Possible installation effects on density meter in a fast loop sampling system.

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Preface.

The oil and gas business has increased their demands for fast loop sampling systems with reduced footprint and cost. To fulfil these requirements, we have designed more compact systems and reduced the construction time by introducing a "smart component installation". This has involved stacking of instrumentation and introduction of assembly blocks to reduce space and installation time.

Introduction

During assembly and testing of a fast loop system we observed readings from the density meters with periodic anomalies. Further examinations were executed on different fast loop systems to collect necessary information for a study of possible installation effects on a density meter in a fast loop system. Tests were initially performed on existing fast loop systems, and later on a test installation consisting of a density meter and an intrusion device which simulates a generic grab sampling device penetrating the fast loop while performing a grab. This test setup will be discussed in more detail and the test results will be explained.

Test of systems during assembly.

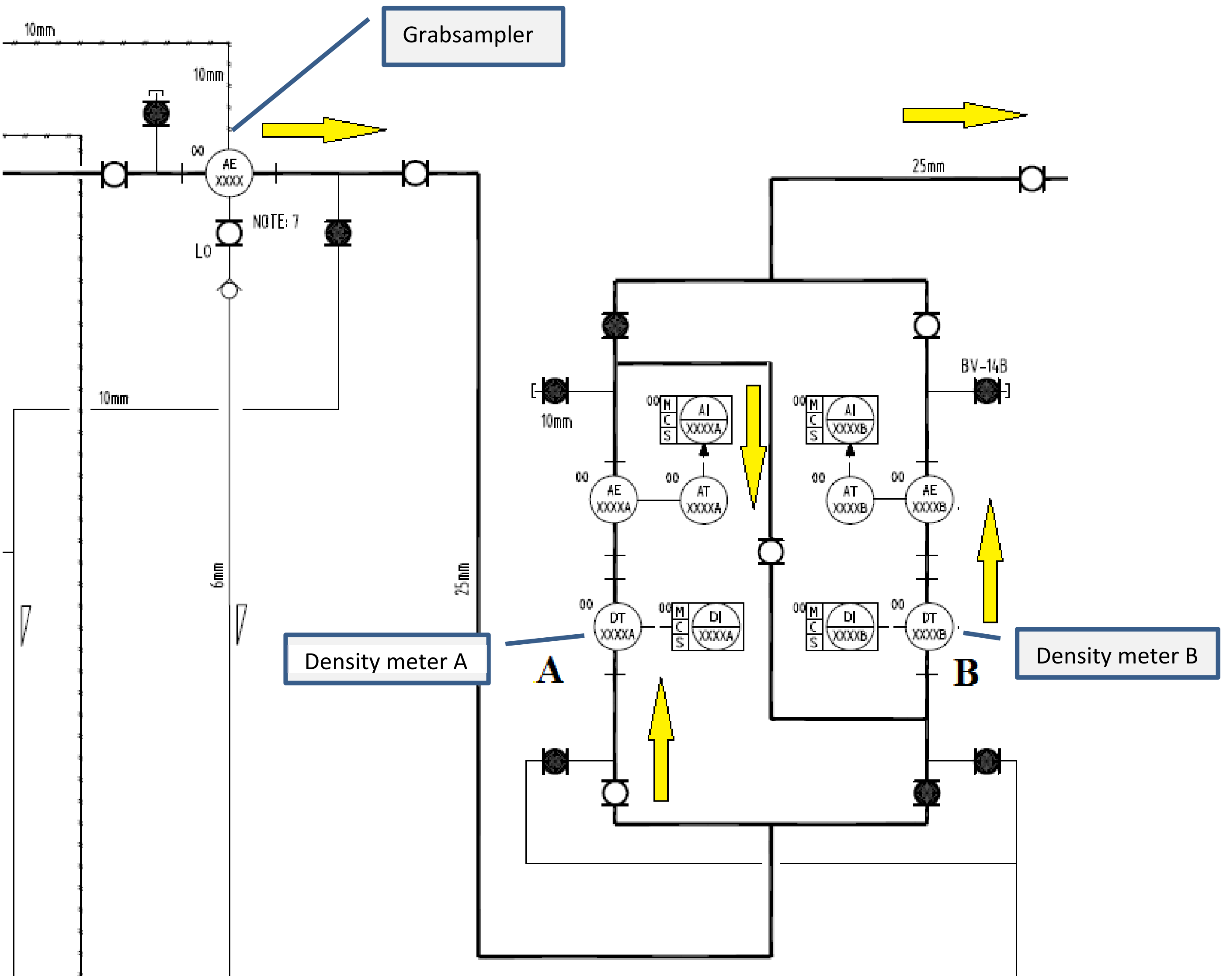
Logging software was developed using a Siemens PLC with a high-speed counter module and a C-Sharp software to collect and present the findings. The test setup was neither calibrated nor selected for high precision measurement but were based on off-the-shelf standard PLC equipment.

The purpose of this test setup was to verify that the installed instrumentation was working and communicating with external equipment. Flowmeter, temperature transmitters, pressure transmitters, level transmitters for sample receivers, density meters and grab samplers were all connected to the system and tested during operation of the fastloop system.

It is important to understand that the signal from the density meters are raw frequency signals not compensated for temperature variations.

Test of sampling system for a batch export metering station

The first test was performed on a sampling system for a batch export metering station. A typical system design with a single grab sampler upstream of 2 density meters and 2 water cut sensors installed with isolation valves and cross-over valve utilizing a serial or parallel configuration of the instrumentation.
The test was performed using hydraulic oil in the fast loop, and pressure and flow were provided by a hydraulic power pack.



Extract from a typical system diagram for a batch oil export sampling system. Valve arrangement is set up for serial configuration. Yellow arrows show flow direction.

Picture shows the density meters mounted with watercut sensors stacked on top.

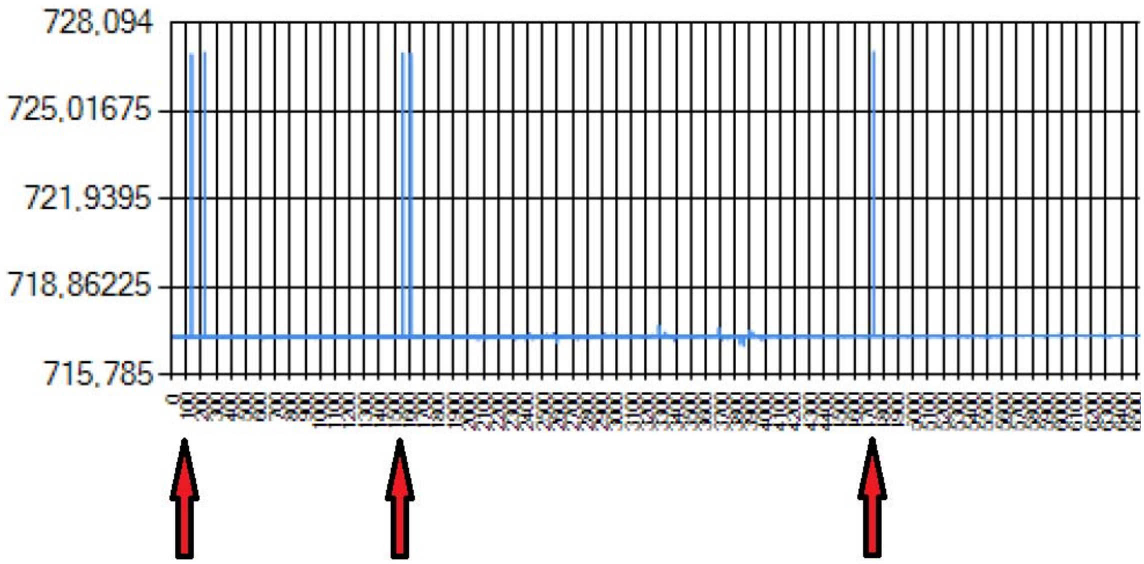
Initially tests during FAT indicated that when the density meters were set up in a serial configuration there were some disturbance on the signal from the density meter mounted upstream close to grab sampler, i.e. Density Meter A.
The Density Meter A is mounted downstream of the grab sampler with approximately 3 meters of tubing between grab sampler and density meter. (ref 00-DT-XXXXA on extract from typical system drawing).

We performed a new test on the system concentrating on Density Meter A. The instrumentation was set up in a serial configuration and the grab sampler was continuously sampling at a rate of 20 cycles per minute which is more than twice the sampling rate for a daily sampling system. Frequency from the Density Meter A was measured over a period of 30 minutes and the software was polling the PLC 6500 times during the test period.

The test system registered a maximum peak frequency reading from Density Meter A of 727,094 Hz.

Density meter A

Density sensor 1 min reading: 716,785
Density sensor 1 max reading: 727,094
Density sensor 1 average reading: 717,132356212657



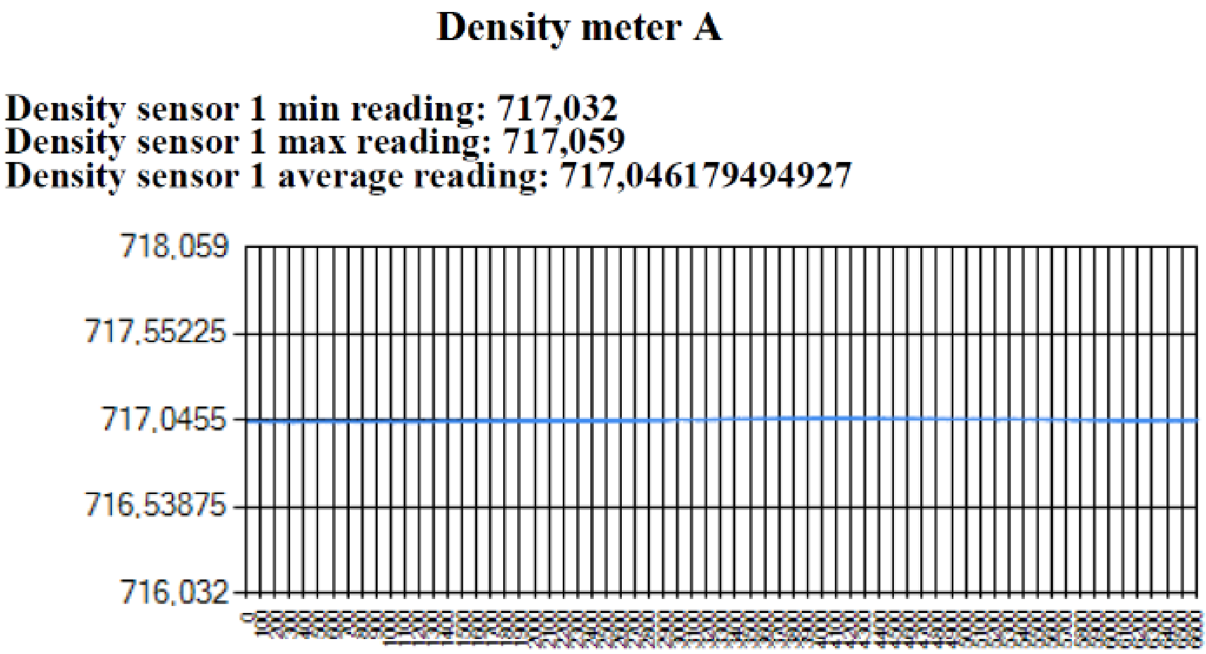
Red arrows indicate areas with abnormal readings from the densitometer. The Density Meter A is mounted downstream of the grab sampler with approximately 3 meters of tubing between grab sampler and density meter. (ref 00-DT-XXXXA on extract from typical system drawing)

The test performed on the system indicates disturbance on the frequency signal coming from the density meter. Further tests were executed to determine the source of the disturbance.

Test with no instrument air supply.

Instrument air supply to grab sampler was shut-off, fast loop was run with flow and 24 VDC pulse chain to activate solenoid valve periodically. During this test no disturbance was observed on the frequency signal coming from the density meter.

This test eliminates the solenoid on the pneumatic valve as the source for the disturbance.



When fastloop was run with grab sampler deactivated there were no disturbance on the signal coming from the density meter A.

Test with no flow in fast loop.

Instrument air supply was turned back on and the grab sampler was continuously sampling. Hydraulic power pack was stopped and there was no hydraulic oil flow in the system, fast loop tubing was still full of oil. During this test no disturbance was observed on the frequency signal coming from the density meter.

This test eliminates mechanical vibrations from the air operated linear actuator that drives the grab sampler.

These findings indicate that disturbance on the frequency signal from the density meter is only present when there is flow in the system and when the grab sampler is sampling.

From the test, we extracted the following values:

Average frequency reading from density meter A with no disturbance on signal.	717,046
Average frequency reading from density meter A, density meters configurated serial, grab sampler was continuously sampling at a rate of 20 cycles per minute.	717,132

Summary after test of sampling system for a batch export sampling system.

The measured average frequency deviation was put into a density calculation spreadsheet used for fiscal oil metering calculations which gave us a calculated deviation on standard volume of 0,06%.

Considering the following:

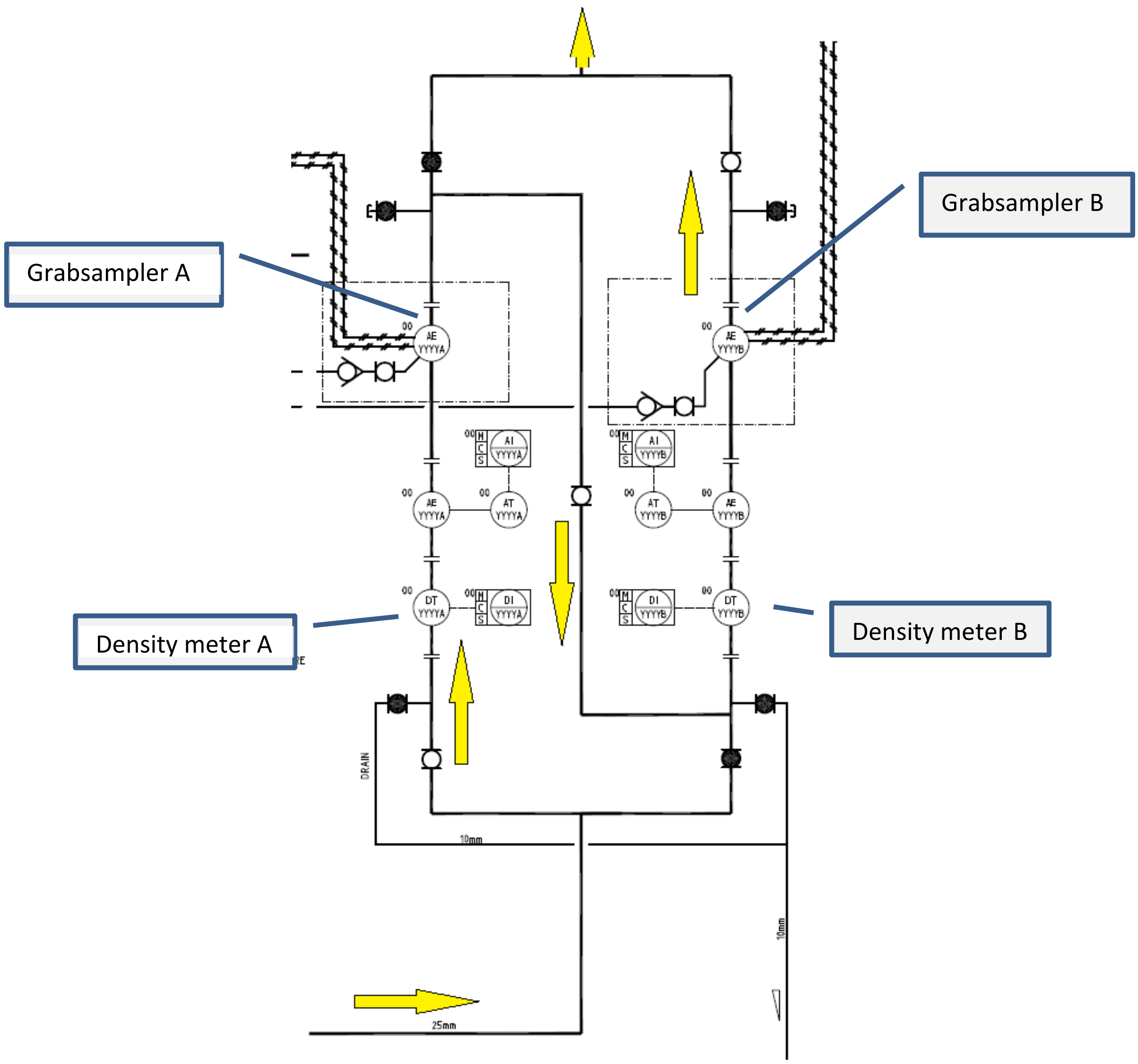
- The design of this system complies with industry practice.
- Several similar systems are in operation worldwide.
- Test setup used standard low-resolution data acquisition PLC modules.
- No calibration parameters were implemented for the density meter.
- No temperature compensation on the system
- Grab sampler was activated twice as often as expected.

we found the calculated deviation to be within the requirements of the Norwegian Petroleum Directorate set forth in the "Regulations on Petroleum Measurement for Tax Considerations and the Calculation of CO_2 Fee" for measuring density of oil.

Nevertheless, test results indicate that there is a possible installation effect on the density meter and decision was made to follow this up on future systems.

Test of sampling system for a continuously export metering station

The next test was performed on a sampling system for a continuous export metering station. A typical system design with 2 grab samplers, 2 density meters and 2 water cut sensors.
One density meter, one water cut sensor and one grab sampler were stacked and formed one column, the remaining density meter, water cut sensor and grab sampler formed a second column. The columns were installed with isolation valves and cross-over valve utilizing a serial or parallel configuration of the two columns. The tests were performed using hydraulic oil in the fast loop and pressure and flow were provided by a hydraulic power pack.

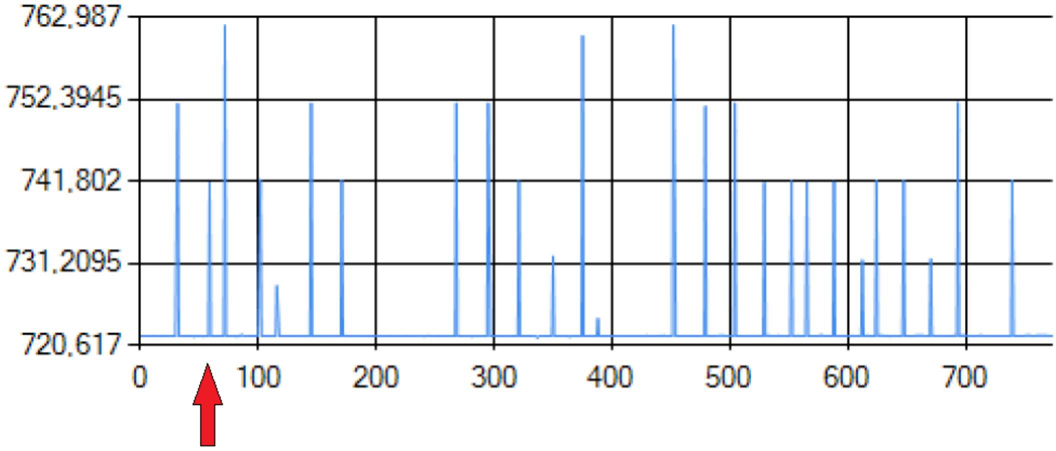


Extract from a typical system diagram for a continuous oil export sampling system. Valve arrangement is set up for serial configuration. Yellow arrows show flow direction.

Initially tests during FAT indicated some disturbance on the signal for both density meters. In this test only the serial configuration was tested and only Grab Sampler B was activated. (ref 00-AY-YYYYB on extract from typical system drawing)

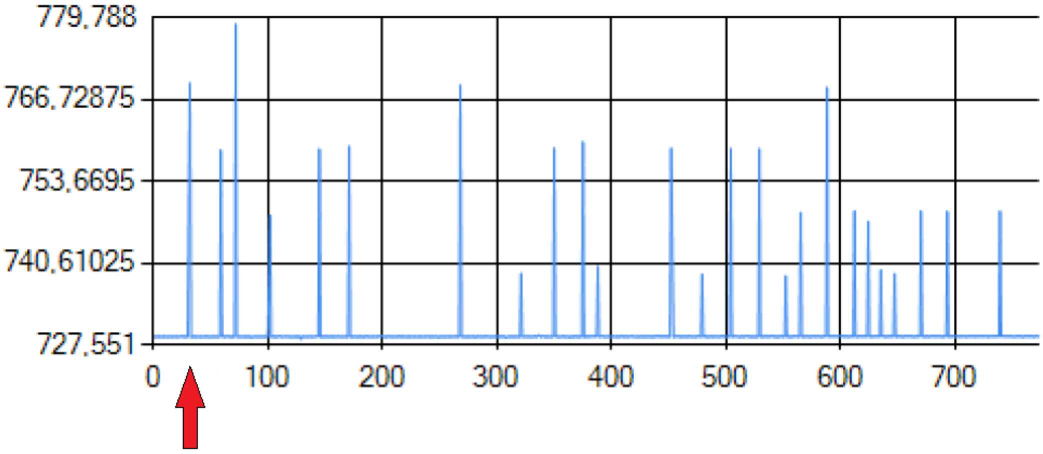
Density meter A

Density sensor 1 min reading: 721,617
Density sensor 1 max reading: 761,987
Density sensor 1 average reading: 722,708357881138



Density meter B

Density sensor 2 min reading: 728,551
Density sensor 2 max reading: 778,788
Density sensor 2 average reading: 729,748325581397



Red arrow indicates an area with abnormal readings from the densitometer, the abnormal readings are repeated during the test.

Summary after test of sampling system for a continuously export sampling system.

The test performed on the system indicates there is a disturbance on the frequency signal coming from both Density Meter A and Density Meter B. The test also suggests that the disturbance is more extensive on Density Meter B than on Density Meter A. However, both density meters show more disturbance on frequency signals than expected.
Decision was made to investigate this further.

Investigating further

The results from the tests executed during assembly of the sampling systems indicated that the readings from a density meter could be influenced by a grab sampling sequence. To investigate this further a test setup was assembled.

Preparing a test setup

A density meter was installed in a loop with an intrusion device connected to the density meter outlet flange. For the test purpose, hydraulic oil was used and necessary pressure and flow were obtained using a hydraulic power pack.

The intrusion device, which consist of a pneumatic operated linear cylinder, was installed in a T-piece and when activated the cylinder shaft moved into the fluid flow creating a partial restriction of the stream. To control the operation of the intrusion device a PC running a small software application was used to turn a solenoid valve periodically on and off, which in turn engaged the intrusion device.

The linear cylinder was installed in such a way that the cylinder shaft never touched the tube walls during activation, hence the intrusion device never created any mechanical vibrations to the system that could give false readings from the density meter.

Picture showing the intrusion device mounted in a Tee.

A PicoScope 2206B digital oscilloscope was used for the recording of density meter signal. The PicoScope software has the possibility to record curves and to superimpose several curves on top of each other. We expected this possibility to be what was needed to get a better understanding of what happens during a grab sampling sequence.
The density meter was connected to a MTL5032 barrier and the oscilloscope was connected to the barrier input such that the oscilloscope readings would reflect the real output from the density meter as a flow computer would see it.

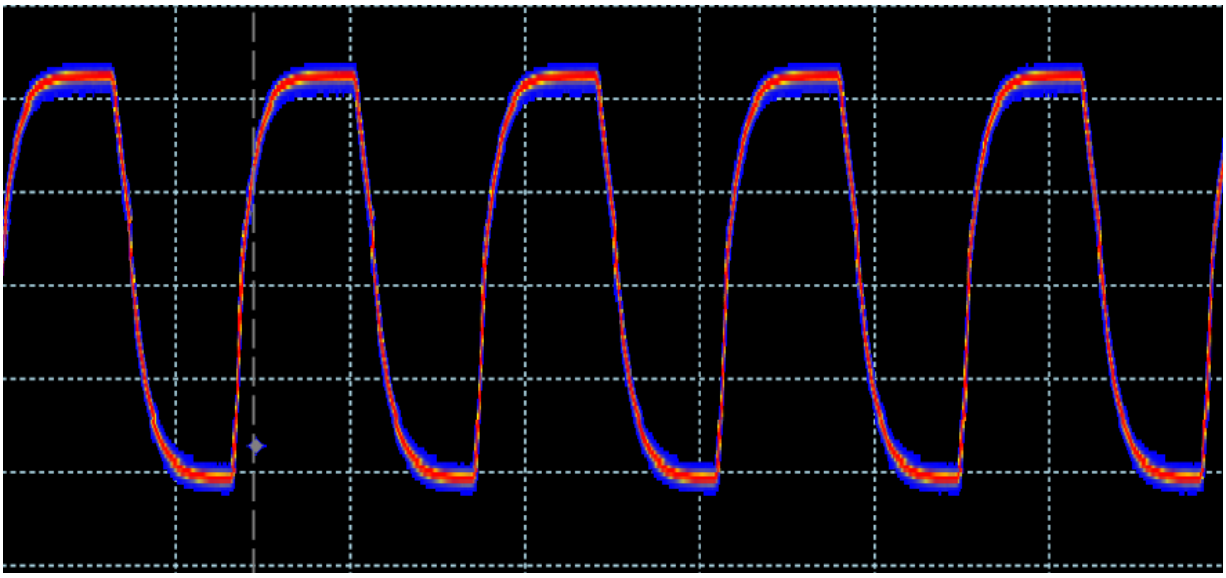
Picture shows the oscilloscope connections to the density meter.

Picture shows the oscilloscope unit.

Reference test

A test was made for reference. We ran a flow through the density meter without activating the intrusion device. The graph shows minor to no fluctuation in frequency but some ripples on the curve amplitude.

It is important to remember that all readings from density meter are raw values not corrected for temperature deviations.
Since all values are raw values we will not concentrate on the absolute numbers but on the deviations.



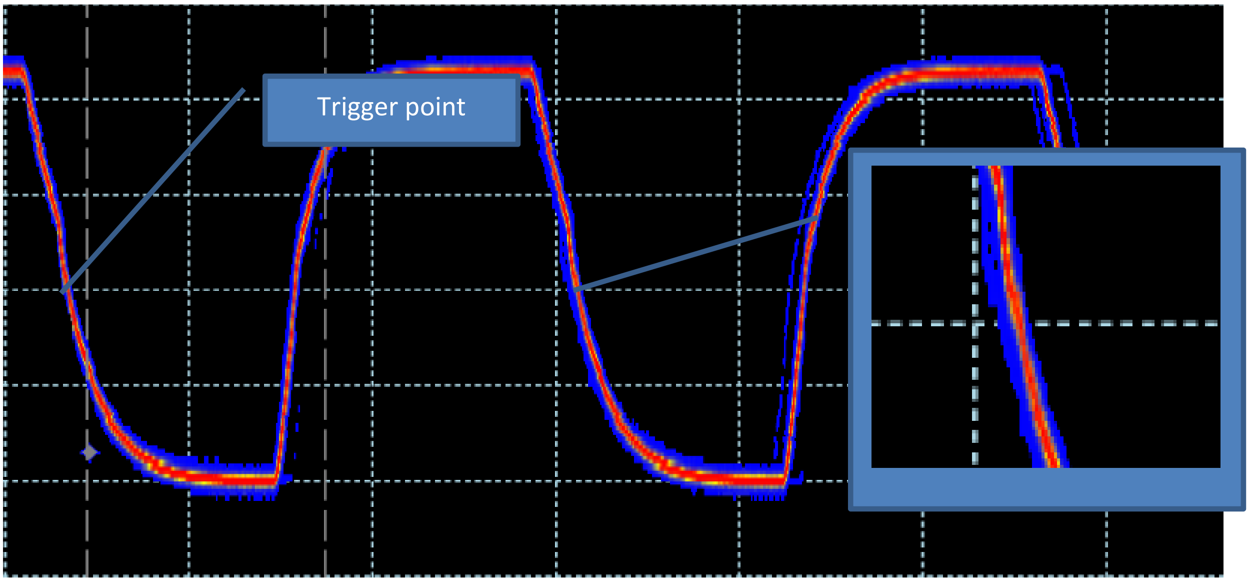
Explanation of graph.

The scope is set up for “Persistence mode” and will superimposes multiple waveforms in the same view, with more frequent data or newer waveforms drawn in brighter colours than older ones. This is useful for spotting glitches, when we need to see a rare fault event hidden in a series of repeated normal events. The colours indicate the frequency of the data. Red is used for the highest-frequency data, with yellow for intermediate frequencies and blue for the lowest frequent data. In the example above, the waveform spends most of its time in the red region, but noise causes it to wander occasionally into the blue and yellow regions.

Test with intrusion device mounted upstream of the density meter.

Hydraulic oil is flowing through the system, pressure is approx. 15 barg and the flow direction is through the intrusion device mounted upstream of the density meter inlet flange and through the density meter returning to the hydraulic power pack tank.

The intrusion device was continuously engaged with a duty cycle of 50 % with a total of 4 seconds for each sequence. Density was measured over a period of 4 minutes.



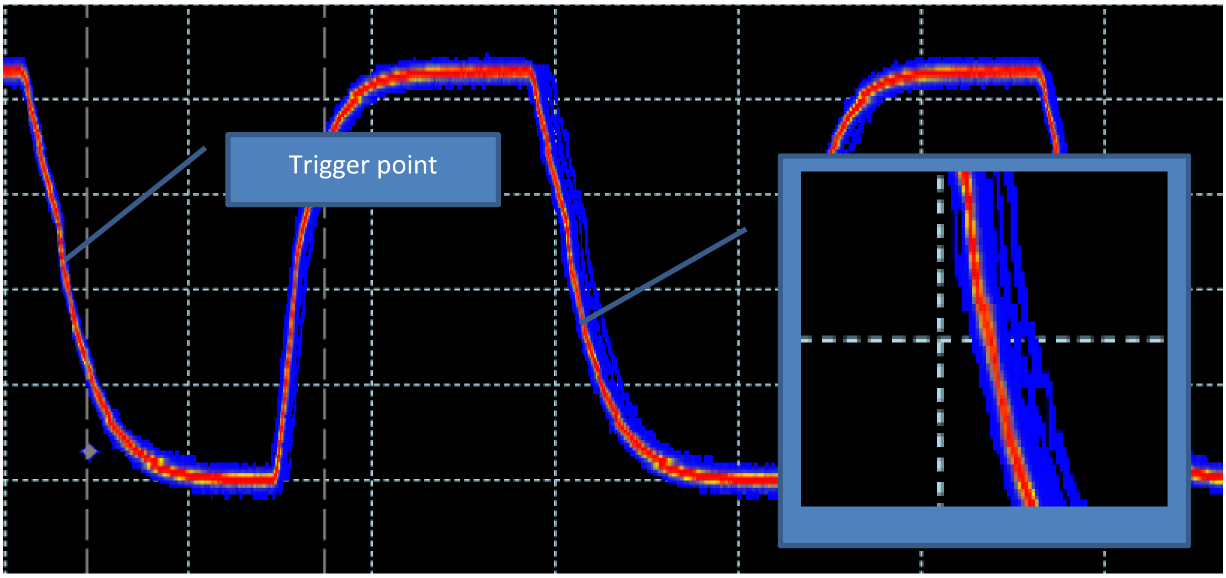
Explanation of the graph.

From the graph, we can see that there have been variations in frequency. The graph indicates that engaging the intrusion device has influenced the frequency readings from the density meter.

Test with intrusion device mounted downstream density meter.

Hydraulic oil is flowing through the system, pressure is approx. 15 barg and the flow direction is through the density meter, entering the intrusion device mounted directly onto the density meter outlet flange before returning to the hydraulic power pack tank.

The intrusion device was continuously engaged with a duty cycle of 50 % with a total of 4 seconds for each sequence. Density was measured over a period of 4 minutes.



Explanation of graph.

From the graph, we can see that there has been an increased variation in frequency after shifting the intrusion device to the outlet flange of the density meter. The graph indicates that installing the intrusion device downstream and directly onto the density meter outlet flange has increased the frequency variations significantly.

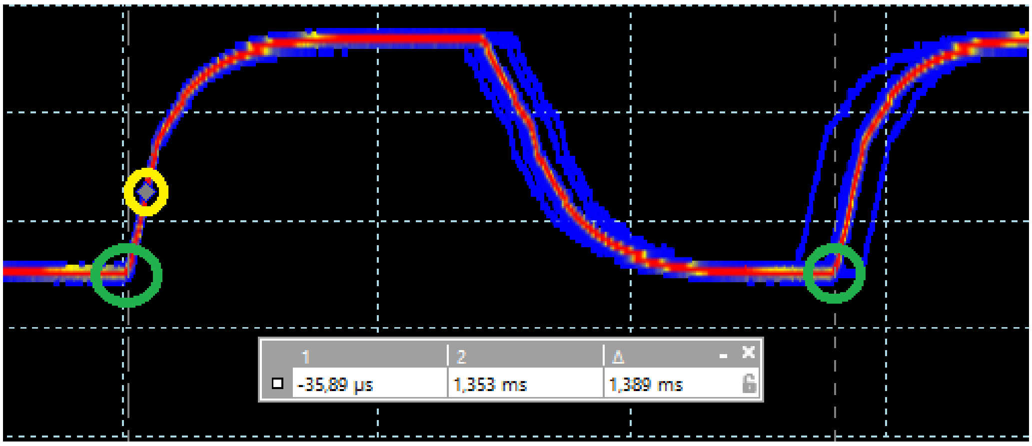
Test with increased pressure and flow.

The initial test propose that the influence is higher when the intrusion device is located downstream of the density meter. This test focus on an installation with intrusion device mounted directly downstream of the density meter. Pressure is increased to 20barg which also increases the flow. Flow rate is not measured as it is not important. Yellow circle indicates oscilloscope trig point, green circles indicate measured time.

The intrusion device was continuously engaged with a duty cycle of 50 % with a total of 4 seconds for each sequence. Density was measured over a period of 4 minutes.

Mean, high and low frequencies are estimated from the graph using rulers positioned on the graph which will report Δt between the two positions. The ruler positions are indicated with green circles on graphs.

Mean frequency

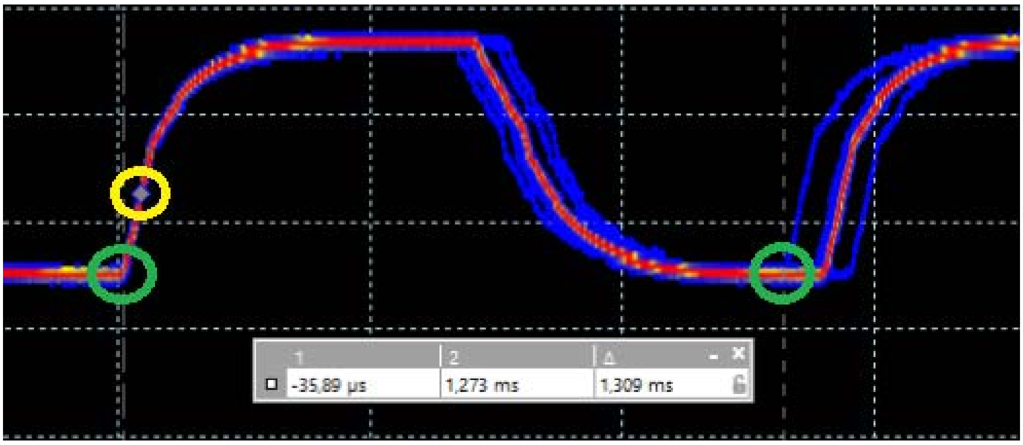


Average frequency is estimated for the largest number of repetitive curves.

f= 1/t => 720Hz.

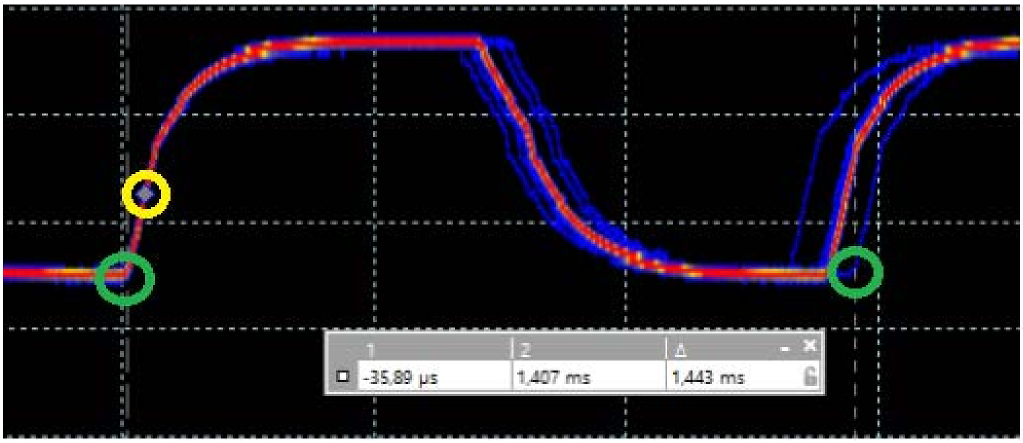
Mean frequency reading of ≈ 720Hz coincides with previous tests done on similar hydraulic oil and is a reading to expect from the density meter running in this test setup.

High frequency reading



High frequency reading is estimated for the curve with low cycle time.
f= 1/t => 763Hz.

Low frequency reading.



Low frequency reading is estimated for the curve with high cycle time.
f= 1/t => 693,0Hz.

Summary after test with increased pressure.

This test shows there is an impact from the intrusion device when activated.
The installation of the intrusion device either upstream or downstream of the density meter will have impact on the readings from the density meter, however it appears that installing the device upstream gives less impact.

Mean	High frequency reading	Low frequency reading
≈ 720 Hz	≈ 763Hz	≈ 693Hz

This test shows that there has been shifts in frequency from the expected 720Hz up to 763 Hz and down to 693Hz, further the test indicates there are frequency shifts to both higher and to lower frequencies.

Extended test

To investigate how the frequency shifts behave we will need to read the feedback in detail from the density meter after doing one intrusion device sequence.
To achieve this, we made a C-Sharp software using the PicoScope API (Application Programming Interface) to connect to and stream data directly from the Oscilloscope. The data received is in the form of an integer value between -32768 and 32767 which represent a point on the measured curve. We selected to do one sample each microsecond, giving us ≈ 1400 samples for each cycle which should be sufficient to detect the transition from positive to negative value and to calculate frequency of each cycle detected based on samples taken between each transition.
We did 10.000.000 samples in total to be able to analyse each curve for a number of seconds before and after the execution of an intrusion device sequence.

All previous tests show that the influence on the density meter is higher when the intrusion device has been installed downstream the density meter so this was our approach for the extended test.

We connected the intrusion device to the density meter and hooked the hydraulic power unit to create a flow of hydraulic oil through the density meter and the intrusion device mounted downstream the density meter. Flow achieved is unknown but pressure at hydraulic power unit output was 32 barg. Oscilloscope was connected to density meter output and sampling of density meter output was engaged. The intrusion device was engaged for one cycle, i.e. the intrusion device pushed the piston rod into the oil stream, stayed there for some time before it was retracted.

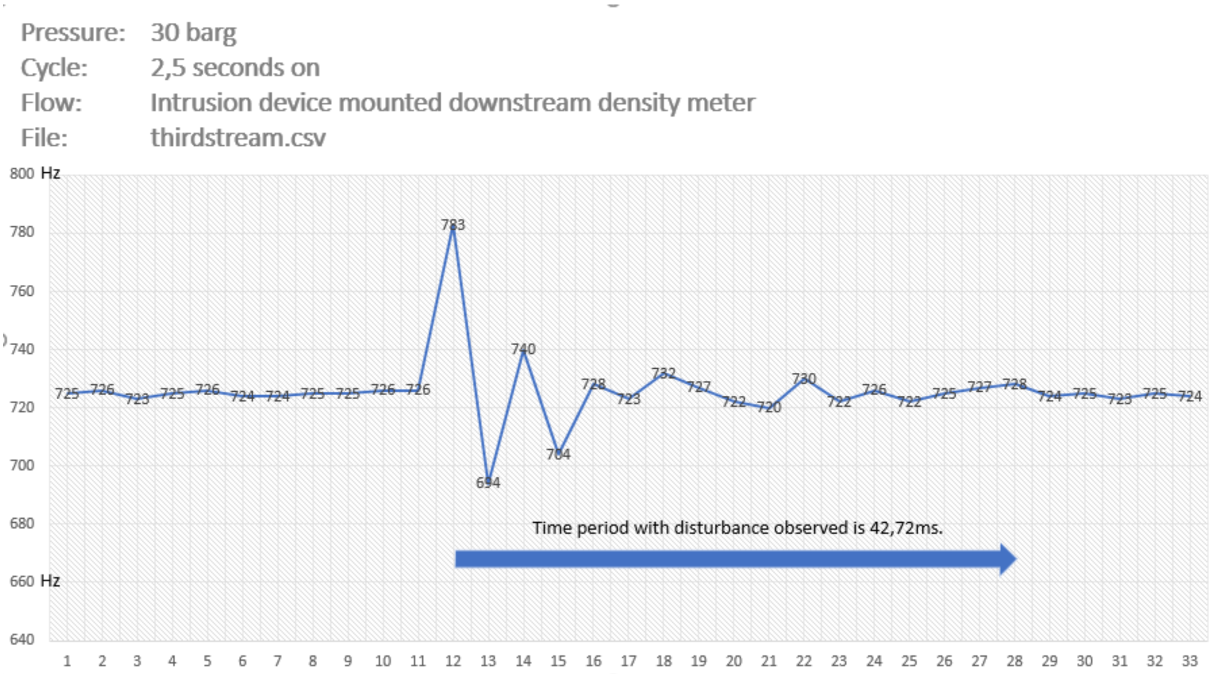
The result from the sampling was 10.000.000 (ten million) readings giving 38Mb of data in this format:

```
chA# -10209
chA#  -9698
chA#  -9443
chA#  -8677
chA#  -8422
chA#  -7912
chA#  -8167
chA#  -7656
chA#  -6891
chA#  -6891
chA#  -6635
chA#  -5870
chA#  -6125
chA#  -5614
chA#  -6125
chA#  -4594
chA#  -4338
```

Each number represents the voltage of the density meter signal at a given time and the next number in the list represents the voltage 1 µs (microsecond) later. We implemented a filtering function into our software to clean the received data to create consistent transitions from positive to negative values and counted the number of samples from one transition to the next. Doing so for all received samples gave us the elapsed time for each cycle, hence we got the frequency for each cycle.

We put the information into an excel sheet and created graphs based on the input.

A test was performed with a pressure of 30 barg, the intrusion device was installed downstream of the densitometer and it was engaged for 2,5 seconds.



Mean undisturbed signal	High frequency reading	Low frequency reading
≈ 725 Hz	≈ 783Hz	≈ 694Hz

This test indicates there will be a disturbance on the signal from the densitometer for a period of 0,04272 seconds with a high peak reading of 783 Hz and a low peak reading of 694 Hz.
From the test data, we found that the mean frequency during the period when signal was disturbed was 726,65 Hz. Mean frequency for undisturbed signal was 725 Hz.
We assume that for a daily Promix system the grab sampler will do one grab each 8,64 second.
Our test indicates that the disturbance is only present for 0,04272 seconds. The mean frequency shift for one grab sampler sequence will be:

$$x = \frac{(726{,}65-725)*42{,}72}{8640} = 0{,}008158Hz$$

The measured average frequency deviation was put into a density calculation spreadsheet used for fiscal oil metering calculations which gave us a calculated deviation on standard volume of 0,006%. This result, using high precision data acquisition instrument, suggests that the real impact on the frequency reading from the density meter is much smaller than seen from the initial tests.

The test was repeated using the following conditions:

- A second test was performed with a pressure of 30 barg, the intrusion device was installed downstream of the densitometer and it was engaged for 1 seconds.

- A third test was performed with a pressure of 34 barg, the intrusion device was installed downstream of the densitometer and it was engaged for 1 second.

Same effect with approximately same result was found when testing with different pressures and different duty cycles.

Conclusion

TechnipFMC found that there is an installation effect on a density meter signal due to a periodical flow restriction imposed by a grab sampling device penetrating the tube interior in a fast loop system.

Our test examining the density meter reading in detail revealed that for the time when disturbance was present on the signal, generally a frequency shift to higher frequency was followed by a frequency shift to a lower frequency. Calculating the mean frequency for said time indicates a very small overall frequency shift in total.

The effect will most likely relay on both fluid properties and fast loop properties. Examining this has not been a part of our test.

Our findings indicate that a periodical restriction downstream of the density meter will have a larger impact on the density meter signal than if mounted upstream.

Way forward

TechnipFMC will review the design for sampling systems for continuous export metering stations to reduce any possible disturbance to the density meter readings caused by other instrumentation.

TechnipFMC will gather data from operating installations in the field to investigate the extent of possible density meter installation effects on delivered systems.

TechnipFMC is investigating the possibility to extract a representative sample by using a non-intrusive sampling device to avoid any possible disturbance from possible flow restrictions caused by a grab sampling device.

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.