



# Crude Oil Sampling Customer Satisfaction

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## Summary

Loss control specialists wish to be sure of both the quantity and quality of the oil received on board ship and at point of discharge (receipt port). Confidence in the measurement accuracy reduces risk and improves the demand price of the batch. The quality measurement accuracy is a function of all the steps involved in sampling, failure to maintain the representivity of the sample at any point i.e. from pipeline to analysis invalidates the sample by introducing random errors.

Jiskoot is unique in that we can provide the design and all the components/sub-systems required to maintain sample representivity through to analysis. Jiskoot also provides site installation, training and proving.

Installation of the best equipment available will not ensure accuracy unless great care is taken over the complete system design. There is a consistent and growing body of evidence of inadequate compromise that leads to avoidable errors. System design can also optimise the equipment selection to suit the operational characteristics and physical placement of the equipment.

This paper will outline some of the problems and how they can be addressed, for both shipment and receipt terminals.

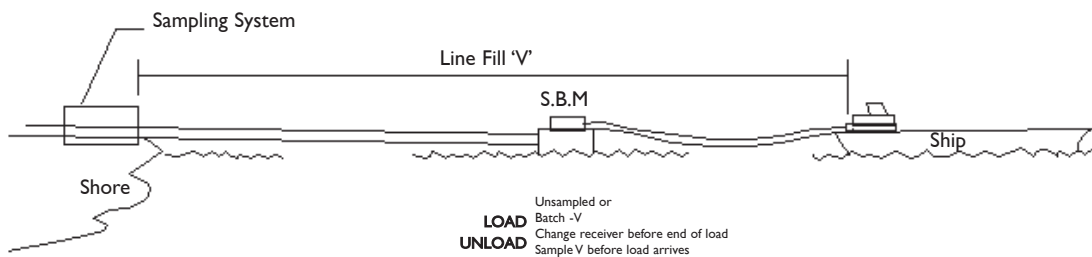
## Introduction

The API 8.2 was originally published in 1983, the IP 6.2 in 1986 and the ISO 3171 in 1988; in reality the ISO work preceded the IP standard though it was published later.

Until this year, in practice, the IP 6.2 was the most recent standard and included results from the many trials that went on in the early and mid '80's. Recently considerable testing has been performed both in the US, EC and elsewhere on samplers, leading to revisions to the standards, which means that systems formerly complying to the revised API may no longer meet the ISO or IP standards. There are several areas of debate that are of interest and these stem from fundamental system design issues.

Many of us have outlined that there are four steps required to achieve a representative sample, there are in fact six:

1. *Installation position relative to the custody transfer position*
2. *Homogeneity of Pipeline Contents*
3. *Extraction of a flow proportional and representative sample*
4. *Sample handling and mixing*
5. *Laboratory analysis*
6. *Prove all of the above and show ongoing performance*



### Location of the sampling system relative to the custody transfer

The location of the sampling system relative to the custody transfer position can be critical to the accuracy of the sampling operation. The volume of the pipeline between the custody transfer position and the sample position is often called the Line Fill Volume (“Linefill”). This can be relevant if the Linefill is substantial relative to the batch volume and also depending on whether the properties of the Linefill are expected to differ from the bulk batch properties. In a discharge operation, substantial Linefill (such as between an SBM and a land mounted sampling system) can be used to dump the worst parts of a batch in the hope that they may be allocated to the next ship discharging. The end of any cargo is likely to contain more sediment, heavy fractions and water than the bulk of the discharge.

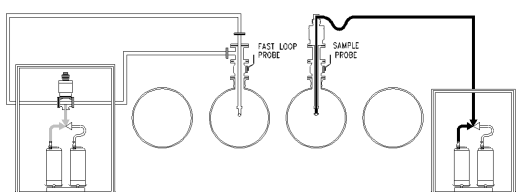
### Linefill Must be Handled Correctly

One of the major problems in this situation is that the analysis results are normally required before the vessel sails, and cannot wait for another ship to displace the line so the sampler can sample what has passed the custody transfer point.

Two approaches may be taken to resolve the line fill issue:

1. Ignore the problem.
2. Sample the Linefill into a separate receiver in an attempt to generate enough sample to analyse; this normally requires that the sampling system operate at a very high rate over a relatively short duration. The minimum volume required for analysis will constrain this possibility.

In a loading situation, the volume between the sampling system and the custody transfer point is



Dead Volumes of Fast Loop Systems are Less!

frequently sampled at a rate proportional to that which is determined by the next batch size expected to load. This becomes a problem if the planned next batch volume is changed for any reason.

Of similar importance to the Linefill issue is the “Dead Volume” within the actual sampling system, this is the volume of sample between the point at which the sample is isolated from the pipeline and the sample receiver.

This becomes a design issue in some systems for operational reasons. Where, for example, an in-line sampler is installed in a location inconvenient for operators to retrieve the samples, or where the sample device is remote from the receivers. In either case, consideration should be given to the Dead Volume (of grabs that have been extracted) that does not end up in the receiver. Some designers will sample at a high rate at the end of the batch to displace the Dead Volume to the receiver; and likewise at the start of the next batch displace the Dead Volume to slops before starting to collect the real sample. Dead Volume problems are made worse by the fact that a line that does not consistently slope down towards the receiver can form a U-trap which will retain water.

### Pipeline Homogeneity

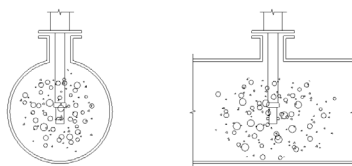
This is a greatly misunderstood and misapplied area of sampling, there tend to be great problems in this area, both when loading and discharging cargo. Loading situations can be better controlled because the flowrate’s rangeability can be less and the water content of the oil can be reduced by correct shore procedures such as water drawing the tanks. In discharge operations the flowrate is determined only by the ship (and any backpressure caused by shorelines) and this is subject to other operational problems such as tank line ups, crude oil washing and stripping. The flow range for loading rarely tends to exceed 5:1 whereas for discharge is rarely better than 30:1! It is our experience that some type of mixing is required for almost all installations, both load and discharge, be it by choosing a sampling position after a series of

elbows, bends, valves or using a mixer.

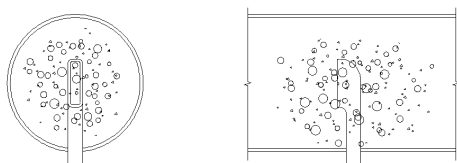
When considering the type or adequacy of pipeline mixing the designer should study both the REAL rangeability and the sample extractor design. It is a major oversight to state that the average flowrate is the design point for the system because the minimum flowrate only happens for a short time or for a small percentage of the batch. These points are precisely where the worst problems occur.

Other than the issue of mechanical strength of the sample extractor, it is important to remember that the required dispersion quality is a function of the extraction device, i.e. the size of the opening.

In principle the dispersion quality of the oil is a function of the turbulence induced by piping elements or mixing device. If the extraction mechanism was capable of taking a slice of the whole cross section, then no mixing would be required! Following this argument logically, the



*Small sample probe entries can only cope with small water droplets*



*Large sample probe entries can cope with large water globules*

larger the size of the opening to the extractor, the less sensitive it will be to dispersion quality.

In considering mixing devices the designer should have several points on his list:

- What is the dispersion quality required by the extraction device?
- Where should the extractor be placed in regard to the mixing elements?
- What is the pressure drop caused by the mixing device, or the running costs?
- What utilities are required?
- How maintainable is the mixer?
- What is the real rangeability of the device?

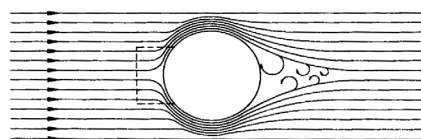
One point often overlooked in the installation of extraction devices is a misinterpretation of the standards; the take-off point and the orientation of the extractor. If the pipeline is adequately mixed for the extraction device, the cross-sectional position

of the take-off is irrelevant provided wall effects are avoided. The orientation of the take-off i.e. vertical or horizontal is irrelevant to a fast-loop sampling system as there is no potential for gravitational separation to occur within the take-off probe if correctly designed, though it is critical to in-line extractors.

### **Extraction of a flow proportional and representative sample**

This involves several major considerations, the most obvious is the issue of flow proportionality and most designers have little problem achieving this within their control systems.

One overlooked issue within fiscal metering systems is particularly evident when sampling at high rates; all flow computers work on a time based cycle and unless the sample grab is interrupt-driven the intergrab time/volume can be found to vary substantially. i.e. if the computer cycle time is 1 second, frequently the system will only be able to



*Bluff Body Effects*

initiate samples in increments of one second! 30 grabs/min is one every 2 seconds and 31 grabs/min is 30 at 2 seconds plus an extra grab on the last cycle!

Regarding the extraction of a representative sample, a body of work is now in progress with regards to the ability of sampling higher water concentrations, between 10 and 100 % (the NEL HI-WATER project). All vendors would acknowledge that extracting a sample from a homogeneous fluid is easy, however, extracting one from a poorly distributed and dispersed medium such as crude can be problematical. It is best to ensure that the sampling extractor draws its sample from a stream that is as well dispersed as is possible, this will reduce the sensitivity of the sample to any issues of gravitational separation (i.e. streamline patterns) as well as increasing the overall probability that a good sample may be extracted. In short, what this means, is that the sample extraction mechanism should be suited to the medium which it is sampling, fast “capture” action, less disturbance to streamlines (by the use of a pitot style entry) and large opening to the extraction device will ensure better representivity in pipelines with poorer mixture quality.

### Sample Handling and Mixing

Frequently little consideration is given to the sample handling and mixing process by the system designer. The handling, mixing and analysis requirements should be some of the first points to be considered!

Many installations are completed by project departments who then hand them over to operations only to find that a whole new section of engineering and logistics are undertaken because all the steps were not adequately considered. It would be most unusual for any group to undertake more operational responsibility without comprehending the need, and if possible ensuring that the operation fitted with their practices.

In designing a sampling system the type of receivers are a key issue and how they are handled, mixed, subsampled and samples stored is critical. The type of receivers used depends greatly on the type of operation. Facilities that transport a variety of crudes will have different demands for interbatch contamination than those shipping out a single and consistent crude type. When sampling for example for heavy metals, the system and receivers must be extremely well cleaned, whereas if the system is for loading, say Brent crude, every batch from the same tank, then some cross contamination is unlikely to cause a significant bias. Likewise the considerations of RVP and density will vary by operation.

One item on which all designers should be clear is that of the quality of the operations staff used for each step of the process. In general the number of critical handling steps undertaken in the field should be minimised because these steps are largely uncontrolled and unauditible. This is why in general we recommend portable receivers; uncoupling a portable receiver and removing it to a laboratory takes a mixing and subsampling procedure and places it in an environment with a much higher degree of control (and comfort!).

Another issue raised frequently is loss of light ends, particularly with higher vapour pressure oils. The loss of light ends can of course affect density measurement but this can be easily avoided by ensuring that the receiver relief pressure is set above the RVP of the fluid at the maximum temperature that the receiver is likely to experience. It should also be pre-purged with a light inert gas blanket.

Where the product is a light hydrocarbon or perhaps where the oil is spiked with gas, such as happens in the North Sea then high pressure receivers must be used. The constant pressure

cylinders used for light hydrocarbon are generally not suited to crude/water duty as sufficient energy cannot be imparted to the fluid to mix it for sub sampling. Cylinders with "balls" or manually agitated baffles have consistently been found inadequate for dispersing water into crude pre-analysis. Jiskoot and several vendors can provide proven receivers suitable for this duty.

### Laboratory analysis

The laboratory analysis step is of course the key to the whole system and without adequate analysis methods any efforts to provide a representative sample, have no value. In general ASTM 4007 (Centrifuge) has been dropped in favour of Coulometric Karl Fisher which has been found substantially better; however care should be taken over some sensitive issues within this method such as reagent matching to cell and titration procedures.

### Prove all of the above!

The real test for a sampling system is to prove the system in its entirety i.e. as a complete system, this can only be done by water injection and there are many who will provide this service. Third parties should witness this operation and all the inspection companies should be invited to attend. There is no substitute for proving a sampling system, it should be repeatable and repeated if primary characteristics of the system are changed e.g. crude types, operational rates, fundamental system components etc.

The API also now allows a component testing approach which is accredited with equal validity to a system proving. It is our position that this does not provide as good an overall test for several reasons:

- Component testing requires that the system be divided into several key areas such as pipeline profile, sample receivers etc.
- Each one of these tests must have an associated laboratory analysis which of course increases the uncertainty of the overall analysis.
- Further to this point a pipeline profile can CONFIRM a problem but it cannot verify the suitability of the extractor design. Due to practical considerations a profile probe may only have openings designed, and sized a certain way (normally 6mm). For a profile probe to substitute for a sample extractor take-off, the profile probe would require openings of the same size, design and operational characteristics as the sample

extractor to allow it to respond in the same way i.e. a sampling system with a 33mm take-off would require a profile rake with 33mm openings!

A proving exercise therefore provides a result with better overall credibility. However we always recommend that the sample handling, mixing and

Water%	ISO	API by Tank	API by Meter
0.5	0.050	0.130	0.090
1.0	0.050	0.150	0.110
1.5	0.075	0.160	0.120
2.0	0.100	0.170	0.130
3.0	0.150	0.190	0.150
5.0	0.250	0.230	0.190

analysis be tested as a separate issue before proving because it is frequently an area of failure.

Proving sampling systems probably provides the worst contention between the API's final 8.2 (released November 1994) and the current IP and ISO standards. The API position is clear, the API determined acceptability criteria for the 1983 standard before widespread knowledge of the performance of systems or analysis methods were well established. The acceptability criteria of 0.05% for a fiscal system is clearly a closer tolerance than the accuracy of the laboratory analysis as stated within the standards and herein lies a major problem.

There are two databases of information, one in the US, the other in the EC and there is substantial variance in results. Results from repeated tests from a variety of typical European systems have shown consistent repeatability within the original API/IP and ISO criteria. These results are unmatched within the US database and the question must be why?

There are several reasons that explain the variances, the first must relate to the analysis methods. The body of results from the UK relate to specific crude types, frequently handled by an extremely consistent and experienced staff; based at export terminals. This alone is bound to reduce the repeatability/reproducibility errors. By contrast the US database tends to be from a large variety of sites with different crude types; all import configurations.

The second consideration is over the types of sampling systems proven. In general those in the US database are generally in-line systems whereas those in the EC are fast-loop based. No consideration should be given to receiver types as

in general these are the same. From the body of the paper, a fast-loop system with a large entry is far less sensitive to pipeline water dispersion and distribution.

One aspect on which there is no dispute is the requirement for repeatability, all parties agree that the sampling systems should provide repeatable results i.e. prove within repeatable tolerances.

Once the system is designed and proven to be acceptable, it is necessary to be able to show the shipper that the system operated correctly during the transfer.

There was a long tradition of equipment failure in equipment designed in the 70's and early 80's which has largely been overcome by current technology, however to prevent dispute some form of performance checking should be provided, this should generate CONTINUOUS proof of performance.

The fact that the total demand volume of sample from a system (typically 15 litres or 5 USG) is matched by the actual volume in the receiver at the end of the transfer is no proof of correct sampling. It is necessary that the performance of all the component parts are within acceptable linearity for the complete duration of the operation and can be so proven.

This means the flow measurement, sample control system and the sample volume per grab. Acceptable performance is taken to mean that the volumes achieved and the flow measured are within +/- 10% of demand i.e. performance factors are in the range of 0.9 to 1.1. It would however be a mistake not to point out that if the system provides a 0.9 figure on one batch, a 1.1 on the next and a 0.9 on the next that this is good performance - it shows inconsistency.

Linearity is more important than absolute accuracy. Performance factors for the sampling system, both in regards to the flowmeter performance and to the sample extractor performance, and in combination, should be made for both the complete batch and for short intervals within the batch. Ideally hard copy printout from the system showing actual recorded volumes should be made and signed off by interested parties.

### Choosing a Philosophy - Hierarchy of Sampling

When considering the primary choices for sampling systems, there is evidence to the old idiom that "you get what you pay for" performance. The standards are extremely clear in the fundamental

statement that tank sampling of non-homogenous media is unacceptable, there is a further hierarchy that can be noted:

*Ships Tank*

The worst place to attain a sample is in shipstanks, this is because the shape of the tank internally is poorly known and the dynamics of sampling properly are unattainable .

*Shore Tank*

This is better than the ships tank because the shape is better known, however tests have proven that sampling a shore tank properly is also unattainable.

*Samplers*

Considering the relative virtues of shipboard and other samplers, the designer is faced with the

Recovery Comparison between Shipboard and In-Line Samplers	
Cargo's	40
Crude Types	AH, AL, AM, XL
Total Cargo Volume	39,569,097 BBLs
Shipboard Results	112,327 BBLs Water
In Line Sampling System	125,530 BBLs Water
Water Content Variance	0.033%

requirement to do the best possible job in providing an accurate sample. Given the state of many land based systems installed in the 1970's and early 80's a shipboard sampler can at times represent an attractive improvement.

It will never be possible for shipboard sampling technology to achieve the accuracy's attainable by their land based counterparts because of the constraints imposed by the available equipment, supplies and sampling system location.

Results of direct comparison of a proven land based sampling system against shipboard samplers show a significant undersampling of water by the shipboard samplers used during the same unloading which amounted to an average loss of 0.033% to the party using the shipboards!

*Shipboard Samplers in the Manifold*

Location of a sampler at the manifold provides no assurance of homogeneity of the cross section, it also provides an extremely poor profile for the measurement of flow with the required accuracy. All pneumatic Shipboard Samplers are totally inadequate to the duty because of the rangeability of the pneumatic control systems themselves and the susceptibility of the control systems to the vagaries of what is, at best, a wet ships air supply. Electronic Shipboards do not suffer as much from the flow measurement problems but the pipeline homogeneity remains a problem which cannot be

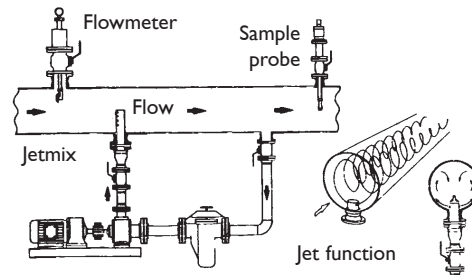
overcome. All shipboard samplers or any manifold or loading arm located samplers will be subject to the question of whether a collection receiver should be used for each sampler and if one receiver is to collect samples from 2 - 4 arms then how to assure the representivity given that the flowmeter performance and volume per grab of the samplers may vary per line.

*Land Based Sampling systems*

Location of the sampling system in a shore based location, on-shore or at the jetty head provides the ability to design correctly and operate the samplers, taking the sample from a single properly mixed pipeline provides the optimum solution.

**What does Jiskoot offer to optimise performance?**

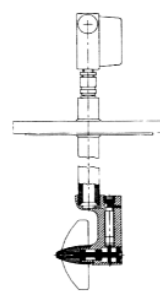
Jiskoot as a turn-key systems manufacturer designs and supplies fully engineered systems. We can



*Jet Mixing - High Rangeability*

supply sampling solutions from Shipboard through to full Fiscal and proven solutions, below are described some of our solutions.

**Pipeline Homogeneity**



*Inturbine*

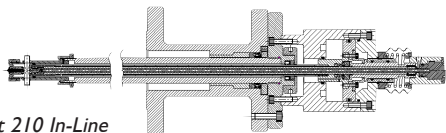
The Jiskoot Jet-Mix® is designed for pipelines with a high degree of flow rangeability. Systems with a rangeability of below 4:1 can be served with static mixers but the range capability of a Jet-Mix® provides infinite turn down by design, the lower the flowrate the more mixing is introduced. This is a system that can be retrofitted to existing pipelines without shutdown. The dispersion quality of the Jet-Mix® is sized to suit the extractor design. This is the most widely used mixing device for large diameter fiscal applications on a world-wide basis.

Batches	Metered Volume (BBLs)	Custody Volume (BBLs)	Flowmeter Performance Factor
231	41,145,560	41,787,636	0.985

## Extraction of a Flow Proportional and Representative Sample

### Flow measurement

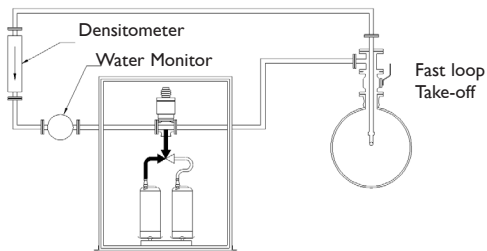
Jiskoot performed a large number of tests on all varieties of flowmeters in the mid '80's including, turbines, strap on and insertion ultrasonic flowmeters. This led Jiskoot to design a large rotor insertion turbine "Inturbine™". The Inturbine is the simplest, most reliable and easily maintainable



Jiskoot 210 In-Line Sampler

meter available. The size of the rotor, 140mm, and the synergy of the design to that of an outboard engine used for motor boats is deliberate.

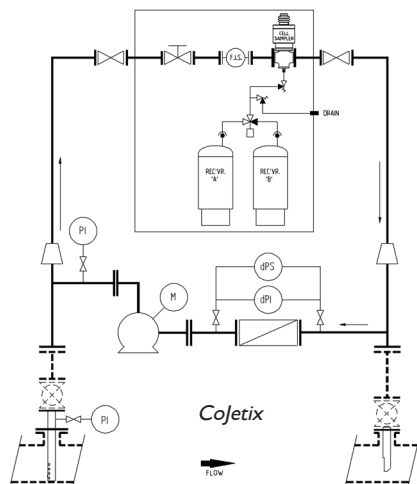
Long term performance results in Egypt yielded an average performance factor of 0.98 where they replaced insertion ultrasonic meters.



This represents ALL the figures, no failures or short volumes were experienced during the trial period.

### Representative Samplers

The bulk of import "receipt terminal" sampling systems installed on a world-wide basis are based on the Jiskoot 210 in-line sample probe. Jiskoot manufactures a full range of sampler types from



product samplers through Shipboard to In-line and Fast Loop.

Recently European sampling technology has moved towards so called "Fast Loop" systems for several reasons, not least improved installations, accuracy and maintainability. They also allow for the integration of other small bore on line devices within the same loop such as densitometers and on-line water monitors.

The accuracy gains are principally from the much larger loop offtake size which reduces the system sensitivity to water in oil dispersion and from reduced dead volume between the sample extractor and the receiver. The take-off can be located convenient to the installation without regard to the location of the main sample extractor and sample receiver housing. The use of a pump in the loop ensures that the water/oil mix which passes through the cell sampler is well dispersed.

The question of Isokineticism is often quoted, by definition this should mean that the velocity of the fluid within the opening to the fast loop of a sampling system matches that of the bulk average velocity in the pipeline. In practice the API originally quoted an acceptable range of 50% - 200% and the IP after testing larger takeoffs a range of 10% - 300%. It is impractical to match the loop velocity to the pipeline velocity at all rates, it has become obvious that with careful design fully Isokinetic flow is not relevant to Fast Loop systems with large bypass pipesize and a correctly designed take-off. There is also confusion as to the velocity requirements within the pipe loop itself, as opposed to the entry. The requirement through the loop must for practical reasons assure minimal pressure drops but maintain the oil without allowing the water to separate; there is an engineering balance to be achieved here.

A further benefit to the fast loop approach is that the part which is likely to require the most service, becomes much easier and safer to service.

Replacement of the key seals in a fast loop system does not require isolation and removal of a part inserted into the main pipeline, it is achieved by shutting the fast loop valves. Typical service time is reduced by 80%.

<b>Size</b>	250 x 150mm	Ø33.5mm	22 x 8mm
<b>Area</b>	37,500mm <sup>2</sup>	881mm <sup>2</sup>	176mm <sup>2</sup>



FAST LOOP



INLINE PROBE

There has been a tendency by designers to try to exclude the use of filters from fast loops. Filters and strainers are frequently considered as the same thing. Strainers installed in fast loops for the purpose of removing large particulates are quite acceptable. They will neither bias the sample against sediment or water as the loop flowrate flushes the filter volume some 1200 times per minute!

Because Jiskoot has developed both Jet-Mix® and Fast Loop “Cell” samplers, it was natural to combine the two elements into what is known as a Co-Jet-Mix® system. The Co-Jet-Mix® allows optimal sizing of the system. The inlet of the Jet-Mix® loop is supplied with a large scoop takeoff, this reduces the amount of energy dispersion required and the sensitivity of the system to pipeline profile.

The system fast loop is taken across the Jet-Mix® pump where the oil and water are well dispersed. The argument is sometimes raised that the system is taking a sample of oil that has already been sampled because the suction is downstream of the jet. This is correct but the design works in the same form as a capacitor which is beneficial. The maximum error that this could cause to the sampling system under the worse possible circumstances would be the volume of the Jet-Mix® loop divided by the volume of the BATCH!

### Sample handling and mixing

Jiskoot has a range of sample receivers suited to both low and high vapour pressure crudes, the simplest is a “Cubitainer”, developed in conjunction with the Trans Alpine pipeline (TAL), which is a disposable receiver designed not to vent, through

to our PR-53 all stainless receiver which is frequently copied, to our PIM type receiver which is a dual piston sample receiver for high vapour pressure crudes.

Laboratory mixers are available to mix each of our receiver styles and these can vary from fairly simple pumped loops through to an integrated laboratory mixing system with PC reporting, running under MS Windows. The degree of sophistication varies according to the needs of the user, if a large number of samples are handled then an integrated system is useful. The Lab PC system weighs the sample receivers, suggests mixing times, logs the mixing duty and integrates data from Karl Fisher, Densitometer, temperature and pressure into a report that is uploaded to a local area network and integrated into a SCADA supervisory reporting system.

### Sampler Control Systems

Jiskoot supplies a wide range of sampler controllers from simple divider counters through to sophisticated micro-processor control systems providing full reporting, logging and interfacing to a SCADA system such as those supplied to terminals at MOT and Arab Petroleum Pipelines (SUMED). Jiskoot also supplies the only certified zone 0 shipboard sampling system, with full data logging for those that require this duty.

Full Scada systems that provide a graphical user interface to multiple sampling systems as in the case of Sumed also provide for a link to their plantwide computer system and integrate the lab results directly into bills of lading.



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