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Summary of Mis-Measurement CFD and Flow Tests

Cadent Gas Limited

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2	19/07/2022	Issued to Cadent	S Black	M Laing
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Report Production

	Name of Responsible Person(s)	Signature
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Technical Peer Review by	Dr. Sandy Black	
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EXECUTIVE SUMMARY

TÜV SÜD National Engineering Laboratory and i-Vigilant Technologies have been contracted by Cadent Gas Limited as an independent technical experts (ITEs) to calculate the mis-measurement associated with incorrectly installed orifice plates in a natural gas metering station.

Having completed separate assessments and submitting reports to Cadent, both ITEs have had opportunity to discuss the results of their assessments with each other. Although some differences in original reported values exist, these can be explained through understanding of each other's methods. There were no major differences to warrant disagreement or concern.

This summary report details a mutually agreeable, single conclusion for the estimate of mis-measurement for this application with the specifics explained within the main body.

In conclusion, the ITEs have agreed on the following correction factors for Gas Days where mis-measurement occurred:

Gas Day Start	Gas Day End	Correction to apply
23rd May 2019	23rd May 2019	1.04310
24th May 2019	19th May 2020	1.06084
20th May 2020	20th May 2020	1.05110
21st May 2020	22nd February 2021	1.04709
23rd February 2021	23rd February 2021	1.01373

The values were based on a correction factor of 1.06084 for the plate installed on 23rd May 2019 and 1.04709 for the plate installed on 20th May 2020. For plate change over days, the correction factors have been calculated pro rata for each day based on the operational time.

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1 INTRODUCTION

TÜV SÜD National Engineering Laboratory (hereinafter NEL) have been contracted by Cadent Gas Limited (hereinafter Cadent) as an independent technical expert (ITE) to calculate the mis-measurement associated with an incorrectly installed orifice plate in the natural gas metering station. With the potential mis-measurement value exceeding the 800 GWh barrier, i-Vigilant Technologies (i-Vigilant), a second ITE was contracted to also calculate the mis-measurement.

The NEL assessment was completed with Computational Fluid Dynamics (CFD) with the method and results described in [1] and mis-measurement calculation described in [2]. The CFD was verified through comparison with a correlation based on previous calibration and test data of orifice plates installed in forward and reverse direction.

The i-Vigilant assessment combined two different CFD modelling solvers and a physical flow test using a clamp-on ultrasonic flowmeter (USM) at a single flowrate for both of the plates. The CFD approach is described in [2], the USM flow test shown in [4] and the final summarised report on the mis-measurement by i-Vigilant provided in [5].

In general, both ITEs have provided closely similar results although they are not identical. This report highlights the differences and states the final conclusions of the mis-measurement values after discussion and consensus between the two ITEs.

2 SCOPE OF WORK

The scope of work of this report is to:

- Convene a meeting between the ITEs to review and discuss the findings of each ITE report
- Identify any material differences between the technical findings
- Provide a mutually agreeable, single conclusion for the estimate of mis-measurement.

3 SUMMARY OF REPORTS

3.1 ITE 1 – NEL

As described in [1], the expected error in discharge coefficient from installation of two orifice plates installed in reverse orientation was calculated using CFD modelling. The data for the models was provided by Cadent and the geometry of orifice plates and system were obtained through a mixture of information provided by Cadent and independent measurements of the plates via laser scanning.

The results of the CFD show a shift of discharge coefficient in the region of 6.88 % and 5.34 % for plates 295/5 and ALRE5036 respectively at a Reynolds number of approximately 14 million. The CFD showed a rising error with increasing Reynolds number which is similar to what has been observed in other studies.

A further study was completed of the modelling method using publicly available data [6]. The installation found in [6] was modelled in a similar manner to this study and the results were found to be within 0.2 % of the test results in [6]. Furthermore, extrapolating the correlation found in [7], which has been developed from the data in [6] and others, showed errors of 0.07 % and 0.68 % for plates 295/5 and ALRE5036 respectively.

3.2 ITE 2 – i-Vigilant

As described in [5], the expected error in discharge coefficient from installation of two orifice plates installed in reverse orientation was calculated using CFD modelling and through flow testing with a clamp-on USM. The input data for the CFD models was provided by Cadent and the geometry of orifice plates and system were obtained through previous calibration certificates.

The CFD was ran with two different solvers which provided different results. The model was also run under slightly different conditions to the CFD completed by ITE 1. The reason for this difference is likely due to updated information provided by Cadent. The result was very similar input conditions but over a smaller Reynolds number range.

The results of the CFD show an average shift of discharge coefficient from both solvers combined in the region of 5.27 % and 3.85 % for plates 295/5 and ALRE5036 respectively. The CFD showed a reasonably linear error with increasing Reynolds number. The difference between the two solvers was found to be around 0.65 % and 0.5 % for plates 295/5 and ALRE5036 respectively with ANSYS Fluent consistently provided the lower error compared with ANSYS CFX.

In addition to the modelling results, physical flow testing was completed onsite over a 4 day period between 16th and 20th May 2022. A clamp-on flowmeter was installed in series with the orifice plates in both forward and backwards orientations. The forward run in plate 295/5 was used to provide a Meter Factor for the USM and essentially baseline the performance to the correctly installed orifice plate conditions. This also had the benefit of removing any additional uncertainties associated with the installation of the USM. After the reverse flow test for plate was run for 295/5, the USM was operated with the ALRE5036 plate installed in the forward direction. Applying the previous meter factor for the USM showed a deviation of 0.025 % only which provides good evidence of the methods repeatability.

The errors observed from the flow test showed a change in discharge coefficient of 6.17 % and 4.52 % for plates 295/5 and ALRE5036 respectively. The flow test result are the values used for the corrections applied from ITE 2.

3.3 Differences in Observed Results of ITEs

Figure 1 and Figure 2 show the summarised results from ITE 1 and ITE 2 for comparison. The results are presented as the error in discharge coefficient (and expansibility) against pipe Reynolds number. The results of ITE 2 are not the averaged results as discussed in section 3.2 but the individual solver results.

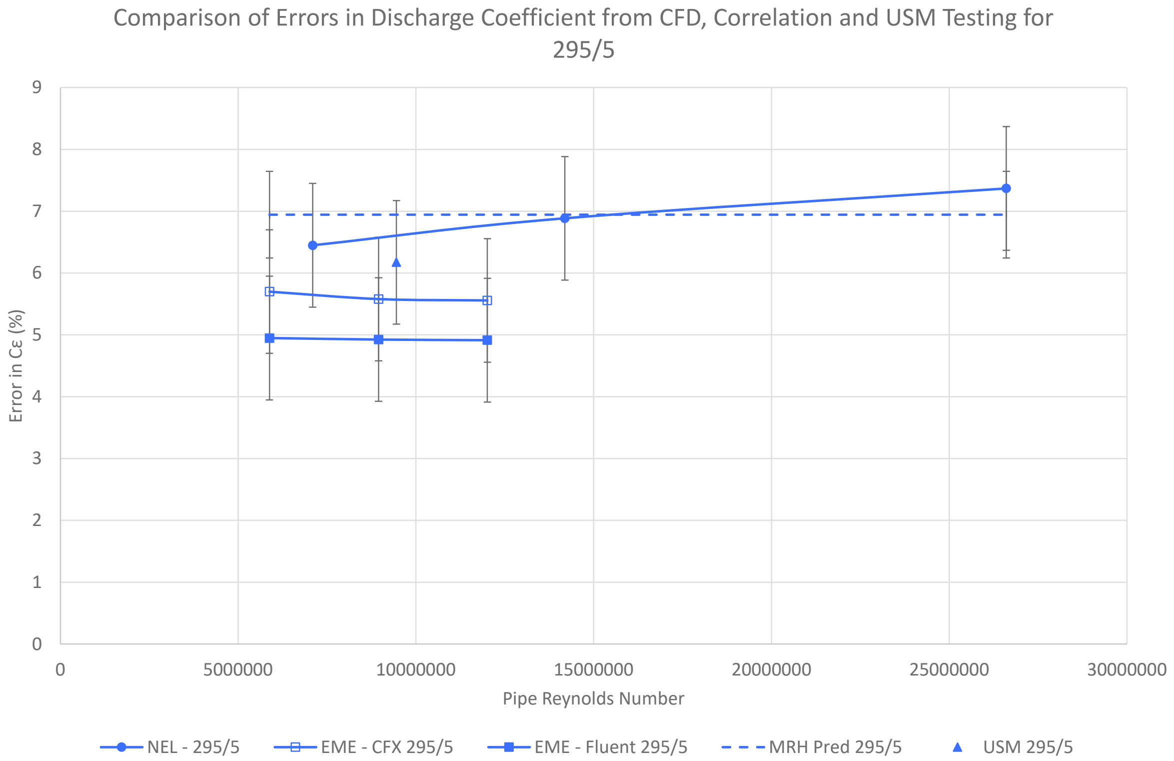

FIGURE 1: SUMMARY OF CORRECTION FACTOR RESULTS FROM ORIFICE PLATE 295/5

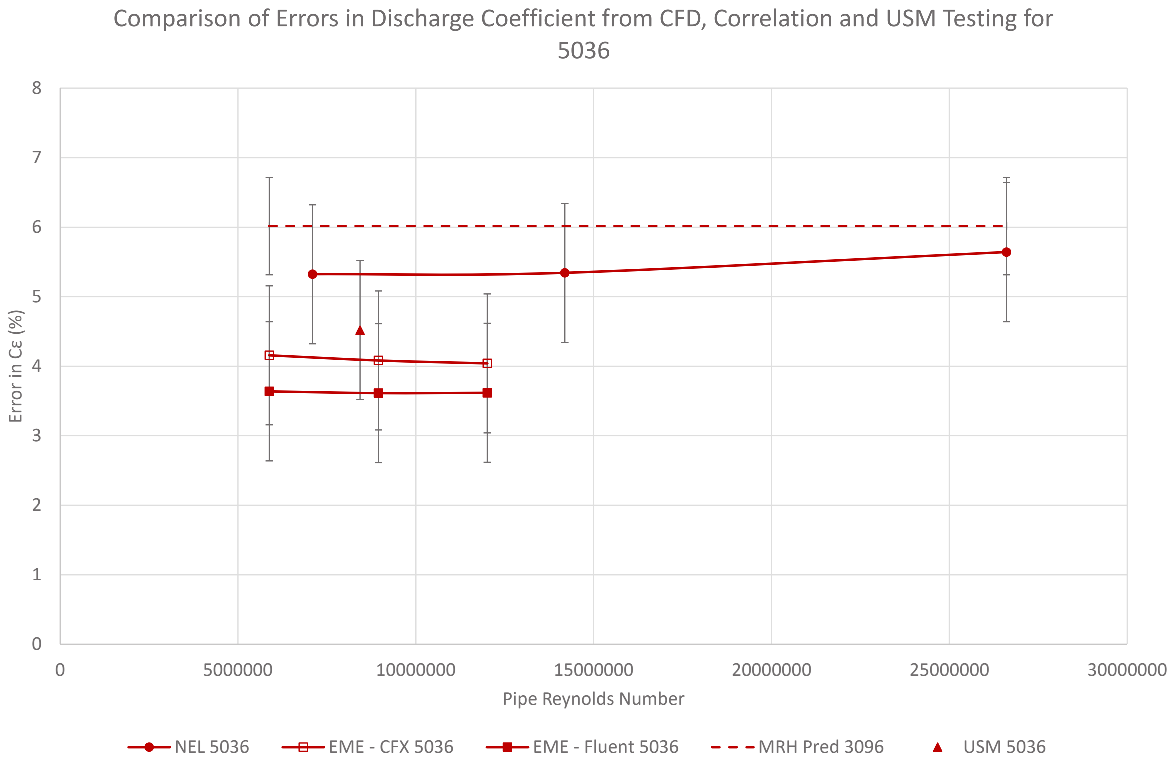

FIGURE 2: SUMMARY OF CORRECTION FACTOR RESULTS FROM ORIFICE PLATE ALRE 5036

Error bars have been included on Figure 1 and Figure 2 to provide a visual aid to the similarity of the different correction factor methods. Each CFD method has error bars of 1 %, the prediction based on historical data (MRH Pred) has an error bar of 0.7 % and the USM has an error bar of 1 % (reduced from a typical expected value through use of Meter Factor). The error bar values are not representative of expected uncertainties and are added only as a visual aid.

As stated previously, although the final results from each ITE are not identical they are relatively similar in both trend and magnitude. The final values reported in [2] and [5] are closer than 1 % from each other in comparison to the gross measured result. Nevertheless, these differences have been discussed between the ITEs and reasonable reasons for the differences have been accepted.

The notable differences are listed below and will be discussed in turn:

- Differences in gross measurement values over the period
- Difference in error linearity with respect to Reynolds number
- Differences in CFD methods/solvers

There was a small difference in gross measurement values calculated over the mis-measurement period between the ITE. The value was very small and less than 0.2 % of total. The reason for the difference has been assumed to be due to the assumed times for daily reporting. ITE 1 assumed a value of 12 noon and ITE 2 assumed a value of 5 am. Given the data supplied is provided in increments of 7 minutes, the 7 hour difference can have an impact on the daily totals. Additionally, there were some challenges in working with the large volume of data supplied by Cadent for the calculation and the format of the data.

The decision has been made to stick with the timings and values as per ITE 2 and the 5 am time. This time coincides with the supplied data files and has a previous day total value which has been used throughout the calculations.

With respect to the increase in error from increasing Reynolds number, whilst this has been observed in other tests and is shown clearly in ITE 1 CFD this was over a wide Reynolds number range. Over the range that is now being considered, the change in error over change in Reynolds number is relatively low.

To avoid a lengthy recalculation process (by individual flow point), the decision has been made to apply a constant correction factor based at an average flowrate. Or in the case for these plates, based at the Reynolds number the USM flow test was carried out at. This allows for a direct comparison of the flow test with the final correction factor proposed in this summary document. It is also a condition where the meters are expected to operate and generally central to its operating envelope. Any deviances from higher or lower flowrates are expected to average out over the duration.

Lastly, a comment on the differences in CFD models and solvers used by both ITEs. CFD is a useful and important tool for quickly and effectively providing information about fluid dynamic systems and the results can help shape and guide research, industrial practices and other management decisions. It allows for data to be obtained where it would otherwise be too expensive or too time consuming to complete in the real world. However, it is also a tool that must be operated by trained and experienced persons. This leads to some subjectivity in setting up, running and analysing models.

The above general caveat, coupled with some different modelled inputs e.g. differences in solvers and models used, small differences in plate geometries, small differences in fluid density etc., and finally the overall uncertainty in any modelling technique all provide reasonable explanations for the differences observed.

In summary, the ITEs have discussed the results and have agreed on a suitable way forward. The decision has been taken to take the average of the correction factor found from ITE 1 and the larger of the correction factor observed from the ANSYS CFX model from ITE 2. From Figure 1 and Figure 2, this is an average of the circles and the hollow squares at the same Reynolds number as the triangle.

4 FINAL CORRECTION FACTORS

As the CFD was not run at the exact conditions of the USM flow test, the points either side of the flow test result were taken and linear interpolation was completed of the 4 sets of data; a set for each ITE and for each plate. At the USM flow test Reynolds number, the correction factors were acquired from this interpolation and then averaged for each plate.

The final correction factor for plate 295/5 was found to be 1.06084.

The final correction factor for plate ALRE5036 was found to be 1.04709.

Figure 3 shows a comparison of the final correction factors for each plate and the USM flow test. The USM flow tests have error bars of 1 %. The results show excellent agreement which provides confidence in the final corrections as it marries both a theoretical modelling approach and a physical flow test that provide similar results.

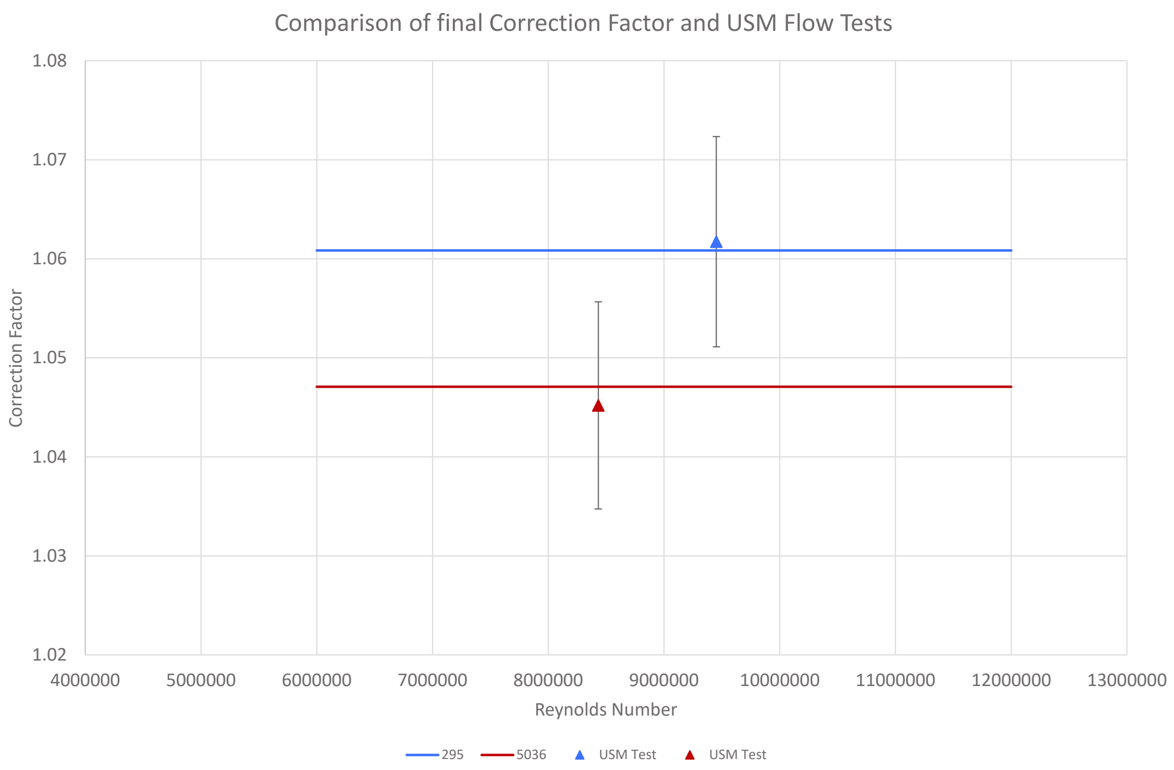

FIGURE 3: COMPARISON OF FINAL CORRECTION FACTOR AND USM FLOW TESTS

5 AGREED CONCLUSION

In conclusion, the ITEs have agreed on the following correction factors for Gas Days where mis-measurement occurred:

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This finding is supported by NEL (ITE 1) who prepared this summary report in conjunction with i-Vigilant (ITE 2).

6 REFERENCES

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END OF REPORT