18th NORTH SEA FLOW MEASUREMENT WORKSHOP 2000

EFFORTLESS OIL ULTRASONIC FISCAL METER OPERATION: Krohne Altosonic-V, with Master Meter approach. Vigdis-Snorre Crossover & the Snorre B export station.

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1 INTRODUCTION

The first two Krohne Altosonic-V ultrasonic liquid meters installed offshore, are used for oil transfer between the Snorre and Vigdis process trains at the Snorre tension leg platform. No maintenance has been performed on the Krohne Altosonic-V meters for the first three years of operation.

This paper is a follow-up of earlier presentations. Frank Svendsen presented the Snorre-Vigdis Crossover early phase challenges in 1998, at the NFOGM annual meeting. He concluded that excellent performance had been achieved and was documented, and that a Faure Herman Helical Rotor master turbine meter was successfully introduced for transfer of traceable volume between, the Compact Prover volume, and volume flow calibration of the Krohne Altosonic-V meters. The two years of fiscal performance for the Krohne Altosonic-V ultrasonic meters at the Snorre-Vigdis Crossover was presented by this author at the NSFMW in 1999. Duty ultrasonic meter K-factor determined from synchronized comparison with the Master ultrasonic meter, after the initial set-up challenges, were all well inside +/- 0,10%. In similar applications, such good results could never be achieved with turbine meters, even with frequent washing and cleaning procedures. It was also regarded as necessary that the master turbine meter should rather be installed between the ultrasonic meters and the Compact Prover, to eliminate possible disturbance to the volume transfer from the turbine meter to the ultrasonic meters. Furthermore, the use of flexihoses between the ultrasonic meters and the master turbine meter during the re-calibration with Compact Prover, was questioned as a possible contributor to the shift found in the calibration of the ultrasonic meters.

2 SNORRE-VIGDIS CROSSOVER BACKGROUND

The Snorre-Vigdis Crossover application allowed for a rather low risk tryout of the new technology from Krohne Altometer, since the contractual agreement for this transfer could accept +/- 0,5% uncertainty. Although this is a platform internal oil exchange, this measurement has to comply with the NPD regulations, because Snorre and Vigdis has slightly different ownership split. Their allocation is also based on individual measurement for their different oil export pipe destinations. The tryout with this new technology was accepted by the NPD. However, the annual traceable re-calibrations were still a requirement, and here experience had to be built. At Snorre-Vigdis Crossover the intention was to connect a portable Compact Prover for diesel circulation for in-situ re-calibration of the Master ultrasonic meter. Regular third party verification onshore was also discussed as a possible part of a verification programme. Duty and Master meter for this installation were identical. Originally, this job was handled as a piping installation. Our instructions to the contractor was to use reducers inside 5 diameters upstream of the ultrasonic meters, in order to create a more ideal flow profile for these meters. This was before we had been informed that the Krohne Altosonic-V had built-in reducers. The contractor interpreted the instruction as straight length requirement and installed the reducers 10 diameters upstream. Also the Compact Prover tie-in connection was located 10 diameters upstream of the Master ultrasonic meter. When this piping for Compact Prover tie-in was tested with flow circulation, flow-reading variations around +/- 7% was observed with stable flowrates. Modifications were necessary for in-situ traceable third party calibration.

Since this became the Krohne Altosonic-V pilot project for facing real world offshore challenges, efforts were put into the retrofit adjustments, made in order to achieve traceable flow calibration of these meters in-situ; with the very firm objective to qualify this technology for regular fiscal use. In order to achieve the repeatability needed for verification of these ultrasonic meters performance, it was necessary to consider the influence on this technology from the dynamic profile variations. With the background information of how dynamic compensations are internally performed, it was concluded that large volume comparisons using the master meter method, would be the most likely route to success. From the early re-calibration attempts with Compact Prover, it was similar concluded that the short-term dynamic profile influence, made it more complex to use flow circulation methods. Any upstream connection method for verification, that could influence the naturally developed dynamic profile must be avoided. An upstream circulation inflow connection would have to be installed far upstream; possibly as far as 40 diameters, to avoid the unacceptable dynamic profile disturbance. Modifications were therefore made for downstream connection of the Compact Prover. Also a turbine meter run was temporarily moved from the Snorre oil export measurement station to this downstream connection position for independent verification, and in order to achieve higher flow capacity than what the master meter at the Compact Prover could provide.

3 DIAGNOSTICS EXPERIENCE, SNORRE-VIGDIS CROSSOVER

The diagnostic tools built into the Krohne Altosonic-V has proven to be very reliable, and is a strong guide to whether the processing and the piping installation is satisfactory. With proper processing, the liquid velocity of sound determined for the 5 beams, is normally found within +/- 0,1 m/sec from the average. Under severe slugging, difference around 100 m/sec has been experienced between the 5 beams. Also the velocity profile information is a strong indicator of unacceptable upstream disturbances. The original tee-connection for the Compact Prover calibration, with flow coming in 10 diameters upstream of the Master ultrasonic meter, showed a strongly distorted profile, in difference from the profile seen in normal operation.

Another useful tool is the Swirl indicator, which has also helped to validate the upstream straight pipe requirement. The higher Swirl Factor reading at the Master USM meter compared to the Duty USM meter, clearly shows that the piping configuration upstream of the 10 D of straight pipe must be included in the performance criteria. Whereas the Swirl Factor is always low for the Duty USM meter, the Swirl Factor for the Master USM is increasing with higher flowrate. The Master USM is automatically compensated for Swirl Factor bias influence. Both meters were installed with 10 diameters of straight upstream length, following a 10"x8" reducer. The Duty ultrasonic meter has practically no upstream disturbance except for the reducer, while the Master ultrasonic meter upstream reducer is immediately downstream of a series of 90 degree bends in different planes.

4 RECALIBRATION WITH COMPACT PROVER AT SNORRE-VIGDIS CROSSOVER 1999

The Compact Prover was now installed downstream of the Faure Herman Helical Rotor master turbine meter. Fixed piping was installed for all connecting pipe-work. The master turbine meter consisted, as earlier, from a complete meter run, including upstream meter run and straightening device, moved from the Snorre export oil metering station into the position held for this purpose downstream of the Master USM. The shift in the results from 1998, when the Compact Prover was installed with flexihoses, between the Master ultrasonic meter and the master turbine meter, was less than expected. The 1999 average K-factor results for the Master ultrasonic meter was approximate 0,1% above the results from 1998 and approximate 0,1% below the average original results from Krohne and NEL. Note however, that the original results from Krohne and NEL were determined in different pipe arrangements, both with long upstream straight lengths. In the in-situ calibration, synchronized pulse count for the Master ultrasonic meter and the master turbine meter was fixed to a one-hour period. During each of these hourly periods, the average turbine meter K-factor is determined from three complete 5 trial calibrations against the Compact Prover. This calibration became a challenge in December 1999, when stormy weather caused unstable flow, and thus difficulties in achieving the turbine meter repeatability requirement, in particular for lower flowrates. However, the ultrasonic meter calibration points that formally were ruled out reaffirmed the official results.

The fixed pipe modifications for the master turbine meter and Compact Prover installations allowed for 50% increase in the calibration flowrate capacity, which still resulted in 50% less capacity than the preferred calibration flow range. Further de-bottlenecking will be performed before the re-calibration 2000 against Compact Prover ; the original 4" calibration tee with 4" valve, downstream of the Master ultrasonic meter, will be replaced with a 6"section.

5 ALL YEAR 2000 PERFORMANCE FOR SNORRE-VIGDIS CROSSOVER DUTY ULTRASONIC METER - ONE DAY OF WATER SLUGGING OPERATION

In preparation for the future application method with ultrasonic meter's Meter Factor determination, the ideal curve for the Duty ultrasonic meter, calibrated with Master ultrasonic meter synchronized pulse count, was established. The 1999 synchronized verification data, compensated for the average shift in Master ultrasonic meter from the Compact Prover re-calibration, was used in the curvefit for the ideal Duty meter K-Factor curve. By comparing the 2000 Duty meter K-factors with the pre-established ideal K-Factor flow dependent curve, we can simulate the bias based on Meter Factor determination.

Except for one day with water slugging operation, more than 95% of the calibration points are inside +/- 0,10% from the pre-established ideal K-factor curve. Note that data represents flow directed both from Vigdis to Snorre as well as Snorre to Vigdis, however, in the same direction thru the ultrasonic meters.

A production well with fluid properties which are difficult to handle, was kept flowing from Snorre to Vigdis thru the Crossover oil metering station, during a period with Statfjord platform maintenance. For many hours , the water separation in the Snorre process was out of control, resulting in water slugging thru the Snorre-Vigdis Crossover ultrasonic meters, with flow signal dropout as the consequence. These dropouts are the only loss of flow measurement experienced for the three years of operation. Dropout happened 7 times and lasted up to 4 minutes, and could clearly be correlated with strong variation in the fluid density measurement, which for short periods indicated almost pure water coming thru the ultrasonic meters. Measured velocity of sound difference of approximate 100 m/sec was observed between the 5 ultrasonic beams. During this slugging operation, the Master ultrasonic meter run was opened for synchronized verification of the Duty ultrasonic meter. In a couple of cases the Master ultrasonic meter continued to function, although the Duty ultrasonic meter dropped out. It is likely that clogging of Duty ultrasonic meter transducers were contributing to the dropouts. The Duty ultrasonic meter K-factor for the hours without dropout was registered as test data. The results shown in the plot for these slugging periods ; inside +/-0,20 % from the established ideal K-factor curve, are indicating the extreme robustness of the Krohne Altosonic-V ultrasonic technology, when facing incompletely processed oil.

The 2000 annual average deviation from the 1999 performance curve is used as an indicator to the validity of our approach. I have to stress that this evaluation can only be regarded as an indication of the long term performance! The present 2000 average bias in K-factor from the pre-established curve, with all the registered data points included, is just above 0,01%. It could be argued that the data from the day of water slugging operation, should be excluded. However, the result, when the data from the day of water slugging is excluded, does not make it easier to accept the final figures ; average bias well inside 0,01%. Although these results are past what we expect to reproduce, it is a very strong indication of the long term repeatability from the Krohne Altosonic-V fiscal meters.

6 SNORRE B CALIBRATION PHILOSOPHY

The Faure Herman master turbine meter will be calibrated in-situ with regular intervals, initially every two months using the portable Compact Prover, temporarily installed. The Compact Prover will be wheeled directly into a fixed piping arrangement. The master turbine meter K-factor curve from the Compact Prover calibration, will be entered into the Snorre B master meter flow computer. The Duty ultrasonic meter will be calibrated with the master turbine meter; thru syncronized pulse count, during the same periods as the turbine meter is calibrated against the Compact Prover for a number of times. The resulting Duty ultrasonic meter K-factor curve or curve shift will be entered into the Duty ultrasonic meter flow computer.

In the operational period between Compact Prover calibrations, the Duty USM Meter Factor will be verified with the master turbine meter within every 4 days, in a synchronized count of pulses. When the ultrasonic meter historical curve is established, we might consider to use the Duty USM meter factor determination as an alert mechanism only, for whether the period between Compact Prover calibrations should be made shorter or longer. The data available indicates that the Krohne Altosonic-V is more reliable than any turbine meter, and that the long term repeatability is exceptional, compared to conventional measurement equipment !

7 SNORRE B FAT VERIFICATIONS AT DANIEL

The FAT at Daniel Industries was carried out with water circulating thru the metering skid pipe-work. However, the pipe-work for the Compact Prover wheel-in connection of the portable Compact Prover is not a part of the metering skid delivery. At the Daniel FAT, flexihoses was used from the portable Compact Prover pipe-work connections, downstream of the master turbine meter, in order to perform a functional test of the system. This functional test clarified a number of issues for the field application of fiscal metering with Krohne Altosonic-V ultrasonic meters.

7.1 Flexihose Problems

Using flexihoses to the Compact Prover, installed downstream of the master turbine meter, resulted in faulty K-factor determination for the master turbine. Significant flexihose bellow pulsation was observed. The bias varied compared to the initial Faure Herman calibration with 0,32% at 95 m^3/hr to 0,63% at 340 m^3/hr, and to 0,43 % at 640 m^3/hr. The evaluation showed that the Compact Prover rods displacement was partially absorbed by the upstream flexihose. However, in the field; fixed piping will be used, eliminating this effect.

7.2 Swirl Diagnostics

The static mixer located approximate 40 diameters upstream of the UFM resulted in swirl factor 0,5, indicating far too high swirl activity level, when the filter basket was removed. The swirl factor was then reduced below 0,3 with the filter basket reinstalled. The filter functioned as a profile conditioner, and also there possibly was some pocket disturbance effect while the filter was removed. This clearly shows that 20D of upstream straight pipe is not a sufficient requirement, as a stand alone criteria, in order to achieve fiscal performance.

However, in the real world situation ; with the filter clogged, the profile adjustment function from the filter might be reduced. The clogged filter might create an even more distorted profile. In normal offshore operation, the filter spool is therefore suggested to be replaced with a profile adjustor plate and a swirl removal tube bundle, in that sequence. During the initial phase, the filter is expected to be required for installation rubbish removal.

7.3 Syncronized Pulse Count Repeatability For Altosonic-V

The required volume for necessary repeatability of the ultrasonic meter K-factor determination was examined. UFM synchronized pulse count, based on the master meter pulse countdown method, resulted in excellent repeatability. With 5 x 17 minutes at 95 m^3/hr; the repeatability result was +/- 0,009%. With 5 x 14 minutes at 340 m^3/hr; the repeatability result was +/- 0,012%. With 5 x 10 minutes at 640 m^3/hr ; the repeatability result was +/- 0,014%. In all cases, this is based on 5 out of 5 trials. Note that pumps were used for the closed loop circulation, with inherent flow variations, similar to that of production facilities. The pre FAT test points also supported the indication; that the Krohne Altosonic-V K-factor repeatability seemed to be a function of time rather than volume. It should also be expected, that the time required is a function of the dynamic profile disturbance.

7.4 Meter Factor Results For Krohne Altosonic-V In The Metering Skid

Based on the very long distance from turbine meter to major disturbance (filter); 70D, the dynamic profile conditions were expected to be practically identical to that of the original master turbine meter K-factor calibration. The FAT data was therefore recomputed, based on the master turbine meter original K-factor curve, which was likely to be reproduced in the Snorre B oil metering skid pipe-work. Using the original Faure Herman calibration curve in the synchronized pulse comparison, the USM meter factors relative to the initial output frequency setting; 1000 Hz at 780 m^3/hr, came well inside the NPD requirements.

Average meter factors based on the initial setting:

At 95 m^3/hr	Meter Factor 0,9980
At 340 m^3/hr	Meter Factor 1,0004
At 640 m^3/hr	Meter Factor 1,0004

8 FUTURE RECOMMENDATIONS FOR FIELD ADAPTIONS

The master meter method approach can be recommended for application of the Krohne Altosonic-V ultrasonic oil meters. The most critical requirement is not whether 10D or 20D upstream straight length is used for the Krohne Altosonic-V. What is more critical is that the dynamic profile thru these ultrasonic meters, are naturally developed ; without severe disturbance elements for at least 50D. It is expected that 90 degree bends in the same plane, can be installed as close as 20D upstream of the Krone Altosonic-V. With similar requirements for the Faure Herman master turbine meter, the original onshore third party calibration curve for the turbine meter is also expected to reproduce itself offshore.

- Piping element installations past the 20D upstream straight length must be evaluated. Elements in the measurement pipe-work, that can be installed downstream of the USM, should be installed so.

- Static Mixer; recommended minimum upstream distance to USM, is more than 50D. Preferred location of static mixer and quality measurements are downstream of the USM.

- Filter for master turbine meter protection should be installed downstream of USM.

- Flexihose should not be used with Compact Prover for master meter and remote system calibration.

For the critical low Reynolds number zones, upstream disturbance can prevent fiscal quality measurement. In these critical zones, tolerance to the measurement of Reynolds number, internally made, is significantly lower. It is absolutely necessary, that the flow profile distribution is kept normal in these zones.

9 FAR FUTURE DESIGN?

In the far future, when the installation criteria for the Krohne Altosonic-V is complete, the master meter and its bypass might be removed from the skid. This will however, unless another type of master meter is used, put too strong of a requirement on the third party calibration, for significant lengths of fixed piping arrangements.

10 KROHNE ALTOSONIC-V FISCAL PRESENTATIONS

[1]	Frank Svendsen Saga Petroleum ASA	Test av ultralydmålere på Vigdis/Snorre Crossover (Norwegian text) (Test of ultrasonic meters at Vigdis/Snorre Crossover) NFOGM annual, Oslo 1998
[2]	Frank Svendsen/ Maron J.Dahlström/ Saga Petroleum ASA	Krohne Altosonic-V tests at Vigdis/Snorre Oil Crossover, Presentation, Saga Internet Home Page 1998
[3]	Maron J. Dahlström Saga Petroleum ASA	Two years of fiscal performance by the liquid 5path Krohne Altosonic-V ultrasonic meter at the Vigdis/Snorre Crossover measurement station NSFMW, Gardemoen, 1999
[4]	C. Jankees Hogendoorn/ Andre Boer Krohne Altometer	Experience with Ultrasonic Flowmeters in Fiscal Applications for Oil NSFMW, Gardemoen, 1999
[5]	Trond Folkestad Norsk Hydro ASA	Proving a fiscal 5 path Ultrasonic Liquid Meter with a Small Volume Prover. Can it be done ? NSFMW, Gardemoen, 1999
[6]	Steinar Fosse NPD	Ultralyd væskemåling (Norwegian text) (Ultrasonic liquid metering) NFOGM annual, Stavanger 2000

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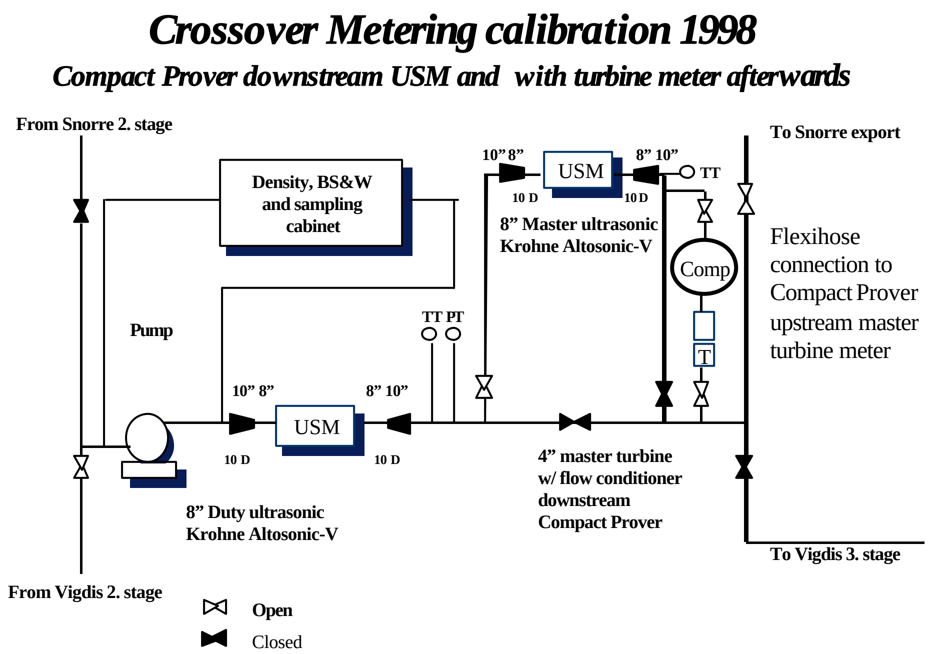
Effortless Oil Ultrasonic Fiscal Meter Operation :
Krohne Altosonic-V , with Master Meter Approach.
Vigdis / Snorre Crossover & the Snorre B Export Station.

NSFMW 2000
Gleneagles

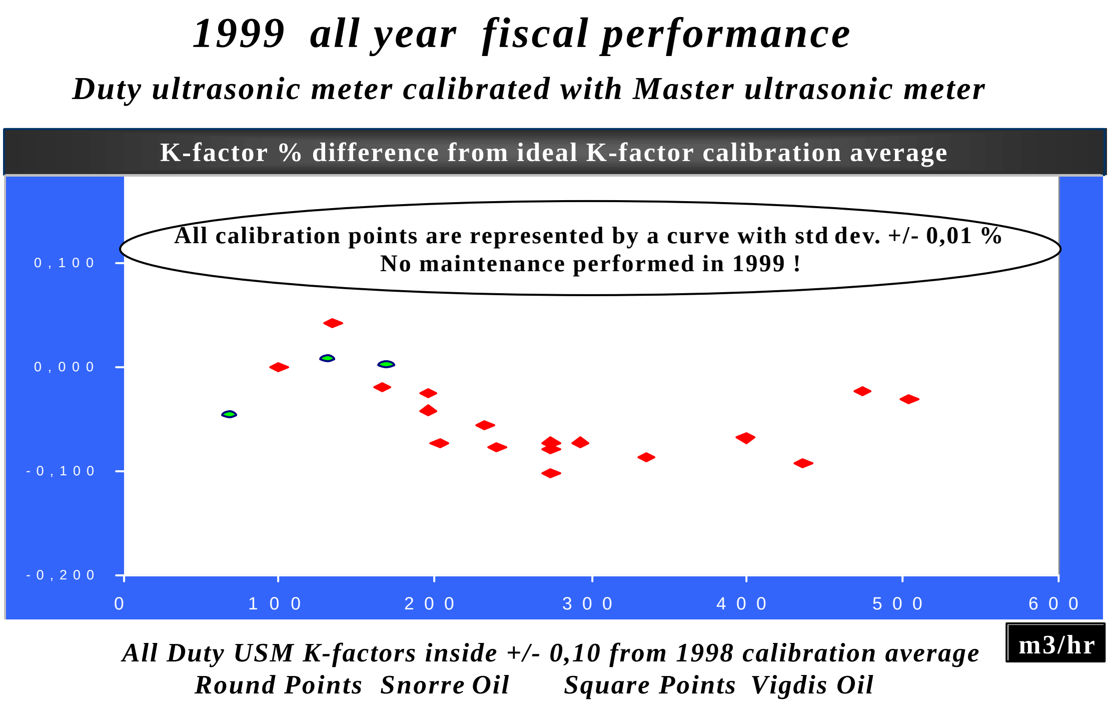
Maron J. Dahlström

Norsk Hydro ASA

Presentation Figure 1



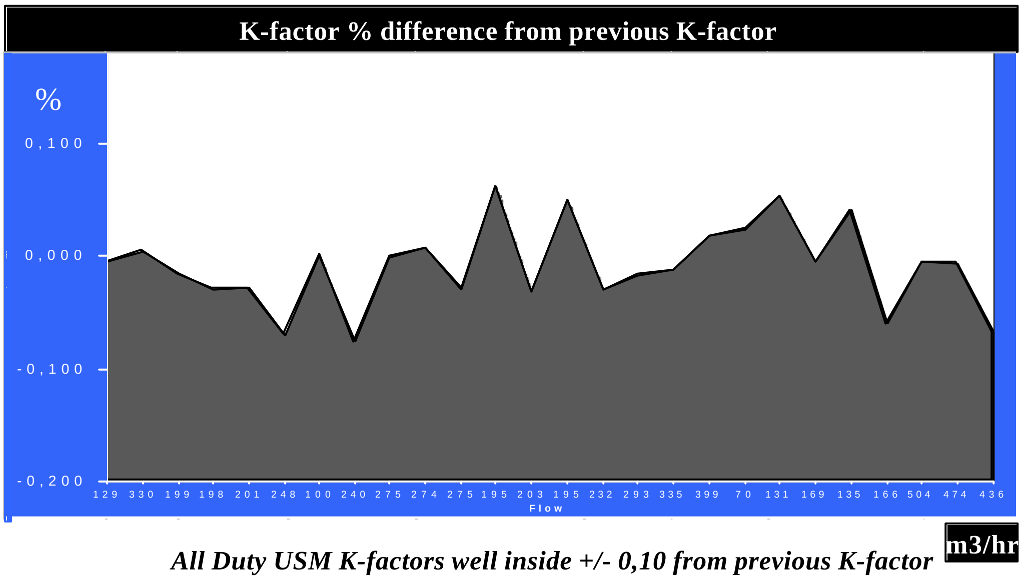
Presentation Figure 2



Presentation Figure 3

Fiscal performance 1999

Duty ultrasonic meter calibrated with Master ultrasonic meter

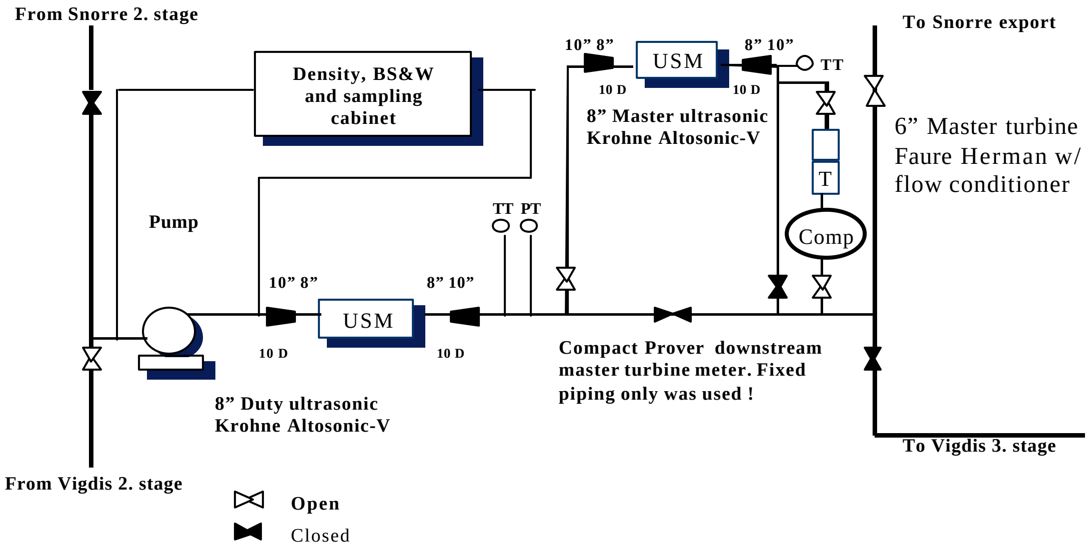


All Duty USM K-factors well inside +/- 0,10 from previous K-factor

Presentation Figure 4

Crossover Metering calibration 1999

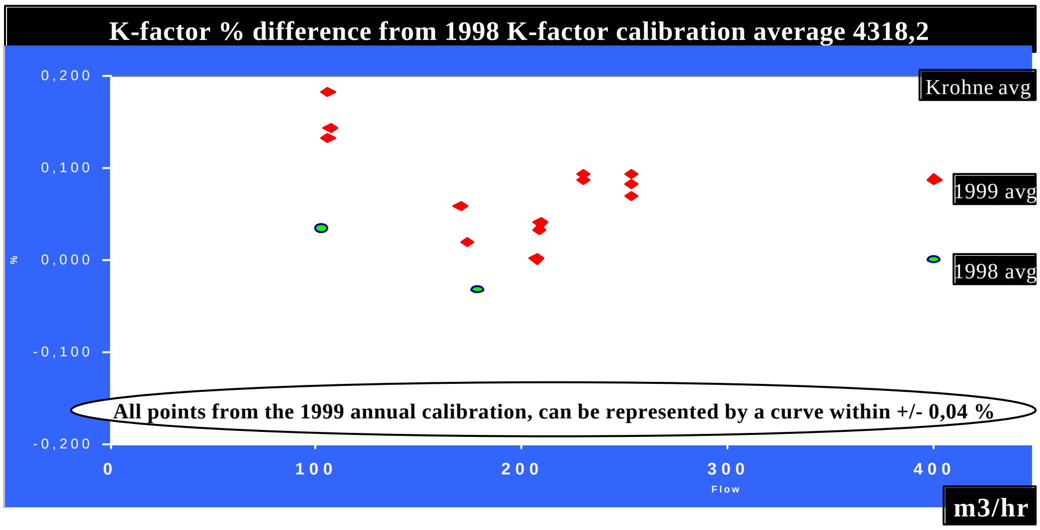
Reference turbine downstream USM and with Compact Prover afterwards



Presentation Figure 5

1999 Compact Prover calibration

Master ultrasonic meter calibrated with master turbine meter

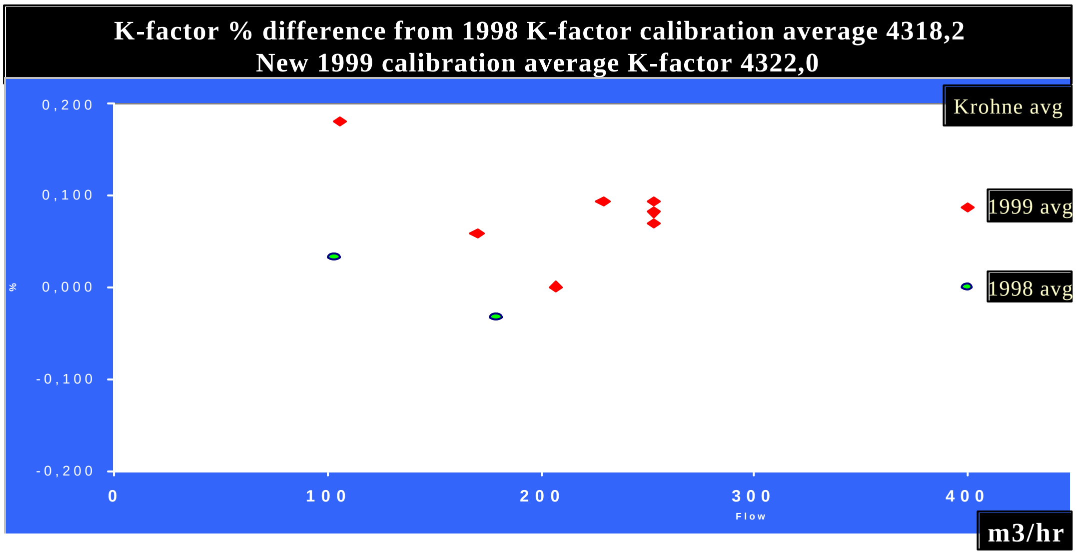


Round points from 1998 calibration . Including not approved points 1999.

Presentation Figure 6

1999 Compact Prover calibration

Master ultrasonic meter calibrated with master turbine meter



Round points from 1998 calibration . Approved turbine points only 1999.

Presentation Figure 7

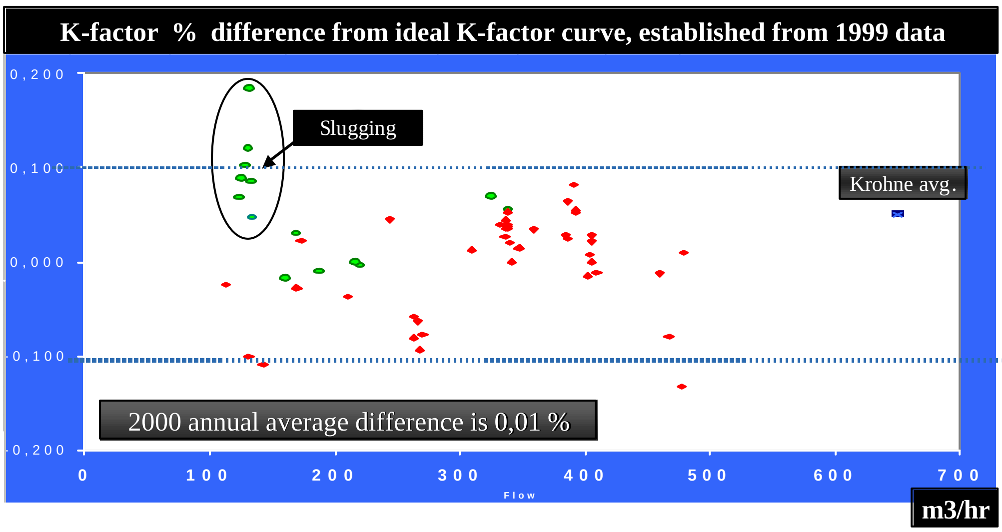
K-factor Master USM meter history

	Krohne jan.-97 Verification	NEL dec.-96 Verification	Saga / Krohne march -98 Verification	Con-Tech / Saga oct.-98 Calibration	Con-Tech / Saga dec.-99 Calibration
Used avg.	4326,9	4326,9	4326,9	4318,2	4322,0
80 m3/hr	4330,9	4329,0			
100 m3/hr				4319,6	
110 m3/hr					4326.1
130 m3/hr			4323,6		
160 m3/hr	4323,8				
170 m3/hr					4320.8
180 m3/hr				4316.8	
200 m3/hr			4330,4		
210 m3/hr					4319,0
220 m3/hr		4323,0			
230 m3/hr					4322,3
250 m3/hr					4321,7
330 m3/hr	4326.8				
360 m3/hr		4322.0			
490 m3/hr	4329,1	4325,0			
640 m3/hr		4327,0			
740 m3/hr	4326.6				

Presentation Figure 8

2000 all year performance

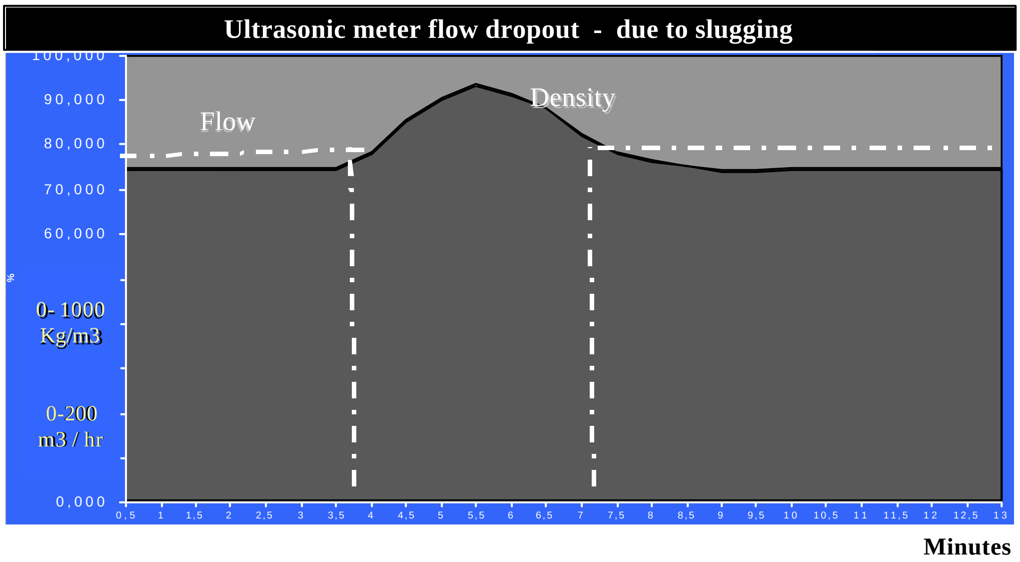
Duty ultrasonic meter calibrated with Master ultrasonic meter



Duty USM K-factors, including all additional test points
Round Points Snorre Oil Square Points Vigdis Oil

Presentation Figure 9

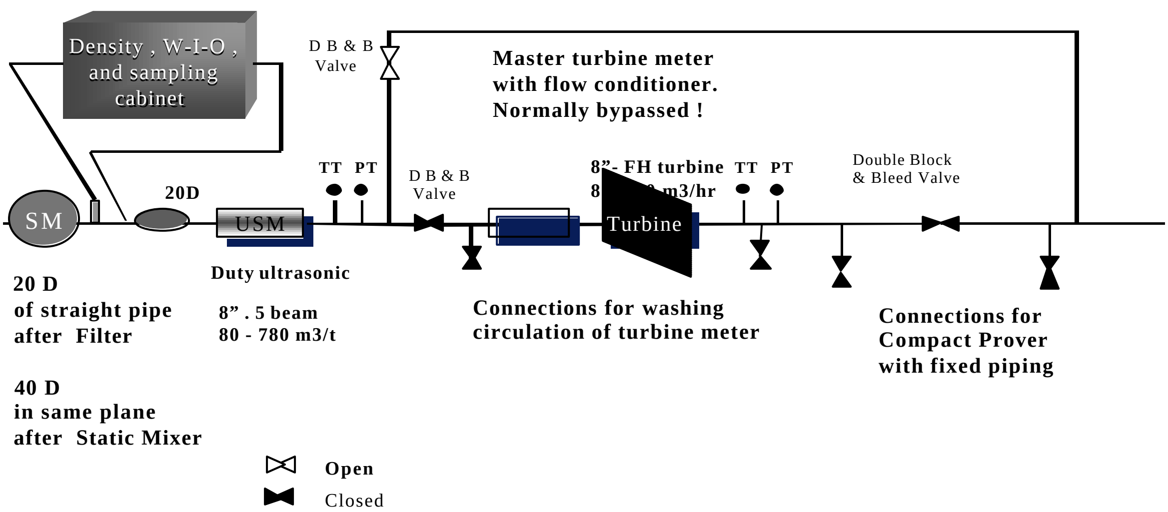
Water slugging performance 2000



Presentation Figure 10

Snorre B configuration :

Fiscal measurement station for oil with USM



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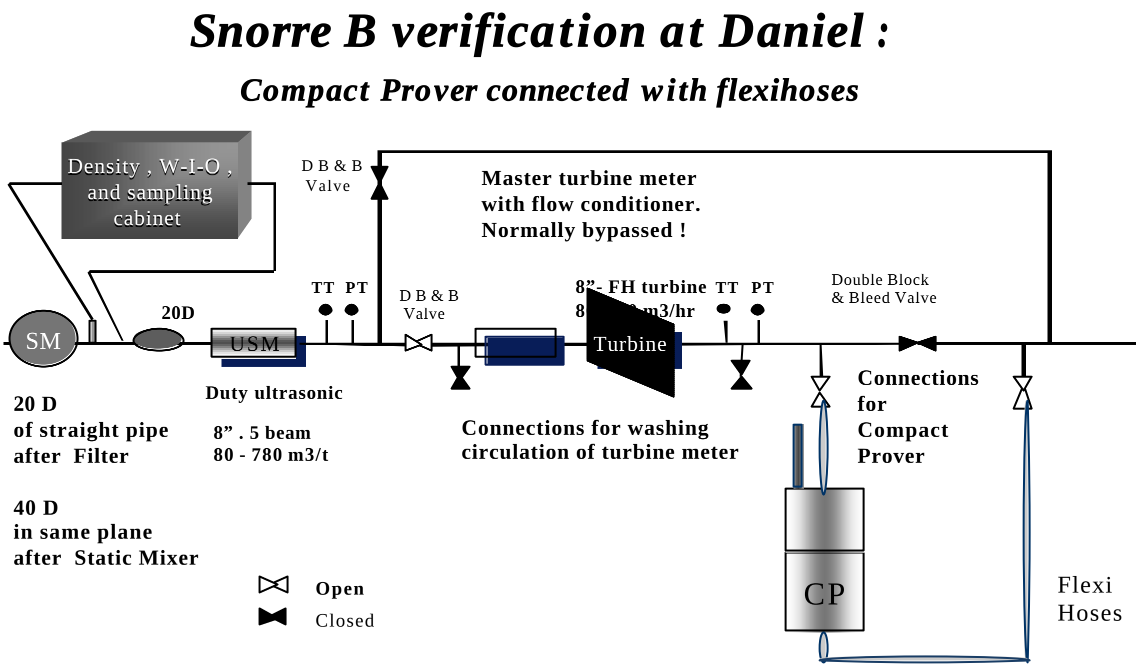

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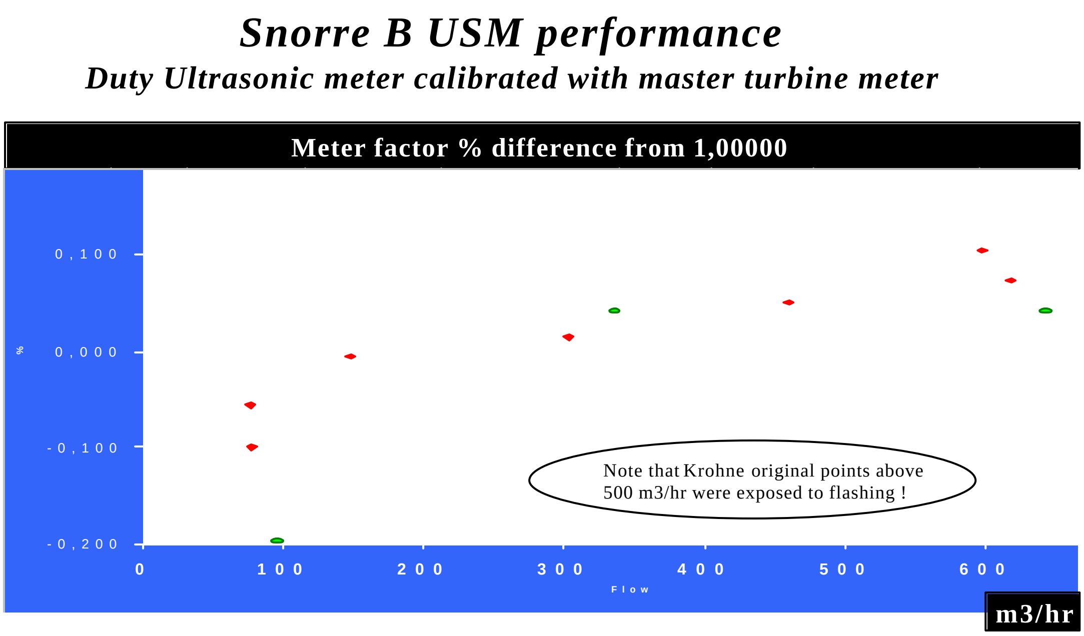
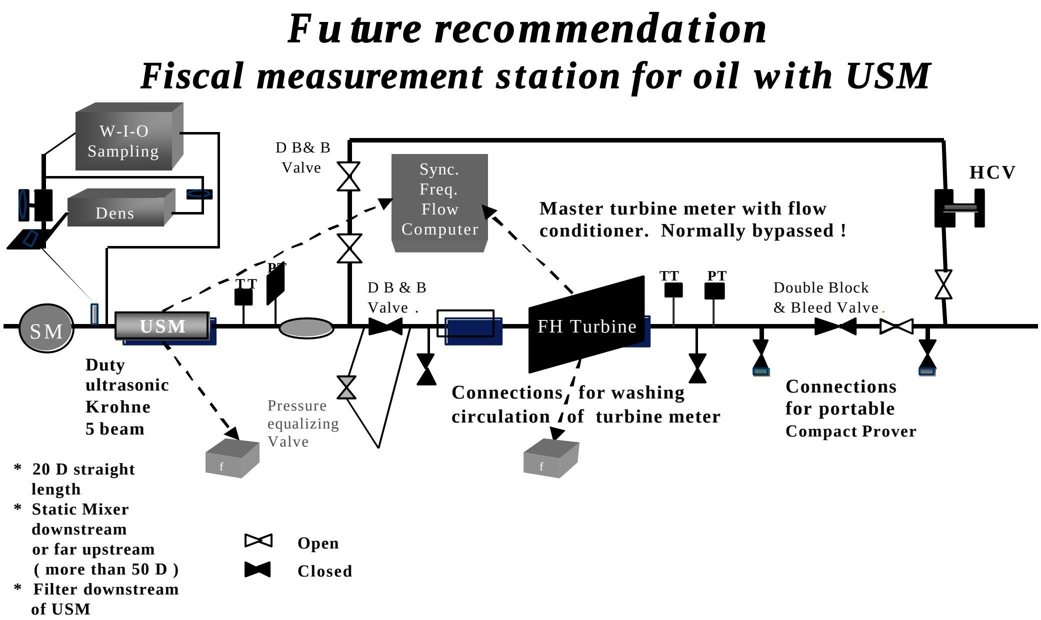


Square points from Krohne original verification & Round from verification at Daniel

Presentation Figure 13



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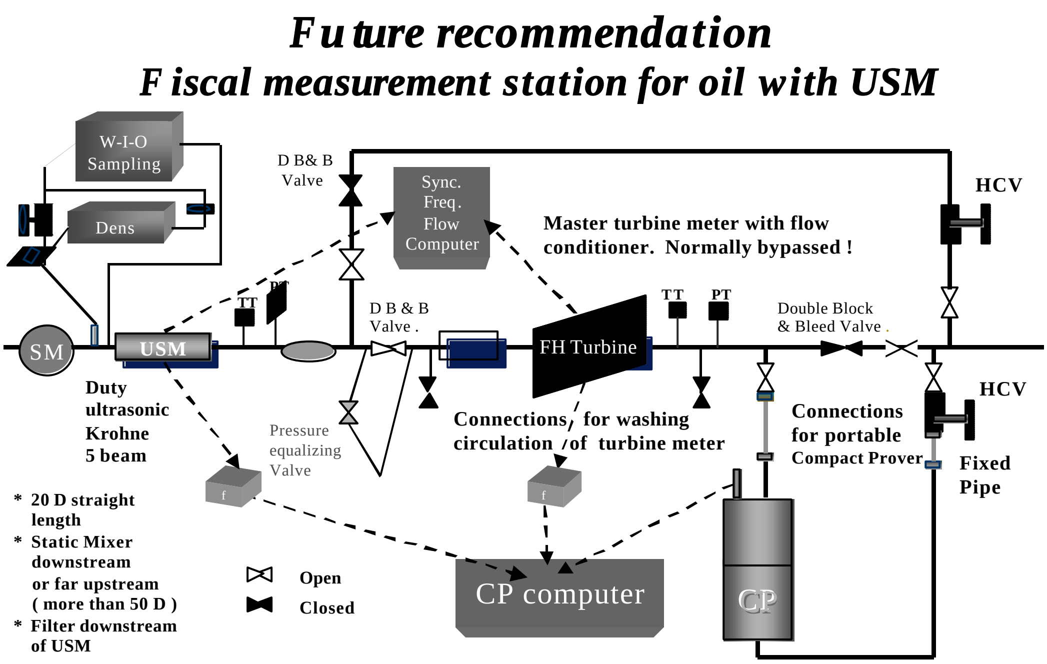
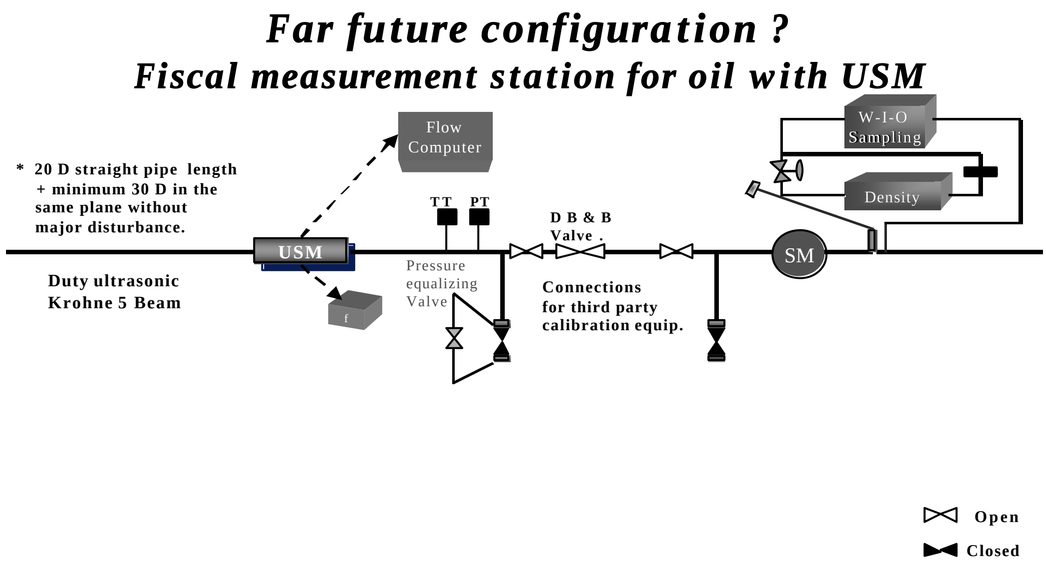


Presentation Figure 15



Presentation Figure 16