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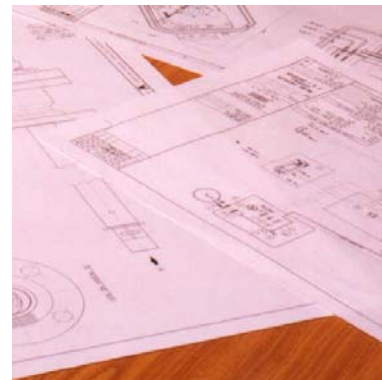
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What international standards govern sampling system selection, design, installation and operation?

There are four major standards that govern 'Sampling liquid hydrocarbons in pipelines'.

They are

1. ISO 3171
2. IP 6.2
3. API 8.2
4. ASTM D4177



Equipment that complies with ISO 3171 will comply with the other standards, so we have used it as the guiding standard. In the teach me section of this web site we discuss and provide guidance on the requirements of the standards.

More about the requirements of the sampling standards [click here](#)

Get the ISO 3171 standard [click here](#)

Get the API 8.2 standard [click here](#)

Get the ASTM D 4177 standard [click here](#)

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What are the most important steps to consider when designing or specifying a sampling system?

In a typical sampling application, the volume analysed is between 1 and 300 billionth of the total batch. When the custody transfer and batch quality is determined by such a small sample it is vital that it is representative of the fluids being sampled. The standards defines a number of steps that need following to ensure successful sampling.



1. Homogeneity of pipeline contents. To ensure that the sample is representative of the fluids flowing in the pipeline the sample must be extracted from a point that is representative of a cross section of the pipeline. This may require mixing. The standards include formula (annexe A and B) to calculate the mixing in a pipeline to assess the suitability of a location for sampling. This calculation should be performed for the worse case condition (minimum flow rate, viscosity and density). [More about mixing](#)

2. Location of the sampling system in relation to the custody transfer point. Ideally this should be at the custody transfer point, but in many cases (such as marine loading/unloading) it is not possible to do this and ensure sufficient mixing at all flow rates. Samples taken at these locations often do not comply with the standards. In these applications the flow turndown also prohibits the use of a static mixer and causes problems with flow resolution. The sampling system can be installed at a more suitable location and the line-fill sampled. [More about line-fill sampling](#)

3. Extraction of a flow proportional and representative sample. The flow rate in the main pipeline may vary and the sampling system must operate flow proportionally to ensure representivity. Every sample grab must be highly repeatable (1cc +/- 2%) irrespective of changes in density, viscosity, pressure or temperature to avoid biasing the batch sample. The total batch sample should comprise enough small grabs to represent the whole batch (for crude oil normally at least 10,000 - 1cc grabs (10 litres). The sampling system performance should be monitored and reported during the batch.

[More about representative sampling](#)

4. Correct sample handling and mixing. Sample grabs are discharged into a sample receiver which should be capable of maintaining the sample without any loss of light-ends. The receiver should have no voids or water traps and it is preferable that it is portable to minimise the possibility of errors or contamination occurring in the field. Before a sub-sample is drawn for analysis in the laboratory, the contents of the sample receiver must be mixed to ensure that water has not settled during the sampling process. [More about sample receivers](#)

5. Laboratory analysis. The laboratory analysis should be conducted in accordance with recognised procedures and standards. The sampling standards recommend Karl Fischer titration as the preferred method of water measurement.

6. Prove the system. In order to confirm the performance of a sampling system it may be necessary to prove the system performance by water injection. The standards define a procedure and method of injecting a known volume of water into a pipeline and using the sampling system to withdraw samples to measure the injected water. This process can be independently witnessed and certified to the satisfaction of all parties concerned. The test of the performance of any sampling equipment is the performance validation by water injection and this is often used as a crucial performance guarantee requirement in system specifications. [More about system proving](#)

The representivity of a sample is only as good as the weakest link in the sampling chain. Every one of the above steps must be considered and resolved as part of the design process to ensure the system and sample complies with the standards.

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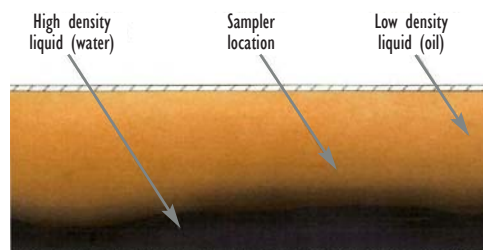
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Why do the standards demand that pipeline contents must be homogenous?



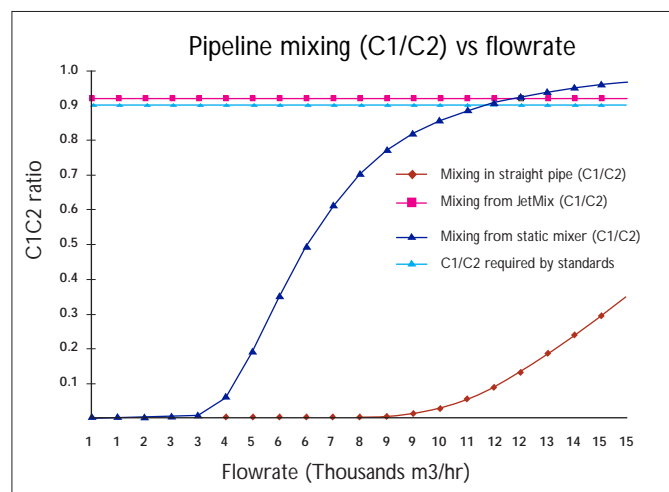
A sample is taken from a single point in the pipeline. Water and oil do not mix and therefore it is vital that the point of sampling is representative of a cross section of the pipeline. This can only be achieved by mixing. Natural mixing can be provided by valves, elbows and natural turbulence generated by the flow.

The standards dictate that the sample should be drawn from the central third of a pipeline in which the water concentration at the top of the pipeline (C_1) should be 90% of the water concentration at the bottom (C_2), i.e. the C_1/C_2 ratio must be at least 0.9. If this requirement is met then the location selected is deemed to have sufficient mixing for sampling. The standards define a set of calculations (ISO 3171 annexe A and API 8.2 annexe B) to assess the mixing at a potential sampling system location. Mixing and dispersion cannot be assessed by determining the Reynolds number alone.

The C_1/C_2 ratio must be above 0.9 for ALL flow rates and fluids that will be transferred through the pipeline. The calculation should be performed for the worst to best-case scenarios to assess the mixing requirements. The worst case scenario

(i.e. where there is the least natural mixing) occurs at the lowest flow rate, density and viscosity. It is also extremely important that the lowest flow rate is not the lowest normal flow rate but the lowest actual flow rate as in many situations (such as marine unloading) the most water will be discharged at the beginning and end of a batch when the flow rate is very low.

[Which type of mixer is best?](#)



The API, IP and ISO standards both include a table to use as an initial assessment of the suitability of a location. This table is calculated at a single density and viscosity and is therefore only valid as a guide. All the standards recommend that the full calculations be performed before selecting a suitable sampler location.

[Click here to see if you need pipeline mixing.](#)

[More about mixers](#)

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Samples taken at different point across a pipeline profile



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How can you decide which type of mixing system is best suited to your application?

Selection of the correct mixer as with any process conditioning depends greatly on the application.

There are two main types of pipeline mixing systems available.

- Static mixers
- Powered mixers



In most applications a powered mixer offers the best solution for many applications because it adds energy to the flow rather than deriving mixing from the flow. This means that powered mixer creates almost no pressure drop and makes them suitable for high turn down applications where minimal pressure drop is important. Many powered mixers can be installed by hot-tap and they are generally removable for pipeline pigging.

In applications where the flow turndown is less than 4:1, the pipeline can be cut to install the mixer and it is acceptable to have a shear type disruption in the flow (i.e. waxing is not a problem) then a static mixer may provide a suitable solution for pipeline mixing. A static mixer normally offers a lower cost alternative to a powered mixer

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What is the accuracy of different sampling systems and which is best for your application?

There are two main types of sampling systems, probe based systems and bypass loop sampling systems. In probe-based systems the sample is taken inside the pipeline and in a bypass loop system the sample is taken from a 1" or 2" bypass loop flowing isokinetically with the main pipeline flow.

Probe based systems tend to be lower cost and accuracy and have a higher measurement uncertainty and maintenance cost. They also have a higher dead volume which can lead to batch cross contamination. Bypass loop systems tend to be more expensive, but more accurate, easier to maintain and have a lower measurement uncertainty and dead volume.



[Comparison between bypass loop and probe based sampling system](#)

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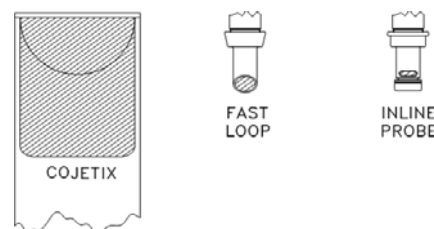
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How do you know if I have a representative sampler?

Assuming that the pipeline is sufficiently well mixed for sampling, then the representivity of a sample is largely determined by the following:

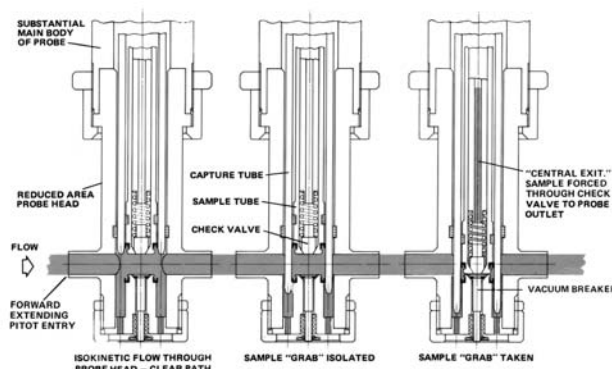
- Flow through the probe sampler or sampling bypass loop must be isokinetic to ensure that the fluids remain homogenous and representative of the pipeline profile. In a probe based system the head of the probe is usually streamlined or has an entry pitot to avoid bluff body effects biasing the flow entering the probe. In a bypass loop system, the loop size must be large enough to be representative of the main pipeline (1" or above) and the velocity in the loop should be sufficiently high to maintain homogeneity (as per the mixing calculations in the standards). Both probe and bypass loop systems must be designed with no voids or water traps.

- The inlet to the sample probe or bypass loop should be 10 times the size of the water droplets created by the pipeline mixing and dispersion equipment.



- The individual sample grabs should be small enough so that enough of them are taken to be representative of the batch (for crude oil at least 10,000 - 1cc grabs (10 litres) is recommended). Each grab sample should be repeatable to +/-2% irrespective of any changes in pressure, viscosity, density or temperature. This points to the use of positive displacement sample extractors, as any device using line pressure for discharge is likely to be affected by process changes. How to ensure a system is working correctly

- The sampler should be operated flow proportionally. The water content changes during the batch and unless each grab sample represents a unit of volume (for example one grab every 50m³) the whole batch sample will be biased and not representative. The accuracy of the flow meter required to pace a sampling system is 10%.



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Which type of sample receivers should you use?

Once a representative sample has been extracted from the pipeline, it must remain representative in the sample receiver and when analysed in the laboratory. The standards recommend the use of either fixed or variable volume depending on the properties of the fluids being sampled. Liquids with a high RVP would normally be stored in variable volume receivers minimising the risk of losing light-ends. For practical purposes portable receivers are preferred as the batch sample can be transferred to the laboratory allowing the sub-samples for analysis to be drawn under controlled conditions rather than in the field.



Sample receivers should be designed so that they are easy to clean and have no voids or water traps. The internal finish should inhibit water retention. Receivers should incorporate a facility to mix the contents of the receiver prior to the extraction of a sub-sample for analysis, as it is not possible to sufficiently agitate samples manually. This is normally performed by connection to an external mixer loop that homogenises the sample with minimal heating, which can cause loss of light ends. The analysis sample can be drawn using a septum or valve from the mixing loop.

Receivers should be suitable to be used on a weighing system or include a method of measuring the performance of the sampling system during the batch.

[More about receivers](#)

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What type of control system is recommended by the standards?

The primary function of the control system is to operate the sampling device in a time or flow proportional manner. (more information) This normally requires that the controller have a real-time operating system. The system should allow the operator to enter the batch size and should determine the necessary sampling rate to achieve the correct volume of sample.

The system should monitor the number of grabs and the volume of sample collected to verify at any time during the batch that the sampler is working correctly (normally using a weighing system). At the end of a batch the system should produce a report validating system performance and performance factors during the batch.

Facilities should be provide for monitoring the following:

- Main pipeline flow rate.
- That the sample volume collected is proportional to the totalised flow in the main pipeline (i.e. performance factor).
- The number of grabs.

The system should provide alarms in the event of failure allowing a back-up manual sample to be taken. Alarms should be provided for the following:

- High level in sample receiver.
- Low flow in main pipeline.
- Low flow in sample loop (in bypass loop systems).
- Loss of power.
- Sample probe failure.

The controller may include facilities for batch identification and producing reports at the end of batches and can have a DCS interface. If the system is located at a facility with a large line-fill the control system should allow a separate line-fill sample to be taken at a high sample rate into a different sample receiver. More about line-fill.



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How can you guarantee that a sampling system performs as specified?

The performance of a sampling system is normally monitored by measuring the accumulated sample volume and comparing it with the expected sample volume. The variance allowed across the whole batch is +/-10%.

Performance monitoring is normally carried out both at the end of the batch and during the batch by weighing the mass of accumulated sample. This can be compared with the expected mass of sample calculated in the control system using density. In the event of errors, the control system can trigger an alarm to allow the extraction of a manual back-up sample.

Upon completion of the batch, the control system should produce a report demonstrating that the system has performed within acceptable limits throughout the batch transfer and both parties in the transfer can endorse this document.

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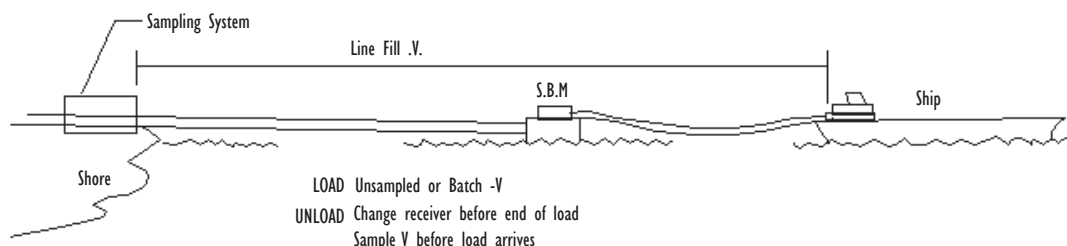
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How can you sample the line-fill between the sampler and custody transfer point?



The volume left in a pipeline after a batch between the sampling system and the point of custody transfer (maybe a metering system or ship's manifold) can be substantial. In the event that this is large it may be necessary to sample the line-fill to measure the quality, as in the case of ship unloading operations this is often when the worst part of the cargo is discharged.

The normal procedure for sampling line-fill is outlined below:

- The sampler must be capable of taking samples at a high grab rate to ensure that enough sample is taken to be representative of the line-fill volume (normally 10 litres).
- The sampling system must have two or more sample receivers with a capability to automatically change between receivers.
- The line-fill volume is a known volume that is programmed into the controller. When the batch starts the controller rapidly takes samples into a sample receiver. When the line-fill volume has passed the sampler (this is known because it operates flow proportionally) the controller automatically selects a different receiver and starts taking a normal batch sample into that receiver.
- The receiver containing the line-fill sample can now be taken to the laboratory for analysis and the result pro-rated with the batch sample by the batch/line-fill volume.
- A new receiver is placed in the system ready to sample the line-fill when the next batch starts.
- The batch sample is analysed in the normal way.

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Using this method it is possible to obtain a representative sample of both the batch and line-fill and avoid the poor mixing and flow profiles problems associated with manifold samplers.



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How can you guarantee, prove and certify that a sampling system complies with the standards?

A sampling system needs proving once installed. Only then can you certify that a system performs as specified. The only way to prove beyond doubt that an installed sampling system complies with the standards is to prove the system by water injection. The procedure is defined in the standards.

The vendor or purchaser can prove the system, and this process can be witnessed and certified by one of the inspection/certification companies.

When designing or specifying a sampling system a key point of consideration would be to ensure that the system performance will be guaranteed if the system is proved by water injection in accordance with the standards.

Once a system has been proved by water injection it is only necessary to re-prove the system if either the fluid properties or the process conditions change provided the system is regularly serviced and the performance monitoring system is functioning correctly.

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