

GUIDANCE NOTE 17

UNCERTAINTY IN METERED INPUTS AND OUTPUTS

SCOPE AND STRUCTURE

GN17.1

This Guidance Note (GN) gives detailed guidance to enable Responsible Persons to:

- assign realistic uncertainties to metered values of energy inputs and outputs
- take account of uncertainties in determining the power and heat efficiencies of a Scheme when completing submissions

The GN also contains a General Simplified Method for determining the overall uncertainties in flow meters.

GN17.2

The structure of this GN is set out below:

Uncertainty and Bias

| | |
|--|-----------------|
| Simple definitions | GN17.3-GN17.4 |
| Relevance to CHPQA | GN17.5-GN17.6 |
| Practical explanation | GN17.7-GN17.11 |
| Acceptable uncertainties for ‘best practice’ | GN17.12-GN17.14 |
| Measurements that are deemed to be ‘best practice’ | GN17.15-GN17.19 |

Estimating Uncertainty

| | |
|--|----------------------|
| Principles | GN17.20-GN17.23 |
| Procedure for combining uncertainties | GN17.24-GN17.25 |
| Simplified method for flow meter uncertainties | GN17.26-GN17.33 |
| Calculation of flow meter uncertainty | Tables GN17-1–GN17-4 |

“Expert Guidance” on the Components of Metering Uncertainties

| | |
|--|-----------------|
| Primary meter uncertainty | GN17.34 |
| Transmitters and computations | GN17.35 |
| Fluid properties | GN17.36-GN17.44 |
| Calibration excluding primary flow element | GN17.45 |
| Calibration of primary flow element | GN17.46 |

Additional uncertainties for out-of-calibration electricity and heat meters

GN17.47

UNCERTAINTY AND BIAS

Simple definitions

GN17.3

Uncertainty: For the purposes of CHPQA this is defined as the range of values, within which there is a high probability (usually 95%) that the true value of a measured (or calculated) variable is estimated to lie.

- See also GN17.8.

GN17.4

Bias is a systematic error in a measurement (or calculated) value that arises from a recognised over or under statement of a quantity or value that influences the measurement. Bias due to primary element or transmitter errors may be addressed by calibration. Incorrect assumptions or calculations errors may also lead to bias. If such a systematic effect is significant in size, (relative to the required accuracy of the measurement), a correction or correction factor should be applied to compensate for the resulting error. GN23 gives detailed guidance on evaluation and correction of bias.

Relevance to CHPQA

GN17.5

The expression of **uncertainty** is an essential indicator of the quality of the monitoring of performance (energy inputs and outputs) of a CHP Scheme under CHPQA. It is therefore required that metered (and calculated) values of energy inputs and outputs meet the reasonable standards which are summarised in this document in order to be considered 'best practice'. For self-assessment any values that do not achieve the required standard are considered to have excess uncertainty. This is then taken into account in the appropriate sections of the submission journey to derive adjustment factors that are used in the calculation of the heat and power efficiencies. Excess uncertainty results in lower heat and/or power efficiencies, and hence reduced value of the QI of the Scheme.

GN17.6

An appropriate correction, (which may be either positive or negative), should be applied to the measured values, where a **bias** can be recognised in a measurement. Otherwise, the uncorrected bias will be added as a $\pm n\%$ to the uncertainty in the measurement, which will result in reduced values for the efficiencies and QI.

Practical explanation of 'Uncertainty'

GN17.7

Uncertainty is usually expressed as a range $\pm n\%$ of the measured output and, in simple terms, accuracy is $(100 - n)\%$. So, a value that can be determined with an uncertainty of $\pm 2\%$ is likely to lie within the range 98% to 102% of the true value.

GN17.8

Uncertainty is the error band that is associated with a particular measurement or derived value. Statistically, it is the bandwidth within which 95% of the outputs of a true measured value will lie as a result of possible systematic errors in the equipment, or calculation methods, used to arrive at the output value. It does not include systematic errors due to incorrect calibrations or wrong assumptions – these errors are known as bias and must be addressed separately (Guidance Note 23).

GN17.9

Uncertainty is sometimes quoted as percent of the full-scale reading (i.e. percent of span). Therefore, for example, an error band or uncertainty of $\pm 1\%$ of full scale becomes an uncertainty of $\pm 2\%$ of the actual value at 50% output.

GN17.10

Uncertainties in metered values may be established from manufacturer's equipment specification sheets, meter data sheets and current calibration certificates. There are also accepted measurement standards that are relevant to particular types of meter. For example, BS EN ISO 5167-1:2022 gives some practical guidance on the computation of the uncertainty associated with orifice plate, nozzles, and venturi tube flowmeters.

GN17.11

A number of standards and engineering texts are available which deal with the evaluation of the various aspects of accuracy and precision, some of which are listed below. These are documents for the specialist. However, BS ISO 5168:2005 does give a worked example of the calculation of uncertainty for the metering of steam flow, and this may be used in conjunction with the relevant sections of BS EN ISO 5167-1:2022 to give a better appreciation of the issues. These two documents have been used in the preparation of this Guidance Note to develop simplified methods of determining uncertainties for flow meters as well as for uncertainties in the calculation of variables that are determined indirectly.

Standards and texts dealing with uncertainty:

BS ISO 5725: – Parts 1 to 6, "Accuracy (trueness and precision) of measurement methods and results".

ISO/IEC Guide 98-3:2008, "Uncertainty of Measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)".

BS ISO 5168:2005, "Measurement of fluid flow. Procedures for the evaluation of uncertainties".

BS EN ISO 5167:-1:2022, "Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full.

General principles and requirements.

Flow Measurement Engineering Handbook (3rd Edition), 1996, Miller R. W., McGraw Hill.

ACCEPTABLE UNCERTAINTIES FOR 'BEST PRACTICE'

GN17.12

In general, in order to be deemed best practice, **individual** metered energy inputs and outputs, (and calculated values), must be determined with an uncertainty of not greater than that set out in GN13.11 and expanded in GN15.6 and Table GN15-1 for electricity metering

GN17.13

Meters for the measurement of energy inputs and heat and power outputs (except for the metering of minor streams as defined in GN13.20 and GN13.21) must have an agreed calibration or replacement schedule in place that is being followed.

Failure to comply with this requirement is likely to result in the imposition of additional uncertainties.

For minor streams it is not necessary to carry out regular calibrations nor is it necessary to determine uncertainty as set out in Guidance Note 17. Instead, a small

default addition to the overall uncertainty is required as set out in GN19.

GN17.14

The requirements for the metering of steam have been simplified. To be accepted as 'best practice' the metering of steam energy should have an uncertainty of no greater than $\pm 2\%$ at full scale or $\pm 3\%$ of actual reading at the normal steam flow ratio, where flow ratio = average flow / meter maximum flow, (Q_{av} / Q_{max}).

MEASUREMENTS THAT ARE DEEMED TO BE “BEST PRACTICE”

GN17.15

Some measurements and uncertainties associated with the determination of energy inputs and outputs are accepted as “Best Practice” for self-assessment. These are covered in GN17.16 - GN17.19.

GN17.16

Where a natural gas energy input is determined by a meter owned by the “public gas transporter” or “relevant licence holder” (Ref: Statutory Instrument 1996 No. 439, The Gas (Calculation of Thermal Energy) Regulations 1996) and used for billing purposes, the quality of this meter is deemed best practice. The uncertainty of such meters may be reported as “less than $\pm 2\%$ ” in the Scheme details section of a submission. For self-assessment, no adjustment of these metered energy inputs is necessary, providing the calorific values are taken from the gas bill for the relevant time period.

GN17.17

Where the calorific value of a conventional fuel supplied is declared by the supplier and used for billing purposes, the uncertainty inherent in this calorific value may be ignored for the purposes of self-assessment. This concession applies, providing the calorific values are taken from the fuel bill for the relevant time period. This applies to natural gas, commercial fuel oils and coal or coke.

GN17.18

For commercial fuel oils where no calorific value is declared, the calorific value to be used shall be the “typical” or “average” calorific value (not the “minimum” value) specified by the supplier. The uncertainty inherent in this calorific value may be ignored for the purposes of self-assessment.

GN17.19

For commercial fuel oils and commercial solid fuels, it is acceptable to determine the energy inputs monthly from purchases (delivery notes) and storage tank, bunker or stockpile inventories (opening and closing stock). **Where the change in inventory (positive or negative) accounts for 5% or less of all fuels used in the self-assessment period (normally 12 months) the uncertainty may be reported as $\pm 2\%$ in the Scheme details of a submission.** Where the change in inventory accounts for more than 10% of the fuel used, the uncertainty associated with the determination of the opening and closing stocks should be estimated and the effect on the overall uncertainty of that energy input determined using the method set out for calculated values. However, note that where the use of oil represents no more than 5% of the energy inputs it is acceptable to treat this as a minor energy stream, as set out in GN13.20 and GN13.21 which means that there is no need to calibrate tank level

gauges and the calculation of uncertainty with the minor penalty of a small increase in the energy input adjustment factor FOI.

ESTIMATING UNCERTAINTY

Principles

GN17.20

The Scheme details section of the submission journey requires an estimate of the uncertainty associated with each metered value and calculated value that is required for self-assessment.

GN17.21

For many meters the uncertainty may be readily obtained from specifications, data sheets and calibration certificates without any requirement for further work.

GN17.22

For some meters the derivation of the final output value as energy, required for self-assessment, necessitates a number of consecutive and parallel steps. Considering, as an example, a steam flow meter, the following steps may be involved to arrive at the energy output:

- An orifice plate produces a differential pressure
- this is then converted to a 4-20 mA electrical output by a transmitter
- the electrical signal is then processed by a flow computer (or similar):
 - taking account of density (which may be derived from simultaneous measurements of pressure and temperature, or by assuming constant temperature and pressure values) to derive the mass flow
 - mass flow may be displayed or recorded as a rate of flow and totalised to give an integrated mass
 - the computerised data acquisition system (DAS) may be programmed to apply a derived specific enthalpy (derived from simultaneously acquired pressure and temperature data) to give an output in energy units, kW (rate) or kWh (cumulative). Alternatively, a constant specific enthalpy may be assumed to produce these energy output parameters.

The overall uncertainty is clearly influenced by the uncertainties associated with the primary element and each subsequent step, and its derivation can become complex.

GN17.23

In complex cases, such as that outlined in GN17.22, these guidance notes aim to simplify the process by providing a logical and easy-to-follow stepwise approach. This approach uses, where possible, reasonable generalised values of uncertainties in tabular form for the elements of the measurement that can be applied in a simplified formula to give an acceptable estimate of overall uncertainty. The general procedure for deriving an overall uncertainty value is described in GN17.24 and GN17.25. However, GN17.26 - GN17.33 present a Simplified Method for determining overall uncertainties for fluid flow meters, such as gas meters, steam meters and water flow meters etc. It is expected that Applicants will normally opt to choose this simplified

approach where it is difficult to determine actual figures when assessing the overall uncertainties of their various flow meters. Detailed “expert” guidance for flow measurement is given in GN17.34 to GN17.46 for those wishing to derive more specific uncertainty values.

PROCEDURE FOR COMBINING UNCERTAINTIES

GN17.24

The uncertainty of a measurement or calculated value that includes **a number of elements in series** may be expressed as the square root of the sum of the squares of the uncertainties associated with the individual elements. This method is known as a root-sum-square (RSS) combination of uncertainties. For example, a flow measurement may utilise a primary measuring element such as an orifice plate (1), a transmitter or DP cell (2), and a chart recorder or flow computer (3). In this case the overall uncertainty associated with the output value is given by the following expression:

$$\text{Overall uncertainty, } U_o = [U_1^2 + U_2^2 + U_3^2]^{0.5}$$

Example:

The flow of gas oil to a Scheme is metered by a turbine meter primary flow element. This provides a pulse output to frequency to current converter/transmitter which, in turn, sends a 4-20 mA output signal to a flow computer. The flow computer uses programmable fixed values for fluid density and calorific value that are taken from the fuel supplier’s data sheet to provide digital outputs in terms of instantaneous and integrated mass flow and energy. The average flow of oil is 75% of the meter span. The turbine meter is calibrated every 5 years and the transmitter and flow computer together are calibrated annually (considered “best practice” – see Tables GN17-4 and GN17-5).

The uncertainty values for the components that make up the metered energy input are all available from the instrument manufacturers’ data sheets:

Primary element – turbine meter: $U_1 = 1.0\%$

Frequency-current converter/transmitter $U_2 = 0.1\%$

Flow computer $U_3 = 0.5\%$

Overall uncertainty, $U_o = [U_1^2 + U_2^2 + U_3^2]^{0.5}$

Overall uncertainty, $U_o = [1.0^2 + 0.1^2 + 0.5^2]^{0.5} = 1.26^{0.5} = 1.12\%$

GN17.25

A metered or calculated value may depend on a number of measured inputs each with its own uncertainty. This may be the calculation of an energy input or output that cannot be metered directly, or the calculation of mass flow within a flow computer taking account of independent measurements of pressure and temperature. In such cases the influence of the uncertainty in each of the inputs on the uncertainty in the final output value must be determined to give a weighting factor called the sensitivity coefficient (S). The overall uncertainty in the output value is then the square root of the sum of the squares of each of the input value uncertainties multiplied by its sensitivity coefficient.

$$\text{Overall uncertainty, } U_o = [(S1.U1)^2 + (S2.U2)^2 + (S3.U3)^2 + \dots]^{0.5}$$

If the term “effective uncertainty”, U_e , is substituted for the product ($S \times U$) the equation becomes:

$$\text{Overall uncertainty, } U_o = [U_{e1}^2 + U_{e2}^2 + U_{e3}^2]^{0.5}$$

It may be seen that the equation shown in GN17.24 is a special case of the general equation above, where the sensitivity coefficient of each of the elements of the measurement is equal to unity (one), because each element has a directly proportional influence on the outcome.

An example of the determination of uncertainty in a metered value that involves a number of individual measurements is given below.

Example:

The flow of superheated steam is metered by an orifice plate primary flow element. This provides a differential pressure input to a pressure transmitter which, in turn, sends a 4-20 mA output signal to a flow computer. There is a separate pressure sensor/transmitter that sends a 4-20 mA output signal to a flow computer and there is also a temperature sensor (thermocouple) that provides a mV output signal. The flow computer uses the pressure and temperature input signals to determine the density of the steam at line conditions and its specific enthalpy. These values are used to compute the mass flow of steam and its energy content to provide digital outputs in terms of instantaneous and integrated mass flow and energy. The average flow of steam is 75% of the meter span. The orifice plate is inspected every 5 years and the transmitter and flow computer together are calibrated annually (considered “best practice” – see Tables GN17-4 and GN17-5).

The uncertainty values for the components that make up the metered energy input are:

| | |
|-----------------------------------|--|
| Primary element - orifice plate: | $U_1 = 0.7\%$ (ref: BS EN ISO 5167-1:2022) |
| Differential pressure transmitter | $U_2 = 0.3\%$ (ref: manufacturer’s data sheet) |
| Flow computer | $U_3 = 0.5\%$ (ref: manufacturer’s data sheet) |
| Temperature transmitter | $U_4 = 0.5\%$ (ref: manufacturer’s data sheet) |
| Pressure transmitter | $U_5 = 0.3\%$ (ref: manufacturer’s data sheet) |

For an orifice plate, the computed mass and energy flow is proportional to the square root of the differential pressure and the square root of the density (which itself is directly related to pressure and temperature). It may be shown (BS ISO 5168:2005 or by calculation) that the sensitivity coefficients S_2, S_4 and $S_5 = 0.5$. The coefficients for the primary element and the flow computation, S_1 and S_3 , may be taken as unity since both have a direct effect on the outcome.

So:

$$U_{e1} = S_1 \times U_1 = 1.0 \times 0.7 = 0.70$$

$$U_{e2} = S_2 \times U_2 = 0.5 \times 0.3 = 0.15$$

$$U_{e3} = S_3 \times U_3 = 1.0 \times 0.5 = 0.50$$

$$U_{e4} = S_4 \times U_4 = 0.5 \times 0.5 = 0.25$$

$$U_{e5} = S_5 \times U_5 = 0.5 \times 0.3 = 0.15$$

$$\text{Overall uncertainty, } U_o = [U_{e1}^2 + U_{e2}^2 + U_{e3}^2 + U_{e4}^2 + U_{e5}^2]^{0.5}$$

The Simplified Method for determining uncertainties in flow meters (excluding exceptions listed below)

- Electricity meters refer to GN17.47
- Solid fuel weighing devices (such as weighbridge and belt weighers) refer to GN17.48
- Packaged Heat meters refer to GN17.49

GN17.26

It may be appreciated from the above that the estimation of uncertainty can become complex. However, it may also be seen that the overall uncertainty is usually dominated by one or perhaps two dominant terms in the calculation. Therefore, by identifying the dominant terms it is possible to devise the Simplified Method of estimating uncertainty for flow meters described in GN17.27 to GN17.33. Those wishing to derive more rigorous estimates may do so by reference to the standards cited in GN17.10 and GN17.11 or other relevant documents. All such calculations must be submitted to the CHPQA Administrator for verification and approval.

Detailed “expert” guidance on some of the issues involved in determining a combined uncertainty is given in the final section of this Guidance Note.

GN17.27

In the following sections (GN17.27 to GN17.33), a means of assessing uncertainty is presented that aims to simplify the procedure as far as is reasonably possible without detriment to the overall validity of the outcome. The magnitude of the primary meter uncertainty is generally not a problem. However, the additional uncertainties that can accrue due to lack of pressure and temperature compensation, and infrequent calibration can often increase the overall level of uncertainty well beyond that considered ‘best practice’. It will usually be difficult to quantify accurately all of the individual components that add to the overall uncertainty. In the absence of better, specific information the default values provided in Tables GN17-2 to GN17-4 can be used.

GN17.28

Table GN17-1 (the Worksheet) is a worksheet that must be completed and submitted **for each flow meter that forms part of the self-assessment (except for metering of minor streams)**. This applies whether the flow meter is a direct measure of an energy input or output, or as one of the inputs to a calculated value that itself is part of the self-assessment.

GN17.29

The upper section of the Worksheet simply defines the fluid conditions and the type of flow meter.

GN17.30

Tables GN17-2 to GN17-4 give default values of U_e for use in completing the Worksheet. The Applicant may choose to employ the offered default values, or use

their own values, (or use a mixture of both) when filling up Table GN17-1. However, where uncertainties other than the default values are used (entered in the column “Claimed value of U_e , %”) these must be justified to the CHPQA Administrator by the provision of supporting data or calculations (to be referenced in the column “Ref to source data attached”).

GN17.31

The Worksheet and Table GN17-2 differentiate between “Type 1” and “Type 2” flowmeters.

- A Type 1 meter is one where the primary signal is proportional to the square of the flow rate. Type 1 meters include orifice plate, venturi, averaging pitot and “V-cone” flowmeters.
- A Type 2 meter has a linear output, with the primary signal directly proportional to flow rate. Type 2 meters include ultrasonic, vortex shedding, coriolis, turbine and “Gilflow” flowmeters.

GN17.32

Applicants should fill in the effective uncertainty (U_e) against each parameter shown in Table GN17-1, by either choosing the default values from Tables GN17-2 to GN17-4, or by using their own supported values. For each value of U_e entered in Table GN17-1, calculate its square, (U_e^2). Add up these values to give the sum of the squares of all the U_e^2 values and find the square root of this total. This gives the overall uncertainty for the metered value, (U_o). The excess uncertainty, U_x , is the amount by which the overall uncertainty exceeds the permitted uncertainty for “best practice” (U_{BP}); therefore, $U_x = (U_o - U_{BP})$. This is used later to determine the individual adjustment factor for the flow measurement, F_i , in accordance with GN19. Note that the permitted uncertainty for best practice will have already been determined as described in GN13.10.

GN17.33

The notes GN17.34 to GN17.46 that follow Table GN17-4 give additional “expert guidance” on specific elements of uncertainty to provide more detailed information and to assist those wishing to derive instrument-specific uncertainties. GN18 gives guidance on the application of the method outlined in GN17.25 for the derivation of uncertainty in the values of **calculated** inputs or outputs.

Table GN17-1 – Calculation of Flow Meter Uncertainty (Work Sheet)

| Flow Meter | Tag Number: | Metered fluid: | | | |
|--|-------------------|------------------------------|----------------------------|-----------------------------|--------------|
| Line conditions | Pressure, bar(g): | Temperature, °C: | | | |
| | | | | | |
| Meter type – Primary device (tick appropriate box) | Orifice Plate | Venturi | Averaging pitot | “V-cone” | “Gilflow” |
| | Vortex shedding | Coriolis | Turbine | Other (please specify) | |
| | | | | | |
| Table of Uncertainties | Ref GN | Effective Uncertainty, U_e | | | U_e^2 |
| | | Default value of U_e , % | Claimed value of U_e , % | Ref to source data attached | |
| Primary meter uncertainty | 17.34 | 1.0 | | | |
| Transmitter and computations | 17.35 | 1.0 | | | |
| Fluctuations in fluid properties | 17.36 to 17.44 | Table GN17-2: | | | |
| Time elapsed since last calibration (transmitter to output value) | 17.45 | Table GN17-3: | Use default value | | |
| Time elapsed since last calibration or inspection of primary flow device | 17.46 | Table GN17-4: | Use default value | | |
| Sum of all $U_e^2 = U^2$ | | | | | Total |
| Overall Uncertainty, $U_o = \text{Square root } U^2$ | | | | | |
| Acceptable Uncertainty for “Best Practice”, UBP (GN17.12-GN17.14) | | | | | |
| Excess Uncertainty, $U_x = U_o$ minus UBP ($U_x = 0$ if $U_o < \text{UBP}$) | | | | | |

Table GN17-2 – Default values of additional uncertainty due to fluctuations in fluid properties

| | Meter Type 1* | Meter Type 2** | |
|--|--|-------------------|----------------------------|
| Metered fluid | Effective Uncertainty, U _e | | Additional requirements |
| Superheated steam | | | |
| (a) pressure and temperature compensated | 0.0 | 0.0 | - |
| (b) pressure compensated only | 2.0 | 4.0 | Note 1 |
| (c) temperature compensated only | 2.0 | 4.0 | Note 1 |
| (d) uncompensated | 3.0 | 6.0 | Note 1 |
| Saturated steam | | | |
| (a) pressure compensated | 0.0 | 0.0 | - |
| (b) uncompensated | 2.0 | 4.0 | Note 1 |
| Commercial fuel oils | 0.0 | 0.0 | Note 1 |
| Natural gas | | | |
| (a) pressure and temperature compensated | 0.0 | 0.0 | - |
| (b) uncompensated | 0.0 | 0.0 | Note 1 |
| Other fuel oils and fuel gases | N/A | N/A | Note 2 |
| Heat metering of circulating fluids | 0.0 | 0.0 | Note 1 |

*Type 1: Primary signal proportional to square of flow rate, e.g. orifice plate, venturi, averaging pitot and “V-cone”.

**Type 2: Primary signal directly proportional to flow rate e.g. vortex shedding, coriolis, ultrasonic and “Gilflow”.

Notes

1 The use of the default values is conditional upon the appropriate action being taken to identify and compensate for any bias that results from differences between fluid properties at actual, typical or average flow conditions and the properties used in the computation of the metered energy input or output. Refer to GN23 for the treatment of bias.

2 For these fuels the uncertainty associated with fluctuations in fluid properties, including calorific value, is case-specific and must be established using the methods set out in GN17.25 and GN18.

Table GN17-3 – Default values of additional uncertainty due to time elapsed since transmitter calibration and validation of computation

| Time elapsed since transmitter calibration | Effective Uncertainty |
|--|-----------------------|
| ≤ 2 years | 0.0 |
| > 2 – 3 years | 2.0 |
| > 3 – 5 years | 4.0 |
| > 5 years | 10.0 |

Table GN17-4 – Default values of additional uncertainty due to time elapsed since calibration or inspection of primary device

| Time elapsed since calibration or inspection | Effective Uncertainty Ue |
|--|--------------------------|
| ≤ 5 years | 0.0 |
| > 5 – 7 years | 3.0 |
| > 7 – 10 years | 7.0 |
| > 10 years | 10.0 |

“EXPERT GUIDANCE” ON THE COMPONENTS OF METERING UNCERTAINTIES

Primary meter uncertainty

GN17.34

The manufacturer of a primary meter would normally provide data on the overall meter uncertainty, which would allow for the effect of the uncertainties in a number of individual factors, such as discharge coefficient, expansibility of the fluid, critical dimensions, calibration, look-up tables, etc. This simple figure, which would normally be in the range 0.5% to 1.5% of span depending on the type of meter, can be used to simplify the assessment of overall uncertainty. The Applicant should confirm that the meter is installed in accordance with the requirements of appropriate British Standard and the manufacturer’s specifications in terms of upstream and downstream straight lengths of pipe. The default value given in Table GN17-1 for uncertainty of the primary meter (correctly installed) is 1.0%. This value can be used where the Applicant chooses to employ the **Simplified Method** for determining the uncertainty of flow meters.

Transmitters and computations

GN17.35

The uncertainty from the transmitters and computation is associated with the conversion of the output from the primary device to the transmitted signal, the subsequent downstream output value, and its totalisation. This may be determined from the uncertainties associated with each step, usually available from

manufacturers' specifications, by following the procedures in GN17.24 or GN17.25 as appropriate. It should be noted that some transmitter data sheets specify the uncertainty as a percent of span, so the actual uncertainty is given by this value divided by the flow ratio. The default value given in Table GN17-1 for uncertainty of the transmitters and computations is 1.0%. This value can be used where the Applicant chooses to employ the **Simplified Method** for determining the uncertainty of flow meters.

Fluid properties

GN17.36

The uncertainty due to fluctuations in fluid properties is associated with the computation of the fluid mass flow rate, and its energy content, which are both normally derived from the metered output signals. The mass flow rate requires the density of the flowing fluid, which depends on temperature and, for gases and vapours, pressure and composition. The computation of energy content requires values for the mean specific heat or specific enthalpy of the fluid, again a function of temperature and, for gases and vapours, pressure and composition. For fuels, the calorific value is required. GN17.37 to GN17.44 give the background to the fluid properties that are included in Table GN17-2, and which are used to produce the default effective uncertainty values offered for the **Simplified Uncertainty Methodology for flow meters**.

Superheated steam density

GN17.37

This uncertainty applies to superheated steam flow measurement where the meter does not have automatic compensation for variations in steam density (i.e. pressure and temperature compensation). This uncertainty may be determined by recording a sufficiently large sample of steam pressure and temperature data (over a period of time that is long enough to ensure that the full range of steam flow conditions is represented) and then calculating the corresponding density for each data set. From these the mean density and the standard deviation should be calculated. The uncertainty is then taken as twice the standard deviation expressed as percent of the mean density. Note that the sensitivity coefficient S is 0.5 for Type 1 flowmeters or 1.0 for Type 2 flowmeters (see notes to Table GN17-2). The default values of U_e given in Table GN17-2 already include the uncertainty in the energy computation described in GN17.38 below.

Superheated steam energy computation

GN17.38

This uncertainty applies to superheated steam where a fixed specific enthalpy is assumed and used to determine its energy content (either within the flow computer or manually for self-assessment). The procedure to determine this uncertainty by measurement is as described in GN17.37, but this time it involves calculating the specific enthalpy for each data set using steam tables (electronic versions of steam tables are available, e.g. from ASME). The mean specific enthalpy and its standard deviation should then be calculated. The uncertainty is taken as twice the standard deviation expressed as a percentage of the mean specific enthalpy.

Saturated steam density and specific energy computation

GN17.39

The same considerations apply as for superheated steam, except that steam temperature compensation is not an issue as the saturation temperature depends on pressure only. The default values of U_e given in Table GN17-2 already include the uncertainty in the energy computation. The issue of steam wetness is discussed in GN17.40 below.

Saturated steam wetness

GN17.40

This is uncertainty in the final energy output value that follows from the uncertainty in the condition (wetness) of saturated steam. It does not apply to superheated steam. There are two elements that make up the uncertainty in energy content; (i) the effects of wetness on density and hence the metered mass flow; and (ii) the effect of wetness on the specific enthalpy. It may be shown that a (typical) wetness uncertainty of 3% results in an energy uncertainty of less than 1%. This is unlikely to have a significant influence on the overall meter uncertainty; therefore, for simplicity, the uncertainty due to saturated steam wetness may be ignored.

Commercial fuel oils

GN17.41

Providing the appropriate steps are taken to eliminate bias in the computation of the energy input (using the correct density and calorific value), the additional uncertainty due to variations in fluid properties for commercial fuel oils is unlikely to be significant and may be ignored. The default value is therefore shown as 0.0 in Table GN17-2.

Natural gas and LPG

GN17.42

Providing the appropriate steps are taken to eliminate bias in the computation of the energy input (using the correct density and calorific value), the additional uncertainty due to variations in fluid properties of natural gas and LPG is unlikely to be significant and may be ignored. The default value is therefore shown as 0.0 in Table GN17-2.

Other fuel oils and fuel gases

GN17.43

Since the properties and calorific values of other liquid and gaseous fuels (such as by-product fuels) may be subject to significant fluctuations, no default values can be given in Table GN17-2. For these fuels the uncertainty associated with fluctuations in fluid properties, (including calorific value), is case-specific and must be established by the Applicant using the methods set out in GN17.25 and in GN18.

These deal with the estimation of uncertainty in calculated values.

Heat metering of circulating fluids

GN17.44

These include circulating hot water or glycol solutions and thermal fluids, which may

be natural or synthetic oils. Providing the appropriate steps are taken to eliminate bias in the computation of the energy input (using the correct density and specific heat), the additional uncertainty due to variations in fluid properties is unlikely to be significant and may be ignored. The default value is therefore shown as 0.0 in Table GN17-2.

Calibration excluding primary flow element

GN17.45

Additional uncertainty arises due to the time elapsed since the last calibration of the transmitter and the data capture system (i.e. from transmitter to the logged output value). To be treated as “good practice” at least biennial (every 2-years) calibrations are required. Table GN17-3 shows the additional uncertainty to be added where the calibration intervals exceed two years.

Calibration of primary flow element

GN17.46

Additional uncertainty arises due to the time elapsed since the last calibration of the primary flow device. To be treated as “good practice” a calibration at least every 5 years is required. Table GN17-4 shows the additional uncertainty to be added where the calibration intervals exceed five years.

Exceptions to Simplified Method in GN17.27 to GN17.33

GN17.47

Electricity meters that do not have a valid current calibration certificate or certificate of conformity (see GN13.18) shall have an excess uncertainty of 5% imposed.

Packaged (commercial) heat meters that do not have a valid current calibration certificate or certificate of conformity shall have an excess uncertainty of 10% imposed (see Tables GN 17-3 and GN 17-4).

Note: These excess uncertainties are used to determine overall uncertainty adjustment factors as set out in GN19.

Solid fuel weighing devices (such as weighbridges and belt weighers)

GN17.48

Solid fuel weighing devices that do not have a valid (current) calibration certificate (see GN13.16) shall have an excess uncertainty of 5% imposed.

Packaged Heat meters

GN17.49

Packaged heat meters that do not have a valid (current) calibration or verification certificate or certificate of conformity (see GN13.17) shall have an excess uncertainty of 10% imposed.

Example GN17-1 – Calculation of Flow Meter Uncertainty (Work Sheet)

| | | | | | |
|--|---|--|--------------------------------|-----------------------------|-----------------------|
| Flow Meter | Tag Number: M9(FQ) | | Metered fluid: MP Steam | | |
| Line conditions | Pressure, bar(g) | 10 | Temperature, °C | 200 | |
| Meter type – Primary device (tick appropriate box) | Orifice Plate <input checked="" type="checkbox"/> | Venturi | Averaging pitot | “V-cone” | “Gilflow” |
| | Vortex shedding | Coriolis | Turbine | Other (please specify) | |
| Table of Uncertainties | Ref GN | Effective Uncertainty, Ue | | | Ue² |
| | | Default value of Ue, % | Claimed value of Ue, % | Ref to source data attached | |
| Primary meter uncertainty | 17.34 | 1.0 | 0.72 | O/P data sheet | 0.5184 |
| Transmitter and computations | 17.35 | 1.0 | | | 1.0000 |
| Fluctuations in fluid properties | 17.36 to 17.44 | Table GN17-2: 3.0 Uncompensated SH Steam | | | 9.0000 |
| Time elapsed since last calibration (transmitter to output value) | 17.45 | Table GN17-3: 2.0 30-months | Use default value | | 4.0000 |
| Time elapsed since last calibration or inspection of primary flow device | 17.46 | Table GN17-4: 3.0 6-years | Use default value | | 9.0000 |
| Sum of all Ue² = U² | | | | | Total |
| | | | | | 23.5184 |
| Overall Uncertainty, Uo = Square root U² | | | | | 4.85% |
| Acceptable Uncertainty for “Best Practice”, UBP (GN17.12-GN17.14) | | | | | 3.00% |
| Excess Uncertainty, Ux = Uo minus UBP (Ux = 0 if Uo <UBP) | | | | | 1.85% |

Notes to example GN17-1:

MP steam is supplied to site as superheated steam at a typical pressure of 10bar(g) and a temperature of 200°C. The steam flow meter is an orifice plate with differential pressure sensor. It has been confirmed that the meter's mass flow computation uses the correct steam density applicable to the typical line conditions, so no correction for bias is necessary. The meter is not pressure or temperature compensated, its transmitter was last calibrated 30 months ago and the orifice plate was last inspected 6 years ago (from the mid-point of the self-assessment period). Using the default values given in GN17 (except for the orifice plate itself) the uncertainty associated with this measurement is 4.85%. UBP = 3% of reading.