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North Sea FLOW Measurement Workshop

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Paper 2.1

5 Years Offshore Operational Experience of 3-Path Gas Ultrasonic Flowmeters in Custody Transfer & Allocation Measurement Systems

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1 INTRODUCTION

This paper presents an overview of the practical metering issues experienced on the Custody Transfer and Allocation measurement systems onboard an installation in the North Sea. All data presented is taken from four operational and two new 3-path transit time ultrasonic meters. The data was collected over the period May 2000 to Aug 2006 and is presented blind for confidentiality.

Ultrasonic measurement technology has been used by many operators in the North Sea for many years now. The paper highlights some of the potential issues facing users of this technology in Custody Transfer & Allocation applications.

2 SUMMARY OF EXPERIENCES

General experience over the past five years has been varied. Some interesting issues have affected the ultrasonic flowmeters, such as:

- During a new meter calibration at a European Gas Test facility – A Swirl path on a twelve inch meter had a severe loss of performance at 10% of the flow range only but had 100% performance at 5, 20, 50, 70 & 100% of the range

- First Stage Separator problem led to suspected noise induced meter electronics failure (severe performance loss on all paths)

- Observed performance loss on the Axial path at operating conditions required a transducer change out - subsequent calibration shift recorded, which could be attributed to the transducer change out, was 0.45%

- Performance loss on the axial path required a transducer change out - subsequently the new transducer failed at stream pressure causing a gas leak on the plant. The meter was removed so that the transducers could be replaced. Each transducer was pressure tested to 340 bar

…and there were some successes too, namely:

- Extending the flowrate envelope on an 8 inch Allocation meter, by testing at a European Gas Test facility up to 30 m/sec and above
- Online identification and reporting of faults
- Change of operating philosophy and subsequent reduction in exposure (procured spare meters), and successfully challenged established practise and changed recertification philosophy to use new calibration spools

2.1 Online Diagnostic Monitoring & Evaluation

Online performance monitoring and evaluation was undertaken using the following comparisons and parameters as measures of operational efficiency, as recommended by the manufacturer [1]:

- Velocity of Sound (VofS) and Raw Gas Velocity comparison between all paths
- AGC Level Ratio
- Gas Velocity Check (All paths, Zero flow, Operating conditions)
- Theoretical Velocity of Sound comparison at Zero Flow
- Noise Ratios
- Individual Path Performance

It was observed from the historical evidence that the majority of diagnostic performance issues occur on the Axial measuring path L2. During the review period only one fault was witnessed on the double bounce Swirl paths L1 or L3.

All data is extracted and recorded in 'Log Files' using the manufacturer's supplied software. The measurement technicians on the platform had been instructed to record data when the following occurs:

- Any process upset which may potentially have caused contamination in the flow lines
- Sudden or unexpected changes in flow rates with no consequent change in the process conditions
- When placing a stream on or offline for preventative maintenance. This involved recording an online log for the currently online stream, an online log for the stream coming online and also a zero log file for the stream online when it comes offline
- After installation (at weekly intervals until qualitative performance is verified)

Specific notes to technicians for the recording of routine log files:

- Ensure the velocities of the individual paths are logged
- For the 'Zero Check', ensure the gas inside the pipe section is stable, at operating conditions (no temperature convection, no pulsation of gas and no leakage/passing of block-valves). On occasions, it may not be possible to perform a zero-flow check either due to lack of suitable isolation or because environmental effects impact on the stability of the meter.
- To record an online flowing log-file a stable flow is desired. It is recommended to take a log-file for a minimum of 3 minutes (if possible at different flow rates e.g. 70% and 20% of the maximum flow rate). If it is not possible to control the flow to the preferred flow rates, any other flow rate available for making a log-file should be used i.e. up to 100%, thus providing data at normal operating conditions

Each parameter in the log file record was analysed onshore for signs of deviation from the previous record. Log files contain 'by the second' data and can be recorded for any given length of time. Therefore, a 'snap shot' was calculated by taking the average of each parameter in each log file, and this was compared with the history to provide the performance metric for each meter. Figures 01a and 01b below show details of the calculated average of several log files for six inch Meter 'A'.

	6" Meter 'A'		*Performance*				*Corrected*	*Vol. Flow*			
Date	*Comment*	*Sample Rate*	*L1*	*L2*	*L3*	*Average VOS*	*Gas Velocity*	*@ Line Condition*	*Swirl*	*Press*	*Temp*
13/04/4	Online Str 1 @10:37	15.0	15.0	*10.7*	15.0	427.33	10.4	505.0	1.1	161.0	38.40
15/07/4	Online Str 1 @15:53	15.0	15.0	*13.9*	15.0	429.90	11.5	561.3	1.0	162.4	34.10
05/07/5	Online Str 1 @10:37	15.0	15.0	15.0	15.0	416.16	7.8	380.0	1.0	165.93	34.90
14/03/6	Test Facility	15.0	15.0	15.0	15.0	377.09	8.4	411.1	1.6	48.33	1.78
15/03/6	Test Facility	15.0	15.0	15.0	15.0	373.00	26.9	483.7	1.5	48.08	11.62
31/07/6	Online Str 2 @15:05	15.0	15.0	15.0	15.0	409.54	6.4	313.3	0.9	154.71	34.50
27/08/6	Online Str 2 @15:57	15.0	15.0	15.0	15.0	411.42	5.6	272.3	1.2	151.41	35.00
31/08/6	Online Str 2 @08:33	15.0	15.0	15.0	15.0	402.51	4.8	231.9	1.1	146.99	34.20

Table 01a: Meter 'A' – Recent ONLINE History – Average Log File Data

6" Meter 'A' cont.	*Individual Path VOS*			*Raw Gas Velocities*			*Velocity of Sound Ratios*			*AGC Level Ratio A/B*		
Date	*L1*	*L2*	*L3*	*L1*	*L2*	*L3*	*1 to 2*	*1 to 3*	*2 to 3*	*L1*	*L2*	*L3*
13/04/4	425.85	*428.96*	427.43	11.4	*6.09*	11.1	*-0.73%*	-0.37%	*0.35%*	1.00	*1.76*	0.99
15/07/4	428.19	*431.49*	429.74	10.8	*16.50*	10.5	*-0.77%*	-0.36%	*0.40%*	1.00	*0.52*	0.98
05/07/5	415.88	414.97	417.44	7.90	7.84	7.66	0.22%	-0.37%	-0.59%	1.00	0.99	0.99
14/03/6	376.82	376.01	378.06	8.60	8.53	8.21	0.21%	-0.33%	-0.55%	1.05	0.96	1.04
15/03/6	375.97	375.17	377.21	10.2	10.1	9.77	0.21%	-0.33%	-0.54%	1.03	0.95	1.03
31/07/6	409.31	408.44	410.74	6.51	6.46	6.33	0.21%	-0.35%	-0.56%	1.00	0.98	1.00
27/08/6	411.21	410.31	412.64	5.68	5.61	5.49	0.22%	-0.35%	-0.57%	0.99	0.99	1.00
31/08/6	402.30	401.46	403.71	4.84	4.79	4.68	0.21%	-0.35%	-0.56%	1.00	0.99	1.00

Table 01b: Meter 'A' – Recent ONLINE History – Average Log File Data (continued)

The operational philosophy since first production was to keep and maintain detailed records of each meters performance, particularly between recertifications, in order to provide a baseline for the subsequent recertification and for the next period of service. The recorded data was also used as evidence of qualitative performance of the meters. The long term objective is to provide historical evidence to support relaxation of the meter recertification periods from the regulators and other interested parties including the pipeline operator.

Up to 31/08/06 approximately 95 log files for Meter 'A', 93 for Meter 'B', 27 for Meter 'C' had been recorded and analysed.

2.1.1 Velocity of Sound (VofS) & Raw Gas Velocity comparison between all paths (Normal Flowing Operating conditions)

This is a direct check by comparison of each path's Velocity of Sound and Gas Velocity data with the other paths.
The VofS is derived from the average travel times (upstream and downstream) and the acoustic path length. The VofS check was performed to confirm that the individual paths VofS tracked each other. The VofS tolerance used was ±1.0%.

The Raw Gas Velocity of the axial path was also compared to that of the swirl paths to ensure that they also tracked each other. The tolerance used was ±1.0 m/sec. If acceptable, this check confirmed that there were no significant problems with the meter and that there were no significant changes in the operation of the plant which might have resulted in velocity profile changes at the meter. The axial path raw gas velocity is sensitive to the flow profile and a severe profile disturbance would be observed in the axial raw gas velocity if it existed.
Some examples of detected faults are shown below in figures 01 to 04:

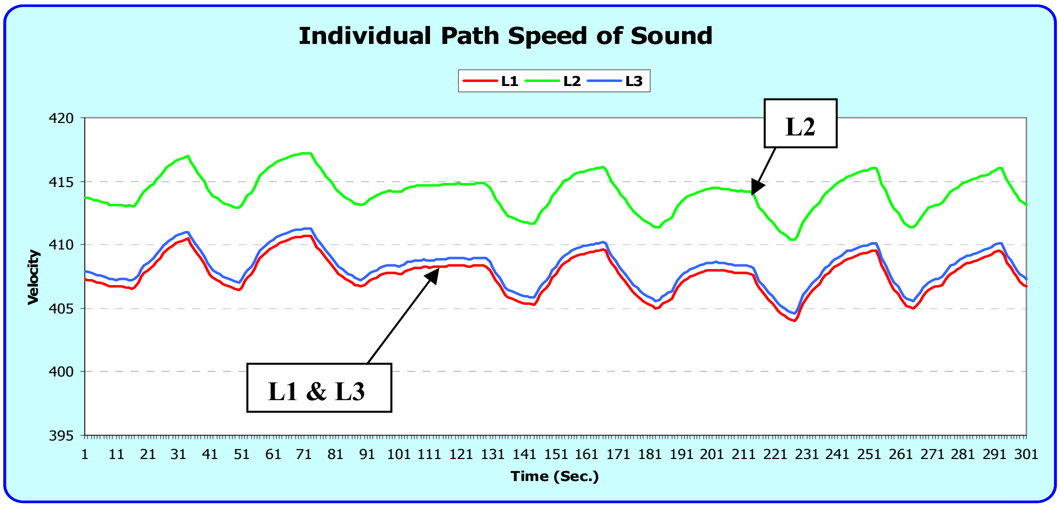

Figure 01: 07/07/06 – Problem evident on Meter 'B' Axial path L2 – Velocity of Sound reading high

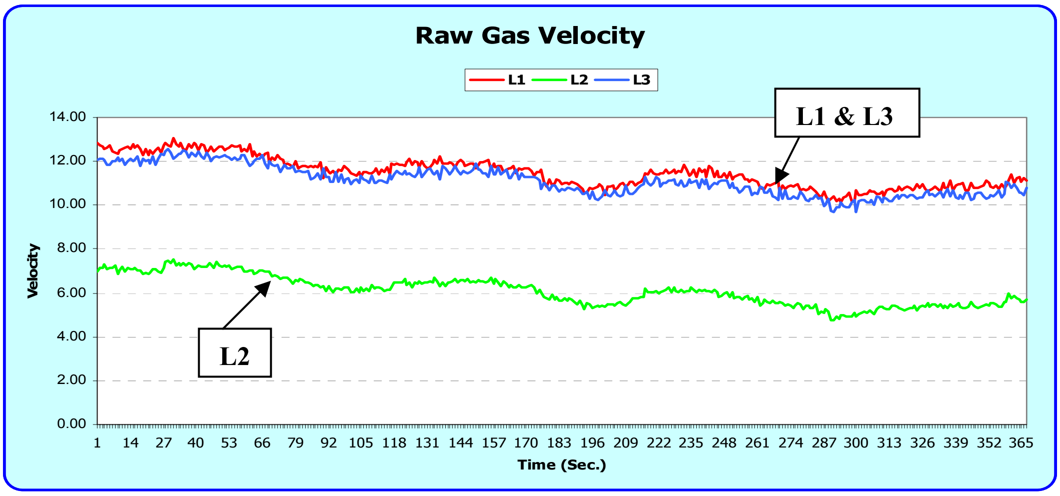

Figure 02: 13/04/04 - Contamination Detected? – Meter 'A' Axial path L2 fault – Raw Gas Velocity reading low

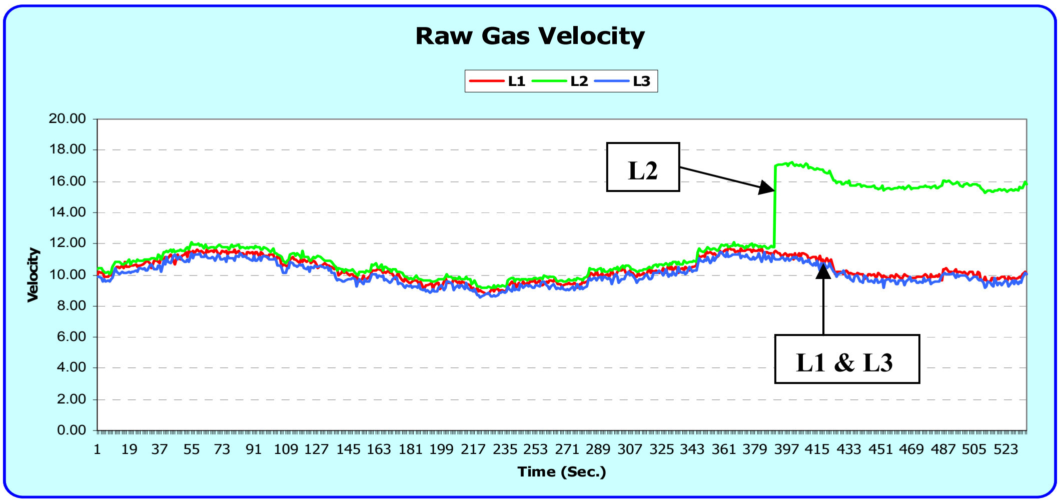

Figure 03: 15/07/04 - Contamination detected? – Meter 'A' Axial path L2 fault – Raw Gas Velocity jumps to reading high

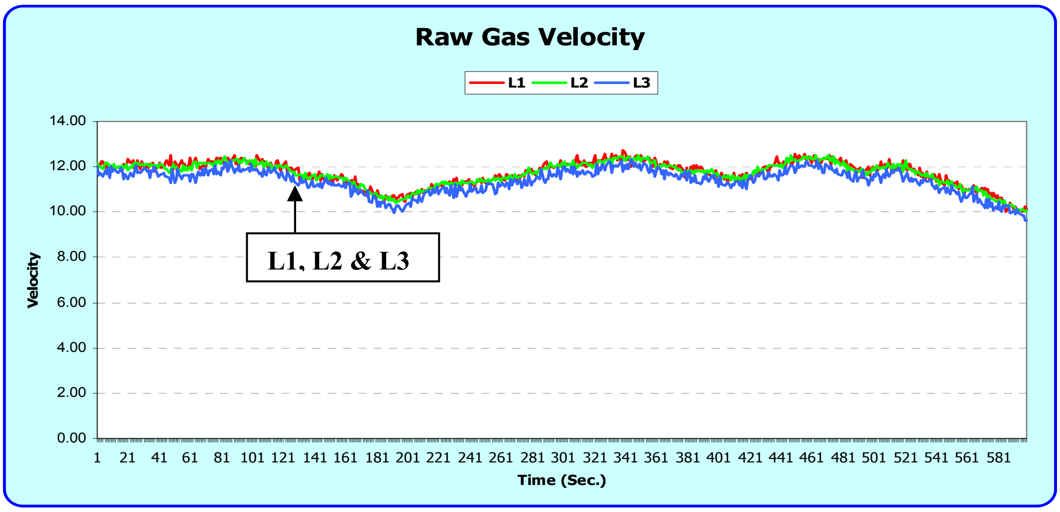

Figure 04: 22/07/04 - Contamination removed from Meter 'A' without mechanical intervention

For the fault conditions noted in figures 02 & 03, the meter stream was depressurised, vented down and put back online. The fault with the axial path on Meter 'A' was cleared (see figure 04). As this appeared to be an intermittent type issue relating to the signal quality on the axial path, the decision was taken (based on diagnostic data performance of less than 90% [5]) to change out the axial transducer pair at the next opportunity.

Meter 'A' was calibrated in August 2004 and the shift was found to be -0.315% from the previous calibration. The Axial path transducers were then changed out and an 'As Left' calibration was performed, with a resulting *calibration shift of -0.452%.* The meter calibration shift was attributed to the transducer change out.

Since changing the axial path transducers on Meter 'A', there have been no further recorded occurrences of performance loss on the axial path, either offshore in the operational mode or onshore during calibration.

Meter 'B' (not in service at present) transducers will also be replaced at the next opportunity after the meter has been 'As Found' recertified (See Figure 01).

2.1.2 Automatic Gain Control (AGC) Level Ratio

The manufacturer states that *"An AGC circuit automatically adjusts the strength of the received signal. This results in an 'AGC Level' that is inversely proportional to the received signal strength. Consequently, the AGC Level will be proportional to the path length and inverse proportional to the gas pressure.*
At higher flow rates the AGC Levels tend to increase due to the attenuation of the acoustic signal.
An increase in the AGC Level, even when disproportional, would not harm the accuracy of the gas flow measurement, but may indicate that the acoustic signal is attenuated more than normal, for example due to contamination of the piping." Extracted from [4]

The AGC level ratio is calculated as;

AGC of transducer A divided by the AGC of transducer B

Using the comparison of the AGC level ratios over the past 5+ years it has been straight forward to identify 'step changes' in the AGC level ratio for Meter 'A' and Meter 'B'. These step changes were observed in the characteristics of one pair of transducers and their associated measuring paths and were put down to:

- Contamination on the transducer face or pipe floor

On this fault occurrence, the first course of action was to take the meter offline vent and depressurise the stream. The stream would then be put back online and a further log file would be recorded. If the fault still existed then it was possible that the performance of the transducer was starting to degrade, therefore the meter must be removed for recertification and transducer changeout. All removed transducers were returned to the manufacturer for fault diagnosis.

Comparison of AGC levels for the axial measuring path was one of the clearest indicators of potential problems. As can been seen from the trends of the axial paths for Meters 'A' & 'B' in figures 05 & 06, the ratio of the AGC Level Ratio varies considerably when a problem occurs. The acceptable ratio should lie between 1.00 and 1.04, and this was normally the case but at times ratios as low as 0.53 and as high as 1.75 was observed.

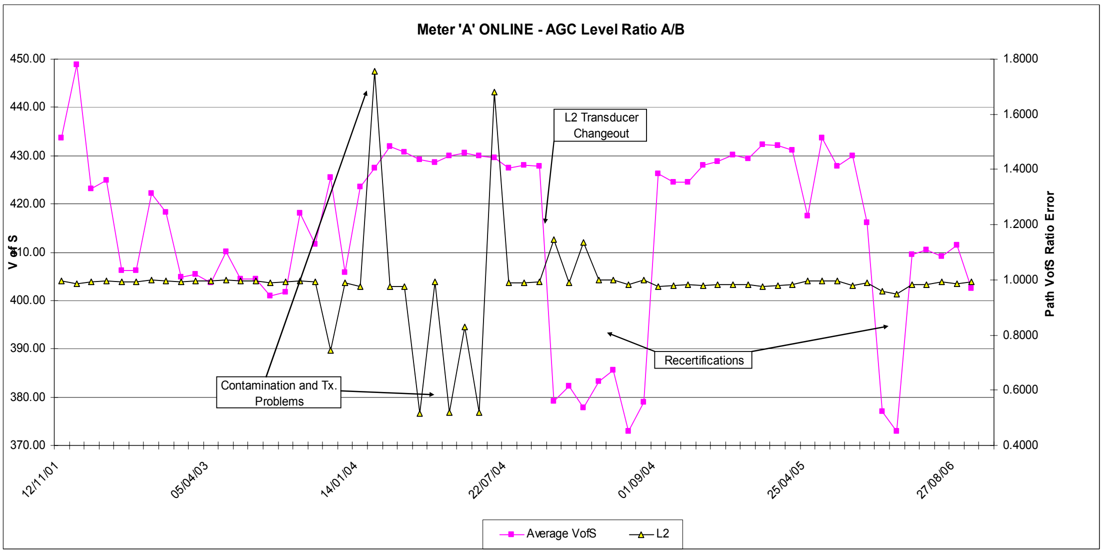

Figure 05: Historical AGC Level on Meter 'A' Axial Path

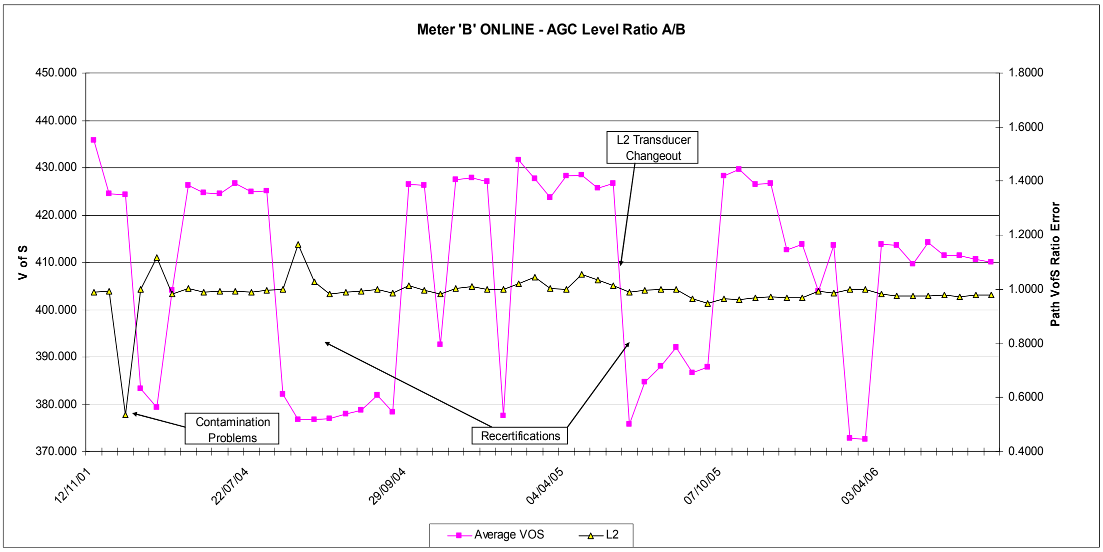

Figure 06: Historical AGC Level on Meter 'B' Axial Path

Historically for Meters 'A' & 'B', the axial path performance levels and signal quality have declined. This resulted in decisions to change out two sets of transducers, both on the axial paths, to try to achieve the best signal quality and performance.

2.1.3 AGC Limit / Level Ratios (Effective Signal to Noise Ratios)

As per the manufacturer's recommendation, it has been observed in Meter 'D' and Meter 'E', that the Effective signal to noise ratio (AGC Limit / AGC Level Ratio) has been high when the meter has been performing well and low when it has suffered from noise interference. For example, when testing Meter 'E' over the extended flow range, the noise ratio fell below ten at gas velocities above 31.1 m/sec. Above this velocity the accuracy of the meter declined, as can be seen from the error against Q_{ref} shown in figure 09.

2.1.4 Gas Velocity Check (All paths, Zero flow, Operating conditions)

This is a direct check by comparison of each path raw gas velocity data with the other paths with the meter shut in. The zero flow raw gas velocity tolerance used was ±0.01 m/sec.
This check was performed in order to establish that there was no performance loss or gas velocity readings on any path at the zero conditions.
Log files are extracted with zero flow at normal operating pressure and slightly reduced temperature conditions. The tolerance of ±0.01 m/sec has proved to be realistic and achievable for the Custody Transfer application. There have been no significant issues detected whilst carrying out this check.

2.1.5 Theoretical Velocity of Sound comparison at Zero Flow

C1	C2	C3	nC4	iC4	nC5	iC5	C6+	N2	CO2	H2S	H20
78.8	9.8	5.7	1.6	0.9	0.4	0.4	0.5	0.5	1.4	0.5ppm	16ppm

	Pressure	Temperature	Velocity of Sound	Density
Typical Values	150 barg	35°C	410 m/sec	180 kg/m^3

Table 2: Typical Composition and Calculated Values

A comparison of the theoretical VofS with the meter-calculated values for each of the paths was performed at zero flow conditions. It is recommended to perform this check between 2 and 6 m/sec [4], however, all checks were performed at zero flow due to the instability of the Custody Transfer flow rates (see figure 01). This test was only as good as the quality of the data collection and it was vital that the meter was fully isolated from the flow and that composition, pressure and temperature information were recorded at the time the log file was recorded (but the temperature always reduced very quickly).

The realistic tolerance for acceptance of this check proved to be ±1.0% of the theoretical value. This is greater than the recommended acceptable tolerance of ±0.25% [4].

The largest discrepancy observed was +0.77%, the lowest was -1.11% with the mean of -0.12% (from 33 recorded zero log files).

A secondary check performed at zero flow conditions was the AGC Level Ratio (as described in 2.1.2 above) comparison. However, unlike at flowing conditions the AGC Level Ratio remained close to unity on all recorded log files. This was even the case when it was suspected that contamination was affecting the meter and transducers.

Due to the operational difficulties associated with collecting representative data required for the theoretical VofS comparison, there was no additional information of value obtained. Therefore, unless there is <u>a stable flow rate</u> and the comparison is performed between 2 and 6 m/sec, this check has little benefit.

2.1.6 Individual Path Performance

The manufacturer states that *“Although, loss of performance can be linked to a rise or fall in the path VofS, the software rejects all signals that do not meet the pre-set signal criteria. Therefore, the diagnostic log file minimum, average and maximum VofS may be suspect for a particular path, but the suspect transducer signals will not be used in the bulk mean velocity calculation. So, even although transducer performance loss is detected, measurement accuracy will not be compromised as long as performance is above 20%.”* Extracted from [5]

No evidence to contradict this statement was found during the review period. Individual path performance loss observed at normal operating conditions offshore (150-160 bar) was not observed onshore at the test facility conditions of 55 bar, and importantly, no significant shifts have occurred at the recertification for meters with observed offshore performance loss.
Is the pressure difference i.e. 160 bar offshore and 55 bar a significant factor? Or perhaps it is the density difference (180 kg/m^3 offshore and 50 kg/m^3 onshore), but should it not be more difficult for the acoustic signal to propagate through the gas with the onshore conditions?

It is not possible to say based on the evidence collected during the review period that measurement accuracy is being affected by the offshore performance loss. However, it was disconcerting to observe performance loss in the operating environment and not in the calibration environment.

As a precautionary measure, meter ‘A’ Axial path transducers were changed out in August 2004, due to the reduction in performance (<90%). Meter ‘B’ Axial transducers were changed out in August 2005 for the same reason.

2.2 Recertification Strategy

Each meter is removed and recertified at a National Flow Calibration Facility after approximately six months in service. The meter is also removed and recertified if it is believed that an error exists from review of the diagnostic data. The meters are calibrated in the condition that they left the line i.e. they are not cleaned (apart from the standard safety critical hydrocarbon removal)

Over the review period, there have been a total of four calibrations on Meter 'A' and five calibrations on Meter 'B'. Meter 'C' is now 'in service' but was only procured in late 2005 and has had only the initial 'clean' calibration performed but should prove valuable for comparison purposes in the long term.

As each meter is recertified, a log file is recorded offshore on the platform with the meter filled with Nitrogen at a pressure greater than 5 bar (usually 15 bar). This log file is then compared with a log file recorded under similar conditions at the Test facility. This allows a comparison check to determine if any of the fundamental measurements or parameters has changed during the transit to the test facility. The check is repeated on each meter when it returns and is refitted on the platform. During the 5+ years in service, this test has not identified any significant problems with the fundamental measurements or parameters. This is due, in part, to the diligent and careful handling of the meters in transit. The author believes this check is of importance in establishing that the meter is in the same condition as it was during 'service', thus supporting any 'As Found' certification shifts.

2.2.1 Adjust Factor - Single Point Flow Weighted Mean Error

Each meter has a single point adjust factor error correction applied after each recertification in accordance with BS7965:2000 Annex C.2 [2]. This was approved and included in the recertification philosophy, to establish a standard and open method for calculating the meter adjust factors.

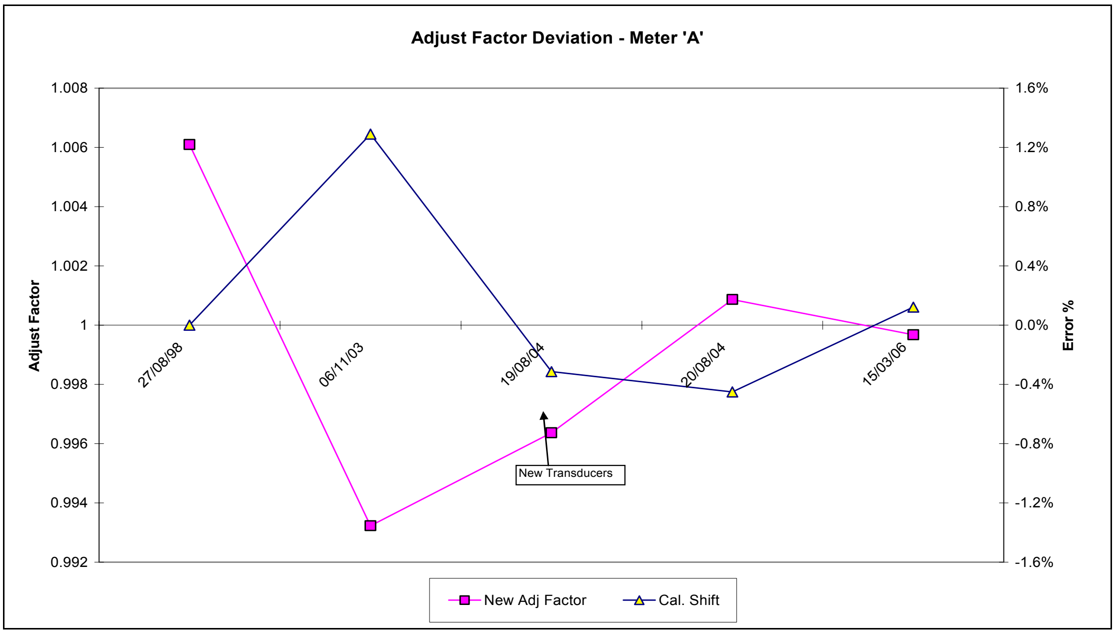

Figure 07: Single Point Adjust Factor Deviation - Meter 'A'

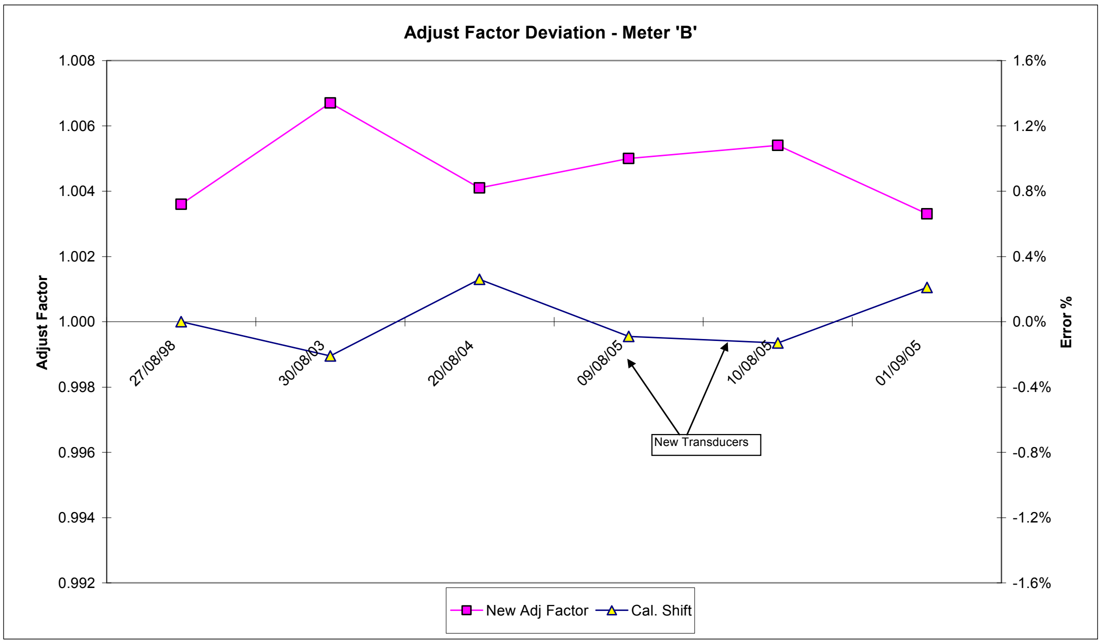

Figure 08: Single Point Adjust Factor Deviation - Meter 'B'

Figures 07 & 08 show the adjust factor deviations for all of the six-point flow calibrations carried out on Meters 'A' and 'B'. Six of these tests have been within the general acceptance criteria of ±0.3% for Custody Transfer recertification shifts. Any shift out with this tolerance was dealt with via an agreed mismeasurement process.

Meter 'A' was more erratic and had one shift of 1.29% (the first 'dirty' calibration) and one of -0.315%.

The Meter 'B' shift at the first 'dirty' calibration was -0.21%.

It was observed that when meters 'A' and 'B' Axial path transducers were changed out (August 2004 and August 2005 respectively) the meter adjust factors returned closer to unity.

2.3 Transducer & Electronics Performance

During the past 5 years three pairs of transducers have been changed out. Two change outs were precautionary due to observed path performance loss and one was for a gas leak.

Date Changed	Reason for Change	Calibration Shift
Meter 'A' Path L2 – 20/08/04	Performance Loss @ Line P	-0.45%
Meter 'B' Path L2 – 10/08/05	Performance Loss @ Line P	-0.06%
Meter 'B' Path L2 – 01/09/05	Pressure Leak In Service	0.21%

Table 03: Transducer Change Outs & Calibration Shifts

It was observed that calibration shifts, post axial transducer change out, can vary quite significantly.

2.3.1 12 Inch Meter 'F' – Factory Acceptance Test

An independently witnessed acceptance test of a twelve inch meter was carried out at a European Flow Calibration facility in December 2005. The results summary from the initial test can be seen in table 04 below:

Average Individual Path Performance Over Complete Flow Range (% of Valid Samples)						
	Point 6 5%	Point 5 10%	Point 4 20%	Point 3 50%	Point 2 70%	Point 1 100%
Path L1	100	*6*	100	100	100	100
Path L2	100	100	100	100	100	100
Path L3	100	100	100	100	100	100

Table 04: Calibration of 12" Meter 'F' – Dec 2005

An interesting phenomenon was noted on Swirl Path L1 at a flow velocity of 3.0 m/sec (10% of flow range). The path performance was excellent at 20% of the flow (Point 4). At 10% of the flow (Point 5), only six percent of the samples were valid. The path then went back to excellent performance at 5% of the flow range. The resulting error against the reference meter Q_{ref} at 3.0 m/sec, was an under measurement of 2.0%.

The phenomenon was observed to be repeatable after increasing and decreasing the flow rates. The performance loss was still observed and the error of -2.0% against the reference meter was still evident.

The manufacturer was unable to ascertain the cause of the performance loss and subsequently, the transducers for this path were deemed to be faulty and were replaced. The calibration, post transducer change out, was satisfactory with no performance loss at any of the test points.

The results of this calibration lead to the conclusion that it is important to test your meter at the actual operating conditions, as the observed phenomenon could possibly be overlooked before the meter was installed. If the meter was installed with a similar fault, it may not be detected during routine monitoring.

2.3.2 10 Inch Meter 'E' – Gas Ultrasonic Meter Electronic Interference

In late 2004, a problem was experienced with a 1st stage Production Separator that resulted in a dramatic decrease in the measured quantity of gas from the separator. The cause of the problem was identified as excessive noise generation (coinciding with an internal baffle plate failure on the separator) interfering and affecting the separator gas off take ten inch meter. This had the effect of causing an under measurement and subsequently allocation mismeasurement reports were required until the problem was resolved. Due to the nature of the problem (separator internals) it was deemed more efficient to try and make the meter measure under these conditions than to take production deferment and isolate the separator for repair.

Investigation in to the meters diagnostic data revealed,

- Overall performance was low. The performance of the swirl paths (L1 and L3) was better than the performance of the axial path (L2)
- Low performance was due to the decreasing AGC limits combined with the relatively high AGC levels
- The AGC levels for the axial path were higher than the AGC levels of the swirl paths (typically, for the AGC level for the axial path should be lower than the AGC level of the swirl paths due to the path length)
- It was suspected that the AGC limits were influenced by noise from a downstream source (production problem stemming from the separator failure). The AGC limits of the A transducers (pointing downstream) are lower then the B transducer limits

	10" Meter 'E'		*Performance*				*Corrected*	*Vol. Flow*	
Date	*Comment*	*Sample Rate*	*L1*	*L2*	*L3*	*Average VOS*	*Gas Velocity*	*@ Line Condition*	*Swirl*
17/12/4	Online	15.00	5.51	2.93	4.49	410.162	16.369	3795.480	7.17
31/05/5	Online SPU cx out	14.18	13.7	14.1	13.7	411.156	18.909	4462.168	-0.85

Table 05: Noise Interference on 10" Meter 'E' – 2005

It was concluded that the noise was increasing when the flow was increasing. If the flow was stable or decreasing the AGC limits were rising up to the maximum value (low noise) [6].

The problem was resolved with a signal processing unit change out (higher power, lower AGC Levels) and the transducer acoustic signal frequency was changed from 100 kHz to 200 kHz. After the modifications were made the meter was recertified, with an average reported shift to Q_{ref} of -0.39%. There was no attempt to reproduce the noise interference at the calibration facility.

2.4 Redundancy Strategy & Exposure

The original system design philosophy was 'fit-and-forget' i.e. with the inherent redundancy built in to the three path meters it was assumed that the meters would not have to be removed for recertification. However, due to problems encountered (and detailed within this paper) after the system became operational, it became apparent that these meters would require to be removed from the line for recertification and / or repair.

Our original system configuration with two metering streams (each with a single ultrasonic meter capable of 100% duty), left the installation exposed to meter / transducer failure during each recertification i.e. the platform would be left with just a single metering stream available during recertification's for Custody Transfer and would also require a Pipeline/Regulator dispensation to operate as such. Therefore, a third meter was procured as quickly as possible to reduce this exposure.

Training in Diagnostic Healthcare Monitoring for the metering technicians is a fundamental requirement for us. Due to the increased complexity of the ultrasonic meters and their associated electronics and diagnostic software, the technicians need to be trained away from the operating environment so that they are adequately prepared for healthcare monitoring, front line performance evaluation, diagnostic data collection, fault diagnosis and reporting.

2.5 Upstream Configuration and Conditioning

There are no flow straightening or conditioning devices upstream of the Custody Transfer or Allocation gas ultrasonic meters. The platform Custody Transfer measurement operates with over 10 diameters of upstream straight length without a flow conditioner.

Therefore, to supplement and possible enhance the Custody Transfer measurement onboard our platform it is proposed to carry out a Computational Fluid Dynamic analysis simulation to confirm any 'installation effects' on these meters.

2.6 Other Practical Operational Considerations

2.6.1 Calibration Pipe Spools

The original recertification procedure was to remove the meter complete with the upstream and downstream pipe spools to ensure that the recertification was as close to the operating conditions as feasibly possible. For practical, operational and safety reasons the original stated procedure is not followed and the current procedure is to calibrate the meter complete with purpose built, identically manufactured onshore calibration spools.

For example, a typical scaffold erection for the removal of the meter + spool pieces would take up to 4 weeks for two men. The scaffolding requirement was excessive because the crane could not reach the Fiscal metering skid and the meters had to be moved to a suitable laydown area in order that the crane could uplift them. The safety risk combined with the cost and time meant that there exposure could be reduced by changing the recertification method to using dedicated recertification spools. The recertification spools are identical in every way to those that are in service offshore.

There was no significant shift observed when changing from old to new spools i.e. Meter 'A' and Meter 'B' both had 'As Found' shifts of less than 0.2% (less than the Test facility uncertainty) at the next recertification opportunity. This was deemed acceptable to all parties involved in the recertification of these Custody Transfer meters.

2.6.2 Pressure Leak

A pressure leak from a transducer occurred offshore in August 2005 (post recertification at the flow facility). This resulted in a gas leak on the plant. Subsequent investigation revealed that the leak came from the transducer body.
The manufacturer could not establish how this leak occurred given the quality control procedures in place during manufacture of the transducers (pressure rated and Quality Control checked to 340 bar).

However, the lesson learned from this instance was that all transducers and meters must be pressure leak checked above operating pressure of 160 bar, prior to return offshore to service.

2.6.3 Custody Transfer Recertification Tolerance

The generally accepted Custody Transfer certification tolerance between successive calibrations is ±0.3% (this was agreed by all parties and is larger than the calibration facility uncertainty value of 0.23%). If an 'As Found' recertification was in excess of this tolerance, it was agreed that a mismeasurement would be applied over the period.
Since 2003, there were no shifts significantly higher than the threshold. With Meter 'A' at -0.315% being the largest (see figures 07 & 08).
The evidence collected during the review period confirms that the ±0.3% is an acceptable criterion.

2.6.4 8 Inch Meter 'D' – Extending / Establishing Maximum Flow Range

During the acceptance testing of eight inch Meter 'D' at the European Flow Calibration facility in December 2005, further testing was performed to establish the maximum operating flow range of the meter. The results of the 8 point calibration can be seen in figure 09:

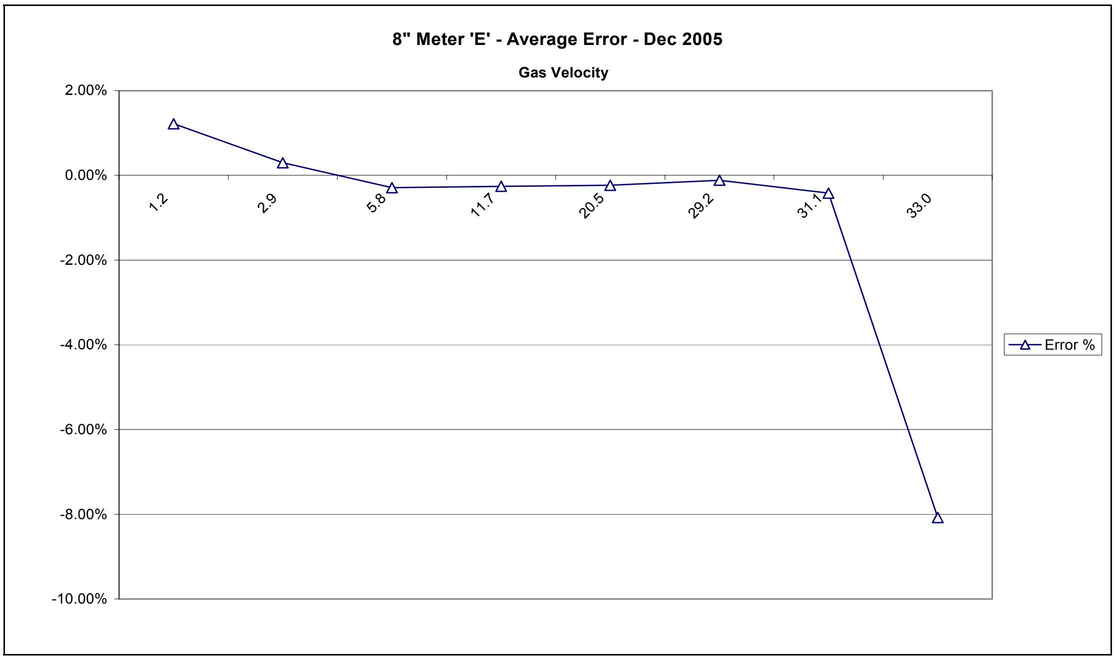

Figure 09: Calibration of 8" Meter 'D' – Dec 2005

The meter under test in this case was to be installed and used on a Test Separator gas outlet line and the purpose of the testing was to establish at what point the meter would exceed an error tolerance ±0.5% with respect to Q_{ref}. It was necessary to carry out this check to determine, from an operational perspective, the absolute maximum of the meter. Particular well configurations, with high GOR's to the Test Separator had the possibility of exceeding the manufacturer's stated maximum fluid velocity of 30 m/sec. The maximum fluid velocity point lies somewhere between the averaged values of 31.1 m/sec and 33.0 m/sec.

The results from this test confirmed to the operations and measurement personnel that the meter was capable of being used to 3300 m^3/hr instead of the previous limit of 3000 m^3/hr.

It was observed that at 33.0 m/sec the meter under measured considerably, even though average path performance for all 3 paths was not less than 20%. At the gas velocity of 33.0 m/sec, the Axial path average performance was 94% and the Swirl path' performance was 70%.
The sharp drop in accuracy is clearly distinguishable above 31.1 m/sec. Is this the point where the acoustic signal diffraction phenomenon has degraded the accuracy?
Performance has to be use in conjunction with other parameters to determine meter performance and actual shifts.

Eight inch Meter 'E' was accepted from the manufacturer with an adjust factor of 1.0015.

2.6.5 Corrosion Under Insulation (CUI)

One of the twelve inch meters suffered badly from CUI. This was uncovered during inspections of all meters in early 2005. All insulation was therefore removed from non Custody Transfer meters. Custody Transfer meters are regularly inspected for CUI and are well protected from moisture ingress. All meters are manufactured in 316 stainless steel.

3 CONCLUSIONS & RECOMMENDATIONS

Multi-path gas ultrasonic meters are here to stay, but they still require a great deal of attention and management; diagnostic data is the key to this. However, the diagnostic data still does not give any definitive quantitative answers for noted issues i.e. for issue X the potential calibration shift may be Y or it may be Z – at the moment the only real decision that can be made is that something is right or wrong. Interpretation is still required to determine what, if anything, the data is indicating and what decisions must be made.

From the experiences over the last 5+ years, a number of lessons have been learnt and the following recommendations are made to users of these types of gas ultrasonic meters:

- A Nitrogen pre certification check is important in establishing that the 3-path gas ultrasonic meter is in the same condition as it was during ‘service’, thus supporting any ‘As Found’ calibration shifts.
- Performance degradation and path loss occurs offshore in live operating conditions but not during verifications at the flow facility. There is a potential here to overlook performance loss if diagnostic log files are not recorded routinely and a history is not built up.
- Pressure leak check all 3-path gas ultrasonic meters (with new transducers) to above operating pressure before they are installed offshore.
- Velocity of Sound comparisons with theoretical values can only be carried out to a tolerance of ±0.25% if there are stable flow rates, stable pressures and temperatures and the comparison should be done between the recommended 2 and 6 m/sec. Checks carried out at zero flow proved problematic in the operational environment.
- Recertify any 3-path gas ultrasonic meters which have had a transducer pair changed out. Maximum shift recorded -0.45% which is greater than the meter acceptance criteria of ±0.3%
- Recertify all 3-path gas ultrasonic meters at flow rate points as close as possible to the actual operating flow rates to establish that there are no unidentified errors.
- All operators of Custody Transfer meters should continue to be aware of the risks posed by Corrosion Under Insulation

4 REFERENCES

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