19th NORTH SEA FLOW MEASUREMENT WORKSHOP

Field Experience With Multipath USMs – Ultrasonic Meter Vs Turbine Meter Trial

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1 INTRODUCTION

In recent times Advantica Technologies Ltd, in close collaboration with Transco and Ultrasonic Meter manufacturers, have carried out short and long term studies and experiments on multipath ultrasonic meters[1]. The aims of these exercises were to identify installation effects on the meters and to gain a better understanding and confidence of their performance against 'other' metering systems.

As part of this work, examination of the effect of noise generation by three of the most popular pressure regulators used by Transco at metering stations was studied. Long-term performance of one of the multipath ultrasonic meters was also undertaken as part of the same exercise[2]. An 18-inch multipath USM was installed at an operational site upstream of an existing orifice plate metering system to monitor its long term operation and compare its performance with the orifice plate system. During this work, issues such as correction methods and compatibility of multipath ultrasonic meters with currently available flow computers were also addressed.

During 2000 and 2001, a metering system comprising of a different multipath ultrasonic meter and an Instromet SM-RI turbine meter was commissioned and installed at one of the metering stations, upstream of a multistage pressure regulator. The aim of this exercise was to understand calibration methods between different multipath ultrasonic meters, identify best possible correction methods, compare the long term performance with a very accurate and stable flow meter and gain experience with the installation, commissioning and operation of the multipath ultrasonic meter using one of the most popular flow computers in the market.

This paper presents calibration results, installation details and long term comparison results between the turbine and the ultrasonic meter. Interpretation of various diagnostics data obtainable from the flow computer and the comparison of diagnostic data received from the ultrasonic meter with a conventional gas property calculation package (GasVLe[3]) is also presented.

2 CALIBRATION

2.1 Meter and Spool Details

A 12 inch SM-RI turbine meter with a claimed accuracy of ± 0.5% with the new X4X built-in flow straightener and a 12-inch five-path Q.Sonic ultrasonic flow meter were purchased from Instromet together with the upstream and downstream spool pieces.

A photograph capturing the configuration details is shown in Figure 1 below. The turbine meter is installed 10D downstream of a full bore ball valve and 10D upstream of the USM. A further 10D straight pipe length is installed downstream of the USM.

Two Honeywell pressure transducers were installed directly, one on the USM and the other on the turbine meter, to provide pressure readings for both meters. Temperature readings were provided by two platinum resistant thermometers installed 3D downstream of each meter.

Figure 1 Ultrasonic Meter and Turbine Meter Installation

2.2 Calibration

The two meters were calibrated at the Bishop Auckland Test Facility using the configuration described above. The meters and meter spools were transported to the test facility where they were assembled prior to calibration. The Bishop Auckland calibration facility is UKAS accredited for volume flow measurement and utilises a series of 4”, 6”, 8” and 12” turbine meters as reference meters giving a maximum accredited flow rate of 19,500 acmh. The facility is connected to the UK National Transmission System (NTS) and it operates in two flow modes, dependent upon the pressure and flow rates required. Typically the site operates in the range 50 to 60 bar pressure, providing extremely good reliability and stability of flow. More details of the facility were described in a previous paper[2].

The turbine meter was calibrated in the normal way, logging frequency readings from both the reference and the test meter for a period of 100 seconds. Both the pressure and the temperature readings for the reference and the test meter were also recorded and averaged at 10 second intervals. This procedure was repeated twice more, averaging all three calibration data for each flow rate through the meters. If the meter errors indicated by the three test runs were not within the test facilities expected tolerance limits, additional test point(s) were taken to minimise the effect of any random errors associated with the data points obtained. Calibration details of the turbine meter are shown in Figure 2 below.

The ultrasonic meter was connected to the site flow computer in the frequency mode and calibrated just like a turbine meter. Calibration details of the meter are also shown in Figure 2. The meter's serial output was also connected to a computer where the manufacturer's system software enabled the meter configuration details to be confirmed and the diagnostics data to be monitored during the calibration period.

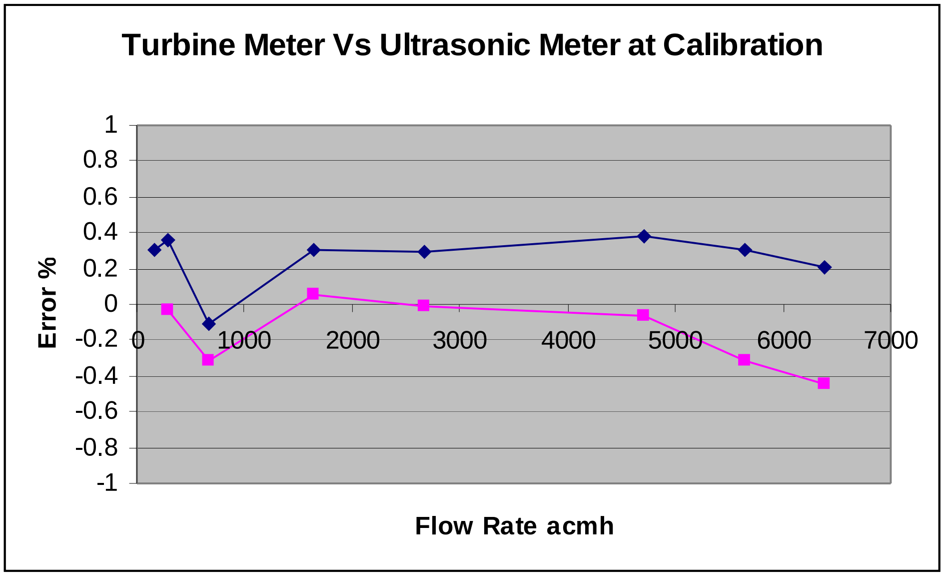

Figure 2. Turbine and Ultrasonic Meter Details at Calibration

After the calibration, a new meter adjust factor (normally 1.0000) was calculated, but it was not updated in the meter diagnostics, instead multiple 'k' factor correction (linear interpolation) was later employed on the flow computer.

It should be noted that multiple 'k' factor corrections or multiple linearisation within certain flow computers are only possible if the ultrasonic meters are calibrated in the frequency (pulse) output mode. This will be covered in detail under the flow computer section.

3 INSTALLATION

3.1 Hardware Installation

The site where the two meters were installed is an operational site and therefore careful configuration of the two meters and the secondary instrumentation was necessary to keep the site operational as well as to allow monitoring and comparison between the two meters continuously. The two metering systems used flow computers, which were kept independent from each other when carrying out the necessary flow computations. Both flow computers were connected to a remote data collection and storage system, via a data logging system especially designed for this site. Pressure and temperature data was received from two separate pressure transmitters, positioned on the meter bodies and two independent temperature sensors, positioned downstream of each meter.

Two flow computers of the same make were employed on the site; one was connected to the turbine metering system frequency output and the other to the USM frequency as well as the serial output. The flow computers were connected to each other, using the peer-to-peer facility. A gas chromatograph, installed on the upstream of the two meters, provided gas composition data to the turbine meter flow computer, which was shared with the ultrasonic meter flow computer.

Two 4-inch multistage Jetstream pressure regulators, installed downstream of the two meters, provided pressure cut from 70 bar to 55.2 bar and then from 55.2 bar to 37.2 bar.

3.2 Flow Computer Details

Both flow computers operate independently, calculating turbine and USM actual and standard flow rates simultaneously. Density, relative density and calorific value calculations are also performed to the relevant standards. Full gas composition is obtained from the gas chromatograph, where the line density and the relative density are calculated.

Both flow computers are capable of using linear interpolation technique to carry out multiple 'k' factor corrections. From the meter calibration certificates it was possible to calculate the relevant 'k' factors for both the USM and the turbine meters and input these into the flow computers.

For turbine meters, straightforward interpolation within the flow computer using multiple 'k' factors is possible. For ultrasonic meters, this will be very much dependent on the flow computer capability. Some flow computers, including the ones on this site, are only capable of carrying out multiple 'k' factor correction using the pulse output from the ultrasonic meter. In this case the USM was calibrated using the pulse output from the meter and therefore it was possible to treat the meter similar to a turbine meter.

Diagnostic data from the ultrasonic meter was obtained through the serial RS-485 output. This output provided gas velocities, actual flow rates, speed of sound, etc., to enable monitoring of the meters performance during its operation. The ultrasonic meter flow computer accepts frequency pulses direct from the meter, and gas velocity and flow rate through the serial connection. If a pulse signal is available, the flow computer will use this for calculations, as long as the calculated flow rate is within a user defined 'flow rate deviation percentage' of the flow transmitted serially by the ultrasonic meter. If a pulse signal is not available, failed or user-inhibited, the flow computer will use the gas velocity transmitted by the ultrasonic meter. The flow rate calculated by this method must also be within the 'flow rate deviation percentage' of the flow transmitted serially by the ultrasonic meter.

3.3 Frequency Vs Serial Issue with USMs

It is claimed that the most accurate way of transmitting the ultrasonic meter flow measurement to a supervisory system (e.g. flow computer) is via the serial link. This is because the ultrasonic meter calculates the actual flow rate and converts it to frequency. It is also claimed that over a long period of time, the accuracy of the flow measurement using the frequency mode is as good as the serial link, however over a short period of time the frequency output from the ultrasonic meter may not be equal to the flow rate calculated by the meter. Some flow computers are capable of using serial and/or pulse output from multipath ultrasonic meters to carry out multiple ‘k’ factor interpolation. It is therefore important to select flow computers to suit ultrasonic meters or vice versa. It should be noted that if the flow computer is only capable of using the pulse option, then preferably the high pressure calibration of the meter is conducted in the pulse output mode. This will enable the ‘k’ factor data to be included in the flow computer configuration. If however the ultrasonic meter is calibrated in the serial mode and the flow computer is not capable of carrying out ‘k’ factor corrections using this mode, then a new meter factor and a new zero offset value is calculated and entered into the ultrasonic meter drive unit. From these two new values, it is possible to adjust the calibration error curve, using ‘least mean square’ correction to produce a new set of error values.

4 COMMISSIONING

The turbine meter was commissioned in the usual way, making sure that the system was pressurised slowly, following the manufacturers commissioning guidelines. Turbine meter details, such as the ‘k’ factors, were entered into the flow computer to make sure that multiple ‘k’ factor correction is carried out.

The ultrasonic meter pulse-output connection to the flow computer is similar to a turbine meter. With the serial connection, it was necessary to check the meter details, such as speed of sound, flow velocities, meter factors etc. It was noticed at this stage that the meter individual cord velocities and the individual speed of sound readings were not obtainable from the meter. The electronics board on the meter was then replaced to enable these readings to be accessed also. Recording of the meter diagnostics before and after the electronics board change was made to make sure that there were no significant changes.

5 FIELD OPERATION AND RESULTS

Some difficulty was experienced with the ultrasonic meter pulse output during the commissioning. Maximum frequency obtainable from the meter was limited to 1250 Hz due to the capacitance effect of the interconnecting cable. This was resolved by reducing the time constant of the connection. It was also noticed that although the site gas flow was shut off and the turbine meter was showing zero frequency output, the ultrasonic meter was still registering erratic frequencies of between zero and 50 Hz.

Remote monitoring of the two meters was carried out using the existing telephone lines. A dedicated data logger was installed, connected to the two independent flow computers and configured remotely to access and log the following information, in order to make sure that metrological comparison between the two metering systems can be carried out and the health of the ultrasonic meter can be monitored:

Turbine meter flow computer data logged

Actual flow rate - m3/h
Reference flow rate - m3/h
Actual volume - m3
Actual 0.5 hourly volume - m3
Reference volume - m3
Reference 0.5 hourly volume - m3

Stream pressure - barg
Stream temperature - degC
Stream density - kg/m3
Meter frequency - Hz
Meter K-factor in use - pulses/m3

Ultrasonic meter flow computer data logged

Comms. Actual Flow Rate - m3/h
Actual flow rate - m3/h
Reference flow rate - m3/h
Actual volume - m3
Actual 0.5 hourly volume - m3
Reference volume - m3
Reference 0.5 hourly volume - m3

Stream pressure - barg
Stream temperature - degC
Meter K-factor in use - pulses/m3
Stream density - kg/m3
Meter frequency - Hz

Calorific value
Relative density
Methane - mol%
Nitrogen – mol%
Carbon dioxide - mol%
Ethane - mol%
Propane – mol%

i-Butane – mol%
n-Butane – mol%
i-Pentane - mol%
n-Pentane - mol%
Hexane - mol%

In addition, the majority of the serial data provided by the ultrasonic meter was also logged and remotely transferred. These included:

Calculated velocity of sound - m/s
Error between calculated and measured VoS
USM VoS – m/s
USM gas velocity - m/s
Path 1 - 5 VoS - m/s
Path 1 - 5 Gas Velocity - m/s
Path1 - 5 performance
Path1a – 5 b AGC ratios

Comms lost
Pulse lost
FloRateDelta
VoSalarm
AGCalarm
Sample 1-5 alarms

During field operation, the performance of the USM transducers and their associated timing circuitry and metrology was assessed by comparing the speed of sound on each chord and secondly by comparing the measured, average speed of sound with a theoretical value calculated from the gas composition, temperature and pressure. Using the gas composition data from the gas chromatograph together with the measured pressure and temperature, a theoretical value of the speed of sound was calculated, using the Advantica programme GasVLe. An example of comparing the two values (GasVLe Vs USM speed of sound) is shown below (Figure 3).

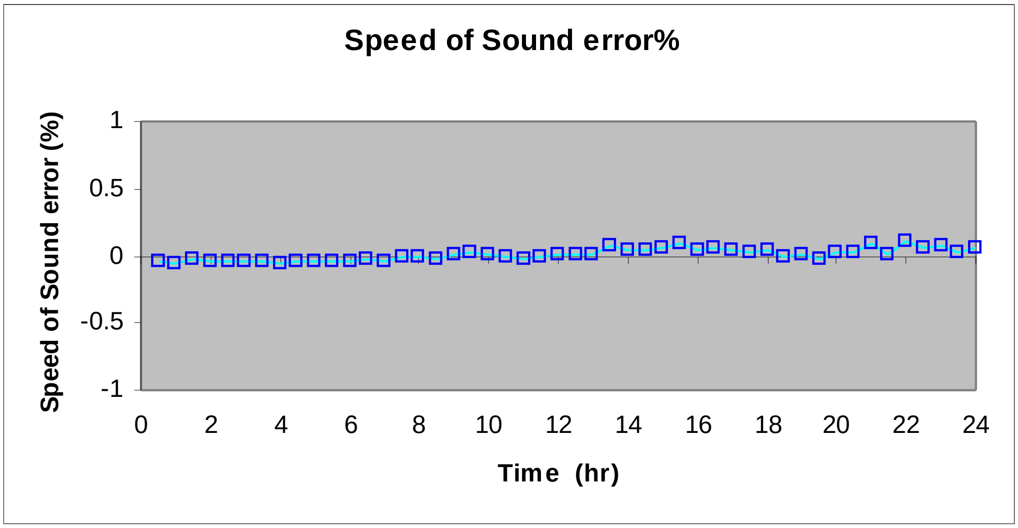

Figure 3. Speed of sound comparison between the GasVLe and Ultrasonic Meter

It can be seen here that the two different methods of deriving the speed of sound varies by a maximum of ± 0.2%. This comparison confirms that there are no obvious errors in the operation of the timing or in the dimensional data in the ultrasonic meter. This technique was used through out the trial to confirm the validity of the speed of sound readings from the ultrasonic meter.

At the start of the trial, the ultrasonic meter flow computer was configured to operate normally, i.e. it was allowed to choose the flow rate for calculations (pulse, serial or gas velocity). The flow computer first tries the pulse signal, then the transmitted gas velocity and finally the transmitted flow rate as explained in section 3.2. Daily comparisons between the turbine and the ultrasonic meters half hourly actual volumes in this mode of operation are plotted below (Figure 4).

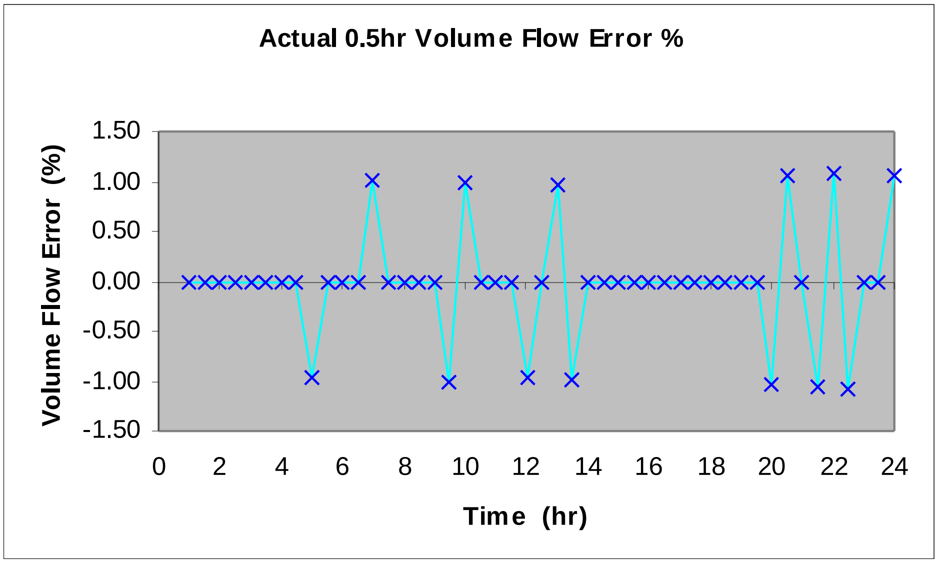

Figure 4. % Difference in the actual volumes passed between the turbine and the ultrasonic meters (with the flow computer operating normally)

This is a typical example of how the two meters compare with each other over a 24-hour period. Majority of the time the two meters agree with each other to an accuracy of well within ±0.1%. Only occasionally this difference extended up to ±1%. If the two meters' outputs were averaged over 24-hours, the maximum deviation between the two was ±0.1%. This trend was found throughout the trial. Taking into account the uncertainty of the test facility, this difference lies well within the calibration results of the two meters.

In order to check the effect of using just one source of flow rate, the flow computer was forced to use frequency-derived flow. Data logged over a 24-hour period is shown in Figure 5 below. A significant difference between the two meters can be seen here. The ultrasonic meter is registering volumes up to 5% lower than the turbine meter. Average deviation between the two meters over a 24-hour period was increased to around 4%.

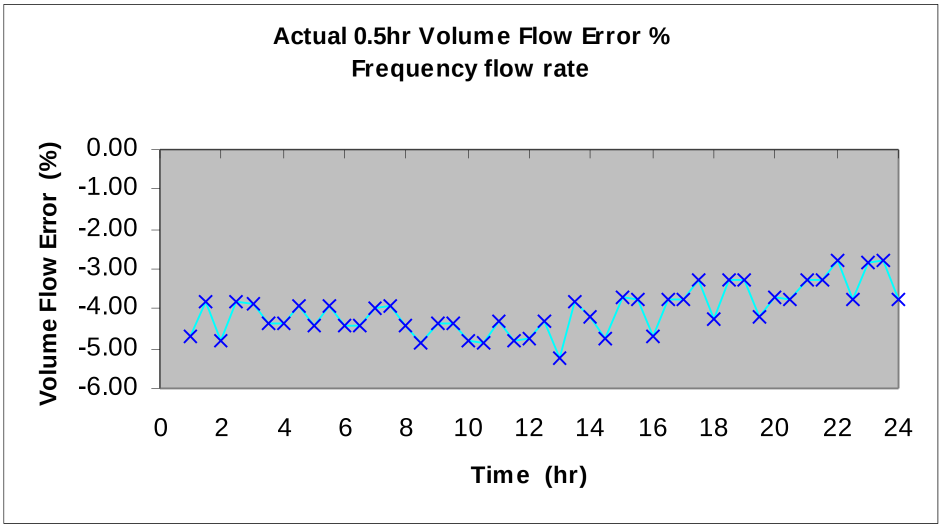

Figure 5. % Difference in the actual volumes passed between the turbine and the ultrasonic meters with the flow computer operating in frequency flow rate

Further investigation was carried out to establish this deviation between different modes of operation of the flow computer. To do this, the frequency input from the ultrasonic meter to the flow computer was inhibited and the flow computer was forced to use the gas velocity-derived flow only. Comparison results between the turbine and the ultrasonic meter from this exercise are plotted below (Figure 6).

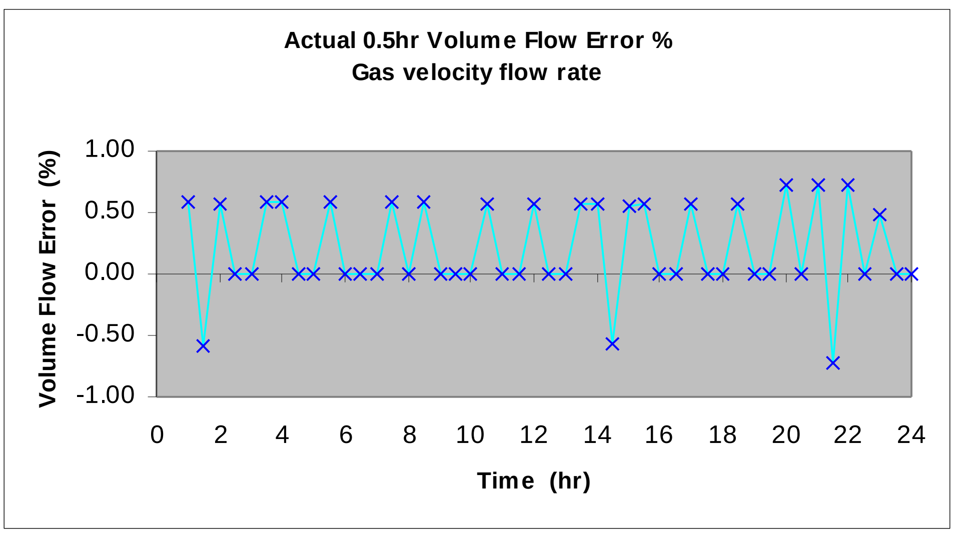

Figure 6. % Difference in the actual volumes passed between the turbine and the ultrasonic meters with the flow computer operating in velocity flow rate mode

A further exercise was carried out such that only the serial flow rates are taken into account and used for calculations. To do this, the ultrasonic meter pipe diameter details within the flow computer were increased by 50% (inhibiting velocity flow) and the frequency input was also left inhibited. The two meters' volume flows in this mode of operation were logged and a sample 24-hour results are plotted below (Figure 7).

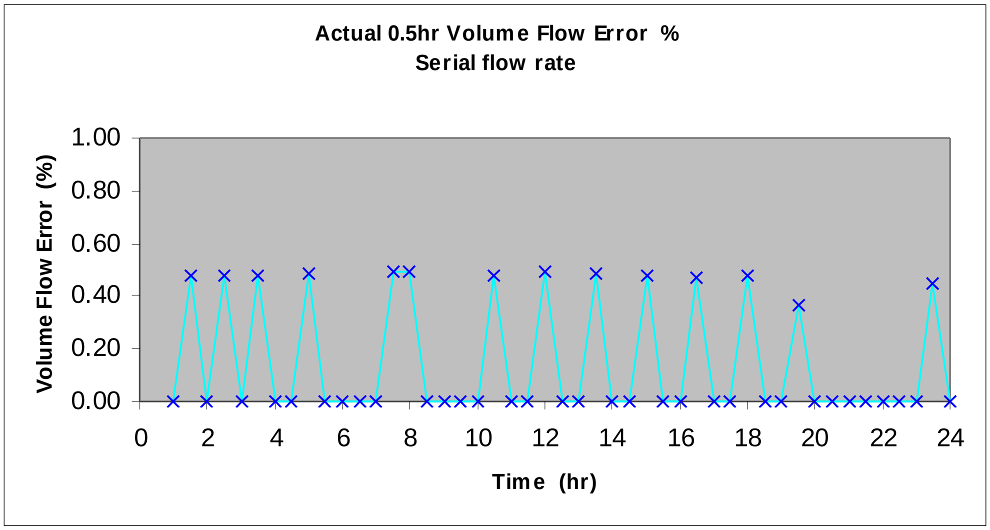

Figure 7. % Difference in the actual volumes passed between the turbine and the ultrasonic meters with the flow computer operating in serial flow rate mode

These results are very similar to the results obtained when the system was operated in the velocity mode. Again, the two meters agree with each other to an accuracy of ±0.1%. Interesting to note however that in this mode of operation, if the difference is not 0.1% between the two meters, the ultrasonic meter is permanently over reading the turbine meter by 0.5%.

A further test was carried out to see if the results of the first exercise (normal mode of operation) could be repeated. The flow computer was configured back to its original set-up and further data was collected in this mode of operation. The results of this test are shown below (Figure 8). The agreement between the two meters is back to normal, i.e. they are in agreement to an accuracy of ±0.1%, with occasional difference of up to ±0.5%.

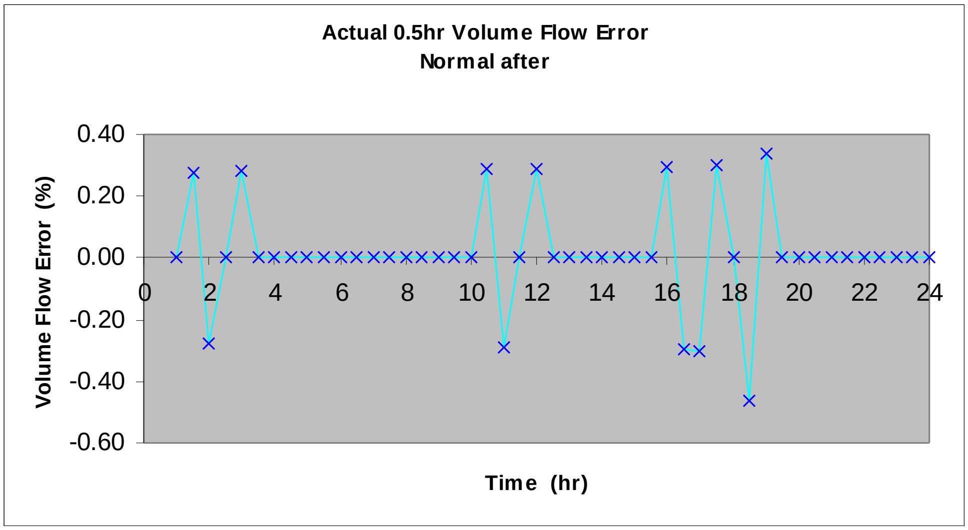

Figure 8. % Difference in the actual volumes passed between the turbine and the ultrasonic meters (with the flow computer back to operating normally again)

Flow Rate Influence on Ultrasonic Meter Accuracy

The two meters were operated at different flow rates representing sites 20%, 40%, 80% and 90% of maximum flow rates to establish if the flow disturbance created by the turbine meter would influence the ultrasonic meter accuracy. This was monitored during the different modes of operation of the ultrasonic meter. An example of this is shown below (Figure 9 & 10).

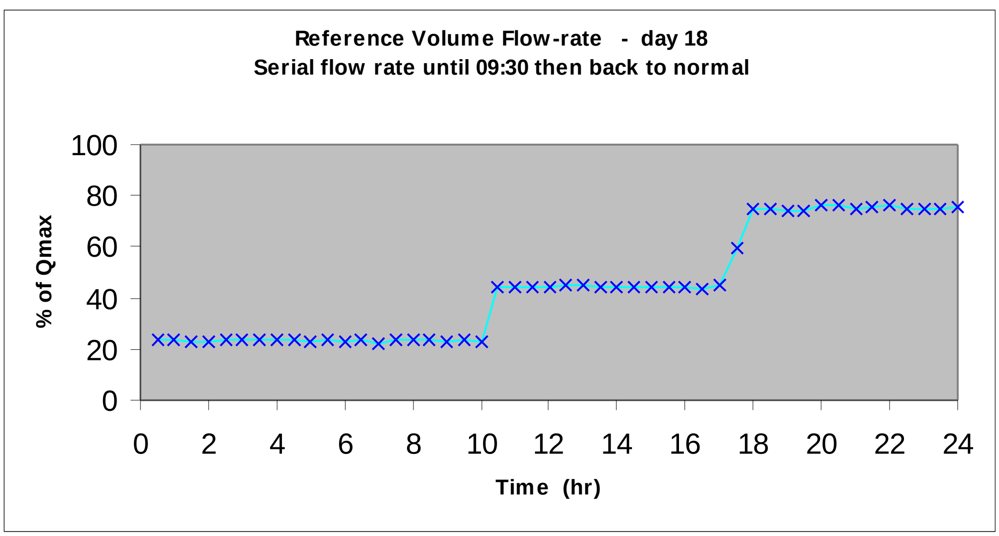

Figure 9. Flow rate changes through the turbine and ultrasonic meters

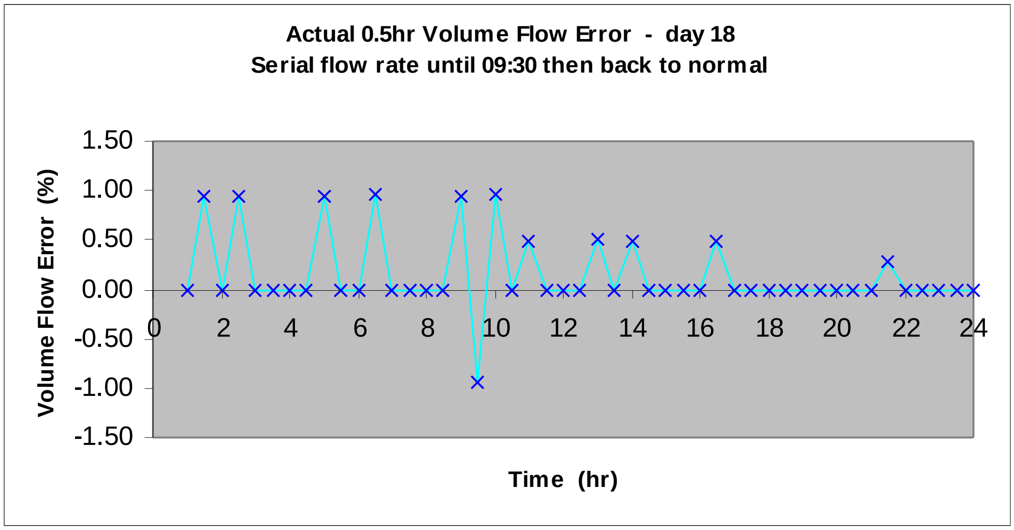

Figure 10. % Difference in the actual volumes passed between the turbine and the ultrasonic meters during change over from serial to normal operation.

Figure 9 shows the increase of flow rates in time. At the start, the flow computer was operating in the 'serial' mode, with the flow rate set to 20% of maximum flow. This was changed to the 'normal' mode of operation and at the same time, flow rates were increased from 20% to 40% and gradually to 80% of maximum flow. Figure 10 shows the results between the two meters during this time. The error between the turbine and the ultrasonic meters varies between 0.1% and1% up and until the flow computer mode of operation changes from serial to normal (9:30). After this time, the error between the two meters reduces to 0.1%, with occasional difference of 0.5%.

6 CONCLUSIONS

An Instromet multipath ultrasonic meter and an SMR-I turbine meter operate successfully with very small error (±0.1%) between the two meters. This error increased to 4% when the flow computer was forced to calculate flow rates using the pulse output from the ultrasonic meter.

From this trial, it was established that the most accurate way to operate the ultrasonic meter is to let the flow computer decide the mode of operation for flow rate calculations. It is not yet fully understood if the flow computer uses the ultrasonic meter calibration 'k' factors for flow rate linearisation.

Better understanding of the flow computers is necessary to establish correct operation with ultrasonic meters.

Although there is a very large pressure cut through the pressure regulators on the downstream of the metering systems, this did not influence the operation of the ultrasonic meter. Turbine meter positioned upstream of the ultrasonic meter did not adversely effect the ultrasonic meter operation also.

Comparison between the ultrasonic meter speed of sound and the speed of sound calculated from gas composition, pressure and temperature shows a very small deviation of $\pm 0.2\%$.

7 REFERENCES

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