nationalgrid

Unaccounted for Gas Report

National Grid
Gas Transmission

July 2012

Target audience

Ofgem and other interested industry parties

About this document

This document sets out the work done by National Grid Gas in its role as System Operator, to investigate potential causes of Unaccounted for Gas. It is published to meet special condition C29: Requirement to undertake projects to investigate the causes of Unaccounted for Gas (UAG).

Any questions on this document should be referred to Gasoperations.Shipperliaison@nationalgrid.com

Table of Contents

1. Introduction 2

2. Activities April – July 2012 3

Appendix A - Licence Condition C29 7

Appendix B - NTS Shrinkage 9

Appendix C - Previous UAG Reports 11

Appendix D - UAG Trends since 2007 13

Appendix E - Meter Reconciliation 16

Appendix F - Meter Witnessing 19

Appendix G - Data Centred Investigations 22

Appendix H - NTS Cumulative Meter Uncertainty Study 26

Appendix I - IFI Funded Programmes 27

Introduction

1. National Grid Gas (NGG) in its role as System Operator (SO) for the National Transmission System (NTS) has a role in the identification and management of Unaccounted for Gas (UAG).

2. UAG is a consequence of measurement error and as such is wholly reliant on metering and data quality. The permitted tolerance for fiscal metering equipment connected to the NTS at entry is plus or minus 1%; for exit meters, the tolerances vary and are set out in supplemental agreements. UAG was approximately 0.5% of throughput.

3. Under the current arrangements, all NTS metering and measurement responsibility resides with the asset owner/operator and, with the exception of 30 legacy sites, is outside our direct control. This requires a collaborative approach across all parties, and we have a role in working with meter owners and impacted parties to ensure sharing of information and best practice where it is appropriate for us to do so.

4. In 2011/12 the absolute volume of UAG was 4,925 (GWh). The cost of buying UAG was £83m in 2011/12 and these costs are paid by shippers through the SO commodity charge. The existence of UAG in some circumstances may be an indicator of a misallocation of costs until such time as meter reconciliation occurs in accordance with UNC processes. during the last financial year.

5. This report sets out the work we have carried out to investigate the causes of UAG. This is the first report that we are publishing under our new licence condition (see Appendix A) which requires us to report periodically on the work being undertaking to investigate potential causes of UAG.

6. We have continued to undertake meter reconciliations, witnessing of meter validations and are using data centred techniques to investigate potential causes of UAG. In addition, we have initiated a range of projects with independent experts to focus on specific areas that may provide further clarity on UAG drivers.

7. As this is the first report, we have included a description of our role in the management of UAG (Appendix B), summaries of and links to previous UAG reports (Appendix C), a history of UAG trends (Appendix D), and descriptions of various UAG investigations which are being undertaken (Appendices E – I).

Our activities April - July

8. UAG levels have reduced from previous years, as shown below:

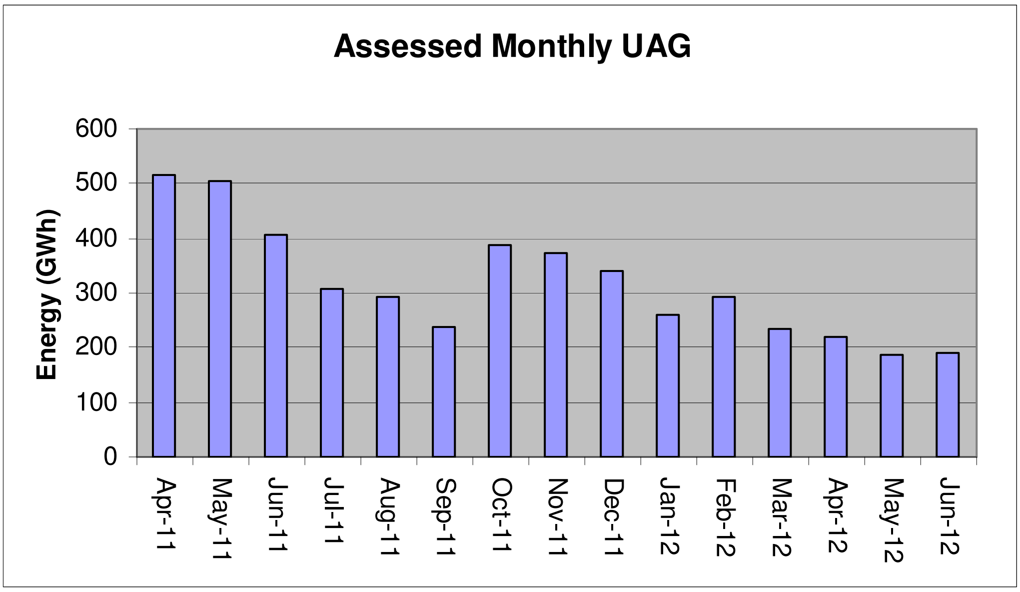

Figure 1: Assessed Monthly UAG April 11 – June 12

9. Investigations have not identified a single source for this change, but a series of changes are having a positive impact, as follows:

- The close links between asset owners and ourselves are beginning to result in a more proactive approach to measurement and data quality which is feeding through to all levels of metering management across the NTS;
- NGG and some DN asset owners have embarked on a comprehensive series of meter upgrade programmes. These programmes are installing the latest meter and flow computer technologies which give a greater range of on-line diagnostic capabilities;
- The expansion of financial schemes such as the EUETS[1] carbon trading arrangements has placed the onus on all participants in the scheme to demonstrate their compliance. This has seen considerable emphasis being placed on the gas metering equipment and its ongoing management; and
- Through the DN liaison meetings and increased NGG site presence, there is greater awareness of the significance of metering and its management in terms of the direct causal link to UAG.

10. The specific activities we have undertaken are summarised below.

Meter reconciliation (see Appendix E for more detail)

11. NGG, in its role as the Shrinkage Provider, reconciles measurement errors on behalf of the gas community in line with out obligations. This is the

[1] EUETS European Union Emission Trading System

primary mechanism for the re-apportionment of costs associated with NTS meter errors.

12. All demand meter errors that result in measurement bias and are discovered or not corrected within the close out period will be the subject of a Measurement Error Report (MER). This is produced by or on behalf of the respective asset owner and provides a technical assessment of the error and its magnitude and is used to define the corrected daily quantities to be reconciled. All MERs are reviewed by us before being processed for invoice.

Meter validation witnessing (see Appendix F for more detail)

13. To facilitate the witnessing of meter validations there are rights and obligations for relevant parties within the Uniform Network Code (UNC) or via their connection agreement:

   - Downstream parties are obliged to notify upstream parties of any planned maintenance in relation to measurement equipment[2].

   - An upstream party shall be entitled to witness any validation carried out by the downstream party[3].

14. We have a programme in place to attend all sites over a five year period. Sites are selected based upon evidence based criteria. Particular attention is given to sites with:

   - A history of errors or faults;
   - New metering equipment installed;
   - Any observations or recommendations from previous visits; or
   - No previous visit or a longer duration since our previous visit.

15. This activity, along with the oversight given to us by reviewing all MERs, gives the potential to identify errors, to share best practice and to improve awareness of our UAG management initiatives and the wider impact on the community of meter errors.

Data Centred Investigations (see Appendix G for more detail)

16. In recent years there has been significant effort made to develop data centred analysis techniques within our teams which are capable of identifying potential meter errors independently of inspection activity and to complement other site and control room based monitoring.

17. We are aware that it is unlikely that a single method or technique will be capable of identifying every potential error. Thus the range of data centred approaches form a ‘tool box’ that support our management of UAG by potentially providing evidence of meter anomalies worthy of further investigation.

---

[2] 2.1.3 The downstream Party shall notify the upstream Party of any planned maintenance in relation to Measurement Equipment, in accordance with the provisions on Measurement Equipment Maintenance in Section G.

[3] UNC OAD section D 3.1.4 the upstream Party shall be entitled, but shall not be obliged, at its own cost to attend and witness any validation carried out by the downstream Party in accordance with this paragraph 3.

18. Our current activities are focussed on the use of two particular techniques: data mining and Statistical Process Control (SPC). These techniques, along with a description of the way they are being applied, are described in further detail in Appendix G.

19. The combination of techniques that we are currently using has been successfully tested against the two most significant meter errors of recent years. This gives confidence that similar events could be identified at an early stage.

NTS Uncertainty level study (see Appendix H for more detail)

20. Uncertainty limits for individual system entry and exit points are defined, either by their specific connection agreement to UNC or via contractual limits set between National Grid and third parties. Sites are designed for compliance with these limits.

21. A typical orifice plate meter has the greatest uncertainty at the very bottom of the operating range and thus utilise a range of differential pressure measurement devices to providing greater sensitivity across the meter range. Ultrasonic meters and turbines are well characterised by calibration, and tend to have a flat uncertainty profile across their intended working range.

22. Entry and exit points on the NTS use a mix of the three major metering technologies. While these meters will operate within their respective tolerances, the cumulative effect of their measurement uncertainty on UAG is not fully understood.

23. To address this, a pilot cumulative measurement uncertainty has been the subject of a research programme conducted with TUV NEL in 2012 in an attempt to quantify the magnitude of these uncertainties. The results of this study[4] are still being evaluated. We will discuss this in the next UAG report.

IFI Funded Programmes (see Appendix I for more detail)

24. We have initiated two programmes under the Innovation Funding Initiative (IFI), which aim to address particular areas that have UAG relevance but are also of wider interest to the gas community. These are:

- The performance of gas chromatographs when required to measure low CO_2 levels in natural gas – this requirement is driven by increasing volumes of LNG (which has no CO_2) on the network; and

- The impact of orifice plate meters running at lower differential pressures than their optimal design; this may affect their performance and the purpose of this work is to quantify this effect.

25. The results of these initiatives will be reported when complete.

Review and prioritisation process

26. Any one of the initiatives described above could flag up a site for further investigation. In order to ensure that resources are not committed unnecessarily, a process has been instigated to review any potential sources of error with other techniques, prior to requesting further information and involvement from meter owners.

[4] TUV NEL Project No. NRR011, Report No. 2012/142

27. Any potential UAG issue highlighted by the in-house data analysis is investigated thoroughly with a carefully defined set of processes. If, following all the additional checks, there is still some cause for concern, there is a body of evidence that can be shared with the respective asset owner to assist in the clarification of the issue.

28. This process is particularly important for the data centred investigations, as statistical techniques can sometimes give misleading results and it is important to provide a sense check prior to raising any concerns.

Summary

29. The work that has been undertaken between April and July builds on the previous UAG investigations, using a robust review process and sharing the information and the processes by which the investigations are triggered with the meter owners and the wider community.

30. This work programme is ongoing and covers the areas detailed in Appendices E to I. Specific results from this work will be included in the next report, which is due to be published on 1 Feb 2013.

31. The prevailing levels of UAG at the current time have reduced and the processes currently in place should assist in finding the causes of any future step changes.

Appendix A - Special Condition C29: Requirement to undertake UAG Projects to investigate the causes of Unaccounted for Gas (UAG).

1. This appendix contains a copy of the licence condition that this UAG report is published under.

2. The licensee shall use reasonable endeavours to undertake the UAG Projects as specified in this condition for the purposes of investigating the causes of Unaccounted for Gas in the formula year t=11. The UAG Projects shall include but need not be limited to those set out in paragraph 4. Where the licensee does not undertake certain UAG projects it shall clearly set out its reasoning in the UAG Reports referred to in paragraph 2.

3. The licensee shall publish UAG Reports of the findings of these UAG Projects on its website and provide a copy of the UAG Reports to the Authority. The licensee shall publish the UAG Reports by 1 August 2012, 1 February 2013 and 1 May 2013, or such other dates as agreed by the Authority.

4. Within one month of publishing a UAG Report the licensee shall publish on its website all the relevant data referred to in the UAG Report. Where there are legitimate reasons for not publishing certain data on the website the Authority may consent for the licensee not to do so.

5. For the purposes of this condition: “UAG Projects” means the projects currently undertaken by the licensee including:

   (i) the witnessing by the licensee of the validation of Measurement Equipment (as defined in the network code OAD Section D1.2.1) at NTS System Entry Points (as defined in the network code TPD Section A2.2.1) or Supply

   Meter Installations (as defined in the network code TPD Section M1.2.2) at NTS Exit Points (as defined in the network code TPD Section A3.4.1);

   (ii) investigation and analysis of data in order to seek to identify causes of UAG (which may include data-mining analysis and a pilot project to consider the assessment of inherent NTS measurement uncertainty).

   “UAG Report” means the report of the findings of the UAG Projects undertaken by the licensee. The UAG Report shall detail the UAG Projects the licensee has undertaken in the previous period, the UAG Projects it proposes to undertake in the next period and the licensee’s views on how the findings of the UAG Projects may be taken forward in order to reduce the volume of UAG. The UAG Report shall also detail the reasons why any UAG Projects have not been undertaken in the formula year t=11.

   “Unaccounted for Gas” (UAG) means the amount of gas (GWh) that remains unaccounted for after the Entry Close-out Date (as defined in the network code TPD Section E) following the assessment of NTS Shrinkage performed in accordance with the network code TPD section N paragraph 2.3.

Appendix B – NTS Shrinkage

1. One of the key aspects of our management of the NTS is our role as the Shrinkage Provider. This role is defined in the Uniform Network Code (UNC)[5]and places a responsibility on us to forecast, procure and manage NTS Shrinkage appropriately on behalf of all system users.

2. The UNC also defines NTS Shrinkage in terms of three components:

    i. Own Use Gas (OUG), which is the fuel gas used for compressors that maintain pressure and flow in the NTS;

    ii. Unbilled Energy, normally referred to as CV[6] Shrinkage (CVS), which is the difference between delivered and billed energy of a charging zone as a consequence of the Flow Weighted Average CV (FWACV) process; and

    iii. Unaccounted for Gas (UAG), which is the quantity of gas that is required to maintain the energy balance (the difference between NTS inputs and outputs). UAG is considered to be the consequence of data or meter error and is thus a relatively complex component of shrinkage, involving not only the mechanical behaviour of high pressure metering systems but statistical variations in their operation.

3. NTS Shrinkage is calculated (assessed) and forecast daily. Its cost is recovered through the SO commodity charging mechanism. Since April 2002, NTS Shrinkage has formed part of the SO Price Control Review (Incentive) process and there has been considerable community interest in its behaviour. The NTS shrinkage performance between 2003 and 2012 (inclusive) is presented in Figure B.1 in terms of the magnitude of each principle component.

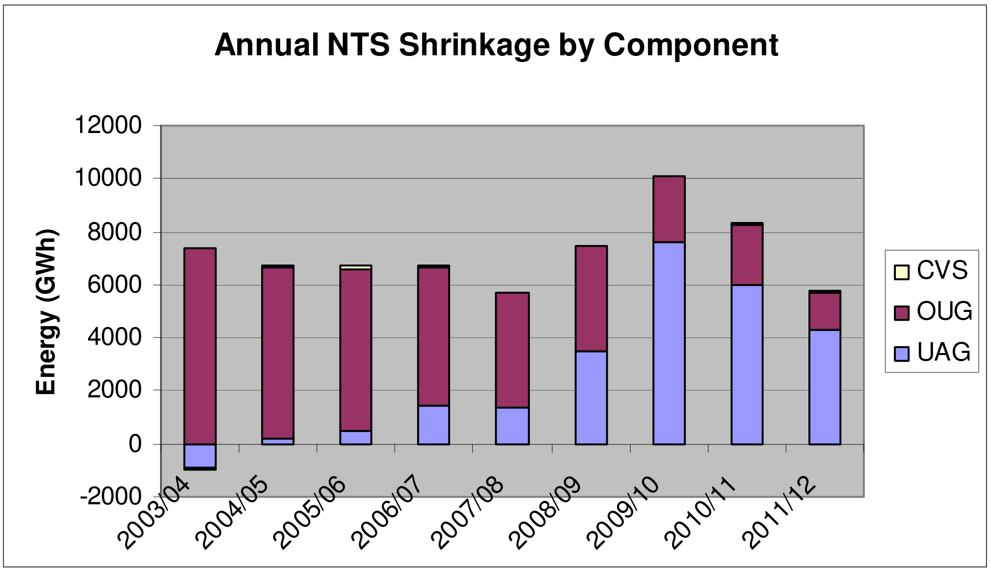

Figure B.1. NTS Shrinkage from 2003 to 2012 inclusive.

5 NTS Shrinkage Provider role is defined in Section N of the Transportation Principle Document (TPD) of the Uniform Network Code (UNC).

6 Calorific Value (CV) is a measure of the thermal energy of the gas usually quoted in MJ/m^3

4. The period was characterised by relatively constant total annual shrinkage energy until 2009/10 whereupon the annual totals increased markedly before returning to the 2007/08 levels in 2011/12. The component make up of these respective years was considerably different with UAG contributing 25% of total shrinkage in 2007/08 but 75% in 2011/12.

5. As the operator of the NTS, we have a direct influence on OUG usage and CVS mitigation. We have undertaken a number of initiatives to efficiently manage OUG and CVS, and the effective control and the minimisation of these shrinkage components is testament to the success of these programmes.

6. By contrast, UAG, which is the consequence of measurement error, is wholly reliant on entry and exit metering and data quality. Under the current arrangements, all NTS metering and measurement responsibility resides with the asset owner/operator and, with the exception of 30 legacy sites, is outside our direct control. This places significant responsibilities on asset owners to ensure that all aspects of metering and measurement are discharged in accordance with the respective commercial and statutory obligations.

Appendix C - Previous UAG Reports

1. In November 2008 Ofgem requested that we publish a detailed report into the causes and remedial actions necessary to reduce the recent increases in the NTS Shrinkage assessed[7] UAG component. There was a concern that there was 'little information as to the causes of the increase' with attendant cost implications to gas customers.

2. In January 2009, we published our report[8] which provided a comprehensive review of the then current UAG thinking and presented much of our analysis. The report highlighted:

- The prevailing ownership and operating regime of NTS metering;
- Measures undertaken by NGG in the management and development of the understanding of the complex nature of UAG. This approach was split between practical, experimental, theoretical and statistical analyses; and
- That despite all the research and analysis conducted and presented, there was no evidence of systematic accounting errors in the determination of UAG and therefore, UAG was still considered to be the result of meter and/or data error.

3. While the report made no firm conclusions as to the exact cause of UAG or its recent trends, it did propose a framework to improve our future management of UAG by:

- Increased use of statistical based analysis techniques;
- Increased site based meter witnessing activity; and
- The development of additional research programs to improve the understanding of meter performance.

4. As part of a continued dialogue with the community, in June 2011, we published a open letter[9] to ‘inform all industry participants on the progress achieved to date by National Grid NTS in reducing Unaccounted for Gas....’, and highlighted:

- The incentive performance to date;
- The effect of recently discovered significant meter errors at the DN offtakes of Braishfield and Aberdeen on overall UAG performance;
- The UAG projects being undertaken by us in the management of UAG including:
    - The formation of a dedicated UAG project team to promote best practice;
    - The development of various data mining techniques;

---

7 Assessed UAG is defined as net daily UAG as calculated as difference between the net inputs and outputs of the NTS inclusive of any linepack change, own use gas (OUG) and Calorific Value Shrinkage. UAG is also quoted in energy.

8 Report published at http://www.nationalgrid.com/NR/rdonlyres/...../OfgemUAGReport.pdf

9 Report published at www.nationalgrid.com/NR/rdonlyres/...../UAGIndustryUpdateJune2011.pdf

- The widening of the meter witnessing campaign to include terminals and storage facilities indicating a recent success of this initiative; and
- An intention to undertake an independent pilot study to assess the combined measurement uncertainty of the NTS.

Appendix D - UAG Trends since 2007

1. The assessed UAG performance since April 2007 is presented in Figure D.1 with the annual figures in the respective yearly columns. It demonstrates the very sharp increases in UAG from 2008/09, peaking in 2009/10 before beginning to decrease again in subsequent years. Despite the reduced levels, UAG in 2011/12 still out turned 774 GWh (22%) above 2008/09 levels. For the latest view of UAG, the 2012/13 data is presented in terms as a composite of the actual assessed levels for the first three months of the year (604 GWh) and a pro rata extrapolation to give a hypothetical annual outturn of 2412 GWh.

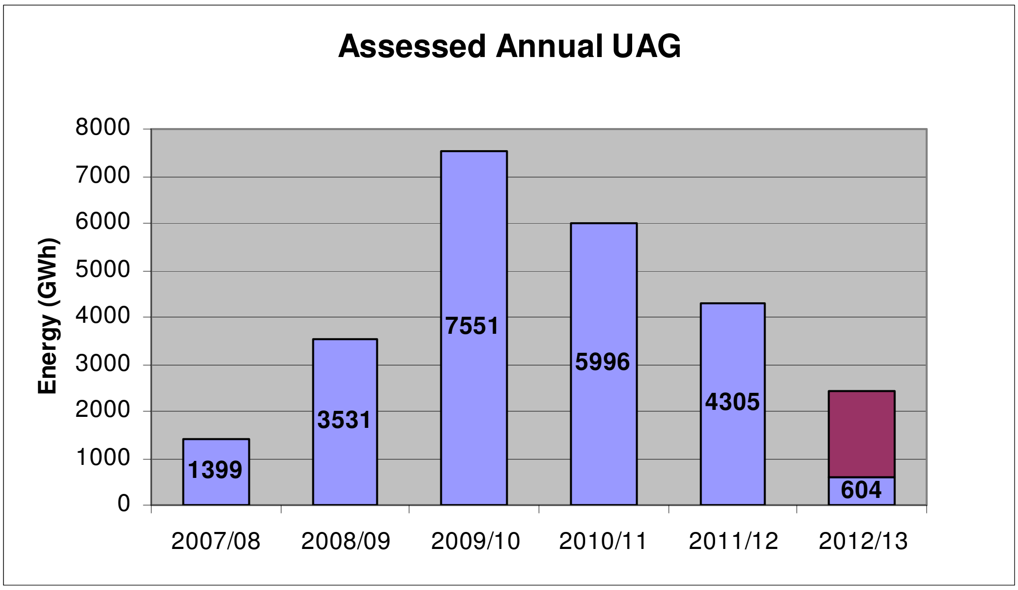

Figure D.1. Assessed UAG from 2007 to 2012 inclusive.

2. Annual assessed UAG levels can be slightly misleading and more useful indicators of UAG behaviour are monthly and daily trends. The monthly assessed UAG totals are presented in Figure D.2 from April 2011 to June 2012 inclusive and exhibit a monthly average UAG of 317 GWh for this period. Overall the period is one of gradual decreases in monthly UAG with some month on month variations, October to December 2011 for instance, where UAG totals increased before falling back again in early 2012. The first six months of 2012 continued to mirror these decreases with a monthly average of 213 GWh.

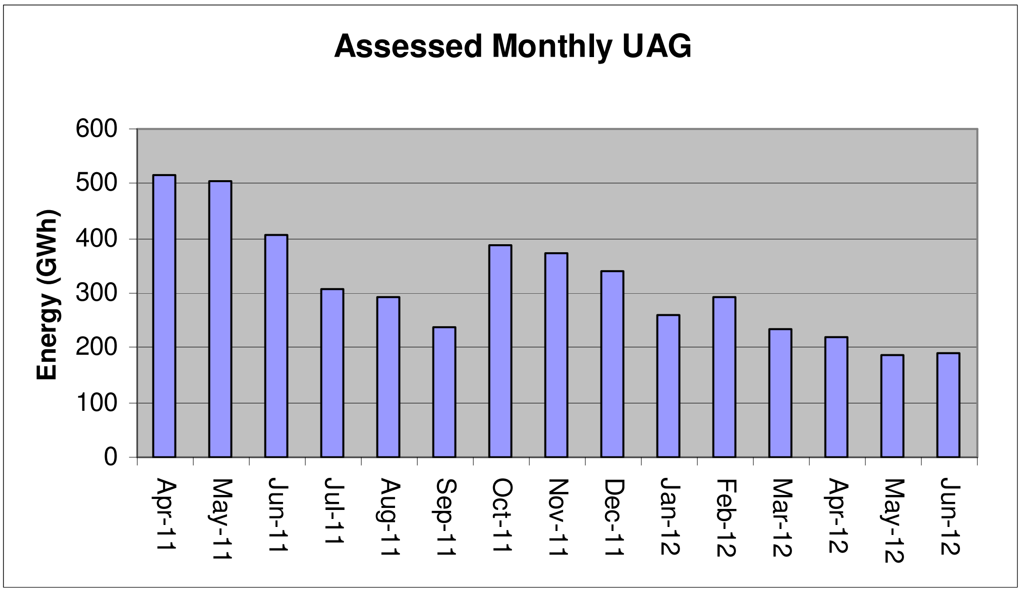

Figure D.2. Monthly Assessed UAG from April 2011 to June 2012 inclusive.

3. The daily profile of assessed UAG from October 2011 to June 2012 inclusive is presented in Figure D.3. The yellow trend line shows a 7 day rolling average for the same period. UAG has exhibited a shift in the baseline daily average from 12.5 GWh in October 2011 to 6.3 GWh in June 2012. The behaviour is also characterised by a reduced frequency of large daily UAG excursions in excess of +/-20GWh.

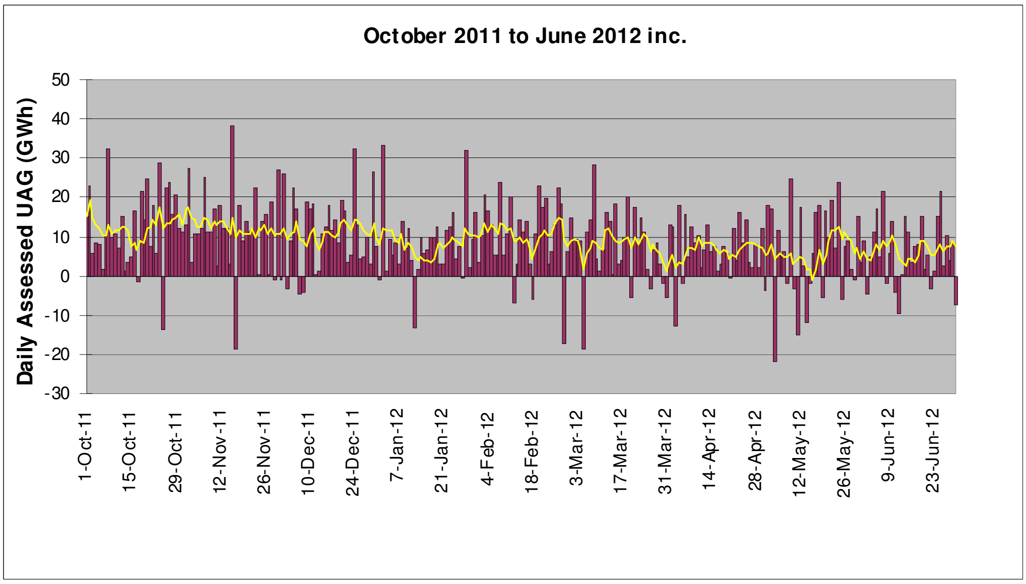

Figure D.3. Daily assessed UAG. October 2011 to June 2012 inclusive.

4. For the period April 2009 to March 2012, UAG was separately incentivised. The incentive compared the annual absolute UAG against a fixed annual target of 2862 GWh. The incentive performance is presented in Table D.1 and indicates that there was no incentive benefit for NGG in this period despite our efforts to find and resolve UAG drivers.

Year	2009/10 (GWh)	2010/11 (GWh)	2011/12 (GWh)
Assessed UAG (GWh)	7551	5996	4305
Absolute UAG (GWh)	7718	6313	4900
Incentive Profit (£)	0	0	0

Table D.1. NGG UAG Incentive Performance since 2009

5. During this time we continued to work to develop strong external relationships with all stakeholders while also enhancing internal capabilities in the areas of meter reconciliation, witnessing and data mining/analysis techniques.

6. The management of UAG requires a number of fidelity checks to ensure that the assessed value is not presenting an incomplete picture of its true magnitude. For data related errors this process of checking is normally completed within the respective demand and supply close out periods[10]. For meter related errors these can be discovered by a variety of sources which include:

- An asset owner discovering a fault during normal operation (meter alarm state);
- NGG informing an asset owner of potential disparity with daily figures as a consequence of its own internal data checks; or
- A meter validation provides evidence of systematic measurement bias.

7. The timeframe for the discovery of meter errors can vary and thus a true picture of UAG sometimes only emerges after any reconciliation process has been completed.

[10] The Close out period for Supply point measurement is the 15th business day of the succeeding month where after no subsequent corrections can be made. Demand point measurement is closed out five days after the gas day.

Appendix E – Meter Reconciliation

1. NGG, in its role as the Shrinkage Provider, is obligated to reconcile measurement errors on behalf of the gas community as this is the primary mechanism for the re-apportionment of costs associated with NTS meter errors.

2. All demand meter errors that result in measurement bias and were discovered or not corrected within the close out period will be the subject of a Measurement Error Report (MER). This is produced by or on behalf of the respective asset owner and provides a technical assessment of the error and its magnitude and is used to define the corrected daily quantities to be reconciled. All MERs are reviewed by us before being processed for invoice.

3. To identify the underlying level of UAG, it is necessary to account for reported meter errors as this will allow us to define the outstanding measurement error. Table E.1 presents this analysis between 2008 and 2012. A major proportion of the increases in UAG between 2009 and 2011 result from of the discovery and rectification of significant meter errors at the offtakes of Braishfield and Aberdeen.

	2008/09 (GWh)	2009/10 (GWh)	2010/11 (GWh)	2011/12 (GWh)
Assessed UAG	3531	7551	5996	4305
Reconciled Meter Error Correction[11]	(375)	(3178)	(1222)	52
Corrected UAG (net of Meter Error)	3156	4373	4774	4357

Table E.1 The cumulative magnitude of meter error reconciliation on Assessed UAG.

4. Table E.1 also indicates that the underlying level of UAG when corrected for all reconciled meter errors was still at an annual average of 4501 GWh since 2009. This suggests that there was still measurement bias in the system which had not either been discovered or corrected during this period.

5. The projected UAG outturn for 2012/13 (See Figure D.1) based on prevailing levels of UAG show a significant fall in the annual forecast when compared with previous years. Current investigations have not identified a direct cause of this reduction, however there are a number of factors, as a result of the work undertaken over the last few years, which may be contributing to this overall reduction in UAG levels:

[11] The Corrected UAG totals contain estimation of large meter errors that have not completed the reconciliation process but have been notified by the respective DN on the Joint Office web site. The figure quoted is an aggregated total of all reconciliations for the respective year.

- The close links between asset owners and ourselves are beginning to result in a more proactive approach to measurement and data quality which is feeding through to all levels of metering management across the NTS;
- NGG and some DN asset owners have embarked on a comprehensive series of meter upgrade programmes. These programmes are installing the latest meter and flow computer technologies which give a greater range of on-line diagnostic capabilities;
- The expansion of the EUETS[12] carbon trading arrangements has placed the onus on all participants in the scheme to demonstrate their compliance. This has seen considerable emphasis being placed on the gas metering equipment and its ongoing management; and
- Through the DN liaison meetings and increased NGG site presence, there is greater awareness of the significance of metering and its management in terms of the direct causal link to UAG.

6. All meter errors, with the exception of entry point meter errors, are reconciled through the neutrality and commodity charging mechanisms. Any entry point meter correction is subject to a different reconciliation rule to that of NTS offtakes. These rules preclude any subsequent adjustment to the end of day figures of the entire month after the 15th business day of the succeeding month. Therefore, any issues identified at entry after this closeout period will not result in reconciliation.

7. The majority of meter errors in recent history can be traced to physical faults with equipment on site. However, in terms of magnitude of error, human errors account for the vast majority of energy reconciled on DN offtakes. This is largely explained by the presence of a single significant meter error arising from human error. Frequencies of errors associated with VLDMC metering are little different, however the magnitudes of these errors are split more evenly. These proportions are illustrated in Figure E.1.

[12] EUETS European Union Emission Trading Scheme

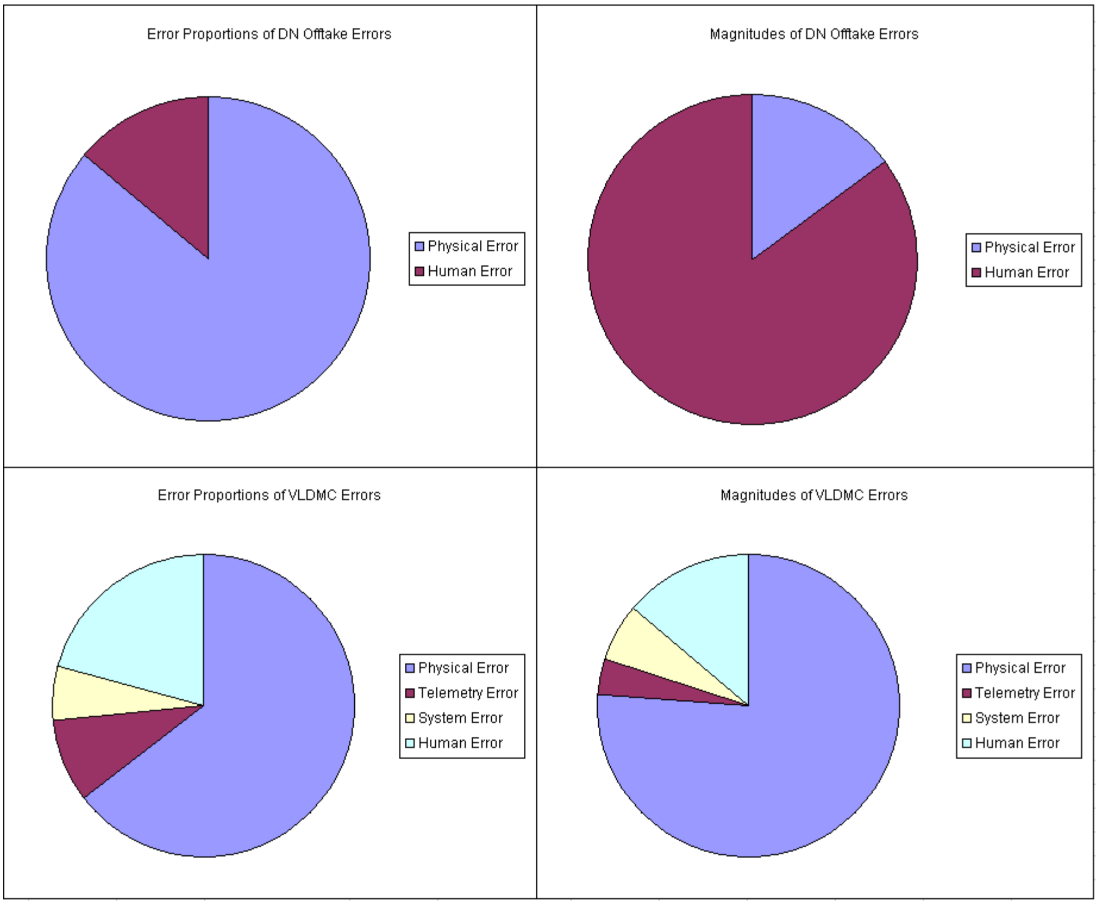

Figure E.1 Causes of Meter Errors – Proportions by Cause and Magnitude

8. The importance of equipment quality, training, procedures and experience specific to the site being worked upon are highlighted as being the most significant factors in avoiding meter error. In most cases we are not the meter asset owner and as such decisions relating to user training or the re-use or replacement of older equipment are outside of our direct control.

Appendix F – Meter Witnessing

1. A conclusion of the January 2009 report[6] was that we should enhance our meter witnessing activities. This activity has the potential to identify errors, promote awareness of our UAG management initiatives, share best practice based on experience gained from previous meter witnessing activities and meter reconciliation and to develop broader communication across interested parties.

2. There are 121 Distribution Network offtakes, 56 directly connected loads (power stations, industrials etc), 8 storage sites and 2 interconnector sites measuring gas taken from the NTS. Additionally there are 28 terminals, interconnectors or storage sites metering gas delivered to the NTS.

3. We endeavour to visit every site within a five year period to ensure consistency across all sites. A summary of recent site visits is shown in Table F.1 below. It should be noted that the 2012/13 figures are for sites visited in the year to date; further visits will be carried out and reported on in subsequent reports.

4. Sites are selected based upon evidence based criteria. Particular attention is given to sites with -

- A history of errors or faults;
- New metering equipment installed;
- Any observations or recommendations from previous visits; or
- No previous visit or a longer duration since our previous visit.

Site Type	DNO Off Takes	Third Party	Terminal / Storage	Total
2009/10	25	8	11	44
2010/11	17	8	7	32
2011/12	16	6	9	31
2012/13 to date	11	9	5	25

Table F.1 Site Meter Witnessing Visits Undertaken

5. Site visits help check that appropriate annual calibration tests are conducted in line with guidelines and that metering systems are maintained appropriately and fit for purpose. For Distribution network offtakes, the test procedures are described in the UNC and are referred to as T/PR/ME/2[13].

[13] http://www.gasgovernance.co.uk/OADDocs

6. To facilitate the witnessing of meters certain rights and obligations are granted to relevant parties within the Uniform Network Code (UNC) or via their Connection Agreement:

- Downstream parties are obliged to notify upstream parties of any planned maintenance in relation to measurement equipment[14].
- An upstream party shall be entitled to witness any validation carried out by the downstream party[15].

7. Witnessing activities are undertaken in collaboration with Network Operators and third party asset owners. We aim to attend sites during routine maintenance periods to avoid duplication. On occasions, short term rescheduling of this maintenance means a target site cannot be attended; in this circumstance the site will be prioritised for the following year.

8. For third party, storage and terminal sites, the witnessing programme has been developing and is now beginning to cover about 15% of sites annually.

9. Over the last few years when NGG have been witnessing meter validations, a number of issues which could lead to meter errors have been identified. Similarly, work in reviewing meter errors as part of reconciliation work has built up a base of experience. Examples of these issues are provided below:

- Human factors – for example use of incorrect fixed factors;
- Site Design – for example site specific issues such as the use of constrained pipe run that affect compliance with industry standards;
- Policy – for example variations between maintenance regimes between third party operators; and
- Equipment performance – for example analogue to digital conversion drift and ingress of rainwater.

10. When witnessing meter validations, we will share our experience of previous issues with the operators on site to minimise the risk of re-occurrence. It should also be noted that the identification of issues frequently occurs as part of the validation process being carried out by the meter owners.

11. Generally, observations are discussed with the site technicians during the visit and are communicated to the site owner in the form of a report. Any follow up actions are reviewed during quarterly liaison meetings with DN's, or as required with other site owners.

12. Irrespective of our attendance, we will continue to monitor and review meter validation reports submitted by DNs and third parties. This serves

[14] 2.1.3 The downstream Party shall notify the upstream Party of any planned maintenance in relation to Measurement Equipment, in accordance with the provisions on Measurement Equipment Maintenance in Section G.

[15] UNC OAD section D 3.1.4 the upstream Party shall be entitled, but shall not be obliged, at its own cost to attend and witness any validation carried out by the downstream Party

as a sense check and enables any areas of concern to be raised.

Appendix G – Data Centred Investigations

1. In recent years there has been significant effort to develop data centred analysis techniques capable of identifying potential meter errors independently of inspection activity and to complement the other site and network control room based monitoring.

2. We are aware that it is unlikely that a single method or technique will be capable of identifying every potential error. Thus the range of data centred approaches form a 'tool box' that support our management of UAG by potentially providing evidence of meter anomalies worthy of further investigation.

3. Any potential UAG issue highlighted by the in-house data analysis is investigated thoroughly with a carefully defined set of processes. If, following all the additional checks, there is still some cause for concern, there is a body of evidence that can be shared with the respective asset owner to assist in the clarification of the issue.

4. The launch of the in-house analysis programme was presented to all DNs in May 2012. Other third party asset owners are also being made aware of our data analysis methodologies.

5. Our current activities are focussed on the use of two particular techniques: data mining and Statistical Process Control (SPC). These are described in further detail below.

G.1 Data Mining Techniques

6. We are investigating the use of data mining techniques to identify potential sources of UAG. As indicated in the section on meter witnessing, there are over 200 meters that contribute to the UAG calculation. The aim of data mining techniques is to identify relationships between trends in UAG and the meters which contribute to its value. As such, data mining can identify candidates for further investigation but is not likely to identify specific faults.

7. To implement data mining techniques, we have used IBM's SPSS[16] Modeller package. The analysis has been developed with the aid of consultancy provided by the Industrial Statistics Research Unit (ISRU) of Newcastle University. The work has resulted in the decision to focus on the use of two advanced statistical techniques; Classification & Regression Trees (C&RT) and the Chi-squared Automatic Interaction Detection (CHAID) for the purposes of identifying possible contributors to UAG.

8. Within a given data set, both techniques will always identify a meter which best correlates with UAG. However, the relationship between the two is not necessarily significant in statistical terms. The work carried out to date has provided a means of identifying those instances where the relationship has a level of significance and flagging up where a specific site appears more frequently. This is being used to identify sites that merit further investigation.

9. Further refinements of the data mining activities are being completed to allow a greater volume of data to analysed and improve subsequent

[16] http://www-01.ibm.com/software/analytics/spss/

output evaluation. The overall programme is still in its early stages but already considerable progress has been made in identifying potential UAG issues and these are being investigated further.

G.2 Statistical Process Control (SPC)

10. We are developing the use of SPC techniques to aid the investigation of UAG. The aim in this area is to develop datasets or models where changes in underlying process behaviour can be detected with a view to identifying the onset of an issue which is driving UAG. As with data mining, the analysis has been developed with the aid of consultancy provided by ISRU.

11. To date, the techniques used are based on two approaches:

    - The use of control charts and action limits; and

    - The use of Cusum charts to detect changes.

G.2.1 Power Station Efficiency

12. There is a large volume of data available in the public domain with regards the generation output of power stations, available via the Balancing Mechanism Reporting System (www.bmreports.com).

13. The availability of this data, when combined with our gas flow data, enables a number of types of analyses to be conducted around the efficiency of the power plant. In principle, gas turbines are expected to operate in a relatively narrow efficiency band. Any apparent increases or decreases in plant efficiency could be an indicator of a meter mis-measurement or a particular explainable variance in site operation.

14. The analysis has been refined and is defined as a time series of the electrical output and gas usage for each appropriate site. This allows the plant efficiency over its operational range to be determined with any deviations from the base trend line outside defined trigger lines being highlighted and investigated further. One such plot is presented in Figure G.1.

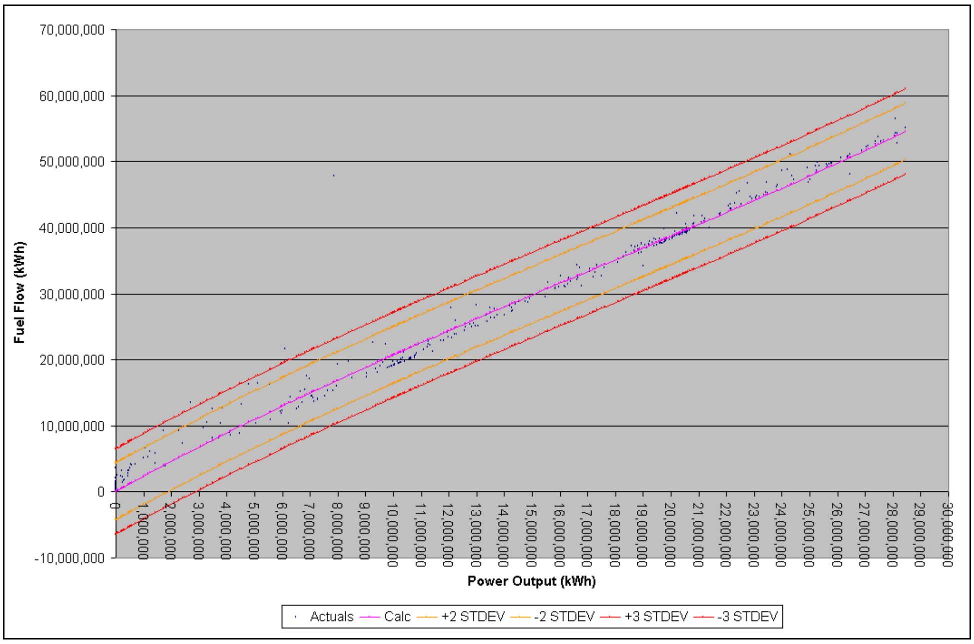

Figure G.1. Performance Plot of a typical CCGT plant. The normal performance data is expected to be within the tramlines.

15. This method provides a powerful tool for identifying potential faults on meter systems associated with large, relatively continuous loads. The method may not be suitable for all industrial loads, other than those that regularly run at a continuous level, but it is expected that the majority of directly NTS connected power stations can be accommodated by this method.

16. This form of analysis of this type of site is now embedded within our core UAG activities. Its ability to readily detect any anomalous site behaviour makes it a suitable early warning tool of potential issues with site metering. This work builds on our comprehensive network of contacts with the power generators and greatly assists in the management of issues with these large gas users.

G.2.2 Cusum Applied to Changes In UAG

17. The use of cumulative sum (Cusum) techniques is being applied to the trend of UAG itself. The approach here is to use a historic value for mean UAG and for each subsequent day, add the difference between Assessed UAG and this mean value to a running total. If UAG remains at the historic mean, this cumulative sum will vary around zero over time. However, a change in slope indicates a change in underlying UAG with the date of any slope change being a period worthy of investigation.

18. An advantage of this technique is that it overcomes some of the problems of variability in UAG where the standard deviation of UAG is itself larger than its mean. This observation suggests that noise-type effects may be manifested at such a level which may obscure the finding of systematic bias in the network.

19. The latest analysis confirms that there has been a period of stability since April 1st 2012.

G.2.3 Cusum Applied to a Weather/Demand Model

20. Another application of this technique is to create a model which predicts flow through a meter or set of meters based on weather data then look at the cumulative difference between forecast and actual flows. This sort of model is applicable to Local Distribution Zones (LDZ) or sub-LDZ networks where demand is primarily temperature sensitive. For the purposes of this model, composite weather variable (CWV) has been used along with a simple linear regression model to predict demand.

21. There is a requirement to identify offtakes or groups of offtakes which form a demand grouping as otherwise flow through the meters may be influenced by flow switching behaviour rather than underlying demand.

22. This technique has been tested on the Aberdeen flows over the period of its significant meter error and has been found to detect its start.

23. In addition to identifying suitable networks and sub-networks to allow this method to work, there is evidence that last winter's weather/demand relationship had changed so new regression models may be required. This effect has been noted in National Grid's Winter Outlook document.[17]

[17] http://www.nationalgrid.com/NR/rdonlyres/924D55BC-9EA9-43BF-B3E7-55E2CFC6FDC6/54847/WinterConsultationReport201214.pdf

Appendix H – NTS Cumulative Metering Uncertainty

1. Uncertainty limits for individual system entry and exit points are defined, either by their specific connection agreements or via contractual limits set between National Grid and third parties. Sites are designed for compliance with these limits.

2. A typical orifice plate meter has the greatest uncertainty at the very bottom of the operating range and thus utilise a range of differential pressure measurement devices to providing greater sensitivity across the meter range. Ultrasonic meters and turbines are well characterised by calibration and tend to have a flat uncertainty profile across their intended working range.

3. Entry and exit points on the NTS use a mix of the three major metering technologies. While these meters will operate within their respective tolerances, the cumulative effect of their measurement uncertainty on UAG is not fully understood.

4. To address this, a pilot cumulative measurement uncertainty has been the subject of a research programme conducted with TUV NEL in 2012 in an attempt to quantify the magnitude of these uncertainties. The results of this study[18] are still being evaluated. We will discuss this in the next UAG report.

[18] TUV NEL Project No. NRR011, Report No. 2012/142

Appendix I – IFI Funded Programmes

1. We have initiated two programmes under the Innovation Funding Incentive (IFI) and aim to address particular areas that have UAG relevance but are also of wider interest to the gas community.

I.1 Chromatography and the response to the lack of a presence of CO_2

2. Liquid Natural Gas (LNG) does not contain CO_2, due to the liquefaction process. With LNG now representing a significant proportion of UK gas supply, large areas of the NTS are receiving neat or rich LNG gas mixes. Since all gas component determination is by gas chromatography, it is appropriate to consider the performance of gas chromatographs (GCs) when required to measure to low CO_2 levels in natural gas.

3. This becomes even more relevant when it is considered that all typical GC calibration gases contain small percentage levels of CO_2. While not expected to be significant, there is the possibility that there may be a change in the outputs of results due to the behaviour of the underlying test equipment and mathematics.

4. We are working in conjunction with a UK calibration facility to examine the performance of a range of commercially available chromatographs when subjected to a range of typical LNG natural gas concentrations. This should quantify the risk associated with this issue. The ultimate result of this work could be to improvements to necessary industry standards.

I.2 Orifice Plates running at Low Differential Pressures

5. The design and operating conditions of NTS offtakes has changed. Offtake pressures are normally well in excess of the optimum design pressure. For an orifice plate metering system there are potential issues when the gas flow is at the low end of the measurement range. There are instances where sites operate at very low differential pressures for considerable periods.

6. With the exception of start up and shut down flow transients, all orifice plate meter systems are expected to operate well inside the normal operating range of the differential measurement device. There is a body of experimental evidence to suggest that low flows and hence low differential pressures result in a negative measurement bias (under read). This would lead to mis-apportionment of gas cost across the community.

7. Previous published[19] work provided a large set of data relating to the use of low differential pressures across a range of orifice plates of differing beta ratios. This work illustrates that the measurement efficacy of orifice plates at low flow rates deteriorates rapidly.

8. Recent experimental work conducted by NGG at the GL Bishop Auckland test facility on an orifice plate assembly at typical NTS pressures appears to confirm the observations of the earlier research work. Further tests are to be conducted to validate the initial NGG test data. An example of test data along with the previously published data is shown in Figure I.1.

---

[19] George et al. Assessment of Orifice Meter Flow Measurements with Low Differential Pressures. Final Report SwRI PR-015-08605 (2009).

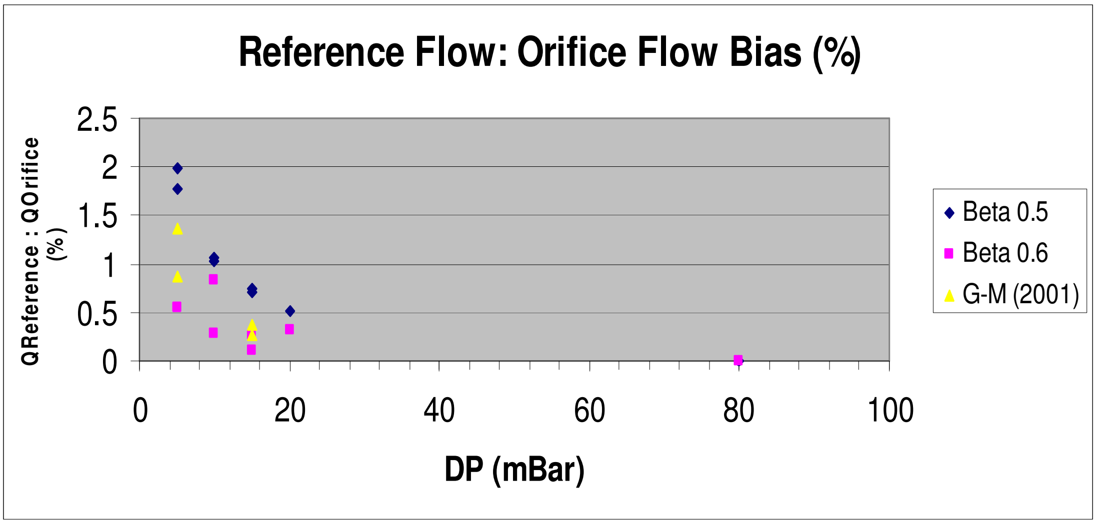

Figure I.1 Experimental Data From Orifice Plate Low Flow Trials

9. Following the additional test data it is proposed to use the results to progress the debate with asset owners in an attempt to minimise low flow operation and thus further assisting in the lowering of UAG.