ISO 3171 Production Hydrocarbons Allocation Sampling for challenging "Tie-ins" with pressures close to RVP breakout.

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Summary

Introduction

There are an increasing number of applications where sampling is required for crude oils and condensates at close to vapour breakout in production environments.
These are typified where the quality measurement must be extracted/made in the "oil" leg of a separator. The exertion of back pressure (pressure loss) on the liquid leg to expand the operating envelope is generally not acceptable due to the effect that this will have on the separator efficiency and this frequently precludes the use of normal metering technologies.

These conditions represent some of the hardest for quality determination.

In conventional separators, velocities are low to promote separation of the gas and liquids and the therefore the gas pressure within the liquid phase is close to breakout. Frequently there is an envelope of less than 0.5 bar below the operating pressure at which the fluid will start to cavitate. Concurrent with the low velocity is the expectation of some free water that would require mixing to ensure representivity.

There are frequently also severe restrictions on space and the piping arrangement in which to achieve a representative off-take. The "rules" that are applied to representative sampling are equally applicable to the use of water monitors (watercut, OWD) and to densitometers.

An integrated quality measurement system that prevents any impact on the process and also provides the required mixing to allow extraction of a representative offtake that can be used for physical samplers as well as process instrumentation such as densitometers, viscometers and water cut monitors can be achieved by careful design. Jiskoot has adapted its CoJetix technology to meet these goals.

Sampling Requirements

Conventional sampling requires that four steps be met :
- Adequate dispersion and distribution of the pipeline content cross section
- Representative sampling of the batch
- Sampling handling and mixing
- Laboratory analysis

Our industry should never overlook any of the above steps, whether the objective be extracting a physical sample or to provide a representative flow to a process analyzer; but we are frequently surprised by how often the overall requirements are overlooked.

Dispersion and Distribution

A cursory reading of the current standards provides a table informing the user of the potential problems with poor mixing at low velocities. Unfortunately many miss the small print and assume that if they meet the requirements in the "table", they have adequate mixing. Those that do this fail to take the opportunity to assess their process against a much more detailed and accurate methodology which also accounts for viscosity and density. For close on 20 years models representing the dispersion and distribution of oil/water mixes have been published both in the ISO (3171 – Annex A), API (8.2 – Appendix B) and the IP (6.2 – Appendix B)standards and its all the more surprising that they are not used as these calculations are easily accessible on the internet. The models allow the calculation of dispersion quality in many configurations including downstream of a variety of devices including meters, valves as well as the more common elbows, reducers, pumps etc.

There are many specialised situations where a deeper understanding is required, for example :

It is not commonly understood that although a vertical pipe reduces the gravitational segregation of oil/water mixes, over a short length it also promotes slug formation and can spin the water towards the circumference of the pipe, i.e. make distribution worse.

Or, for example, that the use of a metering system as a mixing device may not always be successful due to the possibility that the inlet manifold can act as a slug creator (if there is a free water phase at inlet). Under such circumstances the mixing of water into oil in each stream may be acceptable, but the commingling of the streams in the outlet header can yield a poor cross sectional distribution. Given that these methods are available, why do some process engineers still overlook the actual process and make subjective judgments that should fail an easily applied audit of the process? Both engineers and auditors are at fault here.

Representative Sampling of the Batch

This is all about getting a sample to be physically extracted from the pipeline and deposited into a sample receiver that fully represents the batch in question. It remains a constant surprise that many engineers still fail to read the standards in regard to the actual requirements for sample frequency and many appeared blinkered by the de-facto marine discharge requirement of 10,000 samples per batch. Collecting 10,000x1ml samples of a high RVP product and either transporting it under pressure, or mixing and decanting it into a smaller pressurised receiver for transportation to a laboratory is frequently at a detriment to the overall measurement uncertainty. Poor handling and mixing can often result. It should be under this heading that we discuss the sampling mechanism and "Isokinetic" as applied to both in-line and fast loop sampling systems. **Isokinetic -** Implicitly an "in-line" sample probe with a large opening through the head may have a velocity closely matching that of the process through the sample chamber. (Though this may not be true when the opening size is relatively small in comparison to the bluff body of the stem that supports it!)

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However over time two clarifications of the desirability of Isokinetic sampling must be qualified:

1. As the size of the opening to the sampling device increases relative to the expected droplet size, then Isokinetic sampling becomes irrelevant. This was first highlighted in qualification notes from testing within the IP Section 6 part 2

2. If a "Fast Loop" is driven isokinetically i.e. matching the velocity at the inlet to the velocity in the main pipeline, then there is a significant problem at low flow velocities that water and sediment can fall out in the sample loop this is in contradiction to the objective of the "Fast Loop" which is to deliver a representative and well mixed stream to the sampler or analyser.

Sound engineering design should recognise the use of large sampler or sample loop openings and abandon the use or application of the work Isokinetic to oil sampling.

Sample Handling and Mixing
Consideration of the volume of sample that is actually required for analysis and retention and the required sampling frequency is valuable. A 4 litre, high pressure, sample will normally be more than adequate to represent a batch in a production environment.

We also often find demand for high pressure sample receivers to be used on stabilised crude i.e. with an RVP below a bar, this is simply a waste of money.

Even with higher RVP products the sample used for water determination will need to be depressurised for analysis.

Density and On-line water content measurement
We realize that there is growth in demand for using on-line water monitors particularly for allocation (sometimes called Watercut or OWD's – but NOT correctly described as BS&W monitors), indeed there is a paper later this morning dedicated to this subject. But without adequate pre-conditioning of the process stream (pipeline mixing) and suitable and regular re-calibration these devices render little more than trending information.

Sampling technology continues to move from the old style and less accurate "in-line" samplers to fast loop systems. By fast loop, we tend to classify them as a loop with a piping size of 1" or larger nominal diameter and typically a loop flowrate of 4-10 m3/hr. These rates and velocities concur nicely with the demands of OWD's and densitometers.

There are many reasons for this slow migration, the general comprehension by engineers that fast loop systems offer easier installation in a congested process environment and simplified maintenance. Also since a loop is required for density measurement which, according to the standards "should meet the same requirements as for sampling" and more recently the body of evidence that fast loop technology is simply more representative.

It is possible to classify sampling systems into various categories and further to consider the mixing. Since the 1980's there have been significant water injection tests of all types of systems. From the "DIY" samplers constructed by sites, to in-line systems with "Static Mixers" or Power and Jet Mixers.

There have also been a considerable number of tests of fast loop systems with the same types of preconditioning and more recently with the direct integration of fast loops with JetMix systems so-called CoJetix.

One statement of fact :
NO sampling system, unless installed in a biased pipeline profile will measure the absolute water content, ALL sampling systems tend to under measure water content, the only question is by how much. Call this uncertainty or call this systematic bias, gathering real data from over 200 water injection of various systems yields the following summary.

**Water recovery from water injection testing of automatic sampling systems**
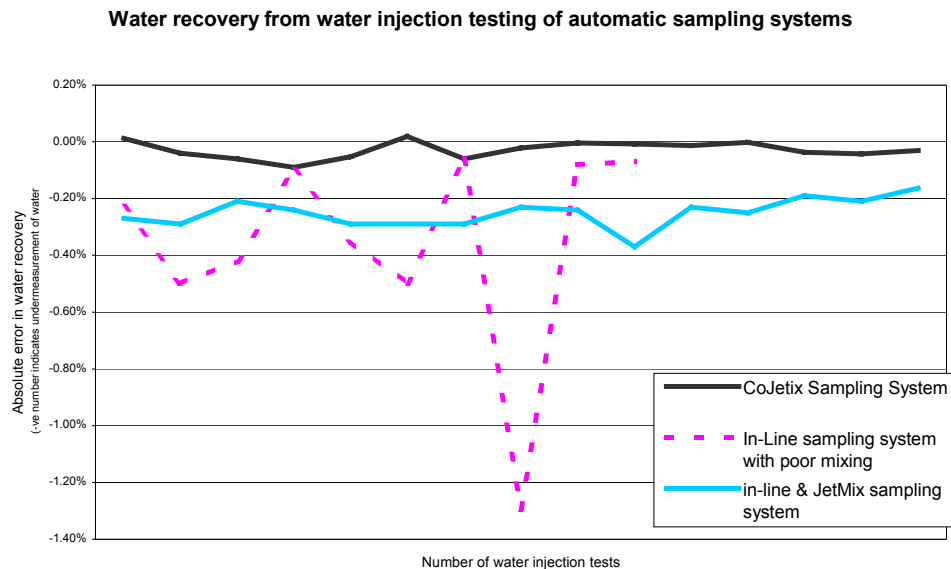
The reason for these results are somewhat obvious:

The under measurement will depend in greatest part in the dispersion and distribution of the water in the pipeline cross section. To minimise these influences a balance between the mixture quality and the size of the opening and flow profile through sampling device seeking to collect a sample are paramount. A fast loop is implicitly more competent than an inline probe by virtue of its larger opening extracting water droplets from a pipeline of equivalent dispersion quality.

Whatever you do for mixing, you MUST pay the price in energy terms, be it through pumping power (pressure loss) in your pipeline or by adding energy such as with a JetMix.

Back to back comparisons of an in-line ("Isokinetic"!) probe behind a static mixer and a CoJetix system indicate a significant average offset (0.15%)
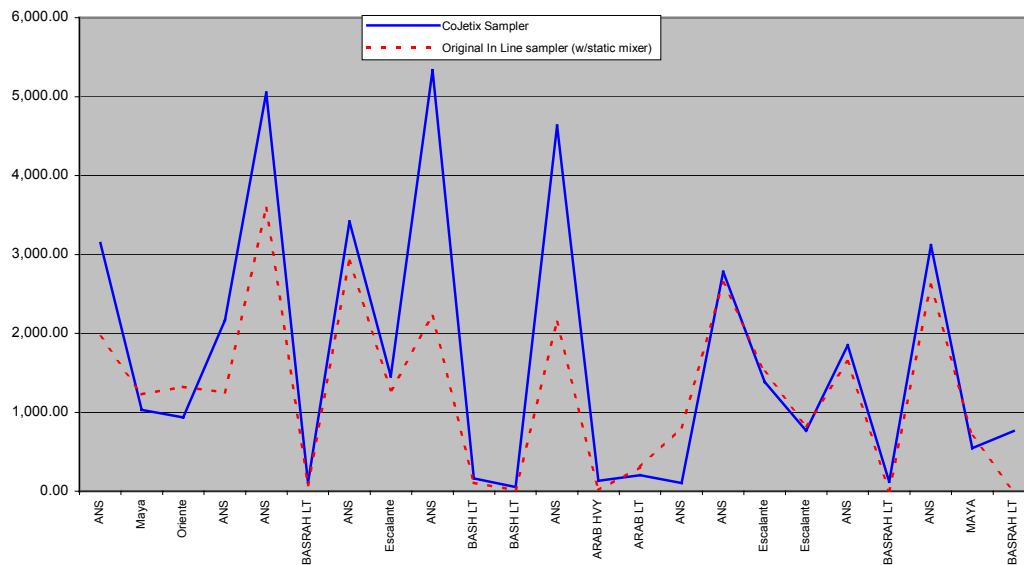
We have also been comparing the results of a variety of water cut monitors back to back against a marine unloading environment, our conclusions are that provided the users rigorously follow the calibration procedures and understands the limitation of the technology, that they are capable of providing excellent trending information.

The summary below indicates the scatter between two different manufacturers units and a proven (physical) sampling system. The two units are in the same loop with a sampler, both density compensated – running batches of the same "blended" crude, sulphur is plotted as a possible cause for the scatter.

ANS Error Relative to Lab Result
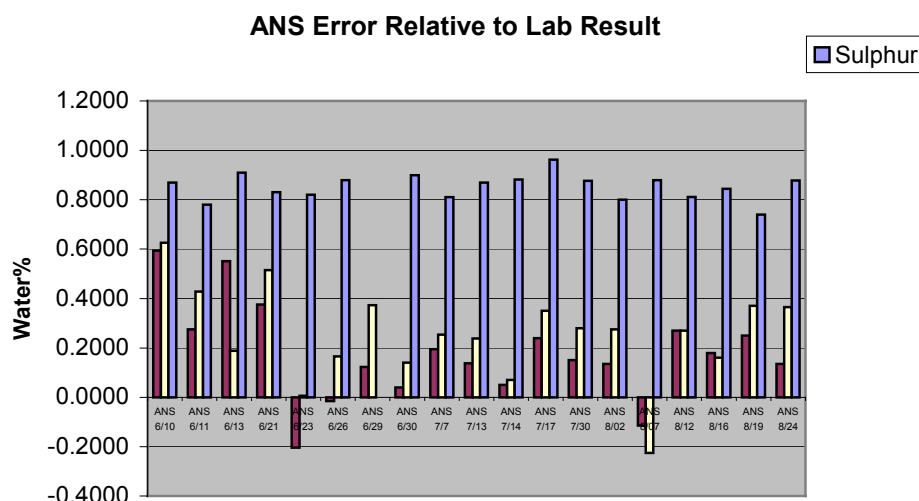
Design Study
Process Values

Liquid Process Data			
Line Size	8"	8"	8"
Pipeline Fluid	Condensate	Condensate	Oil
Flowrate Range	2696 to 12750 bbls/d	6785 to 84800 kg/h (10.6 to 122.1 m^3/h)	8818 to 422700 kg/h (11.4 to 540.5 m^3/h)
Density	645 to 654 kg/m^3	643.1 to 694.1 kg/m^3	746.8 to 782 kg/ m^3
Viscosity	0.5112 cP	1.2 to 1.6 cP	2.0 to 3.75 cP
Line Temperature	55 to 75 °C	30 to 50 °C	42 to 67 °C
Operating Pressure	28 to 63 Barg	11 to 15 Barg	7 to 63 Barg
Water Content	Unavailable	0 to 2%	0 to 2%

Pipeline Mixing

Given that the RVP is within 6psi (0.5 bar) of the process pressure any reduction in process pressure will cause gas breakout.

Since the flow velocities are low, some form of mixing will be required as the separator is expected to allow up to 2 % carryover of water in the oil leg.

The use of a static mixer in this environment would not have worked, (in one case a 50:1 turndown – we would typically suggest, even if pressure losses are acceptable that 5:1 is the attainable limit). The maximum allowable backpressure was 0.5 bar at maximum flowrate and this should have been the static mixer back pressure AT MINIMUM FLOWRATE (and therefore significantly higher at higher flowrates.)

Some form of power (Jet) mixing was therefore desirable. In seeking to employ a pump to extract flow from the pipeline, considerations of available pressure losses within the suction pipeline and the NPSHa vs NPSHr (and specific engineering constraints applied by the buyers) require due care in selection of and positioning of the pumps. If suction head can be increased through elevation, this should be implemented.

A careful design requires consideration of a variety of issues, these include:
- Droplet dispersion and distribution vs. sample system inlet sizing.
- Configuration of the inlet and outlet connections, all the intermediate piping.
- Elevation.
- The obstruction potentially caused by the insertion of an offtake quill and a re-injection jet.

Nominal calculation of the initial distribution yielded the following result.

Pipeline Mixing Quality
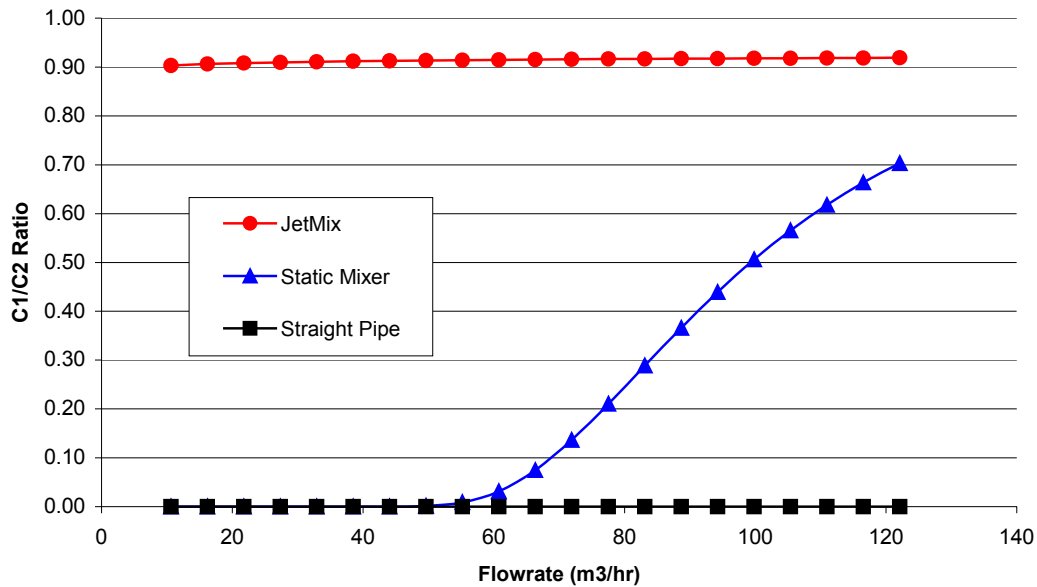
The energy dissipation required for mixing to allow extraction of a sample with a conventional in-line sample probe or fast loop provided an energy addition requirement and pump sizing that was untenable, therefore the energy addition was curtailed in favor of increasing the suction inlet profiling capability of the offtake quill and changing the system into a CoJetix, this allows the mixing energy requirement and therefore demand pumping rates to be reduced.


JetMix nozzle

A further constraint on the design is the compromise between volume and jet velocity (pump outlet head requirements). Jet velocity in conjunction with the jet diameter provides the means for both dispersion and distribution. Small diameter jets at high velocity provide good local energy addition but limited distribution capability due to their faster diffusion. Larger jets provide longer term bulk movement of the flow.

The pipeline section in to which the offtake quill and jet were inserted was increased to ensure that the installation would not impact the overall system pressure losses through obstruction.

The use of a CoJetix also allowed the implementation of the densitometer loop and the use of a water cut monitor, samples are collected into a constant pressure receiver.

Co-Jetix fiscal condensate sampling and analysis system
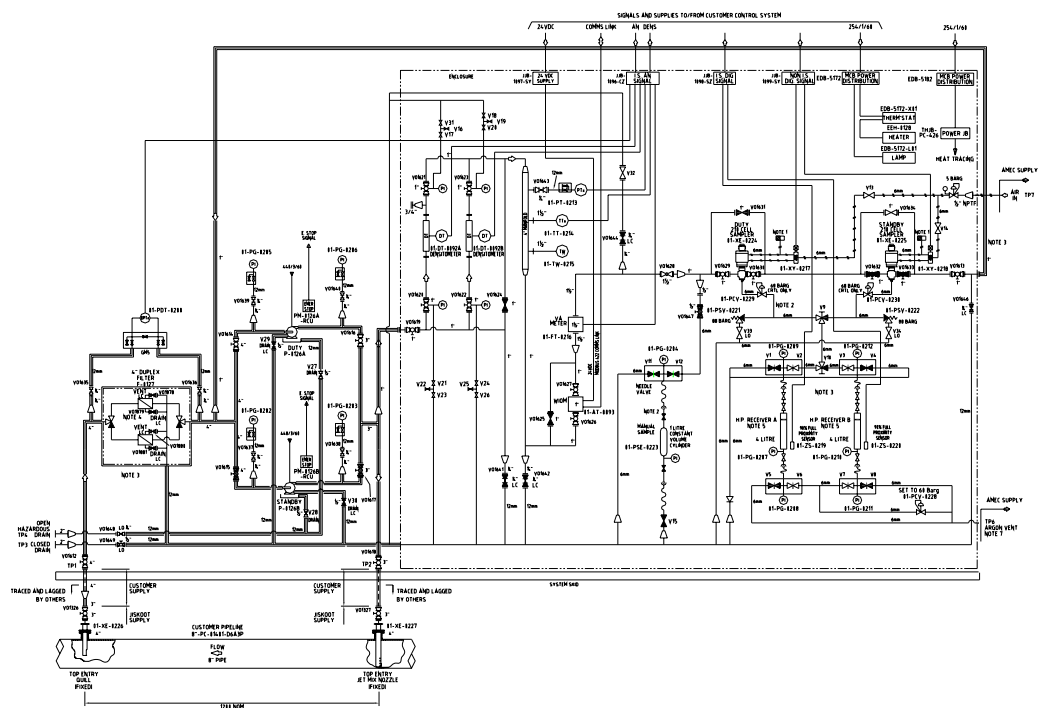
Due to the high RVP of the product the system was designed to be able to use plain and compact (constant pressure) sample collection receivers which can be mixed in a laboratory. These can be mixed with a ShearMix (pressurised shearing vessel) into which the sample is decanted for homogenization. The ShearMix can be used with almost any vendors constant pressure cylinders and allows samples to be extracted from the top and bottom of the vessel to ensure convergence in the analysis results.
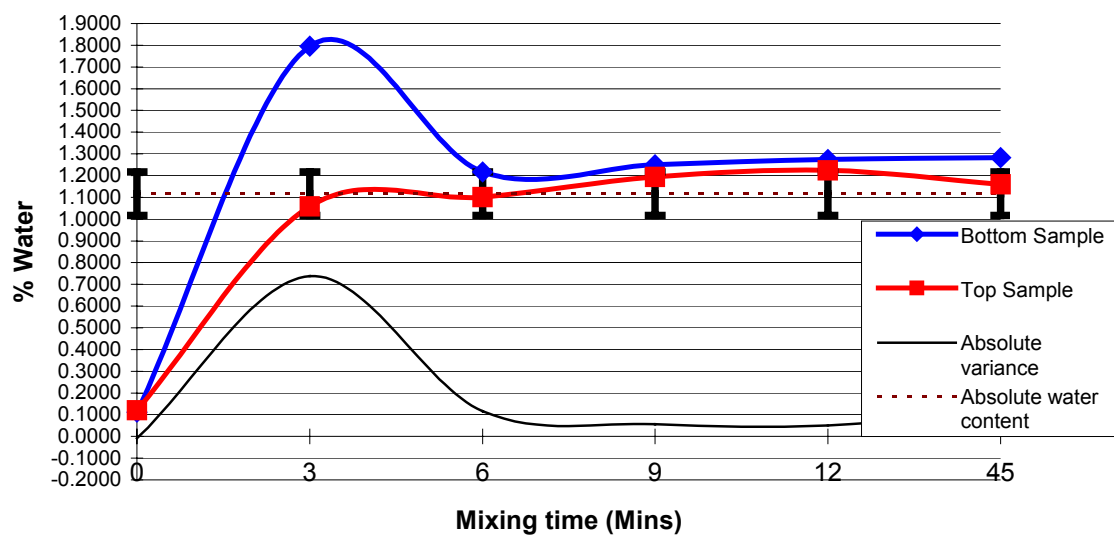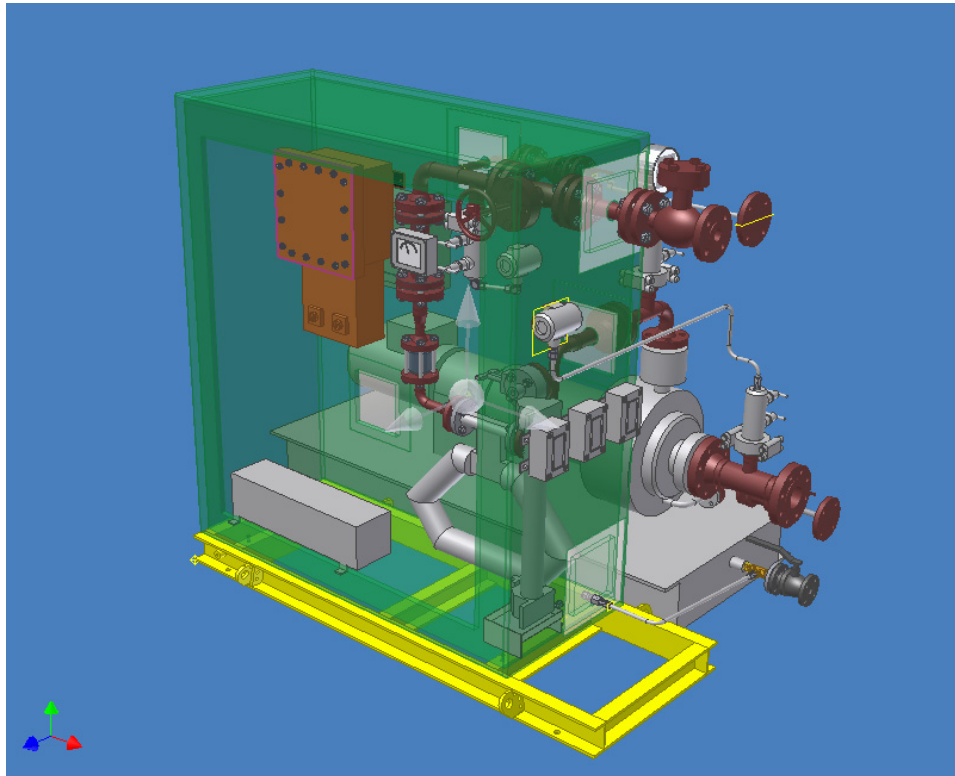

CPC sample receiver

ShearMix - CPC mixer

Water Separation Top to Bottom Vs Mixing Time

A more recent application of this CoJetix style design is to a system where no sampling is implemented but the problem of providing representivity to a watercut monitor remains, under these circumstances the same approach is taken.

Sampling system 3D design model

This style of design, whether it be for a physical extraction of sample, density measurement OR water cut measurement singularly or concurrently can be used in almost any application where measurement uncertainty is important to the overall process audit.

Your income stream in either joint venture environments or where production is taxed on the basis of your measurement depends upon the best measurement achievable.

References

[1] Paper presented at the North Sea Flow Measurement Workshop, a workshop arranged by NFOGM & TUV-NEL

Note that this reference was not part of the original paper, but has been added subsequently to make the paper searchable in Google Scholar.