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Flow Testing an Ultrasonic Meter Outside its Performance Envelope

Another “Real World” System

Gordon J Stobie, Phillips Petroleum Company
Klaus J Zanker, Daniel Industries
Colin Brown, AMEC Services Ltd, Offshore Division
Winsor Letton, Letton-Hall Group

Introduction

In 1998/99 Phillips Petroleum Co UK Ltd decided to exploit the Jade reserves in the Central North Sea via a Normally Unattended Installation (NUI) located some 17 km NW of the existing Judy platform. The Jade NUI facilities would have no processing capability, and multiphase products would flow from Jade to Judy via a 16-inch subsea pipeline. Jade products would be metered as multiphase flows at each of the 4 production wellheads used to develop the field. The products would be processed on Judy via an HP Separator. Following separation, the products would be metered at HP Separator conditions (approx 40BarG and 110 degrees Celsius).

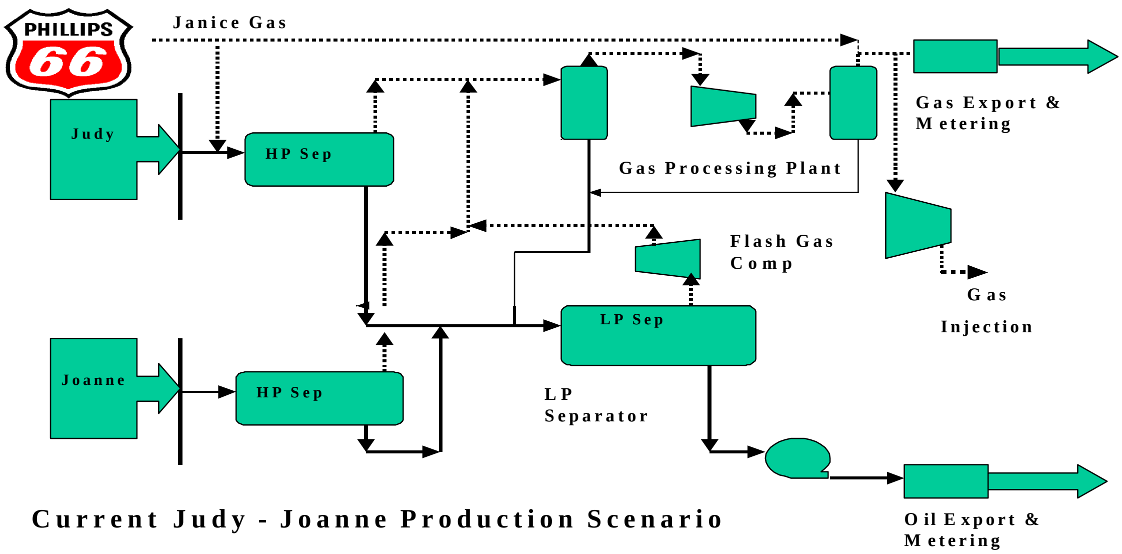
During conceptual engineering, a Jade Gas Meter target uncertainty of +/-1.4% (on a mass/ mass component basis) was assessed to be achievable and accepted by the Judy/Jade partners. Based on this, the volumetric flow rate uncertainty requirement would be in the order of +/- 0.5 to 0.8% (with some safety margin), and it was these target uncertainty considerations which drove the project to select an Ultrasonic Meter as the primary flow meter with which to measure the Jade Gas. However due to difficulties in design (in gaining acceptable upstream and downstream meter lengths), a short meter tube envelope was designed with a flow conditioner in place upstream of the meter. This led to the decision to flow test the meter, pipework and flow conditioner, in order to gain an understanding of how the flows might react to the short meter envelope.

The results of these flow tests are reported here.

1.0 Design Considerations

In the original design for Judy-Joanne, two HP Separators were conceived in order to accommodate production from two distinct production zones, the Chalk/Palaeocene (Joanne) and Precretaceous (Judy) at the Judy production facilities. The separators consisted of identical product take-offs (piping) for the oil, gas and water in order to ensure that any inbuilt/field metering bias was removed. The gas production rates dictated 24-inch gas lines which comprised a horizontal U bend leading to a 9.5m meter tube and Daniel Senior Orifice fitting. The original concept during 1992/93 in detail design was to install Multipath ultrasonic meters (USMs) however confidence in the meter was not sufficient to warrant the risk and Senior orifice fittings were utilized even though orifice plates have never been the most loved flow meter for liquid saturated hydrocarbon gases. The risks to the owners and fiscal authorities were insignificant, however, as the owner mix on Judy-Joanne was identical and no Petroleum Revenue Tax (PRT) or royalty was expected to be payable.

Figure 1 below is an overall schematic of the Judy Joanne facility. Janice is a gas stream imported to Judy, and is not discussed in the paper. It is measured to fiscal standards elsewhere.

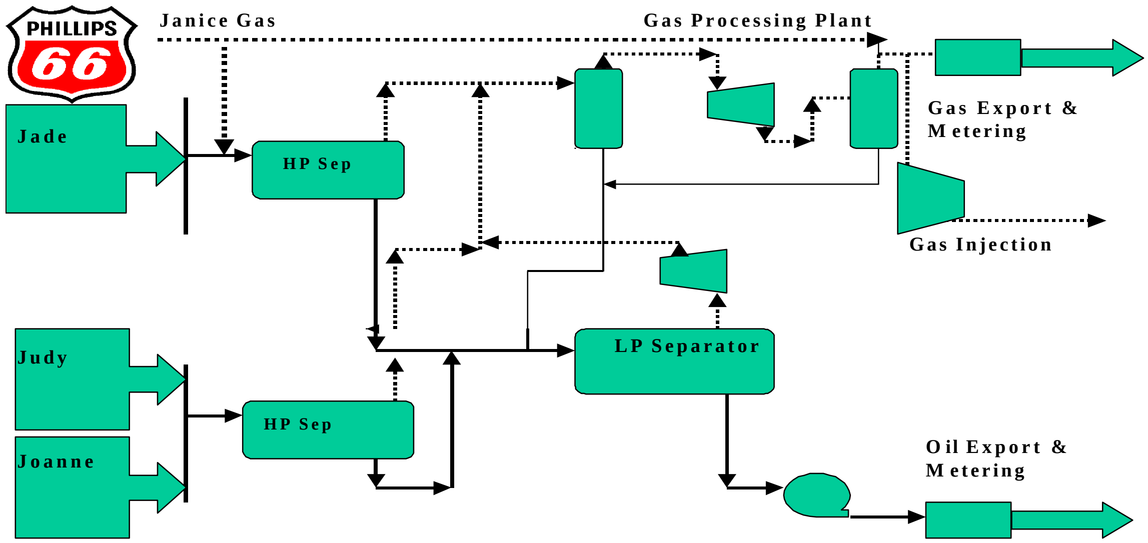


Current Judy - Joanne Production Scenario

Figure 1

With the advent of Jade, however there were to be differing ownerships and the possibility of differing tax regimes. As a result a new approach to flow measurement instrumentation was considered necessary. Production rates had declined sufficiently to allow all the Judy and Joanne production through a single separator, thus allowing Jade its own production separator on the Judy facility and its own meters. Figure 2 overleaf is the modified schematic showing Judy Joanne production combined in a single separator and Jade production flowing into the second separator.

Measurement data would be closely monitored by all parties, and an overall uncertainty of the Jade gas meter is expected to be in the order of +/- 1 to 1.4%. Exactly how this will be managed and controlled has yet to be determined as the authors went to print, however the facility mass balance and external metering audits of the other metering systems and the Jade meters are expected to play a large part.



Proposed Judy - Joanne & Jade Scenario

Figure 2

Following a considerable amount of research, it was decided that Jade gas measurement at the Jade Separator would be carried out using an Ultrasonic Meter that was known to have a proven record in rugged operational conditions.

In this case the Daniel JuniorSonic USM was selected. Given the likelihood that liquids in the gas would be commonplace, its non-parallel chords with downward-facing transducers provide a more robust solution than the more traditional horizontal arrangement.

There a number of reasons that led to this choice, of which three were prime.

1. It was a requirement that a meter be used that would achieve near-fiscal accuracy under normal flow profile conditions.
2. It was necessary to utilise a meter that could be calibrated at an accredited facility and for which a set of linearising points could be calculated and applied at the flow computer.
3. It was desirable to minimise maintenance and re-calibration requirements.

The use of ultrasonic flow meters in wet gas is by no means a new concept. Wilson (1996) reported on the results of a three year research programme called Project Ultraflow, in which it was shown that the meters could not only survive extreme conditions, but also held promise for measuring wet gas properties, such as liquid fractions and flow rates. Robbins (1996) and Stobie (1998) also reported on the successful use of USMs in wet gas production applications.

This decision was by no means clear-cut, and the disastrous results in using USMs to meter gas from an earlier UK North Sea development impacted the decision making process. One particular Jade partner had only heard bad news from this “failed” project (in respect of the gas measurement) and had no idea that he was an owner in an earlier ultrasonic gas measurement project which had been a success. The fact that the success had been in the public domain for some time went a little way in pacifying the situation.

A potential problem for the ultrasonic meter is a possible high pressure process upset that could occur, and would mean that a downstream vent valve would open to relieve to flare. This valve is noisy, and it is possible that ultrasonic noise might travel back along the pipe to the ultrasonic flowmeter and interfere with the meter's ultrasound signals. To help attenuate such a signal, a "target tee" with a blind flange is placed downstream of the flowmeter.

However, whilst the decision was made to install a USM for Jade, it was also decided to retain the existing 24-inch Senior Orifice meter run. This in turn had a major impact on the Jade USM meter installation and its ability to conform to accepted "meter run " conventions.

Leaving the existing 24-inch orifice meter run real estate alone meant that the space for USM installation was extremely limited. Furthermore the best installation point was considered to be immediately downstream of the separator. The result was a total installed meter length of 10.95D from the separator nozzle, which includes a sweeping S bend upstream of the meter, the flow conditioner, a short meter tube, the meter itself, and a 90-degree flanged Tee downstream.

Figure 3 illustrates the installation.

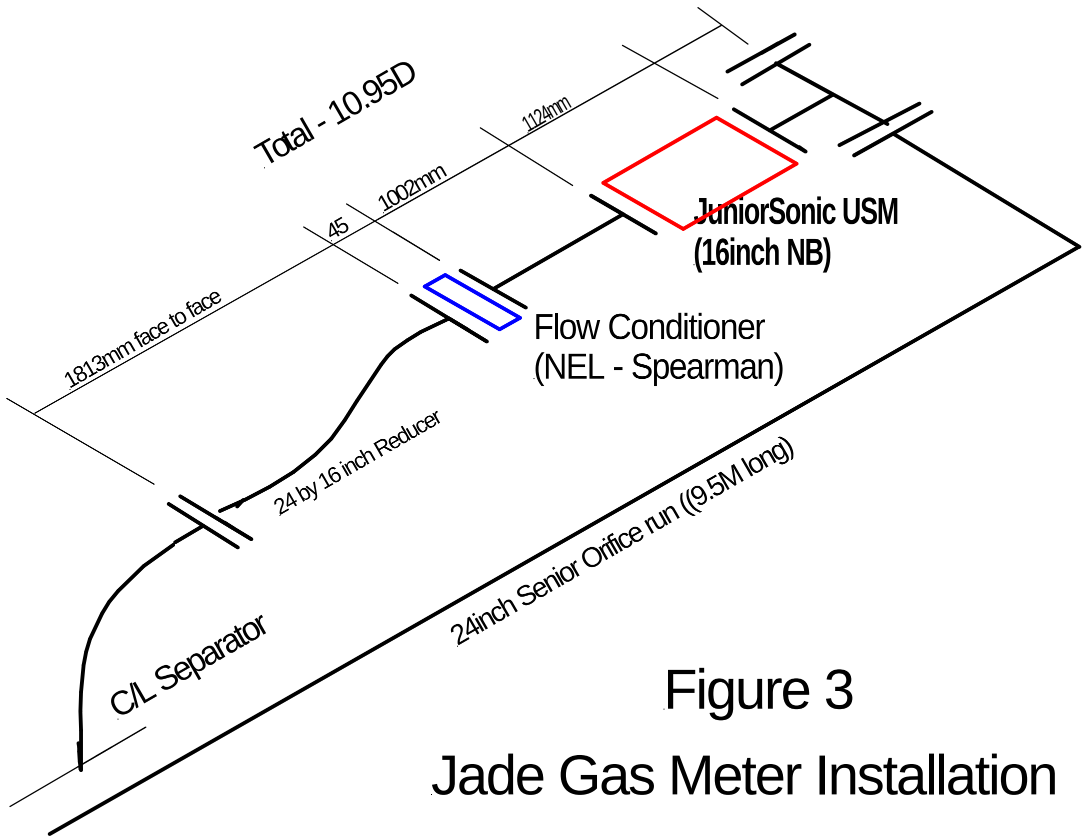


Figure 3

Jade Gas Meter Installation

As a result of this installation configuration, it was clear that conventional metering approaches would be less than adequate. Grimley (1997) showed that un-calibrated single-path meters such as the JuniorSonic can see an offset of as much as 5% when placed downstream of pipework bends seen in normal installations. Two approaches to mitigating the problem were considered.

First, it was considered logical that a Flow Conditioner be used in order to **attempt** to condition the flow regime in the pipework before the meter. The flow conditioner selected was the NEL (Spearman) conditioner, which is a patent-free unit. Results on the use of this flow conditioner were reported by Reader-Harris (1995).

Second, because ultrasonic meters are highly repeatable even in cases such as the one above where an offset might well exist, calibration of the complete set of pipework at a reference facility should identify and allow the correction of any bias error.

In the end, both approaches were chosen.

There was extreme reservation from all parties on the efficacy of the proposed installation and it was decided that a set of full size flow tests would have to be undertaken. The pipework, meter, and flow conditioner were taken to the Bishop Auckland test site, owned and operated by Advantica (formally British Gas Ltd) in an attempt to achieve maximum accuracy.

2.0 Testing

Testing at the Bishop Auckland test plant is now a well proven procedure and no effort will be made to describe the test pad or facilities.

Figure 4 is a photograph of the test pipework of which the inlet piping and hydraulic actuated valve (in grey) is part of the test facility. The test pipework (in white) shows the 24 to 16 - inch reducer, the S bend and then the inlet spool and meter. Nearer the camera is the blind Tee and “trumpet” section used to realign the pipework to the conventional test centre pad.

At this point it was intended to test the flow meter with the upstream pipework, modified downstream pipework and the flow conditioner. To establish a baseline the system was flowed without the flow conditioner.

The uncertainty of the measurements provided by the Bishop Auckland was +/- 0.36%.

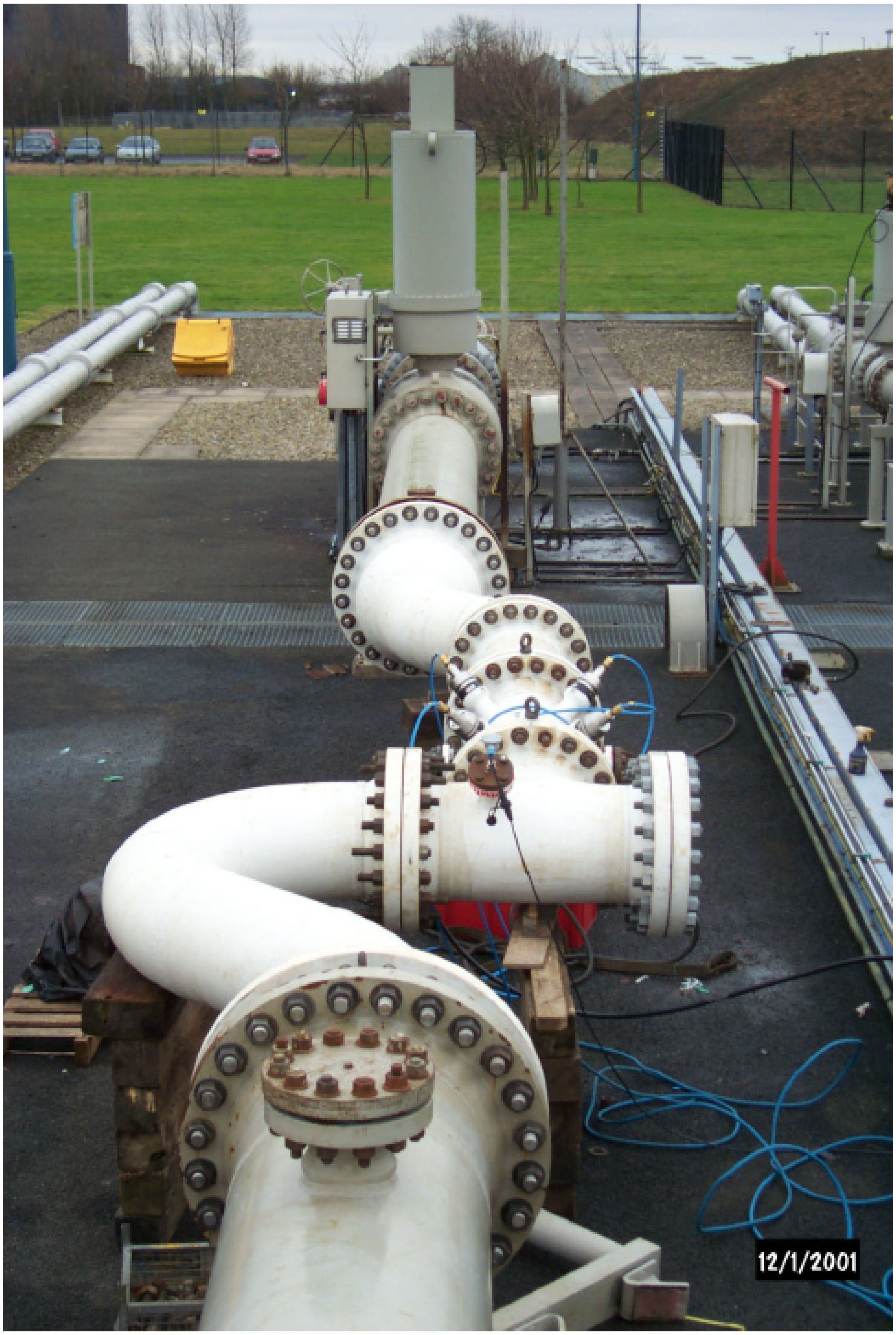


Figure 4 is a photograph of the test pipework installed in the test loop at Bishop Auckland. The flow is coming towards the photographer.

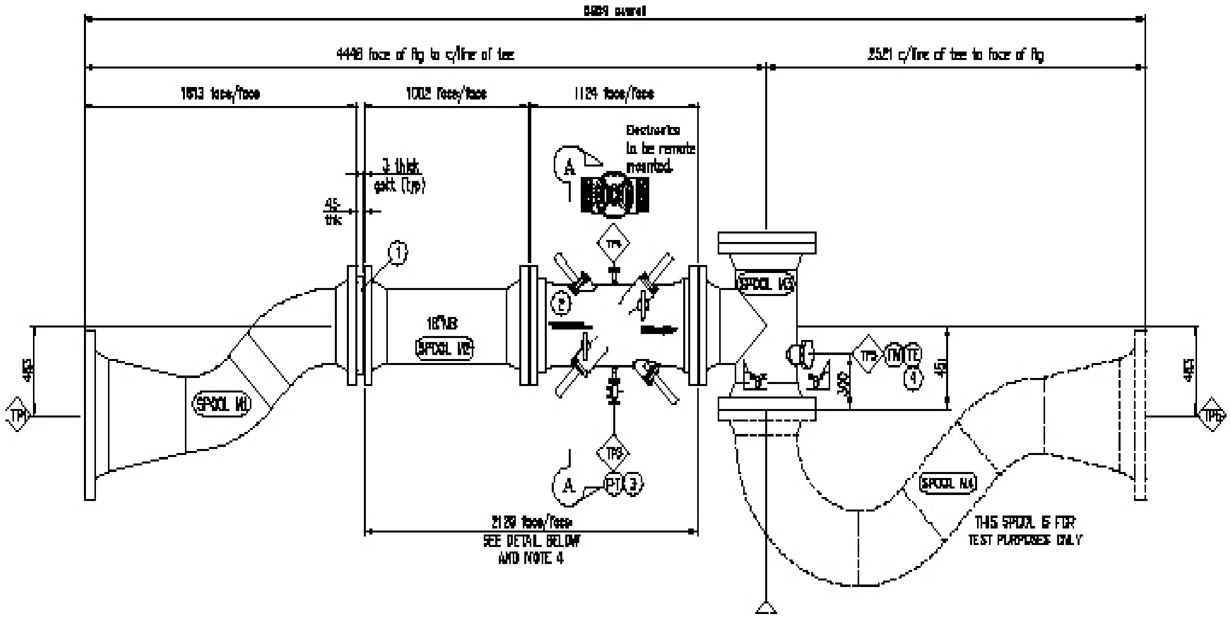


Figure 4A. Pipework used in Flow Test at Bishop Auckland.

Figure 4A above is the plan GA of the test pipework. From the left hand spool we see a 24-inch to 16-inch reducer/offset, the NEL flow conditioner, the upstream meter tube, the JuniorSonic meter, and the downstream blind tee. This is part of the production pipework. The “elephant trunk” was purpose-built to facilitate the flow test.

3.0 Results

3.1 Flow test with and without the Flow Conditioner

The following results were obtained.
Tests were carried out to provide a baseline. In each case a series of flow test were carried out at a nominal 21, 15,10, 5, & 2 metres/second. Nominally 5 data point were used in each flow test, however suspect data (due to line packing between reference meter and test meter) have been ignored.

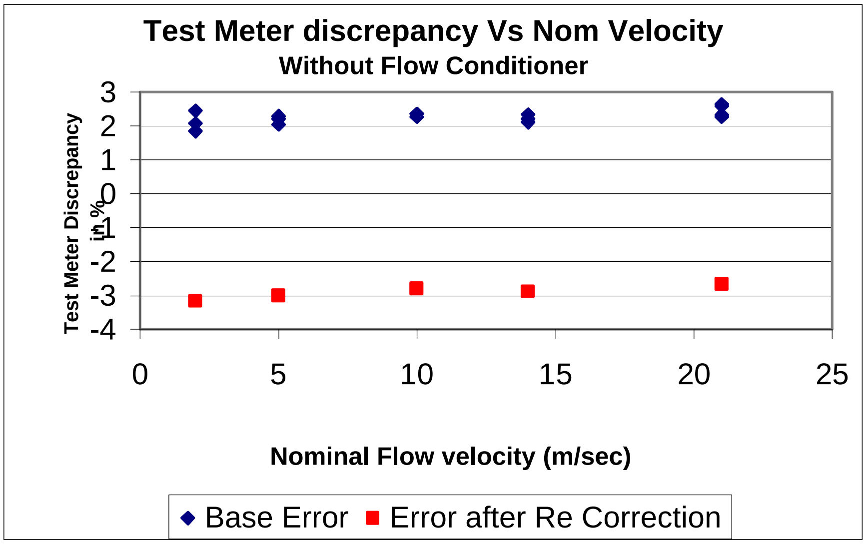


Figure 5 - Flow test results without Flow Conditioner

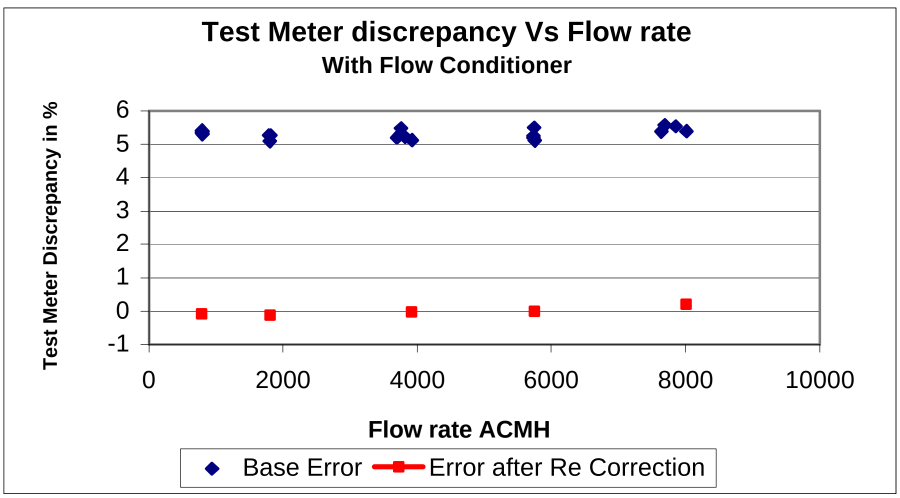


Figure 6- Flow test results with Flow Conditioner

Note that baselines for both graphs are the same, i.e. 8000 ACMH = 21 m/sec.

3.2 Chord Velocities

One of the major attractions of USM flow meters is the ability to extract data from the unit which gives information on the flowing media in the meter. In this case the information of interest is the reaction of the media to the flow conditioners.

Zanker and Stobie (1996) demonstrated that a four-path USM could give details on the flow profile through a convoluted pipe and the improvements that could be gained from using a flow conditioner. The two-path JuniorSonic USM used in the Jade installation does not have the capability of using four path "slices", however the two centerline chords do have the ability to indicate whether there is any significant swirl or profile distortion in the flow.

Figure 7 below shows the A and B Chord velocities, normalized with respect to the average velocity when flowed without the flow conditioner.

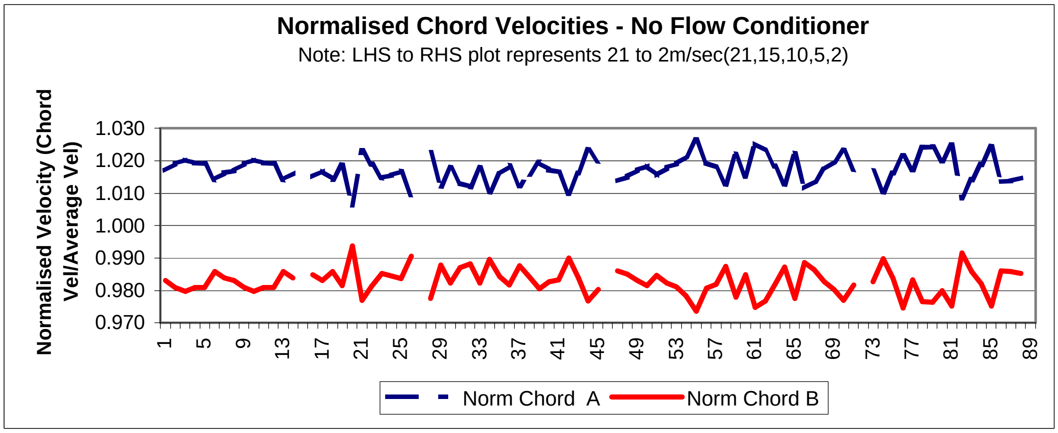


Figure 7 – Normalised Chord velocities – no flow conditioner

Figure 8 below indicates the A and B Chord velocities, normalized with respect to the average velocity with the flow conditioner installed.

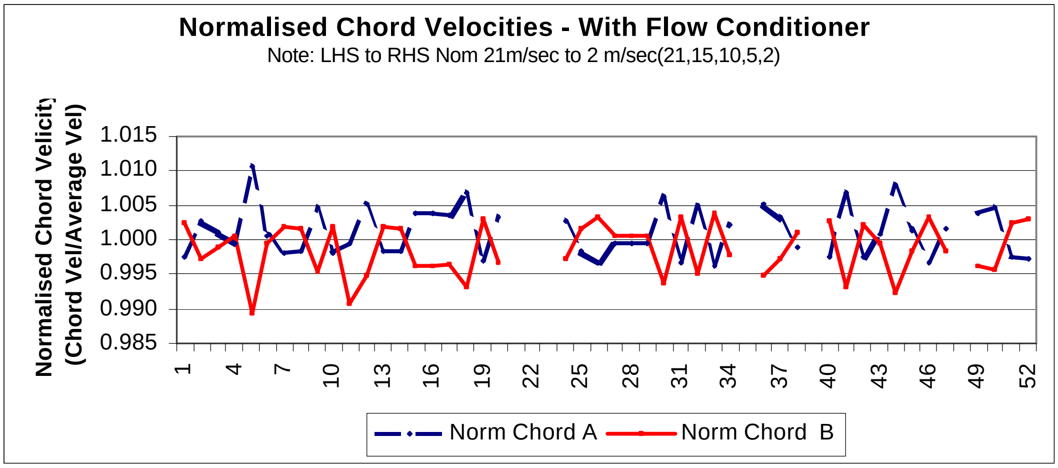
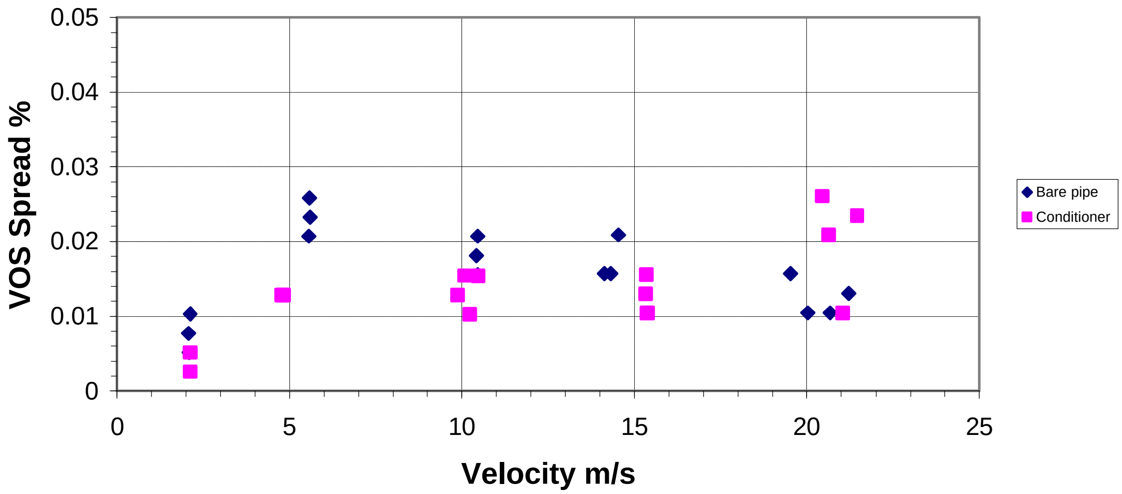


Figure 8 – Normalised Chord velocities – with flow conditioner

3.3 Velocity of Sound

Jade Calibration VOS vs Flow Velocity
Figure 9



Observation of the velocity of sound (Figure 9) both prior to the installation of the flow conditioner and afterwards show that the VOS read virtually the same in both cases. This is not surprising, as the parameters affecting VOS (pressure, temperature and composition) are unaffected by the installation of a flow conditioner.

3.4 Discussion of Test Results

3.4.1 No Flow Conditioner

The meter performed as well if not better than expected in the basic flow tests, and proved itself to be a stable and consistent metering platform, demonstrating a high degree of repeatability.

The offset indicated by Grimley (1997) was clearly present. The meter appeared to over-read by approximately 2.5%. Following Reynolds number correction to account for the centreline velocity, the meter under-read by 2.67 to 3.16% (range 0.49%).

That the flow was disturbed and swirling may also be considered apparent from the A and B chord velocities in Figure 7, which were considerably different and variable. There was a significant chord velocity offset. Chord A is some 1.7% above average, whilst Chord B is some 1.7% below average, with a considerable amount of scatter. That the profile was undeveloped is likely as the Reynolds Number correction did not correct the flow properly as it is only viable if the flow profile is fully developed.

However the readings are relatively stable and in many (non fiscal) measurements this might be considered adequate.

3.4.2 With the Flow Conditioner installed

Following the installation of the Flow Conditioner, it was apparent that the flow profile had become less disturbed and that the swirl had diminished. This had been demonstrated by Reader-Harris (1995) in the NEL Headers Programme.

Whilst the chord velocities continued to show some offset, this was considerably reduced. There is some conjecture that this could be improved further, but without laboratory test equipment (anemometers, sliding pitots, etc. – and this was a practical test with hydrocarbon gas at 40barg – 600psig) it is not possible to verify the conjecture. In respect of "meter error" i.e., how well the USM agreed with the test site meters, the base reading showed an over-measurement of approximately 5.5%.

However after taking the Reynolds number correction into account (which is applicable if the flow profile is fully developed), the error crowded the zero line. This tends to confirm the theory put forward by Zanker (1999) concerning flow profile error and Reynolds number correction that Reynolds number correction is only applicable to fully developed flow.

4.0 Conclusions

-The Daniel JuniorSonic flow meter has demonstrated itself to be a stable flow metering platform in what may be considered to be a disturbed flow regime.

-The NEL (Spearman) flow conditioner has also shown itself to be a performance flow conditioner, even though little testing/meter tube experimental work has been conducted on it in the past few years. The conditioner was able to condition the distorted flows outside of any (as yet) published meter tube dimensional recommendations.

-Taking into account the test site uncertainty, the overall or underlying uncertainty of this meter installed with this pipework and flow conditioner is in the order of +/- 0.4%. This is based on volumetric flows, and ignores the effects which might be the result of production secondary instrumentation errors. This is inside our underlying target for the meter, and makes it suitable for installation and measurement of the Jade fluids.

-These flow tests tend to confirm the theory put forward by Zanker concerning flow profile error and Reynolds number correction that Reynolds number correction is only applicable to fully developed flow.

We note that improvements in ultrasonic wet gas measurement continue to be achieved (Zanker, 2001, Jepson, 2001), and will likely be applicable to projects such as Jade which occur in the future.

The meter, meter tube and flow conditioner are being installed in the Jade production separator on the Judy platform, awaiting first production in late 2001.

5.0 References

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