'96 - 3.2

ULTRASONIC METERING ON AN OFFSHORE GAS PLATFORM

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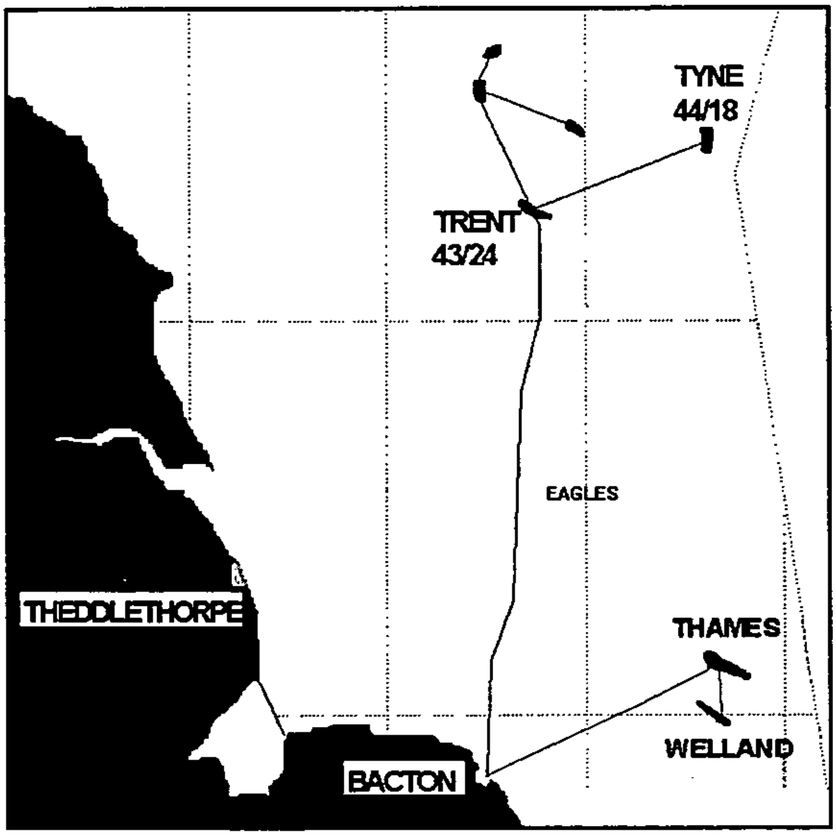
1.0 Summary

A trial was conducted on the ARCO British Limited (ABL) operated Thames Alpha gas gathering platform to evaluate the accuracy and performance of a multi-path USM (UltraSonic Meter) downstream of a production separator and in series with a orifice plate metering station.
Throughout the trial the test meter performed without failures of any kind and demonstrated a very high degree of accuracy and repeatability.
The success of this trial has permitted the use of USM's on two new ABL operated platforms, Trent & Tyne, that are due on stream during September 1996.



Glossary of Terms

USM	Ultrasonic Meter - In this case the multipath ultrasonic meter manufactured by Instromet Ultrasonics bv.
ABL	ARCO British Limited
MAG	ABL Metering and Allocation Group based at Gt Yarmouth.
AGA-8	American Gas Association Transmission Measurement Committee Report Number 8, for the determination of Compressibility and Supercompressibilty for Natural Gas and other Hydrocarbon Gases.
S500	Spectra-Tek Limited flow computer for USM's
S1000	Spectra-Tek Limited metering database.
SCI	Rosemount Supervisory Computer Interface
PCS	Rosemount Production Control System - Series 3
EAGLES	East Anglian Gas & Liquid Evacuation System
Swirl Path	Double bounce ultrasonic path unique to the Instromet Q-Sonic USM
Single Path	Single bounce ultrasonic path unique to the Instromet Q-Sonic USM
Msm3	One Million Standard Cubic Meters
mmscf	One Million Standard Cubic Feet

2.0 Introduction

This report details the USM trial conducted on the Thames platform. *(Please note that at the beginning of the trial the meter manufacturer was Stork Servex b.v. however during the course of the trial the company has changed names and is now known as Instromet Ultrasonic Technologies)*

During the design phase of the Trent and Tyne platforms it became apparent that technology had progressed enough to enable ultrasonic metering (USM) to bid alongside more traditional orifice plate metering systems and that USM met fully the high accuracy needs of allocation metering.

Indeed, the benefits of USM soon became so obvious that, unless contractually instructed to use orifice plate metering, ARCO would not have been acting as a reasonable and prudent operator if it had not have chosen USM. The cost savings to ARCO and its partners in providing a far more compact metering station that would require far less maintenance over its orifice plate counterpart fully justified the decision to choose USM. Coupled with the superior diagnostics of the

USM, that allows for remote (from the beach) interrogation of the meters to monitor performance and reliability, and the option of being able to have the whole meter sent away and check calibrated by an internationally traceable test centre all adds to the "feel-good" comfort factor that USM provides over orifice plate metering.

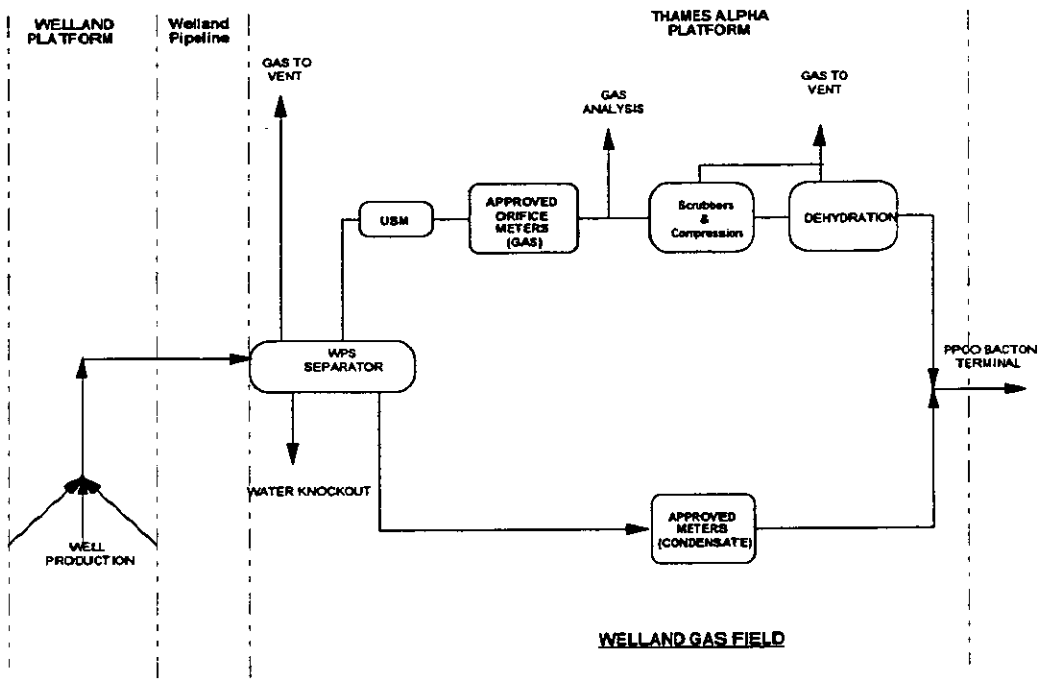
As part of the Trent & Tyne DTI design approval process, the ARCO Metering & Allocation Group (MAG) have purchase a 12" Instromet Q-Sonic 5-path ultrasonic meter in advance of Trent & Tyne coming on line and placed it in series with an existing orifice plate metering station on the ARCO Thames Alpha platform (downstream of the production separator and upstream of the orifice plate metering station). This meter has provided MAG with valuable information as to how USM's perform in an offshore environment and, perhaps more importantly, how USM's compare with a traditional orifice plate metering system.

3.0 Trial Programme on Thames.

(Comparison of USM's against orifice plate meters.)

The measurement philosophy for the Trent and Tyne Fields Development specifies the use of multi-path ultrasonic flow meters for the gas allocation measurement. As yet this technology is relatively untried to the standard required for fiscal or allocation gas measurement, particularly in the UK sector of the offshore oil & gas industry. *(However, NMI and PTB approval for the meter has been received for custody transfer metering).* A 12" multi-path ultrasonic meter was installed on the Thames Alpha Platform on the Welland Pipeline System reception metering station to carry out accuracy tests in comparison with an existing fiscal standard, gas orifice measurement station which was designed and is operated in accordance with Dept. Trade & Industry guidelines and ISO 5167. The only departure from ISO 5167 being that for the use of orifice plates with drain holes.
The Thames Alpha platform is located in block 49/28 of the North Sea and the Welland platform in block 53/4a. The not-normally-manned Welland platform exports it's gas and liquids via the Welland Pipeline System (16" diameter, 17.5 km) to the Thames Alpha platform for minimal processing, metering, compression & dehydration before entering the Thames Pipeline System for transportation to the Phillips Petroleum Company (PPCO) operated terminal at Bacton in Norfolk.

(Fig 1) A process schematic of the Welland gas from well extraction to import at the PPCo terminal.



The process conditions experienced throughout the trial were as follows:

Typical Gas Composition

N_2	4.49	%	Max pressure	90	barG
CO_2	0.48	%	Min pressure	22	barG
C1	90.21	%	Max temperature	20	degC
C2	3.34	%	Min temperature	8	degC
C3	0.83	%			
C4	0.35	%			
C5	0.12	%			
C6	0.18	%			

Typical water to gas (WGR) and condensate to gas (CGR) ratios pre-separation are as follows:-

WGR	7092 kg/Msm3	1.24 BBLS/mmscf
CGR	7489 Litres/Msm3	1.31 BBLS/mmscf

Furthermore, an analysis was carried out of the gas at the conditions prevailing at the gas chromatograph 1st stage let down to determine the amount of water vapour present in the flowing gas. The quantity of water in flowing gas was then calculated. The results were 2150 kg/Msm3 or 0.38 BBLS/mmscf.

The tests carried out have allowed comparison of the different measurement techniques under a wide range of flow conditions. Additional tests provided information on the meter's operation in the event of process problems and instrument failures, specific to the operation of ultrasonic meters.

The tests can be broken down to four distinct parts; onshore calibration, offshore accuracy monitoring, offshore operational checks and an additional post test program.

The meter under test was a 12" Instromet Ultrasonic Technologies Q.Sonic 5-path ultrasonic flow meter. This has been installed in series with the Welland Pipeline System (WPS) metering station located on the Thames Alpha platform. The meter was installed on the 18th September 1995 after onshore calibration of the meter took place at Ruhrgas's test centre in Dorsten - Germany on the 11th September 1995.

Due to initial commissioning problems encountered with the flow computer and coupled with an extended period of zero nominations from the buyer of the gas, the trial did not formally commence until the 5th November 1995.

Because this technology is relatively untried in high accuracy gas measurement applications, there are no recognised standards or guide-lines to assist in the installation and operation of meters of this type. Arco British Ltd have prepared a guide-line to the installation and operation of multi-path ultrasonic flow meters. The tests have been set up in accordance with the methods detailed in this document.

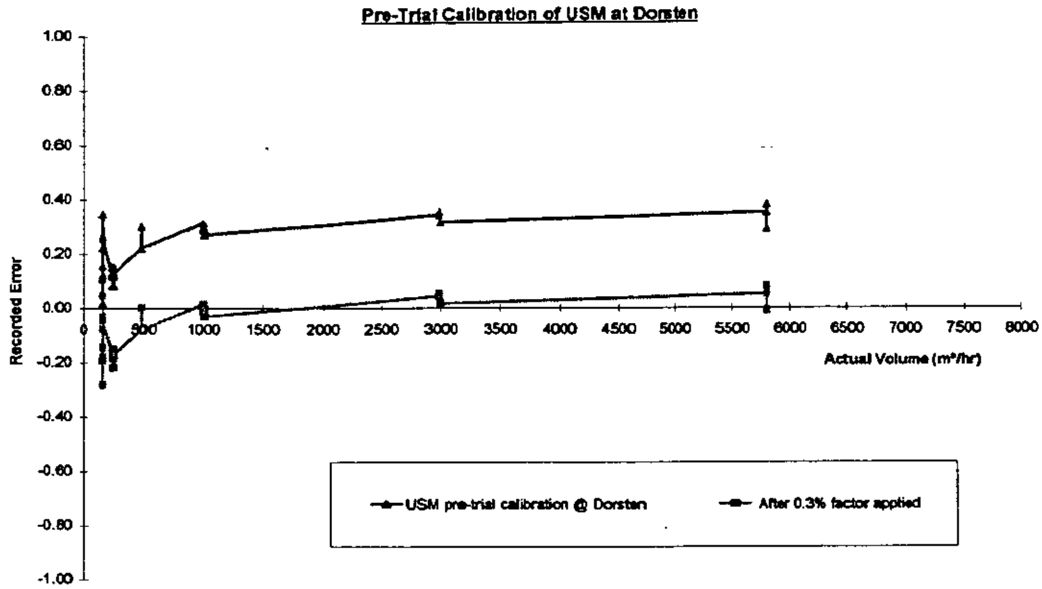
3.1 Onshore Tests

Prior to the meter being installed on Thames platform, it was calibrated and tested at an approved onshore test facility. The calibration was carried out at six flow rates with process conditions of 50.6 barA and 14.8 degC. At the two lowest flowrates (160 & 250m3/hr) six repeat runs were performed and for all other flowrates only three repeat runs were performed.

The results of the pre-trial calibration can be viewed in Figure 2. As can be seen the repeatability and accuracy of the meter was well within the manufacturer's stated limits.

After the meter had been calibrated across its flow range, one of the transducers located in a single path and one located in a swirl path were swapped around. The calibration run was then repeated at two of the flowrates, 160 & 1000m3/hr. Three repeat runs were carried out at these two flowrates and no shift in accuracy could be detected.

(Fig 2) Pre trial calibration at Dorsten

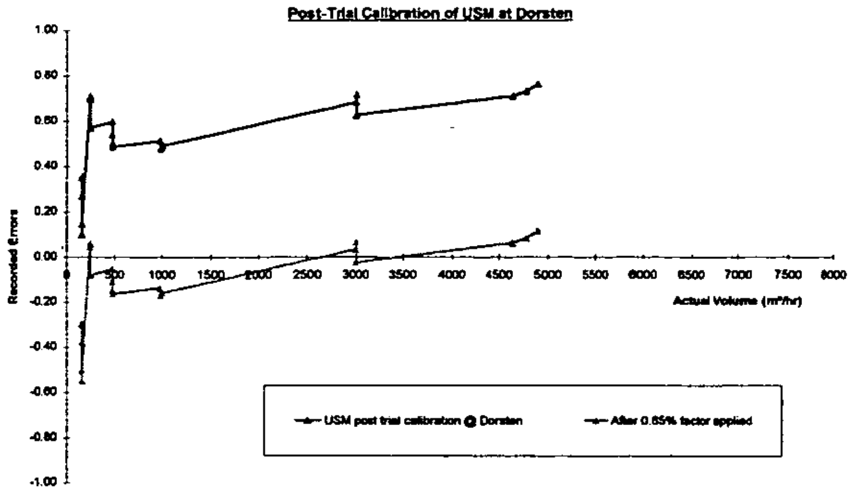


The post trial calibration at Dorsten in Germany was intended to evaluate whether there was any potential long term drift in the accuracy of the meter. The meter was removed from the platform during our annual shutdown. Strict instuctions were issued to ensure that, under no circumstance were the transducers to be removed or touched in any way.

To my surprise, when I arrived in Germany with Instromet to witness the re-calibration, we found that every transducer cable had been cut. To make matters worse, the cables had been cut at the point of entry to the transducer housing.

To try to rescue this part of the trial, the transducers were carefully labelled to ensure that a record of which slot and what orientation each were in. Instromet then manufactured some special new glands and repaired the transducers. The transducers were then refitted to the spool piece and the re-calibration was conducted on the 23rd July 1996. (Instromet confirmed that as a result of the repairs no effect on the accuracy would be detected.) The subsequent calibration results were obtained. - see figure 3.

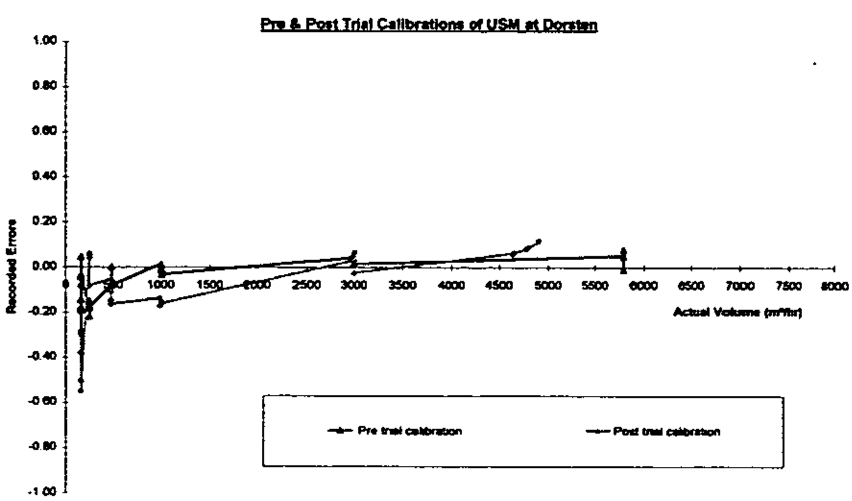
(Fig 3) Post trial calibration at Dorsten.



As can been seen, there is an approximated shift of + 0.35% from the original calibration carried out during September 1995. Whilst this size of shift is still within the design accuracy of the meter, it remains to be seen whether the shift is systematic or random. After discussions with the manufacturer, it would appear that this size of shift is not uncommon, however, in their experience , the shift can be positive or negative.

Obviously, with the data available to date, I cannot justify not sending the meters away for re-calibration on an annual basis. Only by monitoring the result of repeat calibration over the next year or two can we confirm the need or otherwise of annual calibrations.

(Fig 4) Pre & Post trial calibrations at Dorsten combined.



3.2 Offshore Installation of Trial Meter

The meter was installed on Thames platform, upstream of the WPS fiscal metering station. The installation was carried out in accordance with the ARCO British Ltd "Code of Practice for Multi-Path Ultrasonic Flow Meters", Revision 1 May 1995. A copy of which has been submitted to the BSI panel on Ultrasonic Flowmeters [CPL'30'S'1].

The meter run consists of a straight pipe length for 10 diameters upstream and 5 diameters downstream of the meter spool the pressure measurement instrument installed and a further 1 diameter downstream the temperature element was installed. The pipework was not lagged. See Appendix A3 for detailed pipework configuration.

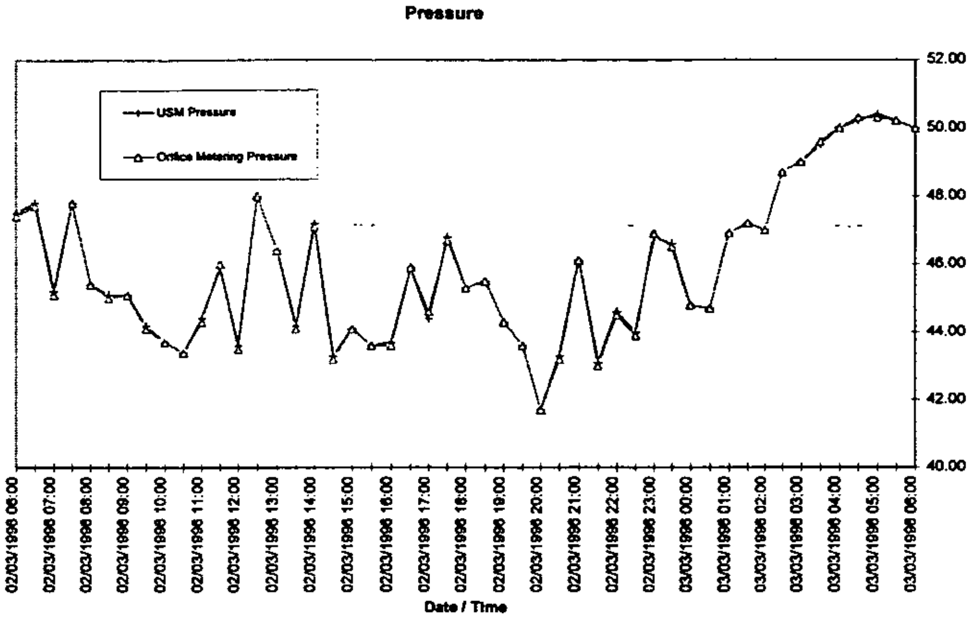
The control electronics for the ultrasonic meter are field mounted at the meter with cabling for power, frequency flow signal, data valid signal and serial diagnostics link run to the control room. Cabling from the temperature and pressure instruments have also been run to the control room.

A Spectra-Tek S500, ultrasonic meter flow computer takes the frequency input from the USM, together with temperature, pressure from field mounted transmitters and density from WPS Stream 1 flow computer to calculate and totalise actual volume flow and mass flow. Please refer to Figure 6 for full details of the instrumentation set up.

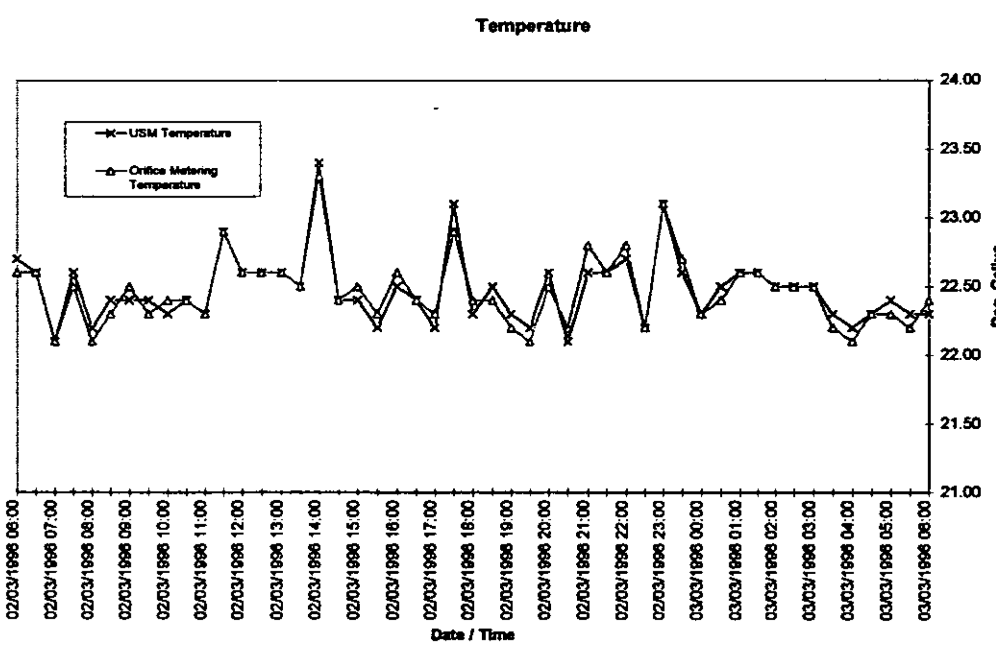
WPS gas orifice stream 1 flow computer has had its configuration modified to give a 4-20 mA output for gas calculated density. (The density being determined from on-line gas chromatograph and using AGA8 - 1985 equation of state). This has been input to the ultrasonic flow computer via a Protech input isolator to enable the calculation of mass flow. The sensitivity of WPS gas density to differences in temperature and pressure between the ultrasonic meter run and WPS gas stream 1 has been closely monitored and it has been felt that no off-line correction of the density is necessary.

Figure 5 (A&B) below shows a typical daily profile of the two metering stations pressures and temperatures.

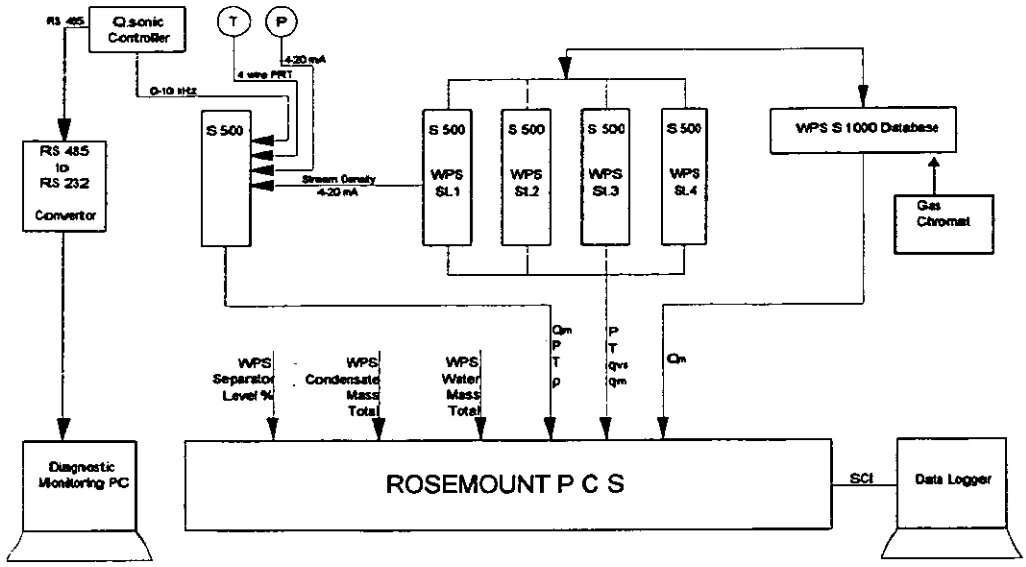
(Fig 5a)



(Fig 5b)



(Fig 6) Instrumentation and data logging schematic.



Secondary instrumentation and the flow computer fitted to the ultrasonic flow meter run have been calibrated monthly as part of the normal maintenance routines. The procedures implemented have been as for the fiscal metering station calibration routines. An additional procedure was developed to enable the calibration of the flow computer frequency input and calculations of flowrates.

3.3 Performance Tests

Offshore performance testing of the meter has been carried out in two parts. For the initial period of three months, testing has been restricted to monitoring the accuracy of flow measurement by the meter. This then continued for the second period but during this time additional tests specific to the operation of ultrasonic meters were carried out.

3.3.1 Accuracy Comparison

The metered throughput of the ultrasonic flow meter has been compared at half hourly and daily intervals with the total metered throughput of the WPS gas orifice metering system. Comparisons have been made on a total mass and actual volume basis.

Separator Levels and Condensate process data have been recorded to enable any correlation between variance in system performance with changes in process conditions to be investigated.

A typical example of the daily data recorded is provided in Appendix A1.

3.3.2 Meter Recovery from Liquid Contamination

Although not deliberately planned, this test has been carried out successfully on at least three occasions:-

1) During one week of the test the chromatograph used on the WPS metering station was out of action due to liquid contamination. In fact the chromat was completely flooded following a large increase in nomination for the Welland field. For the previous 4 months the gas flow rate through the system had been very low and excessive liquid build up had occurred in the inter field pipeline.

   With the increase in nomination and subsequent increase in gas velocity a lot of the excess liquid was carried into the WPS separator. The separator was unable to cope with the large intake of liquids and liquid carry over occurred into the meter tubes.

   As the gas chromatograph is the highest point within the whole of the orifice and USM metering systems it is safe to assume that very large quantities of liquid were present for a short time in the USM.

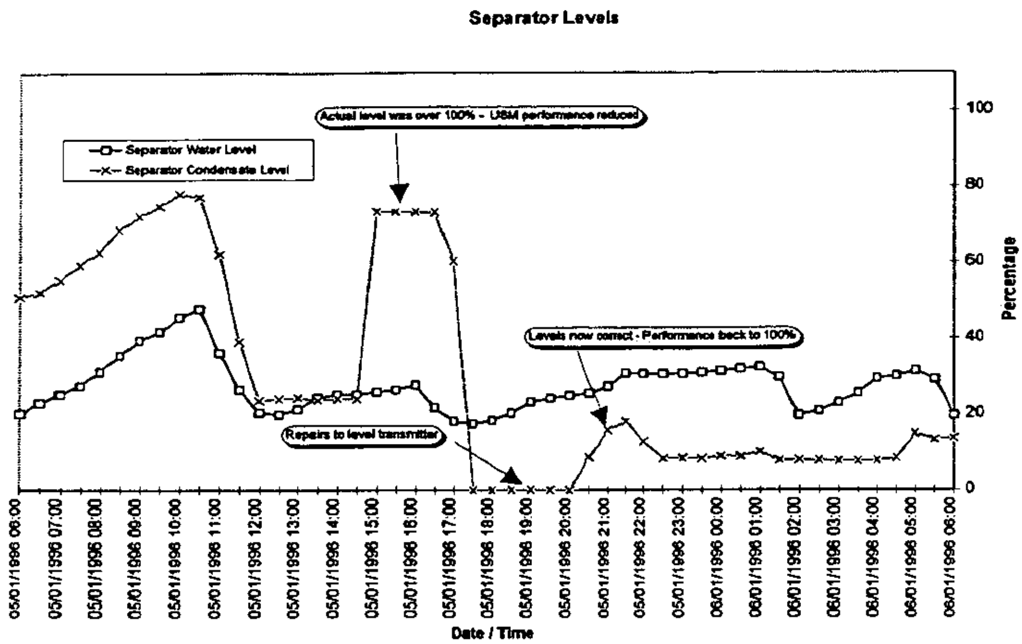
2) On a separate occasion, whilst observing the USM diagnostics in the office, it was noticed the average performance value of the transducers had fallen from 100% down to 85%. This loss in performance (but apparently not accuracy) was directly attributed to a high high water level in the WPS separator and subsequent liquid carry over.

   Once the level was lowered the performance of the transducers immediately returned to 100%.
   (Note: Performance value in this instance is an indication of the number of pulses of ultrasound received compared to those transmitted by a pair of transducers.)

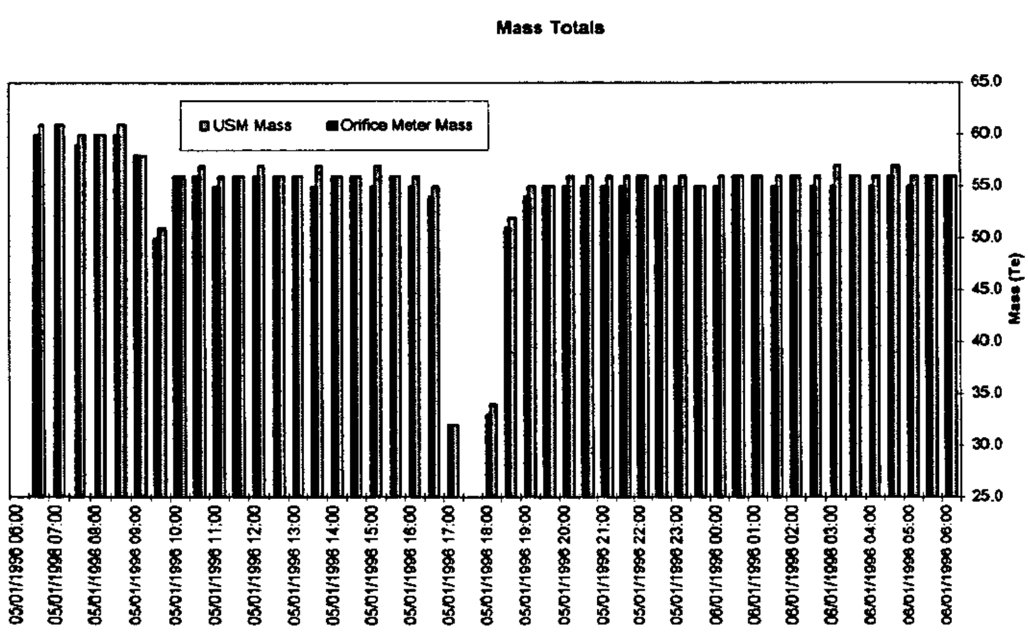
3) On the 5th January 1996, again whilst observing the USM diagnostics in the office, it was noticed that the average performance value of the transducers had fallen from 100% to around 85%.

   Initial enquiries with the Control Room Operators revealed that the separator levels were healthy. However, after inspection of the sight glasses on the side of the separator, a condensate level of 100% was found, as can be seen in Figure 7 below.

(Fig 7) Trend showing separator levels on Contract day 5th Jan 1996.



(Fig 8) Mass totals of USM versus orifice plate system every half hour for Contract day 5th Jan 1996.



Whilst the performance was reduced, interrogation of the individual transducer performance levels was carried out. It was found that transducer pairs 1, 3, 4 & 5 were all at 100% but pair number 2 was around 35%. Pair number 2 is a swirl path pair that out of all the transducers bounces nearest the bottom of the spool.

The performance of transducer pair number 2 was monitored as the separator level was brought down and the effect was noticed immediately.

Some conclusions to be drawn from this is that the USM is capable of detecting liquid content travelling along the pipe without apparent loss in accuracy. (See Figure 8). It has also been useful in monitoring the effectiveness of our production separators.
An orifice plate system (particularly without drain holes) would be building up this liquid content and manual intervention would be required to drain the orifice fittings upstream of the plate, thereby increasing the measurement error.

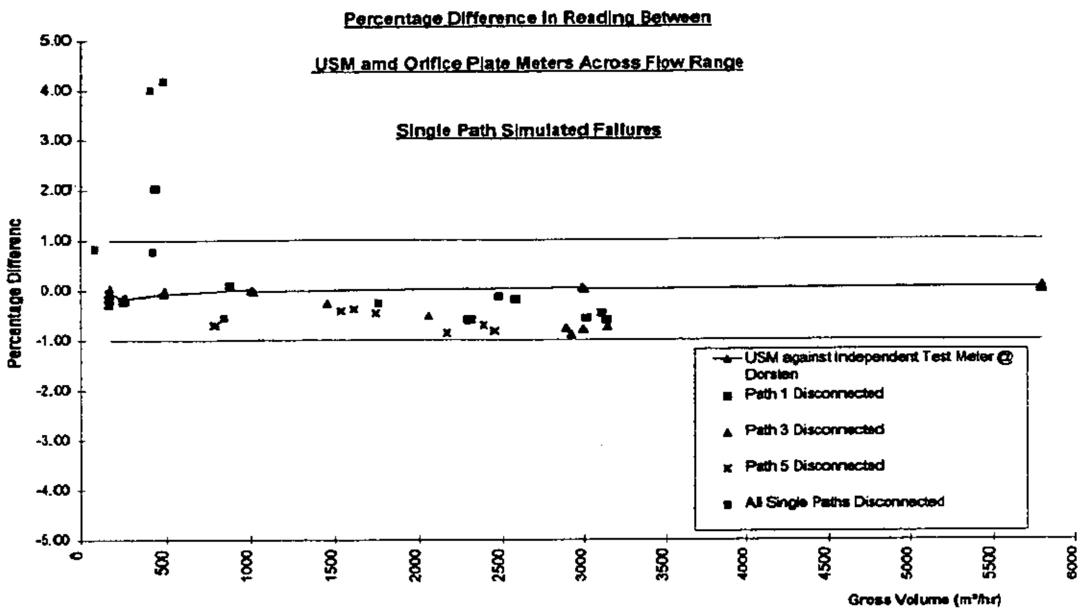
3.3.3 Additional Testing

During the second period, a number of tests specific to the operation of ultrasonic meters were carried out as follows:

Effect of Path Failure on Measurement Accuracy

This test verified the effect that the failure of an individual pair of transducers would have on measurement accuracy. Each pair of transducers were isolated (to simulate transducer failure) individually for a period of at least one week. The change in system difference was monitored to identify the effect on measurement accuracy of a path failure and show any differences between the effect of failure by the single and double (swirl) reflection chords.

(Fig 9) Effects of single path simulated failures



The effects of individual single path pair failures demonstrated that the meter continued to perform to within +/- 1% of the orifice plate system. Unfortunately by the time we got round to deliberately failing all single path transducers the flowrates had dropped significantly and the errors appeared to increase. However, as can be seen from Figure 11, these sort of errors are not untypical for the very small flowrates encountered. Remember, the differences are of percentage reading.

My overall conclusions about failures of single paths are that no significant measurement errors are likely to be encountered and therefore change-out of faulty transducers can be arranged to coincide with planned visits to the platform. Given the fact that the Trent & Tyne platforms will be not-normally-manned, this has proved to be a very valuable evaluation.

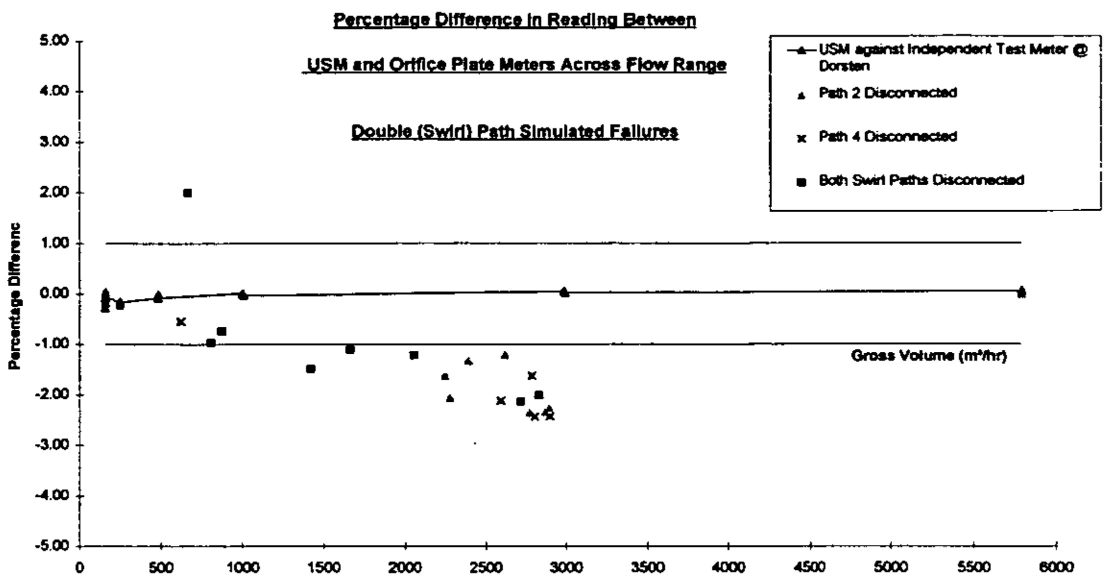
The effects of simulated failure of swirl paths produced a different set of results. (See figure 10). Generally, whether one or both paths were switched off the results showed an under measurement of approximately 1 - 1.5 %.

After consultation with Instromet Ultrasonic BV. , they confirmed that the electronics would automatically switch off a "good" pair of swirl paths if it detected the other pair had failed.

Obviously, should we encounter a swirl path failure with either of the Trent & Tyne meters we need to consider carefully how quickly we need to get out and make repairs.

Should we be in a position that no spare transducers are available, it should be possible to use a single path pair for a swirl path as all the transducers are identical and interchangeable.

(Fig 10) Effects of double (swirl) path simulated failures



Effect of On-Site Transducer Replacement

Unfortunately it is was operationally impractical with the test meter to change out or swap around one of the transducers.

3.4 Data Logging and Analysis

All the data for the above tests (with the exception of some high level diagnostics) were logged onshore via the Rosemount PCS system. This data has been logged on an half hourly basis on a personal computer via an SCI link from the PCS. (See figure 5). The data was then transferred daily via a floppy disk to an "Microsoft Excel" spreadsheet to enable the data to be trended and analysed.

The analysis of data was carried out daily by onshore metering personnel. This has enabled any adjustment to the test procedures to be carried out quickly.

The data logged and analysed via the PCS is as follows:

Data Source	Description	Units

USM Flow Computer	Mass Total	tonnes
	Pressure	bar g
	Temperature	^oC
	Density	kg/m^3
Stream Flow Computers (data for each stream)	Pressure	bar g
	Temperature	^oC
	Mass Flow Rate	t/hr
	Std Volume Flow Rate	ksm^3/hr
WPS Database	Station Mass Total	tonnes
WPS Prod. Condensate	Mass Total	tonnes
WPS Separator	Water & Cond. Level	%

Additional high level diagnostic data has been available onshore and offshore from the ultrasonic meter controller via an RS485 serial link. This has provided invaluable information on the operation of individual transducers as well as specific process data such as flow velocity and fluid speed of sound.

The primary comparison made using the data supplied is of total measured mass throughput by each method.

3.5 Q.Sonic Diagnostics Link

This link can provide measurement and process data as well as additional diagnostic data.

It was intended that the following parameters would be logged, as a minimum, on a daily basis by interrogation of the Q.sonic diagnostics:

- Automatic Gain Control (AGC) Level for each transducer pair.
- AGC Limit for each transducer pair.
- Measured flow velocity
- Measured fluid speed of sound.

and that during the additional meter operational checks, these readings would be logged at a greater frequency.

However, it was found that this was not serving any real purpose. Taking daily spot readings of VOS and transducer performance was not truly representative and it is felt that a more automated system of logging was required such as continuous logging of individual transducer performance and calculated VOS together with averaged transducer performance and averaged calculated VOS.

During the development of the metering database for Trent & Tyne automatic monitoring will be built into the database functionality with alarms to warn the operator in the event that a transducer is potentially failing.

4.0 Analysis of Results Obtained from Trial.

Refer back to Section 2.4 for details of the data that was logged every half an hour:

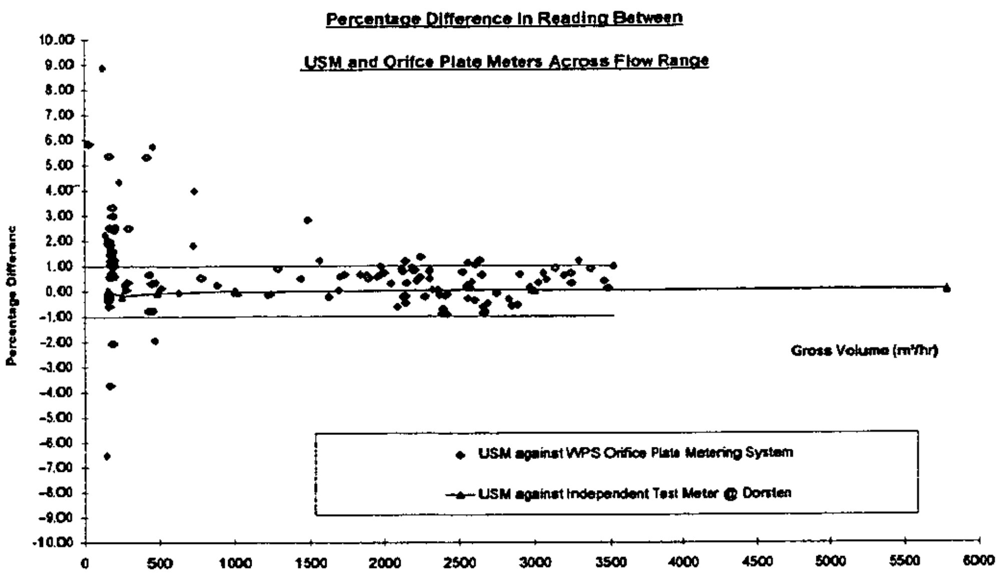
At the end of each day all the data has been transferred to disk for importing into an Microsoft Excel spreadsheet. Once this spreadsheet has been generated, the various data sets are trended and charts produced daily. The daily mass total of the USM and the orifice plate system together with the days average line density are then input into a separate spreadsheet (USM_MASS.xls) for day by day monitoring of percentage errors between the two systems. For the purposes of this trial the errors stated refer to the difference between the gross volume total of the USM against that of the orifice plate system and have been calculated using the following formula:

$$\frac{\text{(USM Actual vol. (m3/hr) - Orifice Actual vol. (m3/hr))}}{\text{Orifice Actual vol. (m3/hr)}} \times 100\ \% \qquad \text{(Eq 1)}$$

The results have been monitored using a number a trends.
Firstly, using the results of equation (1) above and plotting these results using a scatter diagram as illustrated in Figure 11 below:

(Note: Data from the trial obtained during some of the additional testing such as deliberate failure of transducer has been excluded from these results.)

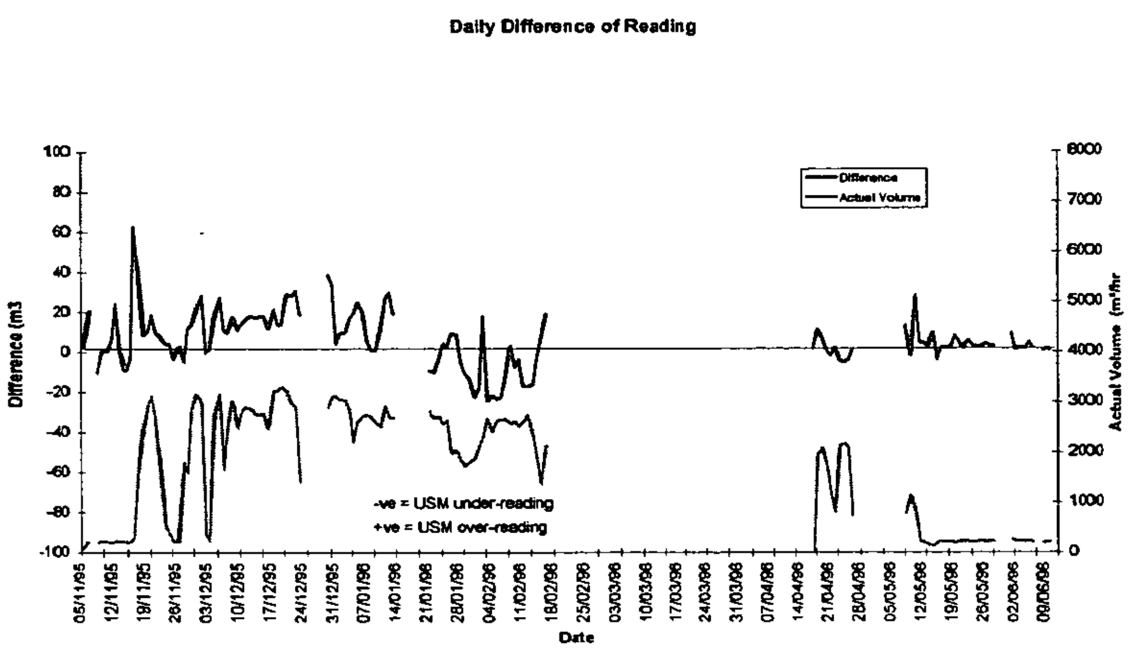
(Fig 11) Daily percentage differences.



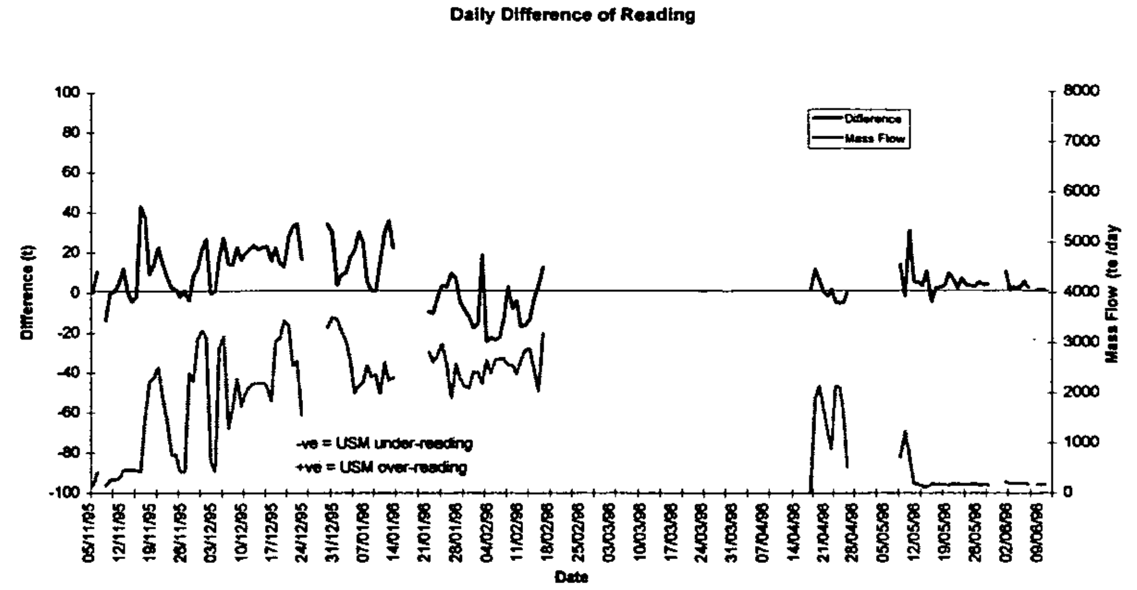
From **Figure 11** above it can be seen that the results obtained generally fall between +/- 1% once away from the lower volumes. It was felt to be a useful exercise to trend these differences on the same chart as that of the flowrates.

The following two figures (Figures 12 & 13) show the difference between the two metering system against flowrate:

(Fig. 12) Difference in terms of actual volume flows.

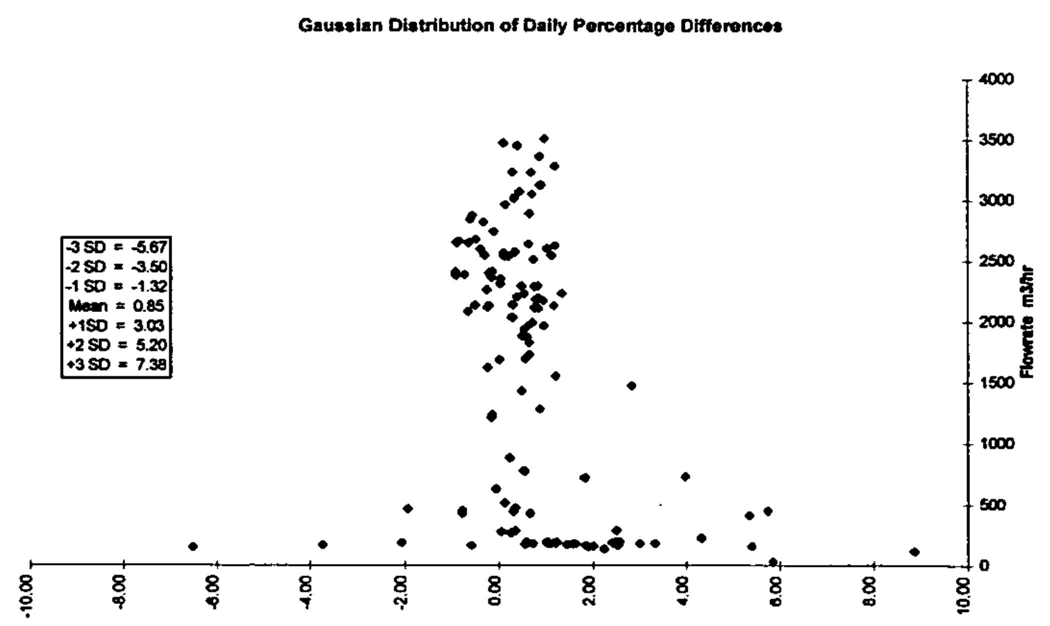


(Fig 13) Difference in terms of mass flows.



The following chart (Figure 14) is a Gaussian normal distribution of the results obtained. For reference, the mean value obtained was +0.8519, one standard deviation was 2.1751 and a 95% confidence level of 0.373 was also calculated.

(Fig 14) Gaussian distribution of results.



The following eight bar charts (Figure 15.1 - 15.8) show the day-by-day differences between the two metering systems. :

Figure 15.1 November 1995

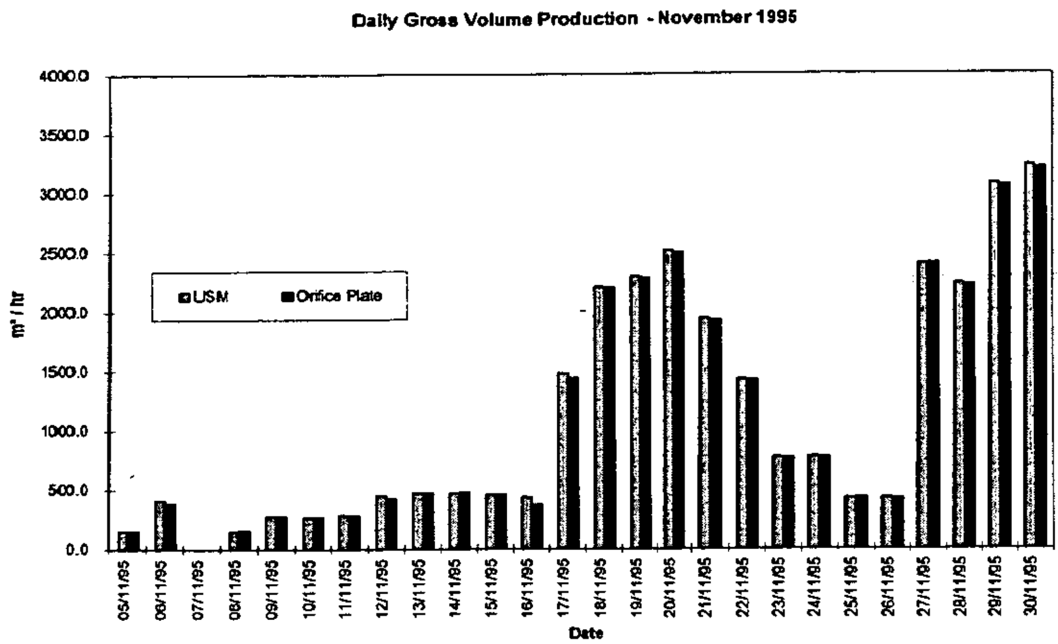


Figure 15.2 December 1995

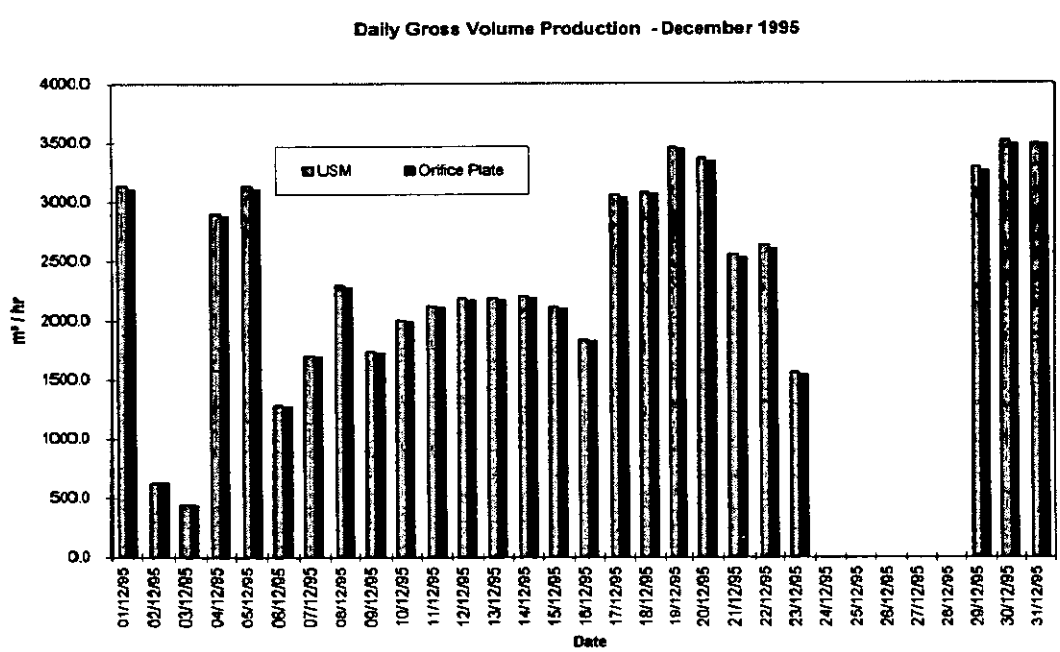


Figure 15.3 January 1996

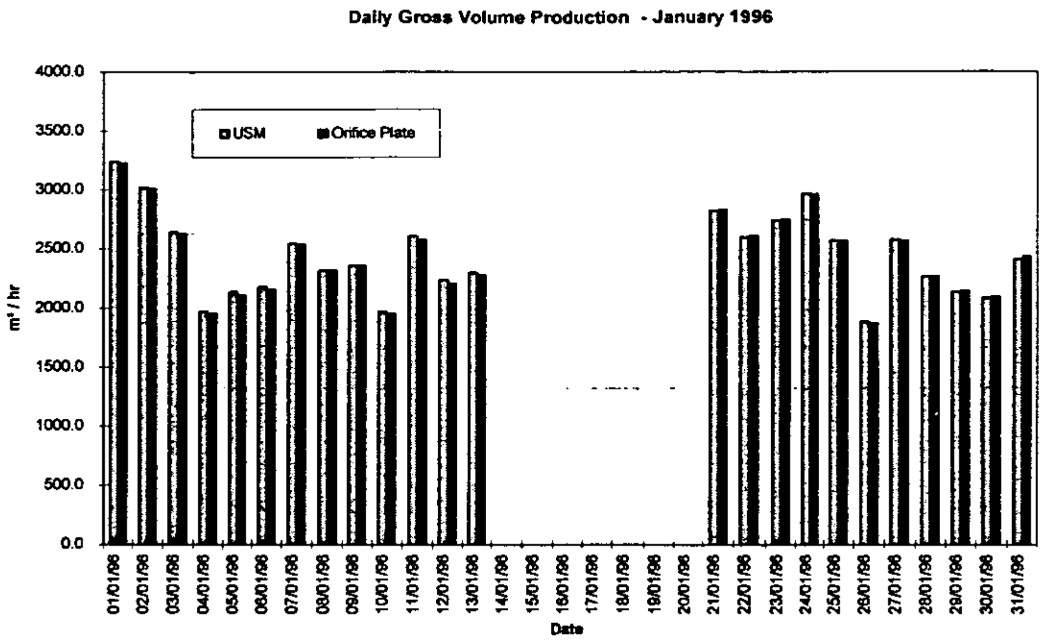


Figure 15.4 February 1996

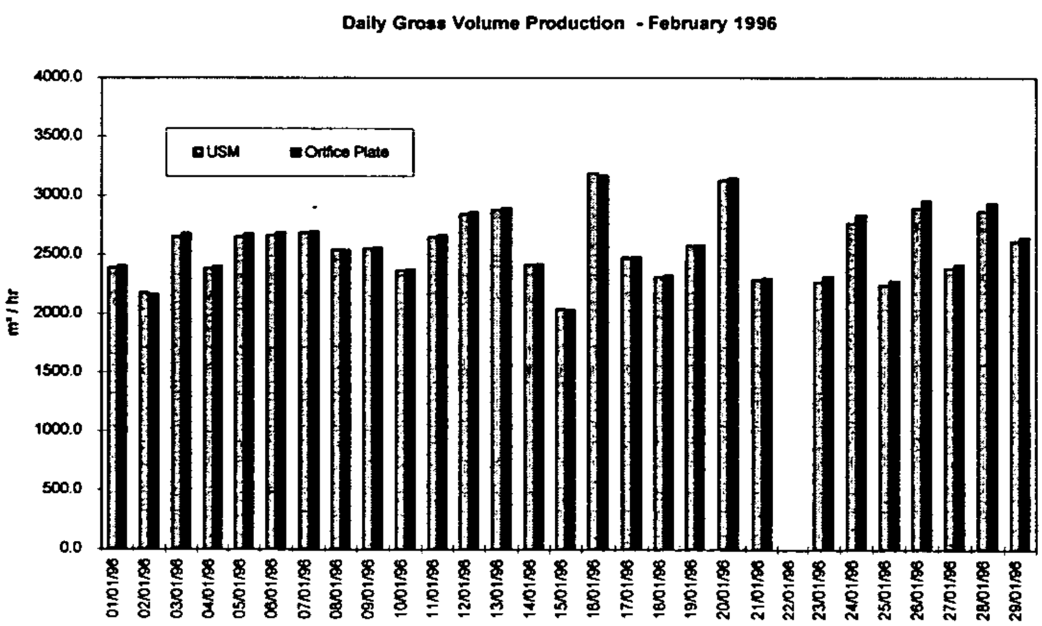


Figure 15.5 March 1996

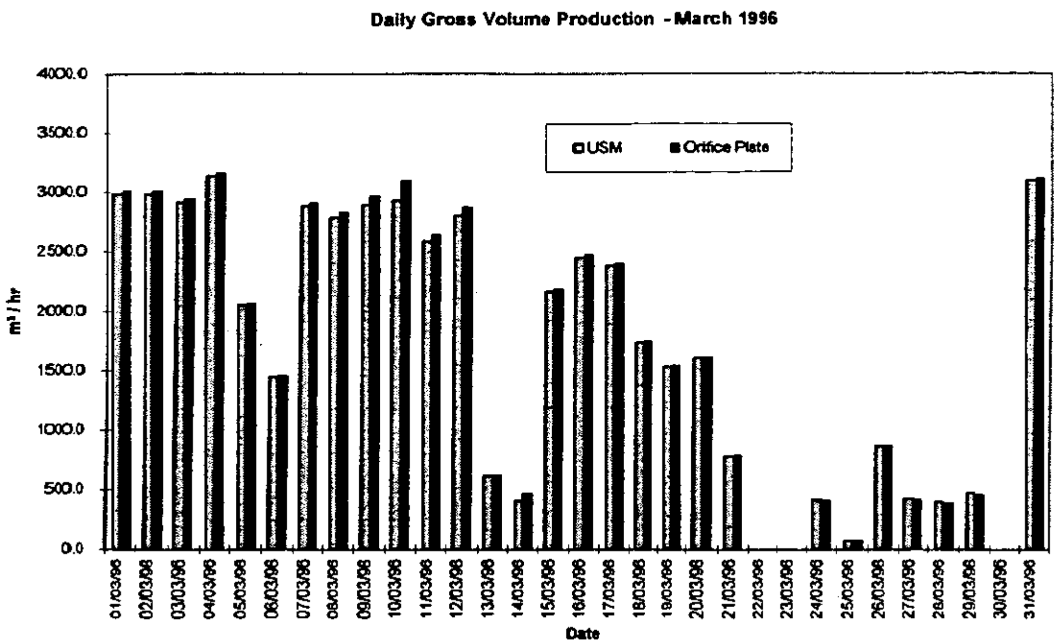


Figure 15.6 April 1996

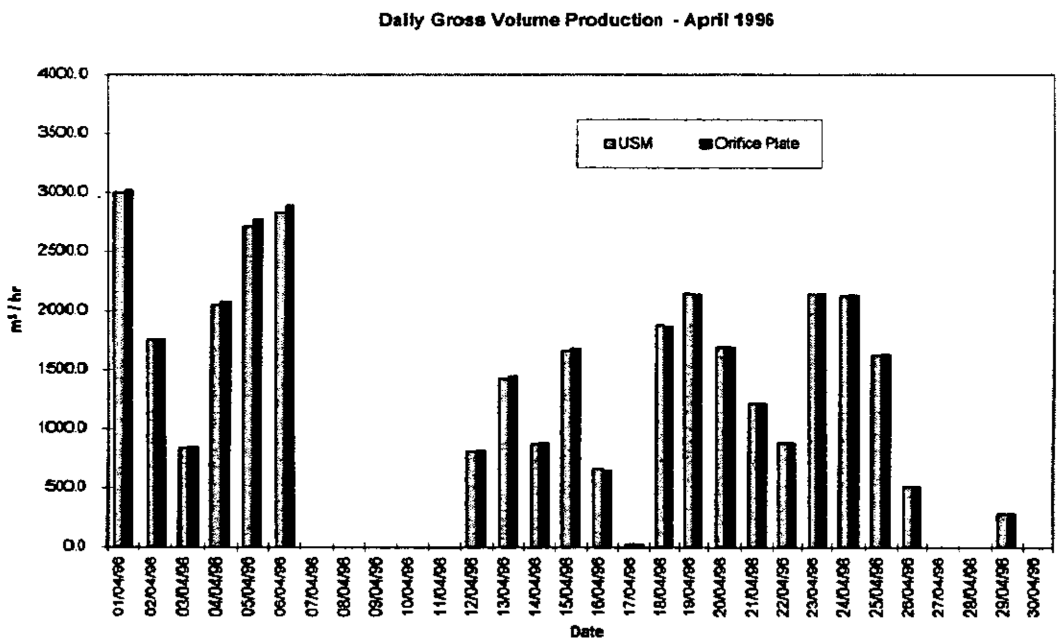


Figure 15.7 May 1996

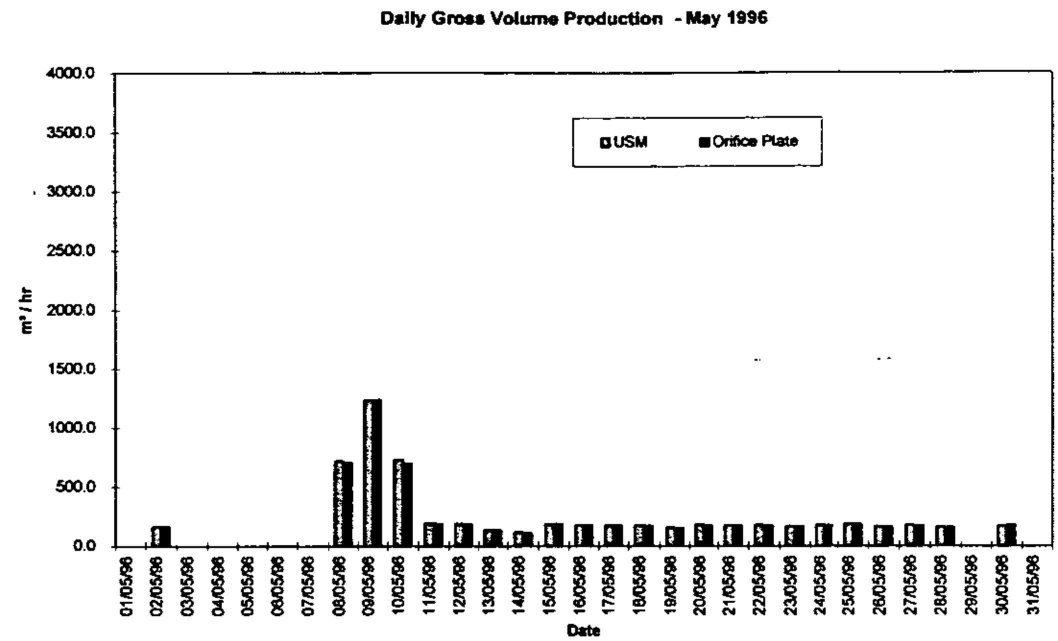
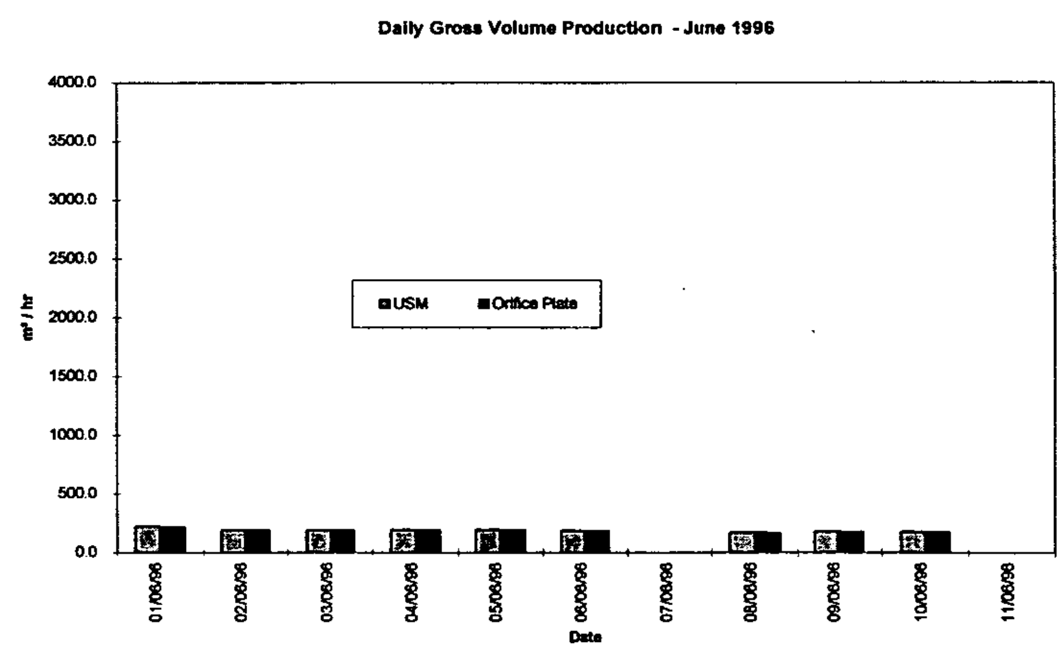


Figure 15.8 June 1996



Data for the following days has not been included :

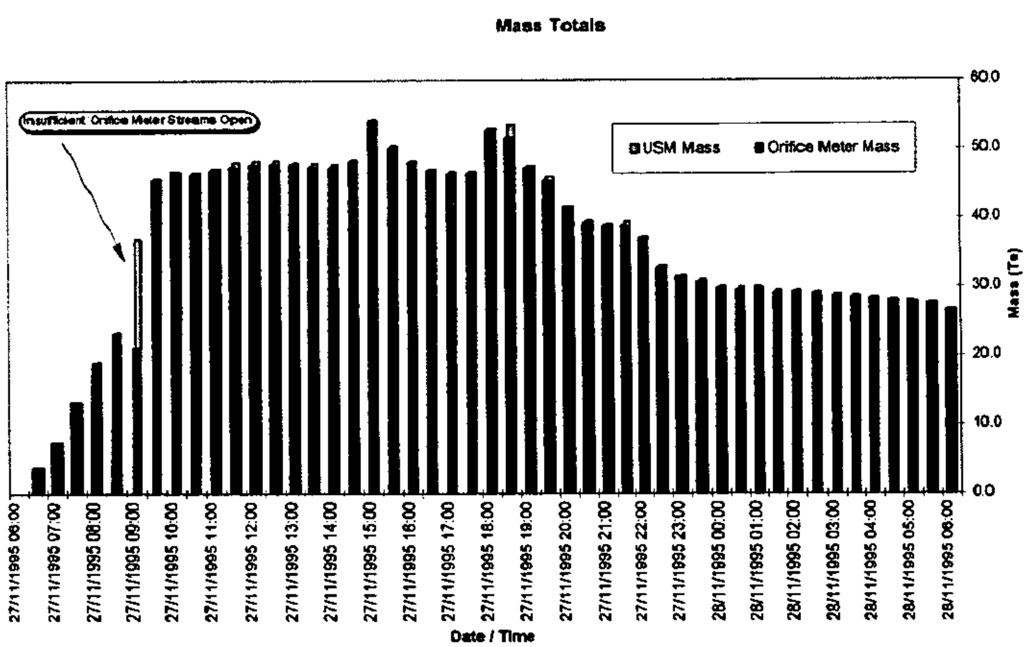
7th November 1995 - No production.

24th - 28th December 1995 inclusive - Stream 1 mistakenly taken off-line. (The USM flow computer uses the density supplied by the flow computer.)

14th - 20th January 1996 - S500 flow computer failure due to circuit board component failure.

On some occasions minor alterations to the WPS orifice readings have been implemented as a result of plant operators not opening or closing orifice plate streams quick enough after changes in production rates. (See figure 16).As the USM is a single stream it never misses any flow, however the orifice plate systems utilises four streams and relies on operator intervention to select the appropriate number of streams.
An example of this is given in Figure 16 below:

(Fig 16) Example of effects of not opening orifice streams in time.



During the trial numerous problems were encountered with the S1000 database. One of the most common faults was that the outputs driven by the database to the PCS would on some occasions be very erratic. On these days only the end of day totals have been used and the data logged by the PCS has been ignored.

After the new flow computer was installed on the 20th January a full set of calibrations were carried out. During this time it was noticed that the density displayed on Stream 1 flow computer did not match exactly that of the USM flow computer. The Protech input isolator was found to be in need of adjusting. After adjustment the density input to the USM matched exactly that of Stream 1 through the range.

For all remaining days the errors are as recorded with no adjustments.

5.0 Conclusions.

As can be seen quite clearly from the Scattergram (Fig 9) and the trend of errors reported each day, the USM has demonstrated repeatable and accurate results. From the initial start date through to the 13th January (pre density input calibration) the average error, or rather difference of reading between the two types of meters, was +0.9264 %. The average difference of reading after the density input calibration was +0.7802 %. The overall average of the results obtained (excluding periods of deliberate simulated transducer failures) was +0.8506 %.

The overall average percentage difference of reading of all the results obtained was +0.3538 %.
(It is comforting to know that our orifice plate metering systems are so accurate !)

Apart from the accuracy of the results, some of the other benefits / conclusions to be drawn so far are as follows:-

The USM has proved to be more reliable and versatile than its orifice plate counterpart. Its ability to detect liquids travelling along the spool pipe with apparently no loss in accuracy is an excellent feature that orifice plate systems cannot compete with as illustrated in BSI 1042 Part 1 Section 1.5 Guide To The Effects of Departure From Conditions Specified in Section 1.1

The comprehensive remote diagnostic tools enables the user to carry out detailed examination of the performance of individual transducer pairs from remote (onshore) locations.

The reduced maintenance / calibrations associated with an USM system (no need for DP cell or orifice calibrations/ inspections of multiple streams) contributes to reducing the number of personnel exposed to working offshore.

The amazing 100:1 turn down ratio and built in redundancy enables metering stations to consist of little more that a single USM and a short upstream amd downstream spool piece.

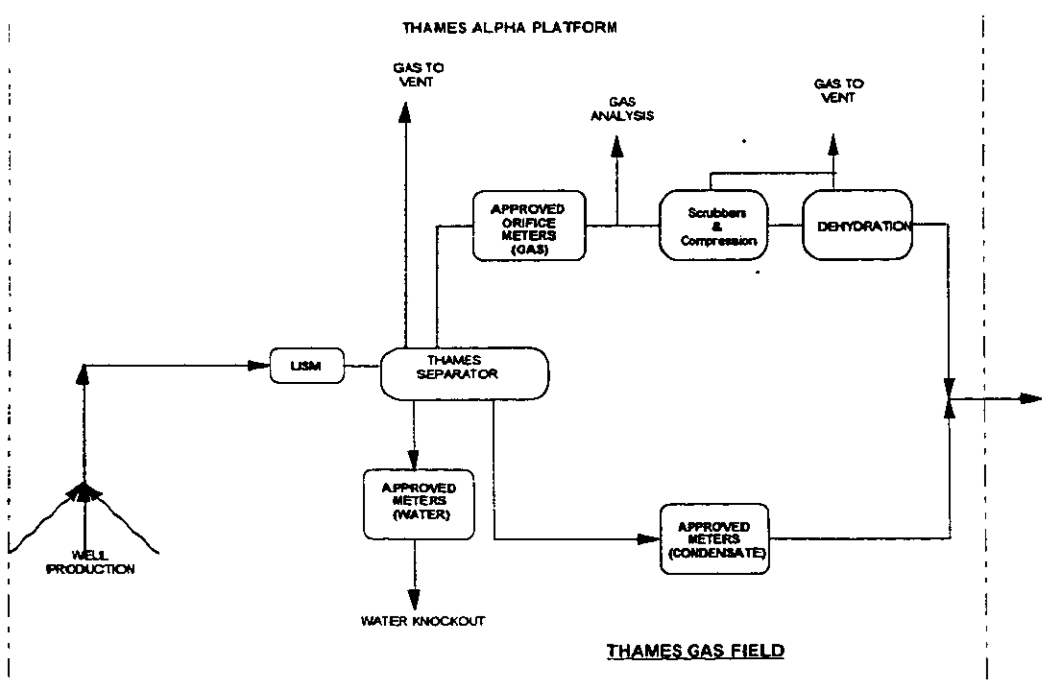
The ability of the meters to be upgraded with minimal costs in years to come by having revised software uploaded or new transducers or new circuit boards fitted contributes to a far more flexible metering system .

The long term evaluation into the issue of whether the meters need to be re-calibrated each year has yet to be concluded. More data and results are needed, however, initial results look positive.

6.0 Future Trials

The trial involving the comparison of the USM against the orifice plate system downstream of separation has now finished. The meter purchased to carry out the trial has been retained and re-located upstream of separation. A new trial is now underway to evaluate the performance and accuracy of the meter on three phase wet gas. The meter has been placed upstream of the Thames field Production Separator, again on the Thames Alpha platform.
We know from the previous trial that the meter is capable of detecting free liquids within the pipe spool, we should be able to use this information and use the various paths as level detectors within the spool and try to compensate the gas flow rate accordingly.
A process schematic of the three phase trial is provided below.

(Fig 16) Three Phase Ultrasonic Trial



A further trial will be commencing with the two Trent & Tyne meters to evaluate the calculated line density from velocity of sound from the USM and comparing this density with that of the gas chromat / AGA8 route. The metering database developed for the Trent & Tyne metering has the ability to continuously monitor and log both calculated densities.

I look forward to sharing the results of these new trials in the near future. Watch this space !!!!!!!!

7.0 Acknowledgements:

Kevin J Robinson: Who, during his time as Metering Supervisor within ABL recognised the potential opportunity to make use of USM's and then had the commitment to ensure that the Trent & Tyne project team made use of this (at the time) untried technology on an offshore gas platform.

Instromet Ultrasonics BV: for their efforts in repairing the transducers damaged by the platform staff and in rescuing the evaluation into the long term accuacy of the meter.

The DTi - GOMB : for their encouragement and support of the proposal to use USM's for Trent & Tyne platforms.

Gwilym Foulkes (SGS Redwood Ltd) for his technical support throughout the trial and in particular in preparing the draft Code of Practice for the Installation of USM's

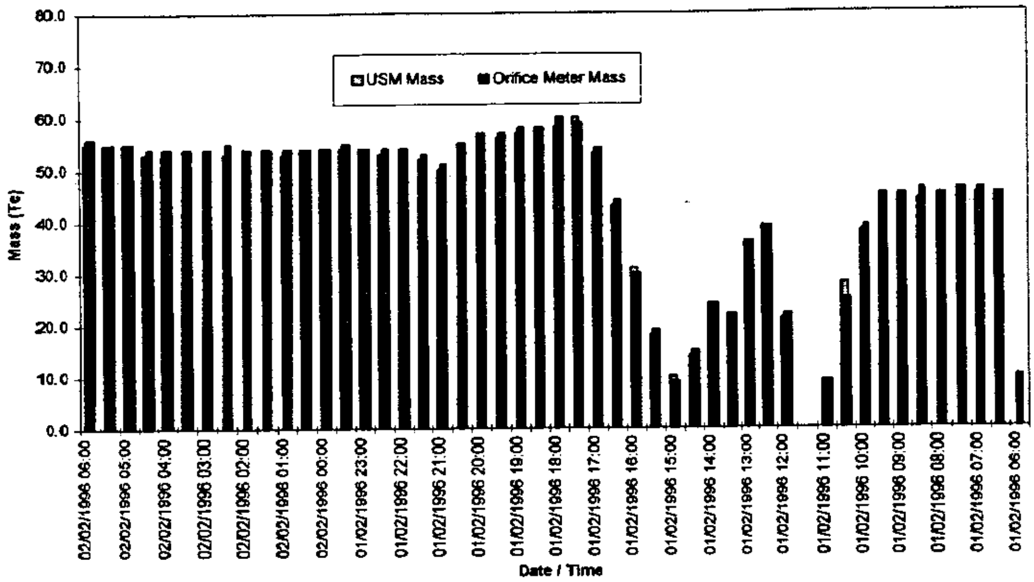
ARCO British Ltd for funding the trial meter used on Thames.

And finally, to all those who provided very constructive feedback to my Preliminary Report (date 6th February 1996), in particular Jacques Agricola (NAM)

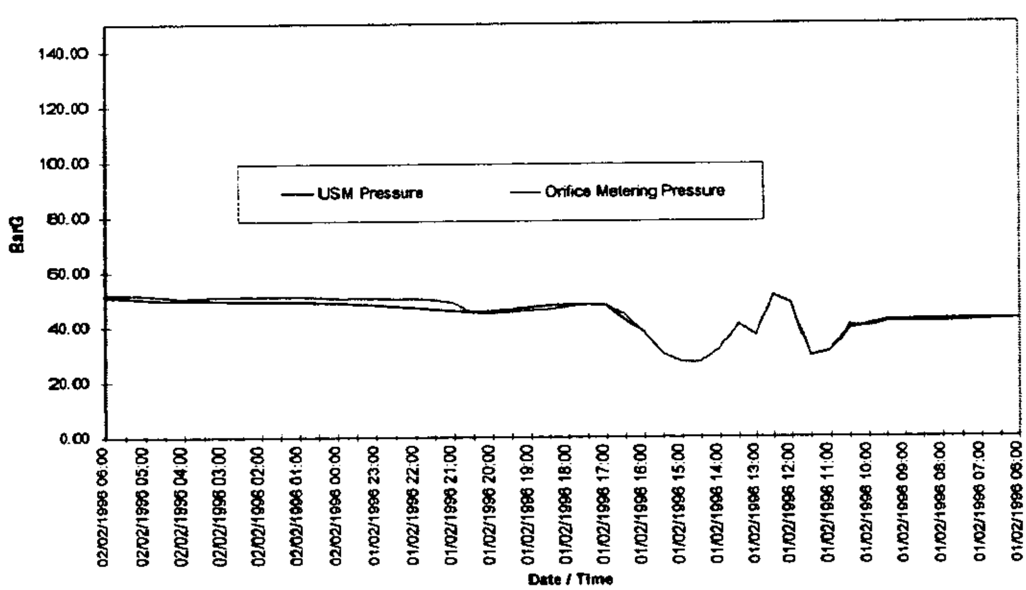
	USM	WPS	
Todays E.O.D Mass	173883.0	186752.0	te
Yesterdays E.O.D. Mass	171762.0	184605.0	te
01/02/1996	2121.0	2147.0	te

	Ultrasonic Flow Computer				WPS Separator			WPS Stream One		WPS D/b	USM	WPS	Condy
	Density kg/m3	Temper. degC	Press. barG	Mass Te	Sep. Water Level %	Sep. Condy Level %	Condy Mass kg	Press. barG	Temper. degC	Mass Te	Mass Te	Mass Te	Mass kg
	36.97	11.87708	44.0938	2121.0			0.00	44.65208	11.91675	2137.0			
02/02/1996 06:00	43.84	10.30	51.10	173883.00	20.59	17.50	0.00	52.1	10.3	186752.0	55.0	56.0	0.00
02/02/1996 05:30	43.84	10.30	50.80	173828.00	19.53	17.10	47393.20	52.0	10.4	186696.0	55.0	55.0	1548.10
02/02/1996 05:00	43.51	10.30	50.30	173773.00	18.77	17.20	45845.10	51.7	10.4	186641.0	55.0	55.0	1839.50
02/02/1996 04:30	42.79	10.30	49.80	173718.00	17.74	17.60	44005.60	51.0	10.4	186586.0	53.0	54.0	1904.70
02/02/1996 04:00	42.39	10.20	49.80	173665.00	7.97	23.10	42100.90	50.5	10.2	186532.0	54.0	54.0	147.50
02/02/1996 03:30	42.75	10.20	49.80	173611.00	7.82	21.20	41953.40	50.8	10.2	186478.0	54.0	54.0	467.40
02/02/1996 03:00	42.85	10.20	49.60	173557.00	7.73	17.00	41486.00	51.0	10.3	186424.0	54.0	54.0	685.20
02/02/1996 02:30	42.92	10.20	49.50	173503.00	7.64	17.00	40800.80	51.0	10.3	186370.0	53.0	55.0	1456.10
02/02/1996 02:00	42.90	10.30	49.40	173450.00	7.66	17.50	39344.70	51.0	10.3	186315.0	54.0	54.0	1424.50
02/02/1996 01:30	42.95	10.20	49.40	173396.00	7.59	16.90	37920.20	51.1	10.3	186261.0	54.0	54.0	645.60
02/02/1996 01:00	42.84	10.20	49.20	173342.00	7.56	17.10	37274.40	51.0	10.3	186207.0	53.0	54.0	1222.80
02/02/1996 00:30	42.68	10.20	49.00	173289.00	7.53	16.70	36051.60	50.8	10.3	186153.0	54.0	54.0	662.30
02/02/1996 00:00	42.35	10.20	48.80	173235.00	0.00	16.60	35389.30	50.4	10.3	186099.0	54.0	54.0	725.50
01/02/1996 23:30	42.33	10.20	48.40	173181.00	0.00	16.70	34663.80	50.5	10.2	186045.0	54.0	55.0	970.50
01/02/1996 23:00	42.32	10.20	48.00	173127.00	0.00	16.60	33693.30	50.4	10.3	185990.0	54.0	54.0	626.00
01/02/1996 22:30	42.14	10.20	47.50	173073.00	0.00	16.40	33067.30	50.2	10.3	185936.0	53.0	54.0	645.20
01/02/1996 22:00	42.07	10.30	47.00	173020.00	0.00	16.40	32422.10	50.2	10.3	185882.0	54.0	54.0	1192.80
01/02/1996 21:30	41.71	10.40	46.30	172966.00	0.00	16.40	31229.30	49.8	10.4	185828.0	52.0	53.0	729.40
01/02/1996 21:00	40.77	10.40	45.80	172914.00	0.00	16.40	30499.90	48.7	10.4	185775.0	50.0	51.0	566.00
01/02/1996 20:30	37.61	9.70	45.50	172864.00	0.00	16.60	29933.90	45.1	9.8	185724.0	55.0	55.0	1049.90
01/02/1996 20:00	37.45	9.70	45.70	172809.00	0.00	16.50	28884.00	44.9	9.7	185669.0	57.0	57.0	2463.50
01/02/1996 19:30	37.84	9.70	46.30	172752.00	38.67	36.60	26420.50	45.4	9.7	185612.0	56.0	57.0	3001.20
01/02/1996 19:00	38.31	9.60	47.10	172696.00	38.70	39.30	23419.30	45.9	9.7	185555.0	57.0	58.0	2733.20
01/02/1996 18:30	38.63	9.80	47.70	172639.00	38.66	42.70	20686.10	46.4	9.8	185497.0	58.0	58.0	1782.30
01/02/1996 18:00	39.41	9.90	48.00	172581.00	38.73	43.80	18903.80	47.1	9.9	185439.0	58.0	60.0	933.80
01/02/1996 17:30	40.18	10.30	48.10	172523.00	38.66	2.40	17970.00	48.1	10.3	185379.0	60.0	59.0	569.70
01/02/1996 17:00	39.94	10.60	47.80	172463.00	38.41	25.10	17400.30	47.9	10.7	185320.0	53.0	54.0	533.30
01/02/1996 16:30	36.77	11.20	42.40	172410.00	37.23	58.30	16867.00	44.5	11.2	185266.0	43.0	44.0	1070.30
01/02/1996 16:00	31.07	11.50	38.20	172367.00	36.74	0.00	15796.70	38.1	11.7	185222.0	31.0	30.0	524.70
01/02/1996 15:30	23.79	15.50	30.20	172336.00	36.36	0.00	15272.00	30.2	16.4	185192.0	18.0	19.0	510.50
01/02/1996 15:00	20.84	23.60	27.10	172318.00	36.33	0.00	14761.50	27.1	22.3	185173.0	10.0	9.0	533.00
01/02/1996 14:30	21.12	23.40	27.00	172308.00	36.29	6.30	14228.50	27.0	18.4	185164.0	14.0	15.0	490.80
01/02/1996 14:00	26.46	6.80	31.90	172294.00	36.19	0.00	13737.70	31.9	7.0	185149.0	24.0	24.0	0.00
01/02/1996 13:30	34.25	7.40	40.80	172270.00	35.97	0.00	13737.70	40.8	7.5	185125.0	22.0	22.0	511.80
01/02/1996 13:00	30.70	5.70	36.60	172248.00	35.82	7.20	13225.90	36.7	6.7	185103.0	36.0	36.0	563.60
01/02/1996 12:30	43.07	11.00	51.40	172212.00	35.71	7.00	12662.30	51.4	11.1	185067.0	39.0	39.0	1568.00
01/02/1996 12:00	40.09	12.10	48.40	172173.00	35.61	69.60	11094.30	48.5	12.3	185028.0	21.0	22.0	2717.58
01/02/1996 11:30	23.11	11.70	29.10	172152.00	35.77	98.30	8376.72	29.1	15.3	185006.0	0.0	0.0	1419.74
01/02/1996 11:00	24.62	14.80	31.00	172152.00	36.08	38.10	6956.98	31.1	16.6	185006.0	9.0	9.0	1341.77
01/02/1996 10:30	32.28	16.60	39.20	172143.00	35.10	37.50	5615.21	40.4	16.7	184997.0	28.0	25.0	667.43
01/02/1996 10:00	31.87	15.80	40.60	172115.00	34.26	35.80	4947.78	39.6	15.4	184972.0	38.0	39.0	1865.68
01/02/1996 09:30	33.42	15.60	42.00	172077.00	32.95	33.70	3082.10	41.5	15.5	184933.0	45.0	45.0	1427.29
01/02/1996 09:00	33.45	15.50	42.10	172032.00	30.84	31.00	1654.81	41.5	15.5	184888.0	45.0	45.0	285.22
01/02/1996 08:30	33.44	15.50	42.60	171987.00	29.97	24.10	1369.59	41.5	15.4	184843.0	44.0	46.0	0.00
01/02/1996 08:00	33.51	15.40	42.60	171943.00	29.26	12.30	1369.59	41.5	15.3	184797.0	45.0	45.0	419.97
01/02/1996 07:30	33.57	15.50	42.60	171898.00	28.22	7.20	949.62	41.7	15.4	184752.0	46.0	46.0	451.45
01/02/1996 07:00	33.75	15.70	42.50	171852.00	25.57	7.20	498.17	41.9	15.3	184706.0	45.0	46.0	0.00
01/02/1996 06:30	34.06	15.70	42.50	171807.00	22.39	7.10	498.17	42.3	15.6	184660.0	45.0	45.0	498.17
01/02/1996 06:00	34.24	15.70	42.50	171762.00	19.59	7.10	0.00	42.5	15.7	184615.0	0.0	10.0	0.00

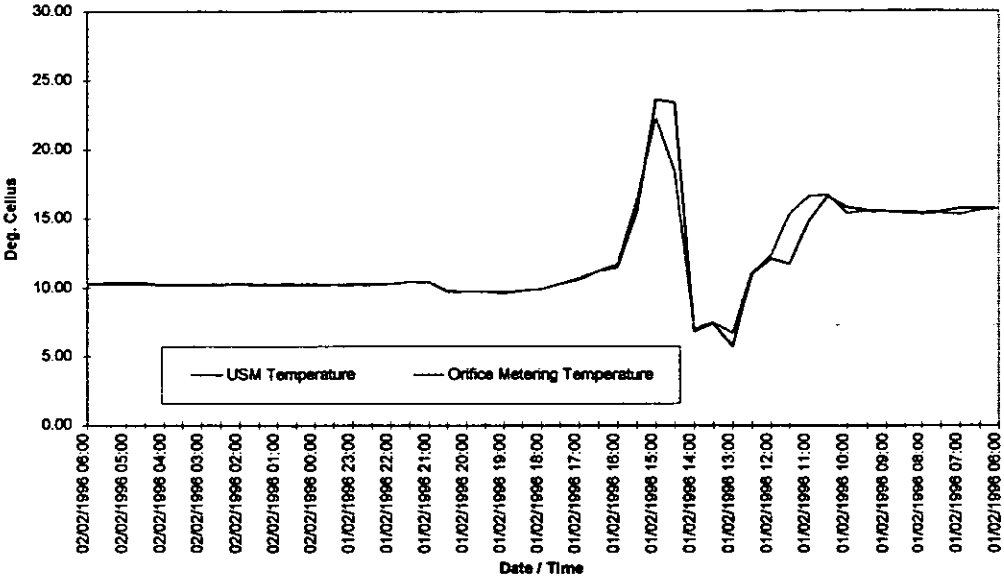
Mass Totals



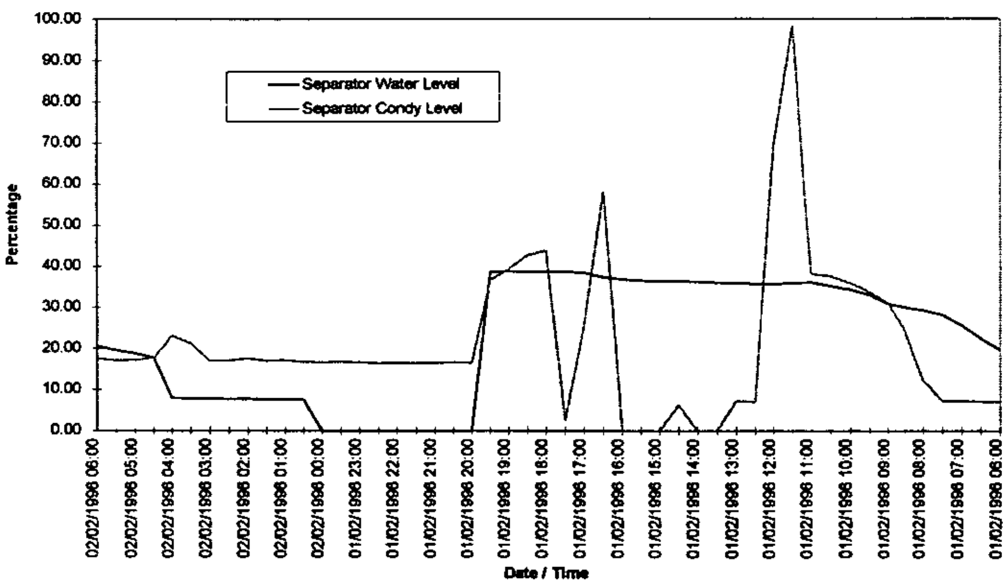
Pressure

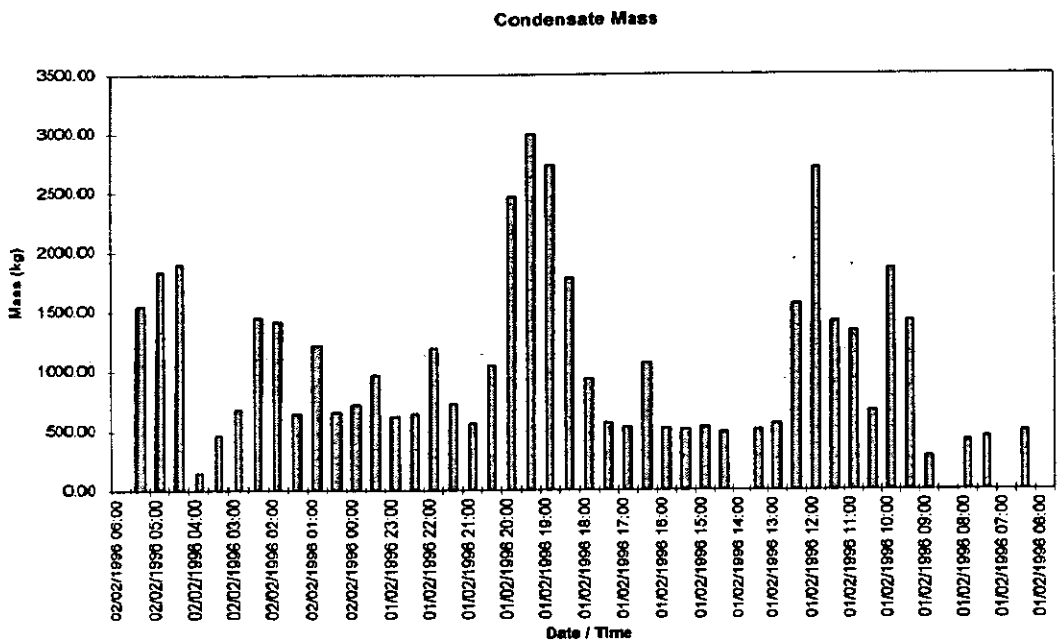


Temperature



Separator Levels




Condensate Mass
3500.00
3000.00
2500.00
2000.00
1500.00
1000.00
500.00
0.00
Mass (kg)
02/02/1996 06:00
02/02/1996 05:00
02/02/1996 04:00
02/02/1996 03:00
02/02/1996 02:00
02/02/1996 01:00
02/02/1996 00:00
01/02/1996 23:00
01/02/1996 22:00
01/02/1996 21:00
01/02/1996 20:00
01/02/1996 19:00
01/02/1996 18:00
01/02/1996 17:00
01/02/1996 16:00
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01/02/1996 14:00
01/02/1996 13:00
01/02/1996 12:00
01/02/1996 11:00
01/02/1996 10:00
01/02/1996 09:00
01/02/1996 08:00
01/02/1996 07:00
01/02/1996 06:00
Date / Time

Appendix A1

Example of Daily Data Logged During Trial

Appendix A2

Full List of Results

Contract Day	Measured Density (kg/m³)	USM Mass (t)	Orifice Plate Mass (t)	USM GVOL (m³/hr)	Orifice Plate Gvol (m³/hr)	% Difference of Reading (Volume) **	% Difference of Reading (Volume) ***	Physical Difference (Volume) (m3)	Physical Difference Mass (t)	Comments ** = Results obtained during normal operation *** = Results obtained during deliberate failure of transducers
05/11/95	17.5	64.7	63.5	154.0	151.2	1.8981		2.8696	1.2053	Very low velocities encountered ... below Qmin at times
06/11/95	21.4	211.7	201.0	411.5	390.8	5.3050		20.7308	10.6631	Very low velocities encountered ... below Qmin at times
07/11/95										No data available
08/11/95	55.6	199.6	213.5	149.7	160.1	-6.5108		-10.4254	-13.9006	Very low velocities encountered ... below Qmin at times
09/11/95	33.5	223.6	223.5	277.8	277.6	0.0569		0.1579	0.1271	Very low velocities encountered ... below Qmin at times
10/11/95	33.6	216.7	216.2	268.9	268.2	0.2534		0.6797	0.5478	Very low velocities encountered ... below Qmin at times
11/11/95	29.0	200.9	196.0	289.1	282.1	2.4977		7.0454	4.8955	Very low velocities encountered ... below Qmin at times
12/11/95	21.1	227.5	215.2	448.9	424.6	5.7228		24.2980	12.3154	Very low velocities encountered ... below Qmin at times
13/11/95	19.2	217.6	216.9	471.3	469.7	0.3435		1.6136	0.7451	Very low velocities encountered ... below Qmin at times
14/11/95	19.7	220.8	225.2	466.1	475.3	-1.9381		-9.2122	-4.3645	Very low velocities encountered ... below Qmin at times
15/11/95	19.4	211.8	213.4	453.9	457.4	-0.7672		-3.5091	-1.6372	Very low velocities encountered ... below Qmin at times
16/11/95	28.6	299.2	256.0	435.3	372.5	16.8749		62.8518	43.1997	Very low velocities encountered ... below Qmin at times
17/11/95	38.6	1370.9	1333.3	1479.7	1439.1	2.8182		40.5578	37.5750	
18/11/95	45.9	2433.3	2423.9	2210.3	2201.8	0.3869		8.5189	9.3782	
19/11/95	53.6	2956.8	2942.7	2298.0	2287.1	0.4793		10.9607	14.1029	
20/11/95	51.8	3129.4	3106.4	2519.6	2501.0	0.7399		18.5047	22.9836	Low frequency cut off set
21/11/95	58.2	2714.7	2699.9	1944.3	1933.7	0.5493		10.6221	14.8313	
22/11/95	48.9	1682.9	1674.8	1433.0	1426.0	0.4858		6.9275	8.1360	Adjusted Orifice plate reading - 3 streams online with very little flow
23/11/95	27.9	517.8	515.0	773.9	769.6	0.5518		4.2469	2.8418	Stream selection problems (WPS original mass = 505.0te)
24/11/95	19.4	362.1	360.2	779.5	775.4	0.5304		4.1125	1.9104	Stream selection problems (WPS original mass = 352.6te)
25/11/95	22.3	228.9	230.7	428.3	431.7	-0.7754		-3.3473	-1.7888	Stream selection problems (WPS original mass = 217.7te)
26/11/95	21.2	217.8	216.4	428.8	426.0	0.6675		2.8434	1.4445	
27/11/95	30.9	1783.9	1787.6	2404.8	2409.8	-0.2052		-4.9445	-3.6679	Orifice readings for 09:00 26/11 adjusted
28/11/95	29.9	1602.1	1593.5	2236.0	2224.1	0.5384		11.9742	8.5793	
29/11/95	38.3	2833.9	2821.4	3079.3	3065.8	0.4421		13.5531	12.4728	
30/11/95	40.6	3157.1	3135.6	3236.6	3214.6	0.6857		22.0417	21.5002	Factor of 0.997 set in USM as per calibration results
01/12/95	39.8	2991.2	2964.3	3134.7	3106.5	0.9075		28.1901	26.9000	
02/12/95	23.5	354.2	354.4	628.9	629.2	-0.0564		-0.3551	-0.2000	
03/12/95	21.5	228.5	227.8	442.7	441.4	0.3073		1.3563	0.7000	Welland Database changed - pulses missed & incorrect stream selection

04/12/95	39.3	2733.3	2715.7	2897.3	2878.7	0.6481		18.6563	17.6000	Stream selection problems (WPS original mass = 2704.2te)
05/12/95	42.0	3159.0	3131.6	3132.7	3105.4	0.8782		27.2707	27.5000	
06/12/95	54.0	1661.6	1647.1	1283.3	1272.1	0.8803		11.1984	14.6000	
07/12/95	60.3	2461.8	2447.9	1699.8	1690.2	0.5678		9.5976	13.9000	Stream selection problems (WPS original mass = 2437.6te)
08/12/95	55.0	3030.7	3007.7	2295.3	2277.9	0.7647		17.4188	23.0000	
09/12/95	69.8	2492.6	2476.3	1735.8	1724.4	0.6582		11.3508	16.3000	
10/12/95	58.2	2792.0	2772.2	1999.1	1984.9	0.7142		14.1767	19.8000	
11/12/95	56.9	2899.7	2877.7	2121.9	2105.8	0.7645		16.0992	22.0000	
12/12/95	54.6	2868.5	2844.8	2188.4	2170.3	0.8331		18.0806	23.7000	
13/12/95	52.6	2760.9	2739.2	2188.2	2171.0	0.7922		17.1984	21.7000	
14/12/95	52.0	2751.0	2728.3	2205.0	2186.8	0.8320		18.1948	22.7000	
15/12/95	54.3	2759.3	2736.0	2116.0	2098.1	0.8516		17.8677	23.3000	
16/12/95	56.2	2472.5	2456.6	1834.6	1822.8	0.6472		11.7980	15.9000	Stream selection problems (WPS original mass = 2357.9te)
17/12/95	43.8	3217.0	3194.4	3057.0	3035.6	0.7075		21.4763	22.6000	Stream selection problems (WPS original mass = 3161.1te)
18/12/95	43.6	3224.1	3209.7	3079.3	3065.6	0.4486		13.7534	14.4000	Database problems - WPS original mass = 2825.9te)
19/12/95	39.7	3293.4	3280.6	3458.0	3444.5	0.3932		13.5447	12.9000	
20/12/95	40.1	3242.0	3214.1	3368.0	3339.0	0.8681		28.9842	27.9000	
21/12/95	48.4	2965.5	2932.5	2551.9	2523.5	1.1253		28.3976	33.0000	
22/12/95	45.8	2894.3	2860.1	2631.0	2599.9	1.1958		31.0889	34.2000	
23/12/95	37.3	1394.7	1378.0	1558.6	1539.9	1.2119		18.6627	16.7000	
24/12/95										Stream 1 off-line therefore incorrect density used
25/12/95										Stream 1 off-line therefore incorrect density used
26/12/95										Stream 1 off-line therefore incorrect density used
27/12/95										Stream 1 off-line therefore incorrect density used
28/12/95										Stream 1 off-line therefore incorrect density used
29/12/95	36.7	2897.5	2863.3	3289.4	3250.6	1.1944		38.8261	34.2000	Stream selection problems (WPS original mass = 2792.8te)
30/12/95	36.9	3110.2	3080.2	3515.6	3481.7	0.9740		33.9108	30.0000	
31/12/95	37.3	3121.7	3118.3	3483.0	3479.2	0.1090		3.7935	3.4000	
01/01/96	39.3	3054.8	3045.9	3241.3	3231.9	0.2922		9.4434	8.9000	
02/01/96	41.9	3043.0	3033.1	3022.6	3012.8	0.3264		9.8337	9.9000	15 - 17:00 hrs Stream 1 plate changed and wrong density used by USM
03/01/96	44.9	2851.7	2833.8	2644.7	2628.1	0.6317		16.6005	17.9000	
04/01/96	46.4	2198.5	2177.5	1973.4	1954.5	0.9644		18.8498	21.0000	
05/01/96	50.7	2604.4	2574.1	2139.3	2114.4	1.1771		24.8893	30.3000	Liquids present in meter tubes - Separator levels not working correctly

06/01/96	52.0	2720.3	2694.9	2179.0	2158.6	0.9425		20.3457	25.4000	Liquids present in meter tubes - Separator levels not working correctly
07/01/96	45.0	2748.9	2743.3	2544.8	2539.6	0.2041		5.1843	5.6000	
08/01/96	48.6	2703.7	2702.7	2318.7	2317.8	0.0370		0.8576	1.0000	
09/01/96	45.7	2586.5	2585.5	2358.8	2357.9	0.0387		0.9120	1.0000	
10/01/96	53.2	2513.3	2498.0	1968.0	1956.1	0.6125		11.9806	15.3000	WPS Database fault for half of day - see printouts
11/01/96	46.7	2922.9	2893.0	2606.6	2580.0	1.0335		26.6646	29.9000	WPS database problems and liquids detected
12/01/96	50.2	2694.2	2658.4	2238.4	2208.7	1.3467		29.7434	35.8000	Liquids detected again
13/01/96	48.6	2683.0	2660.8	2300.1	2281.1	0.8343		19.0316	22.2000	
14/01/96						0.9264				Flow computer u/s
15/01/96										Flow computer u/s
16/01/96										Flow computer u/s
17/01/96										Flow computer u/s
18/01/96										Flow computer u/s
19/01/96										Flow computer u/s
20/01/96										New computer fitted & density input calibrated
21/01/96	41.4	2810.8	2820.0	2826.4	2835.6	-0.3262		-9.2510	-9.2000	WPS mass from ETC / Database problems
22/01/96	43.1	2688.9	2699.3	2601.7	2611.8	-0.3853		-10.0627	-10.4000	
23/01/96	41.3	2726.2	2729.0	2747.4	2750.2	-0.1026		-2.8217	-2.8000	
24/01/96	35.8	2549.6	2545.9	2969.5	2965.1	0.1453		4.3093	3.7000	
25/01/96	42.8	2641.0	2638.3	2573.5	2570.9	0.1023		2.6310	2.7000	
26/01/96	43.7	1980.7	1971.0	1887.9	1878.6	0.4921		9.2453	9.7000	
27/01/96	33.1	2049.8	2042.8	2581.1	2572.3	0.3427		8.8145	7.0000	
28/01/96	34.0	1851.2	1855.8	2267.8	2273.5	-0.2479		-5.6353	-4.6000	
29/01/96	33.4	1714.8	1723.4	2140.4	2151.1	-0.4990		-10.7345	-8.6000	
30/01/96	35.8	1793.5	1805.2	2087.9	2101.6	-0.6481		-13.6207	-11.7000	
31/01/96	32.4	1876.7	1894.2	2416.5	2439.0	-0.9239		-22.5337	-17.5000	
01/02/96	37.0	2121.3	2136.9	2390.8	2408.4	-0.7300		-17.5818	-15.6000	
02/02/96	44.0	2303.6	2285.0	2181.7	2164.1	0.8140		17.6156	18.6000	Database error during stream flow computer change-out
03/02/96	41.7	2663.4	2687.8	2660.3	2684.6	-0.9078		-24.3714	-24.4000	
04/02/96	42.3	2424.6	2446.9	2386.1	2408.0	-0.9114		-21.9457	-22.3000	
05/02/96	41.5	2647.9	2671.3	2656.5	2680.0	-0.8760		-23.4759	-23.4000	
06/02/96	41.2	2642.4	2664.8	2670.3	2693.0	-0.8406		-22.6369	-22.4000	
07/02/96	41.3	2660.0	2673.1	2686.6	2699.8	-0.4901		-13.2310	-13.1000	
08/02/96	42.2	2574.4	2571.4	2544.9	2541.9	0.1167		2.9656	3.0000	

09/02/96	42.7	2618.0	2625.8	2553.6	2561.2	-0.2971		-7.6081	-7.8000	USM adjusted slightly (original 2670.9 te)
10/02/96	43.9	2498.0	2501.9	2370.0	2373.7	-0.1559		-3.7002	-3.9000	
11/02/96	40.7	2593.4	2610.2	2653.8	2671.0	-0.6436		-17.1910	-16.8000	
12/02/96	40.0	2733.7	2750.2	2847.5	2864.7	-0.6000		-17.1871	-16.5000	
13/02/96	33.9	2342.4	2355.6	2882.3	2898.5	-0.5604		-16.2424	-13.2000	Database error warm start for Spectra-tek 16t lost
14/02/96	32.8	1901.8	1904.4	2418.7	2422.0	-0.1365		-3.3066	-2.6000	
15/02/96	27.9	1365.1	1361.2	2042.0	2036.2	0.2865		5.8339	3.9000	
16/02/96	27.9	2135.3	2122.6	3194.1	3175.1	0.5983		18.9975	12.7000	Path 1a Disconected
17/02/96	36.5	2169.3	2172.3	2478.4	2481.8		-0.1381			
18/02/96	38.6	2143.4	2156.2	2313.6	2327.4		-0.5936			
19/02/96	32.1	1987.2	1991.0	2579.9	2584.8		-0.1909			
20/02/96	26.8	2016.5	2028.7	3131.3	3150.3		-0.6014			
21/02/96	27.4	1504.3	1513.4	2290.6	2304.4		-0.6013			
22/02/96										No data available
23/02/96	34.4	1875.1	1914.5	2273.6	2321.4		-2.0580			No1 connected - No2 Disconnected
24/02/96	38.7	2574.0	2636.1	2772.5	2839.4		-2.3558			
25/02/96	34.2	1842.4	1872.8	2243.5	2280.6		-1.6232			
26/02/96	37.8	2626.0	2687.0	2895.3	2962.5		-2.2702			
27/02/96	37.1	2127.0	2155.7	2388.0	2420.3		-1.3314			
28/02/96	37.7	2597.9	2660.2	2871.6	2940.4		-2.3419			
29/02/96	36.4	2287.2	2315.2	2616.9	2648.9		-1.2094			
01/03/96	36.1	2588.1	2608.6	2990.9	3014.6		-0.7859			No 2 connected - No3 Disconnected
02/03/96	36.1	2588.1	2608.6	2990.9	3014.6		-0.7859			
03/03/96	38.2	2670.8	2694.8	2916.9	2943.1		-0.8906			
04/03/96	30.0	2259.9	2276.6	3137.3	3160.5		-0.7336			
05/03/96	24.0	1184.7	1190.9	2052.6	2063.3		-0.5206			
06/03/96	32.6	1137.9	1141.0	1452.6	1456.6		-0.2717			
07/03/96	34.1	2363.8	2381.9	2888.0	2910.1		-0.7599			
08/03/96	40.0	2676.2	2720.4	2787.7	2833.8		-1.6248			No3 connected - No 4 Disconnected
09/03/96	38.5	2678.5	2745.2	2897.9	2970.0		-2.4297			
10/03/96	35.3	2487.7	2625.0	2933.2	3095.1		-5.2305			Suspect finger trouble on platform
11/03/96	39.5	2457.5	2510.6	2591.5	2647.5		-2.1150			
12/03/96	38.3	2581.6	2646.1	2805.5	2875.6		-2.4375			
13/03/96	30.7	458.1	460.6	622.0	625.4		-0.5428			

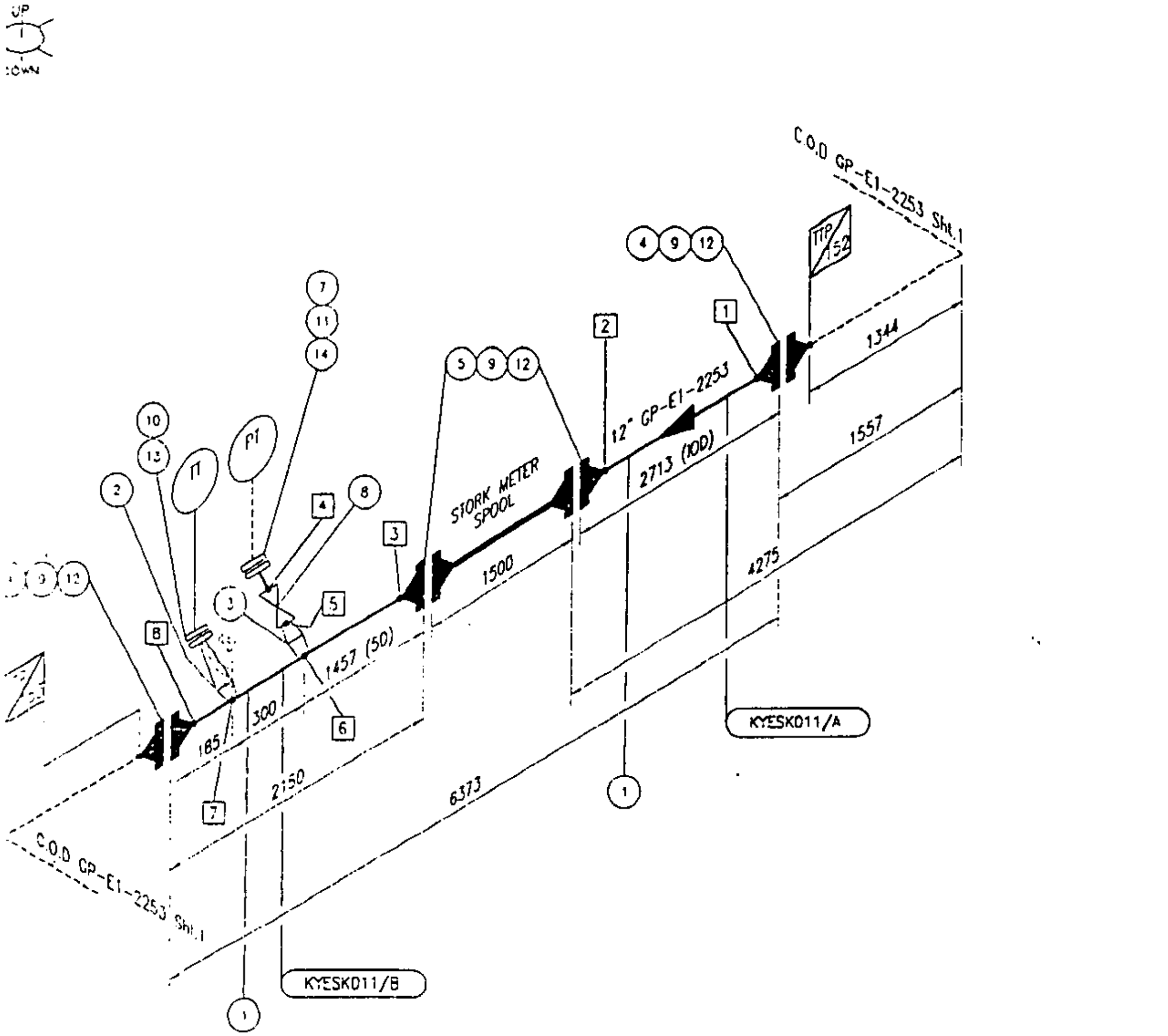
14/03/96	38.9	382.2	437.5	409.5	468.8	-12.6400			Suspect finger trouble on platform
15/03/96	41.0	2133.4	2152.0	2166.7	2185.5	-0.8643			No 4 Connected - No 5 Disconnected
16/03/96	43.1	2533.9	2554.8	2451.3	2471.5	-0.8181			
17/03/96	43.6	2494.2	2512.0	2384.7	2401.8	-0.7086			
18/03/96	42.6	1777.5	1785.9	1740.5	1748.7	-0.4704			
19/03/96	44.3	1633.7	1640.6	1535.3	1541.8	-0.4206			
20/03/96	41.2	1592.9	1599.1	1610.3	1616.6	-0.3877			
21/03/96	42.8	805.6	811.3	785.1	790.6	-0.7026			
22/03/96									No 1,3 & 5 disconnected - No production
23/03/96									No production
24/03/96	44.1	443.0	439.6	418.6	415.4	0.7734			
25/03/96	47.2	85.0	84.3	75.1	74.5	0.8304			
26/03/96	45.9	963.0	962.0	873.8	872.9	0.1040			
27/03/96	43.5	451.0	442.0	431.5	422.9	2.0362			
28/03/96	42.8	416.0	400.0	404.9	389.3	4.0000			
29/03/96	36.2	416.6	399.9	479.3	460.1	4.1760			
30/03/96									No production
31/03/96	28.9	2151.0	2161.0	3100.9	3115.3	-0.4627			
01/04/96	24.7	1784.9	1795.0	3005.2	3022.3	-0.5627			
02/04/96	26.9	1131.0	1134.0	1754.3	1759.0	-0.2646			
03/04/96	39.0	786.0	790.4	840.0	844.7	-0.5567			No 2 & 4 Disconnected - No 1, 2 & 3 Connected
04/04/96	23.1	1140.4	1154.4	2053.6	2078.8	-1.2128			
05/04/96	22.7	1479.7	1511.9	2717.4	2776.5	-2.1298			
06/04/96	22.5	1532.0	1563.4	2833.6	2891.7	-2.0084			
07/04/96									No production
08/04/96									No production
09/04/96									No production
10/04/96									No production
11/04/96									No production
12/04/96	17.4	338.8	342.1	811.0	818.9	-0.9646			
13/04/96	14.5	497.5	505.0	1425.0	1446.5	-1.4851			
14/04/96	47.0	985.0	992.3	873.6	880.1	-0.7357			
15/04/96	44.8	1786.0	1806.0	1662.2	1680.8	-1.1074			
16/04/96	43.7	698.7	685.0	665.7	652.7	2.0000			All paths reconnected

17/04/96	44.2	30.8	29.1	29.0	27.4	5.8419		1.6015	1.7000	
18/04/96	43.3	1951.7	1939.9	1879.8	1868.5	0.6083		11.3654	11.8000	
19/04/96	40.5	2084.6	2078.4	2144.7	2138.3	0.2983		6.3786	6.2000	
20/04/96	41.8	1698.4	1698.0	1691.8	1691.4	0.0236		0.3984	0.4000	
21/04/96	38.9	1133.9	1135.6	1214.9	1216.7	-0.1497		-1.8214	-1.7000	
22/04/96	38.1	808.0	806.1	883.2	881.1	0.2357		2.0768	1.9000	
23/04/96	41.5	2131.8	2136.3	2139.3	2143.8	-0.2106		-4.6159	-4.5000	
24/04/96	42.6	2172.9	2178.2	2125.8	2131.0	-0.2433		-5.1851	-5.3000	
25/04/96	53.2	2076.8	2081.7	1626.6	1630.4	-0.2354		-3.8377	-4.9000	
26/04/96	59.1	729.0	728.1	514.0	513.4	0.1236		0.6346	0.9000	
27/04/96										No production
28/04/96										No production
29/04/96	42.2	289.0	288.0	285.1	284.2	0.3472		0.9867	1.0000	
30/04/96										No production
01/05/96										No production
02/05/96	43.2	171.0	172.0	165.0	166.0	-0.5814		-0.9650	-1.0000	
03/05/96										No Production
04/05/96										No Production
05/05/96										No Production
06/05/96										No Production
07/05/96										No Production
08/05/96	45.0	780.0	766.0	723.0	710.0	1.8277		12.9774	14.0000	Scaling factor changed (0-4ksm3/hr = 0-4kHz) was (0-8km3hr = 0 - 8kHz)
09/05/96	38.5	1144.3	1145.8	1238.7	1240.4	-0.1309		-1.6238	-1.5000	
10/05/96	46.1	809.4	778.4	731.6	703.6	3.9825		28.0200	31.0000	
11/05/96	46.5	219.2	213.9	196.4	191.6	2.4778		4.7477	5.3000	
12/05/96	48.8	221.0	215.8	188.8	184.4	2.4096		4.4424	5.2000	
13/05/96	48.7	160.1	156.6	136.9	133.9	2.2350		2.9933	3.5000	
14/05/96	47.7	135.0	124.0	118.0	108.4	8.8710		9.6187	11.0000	
15/05/96	49.6	223.3	228.0	187.4	191.3	-2.0614		-3.9443	-4.7000	
16/05/96	51.9	222.3	219.9	178.3	176.4	1.0914		1.9251	2.4000	
17/05/96	52.8	225.2	222.5	177.6	175.5	1.2135		2.1293	2.7000	
18/05/96	53.5	223.1	219.9	173.9	171.4	1.4552		2.4943	3.2000	
19/05/96	51.5	196.5	186.5	159.1	151.0	5.3619		8.0971	10.0000	
20/05/96	51.8	227.2	220.6	182.7	177.3	2.9918		5.3060	6.6000	

21/05/96	52.4	224.0	221.7	178.0	176.2	1.0374		1.8281	2.3000	
22/05/96	52.3	226.7	219.4	180.7	174.9	3.3273		5.8199	7.3000	
23/05/96	52.1	209.8	206.0	167.8	164.8	1.8447		3.0395	3.8000	
24/05/96	52.4	225.3	221.8	179.1	176.3	1.5780		2.7822	3.5000	
25/05/96	52.7	238.9	236.0	188.9	186.6	1.2288		2.2932	2.9000	
26/05/96	56.2	223.5	218.0	165.8	161.8	2.5229		4.0810	5.5000	
27/05/96	55.4	236.2	232.4	177.6	174.8	1.6351		2.8579	3.8000	
28/05/96	55.5	213.9	209.7	160.6	157.5	2.0029		3.1542	4.2000	
29/05/96										No production
30/05/96	54.4	225.0	233.7	172.3	178.9	-3.7227		-6.6616	-8.7000	
31/05/96										No production
01/06/96	47.5	258.4	247.7	226.5	217.1	4.3197		9.3796	10.7000	
02/06/96	48.3	225.6	224.3	194.5	193.4	0.5796		1.1206	1.3000	
03/06/96	49.7	227.9	225.1	191.2	188.9	1.2439		2.3493	2.8000	
04/06/96	48.4	226.8	224.5	195.3	193.3	1.0245		1.9802	2.3000	
05/06/96	49.2	233.2	227.4	197.6	192.6	2.5506		4.9134	5.8000	
06/06/96	47.4	213.1	210.6	187.3	185.1	1.1871		2.1970	2.5000	
07/06/96										No production
08/06/96	48.2	197.4	196.3	170.6	169.6	0.5604		0.9506	1.1000	
09/06/96	48.8	209.8	208.3	179.0	177.7	0.7201		1.2798	1.5000	
10/06/96	49.7	209.7	208.5	175.9	174.9	0.5755		1.0066	1.2000	
11/06/96										S500 failed - end of trial

Appendix A2

Test Meter Spool Sketch



ITEM No.	QUANTITY SHOP	QUANTITY FIELD	SIZE	RATING SCH	DESCRIPTION	CAST No.	CERT. No.
1	6M		12"NB	120	PIPE ASTM A333 GR.6		
2	1		12"x1½"	XXS	"PROMAT" WELDOFLANGE 1500# RTJ LTFCS		
					A350 LF2 - SCH 120		
3	1		12"x1"	XXS	"PROMAT" NIPOLET 6000# BW LTFCS		
					A350 LF2 - SCH 160		
4	2		12"NB	120	FLANGE 900# RTJ WN BW LTFCS A350 LF2		
5	2		12"NB	140	FLANGE 900# RTJ WN BW LTFCS A350 LF2		
6	1		1"NB	XXS	FLANGE 1500# RTJ BW WN LTFCS		
					A350 LF2		
7	1		1"NB	XXS	FLANGE 1500# RTJ BLIND LTFCS A350 LF2		
					(DRILL & TAP 1/2" NPT CENTRALLY)		
8	1		1"NB	XXS	GATE VALVE 1500# BW LTFCS GA.13		
9		4	12"NB	R57	OCT. RING GASKET SS TYPE 316		
					ABOVE TO SUIT 900# RTJ FLANGES		
10		1	1½"NB	R20	OCT. RING GASKET SS TYPE 316		
11		1	1"NB	R16	OCT. RING GASKET SS TYPE 316		
					ABOVE TO SUIT 1500# RTJ FLANGES		
12		80	ø1⅜"	-	STUDBOLTS X 290 LONG C/W 3 NUTS		
13		4	ø1"	-	STUDBOLTS X 140 LONG C/W 2 NUTS		
14		4	ø⅞"	-	STUDBOLTS X 125 LONG C/W 2 NUTS		
					STUDBOLTS - A320 GR.L7		
					NUTS-A194 GR.7 SF HVY HEX FCC		

LAST WELD No. THIS DRG.	8	RADIOGRAPHY		
REINFORCEMENT	STRESS RELIEVING	STRESS SKETCH No.		
NO	YES / FULL / ~~PART~~ / ~~NO~~			

INSULATION TYPE	INSULATION THICKNESS	TRACING	PRESSURE TEST MEDIUM	PRESSURE TEST PRESSURE	PAINT COLOUR
-	30	-	WATER	222 BARG	

REFERENCE DRAWINGS NUMBER	TITLE	REV. No.	REVISION	BY	DATE	CKD	APPVD	CLIENT APPVD
E1-2253 SHT 1	8090 ISO 12" E1-2253-SHT 1	1	ISSUED FOR CONSTRUCTION	AMF	2.08.95	AV	PL	

PROJECT: DESIGN ENGINEERING SERVICES FOR KYE LTD

TITLE: TEST METER SPOOL SKETCH

DRAWN	CHECKED	APPROVED	CLIENT APPVD.	SCALE	DRAWING NUMBER	REV
A.FINCH 2.08.95	A. VIPOND 2.08.95	P. LAFFERTY 2.08.95		NTS	9095-G06 [illegible] 01	1

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CAD drawing - not [illegible] modified by hand

[illegible]\CAD\DWGS\G064001

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.