeline conditioning, getting a representative sample is at a high risk of failure.

The sampler should be a positive displacement pump that voids the sample "grab" area with each stroke. This is to ensure there are no contaminants left to alter the next sample or that portions of the sample grab were not directed to the container. This can be accomplished by a variety of positive displacement methods and designs – squeezable collection heads, piston/cylinder designs or piston syringe style designs. The key is to extract a sample and direct the entire collected sample to the sample receiver.

The positive displacement pump concept also should be used so the sample will be pumped into the container, regardless of the pipeline conditions, ambient temperature, wax content, pour point, sand and sediment content, or other physical properties of the sample that inhibit the free flow into the container.

A properly designed insertion sampler ensures an accurate sample is being withdrawn from the flowing stream. The retractable type sampler allows for pigging, inspection, and maintenance without shutdown and isolation of the main line piping.

The world's best sampler is useless unless it sees an optimally mixed pipeline. The world's best mixer is wasted if the sampler cannot properly retrieve the mixture.

And lastly, a very critical point is the sample container. Careful consideration should be taken with the type (pressurized or non-pressurized), style (mixer or non-mixer), and design (features). A poorly designed container will adversely affect your sample analysis. After grabbing a representative sample, it is vital that the container that becomes the depository for the samples is properly designed for the task at hand. A container that allows for

water to cling to the sides and avoid being mixed into the sample at a later point is not properly designed. Lid closures, piping designs, sloping sides, internal lining and coating, the mixing system and similar items of interest are all to be considered in a receiver. The aforementioned standards all address the various features that should be part of the design of the containers. The containers should be proven and show that they indeed provide for an adequate mixing of the retained sample and providing for the small amount of sample to be used in the lab.

Also, High Vapor Pressure Crudes should be closely looked at, as regards high-pressure crude containers. All of these systems should be able to be proven, and certified that with a given product, they truly provide adequate mixing for the lab and the lab tests.

SAMPLING POINT AND DESIGN

A sampler may be located in the pipeline and subjected to flowing velocity conditions, and yet, by design, distort the contents of the stream into the sample collection chamber. While this renders the sampler "isokinetic", it does not help the sample at all, if the collection point does not take FULL advantage of the conditioned flowing stream. The sample taken should be removed from the pipeline at a location where the flowing stream at the sample point is representative of the contents of the stream, and is at flowing conditions (velocity). The sampling device should not alter the profile or velocity of the flowing stream at the sample point, i.e., at the moment of sample. The sample should be physically "taken" in flowing conditions, not simply diverted or routed out from flowing pipeline conditions.

In crude oil sampling "isokinetic" as normally defined, is not the only critical point. A "mixed isokinetic stream" and a sampler that takes full advantage of that condition, is important!

The following are a few typical and widely differing definitions given by major oil companies worldwide, for the term "isokinetic sampling". While some will argue today that the term is mis-applied (and sometimes it is) the concept is nonetheless a legitimate point of interest. These are drawn from standards or company specifications worldwide:

1. If, at the point at which the sample separates from the main flow, the velocities of both the sample and the main flow are equal, then the sampling is said to be isokinetic.
2. If, at the point at which the sample separates from the main flow, the velocities of both the sample and the main flow are equal, then the sampling is said to be 100 percent isokinetic. Lower or higher sampling rates are expressed as percentages of the isokinetic sampling rate.
3. The withdrawal of samples from the main line shall be based upon the isokinetic principle whereby drawing of the sample occurs when the linear velocity of the liquid through the opening of the sampling probe is the same as that in the pipe at the probe opening. These systems shall follow the requirements of API Chapter 8.2. A flow-proportional sampler shall collect samples with provision for time proportioning as a back up.
4. A sample taken from a pipeline in which the linear velocity of the liquid through the opening of the sample probe is equal to the linear velocity of the liquid in the pipeline and is in the same direction as the bulk of the liquid in the pipeline approaching the probe.
5. A sample that contains the same proportions of the various flowing constituents as the total volume of the liquid being transferred.
6. Any technique for collecting a sample from an appropriately mixed flowing stream in which the sample collection chamber is so designed that the stream entering it has a velocity equal to that of the stream passing around and outside of the sample collection chamber.
7. Any technique for collecting a sample from a flowing stream in which the collector is so designed that the stream entering it has a velocity equal to that of the stream passing around and outside the collector.

Inline sampling has long been the desired method for sampling of crude oil. The removal of the equipment for service required either a retriever for the equipment or a maintenance shutdown. Slipstream sampling has become an alternative because it allows the sampler to be isolated and removed for repair without affecting the main pipeline. Years ago, with oil at much lower cost, inline equipment were often left inoperable until a shutdown. At today's prices, this is not acceptable. The need to service the equipment is critical, and shutdowns

are expensive and frequently impractical. Therefore, the equipment must be retrievable manually, mechanically or by an automatic insertion device, or it must be in a system that can be isolated.

There is, however, a major issue of sampling crude oil that is being overlooked in the interest of maintenance. The issue is the integrity of the sample. Ideally, a sampler should be placed downstream of a mixer and retrieve a sample from the pipeline at that point. This is the point where the mixture is at its' best, and that is where an "isokinetic" sample should be taken for the best result. Diverting the sample to a bypass stream and physically sample the product at a removed point raises critical questions about the mixture at that remote point if that system is not properly designed.

Several tests were run in the mid 80's comparing inline sampling and slipstream sampling. The results showed that little or no difference was seen between the two systems.

There is one very major point, which was overlooked in this issue. The inline sampler and the slipstream probe were both located in a large diameter pipeline that was void of any line conditioning. The fact that both samplers had similar results is totally predictable, as neither unit was introduced to the free water flowing at the bottom of the pipeline. It went undetected.

Whether the user favors an inline sampling device or a bypass/slipstream sampling device, the main pipeline must be conditioned for distribution and dispersion of the water across the diameter of the pipeline. Without this having been done, the integrity of the sample is positively in question.

The important issue related to the slipstream sampling system is that if you avoid the use of the main line mixer/conditioning, the whole sampling issue is open to serious question and debate. A slipstream sampling system requires the same main line conditioning as an inline probe sampling system. From that point on, a slipstream system becomes a very difficult and expensive system to install and maintain. The slipstream system must be truly representative of the main pipeline. This requires several additional considerations in design.

A probe must be properly designed to divert the flow out of the pipeline into the slipstream. The inlet of the probe is to be formed so as to cut a coupon from the stream and not encourage or discourage water entry other than that which is representative of the amount in the pipeline.

The flow in the slipstream must be controlled and closely duplicate the velocity in the pipeline. If the slipstream pump is too slow, a bow wave effect will be present at the probe entry, free water will negotiate around the entrance and a low water cut will enter the system. If the pump is too fast, it will create a suction of the probe entry, encourage free water into the entrance and a high water cut will enter the system. A slipstream system thus may require a variable speed motor and pump, along with a controller. This will also require additional power and maintenance over the life of the system. Conditions of a 30:1 plus turn down ratio in flows will simply add wear and tear to the pump and motor in this service.

The slipstream system requires additional piping, valves, meter signal for flow rate and a redundant mixer immediately in front of the sampler, to re-mix the slipstream.

Unless the slipstream is at optimum performance, it most likely falls short of providing the product, which is present at the outlet of the main pipeline mixing system. A handful of unnecessary variables have been added to the sampling system to cause a doubt of the integrity of the sample, as well as increase the difficulty of proving the system. A properly designed slipstream can be a truly isokinetic system, but it will also be more expensive and maintenance prone. An inline sampler which is removable under pressure, is an easier installation, and also provides a truly isokinetic sample point for the actual physically taken sample. The sample that is available here will never be any better and, in reality, can only become worse. This favored approach has been tested and proven for years.

VALIDATION AND MONITORING

While this paper focuses on the equipment that can be found in a typical crude sampling system, it is equally important to be in full control and understanding of the laboratory test procedures that will be used, the handling of the sample to the lab and in the lab. Our standards give guidance on this process.

And, once the system design is settled and the equipment is chosen, proper installation is a must. Following the initial installation, conducting a water injection test should validate the system.

Once the system is compliant with the acceptance criteria set forth in the standards, the system should be designed such that the operator can monitor the performance and be able to quickly notice any deterioration in the systems performance.

CONCLUSION

Without adequate mixing for distribution and dispersion of the total product, no sampler can provide an accurate sample. Likewise, a sampling device that is not designed and positioned for isokinetic sampling of crude oil cannot provide a representative sample of the conditioned pipeline. And without taking a full system approach and taking ownership of the process, your sampling system is not likely to provide you with the security and integrity that you need and desire for such a critical part of your company's business plan. Measurement is truly the cash register for your organization. At today's prices for a barrel of crude, it is a major financial consideration. Millions of dollars are in the balance.

Sampling is truly an art. Failure to use proper techniques can cost companies huge sums of money daily. Sampling is too critical to be left to guess work, old outdated methods, or unproven techniques.

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