GL Noble Denton

Report Number: 11827 *14 November 2011*

Horndon Significant Meter Error Report

GL Noble Denton Restricted

Confidential, Restricted to: National Grid Gas Distribution *& GL Noble Denton*

Prepared for:

Stuart Gibbons

National Grid Gas Distribution

Hinckley Operational Centre
Brick Kiln Street
Hinckley
Leicestershire
LE10 0NA

Prepared by:

Ben Kirkman

GL Industrial Services UK Ltd trading as GL Noble Denton

Holywell Park
Ashby Road
Loughborough Leicestershire
LE11 3GR
United Kingdom

Tel: +44 (0)1509 28 2266
Fax: +44 (0)1509 28 3080

E-mail: ben.kirkman@gl-group.com

Website: www.gl-nobledenton.com

Customer Reference: WRF 1-6IV925

GL Noble Denton

Report Number: 11827
Issue: 1.1

Report Issue / Amendment Record

Report Title: Horndon Significant Meter Error Report	
Report Number: *11827*	**Project Title:** Horndon SMER **Project SAP Code:** 1/17585

Amendment details

Issue	Description of Amendment	Originator/Author
1.0	Original	Ben Kirkman
1.1	Note added to section 2.2 for clarification	Ben Kirkman

Report approval

Issue	Checked by	Approved by	Date
1.0	S Kimpton	N Bryant	15th November 2011
1.1	S Kimpton	N Bryant	2nd February 2012

Previous issues of this document shall be destroyed or marked SUPERSEDED

Report Number: 11827
Issue: 1.1

Project Code: 1/17585

Distribution

Name	Company
Stuart Gibbons	National Grid Gas Distribution Hinckley Operational Centre Brick Kiln Street Hinckley Leicestershire LE10 0NA

Executive Summary

Site name	Horndon Offtake
DNO	National Grid Gas Distribution
LDZ	North London
Error start date	15th September 2008
Error corrected date	7th July 2010
Size of error (over or under read)	160.53 GWh under-registration
Error description	Following a temperature transmitter replacement the connections between the element and the transmitter became loose. This resulted in an increase in resistance and hence an over-read of temperature.
Meter type	Orifice Plate
SMER Unique Reference No	NT008
Compiled by	Ben Kirkman (GL Noble Denton)

Contents

1 Error Description

Horndon Offtake metering consists of one 24" orifice plate metering system with a gas chromatograph for PTZ correction. The temperature measurement system uses a 3-wire RTD probe which is connected to a temperature transmitter which converts the resistance reading into a 4-20 mA signal. The 4-20 mA transmitter output is wired into an Omni flow computer via barriers.

A T/PR/ME/2 validation (and audit) during July 2010 identified an anomaly on the meter temperature measurement system. The CP13 check is a spot check comparison between the temperature element and a reference temperature device with a tolerance of ±0.5 °C. In this case the test identified a temperature error of +6.73 °C. The cause of the error was identified as a loose connection on the temperature element which on tightening reduced the error to within the test tolerance. The increase in resistance caused an increase in temperature and a reduction in density leading to an under-registration of flow.

Initial investigation highlighted a varying positive error starting in July 2008 and a second period of intermittent negative error between December 2005 and July 2008. The temperature transmitter was replaced on 31st July 2008 and is thought to be the cause of the positive temperature error.

2 Methodology

There is no other recorded temperature measurement at Horndon Offtake however the above ground installation also contains a metering system for the transmission supply point for Horndon (Barking PS) which has a recorded temperature (via telemetry). This temperature was found to be unsuitable for comparison because it is located after the water bath heaters, which control the temperature to a set point.

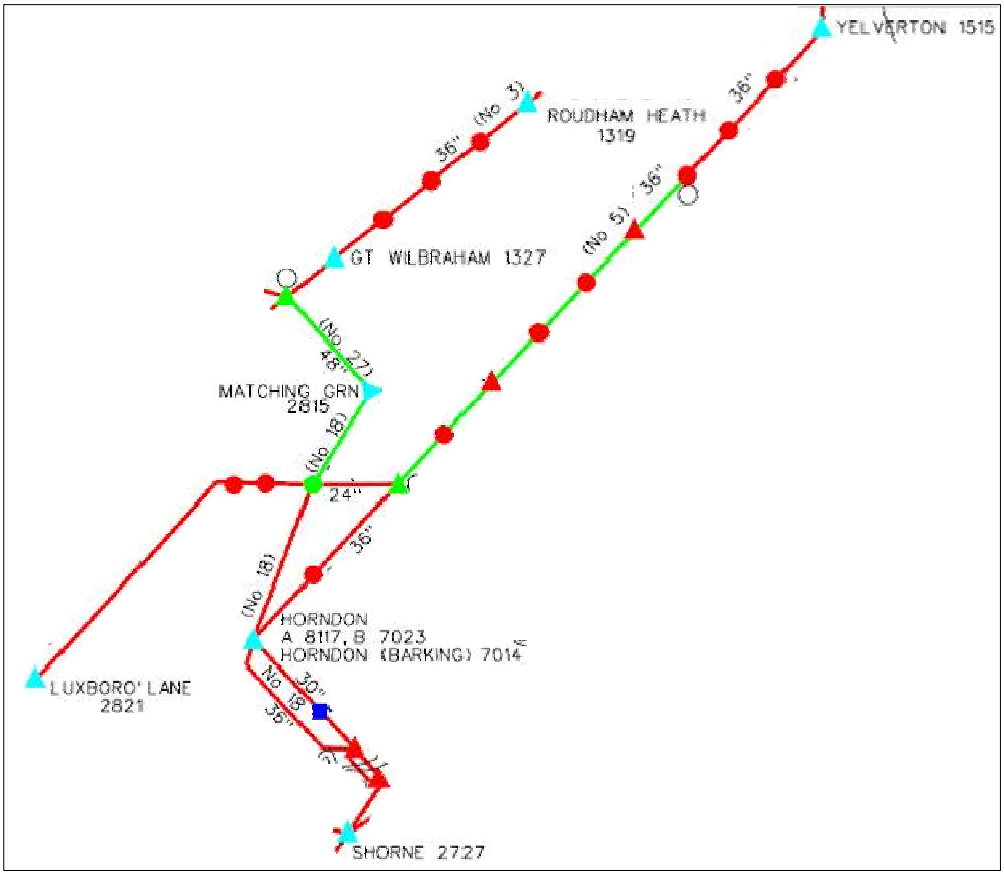

Figure 2.1 - Transmission Network Site Map

2.1 Bias and Standard Deviation

Temperature measurements from nearby offtakes were looked at to see if there was any correlation. These were taken from Matching Green, Luxborough Lane, Shorne, Yelverton, Roudham Heath and Great Wilbraham offtakes for the period after the temperature problem had been resolved July to December 2010.

The temperature measurements are made at a location downstream of the orifice plate. The differential pressure across the orifice plate causes a small temperature drop which can be simplified to 0.5 °C per bar of pressure drop. This correction was made to all the downstream temperatures converting them to upstream temperatures. These were then compared on a 4-minutely basis and the bias and standard deviation of all the temperature differences at each site were recorded. Where no gas is flowing the measured temperature is significantly influenced by ambient conditions hence comparisons were only made where both Horndon and the other site were flowing simultaneously.

	Bias	Std Dev
Matching Green	+1.32	1.11
Luxborough Lane	+0.52	1.65
Shorne	-0.26	1.84
Yelverton	-2.44	1.56
Roudham Heath	-3.51	1.81
Great Wilbraham	-2.90	2.01

Table 2.1 - Initial calculation of Bias and Standard Deviation

Table 2.1 lists the bias and standard deviations. The bias exists because of differences in site installations (e.g. pipe geometry) and geographical location and is generally of greater magnitude for the sites that are further away from Horndon (e.g. Roudham Heath) as shown in Figure 2.1.

The standard deviation is a measure of the correlation between temperature profiles at different sites. The sites with lower standard deviation generally match the temperature profile of Horndon more accurately.

2.2 Step Changes in Temperature

The analysis then looked at data between 2005 and 2010. The same downstream to upstream temperature correction was used and the bias for each site was corrected. This temperature was compared to the upstream temperature at Horndon to produce a temperature difference for each site on a 4-minutely basis. The temperature differences for all the sites were averaged excluding instances where Horndon or the other site used were not flowing.

This clearly illustrated the positive error starting in September 2008 however it also revealed some unexpected step changes in temperature difference. Detailed investigation showed that these step changes in temperature coincided with significant changes in gas composition as illustrated in Figure 2.2 and Figure 2.3. The average temperature of the other sites is shown in yellow and the difference between this and Horndon is shown in red.

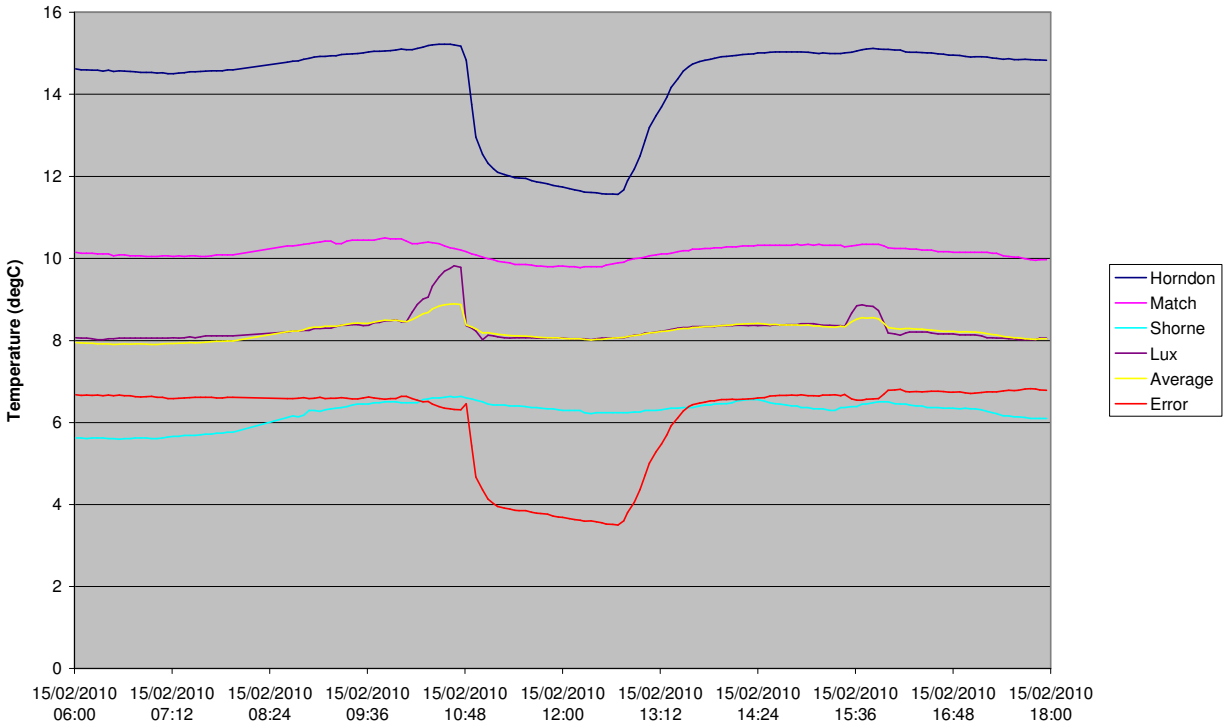

Figure 2.2 - Unexpected temperature step change at Horndon

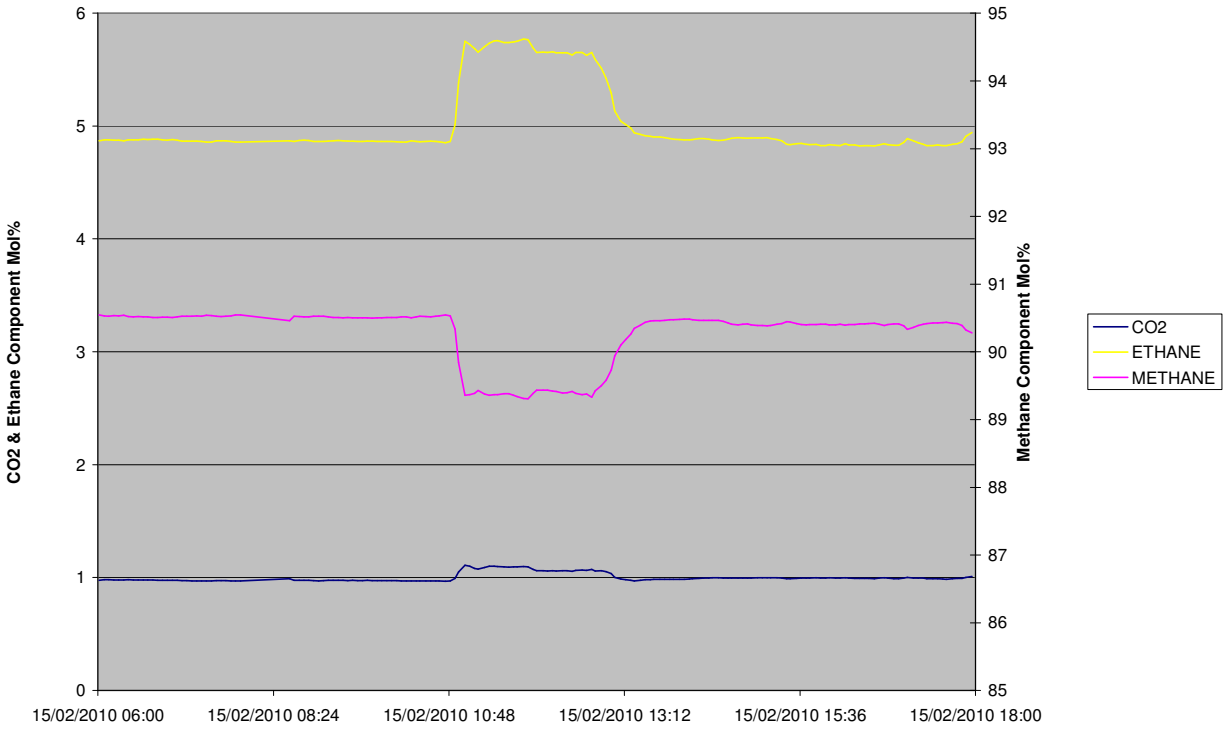

Figure 2.3 - Gas composition step change

Due to it's location at the intersection of 4 feeder mains, the change in gas composition was attributed to a change in the way the Horndon offtake was being fed. For the same periods the pressures in the network

were investigated and highlighted a further relationship. Examining the pressures gives an indication of flow direction in the network, as the gas will flow from the point of higher pressure to lower pressure. The pressures at Horndon and Matching Green were very similar at the times when the step changes occurred and this suggested a change in flow direction which supports the change in gas composition and temperature[1].

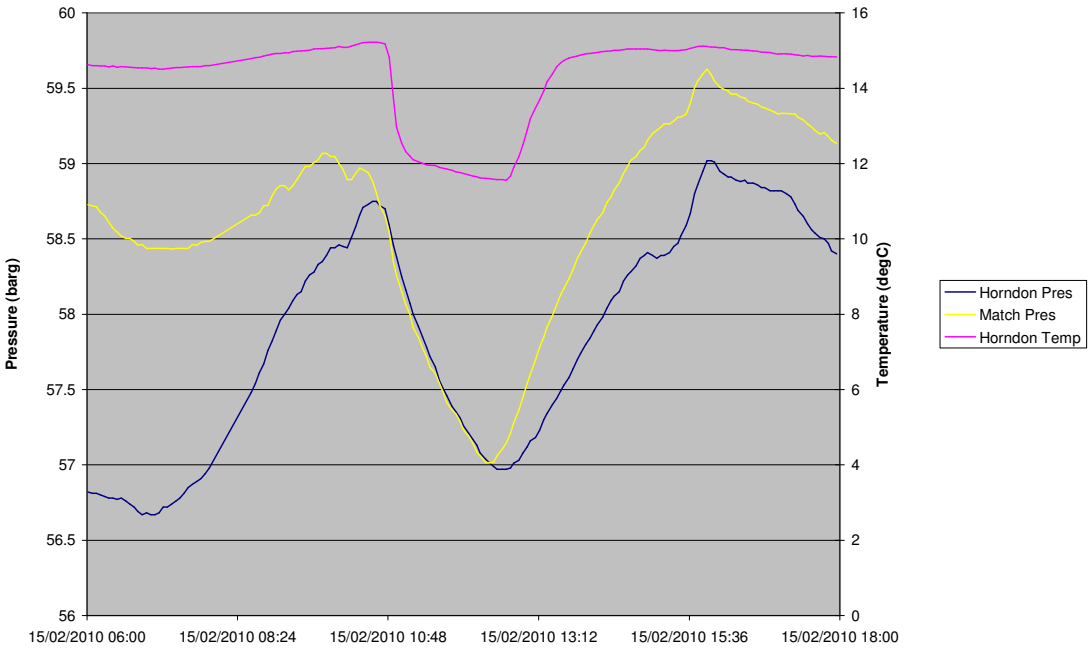

Figure 2.4 - Change in pressure profile

This type of temperature drop when examined in isolation could be identified as an intermittent low temperature error; however the supporting pressure profile and change in gas composition indicate that it is a real temperature change and not an additional error.

2.3 Recalculation of Bias and Standard Deviation

The data for July to December 2010 was categorised based on whether the pressure at Horndon was higher or lower than Matching Green. As anticipated this produced two significantly different bias readings for each site. The bias was between 0.9 °C and 2.4 °C higher when the pressure was higher at Horndon compared to when the pressure was higher at Matching Green. The standard deviation was significantly reduced for each dataset which indicates an improvement in correlation and supports the use of this enhanced method.

To further refine the analysis, data was excluded from the bias calculation where either Horndon or the site in question had just started flowing as the temperature needs to stabilise before it reflects the real gas temperature after being at ambient temperature.

[1] The report does not suggest that the change in temperature is caused by a change in thermodynamic properties. The report suggests that the change in gas composition is evidence that the gas source is changing and the two different gas sources have different temperatures, hence a step change in temperature.

	Higher pressure at Horndon than Matching Green (H)		Lower pressure at Horndon than Matching Green (M)		*Initial calculation*	
	Bias	**Std Dev**	**Bias**	**Std Dev**	*Bias*	*Std Dev*
Matching Green	+1.72	0.76	+0.83	0.59	*+1.32*	*1.11*
Luxborough Lane	+1.09	0.63	-0.47	0.83	*+0.52*	*1.65*
Shorne	+1.15	0.99	-1.23	1.00	*-0.26*	*1.84*
Yelverton	-1.61	0.97	-3.60	1.02	*-2.44*	*1.56*
Roudham Heath	-2.58	1.32	-4.91	1.08	*-3.51*	*1.81*
Great Wilbraham	-1.90	1.55	-4.42	1.22	*-2.90*	*2.01*

Table 2.2 - Final calculation of Bias and Standard Deviation

Roudham Heath, Great Wilbraham and Yelverton were excluded from further analysis because of their large standard deviation and bias which is attributed to being further from Horndon. The bias values for the other sites shown in Table 2.2 were used in the final determination of the bias corrected upstream temperature for each site.

2.4 Temperature Differences

The temperature difference was recalculated for each site as the difference between the upstream temperature for the site in question corrected for the new bias values and the upstream temperature calculated for Horndon at the same time. The temperature differences for all sites were averaged on a 4-minutely basis and a mean was taken on a daily basis. These daily mean temperature differences are plotted in Figure 2.5.

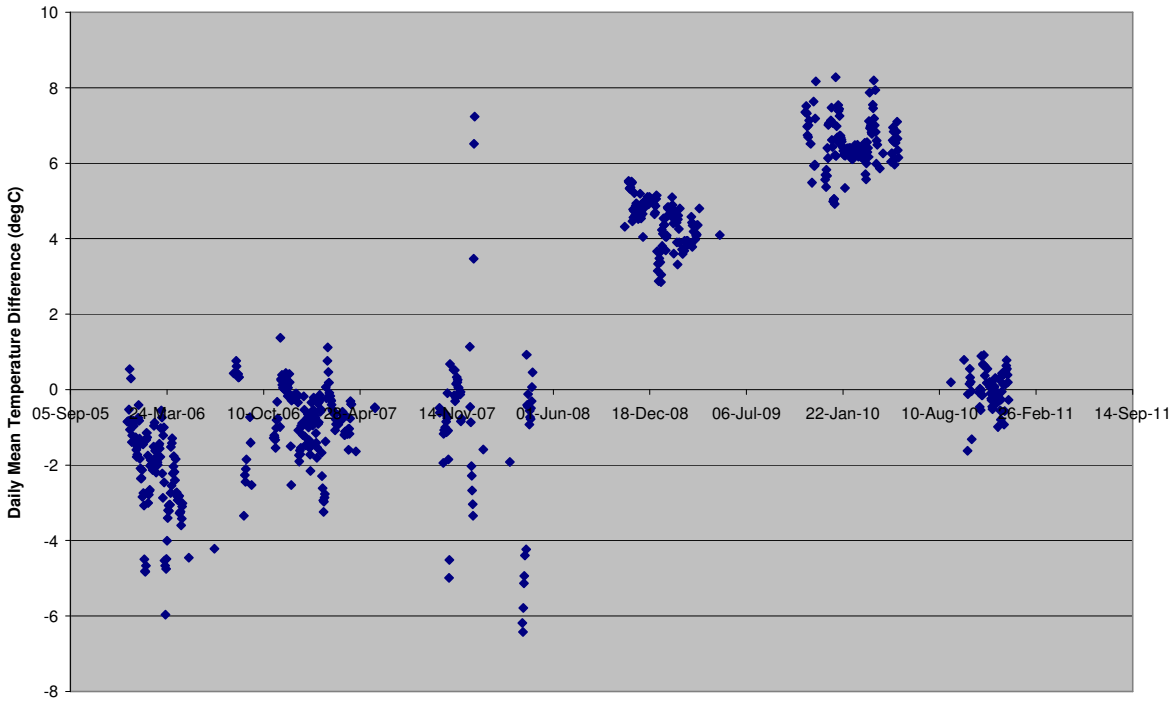

Figure 2.5 - Daily mean temperature differences

Figure 2.5 highlights two consistent periods of positive temperature error. Between October 2008 and July 2009 the error is around 4.5 °C; and between July 2009 and July 2010 the error is around 6.5 °C. This second period agrees with the 'As Found' temperature spot check which highlighted an error of 6.7 °C. The period from July to December 2010 shows a zero error for the period used in the determination of the bias values.

3 Error Quantification

3.1 Intermittent Negative Error Period (up to July 2008)

The data before July 2008 showed positive and negative temperature differences fluctuating around zero. The majority of these temperature differences were considered to be zero errors or within acceptable levels of deviation from zero. There were some temperature differences that were greater in magnitude and required further investigation.

From 26th January until 11th March 2006 the temperature at Matching Green was higher than the other sites. Before and after this period the temperatures agreed with the other sites so the higher temperatures are thought to be due to high demand and an increase in compressor station outlet temperature. The resultant negative temperature difference is not considered to be an error.

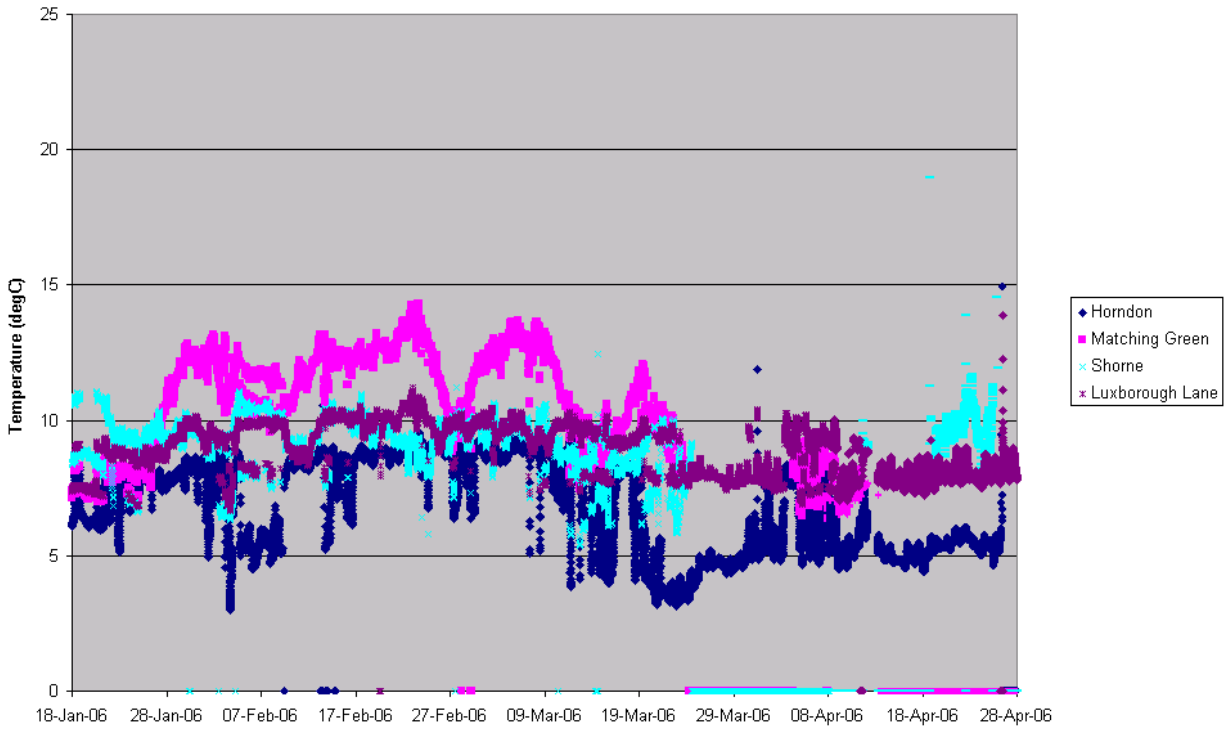

Figure 3.1 - January to April 2006 temperature profile

Throughout the period from January to April 2006 Horndon intermittently experienced low temperatures sometimes for extended periods of time. When examined alongside the network pressure data it can be seen that these steps in temperature correspond to changes in the pressure differential between Matching Green and Horndon. An example of this is shown in Figure 3.2 (where DP is the pressure differential between Matching Green and Horndon). This suggests that the recorded temperature changes are real changes in gas source at Horndon and not an error.

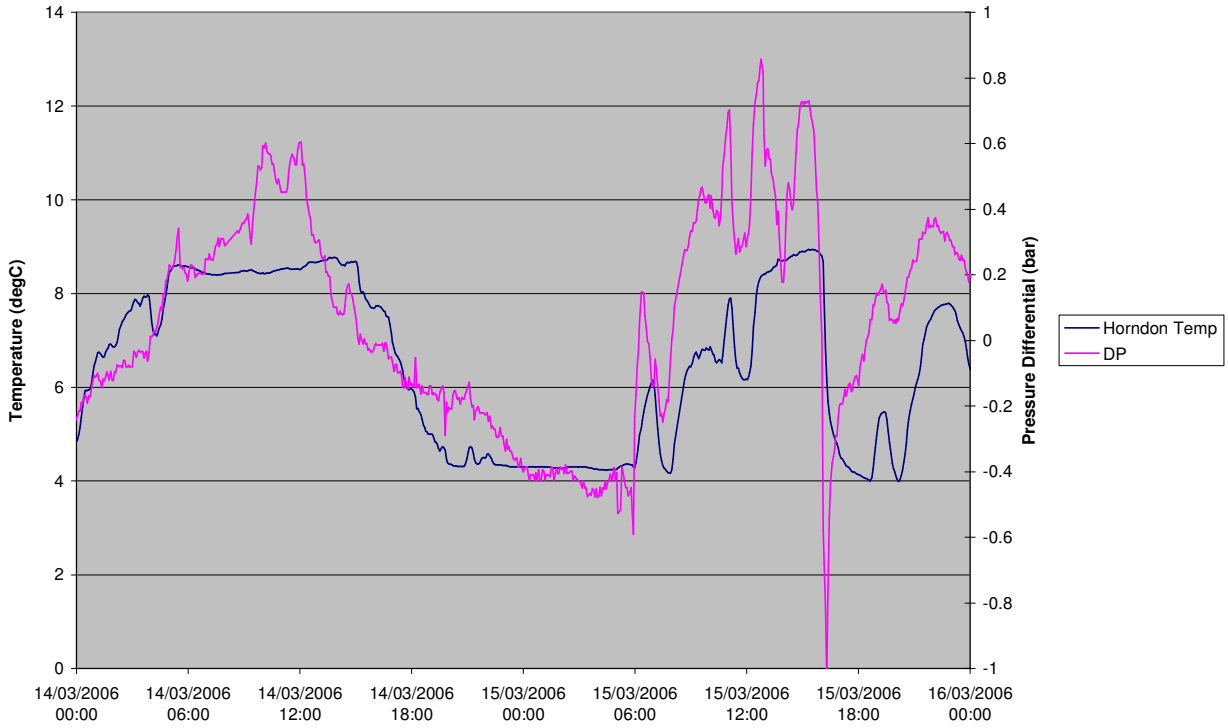

Figure 3.2 - Correlation of pressure differential and temperature

On 29th and 30th October 2007 the temperature was ~5 °C lower at Horndon than the average of the other sites. This can be attributed to a high temperature at Shorne (see Figure 3.3) and because the temperature at Horndon does not deviate before, during and after this point it is not considered to be an error.

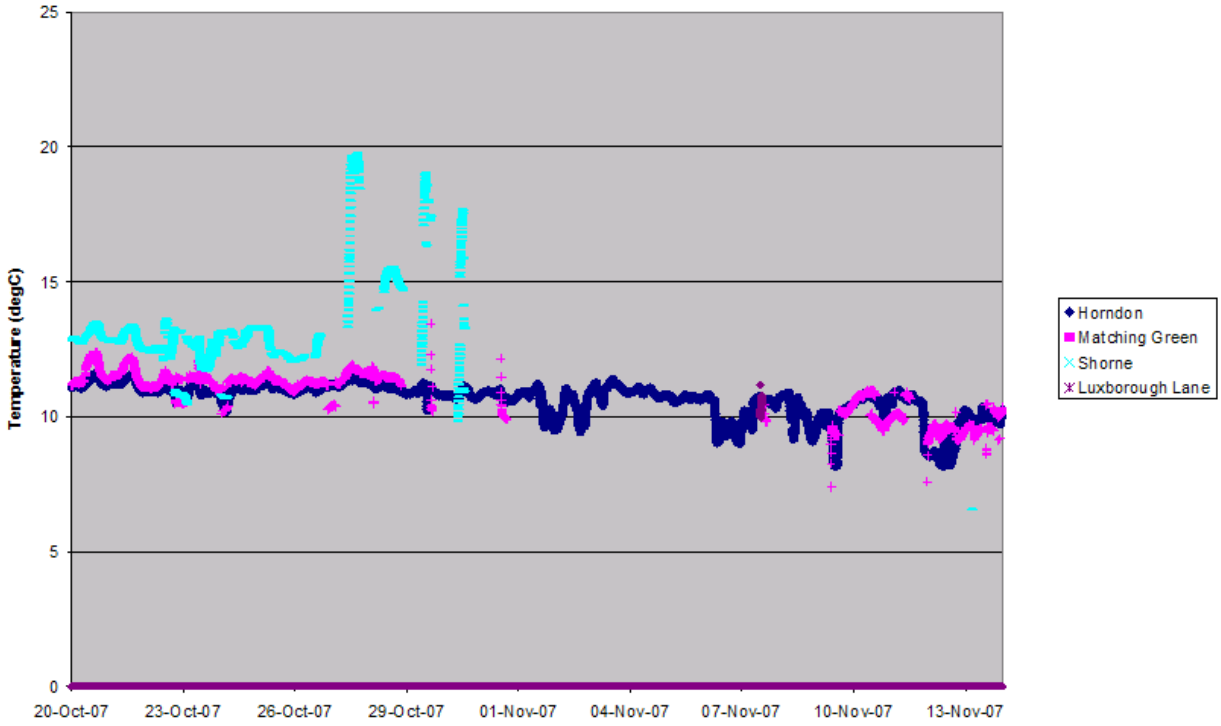

Figure 3.3 - October 2007 temperature profile

From 11th to 21st December 2007 the temperature appeared to increase in certain parts of the network, which could be due to high demand and increased compressor station outlet temperature. The gas temperatures gradually increased at Shorne and Luxborough Lane offtakes, followed by a period where the same temperatures were seen at Horndon, before gradually decreasing at Shorne and Luxborough Lane (see Figure 3.4). Before and after this period the temperatures agreed at all sites which is evidence that the temperatures experienced were real gas temperatures and not an error.

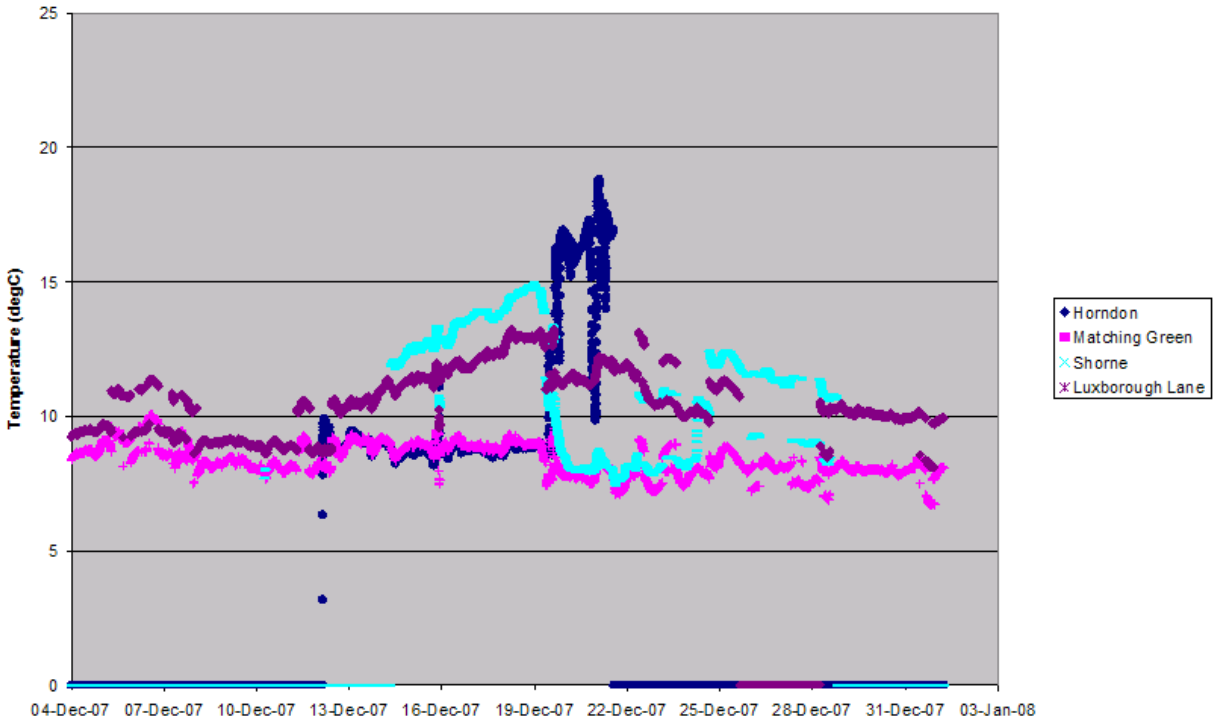

Figure 3.4 - December 2007 temperature profile

Between 29th March 2008 and 6th April 2008 the temperature was ~5 °C lower at Horndon than the average of the other sites. This can be attributed to a high temperature at Matching Green (see Figure 3.5) and because the temperature at Horndon does not deviate before, during and after this point it is not considered to be an error.

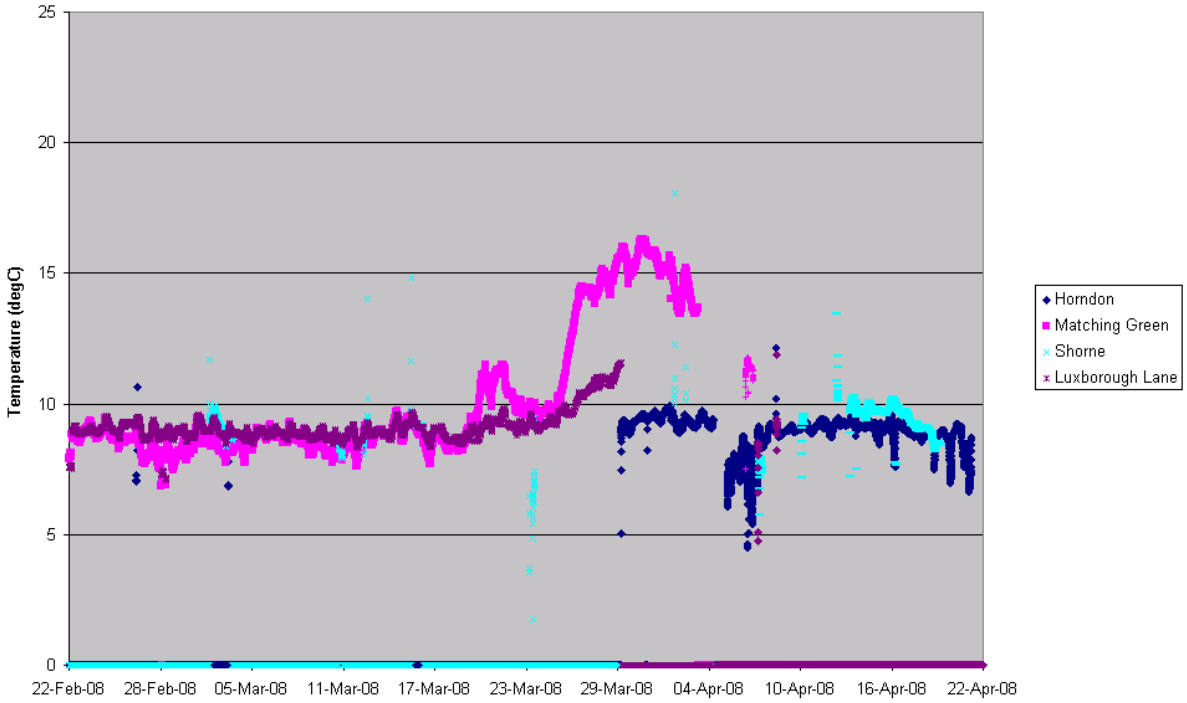

Figure 3.5 - March 2008 temperature profile

3.2 Initial Positive Error Period (September 2008)

In the initial period of the positive error the magnitude of the error varied significantly.

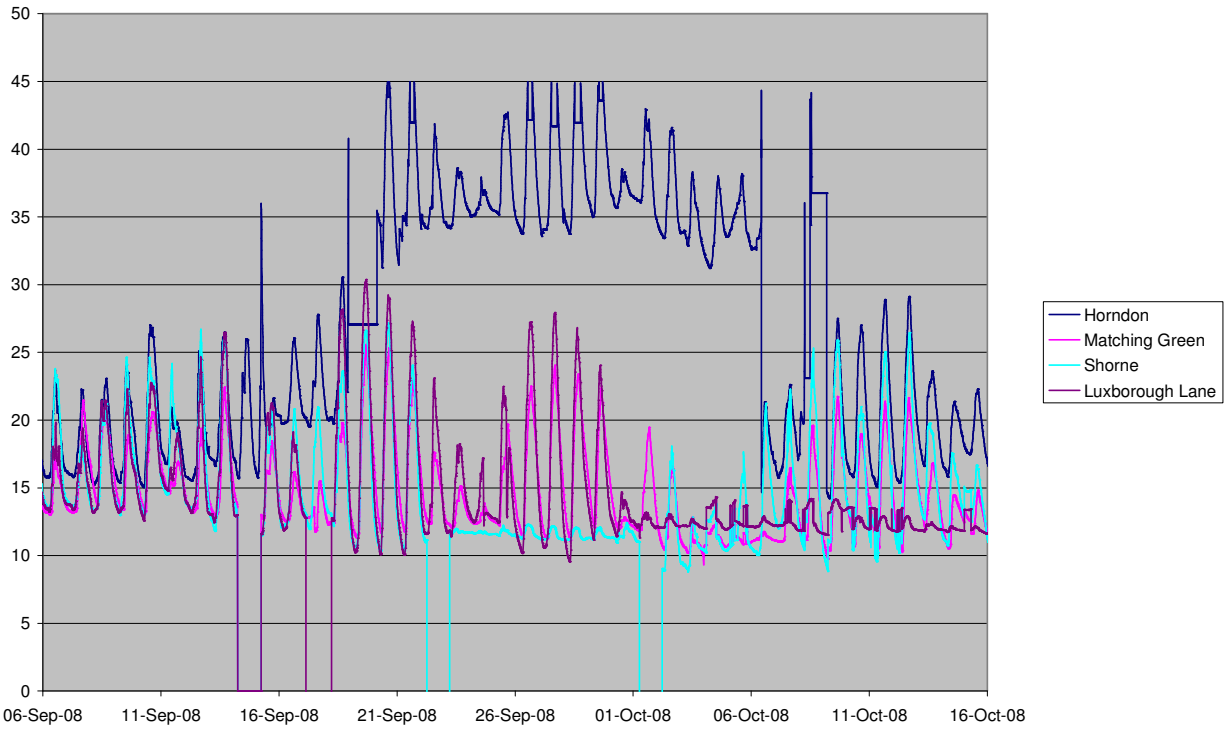

Figure 3.6 - September 2008 temperature profile

On 15th and 22nd September 2008 Horndon was flowing for a short period of time when none of the nearby sites were. This meant the proposed methodology did not produce a temperature difference for these days and so a default temperature error would have been used. The transient nature of the error at this point would have led to an inaccurate assignment of default temperature error therefore a detailed analysis was undertaken for both of these days to establish a more robust temperature error. As there was no flow at any of the sites at this time the measured temperatures reflected that of ambient and all the sites roughly followed each other. Comparing all sites illustrated the change in the magnitude of the error over this period. Following the period of flow on both days the temperature difference gradually increased as the measured temperature at Horndon started to reflect the ambient temperature again. On both occasions this tended to a certain level of error which was held for more than a day as demonstrated in Figure 3.7.

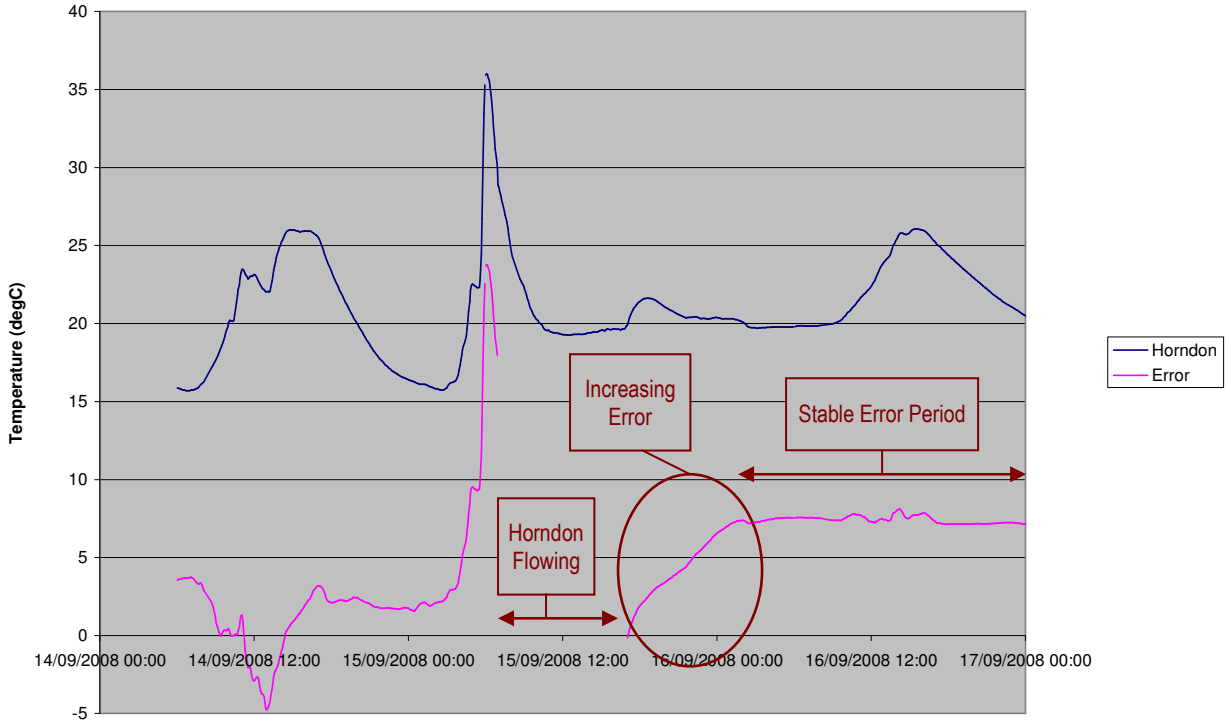

Figure 3.7 - Temperature and error profile for 15th September 2008

The first 24 hours of steady error were averaged and taken as the temperature error at the time of flowing.

Gas Day	Period Used for Average Error	Average Error
15th September 2008	01:59 16th Sep 2008 to 01:59 17th Sep 2008	7.39 °C
22nd September 2008	18:00 22nd Sep 2008 to 17:56 23rd Sep 2008	22.06 °C

Table 3.1 - Calculation of temperature errors for September 2008

These temperature errors were then used to calculate the volume error along with the temperature errors for the main period as explained in section 3.3.

3.3 Main Positive Error Period

As illustrated in Figure 2.5 there are two consistent periods of positive temperature error. Between October 2008 and July 2009 the error is around 4.5 °C; and between July 2009 and July 2010 the error is around 6.5 °C. In the cases where no flowing data was available and therefore no mean daily temperature error could be calculated the mean of the daily temperature errors in the surrounding period was used as shown in Table 3.2.

Period	Mean of Daily Temperature Errors
October to December 2008	4.91 °C
January to June 2009	4.15 °C
July to December 2009	6.65 °C
December to July 2010	6.48 °C

Table 3.2 - Mean of Daily Temperature Errors

A Monte Carlo simulation was carried out to establish the sensitivity of the flow error to various inputs (pressure, temperature, differential pressure and gas composition). The flow error was found to be sensitive to pressure fluctuations therefore it was necessary to recalculate the flow rates from the raw data on a 4-minutely basis. The raw data contained a small number of erroneous points when validations were occurring and false readings were witnessed. These were manually corrected and an auditable record of these changes was kept. There were also some periods of missing data which were treated using the following rules:

- Where the duration was less than 30 minutes the last good values were used.
- Where the duration was greater than 30 minutes the data was excluded with the exception of essential data
- Essential data is defined as Horndon temperature, pressure or differential pressure or Matching Green pressure, which are all fundamental to the methodology. Where this was missing it was interpolated.
- No data was available for Horndon from 10:06 on 5th July 2010 until 17:03 on 8th July 2010. The 5th and 7th July 2010 (when the error was resolved) were not recalculated because of the lack of data, the treatment of these days is discussed at the end of this section.

The corrected temperature was calculated from the measured temperature minus the daily mean temperature error. One set of calculations was made on a four-minutely basis using the corrected temperature and another using the measured temperature. Daily volumes were calculated for both sets of data, the ratio between them being described as the 'daily correction factor'. The uncorrected daily volumes were compared to the billed daily volumes to ensure that the calculation method does not introduce significant errors. Where the discrepancy between the two was greater than 10% the daily correction factor was replaced by a default daily correction factor (with the exception of 22nd September 2008). The default daily correction factor was calculated using the mean of the daily correction factors for the surrounding period and are shown in Table 3.3.

Period	Default Daily Correction Factor
October to December 2008	1.013859
January to June 2009	1.012196
July to December 2009	1.018630
January to July 2010	1.018859

Table 3.3 - Default Daily Correction Factors

The daily correction factor will be applied to the billed daily volume and energy totals. The daily correction factors are listed in APPENDIX A.

The default daily correction was applied to the 5th and 7th July 2010 because of missing data, however because the error was resolved on 7th July 2010 it is recommended that only half the error on this day is reconciled. The daily correction factor in APPENDIX A reflects this recommendation.

4 Recommendations

It is recommended that the error, an overall under-registration of 160.53 GWh, be reconciled using the daily correction factors in APPENDIX A. To avoid similar problems occurring in the future it is recommended that any 3-wire RTD systems are replaced with 4-wire RTD systems.

Appendix A Daily Correction Factors