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FLOW PROGRAMME

Flow Measurement Guidance Note No. 34

[illegible] Upstream [illegible] Ultrasonic [illegible]

Introduction

Transit-time ultrasonic flowmeters are increasingly being used in various industries. However it has been recognized that their performance can be significantly affected by upstream pipe fittings. Pipe bends, reducers, valves, etc. all distort the flow profile from the fully developed condition for many diameters downstream. Any transit-time ultrasonic meter encountering this distorted flow profile will be affected. This is known as an installation effect.

Funded by DTI's Flow Programme, NEL has studied these effects [1] and this Guidance Note draws on those studies to give guidance on the causes and extent of the effect on both mid-radius and diametric path ultrasonic meters.

Figure 1 NEL Oil Test Facility

Test Procedure

Both clamp-on and wetted-transducer meters were tested downstream of a triple-bend configuration as shown in Figure 2. The tests were performed in lubricating oil at 20°C and at velocities of 3 and 4 m/s in 6-inch nominal bore pipework.

The meters were tested at many positions in the range from 3 to 36 diameters (D) downstream of the triple bend. All the installation effect results shown here are deviations from baseline tests, where the meters were calibrated under the same nominal conditions with a long straight length upstream.

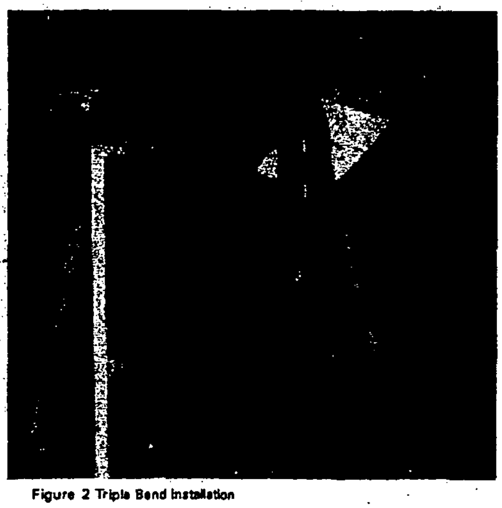

Figure 2 Triple Bend Installation

Applicability of Results

The results from these tests are specific to the installation studied and it is not possible to

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these results directly to other pipe installations (other ultrasonic path designs. However, fro analysis of the meter results and CFD simulatior detailed in [2], it has been shown that the trip bend generates a distorted axial profile th corkscrews down the pipe i.e. a 'bulk swirl' flo regime. This regime is likely to exist to som extent downstream of any two or more close-coupled, out-of-plane 90° bends, and it possible to draw general conclusions and mak recommendations for meters subject to suc conditions.

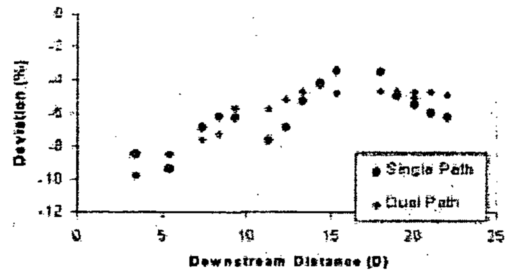

Figure 4 Installation Effect on a Clamp-on Meter

Figure 5 shows the axial velocity measurements at 20 diameters downstream of the triple bend, taken using a traversing pitot tube. It illustrates the flattening effect of the bends on the axial profile. It is this flattening that causes the negative offset seen in both the single and dual-path meters.

4 Effect on Clamp-on Meters

The clamp-on meter paths were configured in a double-traverse, single-reflection mode, which is sometimes referred to as 'V' path configuration. The meters tested could be operated using one or both ultrasonic paths. The meters were tested in both single and dual-path modes. Figure 3 details the clamp-on meter path configuration.

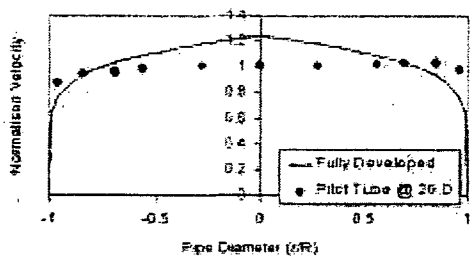

Figure 5 Axial Velocity Profile

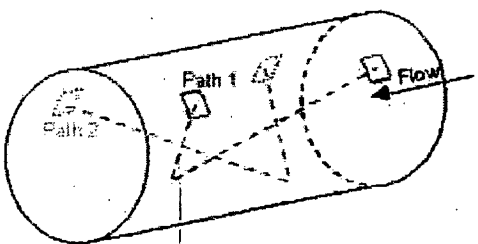

Figure 3 Clamp-on Meter Path Configuration

The effect of the triple bend on a clamp-on meter in this configuration is shown in Figure 4. It shows the results of the meter in single and dual-path configuration. The characteristics show the single and dual-path meter responding in a very similar way. The single-path characteristic fluctuates, as its separation from the triple bend increases, however the negative offset is very similar to that of the dual-path meter. The oscillation in the single-path meter characteristic is caused by the rotation of the distorted axial profile. The oscillation is less evident in the dual-path meter due to the better coverage that this design provides.

nce increasing the number of clamp-on paths not reduce the installation effect caused by lattening of the velocity profile. It only reduces fluctuations caused by the rotation of the rted axial flow and the overall effect is not reduced.

The flattening of the flow profile will generate a negative effect on a diametric path. Therefore it is recommended that, where a flattened flow profile is suspected, (i.e. after multiple close-coupled out-of-plane bends) and flow can be maintained at a constant rate, several measurements should be made at various positions around the pipe (Note: manufacturers' installation recommendations should be followed). If the measurements vary, the greatest value is likely to be the most accurate measurement of the flow.

This recommendation is only valid for clamp-on meters in dual-traverse 'V' mode or in quad-traverse 'W' mode in small pipes, as the pair of traverses tend to reduce the effect of swirl. If single or triple-traverse paths are used the effect of swirl may affect the meter to a greater extent than the flattening effect.

Figure 4 shows that the effect of the triple bend is large even at 22 diameters downstream. This highlights the need to maximise the straight length upstream of clamp-on meters.

Figure 6 shows the difference between the readings on path 1 and 2 against the installation effect. It shows that the difference between path readings gives no indication of the installation effect.

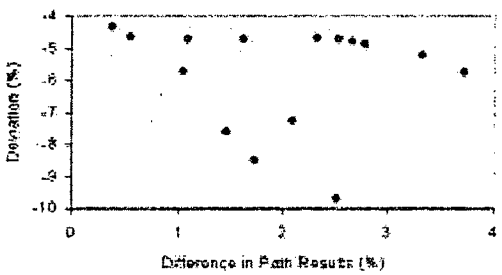

Figure 6 Difference in Clamp-on Paths against Installation Effect

5 Effect on Wetted-Transducer Meters

The meter tested was a dual cross mid-radius path configuration as shown in Figure 7.

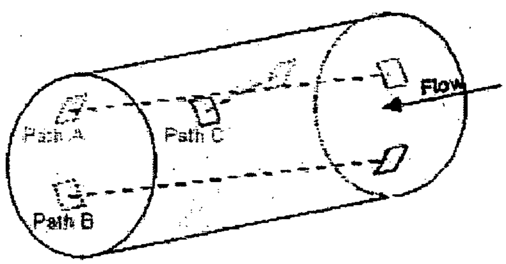

Figure 7 Wetted-Transducer Meter Path Configuration

The installation effect on this meter is shown in Figure 8. The individual path velocities were recorded during the tests. By selecting 2 paths and averaging their results the effect on 2-path meter designs was evaluated. The effects on in-line and cross formation 2-path mid-radius meters are shown in Figure 8. They are derived from paths C & D and B & C respectively.

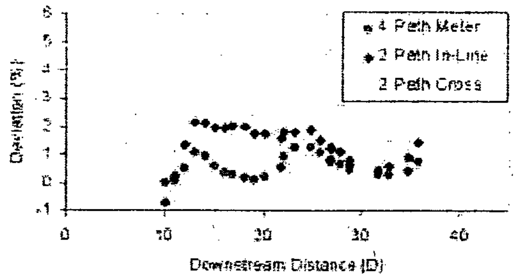

Figure 8 Installation effect on a Wetted-Transducer Meter

Considering that in baseline tests this meter achieved a linearity of 0.25% over a flow range of 1 to 5 m/s, these results show the effect on the full meter to be very significant with a magnitude of up to 1%.

In general these results show that increasing the number of mid-radius paths reduces the installation effect. They also show that in this flow regime an in-line formation 2-path meter operates significantly better than a 2-path cross-formation meter.

Comparing these results with the clamp-on meter results shows that mid-radius paths are less affected than the clamp-on meters 'diametric' paths.

6 Diagnostic Tools

ne of the major benefits of ultrasonic wmeters is the information they can provide in lition to the flowrate.

he path velocity data from the wetted-ısducer meter was recorded and analysed to what useful diagnostic information it could ›vide. Both diagnostics shown here take vantage of the crossed paths on a common plane, of the wetted- transducer meter. Taking the difference of the crossed paths, the non-axial (or swirl) velocity in that plane can be quantified. Alternatively taking the mean of the crossed paths quantifies the axial velocity in that plane.

Two diagnostic measures have been reviewed: a swirl diagnostic shown in Figure 9, which sums the magnitudes of the swirl in both planes, and an axial profile distortion diagnostic shown in Figure 10, which measures the difference between the axial velocities in each plane.

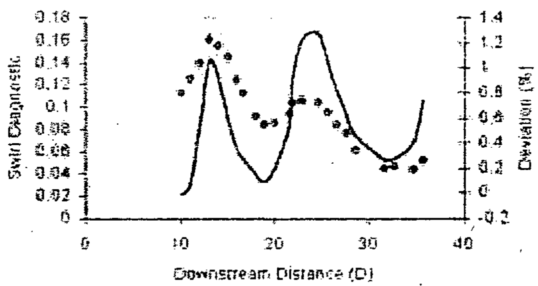

Figure 9 Swirl Diagnostic

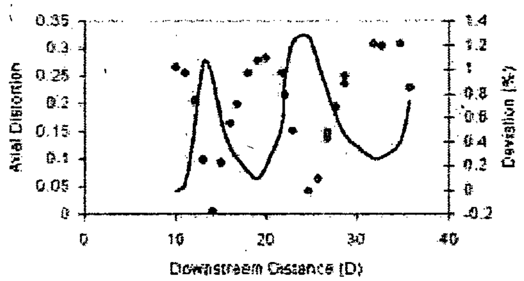

Figure 10 Axial Distortion Diagnostic

The swirl diagnostic shows partial correlation, with the peaks of the diagnostic matching the peaks of the installation effect characteristic. However the axial distortion diagnostic seems to indicate that the meter performs best when the axial distortion is at its peak, which is counter to what might have been expected.

These results show that individual path velocities can provide information on the flow profile within the meter. However four mid-radius paths do not provide sufficient information to predict installation effect.

Summary

1. Transit-time ultrasonic meters are sensitive to installation effects.
2. Straight length upstream of the meter should be maximised.
3. Using more paths in a clamp-on (diameteric path) meter does not reduce the effect.
4. Using more paths in a mid-radius path meter reduces the installation effect of multiple out-of plane bends.
5. Comparison of 4 individual mid-radius path velocities can indicate the presence of an installation effect but cannot be used to quantify the effect.

References

Coull C.J. In-Service Performance of Ultrasonic Flowmeters: Investigation of Installation Effect. Report No. 2002/55, NEL, East Kilbride, Glasgow, October 2002.

Barton, N.A In-Service Performance of Ultrasonic Flowmeters: Application and Validation of CFD Modelling Methods. Report No. 2002/72, NEL, East Kilbride, Glasgow, October 2002.

Acknowledgement

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Contact for Further Information

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Guidance Notes

This series of Guidance Notes is designed to provide, in condensed form, information on flow measurement methods and equipment that has been generated as a result of Flow Programme work. In each case, the Guidance Note is based on the full project report, which is available from NEL.

For a listing and copies of Guidance Notes, please contact:

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