

# GUIDANCE NOTE 23

## CORRECTION OF BIAS IN INPUTS AND OUTPUTS

### SCOPE

#### GN23.1

This GN gives detailed guidance to enable the Responsible Person to:

- appreciate the importance of detecting and correcting bias in the measured or calculated value to restore or maintain the quality (accuracy) of that value.
- take the actions necessary to detect and correct bias.

### SIMPLE DEFINITION OF BIAS

#### GN23.2

**Bias** is a **systematic error** in a measurement or calculated value that arises from a shortcoming in a quantity or value that influences the measurement.

$$\text{Bias \%}, B = 100 \times (V_i - V_t) / V_t$$

Where

$V_i$  = indicated value

$V_t$  = true value

$$\text{Correction factor}, F_c = V_t / V_i = 100 / (B + 100)$$

### RELEVANCE TO CHPQA

#### GN23.3

Where a bias can be recognised in a measurement or calculation, an appropriate correction, which may be either positive or negative, must be applied to the measured or calculated values of that variable.

#### GN23.4

It is the duty of the Responsible Person to ensure that all necessary steps are taken to ensure that the appropriate checks are carried out to detect and correct bias in all measurements or calculations that form part of the self-assessment and that the results of such checks are recorded. Failure to comply with this requirement may result in withdrawal or refusal of Certification under CHPQA.

### SOURCES OF BIAS AND REMEDIAL ACTION REQUIRED

#### GN23.5

Bias due to primary element or transmitter errors may be addressed by calibration. Regular maintenance and calibration of all instruments that are required for self-assessment is a cornerstone of CHPQA.

### **GN23.6**

Bias may result from errors or wrong assumptions in calculations that are built into a metering system. For example, a flow meter measuring steam or gas flow that is not automatically compensated for density (which depends upon temperature, pressure, molecular weight and compressibility) may have a fixed density value built into its computation. Such a fixed value may be based on a pressure, temperature or composition that systematically differs from the actual mean flow conditions (irrespective of short-term fluctuations). This will result in a systematic error (bias) in the measured value that is quantifiable. For historical data a correction factor may be applied to recorded values but, whenever possible, the source of the bias should be eliminated by upgrading the calculation.

### **GN23.7**

Energy inputs or outputs that are derived by calculation from a number of other measurements and assumptions may also be subject to systematic errors (bias as opposed to uncertainty). All calculation procedures must be checked to detect and correct any such errors. All calculation methods must be fully documented and made available for CHPQA inspection.

### **GN23.8**

In general, if a bias can be detected that is significant in magnitude relative to the required accuracy of the measurement, a correction or correction factor must be applied to compensate for the resulting error. Whenever a correction is applied a formal record of its basis and its details must be retained for CHPQA inspection.

### **GN23.9**

Some of the common sources of bias in the computation of energy inputs and outputs are:

- Failure to use the appropriate fuel oil density at the point of measurement in converting from metered volume to mass
- Use of incorrect calorific values
- Inappropriate use of the net (lower) calorific value as opposed to the gross (higher) calorific value
- Use of the actual metered volume of gas at line conditions with a calorific value that is based on gas volume at standard conditions of 15°C/1.013 mbar
- Use of a fixed calorific value for natural gas (when the current value taken from the appropriate gas bill should be used)
- Use of fixed calorific values and/or density or gases that are variable in composition and pipeline conditions
- Failure to use the appropriate hot water density at the point of measurement in converting from metered volume to mass
- Use of incorrect steam density. See GN23.11
- Use of incorrect steam specific enthalpy. See GN23.12

- Failure to express steam specific enthalpy relative to water at 10°C when calculating heat outputs for CHPQA (when the value from the steam tables (relative to water at 0°C) minus 42 kJ/kg should be used)
- Incorrect positioning of decimal place in a sequence of digits read from a meter
- Incorrect information or assumptions regarding the units that a meter reading represents

## DETECTION AND CORRECTION OF BIAS IN STEAM ENERGY OUTPUTS

### GN23.10

Some of the most common and significant errors are due to the use of inappropriate fixed values for steam density and specific enthalpy in the computation of its energy content. GN23.11 and GN23.12 give detailed guidance on this subject. The identification and correction of bias is illustrated by means of Example GN23-1.

### Bias due to incorrect density

#### GN23.11

Where a steam flow measurement is not automatically compensated for pressure (all steam) and temperature (superheated steam) the computation of mass flow will use a fixed value for steam density that may differ from the actual density.

The first step to be taken to detect any bias is to determine the density of the steam at line conditions, which requires knowledge of the line pressure and temperature (superheated steam). These should be determined by taking a series of measurements (at least 40 sets) of pressure and temperature over a period of time that is long enough to ensure that the full range of steam flow conditions will be represented. It is important that reliable (calibrated) instruments are used for these measurements. Ideally the steam density should be determined for each set of readings (using steam tables or steam density tables) and the mean value of all sets of readings calculated. A less demanding alternative, with little loss of accuracy, is to calculate the average pressure and average temperature and use these average figures to derive a mean steam density. The second step, by reference to the meter data sheet, is to determine the density value that is used in the mass flow calculation. The bias is then given by the expression:

$B_{\text{density}} = [(\rho_d / \rho_a)^{0.5} - 1] \times 100$  for meters that measure **differential pressure** (e.g. orifice plate, venturi, pitots, "V-cone", "Gilflow")

$B_{\text{density}} = [(\rho_d / \rho_a) - 1] \times 100$  for meters that measure **volumetric flow** (e.g. vortex shedding)

Where  $B_{\text{density}}$  = bias in mass flow due to density error, %

$\rho_a$  = actual mean steam density

$\rho_d$  = steam density used in calculation of mass flow

To eliminate the bias the mass flow computation should be modified to use the actual mean steam density. To retrospectively correct mass flows, the correction factor ( $F_m$ ) by

which the metered outputs should be multiplied is derived using the expression:

$$F_m = 100 / (100 + B_{\text{density}})$$

Simplifying:  $F_m = (\rho_a / \rho_d)^{0.5}$  for differential pressure flow meters and  
 $F_m = \rho_a / \rho_d$  for volumetric flow meters

### Bias due to incorrect specific enthalpy.

#### GN23.12

Where a steam energy flow measurement is not automatically compensated for pressure (all steam) and temperature (superheated steam), the computation of energy flow will use a fixed value for steam specific enthalpy that may differ from the actual specific enthalpy. Note that flowmeters where the mass flow computation is pressure and temperature compensated may not have compensation for changes in specific enthalpy. The first step to be taken to detect any bias is to determine the specific enthalpy of the steam at line conditions, which requires knowledge of the line pressure and temperature (superheated steam) and which is to be measured as described in GN23.11.

Ideally the steam specific enthalpy should be determined for each set of readings (using steam tables) and the mean value of all sets of readings calculated. A less demanding alternative, with some loss of accuracy, is to calculate the average pressure and average temperature and use these average figures to derive a mean steam specific enthalpy. The second step, by reference to the meter data sheet, is to determine the specific enthalpy value that is used in the energy flow calculation. The bias is then given by the expression:

$$B_{\text{enthalpy}} = [(h_d / h_a) - 1] \times 100$$

Where:  $B_{\text{enthalpy}}$  = bias in energy flow due to specific enthalpy error, %

$h_a$  = actual mean steam specific enthalpy

$h_d$  = steam specific enthalpy used in calculation of energy flow

To eliminate the bias, the energy flow computation should be modified to use the actual mean specific enthalpy. To retrospectively correct metered energy flows, the correction factor ( $F_h$ ) by which the metered outputs should be multiplied is given by the expression:

$$F_h = 100 / (100 + B_{\text{enthalpy}}) = h_a / h_d$$

Note that the adjustment of steam energy outputs to become relative to a datum (base line) of water at 10°C, as required for CHPQA, from the steam table datum of 0°C, is a bias that may be corrected manually. The appropriate adjustment is given by:

$$Q_{10^\circ\text{C}} = Q_{0^\circ\text{C}} \times (h_s - 42.1) / h_s$$

Where:  $Q_{10^\circ\text{C}}$  = heat output relative to a datum of 10°C

$Q_{0^\circ\text{C}}$  = heat output relative to a datum of 0°C

$h_s$  = mean steam specific enthalpy relative to 0°C datum, kJ/kg

## EXAMPLE GN23-1

### CORRECTION OF BIAS IN STEAM FLOW AND ENERGY CONTENT

#### Steam flow measurement

The flow of superheated steam to a site is metered by means of an orifice plate flow meter that is connected via a transmitter to a DCS system. The meter does not have pressure or temperature compensation. The steam flow is stored as an integrated mass flow in tonnes and also in terms of energy in MWh. The mass flow of steam is derived from a 4-20 mA signal that is proportional to a measured differential pressure of 0 – 500 mbar, representing a meter span (range) of 0 - 20,000 kg/h. The computation of mass flow is based on the meter's design steam condition of 20 bar(a) pressure and 250°C. Steam density ( $\rho_d$ ) at these conditions is 8.9673 kg/m<sup>3</sup> and its specific enthalpy ( $h_d$ ) is 2,903.3 kJ/kg (0°C datum).

#### Average actual steam condition

A study was carried out whereby the actual steam pressure and temperature were measured over a range of steam demands. It was established that the average pressure was 17.25 bar(a) and the average temperature was 234°C. Steam density at these conditions ( $\rho_a$ ) is 7.9649 kg/m<sup>3</sup> and its specific enthalpy (0°C datum) is 2,874.8 kJ/kg. For CHPQA self-assessment (10°C datum) the specific enthalpy ( $h_a$ ) is

$$[2,874.8 - 42.1] = 2,832.7 \text{ kJ/kg.}$$

#### Mass flow bias and correction factor

$$\text{Mass flow bias} = [(\rho_d / \rho_a)^{0.5} - 1] \times 100 = [(8.9673 / 7.9649)^{0.5} - 1] \times 100 = +6.1062\%$$

$$\text{Mass flow correction factor} = F_m = (\rho_a / \rho_d)^{0.5} = (7.9649 / 8.9673)^{0.5} = 0.9425$$

#### Energy flow bias and correction factor

$$\text{Energy flow bias} = [(h_d / h_a) - 1] \times 100 = [(2903.3 / 2832.7) - 1] \times 100 = +2.4923\%$$

$$\text{Energy flow correction factor} = F_h = h_a / h_d = (2832.7 / 2903.3) = 0.9757$$

#### Overall energy flow correction factor

$$\text{Overall energy flow correction factor} = F_m \times F_h = 0.9425 \times 0.9757 = 0.9196$$