Product Quality Sampling

A GUIDE TO EQUIPMENT SELECTION, DESIGN, & COMMON ISSUES

BY: JON DECOSTE, P.ENG, MBA

APRIL 2018

Table of Contents

1. Introduction

There are hundreds of things that can go wrong when retrieving a petroleum sample for quality testing. Companies should be doing all they can to reduce issues and errors in sample retrieval and sample testing, as these processes have a direct impact on their bottom line.

Test results are obtained in two steps: (1) *sampling* and (2) *testing*. Human error (as opposed to device error) in the *testing* step is the greatest contributor to the overall error crude quality results. However, it is directly followed by errors in the *sampling* step created by poor sampling processes, issues with composite sample designs, and poor maintenance of quality sampling assets (additional documentation on human error can be found at validere.com).

The considerations outlined in this white paper will help you ensure representative samples are retrieved from operations, resulting in a higher likeliness that trustworthy results are generated from laboratory testing.

This white paper does not address how to reduce errors after a representative sample is retrieved and custody has been taken by a laboratory. If you are interested in how to increase your confidence in petroleum quality testing, resulting in reduced operating costs and bottom line growth, reach out to us at info@validere.com.

2. Sample Container Selection

Millions of spot samples (also called grab samples) are taken each year in the oil and gas industry. Conservatively, it's predicted that 40% of these spot samples are retrieved in a manner that results in quality tests that are non-representative of the product (Based on Validere field case studies). Instead of being discarded, these results get used, and typically have a commercial impact on multiple companies in the supply chain.

Managers should be providing their field operations staff with the knowledge and tools to complete sampling tasks properly. With some forethought, education, and sampling container options, operators can easily ensure good sampling is completed while minimizing operational costs.

There are two factors to consider when determining the correct sampling container for retrieving a product sample:

1. **What is the vapour pressure of the product?**
   Products that have a vapour pressure of less than atmospheric pressure (at atmospheric temperature) do not require a sophisticated sample container. Most crudes fit into this category. A typical one litre plastic container with a screw cap will suffice. However, if the vapour pressure of the product is higher, as in a condensate or NGL, then a sample container that can maintain that product in liquid phase is required. Using a plastic container for a high vapour pressure product will allow light ends to escape and can pose a safety risk. (ASTM D6377 section 8 has additional information on dead vs live crudes, along with detailed processes)

   Safety concern: An operator uses a plastic sample container for a volatile condensate and retrieves this product during a cold autumn day. The operator then puts the container in her truck and proceeds to the sample drop off location. During the trip, the sample warms in the truck's cab, resulting in higher pressure inside the plastic container. The plastic container fails, and the condensate sample explodes in the truck cab, injuring the driver.

2. **What tests will be completed on the sample?**
   Understanding what types of tests will be completed on a sample will help determine the type of sample container that should be used. Additionally, this will help determine the volume of product that should be sampled. Take, for example,

a laboratory completing destructive testing that requires 500cc of product. The product sample provided to the laboratory was 600cc. There will likely not be enough product left for other testing after the destructive tests are completed, eliminating 500cc of the volume. The customer must then compromise and choose what reduced testing they wish to complete.

Product & Tests	Plastic Bottle	Glass Bottle (Clear)	Glass Bottle (Dark)	Cylinder (Atmospheric)	Evacuated/ Glycol Cylinder	Piston Cylinder
Low Vapor Pressure	√√	√√	√√	√	√	√
High Vapour Pressure	X	X	X	X	√	√
Tests						
Light Hydrocarbon & Vapour Pressure	X	X	X	√	√√	√√
Sulphur	√	√	√√	√	√	√
Mercury (Low Vapour Pressure)	X	√	√	X	X	X
Density, Viscosity, BTEX, Total Salt, Filterable Solids, Color, Phosphorus	√	√	√	√	√	√
Organic Chlorides, PH	√	√	√√	√	√	√

Table 1 – Sample container selection
x: No recommended, √: Can be used, √√: Recommended

Even more detailed considerations exist, outside of what has been included in this document. Generally, the best practice is to discuss sampling requirements with the laboratory that will be completing the testing. They can advise on their preference of sample container and volume requirements to complete the requested testing. (Also refer to ASTM D3700, D4057)

2.1. Benefits and Drawbacks of Sample Containers

Container Type	Cost $	Maintenance & Cleaning Cost $	Life Expectancy	Benefits	Drawbacks
Plastic Bottle	$5	N/A	single use	Low cost, lightweight, durable.	Cannot contain light ends. Typically, only good for one use.
Glass Bottle Clear	$10 to $25	$10 per sample	6 months	Capable of containing slightly higher vapour pressure than plastic. Preferred for retaining mercury.	Fragile, heavy, cannot contain light ends.
Glass Bottle Dark Tint	$10 to $25	$10 per sample	6 months	Does not react with sulphur. Retains less contaminants.	Fragile, heavy, cannot contain light ends.
Cylinder (ATM)	$700 to $2000	$20 per sample	10 Years	Rugged, low maintenance.	Higher risk of improper filling and risk of contaminants.
Evacuated/ Glycol Cylinder	$700 to $2000	$25 per sample	10 Years	Typically, washed and vacuum applied by accountable 3rd party. Low risk of contamination.	Can be challenging to ensure full sample retrieved.
Piston Cylinder	$3000 To $8000	$25 per sample & $200 per 25 sample cycles	10 Years	Maintains product liquid phase. No 3rd party required in operation. Uses nitrogen typically found at facilities.	Extremely expensive and high maintenance cost. High risk of improper filling by operator. Can have nitrogen leak into sample.

Table 2 – Benefits and drawback of sample containers
All dollar figures are approximate

3. Composite Sampler Selection

There is a long list of composite samplers to choose from in the market today. We will not touch on all of their unique technologies, nor will we specify brands of equipment. The purpose of this section is to provide information that should be considered when choosing a composite sampler for your meter run, truck off-loading skid, or LACT.

First, let's explain the definition of a composite or proportional sampler. This is a sampling system that takes equal proportions of product volume throughout a time period and accumulates them in a container. The summation of these small volumes retrieved during the sample period are considered a representative composition of the total product during that period. For example, if a LACT is flowing 200 bbl/day and we want to capture a composite sample over a two-week period, we could set the composite sampler to take a 5cc sample every 5 bbl of flow. This would result in 2.8 litres of product at the end of a two-week period, representing the average quality throughout that time.

When choosing a composite sampling system, you can expect to spend between $25,000 to $125,000 (or more) if dealing with multi-product systems. The first question you need to answer is *"does it make economic sense to invest $50,000 into my facility to have a composite sample?"* We would suggest that, if you are looking at the higher end of this expenditure, you will likely pay back the investment within months of operation. If you need help with these evaluations, feel free to reach out to us at info@validere.com.

3.1. Actuated Valves, Sample Pump, & Automation

Automation is a key to any composite sampling system. The system should be capable of achieving the following criteria:

a) Sample pump can be installed in the flowing pipeline or in a sampling speed loop.
b) Sample pump has multiple volume settings (2cc, 5cc, 10cc, 25cc, etc.)
c) Actuated valves can isolate sampling system from process piping.
d) Sample system tubing has a pressure relief valve (PSV) that is set to protect the lowest pressure rated device. This PSV should discharge to drainage or vent lines.

e) Automation should allow for variability in the sampling frequency. The goal is to have the sample container 80% filled during the sample period, (ie: 80% filled during two-week period).
f) The sample system should be designed to maintain the same pressure of the process.

3.2. Sample System Accumulation Container Selection

Depending on the product being sampled, and the tests to be completed on the sample, there is likely a preferred container to accumulate the product. The premise of selecting an accumulation sample container is to maintain a representative sample of the product while minimizing the capital cost of the design.

	Cost	Description	Product	Benefit	Drawback
Atmospheric Container	$200 to $500	The sample accumulation container does not hold pressure. - Jerry-can, Nalgene lab container, stainless steel jar, all with a sealable screw on lid.	- Heavy crude oil - Crude oil with low light ends or vapour pressure.	- Cost effective - Securely preserves composite sample.	- Cannot maintain high vapour pressure products. - Not as durable as stainless-steel containers
Low-Pressure Container	$1,000 to $5,000	The sample container can maintain an internal pressure of 5-15 kPa. Typically, stainless steel construction with a pressure relief valve.	- Crude or condensate having less than a 105 kPa vapour pressure.	- High durability - Preserves light ends in sample.	- Cannot maintain high vapour pressure products. - Maintenance required for pressure relief valves.
High-Pressure Container	$5,000 to $10,000 +	The sample container can maintain an internal pressure of 10,000 kPa. Typically, stainless steel construction without a pressure relief valve.	- Crude or condensate having more than a 105 kPa vapour pressure. - NGL and spec products like ethane, propane, and butane.	- Ensures high vapour pressure products remain in liquid phase.	- More sophisticated design required to ensure proper product flow. - Greater number of parts in sample system creates more opportunity for issues.
High-Pressure Container with sub-sampler	$10,000 to $20,000	The sample container can maintain an internal pressure of 10,000 kPa. The sub-sample container can be an evacuated cylinder, or a piston cylinder and it is used to draw a smaller volume off the main container for laboratory for testing.	- Crude or condensate having more than a 105 kPa vapour pressure. - NGL and spec products like ethane, propane, and butane.	Same as above plus - Sub-sampler reduces transport cost to lab. - Allow for multiple samples to be drawn off main container.	- Risk of poor blend in sub-sampler if the main container doesn't have a mixing function. - Risk of operator errors when filling the sub-sample which can lead to the loss of light ends.

Table 3 – Sample system accumulation container selection

4. Design Considerations

4.1. Speed Loop Design

The speed loop, also referred to as a sample loop, is typically made of high pressure tubing that transports product from process piping to the sample pump and back to the process piping. The purpose of the speed loop is to reduce the time delay between when the sample is retrieved to when it is captured in the composite sampler accumulation container.

a) **Size and length of tubing run:**
   Typically, ½” stainless steel tubing is used for the speed loop and the total length of the speed loop is approximately 4-6 meters. However, longer speed loops may be required, depending on the location of the sampling pump and accumulation container. Speed loops should generally not be greater than 30 meters in total length, and the designer should complete pressure drop calculations to ensure that the flow rate through the speed loops is adequate.

b) **Flow rate:**
   The flow rate of the speed loop should ensure that there is no delay between the sample retrieval and the product flow in the process pipe. Ideally, the velocity of the speed loop should approximately equal the velocity of the process pipe. For example, if two molecules are flowing down the process pipe, one enters the speed loop and one remains in the process pipe, the molecules should meet again where the speed loop returns to the process pipe. Typically, flow is generated from differential pressure across the process pipe. This could be derived from fittings, pumps, or an orifice plate.

c) **Speed loop pump:**
   A pump should be considered for the speed loop if inadequate flow is available from process pipe differential pressure. The speed loop pump should be installed downstream of the sample pump where the tubing returns to the process pipe. (Note: the speed loop pump is not the same as the sample pump. Refer to section 6)

d) **Sample probe:**
The sample probe, which can be part of the sample pump, should be installed in the center third of the speed loop or process pipe. This will ensure well blended product is retrieved for the sample.

e) **When not to use a speed loop:**
A speed loop is not always required. If the sample accumulation container and cabinet are located within a close proximity (1 meter) then the sample pump can be installed directly on the process piping.

(Note: Make sure to consider pig runs and the potential requirements of retractable sample pumps and sample probes.)

4.2. Sample Pump Location

The sample pump is the device that retrieves small volumes from the speed loop and accumulates into the sample container.

a) **Pump volume settings:**
Select a pump that has several volume settings. This will allow for finer adjustment if required. Selecting a pump with 2cc, 5cc, and 10 cc will allow for flexibility on retrieval intervals.

b) **Pump location:**
Pump with built in sample probe: Installation can be in the process piping or in the speed loop. The pump should be installed in a location where the tubing between the pump and the sample accumulation container is minimized. The longer this length of tubing, the higher the delay between retrieving the sample and accumulating it in the sample container. This delay should not be longer than a few hours of operation.

Pump without built in sample probe: The pump is typically installed directly downstream of the sample probe. The length of tubing between the sample probe, sample pump, and accumulation container should be minimized.

c) **Sample pump type:**
It is recommended to use a flow through sample pump with built in probe. This pump design allows the product to continuously flow through the pump probe until it is time for a retrieval to occur. This ensures that any debris is washed away, an accurate sample is retrieved, and will accommodate multi-product process.

4.3. Sample Cabinet Design

Sample cabinets may not always be required. There are a few considerations to review to determine if a sample cabinet is worth the additional expense. Fluctuations in atmospheric temperatures is typically the main decision metric to consider. Will the temperature at the facility rise to a point resulting in an overpressure of the sample container? Does the temperature drop below freezing where ice could form in tubing? The best choice for these scenarios would be to install a sample cabinet.

a) **Warm weather environment**
Sample cabinet should have insulation and be located in an area that does not get direct sunlight. The goal is to keep the sampling tubing and sample container cool in the cabinet. Additionally, the tubing between the sampling cabinet and the sample pump should be insulated.

b) **Cold weather environment**
Sample cabinet should have insulation and a heater (rated for an explosive atmosphere) to maintain the temperature above freezing, and ideally at the operating temperature of the process.

Other considerations include:

c) **Spill containment**
Sample cabinets can be designed with a catch tray that connects to facility drainage. When a leak or spill occurs within the sampling cabinet, all of the product is caught by the catch pan and drains away. This removes the risk of a spill occurring at the facility and reduces the risk of an explosive atmosphere being created in the sample cabinet.

d) **Security**
It may be of interest to ensure only the responsible party has access to the sample container. The sample container holds the product that will ultimately be used to determine the value of the product that was transferred. Cabinets can be designed with lock and key for this purpose.

4.4. Inline Mixer

The purpose of a composite sampler is to retrieve a representative sample from the process product during the sampling period. This can become challenging due to the characteristics of the product coupled with the fluid-dynamics of the piping. For example; the more viscous or colder the atmospheric temperature, the larger the delta between the center of pipe velocity and the outer diameter velocity. This translates into different composition of product on the outer edge of the pipe versus the centre of the pipe. Additionally, if the flow of the process fluctuates, there is a likelihood that heavier products will settle in the pipe.

One of the methods of correcting this issue is to mix the product while it flows with an inline mixer. An inline mixer is typically made of the same diameter pipe as the process pipe and looks like a pipe-pup ranging from 12-36 inches. There are many different designs of inline mixers, therefore it is recommended to discuss your application with a vendor to ensure a homogeneous mix is achieved. The inline mixer should be installed directly upstream of the sampling probe. Again, the vendor of the inline mixer will advise of minimum distance from the sampling probe.

4.5. Spot Sample Ports

Spot sample ports should be considered for installation on the composite sample loop. The spot samples ports are used for problem solving quality events where fast iteration of testing is required. Additionally, they provide a backup sample location in the scenario where the composite sampler is not working. Spot sample ports should be installed downstream of the inline mixer and the composite sample probe. It is a good practise to install quick connect fittings on the sample ports with double block and bleed valves.

4.6. Weight Scale or Fill Gauge

The composite sampling system should have a means of determining the volume in the sample container. Most systems have an option for a fill gauge, and this should be used to ensure the container is not overfilled. Additionally, a rule of thumb is to program the composite sampler to fill the sample container to 80% of its volume throughout the sample period. This will ensure there is some flexibility in pulling the sample late and reduces the risk of an overfilled container.

If a fill gauge is not available, it is recommended to install a weigh scale to approximate the volume in the sample container. Having a method of confirming the volume in the sample container will also reduce the likelihood of a sample being sent to a laboratory with insufficient volume for testing.

5. Top Sampling System Problems

a) **Blocked sample probe:**
Identified by: Low volume in sample container
Fix: Remove sample probe and clean. Ensure to isolate the sample speed loop prior to cleaning.

b) **Lag in sample retrieval:**
Identified by: Samples results do not align with calculated quality or inline quality measurement.
Fix: Ensure the tubing length between the sample pump and the sample container is minimized.
Ensure the speed loop velocity is approximately equal to that of the process piping.

c) **Overpressure sample container:**
Identified by: Samples have lower vapour pressure than expected.
Samples are missing light ends in compositional analysis.
Samples are heavier than compared to inline measurement.
Fix: Ensure sample containers are not being overfilled.
Ensure pressure rating of sample container is not less than product vapour pressure.

d) **Leaking sample container:**
Identified by: Samples have lower vapour pressure than expected.
Samples are missing light ends in compositional analysis.
Samples are heavier than compared to inline measurement.
Fix: Ensure sample container are pressure checked and hold a constant pressure.
Apply a slight pressure to the sample container to ensure a tight seal on lid prior to installing on campsite sampler.

e) **Pump back pressure issue:**
Identified by: Low volume in sample container
Probe is confirmed clean
Pressure at sample loop return is higher than the pressure at sample loop supply.
Fix: Ensure sample pump is designed for a downstream pressure equal to or less than that of measured pressure at speed loop return.
Identify and recent changes to operation or process pipe design that could be affecting pressures.

6. Terminology

1. **Sample container** – a container that is used to retrieve a product sample that will be transported to a location for testing. Sample containers are used for spot samples or to retrieve a sub sample from an accumulation container.

2. **Accumulation container** – the container that is part of the sample system which holds sampled product. The accumulation container may also be the sample container if it is disconnected from the sample system and used for transportation.

3. **Speed loop** – a tubing run that transports product from process piping to the sampler and back to the process piping. Typically follow occurs though the speed loop via differential pressure. Also referred to as a sample loop.

4. **Speed loop pump** – a pump that is used to flow product through the speed loop if a differential pressure is not adequate to achieve flow rate requirements.

5. **Sample pump** – a pump that retrieves a sample from the process pipe or a speed loop and delivers it to the accumulation container.

6. **In-line mixer** – a device that mixes product in process piping before a sample is retrieved.

7. **Cylinder sample container** – a pressure rated stainless steel container, typically with a volume of 1 liter or less, used to retrieve product samples.

8. **Evacuated cylinder** – a sample cylinder that has a vacuum applied.

9. **Glycol cylinder** – a sample cylinder that is prefilled with glycol. The glycol is evacuated from the cylinder when the product sample is retrieved.

10. **Piston cylinder** – a sample container that has a piston inside that travels between the ends of the cylinder. Typically, inert gas is applied to one side of the piston and evacuated when the product sample is retrieved on the opposite side of the piston. The piston maintains a barrier between inert gas and product.