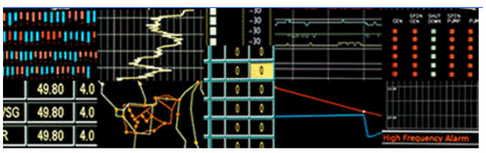
Unaccounted for Gas (NTS)

Ofgem Information Request

Issued 9th January 2009



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Unaccounted For Gas
NG NTS Response to Ofgem data request

1. Introduction

This report has been produced in response to an information request from Ofgem (See Appendix 1 for full details) pursuant to Standard Special Condition A26 of NGG's Gas Transporter Licence in respect of the NTS, received on 28th November, with respect to Unaccounted for gas (UAG).

The report is intended to provide an overview of the issues surrounding Unaccounted for gas and more specifically attempts to answer the questions raised within the Ofgem letter and which are reproduced below.

This report should include:

- *A clear statement from NGG of its best views on the major causes of UAG;*
- *Where NGG undertakes actions already with the purpose of limiting UAG a description of these actions together with details of the impact of these actions on the levels of UAG being experienced;*
- *Results of any analysis that NGG has commissioned with respect to the underlying causes of the increase in UAG levels in the period from 2001 onwards;*
- *Details of any current or future projects currently being considered under the Innovation Funding Incentive, that may benefit the measurement of flow and CV and associated processes;*
- *Summary information that may inform understanding of the causes of the increase in UAG. In particular (but not exclusively) in relation to:*
    - *the standards of metering on the NTS, including the adoption of ISO 5167-2003;*
    - *maintenance of metering and calorific determination devices (CVDDs) for entry and exit metering;*
    - *the quantification of errors / bias associated with all CVDDs and meters connected to the NTS;*
    - *potential developments for the measurement of flow/ CV (for example bulk temperature measurement, or additional spot temperature measurement to assist in the linepack calculation).*

Based on the information provided in the summary, if deemed necessary, Ofgem may request NGG to provide it with more detailed information in timescales to be agreed at the time of the request.

- *An estimation of the expected timescales in which additional actions to limit UAG could be expected to have an effect and an estimate of the potential costs associated with these actions.*

2. Overview

Unaccounted for gas on a day is that energy which remains unaccounted for after taking into account all measured inputs and outputs from the NTS, Own Use Gas consumption on the NTS, CV shrinkage and the calculated daily change in NTS linepack. The diagram below summarises this, and shows the number of input and output meters that may be in service on a particular day.

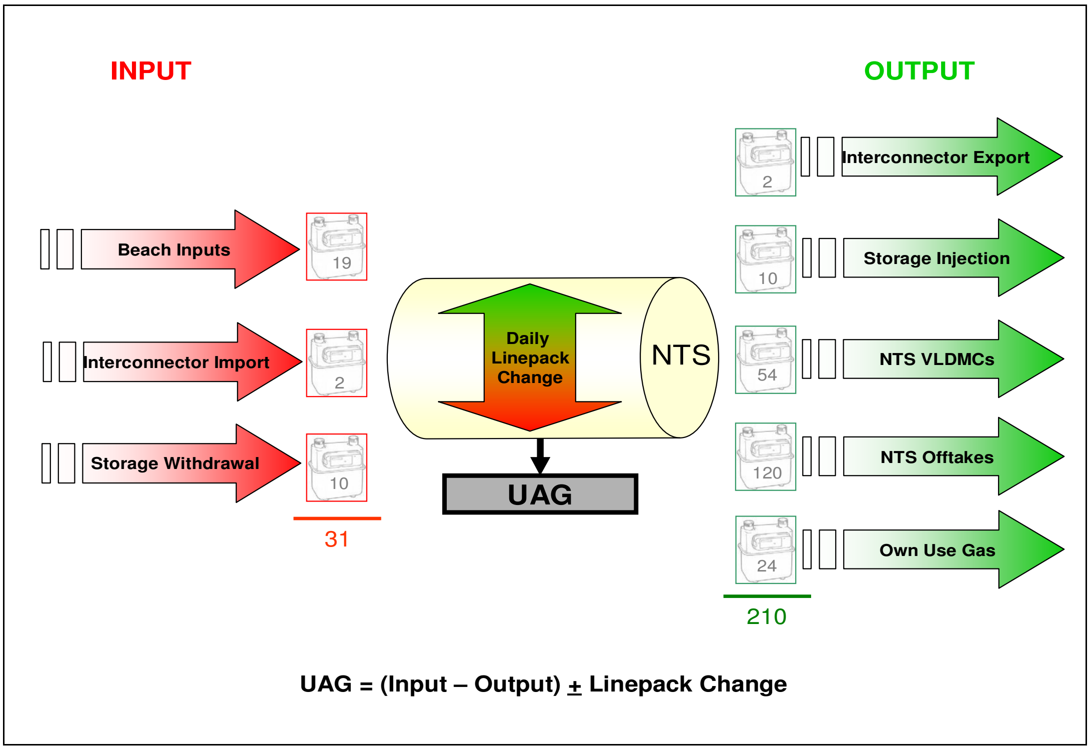

Figure 1 – UAG calculation and metering inputs

2.1 UAG trends

UAG has historically been very volatile creating challenges in understanding the underlying drivers and forecasting future trends. As an example the daily UAG outturn for 2007/8 is shown below in Figure 2.

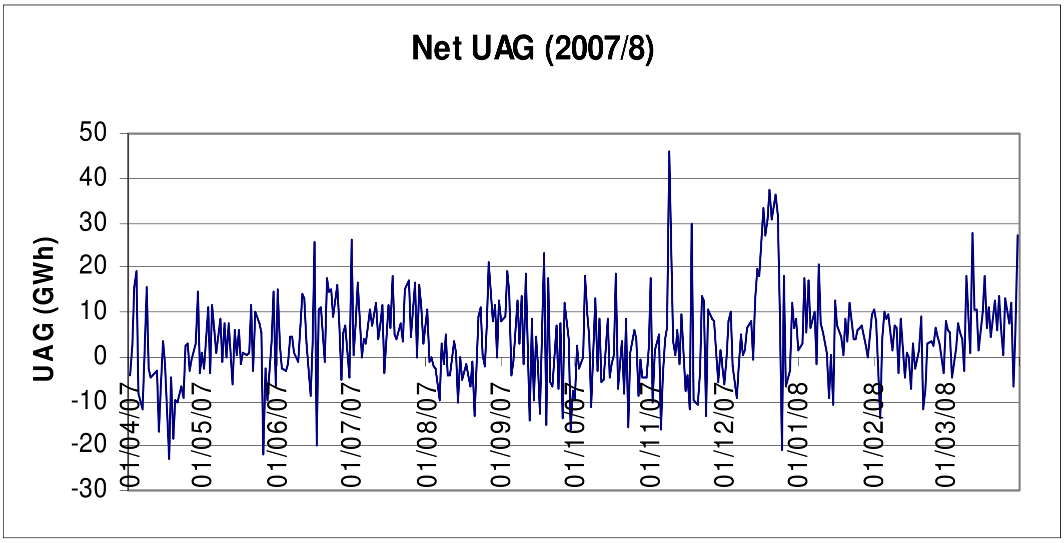

Figure 2 – The Daily UAG profile for 2007/08

When this data is shown at a monthly resolution (see Figure 3) a number of trends can be observed, these can be summarised as a relatively positive, consistently high, trend in the period up to October 2002, a period of very low and often negative UAG between late 2002 and Spring 2005, a cyclical period through the 2005/6 and 2006/7 financial years where we experienced high UAG during the summer months and low/negative UAG in the winters, and then since spring 2007 a predominantly positive trend that appears to be generally rising.

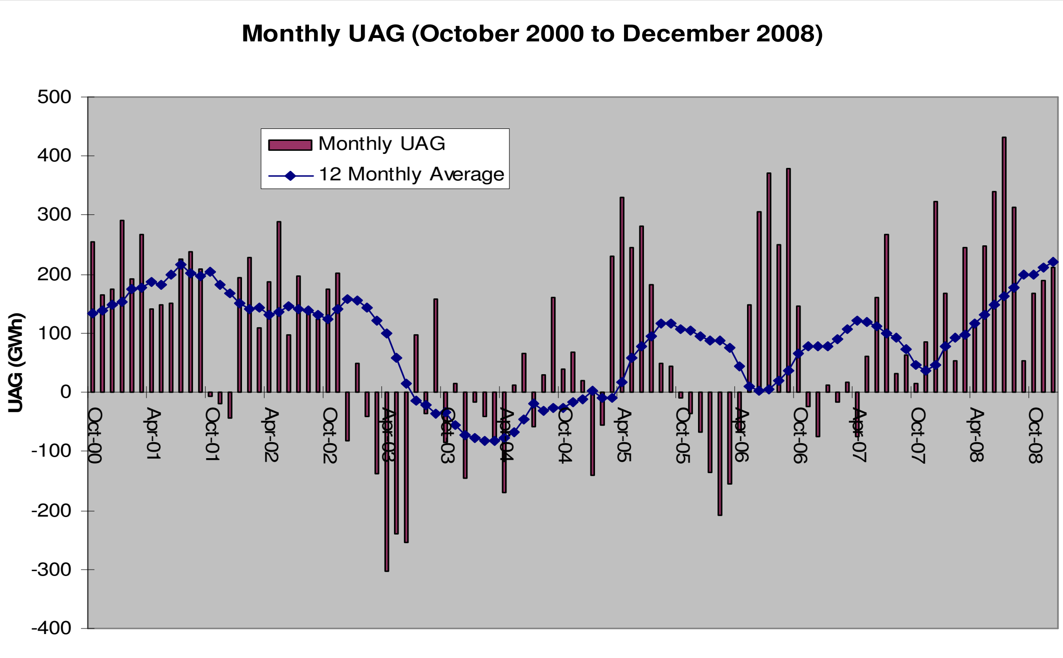

Figure 3 – The Monthly UAG profile for the period Oct 2000 to Dec 2008

When this data is expressed on an annual basis it would appear that UAG has been on a broadly rising trend since 2003 and has now returned to levels similar to those last seen in 2001/2.

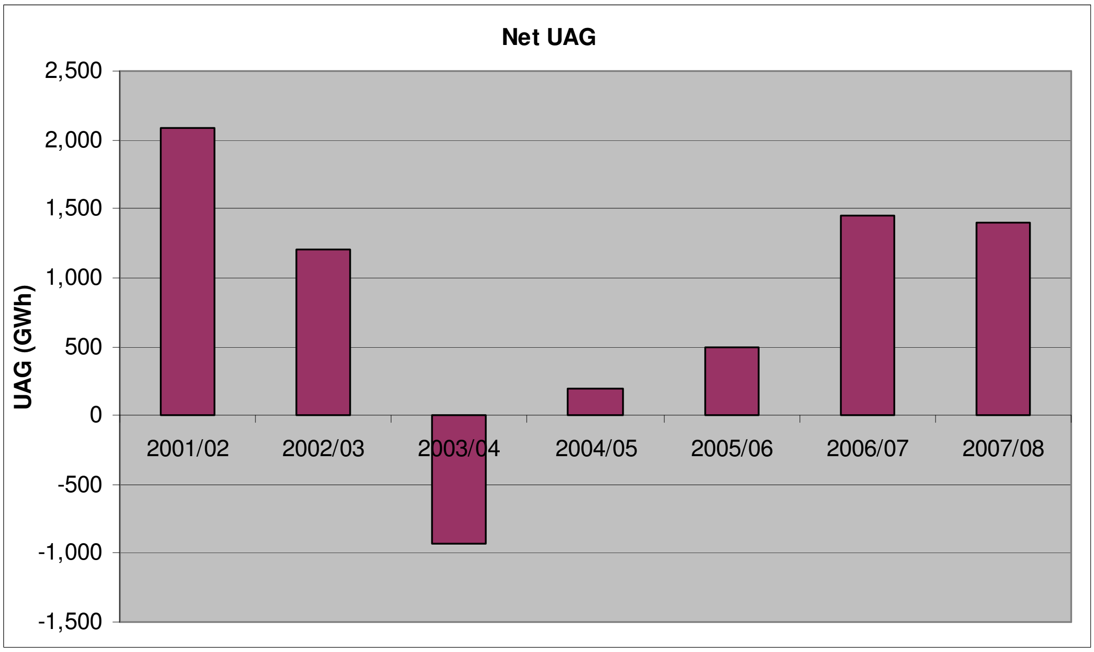

Figure 4 – Annual UAG profile for the period 2001/2 to 2008/9 (incl forecast data for 2008/9)

It should be noted however that when UAG is expressed in daily absolute (or gross) terms then the overall trend is fairly flat across the last 8 year period and it is only the ratio between negative and positive periods that is changing (see Figure 5).

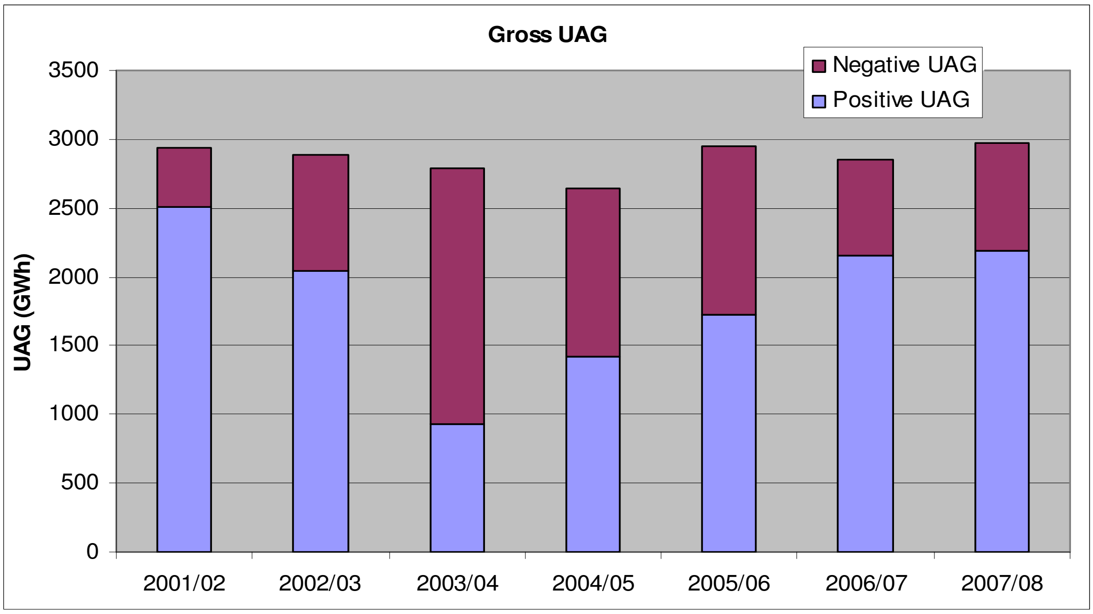

Figure 5 – The Annual gross UAG profile for the period 2001/2 to 2007/8

In an attempt to identify trends and underlying drivers, NG has commissioned a number of studies aimed at understanding the UAG trends being experienced from the Industrial Statistical Research Unit (ISRU) based at Newcastle University. In Appendix 2 is a summary reports from ISRU covering the period from 1997 to 2005 and in Appendix 3 the second report covering the period up to Autumn 2008.

Key findings from the first report were that although no single robust driver could be identified from the statistical data, daily values are not independent of each other in that values in subsequent time periods are closer to preceding values than would be the case for totally random data, however year on year values are independent of each other and the pattern of UAG does not appear seasonal.

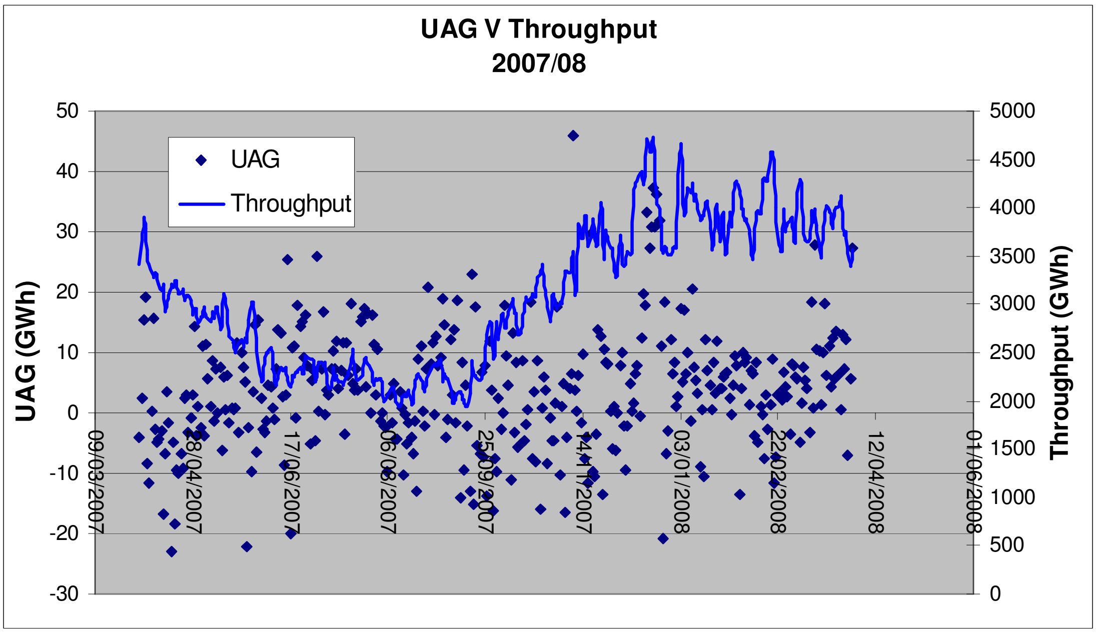

Figure 6 – The Daily UAG profile vs throughput for 2007/08

The follow up statistical UAG study carried out in 2008 incorporated the latest UAG trends to March 2008 inclusive and was focused on developing UAG prediction techniques. The interim report has concluded that following the application of a number of statistical techniques to predict UAG behaviour, a series of ARIMA[1] models did generate a reasonable short term UAG forecast but the confidence limits were wide. The relationship between UAG and other parameters such as weather and average system gas prices did not show any strong dependence as evidenced by the large confidence limits that were applied to the subsequent forecast analysis.

2.2 Meter Ownership

In the UK, the metering at a site is generally owned and managed by the owner/operator of the exit or entry point rather than the upstream party. However, due to legacy arrangements National Grid NTS does currently retain ownership of 32 (of the 200+) meters at exit points from the NTS, but none of the 30, entry sites. National Grid NTS's ability to directly manage the levels of UAG is therefore constrained by the amount of influence National Grid NTS has over meter asset owners. It is asset owners who are responsible for the maintenance and management of the individual metering assets and who may themselves have little or no direct financial incentive to ensuring the metering is accurate.

2.3 Metering Standards

All meter owners are, however required to manage their meters in line with the appropriate standards related to the type of metering installed at the site, and to maintain/validate the metering using procedures defined within the relevant governance documentation or contractual agreements. Gas transmission metering is determined as that which operates at pressures above 38BarG. These metering systems are covered by five principle ISO standards with a number of supplementary standards supporting these. These principle standards can be broken down into two categories, those that use gas composition to determine gas properties and those that govern the installation of standard meter systems employing conventional technologies of orifice plate, turbine and ultra-sonic metering. The main supplementary standards govern the deviation of metering systems from the standard, methods to determine overall meter uncertainties, and methods to determine the performance of on-line gas analytical systems. The maintenance and validation of high pressure metering is currently defined by the industry guidelines generally referenced under the ME2 suite of validation procedures. A generic version of these procedures has now been incorporated in the latest revision of the IGE/GM/4 document.

Currently the overarching documents relating to upstream (off shore) and downstream (direct NTS metering) are the 'Guidance Notes for Petroleum Measurement' Version 7 and the IGE/GM/4 Ed. 2 respectively. Both cover the installation, operation, maintenance and verification of the various meter types. Both documents refer comprehensively to the principle meter standards as present in the Table below.

Generic Area	Standard	Title
Orifice Plate Meter	ISO 5167 : 2003 (Pts 1 to 4 inc)	Measurement of fluid flow by means of differential pressure devices in circular cross-section conduits running full.
	ISO 15377:1998	Measurement of fluid flow by means of pressure-differential devices- Guidelines for specification of nozzles and orifice plates beyond the scope of ISO 5167-1
	ISO 12767:2007	Measurement of fluid flow by means of pressure-differential devices- Guidelines on the effect of departure from the specifications and operating

[1] ARIMA: Auto Regressive Integrated Moving Average. This model is generally fitted to time series data either to better understand the data or to predict future points in the series.

		conditions given in ISO 5167.
Turbine Meter	ISO 9951	Turbine meters used for the measurement of gas in closed conduits.
Ultra Sonic Meter	ISO 17089: Draft	Measurement of fluid flow in closed conduits - Ultrasonic meters for gas -- Part 1: Meters for custody transfer and allocation measurement
Gas Property Determination	ISO 6976 : 1995	Natural Gas- Calculation of calorific values, density, relative density and Wobbe index from composition
Gas Property Determination	AGA 8 :1994	Report No 8. Compressibility Factor of Natural Gas and Related Hydrocarbon Gases.
Performance of Gas Analytical Systems	ISO 10723 : 1995	Natural gas -- Performance evaluation for on-line analytical system
Over Arching	DTi – 2003	Guidance Notes for Petroleum Measurement
Over Arching	IGE/GM/4 Ed.2	Metering practices. Inlet pressure exceeding 38 bar not exceeding 100 bar

Figure 7 : table of principle metering standards applicable to sites connected to the NTS

The ISO 5167 standard was substantially reviewed in the 2003 release to reflect the latest research in the area and the issues created are dealt with in some detail in the relevant sections below.

3. Determination of UAG

As a result of the daily measurement and allocation process, UAG can vary until the readings for both exit and entry metering are closed out. The entry and exit regime operate under different close out windows these being:

- Five days after the Gas Day, normally referred to as D + 5 for NTS exit meters
- Fifteen business days after the month end (at M + 15) for NTS entry meters.

Any amendments to energy measurements up to that time have a direct impact on the level of UAG that will result. Only after the respective close out periods is a true UAG position determined. Thus the UAG position pre and post closed out is largely influenced by differing factors.

Pre close, the UAG position is largely influenced by data error and only after close out can the UAG position be realistically attributed to system as well as data effects

3.1 Identification of metering issues

A meter issue may occur at any time and therefore it is important that processes and systems are in place to identify anomalous operation where possible, and that maintenance routines/validations are of a suitable frequency to identify problems as quickly as is feasible. Identification of metering issues tends to fall into two categories,
a) those found during the gas day, or shortly afterwards in the period prior to close out, by the rigorous checking and reconciliation processes that are put in place by both the distribution and transmission network operators.
b) those that are identified afterwards predominantly by the meter owners during validation or other maintenance and meter assurance activities. Responsibility for measurement assurance (putting in place suitable monitoring, setting maintenance routines etc) lies with the meter owner, however National Grid NTS carries out a number of within day and after the day processes to support identification and resolution of metering issues on the system

3.2 Pre Close Out Processes

National Grid NTS carries out a number of assurance activities on metering data prior to the relevant close out period. This is primarily to ensure that data feeding through to invoice activities is as accurate as possible but also acts to minimise any errors that may otherwise have fed through into UAG.

The type of assurance activities carried out are dependant upon the site type but will typically include some or all of the following checks:

- Review of automatically generated reports from preset system alarms (e.g. where metered flow exceeds defined parameters for the site)
- Comparisons between metered and nominated flow for the day
- Comparison between telemetered and faxed meter reading values received from site owners (where available)
- Average Flow rate equates to Daily Volume (DVOL)
- Integrator difference equates to DVOL
- Sum of HVOLS (Hourly Volumes) equates to DVOL
- Calorific Value * DVOL = Daily Energy
- Percentage check on variation from previous day

Checks of this nature, which are carried out every day, 365 days per year, for every entry and exit point are extremely effective in identifying metering and telemetry issues on the network with any issues identified followed up immediately with the relevant meter owner. Figure 8 below summarises at a monthly resolution the financial impact that these processes have had.

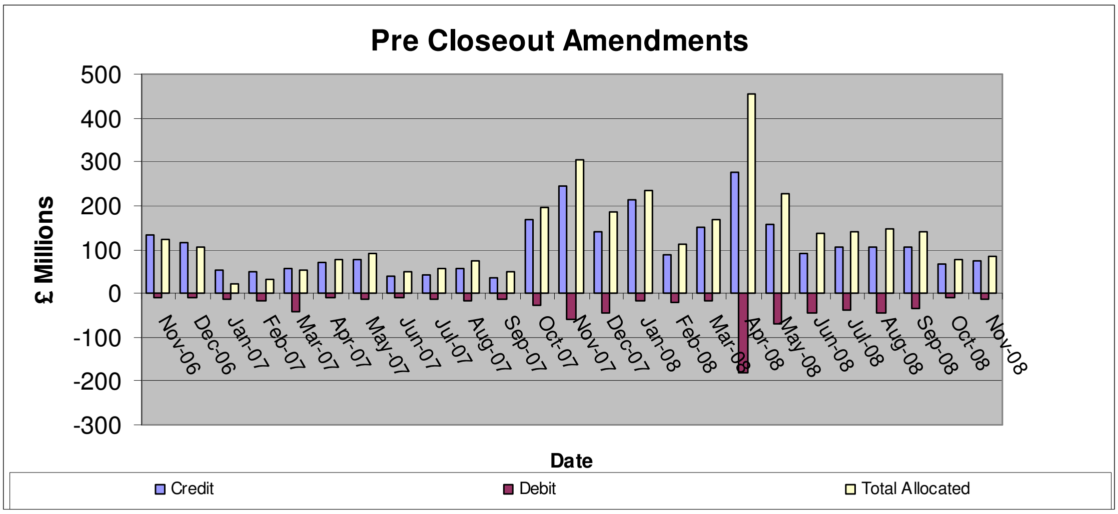

Figure 8 Value of Pre closeout data amendments by month

National Grid is always striving to improve these front end processes. For example, an outstanding issue with this assurance regime (which is often referred to as the after the day process) is that it may not identify the more subtle failure modes that occur, such as component drift that will gradually move the meter reading away from the actual physical flow level. NG is therefore working with Newcastle University to look at developing additional assurance processes such as commissioning sophisticated data mining systems and processes to address this issue.

During 2008 NG NTS also investigated the potential for transferring data reconciliation techniques that are used within other process and utility industries to identify metering systems that are operating outside of their design parameters to the gas industry to support this initiative, however following a significant development effort supported by TUV NEL the conclusion was reached that the technique could not be developed to the level of accuracy to be of value due to the specific metering issues that apply on the NTS network (lack of metering redundancy, compressibility etc).

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3.3 Post close out processes

Any energy amendments required to be made to exit measurements after D+5 (but within a maximum period of 4yrs 364 days) are subject to a reconciliation process between the relevant market participants and the NG NTS shrinkage manager to ensure costs are appropriately directed at the parties that accrued them. The regime does not allow for reconciliation of entry meter errors after M+15 even if an error is identified, therefore any errors identified after this date will not feed into UAG.

The Uniform Network Code (UNC) Off Take Arrangement Document (OAD) defines in Section D Part 5 the requirements for Correction and Estimation of Readings at NTS/LDZ offtakes. Where Measurement Equipment is found to read with systematic bias, the downstream party are required to correct the readings and provide them to the upstream party (National Grid NTS) no later than 14 days after carrying out a validation (this assumes that the issue has been rectified as part of the validation process) Where a fault on a metering system is found at any other time, the DN's are obligated to inform the upstream party within 1 hour of finding the fault. Similar responsibilities are placed upon meter owners at other NTS exit points via provisions placed in the relevant contractual agreement in place between NG NTS and the site owner.

National Grid has until now tracked the status of all meter issues that have been notified to us in a dedicated meter issues tracker. This stores information about the nature of each identified potential mis-measurement and tracks progress from identification through receipt and validation of the meter error report provided by the meter owner, to any reconciliation that may be required. From December 2008 however, following the introduction of UNC mod 185VV, the Joint Office of Gas Transporters has established a website for the notification and tracking of all NTS/LDZ and LDZ/LDZ meter issues and it is now the responsibility of the downstream party (site owner) to notify the Joint Office of Gas Transporters of any potential measurement errors. Mod 185VV was proposed, following a number of large adjustments applied through LDZ reconciliations, to define a process that was more equitable to all impacted parties, provided a higher degree of visibility and defined a level of independent assessment of meter errors for all significant errors. As a result, the requirements for information to be provided in a Meter Error Report are more specific. The concept of a Significant Measurement Error Report (SMER) as an MER that is estimated to exceed 50GWh has also been introduced. In the event of a suspected SMER, an independent technical expert is assigned to produce a binding report quantifying the exact magnitude of the error.

This issues register can be found at http://www.gasgovernance.com/industryinfo/MER/. NG continues to maintain a register for all issues at other types of exit points.

In addition to Routine Validations, the UNC OAD specifies that the upstream party can at any time request that an Exceptional Validation carried out on Measurement Equipment or component thereof. OAD specifies that the downstream party is to acknowledge receipt of this request within four hours and, with reasonable operating conditions, carry out the validation request within three days. It also specifies that an Exceptional Validation Report should be provided to the upstream party within twelve hours.

When it becomes apparent that better measurement data is available post exit closeout, the NTS Shrinkage Provider is obligated to appropriately target costs to the parties that incurred them. When this happens National Grid NTS as the Upstream Party facilitates the reconciliation and provides a level of assurance to the directly impacted users and their counterparties that the re-targeted costs are reflective of the mis-measurement and are equitable to the community. This assurance is provided by the rights detailed within the OAD for DN/LDZ sites, and within relevant contracts for directly connected exit points, which enable National Grid NTS to independently review all measurement error reports(MER) produced by asset owners. This ensures that the technical evaluation of the error quantity is based on the best available data, is derived using a robust methodology with appropriate tools and is an accurate reflection of prevailing mis-measurement.

In addition National Grid NTS is responsible for deriving the reconciliation quantity from corrected reads provided by the asset owner in conjunction with the original billed position. Assurance that this is undertaken with due diligence is afforded by an annual review by National Grid's Independent auditors as well as inclusion in the annual Rbd audit. The reconciliation quantity is passed to the Transporters' agent who generates the necessary energy and transportation invoices to direct the costs to the parties that accrued them via Sarbanes Oxley and SAS70 accredited processes. A summary of the magnitude and value of the reconciliations that National Grid has undertaken over the last 2 years is included in the Figure 9 below

RbD Billing Month	Net volume reconciled (kWh)	Net financial impact (£)
Apr-06	0	£0
May-06	0	£0
Jun-06	-20,333,000	-£558,551
Jul-06	-2,354,724	£39,800
Aug-06	33,247	-£96,705
Sep-06	0	£0
Oct-06	-1,288,405	-£13,530
Nov-06	-2,377,674,971	-£18,290,778

Dec-06	0	£0
Jan-07	0	£0
Feb-07	0	£0
Mar-07	33,982,576	£323,521
Apr-07	278,305,541	£2,800,487
May-07	-889,191	-£5,983
Jun-07	0	£0
Jul-07	0	£0
Aug-07	27,325,095	£205,783
Sep-07	0	£0
Oct-07	-6,668,126	-£43,920
Nov-07	0	£0
Dec-07	0	£0
Jan-08	-31,627,087	-£374,090
Feb-08	80,304,159	£372,451
Mar-08	14,516,450	£403,693
Apr-08	5,610	£121
May-08	-5,994,154	-£85,704
Jun-08	0	£0
Jul-08	0	£0
Aug-08	0	£0
Sep-08	-10,546,517	-£223,308
Oct-08	-1,283,523	-£9,472
Nov-08	0	£0
Dec-08	0	£0

Figure 9 Magnitude and value of reconciliations carried out since April 2006 by month

It is worth noting that the regime currently does not allow any metering issues identified post close out at entry points to be reconciled.

4. Causes of UAG

Following the detailed pre close out processes have been completed, a true UAG position is derived. There are a number of mechanisms, which in the view of NG NTS, can be seen as contributing to the level of UAG being experienced upon the network post close.

In the view of NG NTS the following are likely to be the major causes of UAG (in no specific order) :

- The net impact of meter uncertainty across the system, even if all systems/ sites are operating within their design parameters.
- Errors in metering of gas at a specific site or sites due to the metering operating outside of its design parameters,
- Disparity between the way gas is metered at exit and entry points due to differences in design and operational regimes,
- Site and metering design issues
- Inaccuracy in the calculation of the level of daily linepack,

4.1 Cumulative metering uncertainty

To ensure the compliance with the relevant standards and contractual arrangements metering installations are assessed by determining the uncertainty margins of the equipment in the metering streams. Each stream consists of numerous instruments with an uncertainty band around the metered values. To derive the measurement uncertainty of a complete installation, all theses individual uncertainties have to be combined. The standards for metering installations acknowledge that no metering system is perfectly accurate; however the standards that apply vary depending upon the type and age of the installation.

For example requisite metering standards which apply to existing DN offtake connections require an uncertainty of no more than +/- 2% of volume for flows between 30 to 100% of maximum, and +/- 3.5% of volume for flows from 10 to 30 % . For new DN connections, however, the prevailing standard is +/- 1% of volume for flow between 30 to 100% of maximum. It could be argued that the cumulative impact of these effects across all of the NTS connected metering points should net to zero over time but given the varying standards that apply this is unlikely to be the case on a particular day and will vary from day to day as the operational conditions and configuration changes.

4.2 Metering errors/failures

At any time there will be a finite number of meters that are not operating within their required metering uncertainty range due to:

- Component failure or drift,
- External factors such as contamination,
- Equipment maintenance and calibration,
- The operating regime being adopted.

When a meter is found to be operating outside its permitted uncertainty range or with bias, the error must be corrected and reconciled by the meter owner. The meter owner should maintain sufficient operational records to enable this reconciliation process.

4.2.1 Contamination

Contamination, whether liquid or solid particulate, that is transported through the NTS may have a detrimental impact on metering accuracy where this contamination is deposited on the metering equipment, particularly at orifice plate sites. The impact on metering accuracy is exhibited in 2 ways, the first where the contamination directly interferes with the instrumentation, e.g. clogging up of impulse lines associated with DP cells, and the second where the contamination interferes with the primary metering equipment for example where it adheres to the surface of an orifice plate causing a variance to the design profile of the plate and thus impacting the accuracy of the meter (as the flow equation which underpins the metering assumes a perfectly flat plate with perfectly machined edges and a uniformly shaped orifice). Other common metering types, such as turbine or ultrasonic (USM) are also affected by contamination or debris impacts.

The first problem associated with the interference to instrumentation is relatively rare and at sites where this is known to be an issue a process is in place between the meter owner and NG to routinely check for contamination of this nature.

The second problem which is generally associated with the coating of orifice plates with contamination of a liquid or viscous nature (but can potentially also impact upon turbine and ultrasonic meters) is more likely to occur although the amount of contamination may be so small as to be negligible from a metering accuracy perspective. A key question among the metering community for a number of years has been identifying when the amount and disposition of the contamination becomes an issue for metering accuracy and how this can best be quantified, and where necessary any error reconciled (As the level of contamination on a plate can only be identified when it is removed during a validation this tends to be a post event issue rather than a real time issue).

Advice related to the quantification of the impact of contamination on orifice plates is encapsulated in ISO12767 however there has been widespread concern among the community related to both the accuracy of this data and how the data could be interpreted for the quantification of contamination on actual orifice plates which often bore no relation to the examples and tables within the standard.

As this uncertainty restricted the ability of NG and meter owners to accurately target costs once contamination had been identified, NG instigated a research test programme (between 2003 and 2005) aimed at improving the advice within the above standard to allow reconciliations to be carried out.

The objectives of the detailed test programme were to examine the effects of orifice plate contamination on measured flow rate using the types of oils and greases normally associated with the types of contamination found within the NTS. This programme conducted over sixty individual tests to consider the effect of coating type, coverage and thickness on the measured flow. The results were presented in a joint paper with Advantica (An assessment of the Impact of Contamination on Orifice Plate metering Accuracy. Pritchard. M, Marschall. D, Wilson. J. North Sea Flow Measurement Workshop. October 2004. which can be found in Appendix 4). The paper concluded that any contamination on the surface of an orifice plate did increase the meter measurement uncertainty resulting in an under registration of gas flow. These results were consistent with the work previously undertaken by British Gas that is the basis of the original version of the industry standard ISO12767

A summary of the main findings of the 2004 programme were submitted and accepted for inclusion in the 2007 version of the ISO 12767 standard.

In 2008 National Grid NTS sponsored further research in this area, this time looking at fixed based contamination. This was a continuation of the oil based contamination programme where a resin based coating was applied to the upstream face of the orifice plate. The test gases and pressures were similar to those of the oil based contamination programme. The programme was more selective in coating morphology, thickness and coverage. The results were compatible, within the bounds of experimental error, to those of the previous study, with the maximum error being consistent with the saturation (final) errors observed in the larger oil based programme. This therefore showed that the standard could be adopted for both liquid and solid contamination events,

This research work, and the subsequent education programme carried out with meter owners has now put in place conditions where cases of orifice plate contamination can be accurately assessed on site and any reconciliation issues identified and successfully carried through to a conclusion.

The contamination programmes using both a fixed and viscous contaminant have produced a comprehensive data set for future in-service contamination instances However there is considerable variation in actual contamination cases and for the existing data to be of use it is probably advantageous to be able to use a Computational Flow Dynamics (CFD) type modelling technique to assist in the determination of measurement error and National Grid NTS is currently assessing whether a future project to deliver this additional capability is worthwhile.

4.2.2 Equipment damage/deformation

At sites with very high flow levels, or at sites at risk to impulse loading there is a possibility of the gas flow causing deformation/bending of the orifice plate. As with contamination, any issues associated with a deformed plate can only be identified at a validation when the plate is removed and at that point any error that may have occurred would need to be quantified to allow a reconciliation to take place. Following some examples of deformation being found during validations, and some concerns regarding the ISO12767 standard advice in this area, NG conducted some experimental research in 2005 which broadly validated the standard, but which did identify some opportunity for further work at extreme deformations.

4.2.3 Quality of site maintenance / validation

The accuracy of metering at a site is directly impacted by the maintenance procedures and processes carried out by the meter owner. To ensure that these processes are carried out to the highest quality possible it is important that the procedures adopted reflect the appropriate obligations and best practice and that operatives have the best available training and equipment to allow them to carry out their duties and are supported by a management team who are focussed on resolving any issues identified quickly and effectively. With the large number of different meter owners across the system it is likely that the quality of meter maintenance, and therefore UAG risk, will vary on a site by site basis.

To ensure meter owners are acting appropriately and that processes reflect best practise wherever possible, National Grid NTS operates a validation monitoring and witnessing programme, coupled with a meter owner liaison initiative. The extent to which NG can formally carry out this programme is defined by the provisions of the network code (for NTS/LDZ offtakes sites) and/or the provisions in the relevant contractual agreements between NG NTS and the meter owners (for directly connected exit points, storage sites, interconnectors and entry points). In reality this means that NG NTS has rights to access relevant documentation and to witness validation routines at all exit points and the majority of storage sites but has little or no rights at interconnectors and entry points. At the sites where we do not have formal rights to witness validations we have however sought to build relationships with meter owners who may then allow NG NTS attendance on a voluntary basis.

For NTS/LDZ sites the UNC – OAD specifies in Section D Part 3 that measurement equipment shall be validated no less frequently than once every twelve months, and that the upstream party (National Grid NTS) shall be entitled to witness any validations carried out. The UNC also requires that the methodology, results and any adjustments carried out during the validation, are recorded in a Validation Report which also has to be provided to National Grid NTS following the completion of the validation process.

For directly connected exit points to the NTS and NTS storage sites very similar provisions apply to those in the OAD with respect to the rights of National Grid NTS to witness validations (which are generally termed as verifications within these contracts) and receive relevant documentation, although the relevant shipper or shippers at these sites generally has similar rights as well. It is worth noting however that no maximum time period between validations is specified as standard in these contracts, however National Grid NTS can request a validation to take place if more than six months have passed since the last validation.

As Validation Reports for LDZ offtakes are received by National Grid NTS the results of the tests are reviewed against appropriate criteria (e.g. for NTS/LDZ sites using those set in validation procedure T/PR/ME/2 Part 3) using an internal procedure and proforma with the details of the report being logged in a compliance tracker. This tracks the specific results of the individual components of the validation (highlighting any outstanding issues) as well as compliance with the obligations and timescales specified in the UNC. Checks include a review of the pressure and differential pressure cell dead weight tester coefficients and sense check of Local Gravity Correction Factors. Common issues noted include tests missed completely and/or failed tests not adjusted and retested, excessive instrument drift, and levels of contamination/deformity of orifice plates. Any issues identified from this process are raised directly with the meter owners at the earliest opportunity so that an action plan can be put in place to rectify them. A summary of the validation observations associated with the validation tracking process for years 2006/7 and 2008/9 is included below in Figure 10

	Validation Year					
	06/07		07/08		08/09 (partial)	
	Received	No issues	Received	No issues	Received	No issues
VLDMCs	7.63%	7.63%	89.83%	83.90%	55.08%	52.54%
DN network A	47.06%	29.41%	100.00%	94.12%	100.00%	76.47%
DN network B	52.00%	40.00%	98.00%	58.00%	92.00%	84.00%
DN network C	75.00%	37.50%	100.00%	54.17%	33.33%	20.83%
DN network D	64.71%	47.06%	70.59%	52.94%	70.59%	35.29%
DN network E	9.09%	9.09%	100.00%	100.00%	81.82%	45.45%

Figure 10 : Summary of tracking statistics for validation reports received by NG NTS

This process is supported by the validation witnessing programme which in 2008 aimed to witness around 20% of exit point validations, with rather more than this being achieved in practice (when measured on a pure attendance basis). The witnessing programme for 2009 is currently under development. Sites are selected using a risk based approach, with the initial criteria including the throughput of the site, sites with persistent difficulties passing validations/regular errors, sites that have not been visited by National Grid NTS or an independent auditor before, and sites with new technologies such as ultrasonic meters. Additional/alternative sites are identified as the year progresses depending on errors/issues that arise, with the aim of working with asset owners to resolve them. Following each witnessing visit NG NTS produce a witnessing report identifying issues found and providing recommendations for the asset owner (an example of such witnessing report is found in Appendix 5) Summarised information related to the validation witnessing process for years 2007 and 2008 is included in Figure 11 below :

	Apr 07 to Mar 08		**Apr 08 to Dec 09**	
	No. of sites visited	**% of total**	**No. of sites visited**	**% of total**
VLDMCs	17	35%	14	29%
Storage	1	10%	3	30%
Terminals	0	0%	6	32%
Network A	0	0%	6	38%
Network B	1	9%	0	0%
Network C	5	29%	1	6%
Network D	4	16%	10	40%
Network E	8	15%	13	25%

Figure 11 : Summary of witnessing activities carried out by NG NTS since April 2007

Quarterly Liaison meetings are also held with each Distribution Network owner to review meter assurance activities for that network and to review the overall status of their annual validation programme. A standard agenda for these liaison meetings is attached in Appendix 6.

In the interests of spreading best practice, and identifying common issues for meter owners, in 2008 NG NTS sponsored a joint metering seminar with the DNs to review common issues and identify best practice in a number of areas (e.g. quantification of effects of contamination on orifice plate meter systems, development of spindown test processes for turbine meters etc).

It is virtually impossible to quantify the impact of National Grid actions in this area on the outturn values of UAG especially over a short period of time, however it should be possible to show if the programme is impacting upon the quality of metering management across the system over a suitable period of time by monitoring progress against a number of key indicators such as the number and severity of issues identified, speed of resolution etc. Current statistics being monitored in this area are shown in Appendix 7 with the intention of developing these going forwards.

NTS/LDZ offtakes are also subject to additional assurance activities that are carried out independently of both the meter owner and National Grid NTS. These activities involve an independent audit regime which covers 10% of sites in a year and gas examiners site checks.

From an audit perspective the Distribution Networks employ third party experts to audit NTS / LDZ offtake metering systems. Audits are undertaken in accordance with procedure GMR00022 'Specification for the requirements for Auditing of NTS Offtake Meter Installations'

Sites are selected by the auditors for inclusion within the annual audit programme using a risk based assessment that considers the size, technology, and the operational history of the meter systems. The proposed audit schedule is presented to Ofgem prior to commissioning the work.

Representatives of Ofgem are invited to attend any of the audits and may have a copy of any of the audit reports. Historically once the audits are completed a review meeting has been held where the representatives of the auditors present a summary or their findings.

Each metering system is audited for compliance with the following criteria:

- IS05167-1:1991 (E) for orifice meters
- BS 7965:2000
- ISO9951 for turbine meters
- IS010723 for chromatograph
- Plate deformation
- Good metering practice
- Calibration/maintenance procedures –T/PR/ME2 Part 3 (plus contract amendments)
- Assessment of uncertainty,
- OFGEM letters or directions where applicable

The scope of the audit includes a visual inspection of the equipment that makes up the meter system followed by an Inspection of the associated documentation and records. The audits are scheduled to coincide with the annual meter maintenance so that the auditor may witness the application of a number of the validation procedures.

Following the audit a report is produced in compliance with the format defined within the procedure GMR00022. The audit procedure defines the following categories which are used to log any deficiencies of the meter system that the auditor identifies.

Category 1. A fundamental fault or non-conformance which indicates that the system is not complying with the criteria, and which has led, or is likely to lead, to a mis-measurement, which will require correction.

Category 2. A fundamental fault or non-conformance, which indicates that the system has not been complying with the criteria. The error no longer exists but may require correction of data or calculations.

Category 3. A minor error which is indicative of the system not being operated or maintained correctly or procedure not being followed, which has not led, or is not likely to lead to, a mis-measurement.

For meter systems that employ an Orifice plate, calculations are performed to ensure that the flow rate error due to plate deformation and plate buckling due to differential pressure is less than the 1S0 5167 limits. The plate is checked to confirm that it operates within its elastic deformation region.

4.2.4 Operation of sites versus asset design parameters.

In an ideal world the flow of gas through a metering installation would always be within the 'optimal' accuracy range of that installation, however system conditions may not allow this for some percentage of the time that the site is operational.

At some sites, predominantly on entry, the provision of multi-stream facilities, with the ability to take streams in and out of service, coupled with a relatively constant and predictable daily flow rate, should allow the metering installations to be configured to the prevailing flow conditions to keep them within their ideal measurement envelopes for the majority of the time (although NG NTS has no data to validate whether this is done or not).

At the majority of exit sites, however, installations are single stream (sometimes with a standby stream which has been designed to meet peak flow) coupled with flows driven by consumer demands which may vary significantly both within day and on an annual basis. This means that although these sites have been configured to deal with a wide range of flows, they are more likely to be exposed to flow rates outside of their ideal ranges, particularly at times of low flow. At many sites the required metering uncertainty is less stringent at low flow levels, and it is generally understood that for orifice plate installations in particular the risk of under reading flow and therefore introducing bias to the meter reading is greater in these conditions.

NG NTS has carried out some analysis of the flow to identify sites which are operating for significant periods at loadings below 30% and how this situation has changed over time. Detailed findings from this initial investigation can be found in Appendix 8 but an initial overview of the results suggest that up to a 3rd of sites are operating at below the 30% threshold for the majority of time in summer months, that the situation has got worse since 2004, and that the situation varies significantly between LDZs. As the report identifies further work is now required to understand the issues in more detail, to quantify the potential impact of these operating regimes on UAG and to work with asset owners to identify potential changes to operating regimes to mitigate any issues created.

4.2.5 Appropriateness of validation procedures

The validation procedures which cover the majority of sites at exit from the NTS specify tolerances for each of the individual instruments and transducers within the metering streams. This could introduce effects within the calculation of the cumulative metering uncertainty for the installation which could mean that the measurement has a propensity to a particular side of its operating envelope. For example high end pressure transducers are often validated to the same tolerances as low end transducers whereas it may be necessary to have them calibrated to differing tolerances to prevent a shift within the envelope.

TUV NEL was commissioned by National Grid to produce a report (see Appendix 9) describing all the process required to maintain an offtake metering station and assure the measurements. As well as a general inspection of the procedures, NEL were asked to detail the individual critical data items/variables that are required to calculate the energy at an orifice plate metering system to ensure that there are no omissions in the current processes and procedures. Suggestions to improve the clarity of the procedures were made (for example the detail of the method to check the operation of the temperature probe if no test thermowell is available) as well as suggesting that local barometric pressures are used instead of a nominal 1.01325bar.

National Grid NTS is currently in the process of reviewing this work and identifying the most appropriate route for taking forward recommendations.

4.3 Disparity in meter assurance regimes

Not all metering points associated with the NTS are subject to the same design, assurance or governance regimes, with significant differences between entry and exit sites and the different types of exit sites. These differences will have a number of impacts upon the metering at sites that will potentially lead to UAG being created due to these disparities. In the most extreme case this will lead to the potential for two sites seeing the same volume of gas passing through them legitimately and correctly recording different volumes of gas and in other cases lead to some sites being more prone to errors developing due to the disparities in maintenance regimes etc.

At entry sites the volume of flows and the direct links to revenues and taxation creates an environment where there is a great focus on metering accuracy with sites being manned and generally adopting a frequent (e.g. monthly) metering validation regime. With tax being directly linked to the metered energy, measurement at entry points is closely overseen and audited by DECC[2]. National Grid generally has very limited rights to attend, witness or review a routine validation but will generally be involved when aspects of the site metering equipment are being installed or subsequently changed.

The regime at exit points depends whether the site feeds a DN or a directly connected load such as a power station. At DN offtakes the sites are unmanned, and follow an annual validation routine which is defined within UNC Offtake Arrangements Document (OAD) and generally carried out by the DN's own staff. There is an independent audit regime for these sites which typically covers 10% of sites from each network each year with the outputs from the audit being provided to Ofgem. These sites are also subject to routine independent gas inspection checks. National Grid has a range of rights to witness validations and review relevant documentation defined with UNC (OAD). With no significant link between revenue and metered throughput there may be little financial incentive on DN's to ensure that metering is accurate.

Metering points for NTS directly connected loads are typically unmanned, generally following an annual validation regime using third parties to undertake their validation programme. However the content of the annual validation may vary between sites. There is no independent audit regime at these sites. The Network Exit agreements (NEXAs) generally provide National Grid with witnessing rights and other rights similar to those defined in the UNC for DN offtake sites. The regimes at storage and interconnector sites are generally very similar to those for directly connected loads.

With such significant variances between the management regimes there is certainly a risk that the quality of the validations will also vary between sites.

4.3.1 Disparity in validation procedures

All metering installations connected to the NTS must be maintained and validated on a regular basis, however the validation procedure that must be carried out by the relevant meter owner varies dependant upon the type of site. At entry points the maintenance and validation procedures follow guidelines laid down by DECC, at DN offtakes the sites must be validated to procedure ME2 (Part 3) as specified in the UNC, Directly connected loads with National Grid owned metering installations are validated to ME2 (Part4), and other directly connected loads and storage sites are free to adopt a validation process of their choice (although many do adopt procedures based on ME2 (Part 5), and iGEM document IGE/GM/4 which does give some guidance as to the content of the validation procedure). This is likely to mean that their will be discrepancies introduced to the extent that the different types of site could

[2] Department of Energy , Climate Change

legitimately measure a different volume of gas flowing through for the same physical quantity.

There is an intention that there will be a standalone document under the IGE umbrella outlining validation procedures. This is an ongoing initiative.

4.4 Site design issues

There are a number of metering issues that may lead to UAG that are due to the design of the particular site and metering installation rather than to the operation of the metering installation itself. The prevailing standards with respect to site design have evolved significantly since the majority of exit facilities were connected meaning that a large number of existing sites are not constructed in line with standards that would apply for new sites. With the introduction of the new version of the ISO5167 standard in 2003, two issues in particular came to light, the first relating to the impact of pipework topology on metering accuracy and the second related to the adoption of the new Reader-Harris/Gallagher flow equation introduced into the standard to replace the Stoltz flow equation which had previously been the industry standard.

4.4.1 Impact of pipework topology at sites

The topology of the pipework, valve positions, etc, associated with the metering installation can potentially lead to distortion of the gas waveform with the effect that although the metering installation itself is operating correctly it may actually under or over read the flow of gas through the site, as the equations underpinning the calculation of gas flow assume a uniform cross section of gas flow through the meter. The 2003 version of the orifice plate metering standard (ISO5167) now requires, in most cases, much longer lengths of straight pipework prior to the meter to rectify this issue than was the case when many sites were constructed.

The standard generically deals with any non compliant sites by adding a specified percentage to the uncertainty calculation for the site, however following discussion with parties involved in development of the standard it was understood that on a site by site basis this non compliance had the potential to lead to a level of bias within the metering system.

Using site audit reports where available, a desktop analysis of all NTS/LDZ orifice plate offtakes was carried out to identify instances of questionable compliance with the upstream straight lengths requirement of ISO 5167:2003. This was used to compare the uncertainty associated with both the latest and previous versions of the standard, and to attempt to quantify any bias resulting from installation effects.

81 NTS/LDZ orifice plate meter streams could be assessed from available records. Of which 33 were found to have questionable compliance under ISO 5167:2003, although due to the release of ISO 5167:2003, 14 sites that had questionable compliance according to the 1991 version of ISO 5167 are compliant with the latest standard due to additional detail provided about the separation of the bends in the pipework. Based on this work the potential magnitude of incorrectly measured gas due to the measurement bias introduced has been estimated in the range of 414 GWh and 663 GWh for the 2006/07 year of operation.

To understand if the desktop exercise was in any way relevant to actual sites Computational Fluid Dynamics simulations of 2 sites were carried out in conjunction with the National Engineering Laboratories. The studies were carried out one compliant and one non-compliant site the results of which show that a bias of +0.29% could be present even at a compliant site. The results of the non-compliant installation resulted in a bias of between -1.10% and +0.003% depending on valve arrangements. See Appendices 10a and 10b for the detailed CFD analysis reports.

Overall the conclusions that could be drawn from CFD analysis were that a) even sites compliant with the 2003 version of the standard could exhibit bias, b) bias at the non compliant site was potential greater, c) bias could be negative or positive, d) the valve configuration on the day could have a very significant impact on the level of bias, even at non compliant sites, and could potentially negate the bias introduced.

The results of this report have led to the potential an extended CFD modelling project covering all orifice plate metered sites in an LDZ to try and determine what the underlying consequences of installation effects could be on levels of UAG.

4.4.2 Impact on standard changes on flow calculation

The majority of gas measurement off the NTS is still performed by orifice plate meter systems. The International, European and British standard ISO 5167 which covers the measurement of gas flow by differential pressure measurement (orifice plate or venturi), has over the last decade, undergone a number or revisions culminating in the latest revision in 2003. The principle standard currently applied by all NTS measurement systems is the 1991 revision. The latest 2003 revision incorporates a number of significant changes:

- Discharge Coefficient C (Change from using the Stoltz to the Reader-Harris Gallagher equation)
- Expansibility Factor
- Permanent Pressure Loss
- Upstream Temperature

It is understood that DECC[3] have encouraged the implementation of the change to the 2003 standard for all new and existing upstream beach import metering, however there is no implicit requirement for existing exit points to do likewise, although we would expect all new sites to adopt the latest version of the standard (it is also expected that when existing exit points make significant changes/upgrades to their metering systems that they would also do so).

The overall impact on metering and thus UAG of widespread adoption of the revised standard has undergone significant discussion within the industry. An assessment of the flow calculation differences between the two standards (1991:2003) and the impact these have on the measured flow (energy) from the NTS and VLDMC off takes has now been made by NG and can be seen in Appendices 11 and 12. The conclusions from this analysis were that NTS shrinkage, and hence the shipping community, would be exposed to an increase in UAG energies as a consequence of the adoption of the 2003 standard at offtake metering sites. The magnitude of this risk was estimated to be between 900 and 1000 GWh per annum over and above the existing UAG levels. Since the analysis was conducted on 2007/08 actual flow profiles for the respective sites, this figure can be directly compared in terms of the SO incentive UAG allowance for that period of 1100GWh. This effectively therefore has the potential to double annual UAG levels.

4.4.3 Thermal Lagging

Offtake metering systems at National Grid and the Independent Distribution Networks are audited to ensure compliance with best industry practice and British and international standards. One recurrent finding has concerned the lack of thermal lagging on both the upstream and downstream lengths. The standards and best practice documents recommend that the temperature sensor is placed in a thermowell which is then inserted into the gas stream of the flowing gas. The auditors concerns were that if there were no lagging, then the temperature measured in a thermowell may not be the same as the gas temperature. A temperature difference of 0.5 ºC will impact on volume measurement by as much as 0.3% and therefore this issue was seen as a significant risk from a UAG perspective.

The majority of natural-gas metering systems in the United Kingdom were built in the 1970s with no thermal insulation to protect the temperature measurement from ambient variations. It was thought that the impact of the ambient temperature on the temperature of the flowing gas was so small that it could be neglected.

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[3] Department of Energy and Climate Change (formally DTi/BERR)

National Grid NTS in conjunction with the DNS instigated some research work with Advantica to quantify the risks in the lack of thermal lagging and identify the impact on metering accuracy. The report (see Appendix 13) covers previous experimental measurements and presents new results from a computational fluid dynamics (CFD) mathematical model developed at Loughborough University which show close correlation, and specifically that:

1) The CFD model indicates that the temperature at the bottom of the thermowell is the same as the gas temperature (both with and without insulation) for a range of ambient and gas conditions. Experimental measurements confirmed that the temperature in an unlagged thermowell was insensitive to the most extreme ambient conditions.
2) The CFD model shows that although the temperature within the thermowell stabbing is influenced by ambient conditions the temperature of the gas stream within the pipe diameter is unaffected. This is confirmed by experiment.
3) The CFD model shows that the gas velocity within the thermowell stabbing is very low. In support of this, measurements of temperature within the thermowell stabbing showed that there was a very long response time to temperature changes.
4) The CFD model shows that the temperature of the pipe wall is always very similar to the gas temperature. However, with insulation, the difference is not detectable. Experiments confirmed that an insulated surface temperature measurement was within 0.1 ºC of the temperature in the thermowell.
5) The CFD model shows that local insulation around a thermowell or a surface mounted sensor is sufficient. There is no need to insulate the entire meter run. Experimental measurements have confirmed that local insulation is sufficient for accurate measurements of gas temperature.

This report has given us confidence that no UAG has been created due to the lack of this insulation, that no reconciliations are required and that no future lagging work associated with this issue is required.

4.4.4 Impact of drain holes

Orifice plates with drain holes are presently in use at a limited number of sites on the National Transmission System. They provide a means of reducing metering inaccuracies caused by liquid contamination present in the gas stream. Any liquid contaminate will pass through the drain-hole located along the bottom edge of the orifice plate rather than becoming trapped behind the plate and so interfering with the measurement. Currently orifice plates with drain-holes are permitted in accordance with the relevant standard ISO TR 15377:1998.

The purpose of this particular programme of work was to validate the accuracy of the equation in this standard. Any error in accounting for the drain-hole will result in incorrect volume and energy end of day measurements. Any mis-measurement, in the form of UAG, would impact on the level of NTS Shrinkage for the length of service of the orifice plate.

Analysis of the results found that the equation as in ISO:15377 for correcting the orifice plate diameter for a drain hole appeared to be accurate averaged across a range of beta ratio and drain hole sizes. However, the results also demonstrated that improvements to the calculation could be made.

In order to have confidence in any change to the equation it would have to be supported by considerably more data than is currently available. This would require expanding the programme to cover an increased number of tests covering a wide range of beta ratios and drain-hole sizes. Further confirmation of the repeatability of results would also be necessary.

4.4.5 Impact of large beta ratios

Following a review by National Grid it was identified that one offtake meter was deemed to have operated with a diameter ratio of 0.7509, above the limit defined within section 8.1.7.1 of BS EN ISO 5167-1 1991 and 5.3.1 if BS EN ISO 5167-2:2003. NEL were therefore commissioned to carry out a study of the consequences of operating an orifice plate metering system with a diameter ratio of greater than 0.75. The study found that there were no issues with operating with a diameter of 0.7509 other than the uncertainty being greater than with a ratio of 0.6.

4.4.6 Compliance of new sites

The connection of new sites onto the NTS provides the opportunity to ensure that the contractual frameworks established provide the appropriate rights to enable measurement assurance by NGG. In addition to the establishment of appropriate commercial frameworks NGG can influence the design of the connecting measurement asset to comply with the prevailing standards. During the lifecycle of the design, construction and commissioning of the asset, NGG actively tracks the development to ensure that the completed connection meets the standard required to connect on to the NTS (PAS55) and subsequently operate in a manner that provides safe control of the NTS system. In order to gain assurance NGG undertake a raft of activities including the review of designs, the witnessing of calibrations, receipt of relevant certification, end to end validation of signals etc.

4.5 Impact of linepack calculation

UAG is derived from metered values and the calculated change in linepack. Change in linepack is calculated on a daily basis utilising a model that draws its information from a defined set of pressure and gas compositional mapping points on the NTS system. On any day there will be a level of uncertainty around the calculation due to the finite number of sampling points available.

As part of the extensive review of the all the likely fundamental causal effects of UAG behaviour by National Grid, the potential effect the calculation of NTS linepack may have on the observed underlying UAG volume behaviour was examined. The NTS linepack is calculated every six minutes using measured pressures at each node of the 263 pipe map which makes up the NTS model. To each of these pipes a measured temperature, compressibility and calorific value (CV) is attributed. The gas property is obtained from a limited number of offtake sites and thus some pipe sections are mapped to the same offtake.

The analysis involved a linepack comparison between NTS model and a dedicated network modelling tool across a series of flow (demand) profiles. The results revealed that the offline network modelling tool calculated a higher linepack energy than that of the NTS model at all flow levels. The response of both models was linear across the flow range although the magnitude of the differences between the two models decreased as the NTS demand increased.

The differences in absolute linepack values between the two approaches were not unexpected and are attributed to the granularity between the two methods being very large, i.e. the two models were consistent but differed by an offset related to the different granularity of the models. Essentially the NTS model is coarse with large pipepack regions mapped to a small number of flowing LDZ off takes for the compressibility, temperature and calorific values. The network analysis presented a very fine summation of individual pipepack calculated using its internally derived gas properties within that pipe section rather than the attributed sites.

The NTS model has a number of constraints which require careful consideration before significant changes are possible. However the following are being explored to improve the efficacy of NTS linepack model. These include:

- Improving the attribution of compressibility to pipe section pressure.
- Incorporating additional gas property data already telemetered into the model.
- Incorporate on-line modelling tools to improve gas property mapping.

The current NTS linepack model is complex and exerts a considerable computational overhead on the NTS control system. The linear response of the model in comparison to the offline network modelling tool, suggests that the overall effect of linepack response is consistent across the NTS flow range and should not contribute to the changing nature of UAG. The work around the model and future improvements are under continuous review.

5. Innovation Funding Incentive

As part of the Transmission Price Control Review (TPCR) Ofgem has introduced the Innovation Funding Incentive (IFI) mechanism. IFI was consulted on as an integral part of the TPCR proposals and was widely supported by a large majority of consultees. The primary aim of the incentive is to encourage the Network Operators to apply innovation in the technical development of their networks.

The IFI is intended to provide partial funding for projects primarily focused on the technical development of the networks, to deliver value (e.g. financial, quality of supply, environmental, safety) to end consumers.

The details of the IFI mechanism are set out in Special Condition C8B and Special Condition C14B of the gas transmission license and the Energy Networks Association Engineering Recommendation G85. They can be summarised as follows.

- A Network Operator is allowed to spend up to 0.5% of its Combined Transmission Network Revenue (subject to a minimum of £500,000) as the case may be on eligible IFI projects.
- Network Operator IFI expenditure that is internal expenditure will be allowed as part of the total IFI expenditure accrued by the Network Operator.
- The Network Operator is allowed recover 80% of its eligible project expenditure via the IFI mechanism within the Network Operator’s Licence.

5.1 Current Projects

During 2007/8 there were 3 projects included within National Grid’s Innovation Funding Incentive Transmission Annual Report 2007/2008 that may benefit the measurement of flow and CV and associated processes; these are all discussed in the body of the above report under “Research into Meter Assets” and can be summarised here as :

- Requirements for meter lagging (Meter Tube Lagging)
- Impact of drain holes and high beta ratios on meter accuracy (Orifice plate research)
- Identification of critical data items for meter validation (Meter Assurance Critical Data Mapping)

The primary benefits of the projects are focussed on improved performance of metering assets and an improved understanding of the affects of several criteria on metering but may also benefit the measurement of flow and CV and associated processes.

5.2 Potential future projects

Future projects currently being discussed that potentially benefiti the measurement of flow and CV and associated processes include :

- Impact of installation effects/pipework topology on meter accuracy
- Development of CFD analysis for quantification of effects of meter contamination
- Development of data mining techniques for identification of meter failure

Appendices

Appendices associated with this document are defined below. Each of these is provided within a separate named attachment.

Appendix 1 : Ofgem data request
Appendix 2 : ISRU UAG analysis 1997 – 2005
Appendix 3 : ISRU UAG analysis 2008
Appendix 4 : Contamination paper
Appendix 5 : Example of validation witnessing report
Appendix 6 : DN liaison standard agenda
Appendix 7 : Meter assurance performance indicators
Appendix 8 : Operation of sites at low flow levels
Appendix 9 : Critical measurements report
Appendix 10a : NEL CFD Modelling Report
Appendix 10b : CFD Report
Appendix 11 : Analysis of impact of ISO5167:2003 on flow calculation (2005)
Appendix 12 : Summary of impact of ISO5167:2003 on flow calculation (2008)
Appendix 13 : Impacts of thermal lagging