UKAS INSPECTION
331

Aberdeen
Significant Error Review
ITE Independent Report

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Previous Presentation Summary

- My previous presentation (16th July 2012) provided;
  - an introduction to the SMER cause & effect
  - a description of the site testing methodology
  - the intention to support the site testing result “trend” by CFD analysis
  - an estimate of the period errors.

- As a consequence, I received a number of TMI’s from British Gas on the 24th August 2012 which I responded to accordingly on 31st August.

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Previous Presentation Summary

My last slide summarised the way forward;

- **Await the results of the CFD Analysis**
  - To provide (hopefully) some more precision of error value(s)
- **Finalise the SMER period**
  - Provision of definitive support data
- **Establish the final correction factor(s)**

Site Layout

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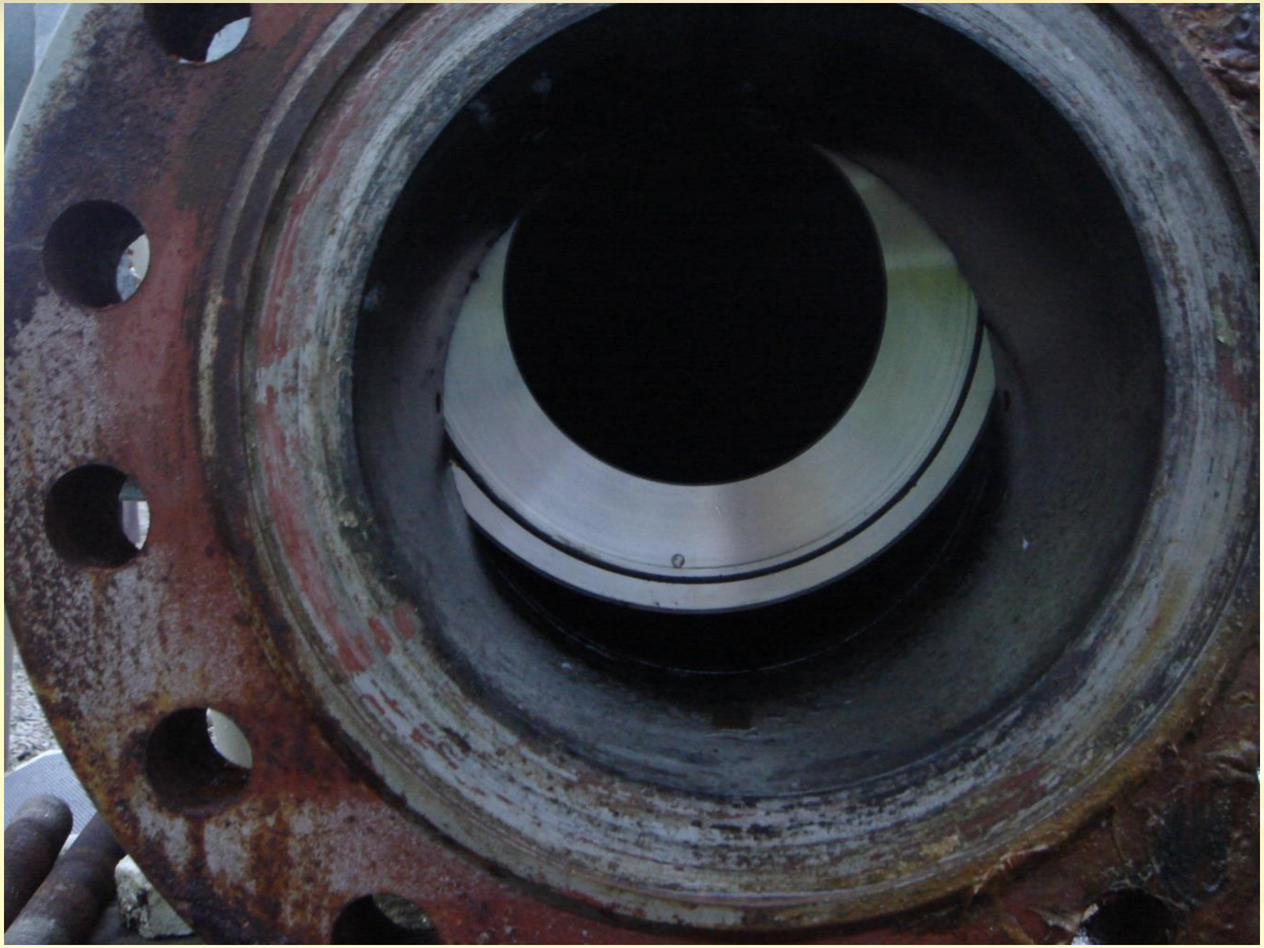
Counter Reading 99985



SMER Period #1
21/7/09 – 27/07/10

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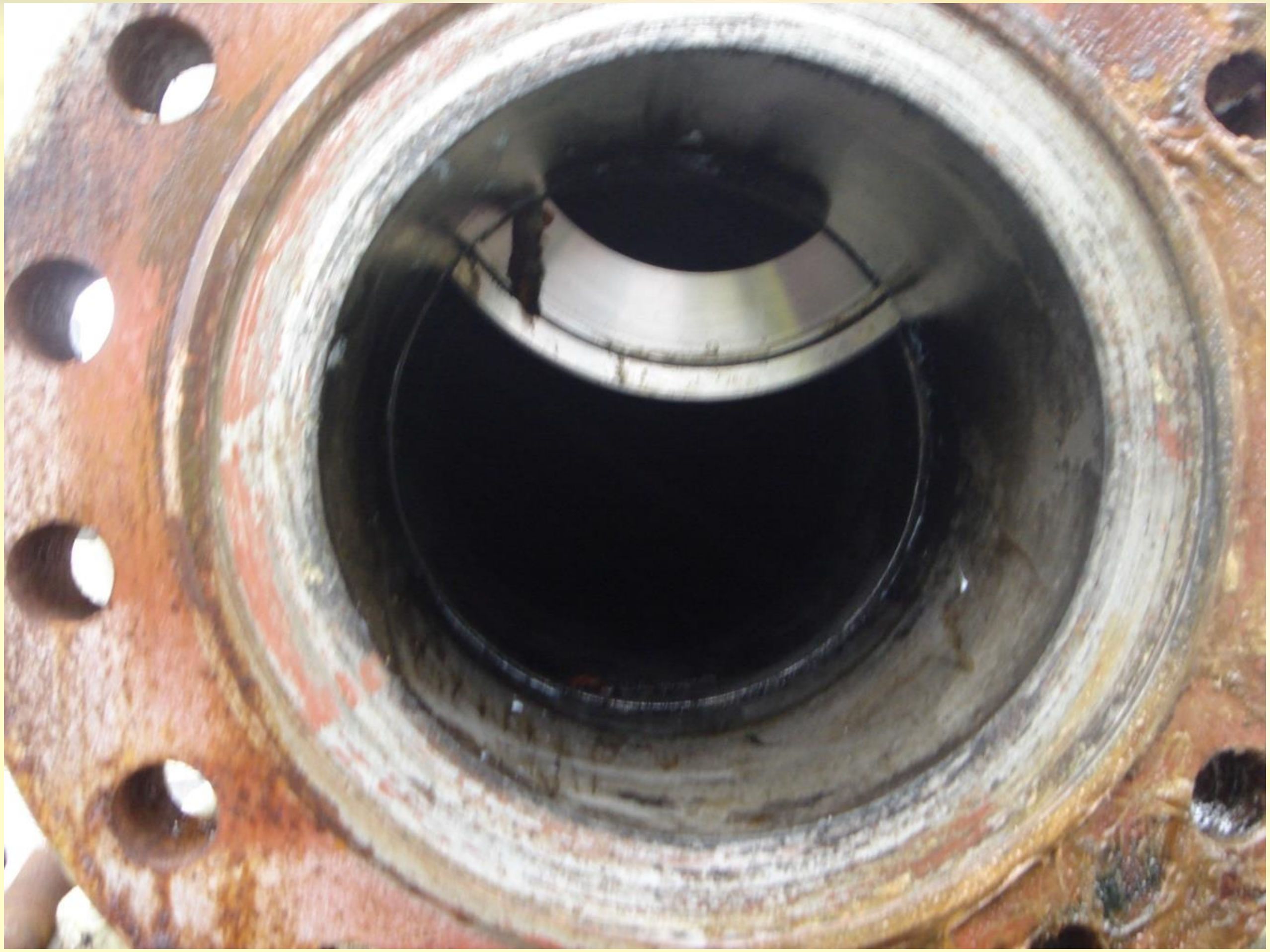
Counter Reading 99950



SMER Period #2
27/7/10 – 10/08/10

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This Presentation Content

- **To summarise the "key" areas addressed within my ITE Independent Report;**

  - **Define the SMER Periods.**

  - **Introduce the 3 sources of error investigation used;**
    1. **Trending of "real time" 4-minute data**
    2. **Site test results**
    3. **CFD modelling results to support the trend(s) shown in 1 and 2**

  - **Present the estimated errors.**

  - **Application of correction factors.**

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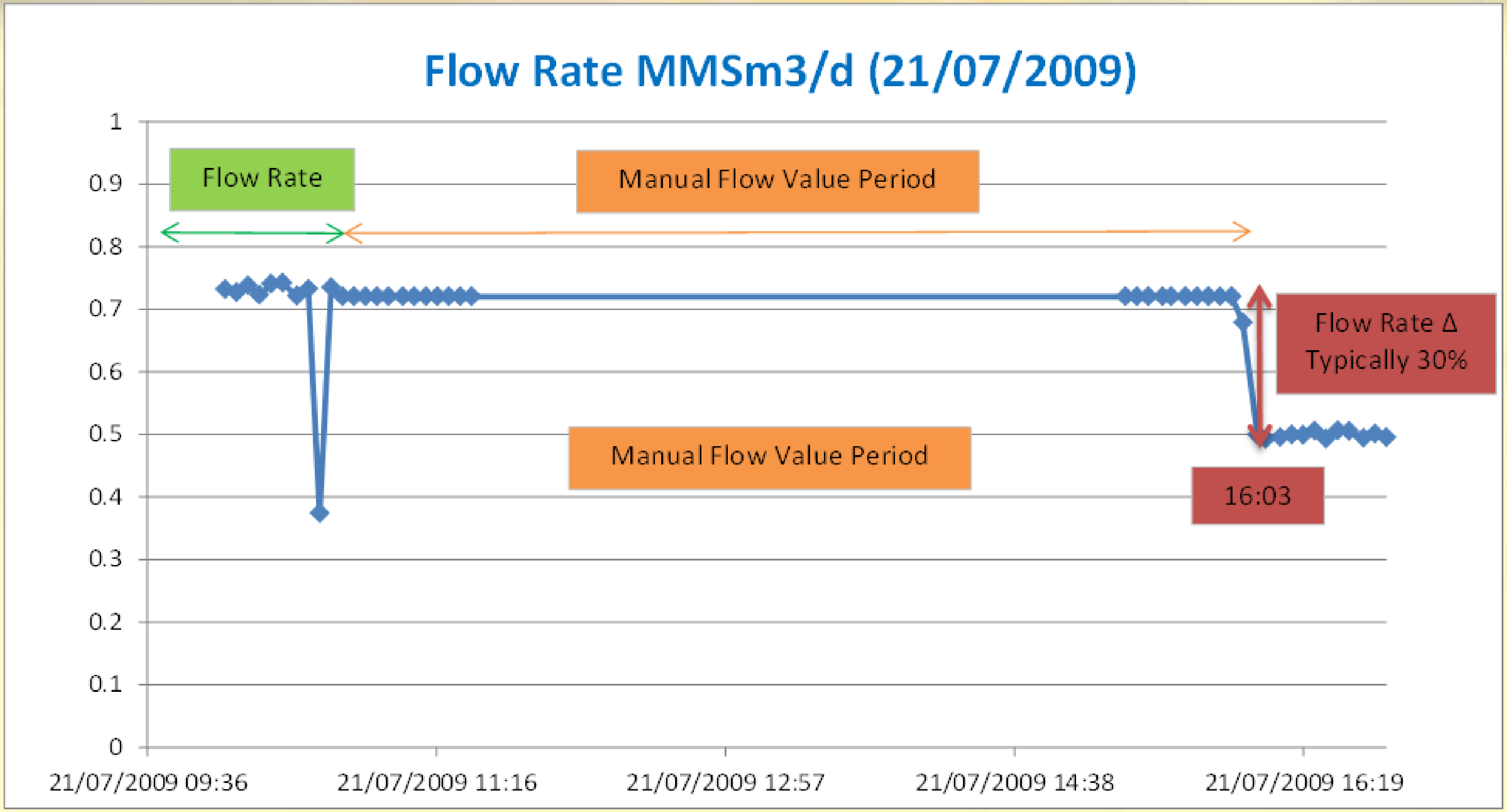
Events of 21/07/09



Events of 21/07/09

- It can be confirmed that the orifice plate inspection activity took place during the 21st July 2009 as it is well documented within the ME2 reporting requirement.
- What isn't so well documented is the "as left" orifice carrier counter reading as there is not a procedural requirement to record this on any form or logbook.
- However, from an independent review of these results and from further discussions with the personnel involved, the most logical counter reading (in the opinion of the Appointed Independent Technical Expert) would be 99985.

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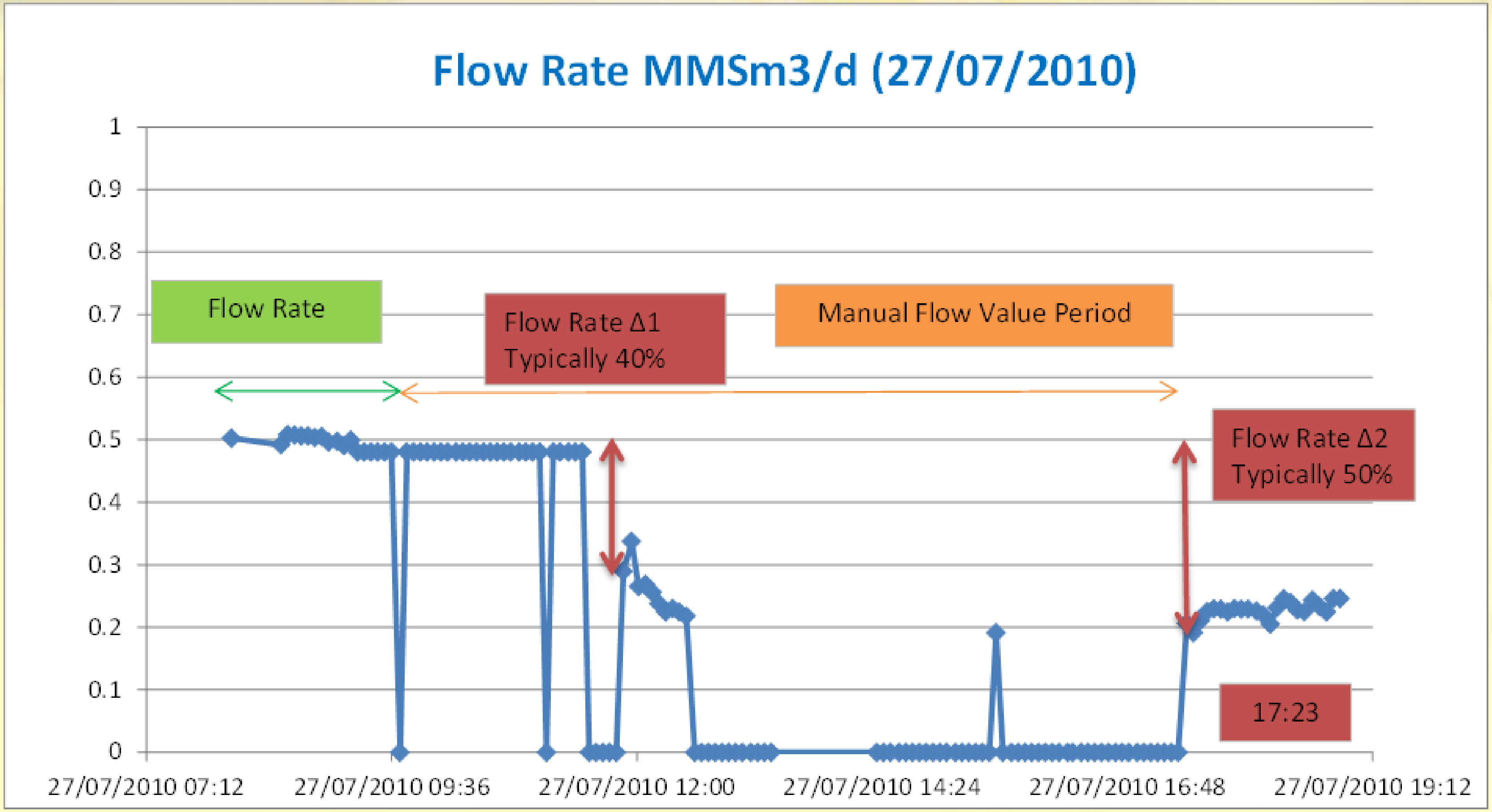
Events of 21/07/09

- The rationale behind this is that given the mitigating circumstances of the visual restriction of the counter reading window and the fact that the value of 99885 is stamped on the data plate as the value for a fully removed plate position, it is quite conceivable that the Maintenance Technician interpreted the whole process incorrectly and ended up at a counter position of 99985.

- None of the other readings would have had any practical relevance in which to "aim" for any other particular counter reading.

Events of 27/07/10



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Events of 27/07/10

- Again, it can be confirmed that the orifice plate inspection activity took place during the 27th July 2010 as it is well documented within the ME2 reporting requirement.
- Again, the "as left" orifice carrier counter reading was not a recorded.
- However, from an independent review of these results and from further discussions with the personnel involved, the most logical counter reading (in the opinion of the Appointed Independent Technical Expert) within this range would be 99950.

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Events of 27/07/10

- The rationale behind this event is that the Maintenance Team on this occasion were targeting 99995 as they were of the opinion that the Manufacturers instructions stated 99995 – 00005 as the counter reading required for a fully "racked" orifice plate (FMC do not recognise this and it is not stamped on the data plate). Therefore, given the mitigating circumstances of the visual restriction of the counter reading window and the fact that the value of 99995 was the intended "aimed" racking position, it is quite conceivable that the Maintenance Technician ended up at a counter position of 99950 (thinking it was 99995).

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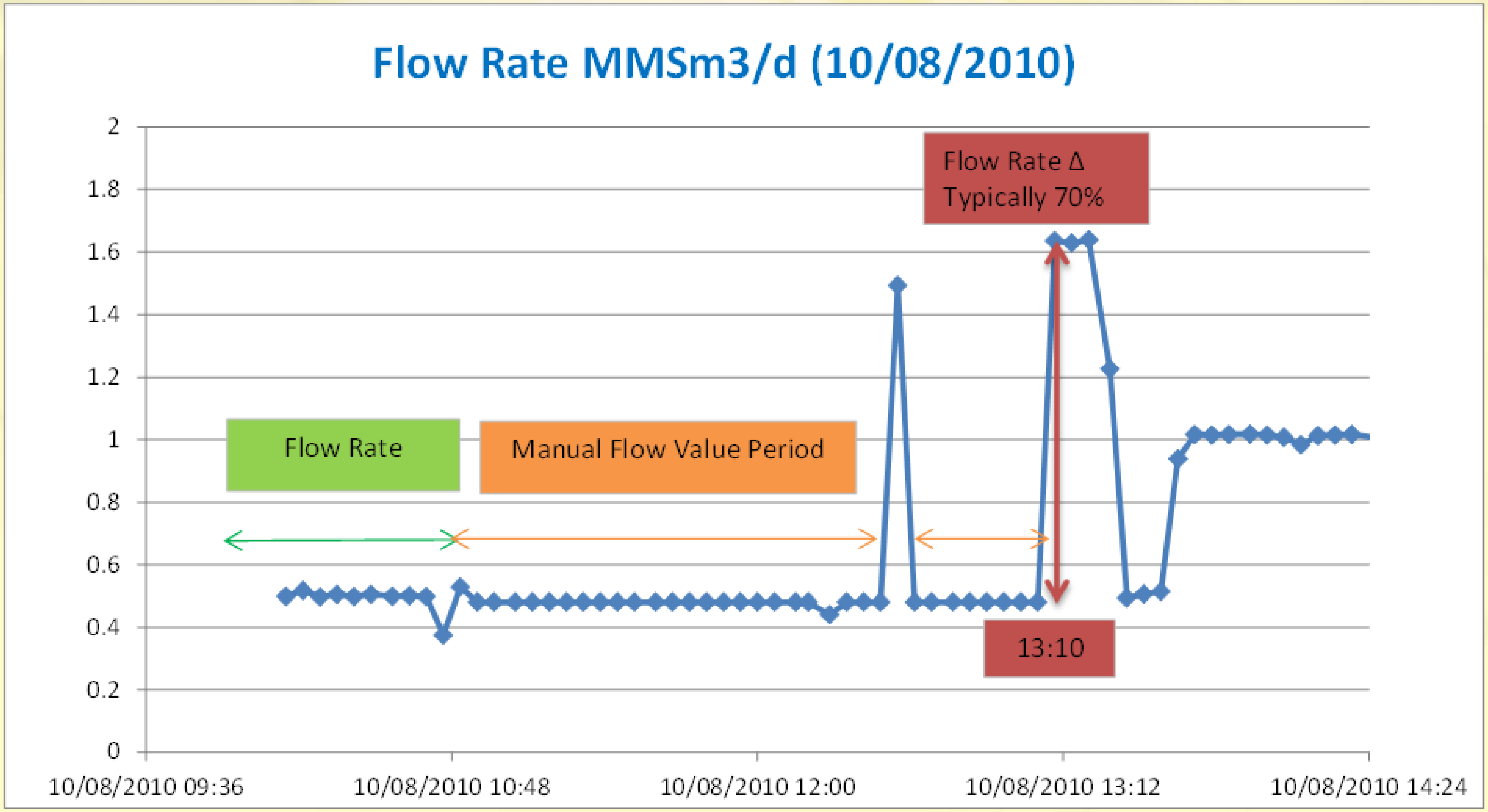
Events of 10/08/10



Events of 10/08/10

- On this occasion site presence was in response to a Site Investigation Visit.
- However, this time the Senior Network Technician requested that the Maintenance Team ensured that the orifice plate assembly was fully seated by winding (or racking) until it would not move any further. The "as found" position was again "mentally" noted as 99995 and additional information suggests that it required approximately an additional 14 turns before it became fully seated. This can be relatively well supported by referencing the FMC Site Measurement Report and using a typical counter ratio of 3.5 to a single turn of the orifice plate assembly shaft.

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Events of 10/08/10

- What is confirmed in a written report by the Senior Network Technician is that on completion of the 10th August 2010 site activities the orifice carrier counter reading was left at 00000 and checked to be fully seated.

SMER Period & Error Source 1

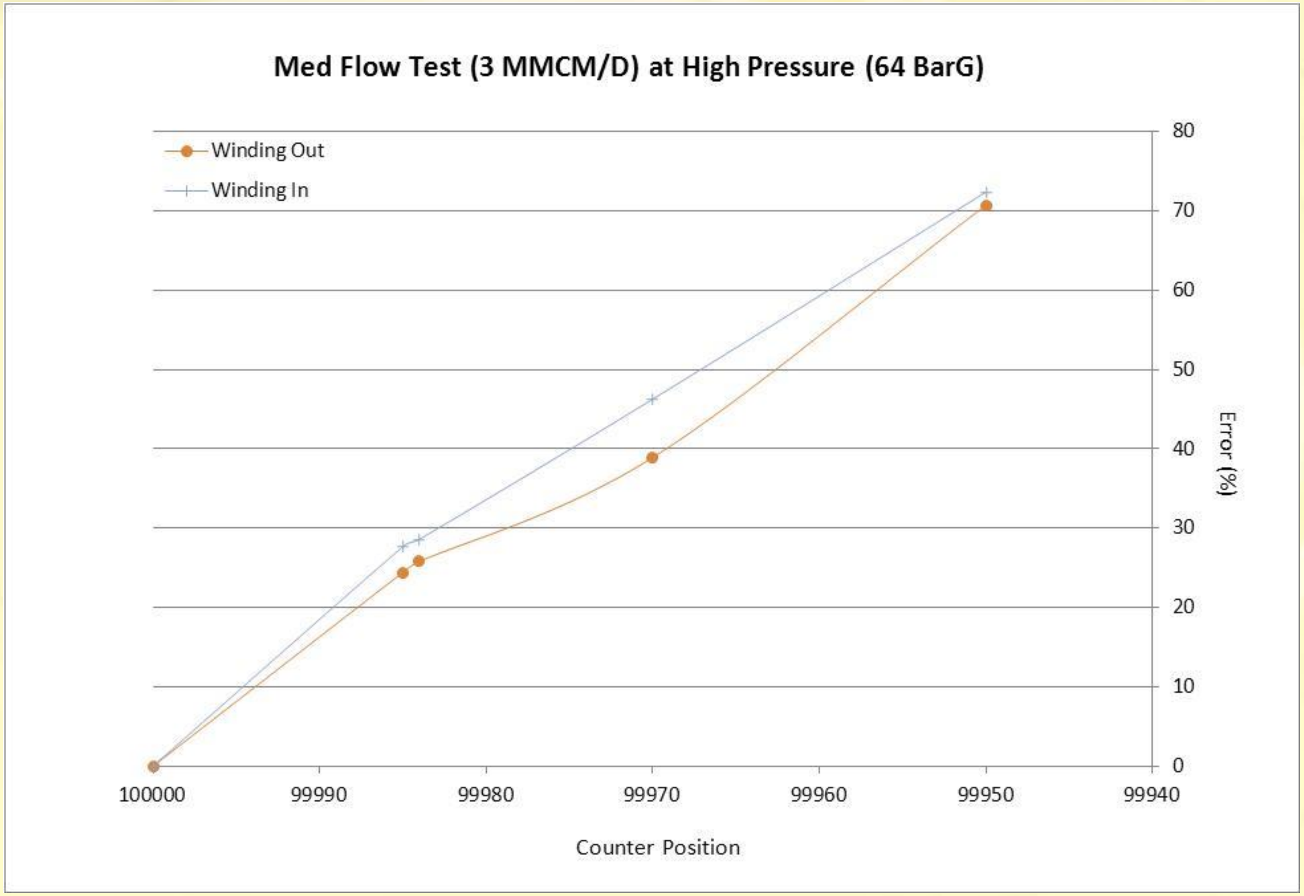
For the SMER period (1) – Counter Position 99985 (Estimated -30%);

- **Start – 16:03 hours on 21st July 2009**
- **Finish – 17:22 hours on 27th July 2010**

For the SMER period (2) – Counter Position 99950 (Estimated -70%);

- **Start – 17:23 hours on 27th July 2010**
- **Finish – 13:10 hours on 10th August 2010**

Site Test Results



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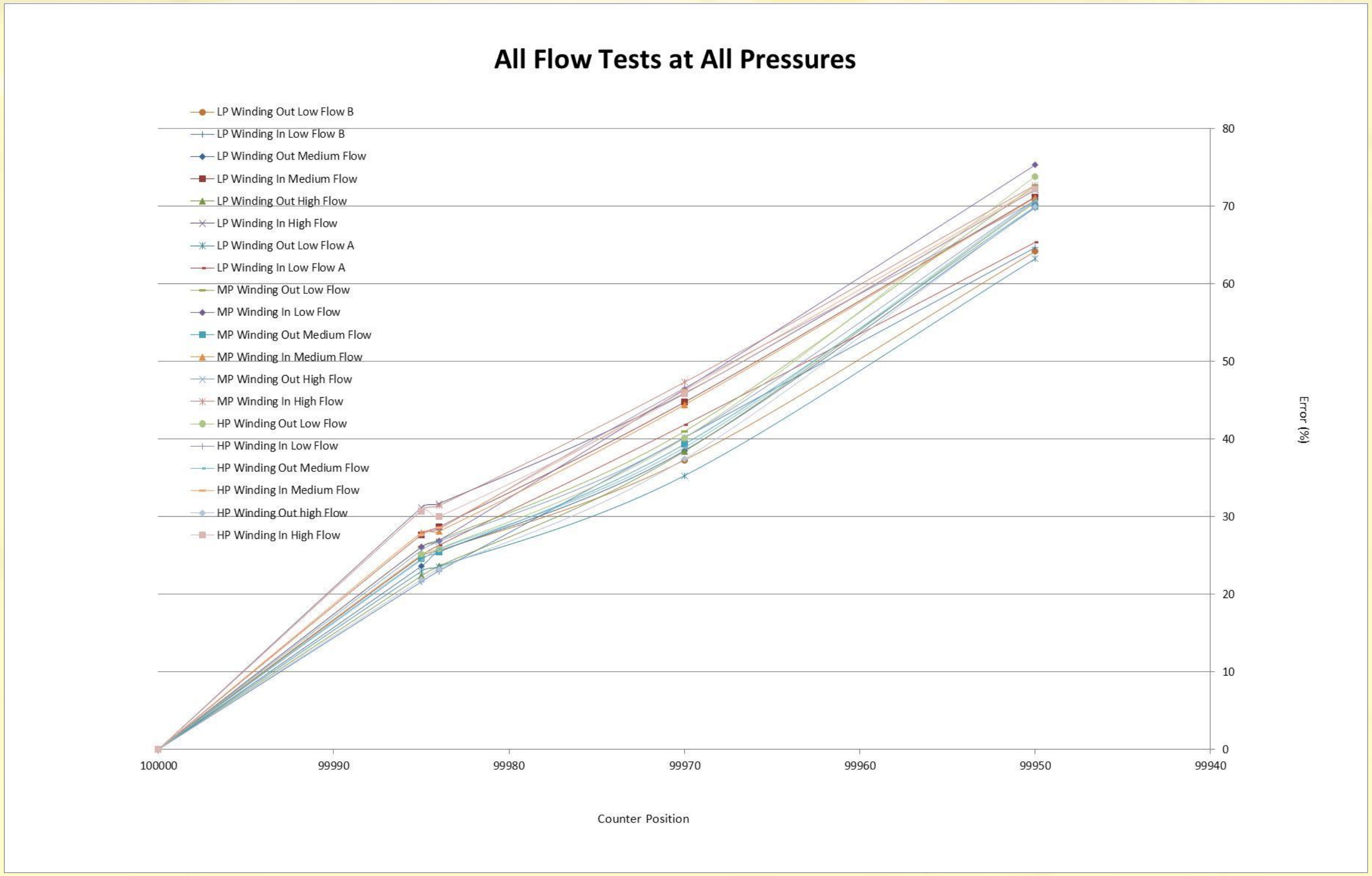
Site Test Results



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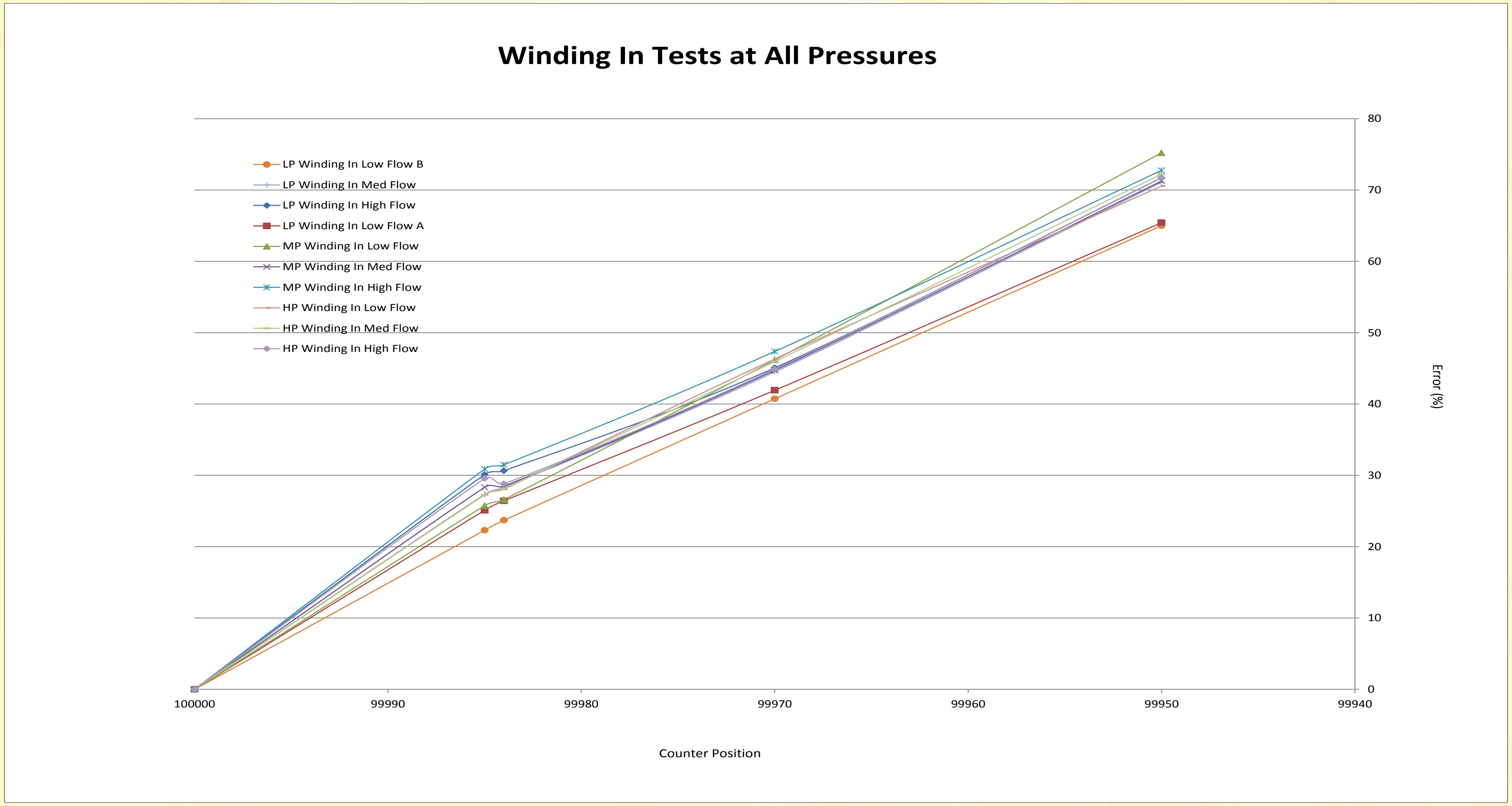
Site Test Results

From discussions with the personnel involved, it would appear that the Maintenance Personnel (following orifice plate inspection/change-out) “wind-in” the orifice plate to the counter position.

Practically, this makes sense in that it would illogical (but not inconceivable) that the Maintenance Personnel would not “wind-in” the orifice plate to the stop and then “wind-out” again to the counter position.

With this in mind, it is the view and assumption of the Appointed Independent Expert that the “winding-in” error values should be used as the basis for both SMER period error evaluations.

Site Test Results



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Site Test Results

TEST 9 - LOW FLOW (A) / LP		TEST 11 - LOW FLOW (B) / LP		TEST 8 - MED FLOW / LP		TEST 10 - HIGH FLOW / LP	
Counter Postion	Error (%)	Counter Postion	Error (%)	Counter Postion	Error (%)	Counter Postion	Error (%)
99950	65.412	99950	65	99950	71.067	99950	71.709
99970	41.926	99970	40.73	99970	44.488	99970	45.072
99984	26.431	99984	23.703	99984	28.328	99984	30.647
99985	25.102	99985	22.308	99985	27.328	99985	30.106
100000	0	100000	0	100000	0	100000	0
		TEST 1 - LOW FLOW / MP		TEST 2 - MED FLOW / MP		TEST 3 - HIGH FLOW / MP	
		Counter Postion	Error (%)	Counter Postion	Error (%)	Counter Postion	Error (%)
		99950	75.213	99950	71.26	99950	72.755
		99970	46.184	99970	44.719	99970	47.369
		99984	26.606	99984	28.492	99984	31.481
		99985	25.749	99985	28.325	99985	30.873
		100000	0	100000	0	100000	0
		TEST 6 - LOW FLOW / HP		TEST 4 - MED FLOW / HP		TEST 7 - HIGH FLOW / HP	
		Counter Postion	Error (%)	Counter Postion	Error (%)	Counter Postion	Error (%)
		99950	70.554	99950	72.209	99950	71.7
		99970	46.313	99970	45.949	99970	44.882
		99984	28.066	99984	28.175	99984	28.819
		99985	27.296	99985	27.236	99985	29.547
		100000	0	100000	0	100000	0

Tabulated Summary of “Winding IN” Site Testing Results

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Site Tests – Error Source 2

- **For the period 21/07/2009 to 27/07/2010**
  - Estimated between **22.3 – 30.9%**

- **For the period 28/07/2010 to 10/08/2010**
  - Estimated between **70 – 75%**

To provide further support of the “site testing trend” and to potentially provide a mechanism in which site testing data could be established as valid (or not) a third error investigation source was commissioned – CFD modelling.

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Computational Fluid Dynamics

Due to the “spread” of site test results, a CFD analysis model (as initially identified by the ITE within the methodology procedure) was constructed by;

Professor W Malalasekera

Professor of Computational Fluid Flow & Heat Transfer

Loughborough University

Whilst proving a “lengthy” support option (in terms of time taken to finalise the results) it does provide a valuable tool for site test result comparison and validation.

CFD Methodology

- The Appointed Independent Expert provided all dimensional and operating data to Professor Malalasekera to enable the CFD model to be constructed.

- The Appointed Independent Expert provided 3 separate "ISO-5167 compliant" flow scenarios (from archive Aberdeen off-take measurement data) ***excluding the actual differential pressure value***, to validate the CFD model (i.e. commencement benchmark against "blind tests"). This requirement additionally satisfies point 4 of the British Gas TMI e-mail dated 24th August 2012.

- When the CFD model was satisfactorily demonstrated against associated "ISO-5167 compliant" flow data, the Appointed Independent Expert provided a series (from the 99970 series of site testing results) "non-compliant ISO-5167" (i.e. "in error" scenarios) to further validate CFD model in this "error mode". Again, this requirement additionally satisfies point 4 of the British Gas TMI e-mail dated 24th August 2012.

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CFD Methodology

- When the CFD model had been satisfactorily demonstrated against associated "ISO-5167 compliant & non-compliant" flow data, the Appointed Independent Expert provided the full 99985 and 99950 counter reading SMER data for associated modelling and completion of a R1 report for further peer review.
- On completion of the R1 CFD report it was issued to TUV SUD NEL for peer review and issue of comments and recommendations.
- Incorporate associated peer review comments within the CFD report (R2).
- Final peer review by TUV SUD NEL of R2 CFD report.
- Issue of R3 (Final) CFD report.

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CFD Results (99985)

Case id	Case considered and identification details	Actual flow rate (m^3/h) and (Mass flow rate, kg/h)	Density (kg/m^3) and viscosity	Model variation	Predicted differential pressure (mbar)	Measured differential pressure	Error %	Remarks	% Difference of error between models (1&2, 2&3)
985-1	**CASE 99985 – TEST 1** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	594.4561 (33696.1843)	56.684 1.24e-5	**Grid_1**	**14.68**	13.784	**6.5%**	Uncertainty in measurements < 5 %	-
				Grid_2	**14.43**		**4.7%**		**1.8%**
				Grid_3	**14.40**		**4.4%**		**0.3%**
985-2	**CASE 99985 – TEST 2** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	1598.6628 (90950.2459)	56.892 1.24e-5	**Grid_1**	**106.25**	103.136	**3.0%**	Uncertainty in measurements < 2 %	-
				Grid_2	**104.71**		**1.5%**		**1.5%**
				Grid_3	**104.36**		**1.2%**		**0.3%**
985-3	**CASE 99985 – TEST 3** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	2396.1463 (138132.993)	57.647 1.24e-5	**Grid_1**	**241.54**	242.939	**0.5%**	Uncertainty in measurements < 1 %	-
				Grid_2	**237.72**		**2.1%**		**1.6%**
				Grid_3	**237.43**		**2.2%**		**0.1%**

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CFD Results (99985)

985-4	**CASE 99985 – TEST 4** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	1540.5865 (92601.981)	60.108 1.25e-5	**Grid_1** **Grid_2** **Grid_3**	**104.23** **102.56** **102.43**	102.495	1.6% 0% 0%	Uncertainty in measurements < 2 %	- 1.6% 0%
985-6	**CASE 99985 – TEST 6** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	534.9225 (32179.62)	60.158 1.25e-5	**Grid_1** **Grid_2** **Grid_3**	**12.62** **12.31** **12.38**	12.062	4.6% 2.1% 2.6%	Uncertainty in measurements < 6 %	- 2.5% 0.5%
985-7	**CASE 99985 – TEST 7** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	2174.3146 (130547.98)	60.041 1.25e-5	**Grid_1** **Grid_2** **Grid_3**	**207.52** **203.88** **203.99**	208.331	0.3% 2.1% 2.1%	Uncertainty in measurements < 1 %	- 1.8% 0%
985-8	**CASE 99985 – TEST 8** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	1729.112 (91847.114)	53.118 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**116.05** **114.17** **113.87**	112.566	3.1% 1.4% 1.1%	Uncertainty in measurements < 1.5%	- 1.7% 0.3%
985-9	**CASE 99985 – TEST 9** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	609.996 (32754.048)	53.695 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**14.63** **14.39** **14.35**	14.067	4.0% 2.3% 2.0%	Uncertainty in measurements < 5 %	- 1.7% 0.3%

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CFD Results (99985)

985-10	**CASE 99985 – TEST 10** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	2415.2228 (128274.12)	53.111 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**226.40** **222.93** **223.02**	217.578	4.0% 2.4% 2.5%	Uncertainty in measurements < 1 %	- 0.7% 0.1%
985-11	**CASE 99985 – TEST 11** Incorrect position - Eccentric dimensions are A = 87.23, B=17.5 mm.	648.0378 (34565.349)	53.338 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**16.40** **16.12** **16.08**	15.981	2.6% 0.8% 0.6%	Uncertainty in measurements < 4.5 %	- 1.8% 0.2%

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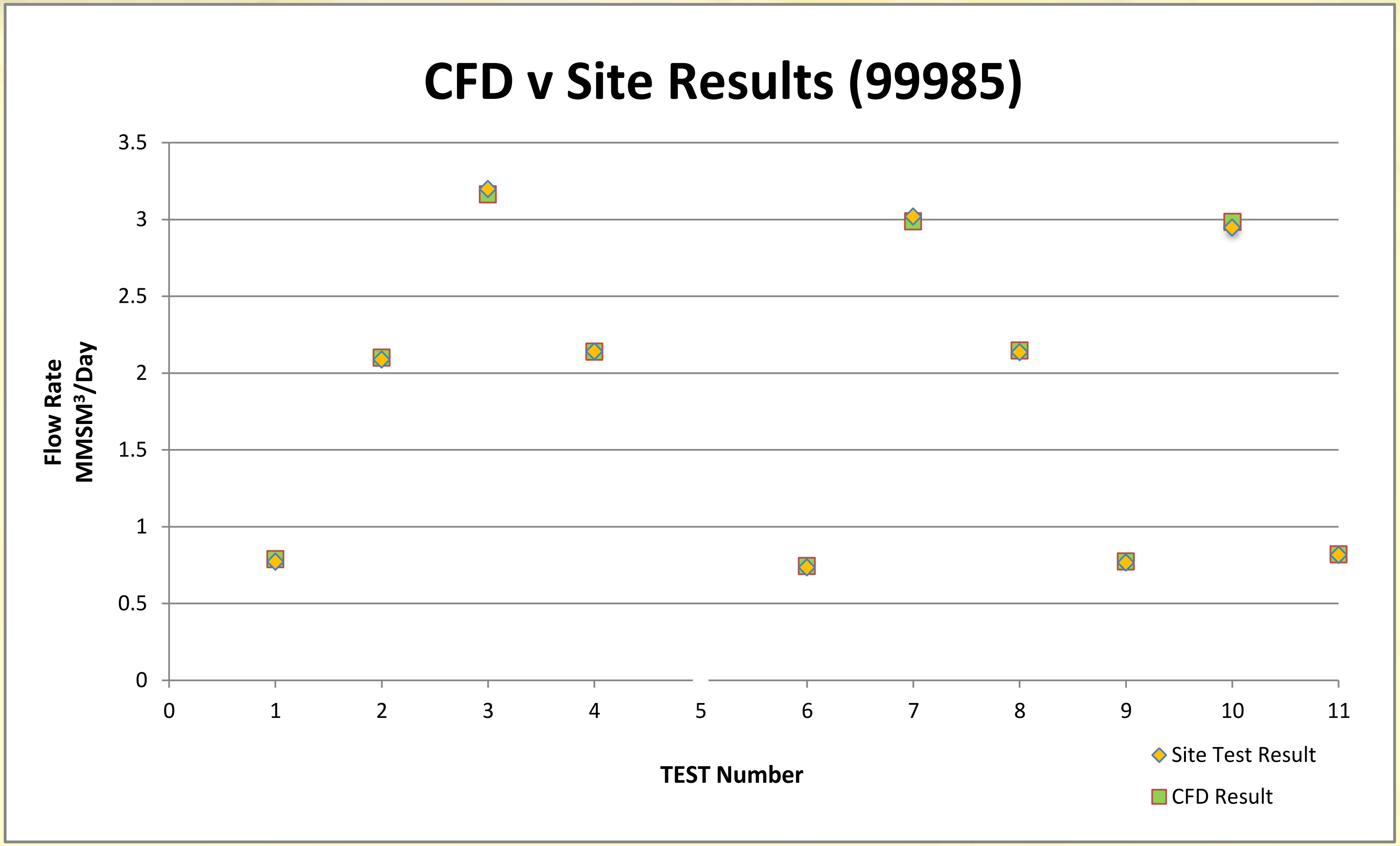
CFD Results (99985)



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CFD Results (99950)

Case id	Case considered and identification details	Actual flow rate (m^3/h) and (Mass flow rate, kg/h)	Density (kg/m^3) and viscosity	Model variation	Predicted differential pressure (mbar)	Measured differential pressure	Error %	Remarks	% Difference of error between models (1&2, 2&3)
950-1	**CASE 99950 – TEST 1** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	588.60 (33364.2584)	56.684 1.24e-5	**Grid_1** **Grid_2** **Grid_3**	**2.08** **1.98** **1.99**	1.39	**49.6%** **42.4%** **43.1%**	Uncertainty in measurements < 5 %	**-** **7.2%** **0.3%**
950-2	**CASE 99950 – TEST 2** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	1619.6945 (92032.9718)	56.821 1.24e-5	**Grid_1** **Grid_2** **Grid_3**	**17.03** **16.23** **16.32**	16.07	**5.9%** **0.9%** **1.5%**	Uncertainty in measurements < 2 %	**-** **4.4%** **0.6%**
950-3	**CASE 99950 – TEST 3** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	2459.8613 (141573.504)	57.553 1.24e-5	**Grid_1** **Grid_2** **Grid_3**	**38.47** **38.02** **37.98**	37.28	**3.1%** **1.9%** **1.8%**	Uncertainty in measurements < 1 %	**-** **1.2%** **0.2%**

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CFD Results (99950)

950-4	**CASE 99950 – TEST 4** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	1564.3494 (94042.855)	60.116 1.25e-5	**Grid_1** **Grid_2** **Grid_3**	**16.79** **16.02** **16.09**	14.60	15.0% 9.7% 10.2%	Uncertainty in measurements < 2 %	- 5.3% 0.5%
950-6	**CASE 99950 – TEST 6** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	541.2844 (32562.3366)	60.157 1.25e-5	**Grid_1** **Grid_2** **Grid_3**	**2.01** **1.92** **1.91**	1.854	8.6% 3.7% 3.2%	Uncertainty in measurements < 6 %	- 4.9% 0.5%
950-7	**CASE 99950 – TEST 7** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	2284.8572 (137055.98)	59.984 1.25e-5	**Grid_1** **Grid_2** **Grid_3**	**35.90** **34.32** **34.28**	33.42	7.4% 2.6% 2.5%	Uncertainty in measurements < 1 %	- 4.8% 0.1%
950-8	**CASE 99950 – TEST 8** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	1748.498 (92917.081)	53.118 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**18.54** **17.84** **17.77**	17.43	6.3% 2.3% 1.9%	Uncertainty in measurements < 1.5%	- 4.0% 0.4%
950-9	**CASE 99950 – TEST 9** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	608.80 (32689.86)	53.695 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**2.27** **2.18** **2.18**	2.83	19.7% 22.9% 22.9%	Uncertainty in measurements < 5 %	- 3.2% 0%

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CFD Results (99950)

950-10	**CASE 99950 – TEST 10** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	2506.863 (133026.445)	53.064 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**37.95** **36.57** **36.43**	34.96	**8.5%** **4.6%** **4.2%**	Uncertainty in measurements < 1 %	**-** **3.9%** **0.4%**
950-11	**CASE 99950 – TEST 11** Incorrect position - Eccentric dimensions are A = 210.5 mm, B=22.5 mm.	633.819 (33806.983)	53.338 1.23e-5	**Grid_1** **Grid_2** **Grid_3**	**2.44** **2.35** **2.35**	3.07	**20.5%** **23.4%** **23.4%**	Uncertainty in measurements < 4.5 %	**-** **2.9%** **0%**

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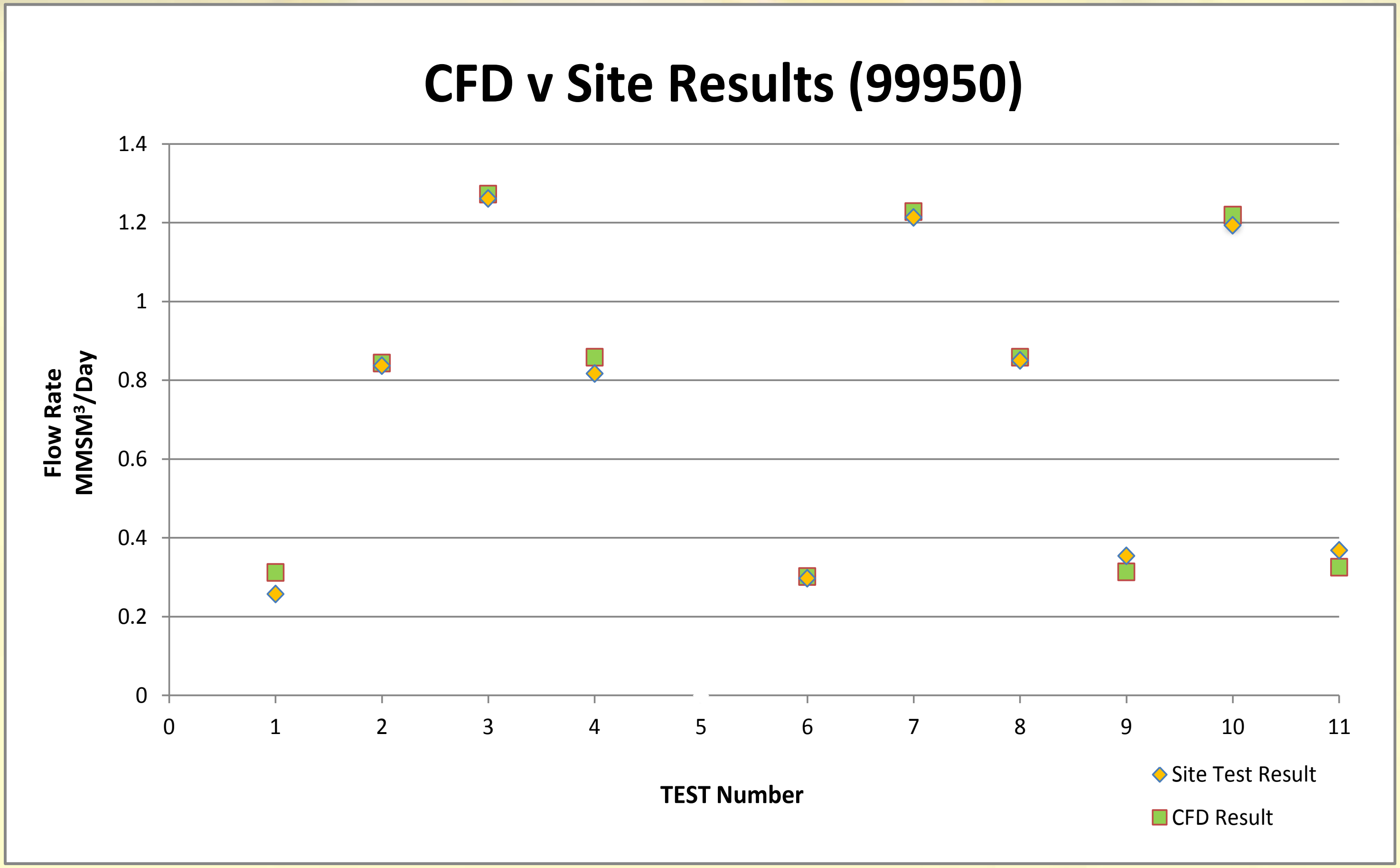
CFD Results (99950)



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CFD Summary – Error Source 3

- **99985 Results Summary**
  - It can be seen from tables presented, that the value of differential pressure obtained from CFD modelling R3 for all test cases, compare very favourably with those obtained from the site testing and support the "general" trend of error.

- **99950 Results Summary**
  - It can be seen from tables presented, that the value of differential pressure obtained from CFD modelling R3 for **most** test cases, compare very favourably with those obtained from the site testing and again support the "general" trend of error. Tests #1, #9 and #11 are the obvious exceptions (potentially due to the high uncertainty of differential pressures <3 mbar).

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CFD Peer Review

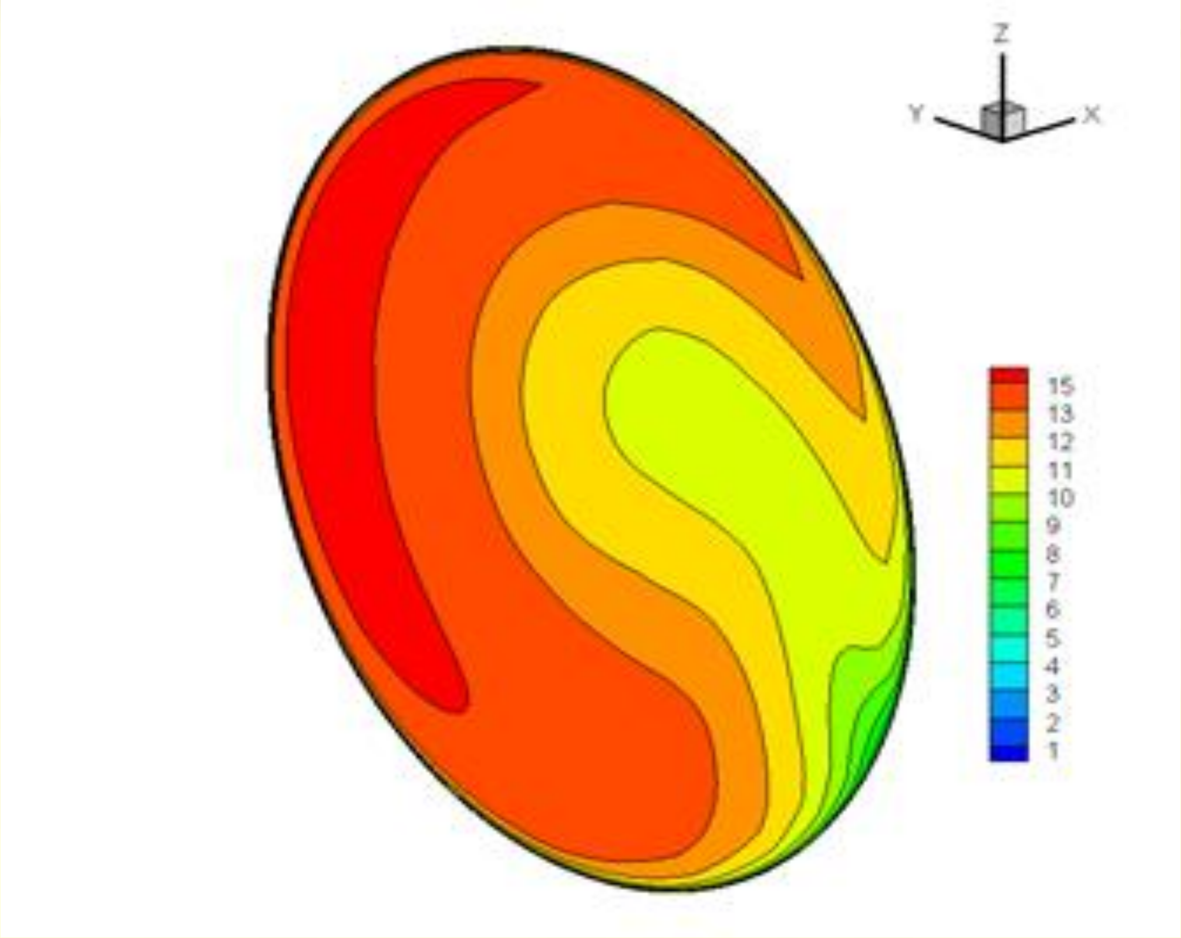
Two NEL comments;

1. For the long model at any rate CFD grid independence has not been achieved; so the contention that the long model is required has not been proved.

   (Note: The Professor advocates the use of a “long model” that encompasses the “full extent of downstream lengths, pipe bends & thermowell – NEL suggest the use of a “short model” incorporating a straight length of 10D only).

Professor’s Response – By plotting the velocity magnitude at the outlet of the 99985 short model using a 10D downstream pipe length, it can be seen the outlet velocity magnitude distribution is clearly asymmetric and not recovered to a general pipe flow profile. Therefore it would require the use of a longer length to impose suitable outlet boundary conditions in the simulations and therefore the use of the current modelling strategy is justified.

CFD Peer Review



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CFD Peer Review

2. There is generally quite good agreement between experiment and CFD but grid independence remains to be achieved.

Professor's Response – It was shown in the report that the difference between the results of Grid 2 and Grid 3 in each case is less than 1%. In many cases the difference is in fact less than 0.5%. It is reasonable to conclude that the finer mesh results have reached a grid independent result. The ultimate test for a numerical model is to compare results with available experimental results. It has been shown that the results obtained with the last grid (Grid 3) in each case agree reasonably well with experimental results.

To Summarise;

As the main aim of the CFD work was commissioned to support the site testing "error trend", the achieved grid independence to typically 0.5% is considered acceptable by the Appointed Independent Expert and further satisfied that no "additional value" can be gained from further CFD activities, therefore the Professors final report (R3 – August 2013) should be considered as acceptable.

SMER Period 1 - Summary

The site results appear to demonstrate that whilst there is no related trend to the difference in operating pressure, there does seem to be a distinct band of error values created by the difference in flow rate and prevalent only to the 99985 counter reading position.

- Low flow error value band (%) 22.308 – 27.296 (Typical ΔP = 13 - 15 mbar)
- Mid flow error value band (%) 27.236 – 28.325 (Typical ΔP = 110 - 124 mbar)
- High flow error value band (%) 29.547 – 30.873 (Typical ΔP = 270 - 280mbar)

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SMER Period 1 - Summary

Given the results of the site testing and CFD modelling, 3 options for which the determination of the most appropriate estimate of measurement error can be defined are;

1. Use all site test results as valid contributions and calculate their average. This option equates to an under-read of **27.387%**.

2. Use only those site test results that agree favourably with the CFD modelling results. As all CFD modelling results are aligned favourably with the site tests then all test results should be considered representative. Therefore this option also equates to an under-read of **27.387%.**

SMER Period 1 - Summary

3. Use only those site test results that agree favourably with the CFD modelling results but in addition, only use the result set(s) that align with the "**average**" flow scenario (low, medium or high) that existed at the end of each day within the SMER period. This option therefore equates to three under-read error values;

- Days where the average flow was designated low flow = 25.114%
- Days where the average flow was designated mid flow = 27.630%
- Days where the average flow was designated high flow = 30.175%

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SMER Period 1 - Summary

In the opinion of the Appointed Independent Technical Expert, Option 3 is the recommended method for the appropriate SMER Period 1 estimate of measurement error as the following criteria are met;

1. As all site test results agree favourably with the CFD modelling analysis so therefore each one must be considered representative.

2. The application of “flow band” related error values will optimise the associated error value used for each day within the SMER period.

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SMER Period 1 - Summary

As the daily average flow equated to low and medium bands only (Appendix E of the report refers), it is therefore recommended that the two flowing error values are used as the basis for the derivation of the estimated correction factor figures;

Low Flow Day Correction Factor = $\frac{100}{100 - 25.114} = 1.335$ (25.114%)

Mid Flow Day Correction Factor = $\frac{100}{100 - 27.630} = 1.382$ (27.630%)

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SMER Period 2 - Summary

As there was no apparent trend in the error values obtained for the 99950 counter reading position due to changes in either operational pressure or flow rate and given the results of the site testing and CFD modelling, again there are 3 options for which the determination of the most appropriate estimate of measurement error can be defined;

1. Use all site test results as valid contributions and calculate their average. This option equates to an under-read of **70.688%**.

2. Use only those site test results that agree favourably with the CFD modelling results. This option equates to an under-read of **71.608%**.

3. Use only those site test results that agree favourably with the CFD modelling results but in addition only use the result set(s) that align with the flow scenario (low, medium or high) that existed during the SMER Period (i.e. Test 6 – low flow). This option equates to an under-read of **70.554%**.

SMER Period 2 - Summary

In the opinion of the Appointed Independent Technical Expert, Option 3 is the recommended method for the appropriate SMER Period 2 estimate of measurement error as the following criteria are met;

1. Only those site test points which agree favourably with the CFD modelling results are used (section 7.6 refers – results of tests 1, 9 & 11 excluded due to the significant discrepancy seen from the CFD modelling results).

2. The site test result(s) that is/are the most representative of the SMER flow rates are used. In this case all flow was within the low flow band (< 0.8 $MMSm^3$/day) with the exception of an 8 minute reported flow duration (7th August 2010 between 15.04hrs and 15:12hrs) following reinstatement of the metering system on completion of site investigation visit (Fault Log 112402 refers).

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SMER Period 2 - Summary

It is therefore recommended that the result of Test 6 (70.554%) is used as the basis for the derivation of the estimated correction factor figure;

Correction Factor = $\frac{100}{100 - 70.554} = 3.396$ (70.554%)

Recommendations

The recommendation of this review is to multiply each of the daily standard volume totals reported within Gemini (during the SMER periods) as follows;

- For gas day 21st July 2009 (SMER Period 1 commencement date) – this will comprise a part day correction based on the low flow correction factor of 1.335 for flow totals accumulated between 16:03 and 05:59.
- For gas days 22nd July 2009 to 26th July 2010 (SMER Period 1 inclusive) – this will comprise a full day correction using either the low flow correction factor of 1.335 or the mid flow correction factor of 1.382 in accordance with the tabulated data detailed within Appendix A of the report.
- For gas day 27th July 2010 (SMER Period 1 finish date) – this will comprise a part day correction based on the low flow correction factor of 1.335 for flow totals accumulated between 06:00 and 17:22.

KELTON

Recommendations

- For gas day 27th July 2010 (SMER Period 2 commencement date) this will comprise a part day correction based on the correction factor of 3.396 for flow totals accumulated between 17:23 and 05:59.

- For gas days 28th July 2010 to 09th August 2010 (SMER Period 2 inclusive) this will comprise a full day correction based on the correction factor of 3.396.

- For gas day 10th August 2010 (SMER Period 2 remedial date) this will comprise a part day correction based on based on the correction factor of 3.396 for flow totals accumulated between 06:00 and 13:10.