# UKETS02 MRR/FAR - Uncertainty Assessments for Installations

February 2025

**Note**

**This document is intended to provide guidance for operators of installations. If there is any inconsistency between the guidance and legislation, the legislation prevails.**



Any enquiries regarding this publication should be sent to us at:
emissions.trading@energysecurity.gov.uk

# Contents

# Overview

This guidance will help operators of installations understand their obligations relating to uncertainty in the UK Emissions Trading Scheme (UK ETS).

The relevant legislation in this area is:

- **The Greenhouse Gas Emissions Trading Scheme Order 2020** (**The Order**) (https://www.legislation.gov.uk/uksi/2020/1265/contents) as amended from time to time
- **The Monitoring and Reporting Regulation** (**MRR**) (Commission Implementing Regulation (EU) 2018/2066 of 19 December 2018) on the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council (disregarding any amendments adopted after 11 November 2020) as given effect for the purpose of the UK ETS by article 24 of the Order, subject to the modifications made for that purpose from time to time
- **The Free Allocation Regulation** (**FAR**) (Commission Delegated Regulation (EU) 2019/331 of 19 December 2018) as it forms part of domestic law as amended from time to time
- **The Verification Regulation** (**VR**) (Commission Implementing Regulation (EU) 2018/2067 of 19 December 2018 on the verification of data and on the accreditation of verifiers pursuant to Directive 2003/87/EC of the European Parliament and of the Council (disregarding any amendments adopted after 11 November 2020), as given effect for the purpose of the UK ETS by article 25 of the Order, subject to the modifications made for that purpose from time to time

# 1 What is uncertainty?

Uncertainty combines the concepts of accuracy and precision, thus quantifying how close emissions data are to the true value. It is important to understand that these terms have different meanings and should not be interchanged. They are defined below.

## 1.1 Definitions

**Accuracy:** This means closeness of agreement between a measured value and the true value of a quantity. If a measurement is accurate, the average of the measurement results is close to the 'true' value. For example, when measuring instruments are calibrated, a series of measurements are compared to the measurement from a certified reference material. Inaccurate measurements can often be overcome by calibrating and adjusting measuring instruments.

**Precision:** This describes the closeness of results of measurements of the same measured quantity under the same condition. That is, how repeatable is the result if the same measurand is measured several times. It is often quantified as the standard deviation of the values around the average. It reflects the fact that all measurements include a random error, which can be reduced, but not eliminated.

**Uncertainty:** This term characterises the range within which the true value is expected to lie with a specified level of confidence.

As shown in Figure 1 below, measurements can be accurate, but imprecise, or vice versa. The ideal situation is precise and accurate. The bull's eye represents the assumed true value, the 'shots' represent measurement results. The bull's eye represents the assumed true value, the shots represent measurement results.[1]

[1] Source: Guidance Document 4 The Monitoring and Reporting Regulation – Guidance on Uncertainty Assessment (https://ec.europa.eu/clima/system/files/2021-10/policy_ets_monitoring_gd4_guidance_uncertainty_en.pdf)

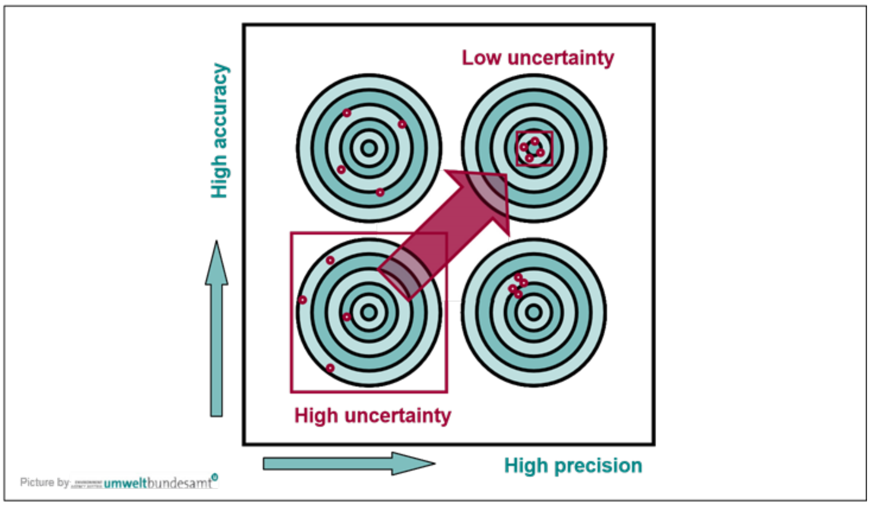
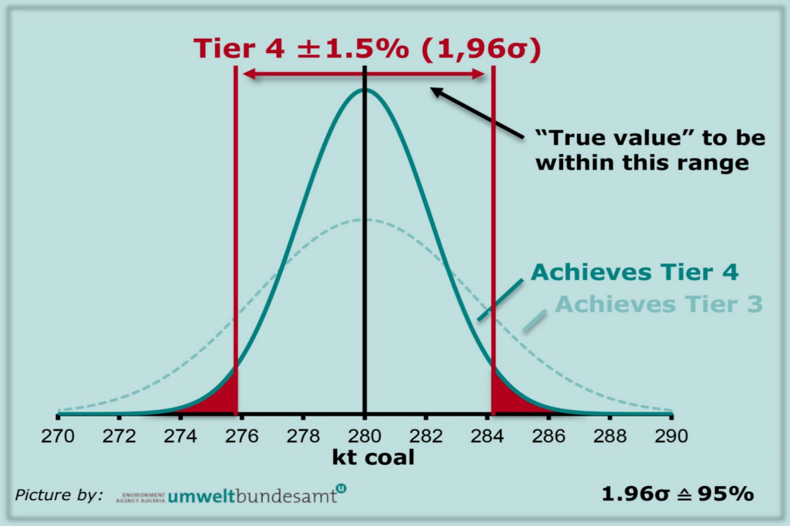



**Figure 1 Illustration of the concept accuracy, precision and uncertainty**

Article 3(6) of the Monitoring and Reporting Regulation (MRR) specifies that an uncertainty must have a 95% confidence level (meaning that there is 95% chance the correct value lies within the interval stated) which, assuming that the dispersion of the uncertainty is following a normal distribution, the standard uncertainty would equal one standard deviation and correspond to a probability of only 68% that the correct value is covered within that range. To increase this probability to 95% the standard uncertainty is multiplied by 1.96 (the **coverage factor**) to calculate the **expanded uncertainty**. In practice this value is often rounded to 2 (2σ).

This is illustrated in the example below.

**Example:** A category C installation consumes 280,000 tonnes of coal annually. For this type of installation, tier 4 is required for the determination of the fuel quantity (uncertainty: ±1.5%). This means that the measurement system needs to provide results that allow the 'true value' to be within 280 ± 4.2 kt (±1.5%) at the 95% (2σ) confidence level, as shown in the graph below.




Source: Guidance Document 4 The Monitoring and Reporting Regulation – Guidance on Uncertainty Assessment (https://ec.europa.eu/clima/system/files/2021-10/policy_ets_monitoring_gd4_guidance_uncertainty_en.pdf)

## 1.2 Uncertainty in the Monitoring and Reporting Regulation

Bands of uncertainty threshold, or tiers, are used to describe uncertainty levels that must be met for specific parameters. The general principle is that operators should monitor to the highest achievable accuracy and, if using a lower tier, strive to reach a higher tier.

The magnitude of emissions involved, and scale of operation means that installations with the largest emissions must monitor their data with the lowest uncertainty (highest tier). Conversely, installations with the lowest emissions can apply some simpler approaches (lower tiers). All operators can use lower tiers if they demonstrate to their regulator that meeting a higher tier is too expensive or is technically not possible.

Article 12(1) of the MRR requires operators to submit an uncertainty assessment with their monitoring plan to their regulator that demonstrates that they comply with the tiers defined in Annexes II, IV and Annex VIII of the MRR, where applicable.

The uncertainty assessment provides:

- Evidence for compliance with uncertainty thresholds for activity data for major and minor source streams. Guidance is provided in Chapter 2.
- Evidence for compliance with uncertainty required for calculation factors for major and minor source streams. Guidance is provided in Chapter 2, section 2.6.
- Evidence for compliance with uncertainty requirements for measurement-based methodologies, if applicable. Guidance is provided in Chapter 3.
- Evidence for the total emissions of the installation where a fall-back methodology is applied for at least part of the installation, confirming that the uncertainty threshold according to Article 22(c) is met. Guidance is provided in Chapter 4.

Operators must submit an uncertainty assessment when they seek approval to a new monitoring plan or when they propose changes to their approved monitoring plan if the proposed changes affect the applied monitoring tiers. The monitoring plan must reflect the tier that is applied and not just the minimum one that is required.

During verification, operators must retain evidence for their verifier that the information used to calculate the uncertainty levels is valid (Article 19(1) of the Verification Regulation.

The MRR allows for several simplification options, providing operators with options to demonstrate that the uncertainty levels correspond to certain tiers, as shown in Figure 2. Those options (or routes) are assigned codes throughout this document. For example, if a calculation based methodology is applied and the activity data of a source stream are monitored by a measurement system outside the operator's own control, chapter 2 and sections 2.3.2, 2.3.3 and 2.3.4 (routes CT-1, CT-2 or CT-3) will provide guidance for assessing uncertainty related to that activity data.

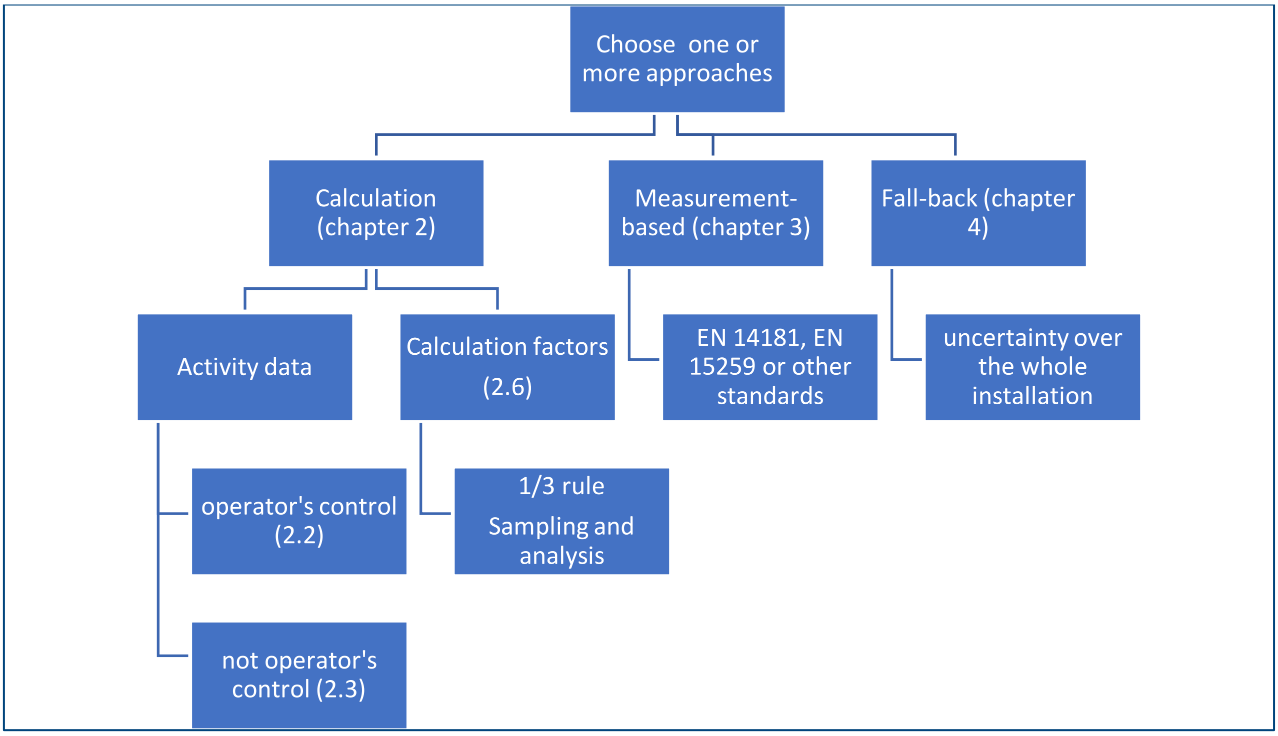



**Figure 2 Overview of chapters in this document regarding determination of uncertainty**

### 1.2.1 Simplifications for low emitting installations, including HSEs

Operators of low emitting installations (as set out in Article 47 of the MRR) and operators of installations that are hospital or small emitters (HSEs) are exempt from:

- submitting an uncertainty assessment to their regulator
- including uncertainty relating to stock changes in their uncertainty assessment

Operators of low emitting installations may use purchasing records, such as gas bills, and estimated stock changes to determine the amount of fuel used. They may also apply, as a minimum, tier 1 for determining activity data and calculation factors unless they can achieve a higher accuracy without additional effort and without providing evidence to their regulator that it is technically not feasible or would incur unreasonable costs.

Due to the legal metrological controls upon fuel billing, low emitting installations may propose an uncertainty value of 6% for individual fiscal gas meters and may assume that the metering of gas complies with tier 1[2] No further evidence or assessment of uncertainty is required. The application of tier 1 may not reflect the true tier achievable by the operator, but it serves to minimise the administrative burden.

[2] See Table 3 in section 2.3.5.2, right hand column for how this is derived for natural gas meters.

Operators of low emitting installations may choose to read their own meters as part of their control measures to ensure accurate records of natural gas consumption. However, this does not impact on the validity of a low emitting installation from applying tier 1.

For major or minor liquid fuel source streams operators of low emitting installations can assume that the source stream meets tier 1 and state that the overall uncertainty meets <7.5%. No further evidence or assessment of uncertainty is required.

If an operator of a low emitting installation or a HSE chooses to apply a tier that is higher than the minimum requirement, they must retain evidence for their verifier showing how they have derived this (unless the operator is a hospital or small emitter that chooses to self-verify their emissions).

The operator must still be able to demonstrate to their verifier, if applicable, how they comply with the required tiers so that their verifier can confirm the validity of the information used to calculate the uncertainty (Article 19(1) of the Verification Regulation).

An exemplar uncertainty assessment for an installation with low emissions can be found in Chapter 9.

# 2 Uncertainty for calculation-based approaches

The equation in the example below shows the standard calculation method for the combustion of fuels. The parameters within the formulae are either activity data or calculation factors:

- **Activity data (AD):** tiers here relate to the required minimum uncertainty over the reporting period of the amount of fuel combusted (see section 2.1).
- **Calculation factors (NCV, EF, OF, BF)).** Tiers here relate to specific methodologies that are set out in the MRR for the determination of each factor, for example using default values or carrying out analyses (see section 2.6)

.

**Example:** Standard calculation method in accordance with MRR Article 24(1) for combustion of fuels

$$\boldsymbol{Em = AD \times NCV \times EF \times OF \times (1 - BF)}$$

Where:

$Em$ …. Emissions (t CO2)

$AD$…...Activity data (fuel quantity) (t or $Nm^3$)

$NCV$ …Net calorific value (TJ/t or t J/$Nm^3$)

$EF$ …. Emission factor (t CO2/TJ, t CO2/t or t CO2/ $Nm^3$)

$OF$ …. Oxidation factor (dimensionless)

$BF$ …. Biomass fraction (dimensionless)

## 2.1 Activity data

This section applies to both the input and output material of a source stream monitored by a mass balance approach, as well as source stream monitored by a calculation approach.

Operators may determine their activity data:

- Based on continual metering of the process which causes the emissions, or
- Based on aggregation of metered amounts separately delivered taking into account relevant stock changes.

The tiers for activity data of source streams are defined using thresholds for a maximum uncertainty allowed for the determination of the quantity of fuel or material over a scheme year (which is a calendar year).

The uncertainty assessment must account for all sources of uncertainty, including uncertainty of measuring instruments, of calibration, any additional uncertainty connected to how the measuring instrument is used in practice, and environmental impacts, unless some simplifications are applicable. The impact of the determination of stock changes at the beginning and end of the period must be included, where applicable (see example 7 in section 8.3).

Table 1 illustrates the tier definitions for the combustion of fuels. A full list of the tier thresholds can be found in section 1, Table 1 in Annex II of the MRR.

**Table 1 Typical definitions of tiers for activity data based on uncertainty for the combustion of fuels**

| Tier No. | Definition |
|---|---|
| 1 | Amount of fuel [t] or $[Nm^3]$ over the scheme year is determined with a maximum uncertainty of less than ± 7.5 %. |
| 2 | Amount of fuel [t] or $[Nm^3]$ over the scheme year is determined with a maximum uncertainty of less than ± 5.0 %. |
| 3 | Amount of fuel [t] or $[Nm^3]$ over the scheme year is determined with a maximum uncertainty of less than ± 2.5 %. |
| 4 | Amount of fuel [t] or $[Nm^3]$ over the scheme year is determined with a maximum uncertainty of less than ± 1.5 %. |

In principle there are two possibilities for determining the activity data in accordance with Article 27(1):

- Based on continual metering of the process which causes the emissions
- Based on aggregation of metered amounts separately delivered taking into account relevant stock changes.

The MRR does not require every operator to equip the installation with measuring instruments at any cost. That would contradict the MRR's approach regarding cost effectiveness. Instruments may be used which are either under the operator's own control or under the control of other parties.

Activity data and/or calculation factors can be determined using measuring instruments that are either under the operator's control (preferred approach) or under the control of another party, such as the supplier of the fuel or material. If a supplier's measuring instruments are governed by legal metrological control, operators may assume that the uncertainty associated with the measurement is reasonably low. If the supplier's measuring instruments are not governed by legal metrological control, the operators could include quality assurance for the measuring instruments, such as maintenance and calibration in the purchase contracts. However, the operator must seek a confirmation of the uncertainty applicable for such meters to assess if the required tier can be met.

If the operator decides to use a supplier's measuring instruments, even if they could use their own instruments, they must provide evidence to their regulator that the supplier's measuring instruments allow compliance with at least the same tier, give more reliable results and are less prone to control risks than applying the methodology based on their own measuring instruments. This evidence must be accompanied by a simplified uncertainty assessment

## 2.2 Measurement systems under the operator's own control

### 2.2.1 General aspects

Operators must ensure that the applicable uncertainty threshold of the tiers set out in Articles 26 and 41 of the MRR are met. Uncertainty assessments are a means to provide robust evidence that the uncertainty of the measurement system meets the required tier.

According to Article 3(29) of the MRR, a measurement system is 'a complete set of measuring instruments and other equipment, such as sampling and data-processing equipment, used to determine variables such as the activity data, carbon content, the calorific value or the emission factor of the greenhouse gas emissions.' The measurement system includes instruments such as temperature and pressure probes, flow meters and telemetry systems.

There can be many sources of uncertainty in a measurement system, such as errors that are caused by a lack of precision (for example, the meter's uncertainty as specified by the manufacturer for use in an appropriate environment, and certain conditions related to the installation of measuring equipment (such as the length of straight piping before and after a flow meter) and a lack of accuracy (for example, caused by ageing or corrosion of the instrument, which may result in drift). The MRR requires that the uncertainty assessment takes account of the measuring instrument's uncertainty, the influence from calibration and all other possible influencing parameters. This can mean that, in practice, uncertainty assessments can be demanding and so operators should focus on the most relevant parameters that contribute to the uncertainty.

The MRR allows several pragmatic simplifications to assessing uncertainty. These are illustrated in Figure 3.

The operator can choose to simplify the uncertainty assessment, if

- The measuring instrument(s) is subject to legal metrological control (Route CO-1). This is the simplest approach. In this case the maximum permissible error in service laid down in the relevant national legal metrological text can be used as the overall expanded uncertainty (see section 1.1 for an explanation of expanded uncertainty).
- The measuring instrument is not subject to national legal metrological control (NLMC) but is installed in an environment appropriate for its use specifications. In this case the operator may assume that the expanded uncertainty over the whole reporting period, as required by the tier definitions for activity data in MRR Annex II, equals:
    - the maximum permissible error specified for that instrument in service (Route CO-2a), or
    - where available and lower, the expanded uncertainty obtained by calibration, multiplied by a conservative adjustment factor (this is explained in more detail in section 2.2.4.4) for taking into account the effect of uncertainty in service (Route CO-2b).

Where the simplifications described above are not applicable, or do not show that the required tier is met, a full uncertainty assessment in accordance with Route CO-3 and Annex II of this document must be carried out.

If the operator cannot demonstrate that the tier required by the MRR has been met, they must take the necessary steps to comply with the MRR by:

- Carrying out corrective action, such as installing a measurement system that meets the tier requirements, or
- Provide evidence to their regulator that meeting the required tier is not technically feasible or would incur unreasonable costs and use the next lower tier in accordance with the result of the uncertainty assessment.

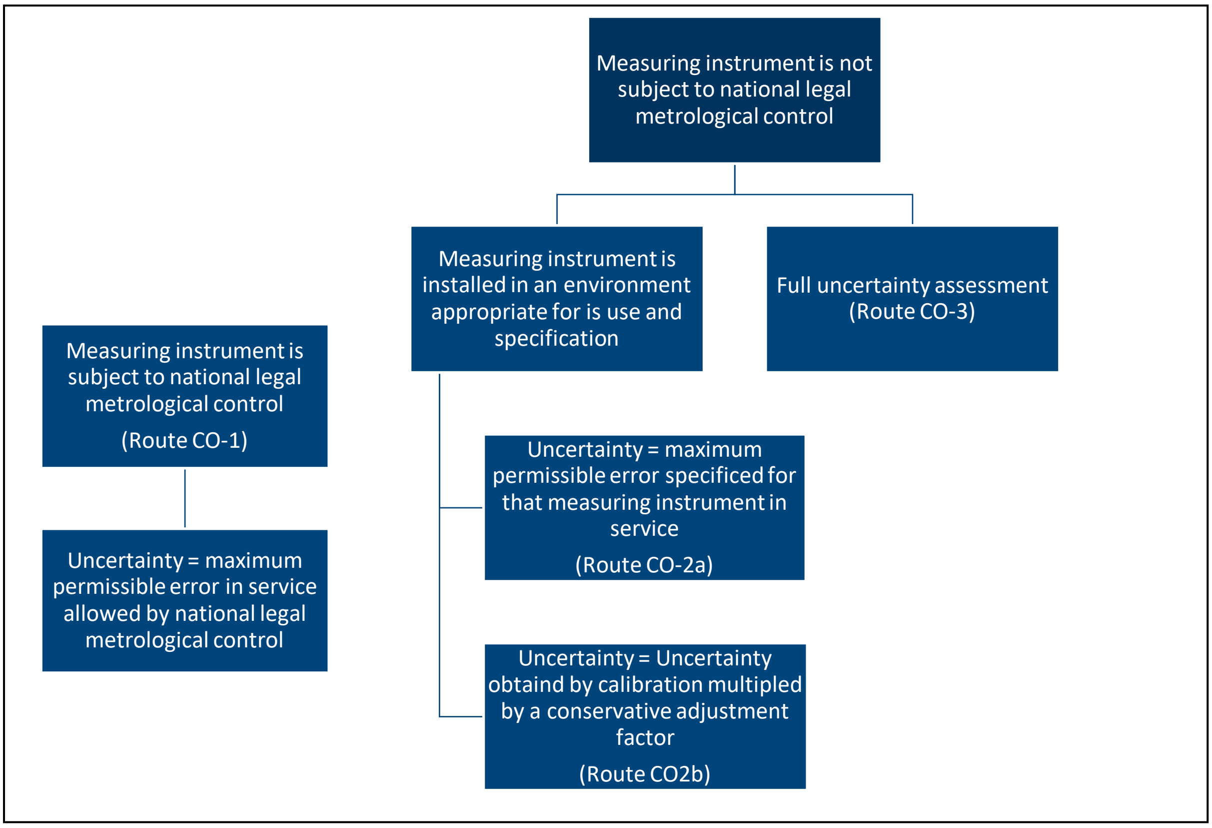



**Figure 3 Activity data for calculation-based approaches: approaches for determination of the uncertainty achieved** ('C' means calculation based, 'O' means instrument is under operator's own control)

### 2.2.2 Simplification 'Route CO-1'

| |
|---|
| Measuring instrument is subject to national legal metrological control (NLMC)<br><br>**Overall expanded uncertainty = maximum permissible error in service (MPES)** |

Article 3(24) of the MRR defines 'legal metrological control' to mean the control of the measurement tasks intended for the field of application of a measuring instrument, for reasons of public interest, public health, public safety, public order, protection of the environment, levying of taxes and duties, protection of the consumers and fair trading.

Measuring instruments subject to national legal metrological control (NLMC) are regulated for consumer protection purposes. NLMC instruments must meet minimum 'essential' requirements for their manufacture and use before they can be sold. The stringent requirements around measuring instruments subject to NLMC mean that they are considered more reliable than measuring instruments not subject to NLMC. For further information see ‘background information on maximum permissible errors under NLMC’ below.

The most appropriate evidence for being under NLMC is a certificate of official verification of the instrument.

Read section 2.3.5 on the specific requirements for natural gas meters for guidance on how to demonstrate that natural gas meters comply with NLMC. Sections 2.4 and 2.5 provide guidance on NLMC for liquid fuels and weighing devices.

**Background information on maximum permissible errors under NLMC**

Under legal metrological control calibration is considered valid where the expanded uncertainty resulting from the calibration procedure is lower than the maximum permissible error (MPE) in verification. The term ‘in verification’ is a metrological term here and must not be confused with verification under the UK ETS.

Furthermore, it is considered that the equipment under regular service (that is, in use) is exposed to measurement conditions that might have an impact on the measurement result (such as temperature, vibration, pressure). This aspect led to the introduction of a parameter called the maximum permissible error in service (MPE in service = MPES). This value represents a fair estimation of the uncertainty of a device under regular operation, which undergoes regular legal metrological control complying with the associated regulations. It sets a threshold for simplified checks which could be applied during regular operation and has therefore to be considered as the uncertainty which needs to be attributed to the daily operation of the measurement equipment. This means that the MPES is more appropriate for use to ensure a fair exchange of goods, the ultimate objective of legal metrological control.

For some measuring instruments the MPE ‘under rated operating conditions’ (values for the measurand and influence quantities making up the normal working conditions of an instrument) are regulated in The Measuring Instruments Regulations 2016 (SI 2016 No. 1153)[3] and The Non-automatic Weighing Instruments Regulations 2016 (SI 2016 No. 1152).[4]

Metrological control systems usually apply a factor of 2 to convert the maximum permissible error derived in verification into the maximum permissible error in service (MPES). Note that this factor is not derived from statistics (unlike the difference between standard and expanded uncertainty) but follows from general experience in legal metrology with measuring instruments which have undergone successful type approval tests.

[3] https://www.legislation.gov.uk/uksi/2016/1153/contents/made
[4] https://www.legislation.gov.uk/uksi/2016/1152/contents

For further background information, the presentation in Annex I of the European Commission's M&R Training Event on Uncertainty Assessment[5] may be helpful.

### 2.2.3 Simplification 'Route CO-2a'

| |
|---|
| Measuring instrument is not subject to national legal metrological control but is installed in an environment appropriate for its use specifications.<br><br>**Overall expanded uncertainty = maximum permissible error in service** |

The second simplification allowed by the MRR, applies to measuring instruments that are not subject to national legal metrological control but are installed in an environment appropriate for their use specifications. Please note that MPE and MPES values for instruments under NLMC are based on experience and they are not transferable to industrial measurement. However, the terms 'MPE' and 'MPES' for instruments not subject to NLMC are used here for simplicity reasons.

Article 28(2) of the MRR allows the operator to use the 'maximum permissible error in service' specified for the instrument as the overall uncertainty, 'provided that measuring instruments are installed in an environment appropriate for their use specifications'. The MPE in service is significantly higher than the MPE of a new instrument and is often expressed as a factor (usually 2) times the MPE of a new instrument.

Where no information is available for the MPES, or where the operator can achieve better values than the default values, the uncertainty obtained by calibration may be used, multiplied by a conservative adjustment factor (see section 2.2.4.4) for taking into account the higher uncertainty when the instrument is 'in service'. The latter approach reflects route CO-2b.

The MRR does not define the information sources for MPES or what 'appropriate use specifications' must be. However, operators may assume that the following are suitable sources for MPES:

- the manufacturer's specifications,
- specifications from legal metrological control, and
- guidance documents such as the UK ETS authority guidance (see Chapter 8 (Annex II) for illustrative conservative values for uncertainty ranges of common measuring instruments and additional conditions).

[5] https://ec.europa.eu/clima/system/files/2020-02/uncertainty_assessment_en.pdf

The uncertainties given in these sources may only be taken as the overall uncertainty if the measuring instruments are installed in an environment appropriate for their use specifications and steps 1 to 4 below are met. If this is the case values taken from these sources can be considered as representing the MPES and no further corrections to that uncertainty value are necessary.

The operator can assume they meet the requirements of Article 28(2) of the MRR, if they provide evidence that all the requirements of the following 4 steps are met:

**Step 1: Operating conditions regarding relevant influencing parameters are available**

The manufacturer's specification for that measuring instrument contains operating conditions that specify the environment appropriate for its use regarding relevant influencing parameters (for example, flow, temperature, pressure, medium etc.) and maximum permissible deviations for these influencing parameters. Alternatively, the manufacturer may have declared that the measuring instrument complies with an international standard (CEN or ISO standard) or other normative documents (such as recommendations by Organisation Internationale de Métrologie Légale (OIML) http://www.oiml.org/), which lay down acceptable operating conditions for the relevant influencing parameters.

If the manufacturer's specifications do not contain requirements for operating conditions regarding relevant influencing parameters, the operator must carry out an individual uncertainty assessment (Route CO-3). However, in simple cases, expert judgement might be sufficient, especially for minor, de-minimis and marginal source streams and for installations with low emissions.

**Step 2: Operating conditions regarding relevant influencing parameters are met**

The operator provides evidence that the operating conditions regarding relevant influencing parameters are met. Evidence could take the form of a checklist of the relevant influencing parameters for different measuring instruments and compare for each parameter the specified range with the used range (see tables 15, 16 and 17 in section 8.1 for examples of influencing parameters). This list should be provided to the regulator as part of the uncertainty assessment when submitting a new or updated monitoring plan.

The result for this step should be an assessment that

- the measuring instrument is installed appropriately
- the measuring instrument is appropriate to measure the medium of interest
- there are no other factors that could have adverse consequences on the uncertainty of the measurement instrument.

Only if all of this is the case, can it be assumed that the MPES described in the 'suitable source' (see above) is appropriate for use without further correction.

### Step 3: Performing quality assured calibration procedures

Operators must compare the uncertainty of their instrument against the requirements of the MRR at least once per year and after each calibration. The uncertainty may be taken from the manufacturer's specifications, or initial calibration certificate if measurement instruments have been installed and used as the manufacturer intended.

Regular calibration (see route CO-2b for more information on 'calibration',) is performed by an institute accredited in accordance with EN ISO/IEC 17025, employing CEN, ISO or national standards where appropriate. Alternatively, if calibration is performed by a non-accredited institute or by a manufacturer's calibration, the operator must provide evidence (for example with a calibration certificate) of the suitability of the calibration method, that the calibration is performed using the instrument manufacturer's recommended procedure, by competent personnel and that the results comply with the manufacturer's specifications.

One way of checking that the measurement device can still meet the required tier level on an annual basis (assuming that it was installed and used correctly) is to demonstrate that the manufacturer's recommended maintenance procedures have been followed.

Complying with this requirement in Article 28 does not necessarily mean the device, for example a gas meter, needs to be removed for calibration every year[6]. However, for other measuring instruments such as weighbridges, annual calibration may be appropriate. Operators can check the manufacturer's recommendations/ technical specification or technical performance standards to help identify appropriate calibration intervals (see Annex I).

### Step 4: Further quality assurance procedures for measuring activity data

Article 59(3) of the MRR requires operators to establish, document, implement and maintain various written procedures to ensure an effective control system, including quality assurance of relevant measurement equipment, and handling of resulting data. Where certified quality or environmental management systems are in place, such as EN ISO 9001, EN ISO 14001, EN ISO 15001 to ensure that control activities (calibration, maintenance, surveillance and loss/failure management etc.) are carried out, it is recommended that these systems also include the quality assurance for measuring activity data under the UK ETS. If, through monitoring the effectiveness of control systems, the control system is found to be ineffective, the operator must improve the control system, updating the monitoring plan or underlying written procedures, as appropriate.

If the requirements of all 4 steps cannot be fulfilled, overall uncertainties may be calculated by combining the uncertainties provided in the 'suitable sources' and a conservative estimate of the uncertainty for the parameter(s) preventing compliance with one or more

[6] Gas meters are not routinely removed for calibration but are often chosen on the basis of statistical sampling. (17/04/2012 note of ETG WG 3/7 following presentation to UK Emissions Trading Group by Mark Way, National Grid)

steps (for example, the flow rate is partially outside the normal operating range) by applying error propagation (see route CO-3 and section 8.2 of Annex II).

### 2.2.4 Simplification 'Route CO-2b'

Measuring instrument is not subject to national legal metrological control but is installed in an environment appropriate for its use specifications

**Overall expanded uncertainty = expanded uncertainty from calibration multiplied by a conservative adjustment factor**

Operators may choose this simplification if the results provide a lower uncertainty than if they follow route CO-2a.

#### 2.2.4.1 Calibration[7]

The performance of regular calibration is the process where metrology (the infrastructure that covers the accuracy, precision and repeatability of a measurement) is applied to measurement equipment and processes to ensure conformity of measuring instruments in use with a known international measurement standard. It involves traceability or comparison with a 'standard' or between different measuring systems. This is achieved by using calibration materials or methods that ensure a closed chain of traceability to the 'true value' performed as a measurement standard.

Calibration should, if possible, be carried out by an EN ISO/IEC17025 accredited calibration laboratory. Appropriate calibration procedures and intervals may be found in the manufacturer's specification, standards provided by accredited laboratories, etc.[8]

Note 1: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2: Calibration should not be confused with adjustment of a measuring system, often mistakenly called 'self-calibration', nor with 'metrological' verification of calibration.

**Example:** Requirements for calibration of a flow meter for nonaqueous liquids with static start/stop measurement

[7] https://www.ukas.com/wp-content/uploads/2023/05/M3003-The-expression-of-uncertainty-and-confidence-in-measurement.pdf

[8] see 'International Vocabulary of Metrology Fourth Edition' https://www.bipm.org/documents/20126/54295284/VIM4_CD_210111c.pdf

For calibration the following aspects need to be considered:

- The flow meter is installed in accordance with the manufacturer's specifications
- The flow meter as well as the rest of the whole calibration system are filled completely and are free from gases
- The flow meter is at operating temperature
- All parameter settings, to the extent available, are documented
- During zero flow rate before and after the measurement no signal indicating a flow is detected
- The calibration conditions (for example, flow rate, temperature, pressure, liquid type) are within the operating conditions
- The flow rate is stable
- The pressure is high enough to avoid gasification or cavitation (the formation and then immediate implosion of cavities in a liquid, which may occur when a liquid is subjected to rapid changes of pressure, for example in turbines). Density and viscosity have an influence on the calibration curve as well. Therefore, it is optimal to calibrate under the same conditions as during (intended) normal operation and to use the same, if available, or similar liquids
- Adjusting to zero ('zeroing') is to be done before and not during a measurement series. Conditions of the liquid (temperature, pressure) are to be documented at the time of zeroing. Zeroing is not required if the output signal for zero flow rate is lower than the range for the zero-value provided by the manufacturer.

The core element of each calibration procedure is the comparison of measurement results with a reference standard by applying a procedure which enables the determination of a calibration function and of measurement uncertainties. The result of calibration will be a reliable assessment of the calibration function, its linearity (where this is a requirement) and the measurement uncertainty. The uncertainty obtained by calibration should, to the extent possible, relate to the operating range of the measuring instrument in actual use. Thus, the calibration procedure should reflect to the extent possible the operating conditions where the instrument is installed.

In many cases the measurand of interest is not measured directly but rather calculated from other input quantities with a functional relationship, for example, a volumetric flow (fV) is calculated by measuring inputs like density ($\rho$) and pressure difference ($\Delta p$) through the relationship $fV=fV(\rho, \Delta p)$. The uncertainty related to the measurand of interest will then be determined as the combined standard uncertainty via error propagation[9] (see Annex II). For the combined standard uncertainty associated with the measurement result, uncertainty contributions of long-term drift and operational conditions are also important influences which must be considered (along with the uncertainty associated with calibration itself).

Calibration certificates typically express uncertainty as the expanded uncertainty, meaning that there is no need to multiply the uncertainty from the calibration certificate by a further coverage factor (see section 1.1 for an explanation of coverage factors). However, if the calibration certificate states a standard uncertainty (i.e. a 68% confidence interval) then operators must multiply that value by a coverage factor, which is usually 2. This coverage factor is not the same as the conservative adjustment factor (see section 2.2.4.4).

#### 2.2.4.2 Frequencies of calibration

Depending on the type of measuring instrument and the environmental conditions the uncertainty of a measurement might increase over time (drift). To quantify and to mitigate the increase of uncertainty resulting from drift an appropriate time interval for recalibration is necessary.

In the case of a measuring instrument subject to NLMC (Route CO-1) the frequency of calibration (re-calibration) is regulated by the relevant legal text.

For other measuring instruments that are not subject to NLMC (for example flare gas meters and fuel gas meters) re-calibration intervals should be based on information provided by manufacturer's specifications or other suitable sources. As the result of every calibration allowing quantification of the drift that has occurred, a time series analysis of previous calibrations may also be helpful to determine the relevant calibration interval. Based on this information the operator should use appropriate calibration intervals subject to the regulator's approval.

In any case the operator must check annually if the measuring instruments used still comply with the tier required (as set out in Article 28(1)(b) of the MRR).

#### 2.2.4.3 Industry practice

Various situations need to be guarded against when it comes to calibration in industrial circumstances, including

- simplifications for applications that do not then meet requirements for calibration according to legal standards

[9] It is more appropriate to call it 'propagation of uncertainty' although 'error propagation' is more frequently used.

- single-point-tests or short checks that may be designed, for example, for checking the zero value and for providing day to day quality assurance, but which do not constitute full calibration
- postponement of calibrations due to favourable ad-hoc checks (suggesting proper operation of monitoring equipment) and due to the costs involved
- failure to follow-up the results of the calibration by making adequate corrections.

Problems may occur when a device is not easily accessible for calibration. For example, it can't be de-installed for checks or calibration during operation of the installation and the process cannot be shut down without major disruption to the installation or to the security of supply associated with the product. There may be long periods between shutdowns of the production process and in such cases a periodic calibration using shorter intervals may not be feasible.

Where only limited possibilities for calibration exist, the operator must seek approval from their regulator for an alternative approach (as set out in Article 60(1) of the MRR), enclosing alongside the submission of the monitoring plan any relevant evidence with regards to technical feasibility or unreasonable costs. The application of alternative standards must be considered within the hierarchy as set out in Article 32(1) of the MRR.

#### 2.2.4.4 Conservative adjustment factor

The expanded uncertainty obtained from calibration is multiplied by a conservative adjustment factor to consider random as well as systematic errors in service. The operator may determine the conservative adjustment factor based on experience, other sources of information, or use a typical value of 2 as a pragmatic yet appropriate approach. The result obtained may be used as the overall uncertainty without further corrections.

However, a conservative adjustment factor is only applicable if the measuring instrument is used within the use specifications (as set out in the last sub-paragraph of Article 28(2)) of the MRR Consequently, the requirements described for route CO-2a (step 1 to step 4) must be met. If those requirements are not met neither route CO-2a or route CO-2b are applicable and a specific uncertainty assessment described under route CO-3 and Annex II of this document is required.

Implementing effective measuring instrument control and management procedures can minimise the risk of the instrument performance varying over time while in service. In these circumstances operators could propose a conservative adjustment factor value of 1 if they can demonstrate to their verifier and their regulator that they have good control over their measuring system; otherwise, a typical value of 2 is appropriate.

### 2.2.5 Full uncertainty assessment 'Route CO-3'

Section 2.2.2 ('Route CO-1' measurement systems subject to NLMC), 2.2.3 ('Route CO-2a' measurement systems not subject to NLMC but is installed in an environment appropriate for its use specifications) and 2.2.4 ('Route CO-2b' measurement systems not subject to NLMC but is installed in an environment appropriate for its use specifications and subject to calibration) describe routes that help simplify how operators comply with their uncertainty obligations under the MRR. Operators don't have to apply a simplified approach and can choose to carry out a full uncertainty assessment, especially if it provides better results. However, the operator must carry out a full uncertainty assessment if none of the simplification routes are possible. Even then, the operator can use the outputs of the simplification routes as starting points for further calculations, for example if using error propagation (see Annex II, section 8.2). This approach not only presents a more pragmatic and less burdensome way for operators to assess uncertainty, but it may also in most cases provide more reliable results.

### 2.2.6 Specific requirements for natural gas meters under operator control

**Example:** An operator uses a turbine meter subject to national legal metrological control for the consumption of a liquid source stream. The operator must determine the density of the liquid to convert the volumetric flow into mass flows. Simplification routes CO-1 or CO-2a/2b can't be applied for the source stream because density is regularly determined by an aerometer if expressed in tonnes. However, the operator could use the uncertainty laid down in the relevant national legal metrological text related to the determination of the volume in the overall uncertainty calculation by error propagation (see example 7 in section 8.3).

Operators that own the gas meter(s) used to determine their activity data may, if the gas meter is used for billing purposes, use the maximum permissible error in service allowed by UK legislation or UK rules (such as industry codes of practice produced by the Office for Gas and Electricity Markets, Ofgem) as their uncertainty value.

For natural gas metering, to make use of this simplification the operator must identify the type of meter to identify the maximum permissible error in service (MPES). See sections 2.3.5.1 and 2.3.5.2 for how to do this.

#### 2.2.6.1 Annual checks to comply with Article 28

Operators must compare the uncertainty of their measurement device(s) against the requirements of the MRR at least once per year and after each calibration. Operators that have installed and used the measurement device as the manufacturer intended may, for example, take the uncertainty from the manufacturer's specifications, or initial calibration certificate.

Complying with this requirement that is set out in Article 28(1) of the MRR does not necessarily mean that gas meters need to be removed for calibration every year. Operators should check the manufacturer's recommendations, technical specification or technical performance standards to help identify appropriate calibration intervals. See Annex I of this document for examples of calibration intervals for typical gas meters.

If the operator calibrates their measurement instruments, they must apply a conservative adjustment factor to the uncertainty determined from the results of the calibration (as described in section 2.2.4.4).

## 2.3 Measurement systems not under the operator's own control

### 2.3.1 General aspects

Operators may use a measurement system outside their own control to determine activity data, if that system complies with at least as high a tier, gives more reliable results and is less prone to control risks[10] than using their own instruments, if available. For these cases, activity data may be determined either by

- amounts taken from invoices issued by the trading partner, or
- direct readings from the measurement system.

Whichever approach is used, the same tiers for activity data are required as for systems under the operator's own control. The only difference is how the operator demonstrates that they comply and what simplifications may be applied.

If operators use invoices as the primary data source for determining the quantity of material or fuel, Article 29 of the MRR requires the operator to demonstrate that the trade partners are independent. In principle, this should be considered a safeguard for ensuring that meaningful invoices exist. In many cases it will also be an indicator of whether national legal metrological control (see route CO-1 in section 2.2.2) is applicable.

Note that there is a 'hybrid' possibility allowed by the MRR: the instrument is outside the control of the operator, but the operator reads the instrument for their monitoring purposes. The owner of the instrument is responsible for maintenance, calibration and adjustment of the instrument, and ultimately for the applicable uncertainty value, but the quantity of fuel or material used can be directly checked by the operator. This is a situation frequently found for natural gas meters.

[10] For guidance on risk assessment see guidance document 'UKETS04 MRR - Data flow activities and control system'.

Figure 4 below shows the way provided by the MRR to comply with the tier requirements in case of measurement systems not under the operator's control (where 'C' means calculation-based and 'T' means instrument is under trading partner control)

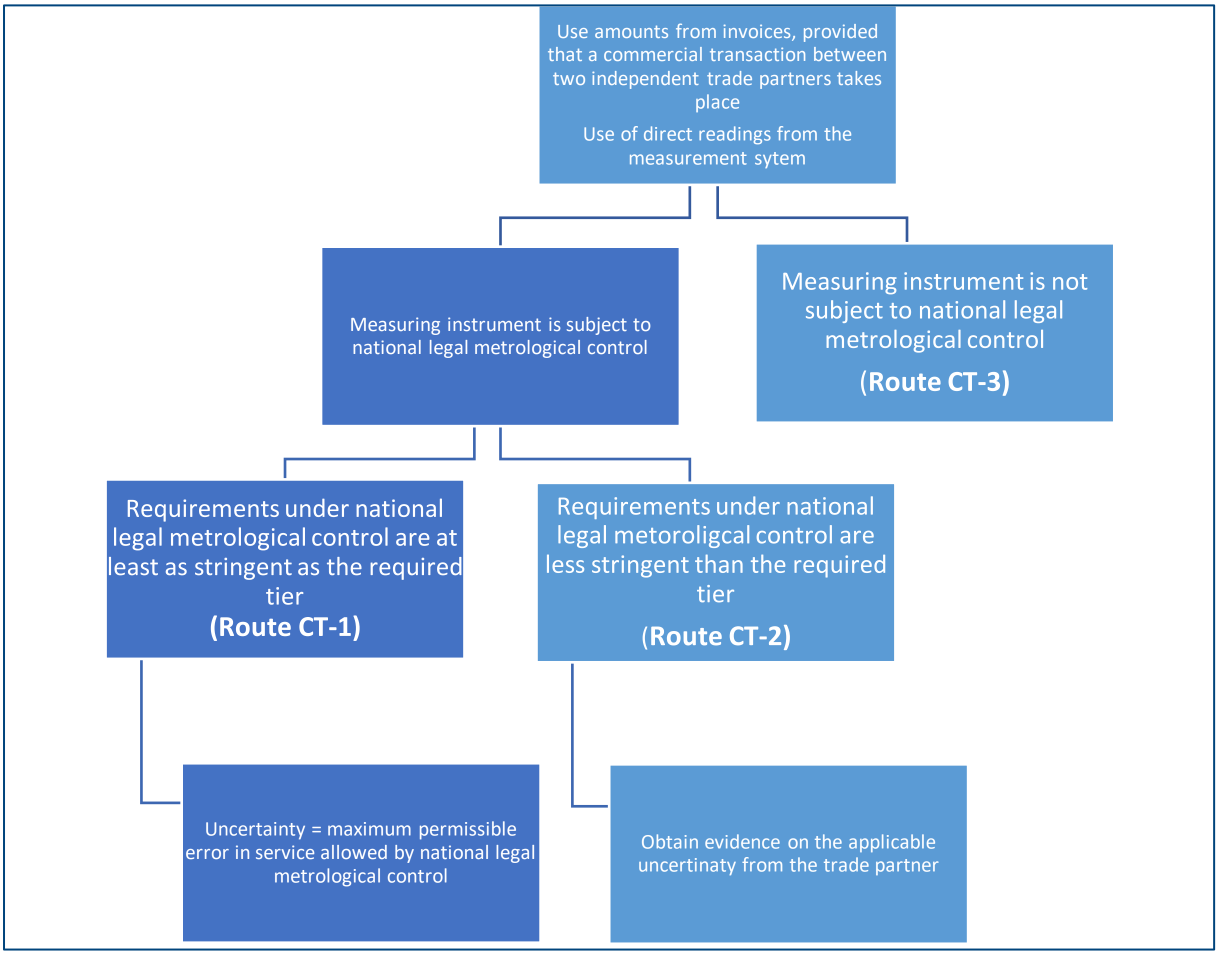



**Figure 4 Activity data for calculation-based approaches: approaches for determination of the uncertainty achieved**

The operator can simplify the uncertainty assessment:

- If the measuring instrument is subject to legal metrological control, the maximum permissible error laid down in the relevant national legal metrological text can be used as the overall expanded uncertainty for assessing whether the tier requirements in accordance with Article 26 of MRR are met (route CT-1).
- If the applicable requirements under national legal metrological control are less stringent than the uncertainty threshold of the tier required in accordance with Article 26 of the MRR, the operator may obtain evidence from the trade partner concerning the expanded uncertainty that is actually applicable (route CT-2).
- If the measuring instrument is not subject to national legal metrological control, the operator may obtain evidence from the trade partner relating to the uncertainty concerned (route CT-3).

If sufficient evidence cannot be obtained from the trading partner (for example, the fuel supplier) the operator may take the following steps:

**Step 1.** Can the operator provide evidence that the uncertainty in a reasonable worst-case scenario is still better than using the operator's own meters and is at least meeting tier 1? Such evidence may be obtained by demonstrating that, for example, this measuring instrument is subject to national legal metrological control and even the least stringent requirements will meet a defined tier (the background information in the exemplar in section 9.1 explains this further).

**Step 2**. If yes, then the tier met in the worst case should be used for further assessments.

**Step 2a**. If the tier met in the worst case meets at least the required tier then no further evidence is needed.

**Step 2b.** If the tier met in the worst case is lower than the required tier, the operator must demonstrate that using their own meters to meet the required tiers would incur unreasonable costs or is not technically feasible.

**Step 3.** If no, then the operator is not meeting at least tier 1 and is applying a fall-back approach (as referred to in Article 22 of the MRR). The operator must demonstrate that using their own meters to meet the required tiers would incur unreasonable costs or is not technically feasible.

### 2.3.2 Simplification 'Route CT-1'

> Measuring instrument of the trade partner is subject to national legal metrological control (NLMC).
>
> **Overall expanded uncertainty = maximum permissible error in service (MPES)**

This simplification is applicable for the same reasons and under the same conditions as described in section 2.2.2 (route CO-1). The operator must demonstrate that the trade partner's measuring instrument complies with at least as high a tier as an instrument available under the operator's own control, gives more reliable results, and is less prone to control risks.

### 2.3.3 Simplification 'Route CT-2'

Measuring instrument of the trade partner is subject to national legal metrological control but the requirements under national legal metrological control are less stringent than the required tier

**'The operator shall obtain evidence of the applicable uncertainty from the trade partner responsible for the measurement system.'**

If the applicable requirements under national legal metrological control are less stringent than the tier requirements set out in Article 26 of the MRR, the operator must obtain evidence from the trading partner that the required tiers are met. The operator must be able to demonstrate that the trade partner's measuring instrument complies with at least as high a tier as an instrument available under the operator's own control, gives more reliable results, and is less prone to control risks.

This may also be based on an uncertainty assessment as explained in Annex II of this guidance, using information on the measuring instruments obtained from the trade partner. Please also see the information given in section 2.2.5 (route CO-3).

### 2.3.4 Simplification 'Route CT-3'

Measuring instrument is not subject to national legal metrological control

**'The operator shall obtain evidence of the applicable uncertainty from the trade partner responsible for the measurement system.'**

This route is similar to route CT-2 above. Where the transaction is not subject to NLMC, the operator must obtain evidence from the trading partner that the tiers set out in Article 26 of the MRR are met. The operator must be able to demonstrate that the trade partner's measuring instrument complies with at least as high a tier as an instrument available under the operator's own control and gives more reliable results and is less prone to control risks.

This may also be based on an uncertainty assessment as explained in Annex II of this document, using information on the measuring instruments obtained from the trade partner. Please also see the information given in section 2.2.5 (route CO-3).

### 2.3.5 Specific requirements for natural gas meters not under operator control

Operators that do not own the gas meter used to determine their activity data, may, if that meter is used for billing purposes, use the maximum permissible error in service allowed by UK legislation or UK rules as their uncertainty value. To make use of this simplification operators must identify the type of meter (see section 2.3.5.1) in order to identify the MPES (see section 2.3.5.2).

#### 2.3.5.1 Identify the meter type

Operators can find out what type of gas meter they have by asking their gas supplier (the business that they pay for gas they consume) for written confirmation of their gas meter's specifications or use the specifications given in a supplier calibration certificate, or supplier contract documentation. The specifications must correspond with the gas bill, the gas meter and the volume converter used (if they are separate instruments). Corresponding information may include a reference number (that matches the reference on their gas bill), the meter serial number and meter type, the date of manufacture, the maximum capacity, as well as details of any secondary instruments such as volume converters.

#### 2.3.5.2 Identify the maximum permissible error in service

Gas meters used for billing purposes must be accurate and will have been approved as suitable for use under one of two UK regulations: the Measuring Instruments (Gas Meters) Regulations 2006 (SI 2006 No 2647)[11] or the Gas (Meters) Regulations 1983 (SI 1983 No 684).[12]

The Measuring Instruments (Gas Meters) Regulations 2006 apply to newer gas meters but also principally to small low pressure/low volume gas meters[13],[14], including domestic meters and light industrial/commercial uses. Gas meters that were type approved under the Gas (Meters) Regulations 1983 can continue to be used so long as they meet the legal requirements. Gas meters that have been ‘stamped’ under the Measuring Instruments (Gas Meters) Regulations 2006 stipulate the maximum permissible error (MPE) and the maximum permissible error in service (MPES), depending on the accuracy class[15] and flow rate range. Table 2 shows the relationship between the MPE and the MPES.

**Table 2 The relationship between the MPES and MPE for different meter types**

| Measurement device | Relationship between MPES and MPE |
| --- | --- |
| Class 1 meter | MPES = MPE |
| Class 1.5 meter | MPES = 2*MPE |

[11] https://www.legislation.gov.uk/uksi/2006/2647/contents/made
[12] https://www.legislation.gov.uk/uksi/1983/684/made
[13] Section 17 of the Gas Act 1986 (https://www.legislation.gov.uk/ukpga/1986/44/section/17) and the ‘stamping of meters’ that displays evidence of conformity only applies to gas meters that supply a quantity of gas at a rate of flow which, if measured at a temperature of 15 °C and a pressure of 1013.25 millibars, does not exceed 1600 m3/h or the equivalent quantity in kilograms.
[14] This is equivalent to a net thermal input of about 16.6 MW (net) or 18.5 MW (gross) which is equivalent to a gas turbine output of about 5 MWe (JEP, 2014).
[15] Regulation 28 of the Measuring Instruments (Gas Meters) Regulations 2006. https://www.legislation.gov.uk/uksi/2006/2647/regulation/28/made

| | |
|---|---|
| Volume converter[16] | MPES = MPE |
| Diaphragm meter/other meter[17] (1983 Regulations) | MPES = MPE |

Standard letters, such as those provided by National Grid Metering may not use the terminology 'MPES' but may state wording such as ‘Rotary and Turbine Meters have an accuracy of ± 1% from 20% to 100% of the flow range, and ± 2% below 20%.’ From this information we can deduce that this is an accuracy class 1 meter or is regulated under the Gas (Meters) Regulations 1983 (see Table 2). Tables 3 and 4 show the MPES of various meter classes and compares them to the tiers that they would achieve (operators should refer to Article 26 of the MRR to identify what tier is needed to apply to major, minor, de-minimis and marginal source streams). It is inevitable that the flow rate will be less than 20% of the maximum flow rate at some point. However, if the meter operates above 20% of the maximum flow rate during normal plant operation, the overall uncertainty is assumed to be within the higher flow.

For large meters, that are out of scope of section 17 of the Gas Act 1986 (https://www.legislation.gov.uk/ukpga/1986/44/section/17), operators can use the uncertainty values (MPES) quoted by the gas supplier (for example, in contract documentation or standard National Grid Metering letter).

All instruments that are applicable to the measurement must be considered. So, if there is a separate instrument for converting the volume, for example, then operators must also take the MPE for this into account also. The MPE for temperature correction devices is ±0.7% and ±1% for other conversion devices. Operators may have more accurate data than this; if operators use their own data, they must be able to demonstrate it to their verifier. Tables 3 and 4 show the calculations with temperature and pressure correction devices.

Note: operators taking gas consumption from invoices must check their invoice to see if their supplier has applied a correction factor. If their suppler has applied a standard factor, then exclude the volume converter accuracy from their calculation; there is no impact on the tier achieved.

### Table 3 Comparison of tier thresholds with various natural gas meter classes (Measuring Instruments (Gas Meters) Regulations 2006)

[16] Paragraph 4 of Schedule 1 of the Measuring Instruments Regulations 2016 (SI 2016 No.1153) https://www.legislation.gov.uk/uksi/2016/1153/schedule/1/paragraph/4
There is no information in this regulation on the requirements for maximum permissible error in service. Operators may assume that the maximum permissible error in service is the same as the maximum permissible error.

[17] There is no information in this regulation on the requirements for maximum permissible error in service. Operators may assume that the maximum permissible error in service is the same as the maximum permissible error.

| | Accuracy class 1.0 (high flow rate, 20% -100%) | Accuracy class 1.0 (low flow rate, 0% - 20%) | Accuracy class 1.5 (high flow rate, 20% - 100%) | Accuracy class 1.5 (low flow rate, 0% - 20%) |
|---|---|---|---|---|
| **Meter accuracy/MPE** | ±1% | ± 2% | ±1.5% | ± 3 % |
| **MPES** | ±1% | ± 2% | ± 3 % | ± 6 % |
| **Volume converter accuracy** | ±1% | ±1% | ± 1% | ± 1% |
| **Uncertainty calculation** | $\sqrt{(1^2 + 1^2)} = 1.41$ | $\sqrt{(2^2 + 1^2)} = 2.24$ | $\sqrt{(3^2 + 1^2)} = 3.16$ | $\sqrt{(6^2 + 1^2)} = 6.08$ |
| **Tier threshold** | 4 | 3 | 2 | 1 |

**Table 4 Summary of MPE and MPES required by the Gas (Meters) Regulations 1983 for various natural gas meter types**

| | Diaphragm Meter | Other meter type (high flow rate, 20% - 100%) | Other meter type (low flow rate, 0% - 20%) |
|---|---|---|---|
| **Meter accuracy/ MPE** | ± 2% | ±1% | ± 2% |
| **MPES** | ± 2% | ±1% | ± 2% |
| **Volume converter accuracy** | ±1% | ±1% | ±1% |
| **Uncertainty calculation** | $\sqrt{(2^2 + 1^2)} = 2.24$ | $\sqrt{(1^2 + 1^2)} = 1.41$ | $\sqrt{(2^2 + 1^2)} = 2.24$ |
| **Tier threshold** | 3 | 4 | 3 |

Without any evidence from their gas supplier of the gas meter accuracy class, the actual meter type and the flow rate range, regulators must take a conservative approach and assume that the gas supplier has installed an accuracy class of 1.5 and therefore will apply a MPES of 6%.  This means that the tier compliance is tier 1, which is acceptable for a low emitter and hospital or small emitter.

The operator's verifier will note a non-conformity with the MRR if the operator is required to apply a higher tier than tier 1 but cannot demonstrate it before the end of the verification process. The operator will have to submit an improvement report to their regulator explaining the steps that they are taking to obtain the necessary information.

## 2.4 National Legal Metrological Control for liquid fuels

Example 7 in section 8.3 describes the uncertainty assessment for stored gas oil. The legal metrological controls[18] upon liquid fuel supply for most liquid fuels used in the UK ETS (regardless of whether the fuel is delivered by vessels or road tanker) means that the MPE and the MPES of the meter measuring systems (defined as the meter and all devices required to ensure correct measurement or intended to facilitate the measurement operations) used by independent trade partners can be assumed to be at least 0.5%. No further evidence of uncertainty is required.

However, this is only one part of the uncertainty assessment, and the uncertainty of the liquid fuel must be determined by assessing the whole metering system, as described in Example 7. Stock leaving the storage tanks may be measured in a variety of ways, such as by using volumetric meters, automatic tank level gauges or manual dips. If these devices are maintained in accordance with the manufacturer's recommendations, technical specifications or codes of practice[19] operators can use the uncertainty quoted in the manufacturer's specifications and calibration certificates as part of their uncertainty assessment.

If the operator's liquid fuel is a de minimis or marginal source stream and if an uncertainty assessment has not been undertaken which involves both the uncertainty of the tanker meter AND the bulk tank meter/dip the regulator will accept an overall uncertainty as 'not applicable' (N/A) and list the source stream category as no tier.

## 2.5 National Legal Metrological Control for weighing devices

The maximum permissible error for weighing devices is dependent on many factors, including the type of weighing device, the accuracy class and the measurement intervals and range[20]. This is too complex to include in this document and operators should refer to the legislation.

---

[18] Schedule 6 to the Measuring Instruments Regulations 2016 (SI 2016 No 1153) and section 4.10.2 of HMRC Reference: Notice 179 (February 2014)

[19] Such as those mentioned in section 4.7 and 4.10 of the HMRC Reference: Notice 179 (see link above) and produced by the Energy Institute.

[20] For details see Schedule 6 of the measuring Instruments Regulations 2016 (SI 2016 No 1153) https://www.legislation.gov.uk/uksi/2016/1153/contents for automatic weighing devices and the Non-automatic Weighing Instruments Regulations 2000 (SI 2000 No. 3236) https://www.legislation.gov.uk/uksi/2000/3236/contents/made for non-automatic weighing devices. It is important to note that Regulation 4.2 of the Non-automatic Weighing Instruments Regulations 2000 specifies that the MPES is twice the MPE. The MPES for automatic weighing devices is the same as the MPE.

A simpler option for weighing devices is to use the calibration route that is described in section 2.2.4.1. The value of the conservative adjustment factor, as described in section 2.2.4.4, is dependent on the risk that the performance of the weighing device deteriorates while in use. This risk can be reduced through maintenance and control procedures.

## 2.6 Uncertainty for calculation factors

### 2.6.1 Frequency of analysis

The tiers for calculation factors (as defined in Article 3(7) of the MRR) are not based on uncertainty thresholds being met but are defined on the basis of using default values (tier 1 or 2) or values derived from laboratory analyses (usually tier 3). However, determinations involving laboratory analyses are linked to required frequency for analyses, as set out in Article 35 of the MRR and Annex VII. One option allowed for determining the required frequency is expressed in terms of the 'uncertainty' related to the frequency of analyses. Article 35(2) of the MRR states:

*"The regulator may allow the operator to use a frequency that differs from those referred to in paragraph 1, where minimum frequencies are not available or where the operator demonstrates one of the following:*

*a) based on historical data, including analytical values for the respective fuels or materials in the reporting period immediately preceding the current reporting period, any variation in the analytical values for the respective fuel or material does not exceed 1/3 of the uncertainty value to which the operator has to adhere with regard to the activity data determination of the relevant fuel or material…"*

This means that the operator may apply a different frequency to that listed in Annex VII of the MRR if any variation in the analytical values for the respective fuel or material does not exceed one third (1/3) of the uncertainty value. The determination of this variation must be based on historical data, including analytical values for the respective fuel or material in the reporting period immediately preceding the current reporting period.

The changes to the MRR from 1 January 2021 put the indirect analysis of the emission factor and carbon content on equal footing with direct analysis if the operator can justify it with an uncertainty assessment. Sections 2.1 and 3.1 of Annex II of the MRR both state for tier 3, point (b): [The operator may use] '…the empirical correlation as specified for tier 2b, where the operator demonstrates to the satisfaction of the regulator that the uncertainty of the empirical correlation does not exceed 1/3 of the uncertainty value to which the operator has to adhere with regard to the activity data determination of the relevant fuel or material.'

Any variation in the analytical value may be determined as the overall uncertainty of uncorrelated input quantities (see section 8.2.1 of this document).

$$u_{total} = \frac{\sqrt{(u_1 \times x_1)^2 + (u_2 \times x_2)^2 + \ldots + (u_n \times x_n)^2}}{|x_1 + x_2 + \ldots + x_n|}$$

Where:

$u_i$ ….. relative uncertainty of the analytical value of sample $i$

$x_i$ ….. samples size of sample $i$

Assuming that the uncertainty of the analytic value of each sample is the same and all sample sizes are similar, the formula simplifies to:

$$u_{total} = u_i \times \frac{\sqrt{n}}{n} = \frac{u_i}{\sqrt{n}}$$

Where :

$n$ …. Number of samples

If the total uncertainty related to the analytical values is known (in most cases it is a direct result of the standard deviation of the analytical values) the requirement minimum number of samples can be determined as:

$$n = \frac{u_i^2}{u_{total}^2}$$

Alternatively, operators can use the Excel frequency of analysis tool[21].

**Example:** A category B installation is burning heavy fuel oil. In the monitoring plan heavy fuel oil is listed as a major source stream to be monitored by a calculation-based approach. The MRR (and approved monitoring plan) requires it to meet tier 4 (±1.5%) for activity data and to determine the calculation factors (emission factor (EF) and net calorific value (NCV)) by laboratory analyses in accordance with Articles 32 to 35 of the MRR. The '1/3' rule requires that the uncertainty related to the determination of the calculation factors does not exceed 0.5% ($U_{total}$ – this is the input parameter for determining the number of samples).

Annex VII of the MRR requires a minimum frequency of analysis for heavy fuel oil of at least six times a year. The operator inputs details of historic analyses into the Excel tool to demonstrate that the uncertainty related to the determination of the NCV is 1.00%. The following table displays the results from historic samples.

[21] https://ec.europa.eu/clima/document/download/0d1499ab-1808-413d-92c3-af85bfbee9b2_en

| Number of samples | NCV [GJ/t] |
|---|---|
| 1 | 42.28 |
| 2 | 42.41 |
| 3 | 42.35 |
| 4 | 42.68 |
| 5 | 42.44 |
| 6 | 42.40 |
| 7 | 42.68 |
| 8 | 42.60 |
| 9 | 42.02 |
| 10 | 42.33 |
| 11 | 42.41 |
| 12 | 42.20 |
| average | 42.40 |
| Uncertainty $U_i$ | 1.00% |

The uncertainty is determined as the standard deviation of the data series (0.45%) multiplied by the Student t-factor for 12 values and a 95% confidence interval (coverage factor = 2.201). The minimum frequency of analysis to meet the requirements of the 1/3 rule is then calculated by:

$$n = \frac{1.0\%^2}{0.5\%^2} = 4$$

In this case, for NCV determination, the operator may be allowed to apply a lower frequency of analysis of 4 times per year instead of 6 times. For the emission factor a similar analysis can be carried out to show whether these requirements are also fulfilled with 4 samples analysed per year.

### 2.6.2 Using supplier information

Operators choosing to outsource the determination of calculation factors, by using information provided by the trade partner supplying the fuel or material, are still responsible for demonstrating compliance with the required tiers (including the requirements of Articles 32 to 35 of the MRR). The example below shows some steps that an operator could follow to use their supplier's data for calculation factors to comply with tier 3.

**Step 1**. Can evidence be provided that an appropriate sampling plan is in place and that analyses are carried out by a suitably accredited laboratory (EN ISO/IEC 17025) for that determinant or by a laboratory meeting the equivalent requirements? If the answer is 'yes' go to 'step 2', otherwise go to 'step 3'.

**Step 2**. the operator is deemed to meet tier 3 for all relevant calculation factors for which this evidence has been provided and there is no need to apply step 3.

**Step 3**. If the answer to step 1 is 'no', then the analytical values obtained from the supplier cannot be considered to meet tier 3. The operator can choose:

a) To take their own samples and analyse in accordance with Articles 32 to 35, or
b) To use available default values and justify to the regulator's satisfaction that carrying out sampling and analysis is technical not feasible or would incur unreasonable costs. As part of an unreasonable cost justification, the operator should consider whether it is possible to apply tier 3 but with a lower frequency of analysis (see section 2.6.1)

**Step 4**. If the operator can't meet step 3 and meet at least tier 1 (step 3b), they must justify to their regulator's satisfaction, based on unreasonable costs and/or technical feasibility, that applying no tier is the only remaining option, as set out in MRR Article 22.

Operators must manage their use of supplier(s) data according to their written procedure for control of out-sourced processes, as set out in Articles 59(3)(f)) and 65 of the MRR. See Chapter 6 of this document for more guidance on uncertainty and quality assurance.

# 3 Uncertainty for measurement-based approaches

Emissions of nitrous oxide (N2O) and transfers of carbon dioxide (CO2) and N2O must be determined using measurement-based methodologies (CEMS). Emissions of CO2 may also be monitored using measurement-based methodologies if the operator can demonstrate that the tiers set out in Article 41 and Annex VIII of the MRR are complied with.

Operators applying measurement-based approaches must list of all relevant equipment in their monitoring plan, indicating its measurement frequency, operating range and uncertainty. Unlike calculation-based approaches, there are no simplifications for measurement-based approaches to determine the uncertainty.

Article 42 of the MRR requires all measurements to be carried out applying methods based on the following standards:

- EN 14181 Stationary source emissions – Quality assurance of automated measuring systems
- EN 15259 Air quality – Measurement of stationary source emissions – Requirements for measurement sections and sites and for the measurement objective, plan and report
- EN ISO 16911-2 – Manual and automatic determination of velocity and volume flow rate in ducts.

And other corresponding EN standards referred to in these standards, such as

- EN ISO 14956 Air quality – evaluation of the suitability of a measurement procedure by comparison with a required measurement uncertainty. This is required by EN 14181 and describes the QAL 1 procedure.
- EN 15267-3 Air quality – certification of automated measuring systems for monitoring emissions from stationary sources. This standard is required to carry out the quality assurance level 1 (QAL 1) procedure. It is an application of EN ISO 14956 and is used to define testing procedures for CEMS and the determination of uncertainties in the measurement.

Article 42 further states: "*Where such standards are not available, the methods shall be based on suitable ISO standards or national standards. Where no applicable published standards exist, suitable draft standards, industry best practice guidelines or other scientifically proven methodologies shall be used, limiting sampling and measurement bias.*

*The operator shall consider all relevant aspects of the continuous measurement system, including the location of the equipment, calibration, measurement, quality assurance and quality control.*"

EN 14181 contains information about quality assurance procedures (QAL 2 and 3) to minimise the uncertainty as well as guidelines on how to determine the uncertainty itself. Guidance for QAL 1 can be found in EN ISO 14956.

As a minimum, quality assurance checks, including parallel measurements with standard reference methods, must be performed once a year by competent staff. In England and Wales, for example, competence can be demonstrated by certification of the individual to the Monitoring Certification Scheme (MCERTS) but this is not mandatory throughout the UK. See Monitoring emissions to air, land, and water [https://www.gov.uk/government/publications/mcerts-personnel-competency-standard-manual-stack-emissions-monitoring](https://www.gov.uk/government/publications/mcerts-personnel-competency-standard-manual-stack-emissions-monitoring)

Operators must notify their regulator if quality assurance requirements are not met and take appropriate corrective action as soon as is reasonably practicable.

## 3.1 How to demonstrate compliance with tier requirements

The tiers for CEMS relate to the maximum permissible uncertainties for the annual average hourly emissions. They are calculated in accordance with the equation below, which is derived from equations 2 (a, b and c) in Annex VIII, section 3 of the MRR:

$$GHG\ Emissions_{average\ hourly}\ [kg/h] = \frac{\sum_i GHG_{conc_{hour\ i}}\ [g/Nm^3] \times flue\ gas\ flow_i [Nm^3/h]}{hours\ of\ operation \times 1000}$$

Values for the greenhouse gas (GHG) concentration and the flue gas flow must be consistent and relate to the same conditions, for example to dry flue gas at standard conditions.

The uncertainty associated with the determination of the concentration is combined with the uncertainty associated with the determination of the flue gas flow:

$$u_{av\ hourly\ emissions} = \sqrt{u_{GHG\ concentration^2} + u_{flue\ gas\ flow^2}}$$

The combined standard uncertainty is multiplied by a coverage factor to obtain the expanded uncertainty. The resulting expanded uncertainty associated with the average hourly emissions is compared to the uncertainty associated with the tier required by the MRR for the relevant emissions source (see Annex VIII section 1 of the MRR).

This calculation can be performed using the uncertainty associated with the determination of the concentration obtained by the QAL1 procedure. For some CEMS this uncertainty is readily available where a QAL1 calculation is attached to an EN 15267-3 certification.

If the CEMS fails to meet the uncertainty threshold of the tier required by the MRR using the uncertainty obtained by QAL1, the operator should either

- use another CEMS
- demonstrate that it is technically not feasible, or they would incur unreasonable costs

However, the uncertainty associated with the determination of the concentration obtained by the QAL2 procedure is the relevant input parameter for demonstrating compliance with the MRR. Only if the CEMS also fails to meet the uncertainty threshold of the tier required by the MRR, obtained by QAL2, do the bullet points above then become mandatory. Note that QAL2 does not take into consideration uncertainty resulting from drift since this is addressed by QAL1 and QAL3.

# 4 Further guidance on CEMS and the application of EN 14181 can be found in guidance note ‘UKETS07 MRR - Use of continuous emissions measuring systems (CEMS)’.Uncertainty for fall-back approaches

Operators may apply a monitoring methodology not based on tiers for selected source streams or emissions sources (also called a fall-back methodology) if all the conditions set out in Article 22 of the MRR are met:

- to apply at least tier 1 under the calculation-based methodology for one or more major source streams or minor source streams and a measurement-based methodology for at least one emissions source related to the same source streams is not technically feasible or would incur unreasonable costs
- the operator assesses and quantifies each year the uncertainties of all parameters used for the determination of the annual emissions in accordance with the ISO Guide to the Expression of Uncertainty in Measurement (GUM) (JCGM 100:2008)[22] or another equivalent internationally accepted standard, and includes the results of the uncertainty assessment in the annual emissions report
- the operator demonstrates to the satisfaction of the regulator that by applying such a fall-back monitoring methodology, the overall uncertainty threshold for the annual level of greenhouse gas emissions for the whole installation does not exceed:
    - 7.5% for category A installations
    - 5.0% for category B installations
    - 2.5% for category C installations

Further guidance for assessing the uncertainty of a fall-back approach can be found in section 8.4 of Annex II of this document.

[22] https://isotc.iso.org/livelink/livelink/fetch/2000/2122/4230450/8389141/ISO_IEC_Guide_98-3_2008%28E%29_-_Uncertainty_of_measurement_--_Part_3%2C_Guide_to_the_expression_of_uncertainty_in_measurement_%28GUM%2C1995%29.pdf?nodeid=8389142&vernum=-2

# 5 Uncertainty in the Free Allocation Regulation

The requirements for taking uncertainty into account are different for complying with the Free Allocation Regulation (FAR) compared to the MRR. Annex VII section 4 of the FAR lists a hierarchy of preferred data sources ranked according to accuracy instead of defining tiers.

Article 7 of the FAR requires the operator to use ‘data sources representing highest achievable accuracy pursuant to section 4 of Annex VII’. Use of other data sources is allowed in cases where the use of most accurate data sources is technically not feasible, would incur unreasonable costs, or where the operator can provide evidence that another chosen method exhibits equivalent to or lower uncertainty.

Unlike in the MRR where uncertainty assessments are mandatory, for the FAR a (simplified) uncertainty assessment is required only to provide a reason to deviate from the main hierarchy of data sources. However, like the MRR, the uncertainty also uses a 95% confidence interval (Article 2(16) of the FAR).

A full uncertainty assessment, as discussed in Chapter 2, must consider:

1. How the instrument’s readings are used for calculating the parameter under consideration (for example, how individual measurements contribute to the uncertainty over the whole reporting year). In the case of indirect determinations, the error propagation law must be applied accordingly for individual measurements.
2. The instrument’s specified uncertainty (based on maximum permissible error given in legislation, or the producer’s specifications, or taken from a calibration certificate, etc.)
3. Factors that influence the uncertainty in use (for example, whether the use environment is in accordance with the specifications, whether ageing, corrosion, or other systematic sources of error play a role, etc.)
4. Further factors, such as conservative adjustment factors for unknown sources of error.

When carrying out a simplified uncertainty assessment, operators should use expert judgement (such as their experience gained from assessing uncertainty for the purpose of annual emissions monitoring and reporting) to decide which of the factors mentioned in points (3) and (4) above can be disregarded, if not easily accessible. For example, if there is information available about the ‘maximum permissible error in service’, there is no need to include a safety margin as environmental and use factors affecting the instrument have already been accounted for. If the instrument is not installed in an environment appropriate for its use specifications, the operator should apply reasonable efforts to assess at least some more important influencing factors.

For more information, see ‘UKETS13 FAR - Monitoring and reporting in relation to the free allocation rules’.

# 6 Uncertainty and quality assurance

All operators must establish, document, implement and maintain effective control systems to ensure that their data conforms to the MRR and their approved monitoring plan, including the quality assurance of measurement equipment (Articles 59(3)(a) and 60 of the MRR) to ensure that their reported data are accurate and reliable.

Information on quality assurance of measurement-based instruments can be found in Chapter 3.

Operators can demonstrate that measuring instruments subject to national legal metrological meet the requirement set out in Article 60 of the MRR to check against traceable international standards by referring to the official calibration certificate.

If components of the measurement systems can't be calibrated, the operator must propose alternative control activities in their monitoring plan and carry out a full uncertainty assessment (route CO-3/CT-3) (see sections 2.2.5 and 2.3.4).

Section 9.3 gives an example of a quality assurance procedure for measurement equipment.

Procedures, such as those for managing outsourced processes (Article 65 of the MRR) are a practical and flexible way of managing quality assurance if data is obtained from multiple suppliers, without having to modify the monitoring plan each time a supplier change. The only constraint is that the overall procedure must stay within the description of the procedure set out in the approved monitoring plan, as shown in the example below.

**Example**: Heavy fuel oil is delivered on trucks owned by different suppliers. The volume flow meters used for determining the purchased amounts are all installed on the trucks, hence outside the operator's own control.

A procedure will be established for keeping track of all measuring instruments involved for determining the activity data of this source stream. A summary of this procedure may contain the following elements:

a) Responsible post or department: for example, the shift manager in charge accepting the fuel delivery.
b) For each delivery at least the following will be documented:
c) Truck number plate
d) Name of the truck's company
e) ID of the volume flow meter
f) Delivered amount

g) Responsible person checks if this truck and/or volume flow meter already has an account in the internal database
h) Responsible person checks once a month whether evidence for flow meter uncertainties has been provided by all suppliers, for example, the latest (official) calibration certificate. If not, responsible person will request such evidence from those suppliers where evidence is missing.
i) Where relevant information is stored.

Please note that this procedure must allow tracking of all measuring instruments involved to an extent allowing calculation of the uncertainty over the whole period and to demonstrate compliance with the required tier. If this is not achieved, the operator must propose alternative monitoring methods (see section 2.6.2) or provide justifications, for example, unreasonable costs.

Notwithstanding the continued need for suitable procedures, an alternative option for demonstrating compliance with the tier requirements can be achieved by providing documents clearly demonstrating which accuracy classes can be used, for example, a contractual arrangement with the supplier demonstrating that only measurement instruments with certain accuracy classes are to be used.

# 7 ANNEX I: Conservative measurement uncertainties for common instruments

The following tables provide an overview of conservative measurement uncertainties (expressed as expanded uncertainties) for certain categories of common measuring instruments as far as putting the instrument on the market and into use is concerned.

Due to the hostile nature of the environment, the recalibration intervals listed in the tables are not suitable for instruments on offshore platforms.

The uncertainty values and additional conditions presented in the tables below should be considered only if more specific information is not available from the manufacturer of the measuring instrument, or from normative documents such as those published by OIML[23]. Where standards are dated, operators must check the latest version of the standards for up-to-date information. Also, these uncertainty values should be considered only if steps 1 to 4 in section 2.2.3 are met. If this is not the case route CO-2a (where the maximum permissible error in service can be used as the overall expanded uncertainty) can’t be applied. For measuring instruments suitable for gases and liquids relevant OIML documents are R137 and R117. For measuring instruments for solids R76 is a suitable source.

Please also note that an interval for recalibration is advised for each instrument and is subject to the regulator’s approval. This implies that after each calibration the requirements to apply simplification route CO-2b (where the expanded uncertainty from calibration multiplied by a conservative adjustment factor can be used as the overall expanded uncertainty) in section 2.2.4 might be applicable and provide more reliable results. This option should always be considered before applying standard values listed below.

The uncertainty values provided in this Annex covers most but not all the factors that could influence uncertainty as they do not take account the effects of the measuring instrument being in service. For example, the values do not take drift into account that may arise from being used. For example, the uncertainty could increase due to aging of the instrument or being used in a hostile environment that leads to corrosion between calibration/maintenance intervals

The overall uncertainty ( $U_{total\ (in\ service)}$ ) must consider the drift by applying the following formula:

$$U_{total\ (in\ service)} = \sqrt{U_{values\ in\ this\ annex} + U_{drift}}$$

[23] Documents containing technical specifications adopted by the Organisation Internationale de Métrologie Légale (OIML). http://www.oiml.org/

Where:

$U_{values\ in\ this\ annex}$ refers to the uncertainty figures provided in this annex

$U_{drift}$ refers to the additional uncertainty caused by the drift.

The $U_{drift}$ should be determined based on robust data on common drift observed for similar instruments between calibration/maintenance intervals. If such values cannot be obtained, the operator should assume conservative values for $U_{drift}$ between 5% (for example in a non-corrosive, low-dust environment) and 7.5% (for example in a corrosive, high-dust environment).

| Rotor meter |
| --- |
| **Medium: gas**<br>Relevant standards: EN 12480:2015+A1:2006<br>Uncertainty for 0-20% of the measurement range: 3%<br>Uncertainty for 20-100% of the measurement range: 1.5%<br>Conditions:<br>• Once per 10-year cleaning, recalibration and, if necessary, adjusting<br>• Annual inspection of the oil level of the carter<br>• Application filter for polluted gas<br>• Life span 25 years |
| **Medium: liquid**<br>Uncertainty for 0-10% of the measurement range: 1%<br>Uncertainty for 10-100% of the measurement range: 0.5%<br>Conditions:<br>• Once per 5-year cleaning, recalibration and, if necessary, adjusting (or at an earlier time when flow liquid of 3500 hours × maximum range of the meter has run through the meter<br>• Annual maintenance according to instructions of manufacturer / general instructions measurement principle<br>• Life span 25 years |

| Turbine meter |
| --- |
| **Medium: gas**<br>Relevant standards: EN 12261:2002 + A1:2006<br>Uncertainty for 0-20% of the measurement range: 3 %<br>Uncertainty for 20-100% of the measurement range: 1.5%<br>Conditions:<br>• Once per 5-year cleaning, recalibration and, if necessary, adjusting<br>• Annual visual inspection<br>• Once per three months lubrication of bearings (not for permanent lubricated bearings)<br>• Application filter for polluted gas<br>• No pulsating gas stream<br>• Life span 25 years<br>• No overload of longer than 30 minutes › 120% of maximum measurement range |
| **Medium: liquid**<br>Uncertainty for 10-100% of the measurement range: 0.5%<br>Conditions:<br>• Once per 5-year cleaning, recalibration and, if necessary, adjusting<br>• Once per three months lubrication of bearings (not for permanent lubricated bearings)<br>• Application filter for polluted liquid<br>• Life span 25 years<br>• No overload of longer than 30 minutes › 120% of maximum measurement range |

| Bellows meter / diaphragm meter |
| --- |
| **Medium: gas**<br>Relevant standards: EN 1359:1998 + A1:2006 |

Uncertainty for 0-20% of the measurement range: 7.5%

Uncertainty for 20-100% of the measurement range: 4.5%

Conditions:

- Once per 10-year cleaning, recalibration and if necessary adjusting
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 25 years

### Orifice meter

**Medium: gas and liquid**

Relevant standards: EN ISO 5167

Uncertainty for 20-100% of the measurement range: 3%

Conditions:

- Annual calibration of the differential pressure transmitter
- Once per 5 years calibration of the orifice meter
- Annual inspection for abrasion orifice and fouling
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 30 years
- No corrosive gases and liquids
- Guidelines for building in orifices, if not stated otherwise by the manufacturer: minimum of 50D free input flow length before the orifice and 25D after the orifice: smooth surface of inner wall.

### Venturi meter

**Medium: gas and liquid**

Relevant standards: EN ISO 5167

Gas: Uncertainty for 20-100% of the measurement range: 2%

Liquid: Uncertainty for 20-100% of the measurement range: 1.5%

Conditions:

Annual calibration of the pressure transmitter

- Once per 5 years calibration of entire measuring instrument
- Annual visual inspection
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 30 years
- No corrosive gases and liquids

**Ultrasonic meter**

**Medium: gas and liquid**

Relevant standards: ISO 17089-1:2010

**Medium: gas**

Gas: Uncertainty for 1-100% of the measurement range: 2%

Gas (clamp on): Uncertainty for 1-100% of the measurement range: 4%

**Medium: liquid**

Uncertainty for 1-100% of the maximum measurement range: 3%

Conditions:

- Once per 5 years cleaning, recalibration and, if necessary, adjusting
- Annual inspection of contact between transducer and tube wall. When there is not sufficient contact, the transducer assembly must be replaced according to the specifications of the manufacturer.
- Annual inspection on corrosion of wall
- Annual inspection of transducers
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 15 years
- No disturbances in frequencies
- Composition of medium is known

Guidelines for building in ultrasonic meters, if not stated otherwise by the manufacturer: minimum of 10D free input flow length before the meter and 5D after the meter.

### Vortex meter

**Medium: gas and liquid**

Gas: Uncertainty for 10-100% of the measurement range: 2.5%

Liquid: Uncertainty for 10-100% of the measurement range: 2%

Conditions:

- Once per 5 years cleaning, recalibration and, if necessary, adjusting
- Annual inspection of sensors
- Annual inspection of bluff body
- Annual inspection on corrosion of wall
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 10 years
- Set-up is free of vibration
- Avoid compressive shocks

Guidelines for building in vortex meters, if not stated otherwise by the manufacturer: minimum of 15D free input flow length before the meter and 5D after the meter

### Coriolis meter

**Medium: gas and liquid**

Gas: Uncertainty for 10-100% of the measurement range: 1.5%

Liquid: Uncertainty for 10-100% of the measurement range: 1%

Conditions:

- Once per 3 years cleaning, recalibration and, if necessary, adjusting
- Stress-free installation
- Monthly control of adjusting zero point
- Annual inspection of corrosion and abrasion

- Annual check on sensors and transmitters
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 10 years

## Oval gear meter

**Medium: liquid**

Uncertainty for 5-100% of the measurement range: 1%

Conditions:

- Viscid liquids (oil): Once per 5 years cleaning, recalibration and, if necessary, adjusting
- Thin liquids: Once per 2 years cleaning, recalibration and, if necessary, adjusting
- Annual inspection of abrasion
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 30 years

## Electronic Volume Conversion Instrument (EVCI)

**Medium: gas**

Relevant standards: EN 12405-1:2005+A1:2006

Uncertainty for 0.95 -11 bar and -10 – 40°C: 1%

Conditions:

- Once per 4 years recalibration and, if necessary, adjusting
- Replace batteries (frequency is dependent on instructions manufacturer)
- Annual maintenance according to instructions of manufacturer / general instructions measurement principle
- Life span 10 years

# 8 ANNEX II: Full uncertainty assessment for source streams

## 8.1 Introduction

This annex provides an overview of the general approach to assess uncertainties if no simplifications are applicable. For further details operators may consult the ISO Guide to the Expression of Uncertainty in Measurement (GUM) (JCGM 100:2008) (see footnote 18).

In principle the uncertainty assessment must include:

- the specified uncertainty of the applied measuring instrument
- the uncertainty associated with the instrument's calibration
- any additional uncertainties connected to how the measuring instrument is used in practice
- the application of the appropriate coverage factor (for example, a factor of 2 to obtain the expanded uncertainty)

If additional measurements such as pressure and temperature are required, the uncertainty of these measurements must also be considered. If the uncertainty information from the manufacturer cannot be applied, the operator must substantiate and justify that any deviations from the specification do not influence the uncertainty. If this is not possible, they must make conservative and substantiated estimations of the uncertainty. Possible influences on the uncertainty include:

- Deviation from specified working range
- Different uncertainties subject to load or flow rate
- Atmospheric conditions (wind, temperature variation, humidity, corroding substances)
- Operational conditions (adhesion, density and viscosity variation, irregular flow rate, in-homogeneity)
- Installation conditions (raising, bending, vibration, wave)
- Using the instrument for a medium other than the one it is designed for
- Calibration intervals
- Long-term stability

The general focus should be on the most significant parameters such as temperature, pressure (difference), flow rate, viscosity, etc., whichever applicable. Significant influences on the uncertainty must be considered and evaluated. The uncertainty can be calculated with the appropriate error propagation formula. Examples for the calculation of a specific uncertainty are given in this annex.

Tables 5 below lists various influencing parameters that might be relevant for uncertainty assessment. There may be other parameters that are not listed here and there may be some parameters that can be dismissed from consideration as they are likely to have minimal impact upon the results. However, it is a useful first starting point when running a risk assessment about the uncertainty of activity data and may help operators focus on the most relevant influencing parameters. Tables 6 and 7 provide some measuring instrument specific influencing parameters, depending on whether the substance being measured is a gas, liquid or solid.

### Table 5 Influencing parameters on the determination of activity data

| | Gaseous source stream | Fluid source stream | Solid source stream |
|---|---|---|---|
| Influencing parameter related to the instrument and its installation | turbulences in gas stream impacts of cladding<br>temperature of environment<br><br>long-run behaviour (calibration and maintenance frequency)<br><br>acceptable measurement range<br><br>electromagnetic fields | turbulences in fluid stream, bubbling of dissolved gases<br><br>temperature of environment<br>long-run behaviour (calibration and maintenance frequency)<br><br>acceptable measurement range<br><br>electromagnetic fields<br><br>storage capacity and monitoring<br><br>phase changes | exposure to wind and radiation<br><br>temperature of environment<br><br>long-run behaviour (calibration and maintenance frequency)<br><br>position on scale<br><br>electromagnetic fields<br><br>storage capacities / volumes<br><br>slope of conveying belts<br><br>start and stop behaviour |

| | | | |
|---|---|---|---|
| | | | acceptable measurement range<br><br>storage capacity and monitoring<br><br>vibration |
| Influencing parameter related to the medium being measured | temperature<br>pressure<br>compressibility factor<br>dewpoint (for some gases only)<br>corrosiveness | temperature<br>density<br>viscosity<br>boiling or melting point (for some rare circumstances only)<br>corrosiveness | purity / humidity<br>accessibility as net weight (e.g. packaging)<br>handling of medium<br>impacts by drying density<br>flow characteristics (e.g. related to grain size)<br>adhesiveness<br>melting point (for some rare constellations only) |

**Table 6 Measuring instrument specific influencing parameters and ways to validate/mitigate them: metering of gases and liquids**

| Measuring instrument | Influencing parameter | Validation/mitigation option |
|---|---|---|
| Turbine meter | Intermittent flow, pulsation | Appropriate operating parameters, avoid pulsation, e.g. by using controlling instruments |
| Bellows meter | Correct detection of temperature and pressure | Use Electronic Volume Conversion instrument (EVCI) |
| Orifice meter, Venturi meter | Damages, roughness of the pipe, stability of | Satisfy EN ISO 5167 requirements |

| | | |
|---|---|---|
| | pressure difference detectors | |
| Ultrasonic meter | Strong noise signals | Reduce noise |
| Vortex meter | Pulsation | Avoid pulsation |
| Coriolis meter | Stress, vibration | Build in compensators |
| Oval gear meter | Resonances, pollution | Dampers, filters |

**Table 7 Measuring instrument specific influencing parameters and way to validate/mitigate them: metering of solids**

| Measuring instrument | Influencing parameter | Validation/mitigation option |
|---|---|---|
| Conveyor belt weighing | Adhesion, sliding if belt is slanted | Use horizontal belt |
| Wheel loader scale | Adhesion | Zeroing after each measurement |
| Wagon weigh bridge | Weighed object not fully on scale | Use big enough scales |
| Hopper weigher, truck weigher, crane weigher | Wind | Use wind protection sites |

## 8.2 Error propagation laws

In many cases the measurand of interest is not measured directly but calculated through a functional relationship from other input quantities being measured. For example, a volumetric flow ($fV$) is calculated by measuring inputs like density (ρ) and pressure difference (Δp) through the relationship fV=fV(ρ, Δp). The uncertainty related to the measurand of interest will then be determined as the combined standard uncertainty via error propagation.

For input quantities it is necessary to distinguish between:

- Uncorrelated (independent) input quantities
- Correlated (interdependent) input quantities

If the operator uses different measuring instruments to determine the activity data of parts of the source stream, the associated uncertainties can be assumed to be uncorrelated[24].

However, this assumption must be carefully assessed for each case as there may be significant correlation between two input quantities if the same measuring instrument, physical measurement standard, or reference datum having a significant standard uncertainty is used.

**Example**: A gas flow measurement is converted from m³ to Nm³ by taking into account temperature and pressure which are measured by separate measuring instruments. These parameters can generally be considered as uncorrelated (see section 8.2.1).

Example: The annual consumption of coal of a coal-fired power plant is determined by weighing the batches delivered during the year with the same belt weigher. Due to drift-effects during operation in practice and due to uncertainties associated to the calibration of the belt weigher, the uncertainties associated with the results of weighing are correlated (see section 8.2.2).

### 8.2.1 Uncorrelated input quantities

If uncorrelated input quantities $X_1$,..,$X_n$ are being used to calculate the measurand $Y = Y(X_1,..,X_n)$ the uncertainty of $Y$ can be determined by:

$$U_Y = \sqrt{\left(\frac{\partial Y}{\partial X_1} \times U_{X_1}\right)^2 + \left(\frac{\partial Y}{\partial X_2} \times U_{X_2}\right)^2 + \cdots + \left(\frac{\partial Y}{\partial X_n} \times U_{X_n}\right)^2}$$

Where:

$U_Y$ …..uncertainty (absolute value) of the measurand Y

$U_{X_i}$ ….uncertainty (absolute value) of the input quantity $X_i$

**Example 1: Uncorrelated input quantities**

$Y = Y(X_1, X_2)$ is defined by the relationship $Y = X_1 \times X_2$

The partial derivatives are:

$\frac{\partial Y}{\partial X_1} = X_2$ $\frac{\partial Y}{\partial X_2} = X_1$

[24] Whether or not input quantities are correlated, and if yes to what extent, is not always straightforward to tell. One statistical approach to identify correlation is to calculate covariances. Further guidance can be found for example in sections 5.1, 5.2 and F.1.2 of the GUM

The absolute uncertainty is then given by:

$$U_{Y_1} = \sqrt{\left(X_2 \times U_{X_1}\right)^2 + \left(X_1 \times U_{X_2}\right)^2}$$

Where:

$U_Y$ …absolute uncertainty of measurand Y

$U_{X_i}$…absolute uncertainty of input quantity $X_i$

The relative uncertainty is given by:

$$\frac{U_Y}{Y} = u_Y = \sqrt{\frac{\left(X_2 \times U_{X_1}\right)^2 + \left(X_1 \times U_{X_2}\right)^2}{X_1^2 \times X_2^2}} = \sqrt{\left(\frac{U_{X_1}}{X_1}\right)^2 + \left(\frac{U_{X_2}}{X_2}\right)^2} = \sqrt{u_{X_1}^2 + u_{X_2}^2}$$

Where:

$U_Y$ …relative uncertainty of measurand Y

$U_{X_i}$…relative uncertainty of input quantity $X_i$

The square sum of the relative uncertainty of the measurand is therefore simply determined as the sum of the squares of the relative uncertainties of the input quantities.

**Example 2: Independent uncertainties of a sum**

A steam boiler that produces process steam is operated by burning gas as fuel. The gas used is supplied to the boiler by ten different pipes. The amount of gas is determined by ten different standard orifice plates according to EN ISO 5167. The uncertainty associated with the determination of the annual consumption of gas (uncertainty of a sum) for the steam boiler is calculated by following formula:

$$u_{total} = \frac{\sqrt{(U_1)^2 + (U_2)^2 + \cdots (U_{10})^2}}{|x_1 + x_2 + \cdots x_{10}|}$$

Where:

$U_{total}$…total (relative) uncertainty associated with the determination of the gas

$U_i$ …….uncertainty (absolute) value of the individual standard orifice plates

$X_i$ …….quantities of gas that are measured annually by the different orifice plates

**Example 3: Independent uncertainties of a product**

A combined heat and power plant has several boilers, all fired by natural gas and no other fuels. The annual quantity consumed is determined by a measurement system at the central transfer station (before distribution to the individual boilers) which consists of a turbine meter, a separate pressure measurement and a separate temperature measurement. The turbine meter determines the flow rate at operating conditions.

For emissions reporting the standard volume of natural gas is relevant. For the conversion of operating m³ into standard m³, measurements of pressure and temperature must be considered. The uncertainty associated with the determination of the natural gas in standard m³ (uncertainty of a product) is calculated by following formula:

$$U_{total} = \sqrt{u_v^2 + u_t^2 + u_p^2}$$

Where

$U_{total}$ ….total (relative) uncertainty associated with the determination of natural gas

$U_v$ ……..(relative) uncertainty of the volume measurement

$U_t$ ………(relative) uncertainty of the temperature measurement

$U_p$ ……..(relative) uncertainty of the pressure measurement

### 8.2.2 Correlated input quantities:

If correlated input quantities $X_1$,..,$X_n$ are being used to calculate the measurand Y=Y($X_1$,..,$X_n$) the uncertainty of Y can be determined by:

$$U_y = \left(\left|\frac{\partial Y}{\partial X_1}\right| \times U_{x_1}\right) + \left(\left|\frac{\partial Y}{\partial X_2}\right| \times U_{X_2}\right) + \cdots \left(\left|\frac{\partial Y}{\partial X_n}\right| \times U_{X_n}\right)$$

Where:

$U_Y$ …..uncertainty (absolute value) of the measurand Y

$U_{X_i}$ …..uncertainty (absolute value) of the input quantity $X_i$

**Example 4: Correlated input quantities**

$Y = Y(X_1, X_2)$ is defined by the relationship $Y = X_1 . X_2$

If the example above was calculated for correlated input quantities, the relative uncertainty would be obtained as:

$$U_y = U_{X_1} + U_{X_2}$$

The relative uncertainty of the measurand is therefore simply determined as the sum of the relative uncertainties of the input quantities.

Please note that this is only applicable for the very special case where all the input estimates are correlated with correlation coefficients of 1. If the coefficient is different from 1, more complex functions for covariances are to be considered which are not within the scope of this document.

For further reading please consult the GUM.

**Example 5: Correlated uncertainties of a sum**

A power plant is coal-fired. The annual consumption of coal is determined by weighing the batches delivered during the year with the same belt weigher. Due to drift-effects during operation in practice and due to uncertainties associated to the calibration of the belt weigher, the uncertainties associated with the results of weighing are correlated.

Therefore, the uncertainty associated with the determination of the coal (uncertainty of a sum) is calculated by following formula:

$$u_{total} = \frac{U_1 + U_2 + \cdots + U_n}{|x_1 + x_2 + \cdots + x_n|}$$

Where:

$u_{total}$ .....total (relative) uncertainty associated with the determination of coal

$U_i$ ..........uncertainty (absolute value) of the belt weigher ($U_1 = U_2 = U_n$)

$x_i$ .........quantities of coal of the relative batches

In this case the (relative) uncertainty associated with the determination of coal is equal to the (relative) uncertainty of the belt weigher.

**Example 6: Correlated uncertainties of a product**

A mineral industry determines the loss on ignition by weighing the product on a table scale before and after the burning process. The loss on ignition is the mass difference after the burning process compared to the initial weight. The uncertainties associated with the results of weighing are correlated, because the same table scale is used.

Therefore, the uncertainty associated with the determination of the loss on ignition (uncertainty of a product) is calculated by the following formula:

$$u_{total} = u_1 + u_2$$

Where:

$u_{total}$ ..... is the total (relative) uncertainty associated with the determination of the loss on ignition

$u_{1,2}$ ...... (relative) uncertainty of the mass measurement before and after heating

## 8.3 More examples

**Example 7: Uncertainty of the amount of stored fuel**

The overall annual consumption of gasoil is calculated from the aggregated deliveries by tank trucks. The trucks are equipped with a flow meter on the truck subject to national legal metrological control with a maximum permissible error of 0.5%. One truck can deliver 25,000 litres of gasoil. After the annual forecast the operator expects to require an average of 750,000 litres annually over the next year. Therefore, 30 tank truck deliveries per year are expected.

The storage tank for gasoil at the installation has a capacity of 40,000 litres. With a cross section of 8m² the expanded uncertainty of level reading is 2.5% of the total capacity.

If the storage facilities were incapable of containing more than 5% of the annual quantity used of the fuel or material being considered, or this was a low emitting installation, the uncertainty of stock changes can be omitted from the uncertainty assessment (MRR Article 28(2) and Article 47(5)). However, the storage tank can contain 40,000/750,000 = 5.3% of the annually used quantity and therefore must be considered for the uncertainty assessment.

The annual quantity Q of gasoil is determined by the following formula

$$Q = P - E + (S_{begin} - S_{end})$$

Where:

P ......... Purchased quantity over the whole year

E ......... Exported quantity (e.g. fuel delivered to parts of the installation or other installations which are not included in the UK ETS)

$S_{begin}$ ... Stock of the gasoil tank at the beginning of the year

$S_{end}$ ..... Stock of the gasoil tank at the end of the year

As the quantity of purchased gasoil over the whole year (P) is not determined by a single measurement but as the sum of many measurements, i.e. 30 truck deliveries, P can be written as:

$$P = P_1 + P_2 + \cdots P_{30}$$

Where:

$P_i$ …..Purchased quantity from one truck

**Example 7: Uncertainty of the amount of stored fuel**

The overall annual consumption of gasoil is calculated from the aggregated deliveries by tank trucks. The trucks are equipped with a flow meter on the truck subject to national legal metrological control with a maximum permissible error of 0.5%. One truck can deliver 25,000 litres of gasoil. After the annual forecast the operator expects to require an average of 750,000 litres annually over the next year. Therefore, 30 tank truck deliveries per year are expected.

The storage tank for gasoil at the installation has a capacity of 40,000 litres. With a cross section of 8m² the expanded uncertainty of level reading is 2.5% of the total capacity.

If the storage facilities were incapable of containing more than 5% of the annual quantity used of the fuel or material being considered, or this was a low emitting installation, the uncertainty of stock changes can be omitted from the uncertainty assessment (MRR Article 28(2) and Article 47(5)). However, the storage tank can contain 40,000/750,000 = 5.3% of the annually used quantity and therefore must be considered for the uncertainty assessment.

The annual quantity Q of gasoil is determined by the following formula

$$Q = P - E + (S_{begin} - S_{end})$$

Where:

P ......... Purchased quantity over the whole year

E ......... Exported quantity (e.g. fuel delivered to parts of the installation or other installations which are not included in the UK ETS)

$S_{begin}$ ... Stock of the gasoil tank at the beginning of the year

$S_{end}$ ..... Stock of the gasoil tank at the end of the year

As the quantity of purchased gasoil over the whole year (P) is not determined by a single measurement but as the sum of many measurements, i.e. 30 truck deliveries, P can be written as:

$$P = P_1 + P_2 + \cdots P_{30}$$

Where:

$P_i$ …..Purchased quantity from one truck

All input quantities for the determination of Q can be considered as uncorrelated.

The level reading on the storage tank cannot be considered as being within one measurement series because of the long time between the measurements (beginning and end of the year). However, as it is still the same measuring instrument that is being used, it is possible for there to be correlation. For the purposes of this example, the assumption is that it is uncorrelated. To know for sure, an assessment should be carried out, for example by determining correlation coefficients, in accordance with the GUM.

Assuming that no gasoil is being exported (E=0) the uncertainty can be determined in accordance with section 8.2.1 as an uncorrelated uncertainty of a sum:

$$U_Q = \frac{\sqrt{\left(U_{S,begin}\right)^2 + \left(U_{S,end}\right)^2 + (U_{P1}) + .. + (U_{P30})^2}}{\left|s_{begin} - s_{end} + P_1 + \cdots + P_{30}\right|}$$

$U_Q$ ........ total (relative) expanded uncertainty associated of Q

$U_{S,P}$....... (absolute) expanded uncertainty of the stock level reading or quantity provided by one tank

The uncertainty related to the stock level reading is the same for both readings. As the difference between $S_{begin}$ and $S_{end}$ cannot be predicted $S_{begin} - S_{end}$ can be assumed as zero. Furthermore, if all $P_i$ are considered as equal quantities having equal absolute uncertainties the equation simplifies to:

$$U_Q = \frac{\sqrt{2 \cdot (U_s)^2 + n \cdot (U_{Pi})^2}}{P}$$

$$U_Q = \frac{\sqrt{2 \cdot (40{,}000 \cdot 2.5\%)^2 + 30 \cdot (25{,}000 \cdot 0.5\%)^2}}{750{,}000} = 0.21\%$$

As mentioned above, this example assumes that input quantities, stock level readings and meters on all trucks, are not correlated. If the uncertainty of a ‘worst-case’ scenario is to be calculated (that is, the measurements are correlated) the overall expanded uncertainty would be 0.57%:

$$U_Q = \frac{\sqrt{2 \cdot (40{,}000 \cdot 2.5\%)^2 + (30 \ \cdot \ 25{,}000 \cdot 0.5\%)^2}}{750{,}000} = 0.57\%$$

As the activity data related to gasoil consumption must be expressed in tonnes the density of the fuel must be taken into account. The expanded uncertainty for determining the bulk density using representative samples is around 3%. Using the formula from section 8.2.1 for uncorrelated uncertainties of a product leads to:

$$U_{Q(tonnes)} = \sqrt{U_{Q(volume)}^2 + U_{density}^2} = \sqrt{0.21\% + 0.3\%^2} = 3.007\%$$

Although the flow metering in this example has a rather low uncertainty, the conversion into tonnes shows that the influence of the uncertainty of the density determination is the most significant contribution to the overall uncertainty. Future improvements should therefore focus on determination of the density with lower uncertainty.

**Example 8: Uncertainty for source streams partly transferred to connected installations not falling under the UK ETS**

When the installation is partly covered by UK ETS (for example, because not all parts of that installation fall within the scope of the scheme), the quantity measurement determined by an internal sub-meter (for this example the expanded uncertainty is assumed to be 5%) for the non-UK ETS part may have to be subtracted from the quantity of the source stream that is measured by the main meter which falls under national metrological control (maximum permissible error is 2%).

Assuming the installation uses 500,000 $Nm^3$ natural gas per year. Out of that amount of natural gas 100,000 $Nm^3$ will be transferred and sold to an installation not falling under UK ETS. To determine the consumption of natural gas of the UK ETS installation, the consumption of natural gas by that connected installation must be subtracted from the total natural gas consumption of the installation. To assess the expanded uncertainty for the natural gas consumption of the UK ETS installation, following calculation is performed:

$$u_{sourcestream} = \frac{\sqrt{(2\% \cdot 500{,}000)^2 + (5\% \cdot 100{,}000)^2}}{|500{,}000 + (-100{,}000)|} = 2.8\%$$

Please note, that the uncertainty of the main gas meter under national metrological control does not have to be assessed. The uncertainty of the internal submeter that is not guaranteed by national metrological control must be assessed and confirmed before being able to determine the expanded uncertainty associated with the source stream.

## 8.4 Uncertainty over the whole installation and Article 22 of MRR is used

**Example 9: Overall uncertainty with a fall-back approach**

A category A installation with annual emissions of 35,000 t $CO_2$ exclusively burns natural gas. The fuel is obtained by a commercial transaction subject to national legal metrological control, so the expanded uncertainty related to the activity data is 2.0%, using the maximum permissible error allowed by the relevant national legislation. The 2.0% is also the uncertainty related to the total emissions as all calculation factors applied are default values and, for reasons of simplicity, not influencing uncertainty (see note below).

Due to an extension of on-site activities, an additional source stream must be added to the monitoring plan and monitored. The operator provides evidence to the satisfaction of the regulator that applying at least tier 1, for example installing a measurement system, is technically not feasible and proposes to use the fall-back approach. The operator provides evidence in accordance with the GUM that an uncertainty assessment for that source stream gives an expanded uncertainty of 18%. The expected emissions from that source stream are 12,000 t CO2 annually.

When applying the fall-back approach to a category A installation the operator must demonstrate that the expanded uncertainty of the emissions for the whole installation does not exceed 7.5%. In this example the operator calculates the uncertainty using the equation

$$Em_{total} = Em_{NG} + Em_{FB}$$

where:

$Em_{total}$.. total emissions of the installation

$Em_{NG}$ .. emissions resulting from natural gas burning (35,000 t CO2)

$Em_{FB}$ ... emissions resulting from the source stream monitored by the fall-back approach (12,000 t CO2)

As the (relative) uncertainty of the overall emissions can be interpreted as the uncertainties of a sum, the overall uncertainty is calculated by:

$$U_{total} = \frac{\sqrt{(2.0\% \cdot 35{,}000)^2 + (18\% \cdot 12{,}000)^2}}{|35{,}000 + 12{,}000|} = 4.8\%$$

The expanded uncertainty related to the emissions over the whole installation doesn't exceed 7.5%. Therefore, the proposed fall-back approach is appropriate.

Note that default values have uncertainty values attached to them which must be taken into account by calculating the uncertainty of the source stream from the independent uncertainties of the product (see example 3) using error propagation.

# 9 Exemplar: installation with low emissions

This section describes an uncertainty assessment that is commensurate for a low emitting installation (as set out in Article 47 of the MRR) and for hospital or small emitters.

## 9.1 Information about the installation

The example installation produces bricks and pavers and emits on average 15,000 t CO2 per year. The table below contains details of the source streams that need monitoring, the estimated emissions, and the minimum tier requirements for monitoring activity data.

| Fuel/Material | Category | Estimated emissions (t CO2 / year) | Minimum monitoring requirements for activity data |
|---|---|---|---|
| Light fuel oil | Commercial standard fuel | 6,500 | Tier 1 (± 7.5%) |
| Clay | Ceramics: Method A | 8,000 | Tier 1 (± 7.5%) |
| Lignite | Other solid fuels (pore-forming agent) | 498 | De-minimis |
| Diesel | Other gaseous and liquid fuels (auxiliary power unit) | 2 | De-minimis |

**Light fuel oil:**

Fuel is delivered by trucks and stored in tanks (the storage capacity of the tanks is less than 5% of the annual total consumed). In this example the operator can show, by using invoices, that there are clearly commercial transactions between independent parties and the measurements used for trading are subject to national legal metrological control (see route CO-1 or CT-1). Therefore, the maximum permissible error in service, as allowed by relevant national legislation, can be used.

> **Note:** to show compliance the operator must demonstrate evidence that the uncertainty threshold of the required tier is not exceeded, for example by requesting the trade partner to provide the official calibration certificate/protocol for the volume flow measurement instruments installed on the trucks. This evidence will allow verifiers to confirm the validity of data used to determine that the tier is met.

Although it is highly likely that national legislation will require an uncertainty of at least 7.5% or better, a document confirming that this instrument is subject to national legal metrological control is needed.

If the national legal metrological legislation also allows measurement instruments with a higher uncertainty for that purpose, further evidence would be needed. Such evidence may be documents clearly demonstrating which accuracy classes can be used, for example, contractual arrangement with the supplier demonstrating that only measurement instruments with certain accuracy classes are to be used.

**Clay**

The operator takes the clay directly from the clay pit. No commercial transaction takes place and any available measurement instrument used is not subject to national legal metrological control. The operator transports the clay from the pit to the installation by truck and it is possible that those trucks could be weighed on a weigh bridge owned by the operator.

The operator can simplify the uncertainty assessment here if the measurement instrument is used in an environment appropriate for its use specifications (see steps 1 to 4, route CO-2a/2b).

**Note**: to apply the proposed route CO-2a/2b, the operator must demonstrate that:

- Information on operating conditions regarding relevant influencing parameters are available
- Operating conditions regarding relevant influencing parameters are met
- It performs quality assured calibration procedures
- It has further, appropriate, quality assurance procedures for measuring activity data

Compliance with these 4 steps is also relevant for light fuel oil (see above). However, the obligations for compliance with national legal metrological control will assure that those 4 steps are met.

The application of these steps is outlined in section 9.2.

In this example, step 1 is met because the manufacturer's specifications for this weigh bridge contains information about the appropriate operating conditions.

To demonstrate that the requirements of step 2 are satisfied, the operator could prepare a simple checklist like the table displayed in section 9.2.

To demonstrate to their verifier compliance with steps 3 and 4, the operator must have an appropriate procedure for quality assurance of the measurement equipment and ensure that all relevant measuring equipment is calibrated, adjusted and checked at regular intervals including prior to use, and checked against measurement standards traceable to international measurement standards (see the requirements set out in Articles 59(3) and 60(1) of the MRR in Chapter 6).

According to Article 47(5) of the MRR, the operator of an installation with low emissions is exempt from taking stock changes into account in the uncertainty assessment. However, this example includes stock changes in the uncertainty assessment to demonstrate how simple the calculation is and how marginal the impact of the associated uncertainty is on the overall uncertainty.

The consumed quantity of clay is calculated as:

$$Q = P - E + (S_{begin} - S_{end})$$

Example 7 shows how the uncertainty related to stock changes can be calculated. Section 9.2 demonstrates how the operator of the example installation uses this approach.

When determining CO2 emissions, activity data and all calculation factors must relate to the same state of the material stream. Annex IV Section 12 of the MRR refers to 'dry' clay but because 'moisture content' is not a 'calculation factor' as defined in the MRR the moisture content must be considered as part of the determination of the uncertainty of the activity data (see calculation in section 9.2). In this example, the clay has the same moisture level (it is all 'dry') see example 3 in section 8.2.1 for uncorrelated uncertainties of a product).

Because the determination of moisture content and the emission factor is carried out by laboratory analyses, a sampling plan covering these parameters must be written, submitted to and approved by the regulator.

**Lignite**

The operator can apply an estimation method to determine the annual emissions from this de-minimis source stream. They may use purchase invoices to determine the annual activity level. The UK ETS authority has not published default values for lignite which would allow the use of tier 2 without any additional effort. Therefore, emissions are obtained by multiplying the amount lignite used by the net calorific value and emission factor provided in Annex VI of the MRR (Tier 1).

**Diesel**

Diesel is also a de-minimis source stream. Precise measurement would be demanding but fuel invoices can't be used because diesel is also used for mobile machinery such as truck loaders, forklifts etc. The operator can, however, apply an estimation method to determine the diesel used in the auxiliary power unit. In this example a common formula is proposed:

$$Activity\ Data\ =\ AOH\ x\ CAP\ x\ (3600\ /\ 10^9)\ x\ (1\ /\ NCV)$$

$$Annual\ emissions\ =\ AD\ x\ NCV\ x\ EF$$

Where

AOH .... Annual operating hours

CAP .... Installed capacity of the auxiliary power unit (kW)

AD ....... Activity data (t)

NCV .... Net calorific value (TJ/t, taken from, for example, MRR Annex VI or the UK national greenhouse gas inventory, if available)

EF ....... Emission factor (t CO2/TJ, taken from, for example, MRR Annex VI or the UK national greenhouse gas inventory, if available)

## 9.2 Exemplar uncertainty assessment

**Light fuel oil**

- Tier applied for activity data: Tier 2 (± 5.0%), based on invoices
- Evidence for complying with the tier requirements: see attached the latest official calibration certificates for the rotary flow meters on the trucks from three suppliers.

**Clay**

- Tier applied for activity data: Tier 2 (± 5.0%), uncertainty achieved = 4.5% (see calculation below)
- Evidence for complying with the requirements of the tier: route CO-2a/2b is used.

**Evidence for complying with the requirements of 'Step 1':**

See manufacturer's specification ('MPES ± 4.0%') in the weigh bridge's operating manual; see sampling plan for determination of the moisture content of the (raw) clay.

Error propagation considering stock changes:

- storage capacity: 7,000 t
- uncertainty related to stock estimation at end of year (conservative estimate): 10%
- average annual amount of clay consumed: 125,000 t
- maximum permissible error in service laid down in manufacturer's specifications: 4%
- uncertainty related to determine the moisture content: 2%

Calculation:

$$u_{wet} = \frac{\sqrt{2 \times (U_{stock})^2 + \left(U_{clay}\right)^2}}{clay\ consumed\ annually} = \frac{\sqrt{2 \times (7{,}000 \times 10\%)^2 + (125{,}000 \times 4\%)^2}}{125{,}000} = 4.08\%$$

$$u_{dry} = \sqrt{u_{wet}^2 + u_{moisture}^2} = \sqrt{4.08\%^2 + 2\%^2} = 4.5\%$$

**Evidence for complying with the requirements in ‘Step 2’:**

Checklist for relevant parameters of the weigh bridge:

| Parameter listed in manufacturer’s specifications | Value specified by manufacturer | Actual applied ranges/conditions | Compliant? |
|---|---|---|---|
| Temperature | -15 – 50 °C | -15 – 40 °C | Yes |
| Measurement range | 2 - 50 tonnes | 10 - 35 tonnes | Yes |
| Wind speed | < 20 m/s | < 15 m/s | Yes |
| Calibration interval | Every two years | Every two years | Yes |

**Evidence for complying with the requirements in ‘Steps 3 and 4’**

See attached the latest calibration certificates for the truck weigh bridge WB-XYZ123 and the quality management procedures in section 9.3.

**Lignite**

- Tier applied for activity data: Tier 3 (± 2.5%), based on invoices

Evidence[25]: see attached the latest official calibration certificates requested from the trading partners delivering lignite.

**Diesel**

- Tier applied for activity data: de-minimis

Approach: Emissions are calculated based on the annual operating hours, the auxiliary power unit’s installed rated thermal input and the national inventory emission factor for

[25] If the certificates are not available, activity data can still be determined using invoices, but it would be a no-tier approach if the operator can’t demonstrate that it is complying with a tier. This is acceptable in this example as it is a de-minimis source stream.

diesel. Conservative estimates of emissions are typically found to be in the range of 1 to 5 t $CO_2$ per year.

## 9.3 Quality management for the example installation

The example below shows a quality assurance procedure for the measurement equipment

**Example for a procedure**

1. The installation is normally shut down between December and February. Measurement equipment (including that for UK ETS) is usually calibrated during that time.

2. Responsible person (deputy manager of O&M) maintains a calendar of appropriate calibration and maintenance intervals for all ETS instruments listed in the measuring instruments table of the monitoring plan. An alert is set for 30 November of each year.

3. Responsible person (deputy manager of O&M) checks which QM activities are required according to the calendar within the next 4 weeks. As appropriate, they reserve resources required for this task in meetings with the plant manager.

4. Calibration and maintenance of ETS instruments is tracked and documented in file 'Z:\ETS_MRV\QM\calibr_log.xls' electronically and hardcopy: Office HS3/27, shelf 3, Folder identified 'QM 27-ETS -nnnn' (where 'nnnn' = year). Information documented contains: ID of instrument, date when instrument was installed, last calibration, meter reading after last calibration, laboratory hired for the last calibration, statement of the last calibrations, date until next calibration is due.

5. For all measurement instruments for which calibration in that particular year is due the responsible person follows the procedure:

    a. Responsible person (deputy manager of O&M) commissions external experts (calibration laboratory).

    b. Responsible person ensures that QM tasks are carried out on the agreed dates.

    c. Responsible person keeps records of the above QM activities.

    d. Responsible person reports back to plant manager on corrective action required. Corrective action is handled under procedure QM 28-ETS

<End of procedure>

**Example for a procedure**

1. The installation is normally shut down between December and February. Measurement equipment (including that for UK ETS) is usually calibrated during that time

2. Responsible person (deputy manager of O&M) maintains a calendar of appropriate calibration and maintenance intervals for all ETS instruments listed in the measuring instruments table of the monitoring plan. An alert is set for 30 November of each year.

3. Responsible person (deputy manager of O&M) checks which QM activities are required according to the calendar within the next 4 weeks. As appropriate, they reserve resources required for this task in meetings with the plant manager.

4. Calibration and maintenance of ETS instruments is tracked and documented in file "Z:\ETS_MRV\QM\calibr_log.xls" electronically and hardcopy: Office HS3/27, shelf 3, Folder identified "QM 27-ETS -nnnn". (nnnn=year). Information documented contains: ID of instrument, date when instrument was installed, last calibration, meter reading after last calibration, laboratory hired for the last calibration, statement of the last calibrations, date until next calibration is due.

5. For all measurement instruments for which calibration in that particular year is due the responsible person follows the procedure:

a. Responsible person (deputy manager of O&M) commissions external experts (calibration laboratory).

b. Responsible person ensures that QM tasks are carried out on the agreed dates.

c. Responsible person keeps records of the above QM activities.

d. Responsible person reports back to plant manager on corrective action required. Corrective action is handled under procedure QM 28-ETS

<End of procedure>

The procedure is a document independent from the monitoring plan. However, a summary of the procedure must be included in the monitoring plan in a standardised table. This could be as follows:

| Item according to Article 12(2) | Possible content (examples) |
|---|---|

| | |
|---|---|
| Title of the procedure | Quality manual (QM) for ETS instruments |
| Traceable and verifiable reference for identification of the procedure | QM 27 ETS |
| Post or department responsible for implementing the procedure and the post or department responsible for the management of the related data (if different) | Q&M office |
| Brief description of the procedure | • Responsible person maintains a calendar of appropriate calibration and maintenance intervals for all instruments listed in the measuring instruments table of the monitoring plan<br>• Responsible person checks which QM activities are required. As appropriate, they reserve resources required for these tasks in meetings with the plant manager.<br>• Responsible person orders external experts (calibration laboratory and/or manufacturer service technicians).<br>• Responsible person ensures that QM tasks are carried out on the agreed dates.<br>• Responsible person keeps records of the above QM activities.<br>• Responsible person reports back to plant manager on corrective action required, if any.<br>• Corrective action is handled under procedure QM 28-ETS, if relevant. |
| Location of relevant records and information | Hardcopy: Office HS3/27, shelf 3, Folder identified ‘QM 27-ETS – nnnn’. (nnnn=year) Electronically: ‘Z:\ETS_MRV\QM\calibr_log.pst’ |

| | |
|---|---|
| Name of the computerised system used, where applicable | MS Outlook calendar, also used for storing documents as attachments chronologically |
| List of EN standards or other standards applied, where relevant | In the instrument list (document ETS-Instr-A1.xls) the applicable standards are listed. This document is made available to the verifier upon request. |

# 10 Emissions from catalytic cracking using CEMS

## 10.1 Background information

Fluid catalytic cracking is used in refineries to convert high-boiling hydrocarbons into lower-molecular weight but higher value products. During this catalytic reaction part of the carbon-containing feedstock forms carbonaceous deposits on the catalyst which causes its inactivation. Therefore, the catalyst must be regenerated by burning off the deposited carbon in air in a separated reactor, called the regenerator. The carbon in the flue gas formed from this regeneration is converted into CO2 either during the regeneration or during a subsequent post-combustion.

For the monitoring of emissions stemming from catalytic cracker regeneration Annex IV section 2 of the MRR states: '[..] by way of derogation from Article 24 and 25, emissions from catalytic cracker regeneration, other catalyst regeneration and flexi-cokers shall be monitored using a mass balance, taking into account the state of the input air and the flue gas. All carbon monoxide (CO) in the flue gas shall be accounted for as carbon dioxide (CO2), applying the mass relation: t CO2 = t CO * 1.571. The analysis of input air and flue gases and the choice of tiers shall be in accordance with the provisions of Articles 32 to 35 of the MRR. The specific calculation methodology shall be approved by the regulator.' This provision clarifies that the determination of emissions from catalytic cracker regeneration in general requires the use of appropriate analytical standards and accredited laboratories following the provisions set out in Articles 32 to 35 of the MRR.

One way to satisfy those criteria can be by application of continuous emissions monitoring systems (CEMS) following the rules set out in Articles 40 to 46 of the MRR. It must be noted that the mass balance mentioned in section 2, Annex IV of the MRR is not a 'real' mass balance as defined in Article 25 but rather a flue gas volume balance according to Article 43(5)(a) of the MRR According to Annex IV of the MRR, section 2, the determination of the annual emissions from the regeneration of catalytic converters from cracking and re-forming processes must be monitored using a balance, taking into account the CO2, CO, oxides of nitrogen (NOx) and sulphur dioxide (SO2) contents in the flue gas from the regeneration and in the amount of air supplied in accordance with Article 43(5)(a) of the MRR.

For CEMS, the annual emissions of the emitted greenhouse gases (GHG) are calculated by the equation provided in equation 1, Section 3, of Annex IV in the MRR):

$$Emissions_{annual}[t] = \sum_i GHG\ conc_{hour\ i}\left[\frac{g}{Nm^3}\right] \times flue\ gas\ flow_i[Nm^3/hr] \times 10^{-6}\ [t/g]$$

Where:

GHG$conc_{hour\,i}$ ....... concentrations of GHG in the flue gas flow measured during operation hour $i$

$Flue\ gas\ flow_i$........ flue gas flow determined for each hour $i$

For each hour $i$, therefore, the emissions from coke are determined as the product of the GHG$conc_{hour\,i}$ and the $flue\ gas\ flow_i$. As the same measurement equipment is usually used through-out the year for each hour $i$, the uncertainties associated with the emissions calculated for each hour should be treated as correlated (see section 8.2.2). Consequently, the uncertainty of the annual emissions is the same as for the emissions of each hour $i$.

In the subsequent processes, a complete conversion of CO to CO2 is assumed:

$$E_{total,coke} = GHG_{conc} \times V_{flue,dry}$$

$$GHG_{conc} = \left(a_{CO_2} + b_{CO}\right) \times \frac{44.01}{22.41 \times 1000}$$

Where:

$E_{total,coke}$ …overall CO2 emissions from coke burned off in t CO2

$GHGconc$ …greenhouse gas (CO2) concentration in the dry flue gas in g/Nm³

$V_{flue,dry}$ ......calculated annual volume of the dry flue gas (see calculation below) in Nm³

$a_{CO_2}$ ...........measured carbon dioxide content in dry flue gas in % by volume

$b_{CO}$ .............measured carbon monoxide content in dry flue gas in % by volume

The volume flow rate of the flue gas to be used in the equation above is usually not measured, so it must be calculated by a balance. In the regeneration, the coke-loaded catalyst is regenerated by an air supply and all combustible constituents are converted to CO2, CO, H2O, NOx and SO2. The calculation of the amount of dry flue gas from the amount of air supplied is done according to the following formula, assuming a constant inert gas content of 79.07% by volume:

$$V_{flue,dry} = \frac{79.07}{100 - a_{CO_2} - b_{CO} - c_{O_2} - d_{NOx} - e_{SO2}} \times V_{air,dry}$$

$V_{air,dry}$ .......volume of dry air supplied in Nm³

$a_{CO2}$ .......... measured carbon dioxide concentration in dry flue gas in % by volume

$b_{CO}$ ........... measured carbon monoxide concentration in dry flue gas in % by volume

$c_{O_2}$ ............ measured oxygen concentration in dry flue gas in % by volume

$d_{NOx}$ ..........measured NOx concentration in dry flue gas in % by volume

$e_{SO2}$ .......... measured SO2 concentration in dry flue gas in % by volume

A prerequisite for the balance shown is that coke contains hardly any nitrogen compounds, or they are converted into NOx (which is usually the case).

## 10.2 Determination of the uncertainty

For source streams the uncertainty thresholds set out in the MRR commonly refer to the determination of activity data. In contrast to that, the uncertainty threshold for emissions from cracking activities relate to the total annual emissions. Therefore, the uncertainty of $E_{total,coke}$ must be assessed and compared against the thresholds of the required tier listed in table 1 of Annex II of the MRR.

As $E_{total,coke}$ depends on two input quantities, $V_{flue,dry}$ and the $GHG_{conc}$, the uncertainty associated with these two components must be assessed:

$$V_{flue,dry} = \frac{79.07}{100 - a_{CO_2} - b_{CO} - c_{O_2} - d_{NOx} - e_{SO2}} \times V_{air,dry}$$

$$GHG_{conc} = (a_{CO_2} + b_{CO}) \times \frac{44.01}{22.41 \times 1000}$$

**Step 1: determination of the uncertainty of $V_{flue,dry}$**

In order to determine the flow rate of the dry flue gas, $V_{flue,dry}$, the volume flow of dry air at standard conditions ($V_{air,dry}$) is needed as well as the composition of the components in the flue gas, namely the concentrations of CO2, CO, O2, NOx and SO2.

**Step 1.1: uncertainty of $V_{air,dry}$**

$V_{air,dry}$ is not measured directly. What is measured is the volume flow of the air supplied at operating conditions and in the wet state. To convert this parameter into the volumetric flow of dry air at standard conditions the measurements must be corrected for temperature, pressure and water vapour content. Therefore, the uncertainty associated with the parameter $V_{air,dry}$ can be calculated as the product of uncorrelated input quantities from the measuring uncertainties of the air flow, the temperature, the pressure and the water vapour content using the following equation as independent uncertainties of a product (see example 3 in section 8.2.1):

$$U_{air,dry} = \sqrt{u^2_{V_{air,measured}} + u^2_T + u^2_p + u^2_w}$$

Each parameter would be determined using appropriate standards, respectively, which also cover the determination of associated uncertainties. For this example, the table below describes the relative uncertainty of each parameter:

| Parameter | Relative uncertainty $u_i$ (expanded at the 95% confidence level) |
|---|---|
| $V_{air}$ measured | ± 2.0% |
| Temperature T | ± 0.5% |
| Pressure p | ± 0.5% |
| Water vapour content w | ± 1.5% |

Using these figures in the formula above leads to an uncertainty related to $V_{air,dry}$ of ±2.6%.

**Step 1.2: uncertainty of flue gas concentration components**

Out of the five parameters listed, CO2 and CO usually show the highest concentrations; the concentration of NOx and SO2 are always very low by comparison. Therefore, related uncertainties are negligible and can be omitted from the uncertainty assessment without any significant impact on the result. Oxygen (O2) can be ignored if the measurement is performed before of the CO post combustion unit but not if the measurement is performed after the CO post combustion unit.

The concentration of CO2 and CO is determined while emitted from the stack. The applicable standard for the continuous emissions monitoring system (CEMS) is EN ISO 14181 which also covers the determination of the associated measurement uncertainty of the concentration.

The table below describes the resulting uncertainties of the CO2 and CO concentrations obtained by CEMS are as follows:

| Parameter<br><br>($x_i$ upper end of the measured range) | Relative uncertainty $u_i$<br><br>(expanded at the 95% confidence level) | Absolute[26] uncertainty $U_i$ = ($x_i$*$u_i$) (expanded at the 95% confidence level) |
|---|---|---|
| CO2: 16%vol | ± 3.0% | ± 0.48vol% |
| CO: 2%vol | ± 3.0% | ± 0.06vol% |

The uncertainty is determined using the following equation as independent uncertainties of a sum[27] (see example 2 in section 8.2.1):

$$u_{GHG_{conc}} = \frac{\sqrt{U_{CO_2}^2 + U_{CO}^2}}{100 - a_{CO_2} - b_{CO}} = \frac{\sqrt{0.48\%^2 + 0.06\%^2}}{82\%} = 0.6\%$$

Using these figures leads to an uncertainty related to the measurement of the concentrations of the flue gas components of ±0.6%.

**Step 1.3: combined uncertainty of $V_{flue,dry}$**

The combined uncertainty of $V_{flue,dry}$ is 2.7% as determined by using the formula for independent uncertainties of a product:

$$u_{V_{flue,dry}} = \sqrt{u_{V_{air,dry}}^2 + u_{GHG_{conc}}^2} = \sqrt{2.6\%^2 + 0.6^2} = 2.7\%$$

**Step 2: uncertainty of $GHG_{conc}$**

The combined uncertainty of $GHG_{conc}$ can then be determined using the following formula for independent uncertainties of a sum (see example 2 in section 8.2.1):

[26] Note that despite figures given in percentages these are labelled as absolute uncertainties as they indicate percentage points related to the parameter concentration. For instance, using the figures in the table the concentration of CO2 would be 16% ± 0.48%, i.e. between 15.52% and 16.48% at the 95% confidence level.
[27] Note that this formula is not fully correct here as parameters are in the denominator which leads to different results when calculating partial derivatives. However, the formula used is simpler but still provides very similar results. Furthermore, it is assumed that uncertainties associated with the concentrations of CO2 and CO are uncorrelated. However, if for example the same equipment (analyser, sampling system, etc.) is used or measurements are performed simultaneously, these assumptions may not be valid, and uncertainties would have to be treated as correlated (i.e. higher uncertainties).

$$u_{GHG_{conc}} = \frac{\sqrt{U_{CO_2}^2 + U_{CO}^2}}{a_{CO_2} + b_{CO}} = \frac{\sqrt{0.48\%^2 + 0.06\%^2}}{18\%} = 2.7\%$$

Using the figures from the table in step 1.2 leads to an uncertainty related to the GHG concentrations of ±2.7%.

**Step 3: overall (combined) uncertainty of $E_{total,coke}$**

The uncertainty related to $E_{total,coke}$ is calculated as independent uncertainty of a product as follows:

$$u_{E_{total,coke}} = \sqrt{u_{V_{air,dry}}^2 + u_{GHG_{conc}}^2} = = \sqrt{2.7\%^2 + 2.7\%^2} = 3.8\%$$

The overall uncertainty of $E_{total,coke}$ is ±3.8%. Note that because expanded uncertainties were used in each step, this overall uncertainty also corresponds to the expanded uncertainty, i.e. the uncertainty at the 95% confidence level as required by the MRR. This value of 3.8% must be compared against the tier thresholds in table 1 of Annex II of the MRR.

If you need a version of this document in a more accessible format, please email alt.formats@energysecurity.gov.uk. Please tell us what format you need. It will help us if you say what assistive technology you use.