JISKOOT™ QUALITY SYSTEMS

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IP Petroleum measurement

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Introduction

The interest in sampling accurately has led to a plethora of studies and the generation of the standards we now use. Much of the original content was based upon what was then known, bolstered with, one hopes, educated guesses. The testing of systems designed within practical/cost limitations has allowed us to accept or reject certain conceptions and better learn the envelope in which we should operate. This paper will outline some of the problems to be addressed and some of the discoveries made.

Status of the standards

The API 8.2 was 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. The IP 6.2 is the most up-to-date published standard and included most of the results from the many trials that went on in the early and mid 80's.

The API commenced redrafting their chapter 8.2 several years ago and this has culminated in a revised 8.2 which is now undergoing ASTM balloting as a joint ASTM/API standard. Work is being performed on fuel oil procedures (ISO 8217) and this committee has requested that consideration be given to 'fit for purpose' equipment to be included in the ISO 3171 which is also now under review. It is therefore appropriate to consider the scope of the standards.

Fluids to which the standards are applicable

The standards listed are applicable to crude oil, both stabilised and unstabilised, and refined products. They are written with the problems of sampling stabilised crude in mind, but are now seeing wider application to other areas including products and fuel oils. Many of the clauses that assume the unhomogeneity intrinsic to crude water mixtures become inapplicable to sampling homogenous products for quality.

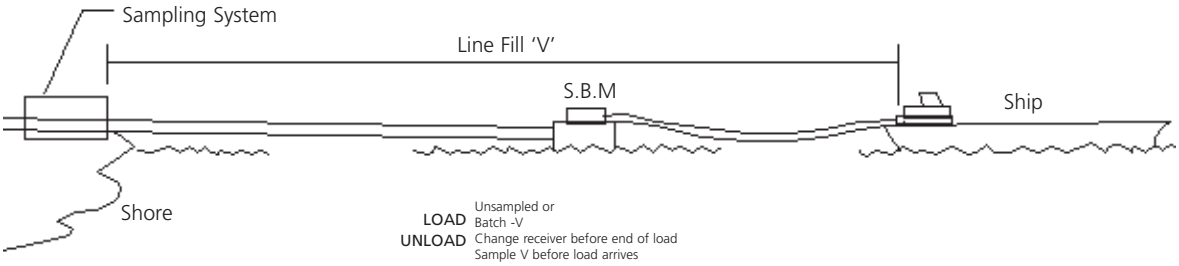
Proportionality

Sample representivity depends on several factors other than the obvious, and fully accepted, requirement for a well mixed cross section. Since the product quality can change over time (in a ship discharge, most of the highest water concentrations are likely to be discharged at the lowest flowrates and we are often met with the question, why don't you take more samples at these flowrates?) the sample must be proportional volume for volume to the whole batch. Having established the proportionality requirement, this depends on the performance of both the flowmeter and the sample extractor.

Flow measurement

The standards in this area have always been somewhat controversial, where the process is relatively 'steady state' i.e. typically pipeline transfer, then the flowrate will probably vary little and no measurement is required. However in a ship discharge operation the turndown is substantial, often 30:1, and flow measurement is crucial.

The question is "how should a flowmeter be judged?" The ISO standard states +/- 10% of point, the API an accuracy of +/- 10% over the flow range, this is liberally interpreted! Practically, it is almost impossible to find a flowmeter to provide +/- 10% of point over 30:1 and in general it is significantly better to achieve some kind of a sample at low flowrates than none at all. The bias that such an approach makes is minimal, provided that the sampler pacing is based on the flowrate and is not taken on a straight 'time' basis. This is particularly pertinent to all-pneumatic sampling systems (shipboard) that can at best achieve a turndown of about 6:1.



Extractor repeatability

The sample extraction mechanism should be insensitive to changes in specific gravity, viscosity, pressure (both line pressure and vapour pressure) and sample frequency. Extractors have been known to show a direct correlation to all of these and even to the collection receiver pressure! Repeatability under all operating conditions should be better than +/- 5%.

Pipeline mixing

Pipeline mixing is only relevant to unhomogenous fluids, the position of the takeoff in a well-mixed line or in a homogenous fluid need only assure that the extractor is not subject to wall effects. Many designers insist that to meet accordance with the ISO 3171, the sample takeoff must be 0.1D below the true centreline in a horizontal pipe. This is untrue - installing the takeoff 0.1D below the centreline does not improve the sample accuracy unless the pipeline is poorly mixed, and if the pipeline is poorly mixed, it is unsuited to fiscal sampling!

Custody transfer position

Not too much attention is paid to this issue, the sampling position relative to the custody transfer position affects what is called the 'line-fill' volume. It is not just simply a matter of sampling the line-fill to a separate container as the interface between batches is not distinct and the volume of sample taken of line-fill can be both untimely (days after the ship has left) and ill suited to analysis (insufficient volume).

Where for example a ship discharges through an SBM, the line from the SBM to shore where the sampling system is likely to be located will end up full of unsampled oil. The next vessel has to displace this volume before its own cargo may be sampled.

Unfortunately the only samplers that can be placed at the exact custody transfer position are so called 'shipboard' or 'manifold' samplers and by placing them at the ship's manifold they are subject to dubious pipeline mixture quality and a poor flow measurement profile. The result of which often ends in under measurement of water.

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%

Isokinetic sampling

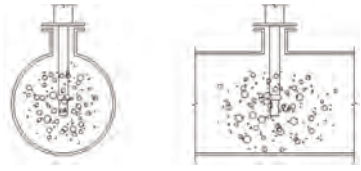
So called 'Isokinetic Sampling' - the matching of the linear velocity in the sample extractor opening with the main pipe is generally not attained. Where in-line probes are used, there must be some form of internal resistance that will prevent an exact match although this is improved by samplers having pitot openings.

Fast loops have changed substantially since the original standards were written, the original loops were 1/4" or 1/2" and ran between 0.15 and 0.5 m/s (hardly 'fast'). There are now a variety of statements concerning loop flows.

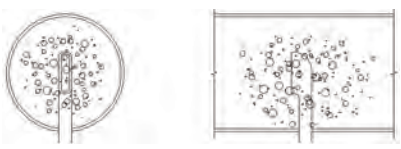
The ISO suggests that the velocity to the sample extractor should match the line velocity, in the API the match is between 50-200%, the IP allows the same as the API but with a suggestion that in large bore 'fast' loops 10-300% is acceptable.

Isokinetic sampling appears to have conceptual validity but practical reality has shown that the larger the opening, the less relevant the issue.

The typical opening size for the modern generation of sample loops is between 25-50mm. The only method by which Isokinetic flow could be achieved by a loop based system would be to control the loop flowrate adding considerably to the system cost. It has been proven not to be required. The key issue is dispersion quality - good mixing implies good dispersion, good dispersion implies finer droplets, and this results in reduced streamline separation.



Small sample probe entries can only cope with small water droplets

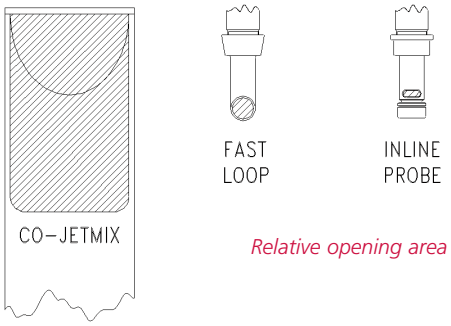


Large sample probe entries can cope with large water globules

Sample loops

The constraint in providing a good sample loop stated in the ISO is to match the pipeline velocity in the loop (in the API to maintain 8ft/s). These requirements would appear to be soundly based but they require qualification.

Size	250 x 150mm	Ø33.5mm	22 x 8mm
Area	37,500mm²	881mm²	176mm²



Relative opening area

The important issue is to maintain good dispersion of the stream up to the point of sample extraction. In 1" and 2" pipes Reynolds and Weber numbers are higher than a larger pipe at the same velocity, so an arbitrary designation of 8ft/sec loop flow based upon main-line flow is invalid.

In designing a loop, the velocity up to the point of sample extraction should be high enough to ensure that water cannot separate, beyond the sample extractor there should be no constraints. A well sized fast sampling loop should also minimise pressure losses. Dispersion quality at the extractor is improved by the pump.

Most of the standards claim that filters should not be placed in the sample loop as this will cause the coalescence of water and removal of sediment. Modern fast loop systems require only a strainer to protect the loop pump. The strainer removes sediment in excess of 3mm, cargoes with large volumes of this sediment size could not be pumped and the volume of the strainer is low compared to the loop flowrate, so no consideration need be given to system bias caused by such a device.

Performance factors

Performance factors are used as an expression concerning the real or 'actual' performance of elements and the whole of a sampling system compared to theoretical or 'calculated' requirements. The standards uniformly allow a performance factor range of 0.9 - 1.1 for the calculated vs. actual sample volume taken and for flow measurement. This concept is batch-based and insufficient to determine the representivity of the sample; as no consideration of linearity is provided, the linearity or proportionality of the system is far more important than an absolute performance factor. A system that takes too little sample, grab by grab at low pressures could easily achieve acceptable performance factors for the whole batch. It is far better to use an interval based factor, i.e. the performance over say 1% increments of the batch.

A further failing of the batch performance calculation is that it does not differentiate repeatability from non-linearity. If the sampler should have a theoretical 1.5ml per grab, but in fact it gives 1.3ml, the batch performance factor would be 0.87, i.e. a fail. The operator should accept the sample because if the incremental performance factor was 0.87 throughout, the proportionality would have been maintained and statistically the sample would have been representative.

Laboratory handling and analysis

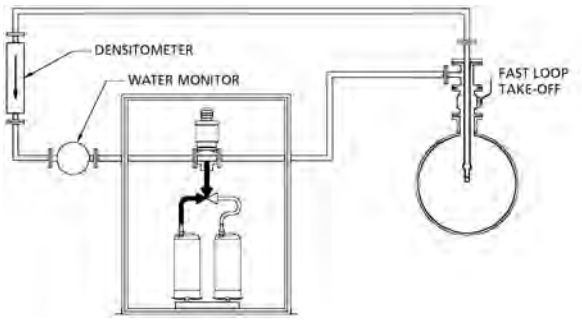
One of the biggest problems faced by system designers concerns sample receivers, handling, mixing and analysis. Frequently careful system design fails due to poor consideration in this area. Inadequate attention is paid to sample conditioning (retention of light ends), re-mixing and withdrawal of the aliquot samples required for analysis. This is generally because the receiver handling is within a totally different operational domain to the rest of the equipment. Scant attention is paid to the relationship between crude type, sample volume and mixing times.

Worse than this, in the fuel oil business, any attention to sample division in accord with good practice is totally ignored. Mixing a single bulk sample to provide three identical samples consists of shaking the collection container! This photograph illustrates a sampling system in use today for fuel oil!

Fast loop vs in-line systems

The EC approach to sampling has diverged substantially from the ideas imported with the oil business in the 1970s, this has been driven by offshore manpower costs, packaging (installation problems) and the general integration of density and sampling.

Large bore fast loop style sampling systems are now widely used and appear to be less installation and dispersion sensitive, manifested in the results of proving systems.



System validation

All sampling equipment requires that it can be validated. One approach is component testing whereby the individual elements that affect the quality of the sampling operation are tested:

This comprises profiling the main pipeline and proving the sample handling and mixing procedures.

Component testing can confirm a problem, but not validate a complete installation.

Profiling

Profiling is a technique to assess the suitability of a specific location for sampling. What a profile can tell you is that the pipeline cross section is inadequately mixed for your profile probe, from this you might interpret that it is not good for sampling. This may not be valid depending on the sampling system used.

Proving

The best approach is an overall system proving, where a known volume of water is injected into pipe upstream of the sampling system and retrieved within the laboratory analysis of the sample collected.

The API originally stipulated that the system should retrieve the water content within 0.05% v/v and many proving tests have to be made on this basis, backed up by analysis of proving tests, the API has now widened the tolerances.

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

After collating the database of available proving results (from in-line probe based systems) the API determined that the original 'A' classification is unattainable on a repeatable basis. However the database of proving from fast loop based systems appears to disprove this theory conclusively.

Future methods for water in oil analysis

Research continues into water in oil measurement, water production rates are increasing and the industry needs to know whether conventional sampling techniques are valid as the emphasis moves towards oil in water! On-line technology has been pushed by the industry desire for multi-phase metering and to further reduce manning levels.

On-line analysis of water content has been around for many years, from the capacitance style probes through to resistive and now microwave techniques. Unfortunately there are no large, full bore, non-intrusive devices yet available. If a bypass must be used, then a slipstream or fast loop design similar to those used for samplers will be required and a major advantage is lost. Their problem with the acceptance of on-line methods are similar, but worse, to those that have plagued Coriolis meters for fiscal measurement.

The most significant issue is proving, to prove an on-line meter physical samples are required - how can these be taken? The obvious answer is with a sampler, this rather defeats the object of the on-line device other than for the provision of live information. The second issue concerns retention samples. In almost all transactions involving two parties, three samples must be provided for the shipper, the receiver and a retention sample for dispute. If no physical sample exists, there is no firm basis for litigation.

Conclusion

The majority of the existing ISO and IP standards have maintained their validity, there are areas where the statements made require a more reasoned evaluation and should not be applied verbatim. It is possible to provide equipment well capable of meeting the accuracy requirements of the industry as has been shown by repeatable proving. To design an accurate sampling system requires more than a simple specification based on the ISO or IP model, extreme care needs to be taken over all the facets of the design through to the laboratory analysis. Sampling equipment cannot be purchased as a commodity, an extremely well specified approach is required. Those companies that purchase samplers as a commodity, such as part of a metering system, have often found themselves replacing the sampling system as a stand alone project as a matter of priority.

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