Method Implementation Document (MID 14181)

EN 14181: Stationary source emissions
Quality assurance of automated measuring systems

Environment Agency
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mCERTS
THE ENVIRONMENT AGENCY'S
MONITORING CERTIFICATION SCHEME

Record of amendments

Version number	Date	Section	Amendment
2.3	June 2010	All	Complete revision to provide for the pilot accreditation scheme for EN 14181. The largest changes are a clarification of the requirements for the functional tests, and the appendices, which include a template for reports for QAL2 and ASTs; and a template for reporting the functional tests.

Status of this document

This document may be subject to review and amendment following publication. The latest version is available on our website at:

www.mcerts.net

Foreword

EN 14181 defines the requirements for carrying out the quality assurance of continuous emission monitoring systems (CEMs) used on installations falling under the Large Combustion Plant (LCPD) and Waste Incineration Directives (WID).

This Method Implementation Document (MID) is one of a series being produced by the Environment Agency to supplement, where necessary, European and international monitoring standards to ensure organisations carrying out regulatory monitoring implement the standards consistently.

For simplicity, this MID will refer to *testing laboratories* to cover both commercial testing laboratories and industrial operators' in-house monitoring arrangements, since EN 14181 uses this term.

Test laboratories carrying out the procedures specified by EN 14181 for installations regulated by the Environment Agency shall follow the requirements of the standard, this MID and our *Technical Guidance Note M20, Quality assurance of CEMs*. For particulate monitors EN 13284-2 and its associated MID also apply. This MID is also used as a basis for accreditation to the requirements of EN 14181, under the MCERTS scheme for manual stack emissions monitoring.

We require all testing laboratories carrying out Standard Reference Method (SRM) measurements under EN 14181 and EN 13284-2 to be accredited to EN ISO/IEC 17025 for the MCERTS standard for manual stack emission monitoring for the applicable SRMs.

This MID also covers the requirements for EN 13284-2, which is an application of EN 14181 for particulate-monitoring CEMs.

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Note: We have revised this MID to support the pilot accreditation scheme for EN 14181. As such, and bearing in mind that pilot schemes evolve, we expect this MID to also evolve, based on feedback from application and field assessments. We also welcome feedback and suggestions for amendments.

Contents

Introduction

British Standard EN14181 describes the quality assurance procedures required to ensure that Automated Measurement Systems (AMS) installed to measure emissions to air – known as continuous emission monitoring systems (CEMs) in the UK - are capable of meeting the uncertainty requirements on measured values required by the applicable European Directives (see section 1 below). This MID will refer to CEMs instead of AMS.

EN 14181 defines three different Quality Assurance Levels (QAL1, QAL2, and QAL3) to achieve this objective. These QALs cover the suitability of a CEM for its measuring task (e.g. before or during the purchase of a CEM), the validation of the CEM following its installation, and the control of the CEM during its ongoing operation on an industrial plant. The standard also defines an Annual Surveillance Test (AST).

Testing laboratories carrying out the procedures specified by EN 14181 for sites regulated by the Environment Agency shall follow the requirements of the standard, this MID and our *Technical Guidance Note M20, Quality assurance of CEMs*. For particulate monitors EN 13284-2 and its associated MID also apply.

The QAL1 requirement assures that the uncertainty of the CEM meets the specified 95% confidence interval (CI) specified in applicable Directives. MCERTS certification for the appropriate ranges and determinands is taken as evidence of CEMs meeting the QAL1 requirements.

This MID supplements EN 14181 and its provisions reflect the clause numbers in this standard, but does not re-state all the provisions of the standard.

We require all testing laboratories carrying out Standard Reference Method (SRM) measurements under EN 14181 to be accredited to EN ISO/IEC 17025 for the MCERTS standard for manual stack emission monitoring for the applicable SRMs. This MID is also used as a specification for accreditation to the applicable parts of EN 14181. Test laboratories can be accredited to EN 14181 under the MCERTS scheme for manual stack emissions monitoring, for organisations.

The pro-forma forms in Appendices 1, 2 and 3 are available separately as Word files.

Note: This MID also covers the requirements for EN 13284-2, which is an application of EN 14181 for particulate-monitoring CEMs

1. Scope

EN 14181 shall be used on all installations covered by the following EU directives;

- Directive on the limitation of emissions of certain pollutants into the air from large combustion plants (2001/80/EC)(LCPD).

- Directive on the incineration of waste (2000/76/EC)(WID).

2. Normative references

- MCERTS – Manual stack-emission monitoring performance standard for organisations. Environment Agency.

- MCERTS – Personnel competency standard for manual stack-emission monitoring. Environment Agency.

- MCERTS performance standards for continuous emission monitoring systems
- MCERTS – Performance standards for portable systems for emission monitoring. Environment Agency.
- Technical Guidance Note M1: Sampling requirements for monitoring stack emissions to air from industrial installations. Environment Agency.
- Technical Guidance Note M2: Monitoring of stack emissions to air. Environment Agency.
- Technical Guidance Note M20: Quality assurance of continuous emission monitoring systems. Environment Agency

The latest versions of the above documents are available from the Environment Agency's web site www.mcerts.net. Test laboratories shall refer to the latest versions of the above documents.

3. Terms and definitions

3.4 Competent authority

In England and Wales the *competent authority* is the Environment Agency.

3.8 Emission limit value

The emission limit value (ELV) cited in EN 14181 is normally the daily average ELV. However, for some existing LCPD installations it is the 48 hour average. The ELV used for the statistical tests under QAL2 and the AST shall therefore be the daily average ELV, or the nearest equivalent ELV.

4. Symbols and abbreviations

No additional requirements to EN 14181.

5. Principle

This MID describes the procedures that test laboratories must follow when applying EN 14181, and to meet the requirements of the UKAS accreditation-scheme for EN 14181.

5.1 General

A *test laboratory* is a company or organisation that carries out the QAL2 and AST requirements as defined within EN 14181. It can be a commercial test laboratory or an industrial operator's in-house monitoring team. Test laboratories shall be accredited to EN ISO/IEC 17025 for the MCERTS performance standards for manual stack emission monitoring for the applicable SRMs.

EN 14181 requires operators to have a procedure for QAL3. We recommend that the test laboratory does not perform a QAL2 exercise unless an effective QAL3 procedure is in place at the regulated installations; for example, as a guideline, there should ideally be at least three months of QAL3 data demonstrating that the readings from the CEM are both stable and comply with the specifications for drift, as required during the QAL1 tests. If there is not an interval of at least three months, the test laboratory shall state the reasons for this in the test report.

Note: Whilst three months is considered to be the ideal minimum interval between commissioning and a QAL2, we recognise that this is not always practical or possible.

5.2 Limitations

When conducting parallel measurements, the measured signals are either taken directly from the CEM, or from the installation's data collection system (e.g. expressed as analogue or digital signal), provided that raw data is collected during the QAL2 and AST. If the data is taken from the operator's DCS, then the test laboratory needs to ensure (as far as practicable) that the data from the DCS is representative of the data taken from the CEM.

5.3 Measurement site and installation

The test laboratory shall assess whether the following provisions are available and then report their findings in Section 2.3.2 of the report, for which there is a pro-forma in Appendix 1, noting any non-compliances. EN 14181 requires provisions for the effective management and maintenance of the CEM, in order to ensure the maintenance of the quality of data. Such provisions include at least the following:

- A safe and clean working environment with sufficient space and weather protections.
- Easy and safe access to the CEM,
- Adequate supplies of reference materials, tools and spare parts,
- Facilities to introduce the reference materials for gaseous-monitoring systems, both at the inlet of the sampling line (where present), and at the inlet of the CEM.
- Compliance with the requirements of MID 15259.

5.4 Testing laboratories performing SRM measurements

Same requirements as 5.1 above.

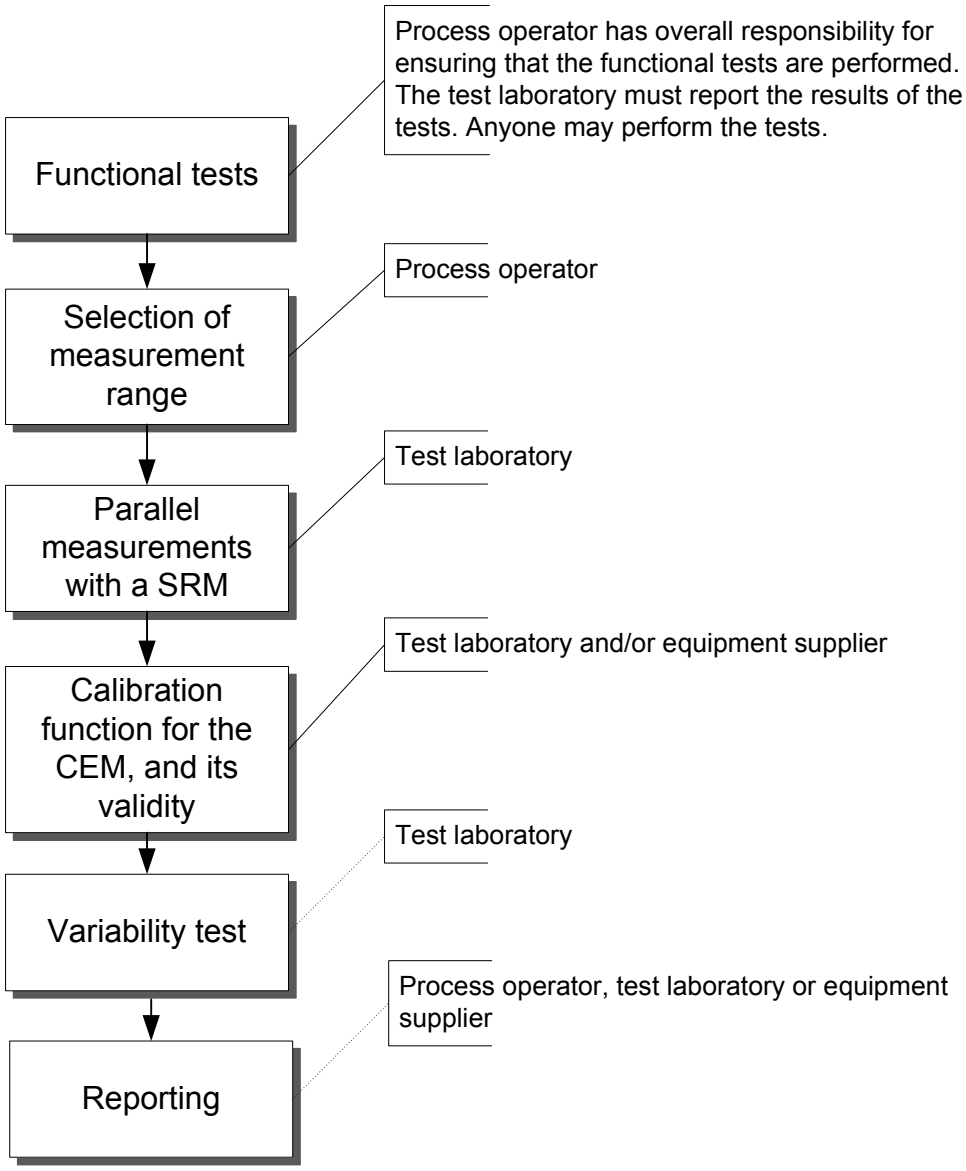
6. Calibration and validation of the CEM (QAL2)

Although QAL2 does not require a linearity check, this test is recommended. The data may also be used to extend the calibration range from the QAL2 tests, providing that the data points from the linearity test are within the 95% Confidence Intervals (CIs) of the calibration function. Additionally, linearity may be required to calibrate a CEM, if the emissions are too low to apply a reliable calibration function derived using SRMs.

6.1 General

Figure 1 shows the responsibilities of the various parties participating in the QAL2 and AST procedures. Overall control of the work can be the responsibility of the process operator, the test laboratory, or an independent third-party organisation (refer to TGN M20).

Figure 1 - Flow diagram showing responsibility for calibration and variability tests



A QAL2 shall be performed within six months of a significant change to plant operation or fuel (but see the Note below.)

A change to plant operation is considered significant if it triggers the need for a permit variation and it changes the emissions profile such that the calibration function is no longer valid.

A change of fuel is considered significant if:

- The change of fuel is known to result in a change in the emissions profile.
- The change of fuel requires a permit variation.
- The change is from any one of the following types to another – gaseous fuel, liquid fuel, solid fuel - and the alternative fuel is used for more than 10% of the time during a year.

- The change is from a single type of fuel to a mixture of more than one type of fuel (or *vice versa*), and the alternative fuel (or mixture) is used for more than 10% of the time during a year.

Note: If there is a significant change of fuel, then the operator should first perform an AST (refer to section 8 in EN 14181 and this document). If the results fit within the 95% CIs of the calibration function, then no further testing is required. If not, then a full QAL2 is required.

However, a new QAL2 for changes in the process or fuel will not be needed if:

- The operator can demonstrate that the change in process does not affect the emissions profile and the original calibration factor remains valid.

- The thermal input is less than 10% per year for the alternative fuel, and/or

- The change in fuel use can be shown to have no significant effects on emissions, when compared to the original fuel.

Following the first QAL2, an AST may be performed instead of a subsequent QAL2 if:

- Daily average gaseous emissions are less than 50% of the ELV in-between QAL2 exercises.

- Daily average particulate emissions are less than 30% of the ELV in-between QAL2 exercises.

- There is no significant change to plant operation or fuel.

If there are significant changes to plant or fuel the operator is required to demonstrate that the calibration function is still valid. A risk based approach can be adopted. If the operator is confident that the calibration function has not changed then an AST can be performed to provide the evidence. If the AST shows that the calibration function is still valid, through a pass of the variability test and acceptance test, then a new QAL2 is not required. If it is known or strongly suspected that a change in calibration function has occurred due to changes in plant or fuel than the operator my choose to go straight to performing the QAL2.

6.2 Functional tests

The functional tests are a mandatory requirement within EN 14181. Either the test laboratory, process operator or CEMs supplier may perform the functional tests. However, the process operator is responsible for ensuring that the functional tests are performed. The test laboratory has three responsibilities with regard to the functional tests:

- The test laboratory shall inform the process operator that the functional tests are a mandatory requirement within EN 14181, and that the functional tests must be performed before the parallel reference tests specified within the QAL2 and AST requirements of EN 14181. Additionally, the test laboratory needs to inform the process operator of the risks associated with not performing the functional tests. The risks of not performing the functional tests before a QAL2 or AST include regulatory enforcement action, and a failure of the QAL2 and AST.

- The test laboratory shall report the results of the functional tests, using the *pro forma* forms in Appendix 1 of this MID.

- If the functional tests are not performed, then the test laboratory shall include the reasons for this in the QAL2 or AST report.

Note: The execution of the functional tests may be outside the control of the test laboratory. However, if the functional tests have not been performed, then the test laboratory still needs to record this (and the reasons for any tests that have not been performed) in the report.

The functional tests should be performed no more than one calendar month before the parallel reference measurements with SRMs. If the functional tests are performed earlier than one month before the parallel reference measurements with SRMs, then the test laboratory shall inform the operator that they should provide verifiable evidence to demonstrate that the results of the functional tests are still valid. This evidence should include at least performance tests to demonstrate that the performance of the CEM has not changed between the functional tests and the parallel reference measurements. Such tests would include at least zero and span data for the entire sampling system (applicable) and analyser.

Note: Even though a test laboratory has informed the operator that it is the operator's obligations under EN 14181, there may be cases where the above conditions are not met and are beyond the control of the test laboratory.

Functional tests are required for oxygen-measuring CEMs, and for moisture-monitoring CEMs if these are present. The criteria for the tests shall be based upon the requirements of the MCERTS performance standards.

Note: Performing the linearity and span test for moisture requires a moisture generator, which can create practical difficulties on site. Whilst we recommend that this test is performed and operators can require their suppliers to perform this test, both operators and test laboratories may apply a risk-based approach if they do not wish to perform the test. However, if the CEM fails the QAL2 variability test due to a failure of the moisture monitoring, then the linearity test for moisture will be required.

Note: Moisture-monitoring CEMs means those CEMs which typically measure one or more gaseous stack-gases on a hot, wet basis.

Whilst anyone may perform the functional tests, Annex A of EN 14181 specifies which tests are required, and where applicable, includes details on how the functional tests are to be performed. TGN M20 provides an elaboration of the requirements of Annex A of EN 14181. We recommend that test laboratories, process operators and CEMs service-providers all include documented provisions for the functional tests, within their management systems. Annex A of EN 14181 and the requirements of TGN M20 should be used as a basis for these documented procedures.

6.3 Parallel measurements with an SRM

(i) Execution of the SRM tests

Only suitably qualified testing laboratories may perform the SRMs required for QAL2 (see section 5.1 above). It must be noted that 15 tests is the minimum number specified in EN 14181, and that it is advised to carry out a greater number in case any tests are deemed invalid. The tests should be performed over the time periods specified in EN 14181. If the test laboratory performs the parallel reference tests over a total shorter duration, then the test laboratory shall provide evidence to show that measurements over a shorter, total duration are representative of the process. Additionally, the length of the sampling day should not compromise safety. Therefore the length of the sampling day should balance the requirements for representative data against the requirements for safety.

Note: For example, if the process is stable, then shorter time-periods could be suitable. Alternatively, historical data, supported by statistical analyses, could be used to show that shorter time-periods are also representative

In terms of sampling strategy and locations, the test laboratory shall meet the requirements of MID 15259, particularly with regard to grid measurements and ensuring that samples are spatially and temporally representative.

Ideally operators should select a time when the emissions are likely to be their highest and most varied; for example, when bag filters are replaced, emissions of particulate are temporarily higher for a short time and this produces an ideal time to measure a wider spread of emissions. However, an industrial process may not be deliberately varied outside normal operational conditions, in order to create higher than normal emissions.

If the test laboratory is using instrumental methods for SRMs, then the SRM monitoring-system may be operated continuously over the three days of the QAL2. Zero and span checks on monitoring systems used within SRMs shall take at least at the start and the end of the monitoring period, and at least once every 24 hours. Test laboratories shall state in their Site Specific Protocol the time intervals between the start-time of each pair of measurements. Furthermore, test laboratories shall demonstrate that the interval between each pair of data provides representative samples, taking into account any process variations.

Note: For example, due to process and/or safety constraints, a test laboratory may only be able to take data at certain times. This may occur during a batch process. In such cases, the test laboratory may leave an instrumental SRM running, but still perform the zero and span checks once every 24 hours. In such cases, it is essential to ensure that the measurements are still representative, and that the SRM is stable over a 24 hour-period.

Monitoring systems used within SRMs must meet the performance standard of the relevant EN standard. An instrument certified under MCERTS will meet these requirements, whilst certified systems must be certified to the appropriate determinands and ranges.

Note 1: TGN M20 provides further guidance on using instrumental methods and on the number of samples.

Note 2: It is recommended that the three days for the QAL2 SRM tests should be spaced apart, so that the data may be analysed after each day. This is especially the case for particulates.

(ii) Averaging periods for SRMs

The averaging period for each SRM measurement should be equal to the averaging period of the short-term ELV; this ordinarily means 30 minutes for WID installations, and 60 minutes for LCPD installations. Test laboratories should consider longer averaging periods if the emissions are low. Test laboratories may use averaging periods of less than 60 minutes for LCPD applications if the test laboratory can demonstrate that the there is no significant difference between 30 minute and 60 minute averaging periods. However, the averaging period must never fall below 30 minutes.

(iii) Outliers

Test laboratories should always consider whether outliers are present. Therefore the test laboratory shall have a procedure for dealing with outliers in the data. Once the test laboratory has eliminated any outliers, then all the remaining data pairs shall be used. Environment Agency Quick Guide RM-14 provides guidance on dealing with outliers and an example procedure, although test laboratories may use any valid procedures for dealing with outliers.

Note 3: The Environment Agency Quick Guide RM-QG14, which describes a procedure for dealing with outliers, is available along with other Quick Guides from the Environment Agency's MCERTS web-site at www.mcerts.net .

As a general guide, when plotting the raw SRM and raw CEM data, if the R^2 value for the linear-regression line is equal or more than 0.9, then it is not ordinarily necessary to perform an outlier test. Additionally, any data points are not likely to be outliers unless they are more than three standard deviations from the regression line.

(iv) Peripheral CEM instruments

a. Oxygen

- Reference monitoring shall be performed for oxygen (O_2), taking at least 15 measurements over the same measuring periods as for the other determinands. It must be noted that 15 tests are a minimum and that it is advised to carry out a greater number in case any tests are deemed invalid.

- A QAL2 shall be performed for O_2 if the CEMs fail the variability test and this failure is due to the installation's O_2 CEMs reporting erroneous concentrations due to a mis-calibration.

- If a QAL2 is needed for the O_2 CEMs, when calculating the variability, use default values of 21% in lieu of the ELV and 10% for a 95% CI.

b. Moisture

- Reference monitoring shall be performed for moisture, taking at least 15 measurements over the same measuring periods as for the other determinands. It must be noted that 15 tests are a minimum and that it is advised to carry out a greater number in case any tests are deemed invalid.

- If the CEM fails the variability tests using the operator's moisture measurements, then the SRM moisture measurements may be used instead. If the CEM then passes the variability tests, then the operator shall remedy the moisture monitoring equipment or methods of moisture determination, and then verify its performance using SRM data and the QAL2 procedures. If a QAL2 is required for moisture, then use default values of 30% for the 95% CI and 30% moisture concentration (v/v) for the ELV.

- EN 14181 allows the operator to use default values for moisture; for example, the moisture concentration may be calculated using other operational data. However, the moisture values must still be validated.

(v) Sample lines and delays

When CEMs and SRMs use any combination of different techniques, different lengths of sampling system and different flow rates, then there will be a difference between the readings of the SRM and CEM at any given time due to the different lag times. Therefore the test laboratory shall have a procedure to determine the lag times, and for matching the data from the CEMs and SRMs accordingly.

(vi) Spread of data over the calibration range

- At least one of the 15 selected data points must be at or near zero. If this condition is not fulfilled, then extra measurements are necessary to attain measurement data at or near zero. EN 14181 states that the test laboratory shall verify that the CEMs read zero when the emissions are zero.

- Near zero is defined as a value 5% or less of the ELV.

- Ideally zero values should be measured when the installation is not producing emissions. If this is not possible, then reference materials shall be used to determine the CEM's response to zero values of the determinand.

(vii) Low level clusters

A low level cluster of data values is defined as a spread of data which is less than the 95% confidence interval of the daily average ELV, and where the resultant SRM and CEM data does not provide a good line of best fit. An R^2 value of less than 0.9 for gases, for example, indicates a poor fit. In such cases, a calibration function may be unreliable. Therefore the test laboratory may use the SRM data to

confirm that the CEM is responding to even low emissions, that the process is compliant with the ELVs, and linearity data may be used to calibrate the CEM.

Note 1: As a guideline, when there are low level clusters, the difference between the average of the CEM and SRM data should not be more than the 95% confidence interval of the daily average ELV.

Note 2: TGN M20 provides further guidance on dealing with low-level clusters of data., whilst Quick Guide RM-06 contains guidance on treating low-level clusters from particulate-monitoring CEMs.

(viii) CEM repairs or replacement and when QAL2 test is required

If all or part of the CEM is repaired, or an identical type of CEM is substituted for the CEM which was initially installed and calibrated, then the Calibration Function determined during the most recent QAL2 shall continue to be used. QAL3 data shall be collected and inspected in the defined manner to determine whether or not a new QAL2 is needed.

6.4 Data evaluation

The test laboratory shall take part in the Proficiency Testing Scheme for EN 14181, and maintain the level of proficiency required to meet the requirements of the scheme.

Refer to EN 14181 for examples of QAL2 tests for gaseous CEMs.

Refer to EN13284-2 for examples of QAL2 tests for particulate CEMs.

6.4.1 Preparation of data

Refer to EN 14181 for an example of a calculation

Ordinarily test laboratories shall prepare the data according to the requirements of EN 14181, and determine a calibration function using data at the conditions experienced by the CEM.

6.4.2 Establishing the calibration function

Refer to EN 14181 for an example of a calculation.

The scale of the CEMs measurement range shall be scaled according to the ELV (e.g. 2x the short-term ELV in order to capture the expected peaks in emissions) and not the range measured during the QAL2. For example, if the ELV is 60 $mg.m^{-3}$ for HCl and the range measured during the QAL2 was varied from zero to 20 $mg.m^{-3}$ expressed as a half-hourly average, then the CEM should ideally be set to measure of range of zero to 120 $mg.m^{-3}$.

EN 14181 is based on the premise that CEMs have a linear response to increasing values of a determinand. This premise is generally correct for all types of CEMs, with the exception of some types of particulate CEMs. These may ordinarily have a linear response; however, the particulate measured may result in a non-linear response due to variations in particle size and shape. For the calibration of particulate CEMs, refer to EN13284 Part 2 and the corresponding MID for EN 13284-2.

6.5 The calibration function of the CEM and its validity

Refer to EN 14181 for an example calculation.

(i) Cases where the emissions are sufficiently high to apply Methods A or B

In general, if the data is sufficiently linear to derive a valid calibration function, then:

- Based on the calibrated CEM data, the calibration range may ordinarily be extended by 10% for gases and 100% for particulates (if the particulate CEM is demonstrably linear),.

- The calibration range may be extrapolated further for gases using reference materials. The calibration function is extrapolated to the ELV. This extrapolation is valid if the difference between a reading from a reference point (e.g. a span gas) at the ELV, and the extrapolated calibration line at the ELV, is not more than the 95% confidence interval (CI) of the ELV.

Note: A valid calibration should ideally have a correlation co-efficient of the regression line of at least $R^2 = 0.9$. However, it can be lower than this, especially for clustered results, which especially applies to particulate matter. Therefore if the results are for clusters of particulate data, an R^2 as low as 0.5 is not uncommon, and can still produce a pass in the variability test.

If the emissions then exceed the maximum value (plus the allowable 10% extension) recorded during the initial SRM tests, then the provisions of section 6.5 of EN 14181 shall ordinarily apply (see Note 2), such that a new QAL2 is required if:

(1) more than 5 % of the number of measured values from the CEM, calculated weekly, are above this value for more than 5 weeks in the period between two ASTs or QAL2 tests;

(2) more than 40 % of the number of measured values from the CEM, calculated weekly, are above this value for more than one or more weeks.

Note: Extending the calibration range using reference materials is necessary to provide assurance for any CEM readings above the maximum of the SRM values, plus the allowable 10% extension. However, if the CEM readings are repeatedly above this value, such that the limits in (1) and (2) above are exceeded, then this shows that the original SRM readings may not be sufficiently representative. Therefore historical data for the installation should be used to determine sampling times when the emissions will be representative.

However, there may be cases where a process operator would need to perform a QAL2 several times due to the unpredictable nature of emissions, in order to meet the requirements for a sufficient spread for a valid calibration range. Therefore the Environment Agency may be able to waive the above requirements, if the operator can demonstrate the unpredictable nature of emissions, and if surrogates can be used to extend the valid calibration range, to a degree of accuracy which is acceptable to the Environment Agency. In such cases, then the VCR may be extended using reference materials up to 2x the ELV, provided that the highest reading with a surrogate does not differ from the extrapolated calibration function by the more than half the 95% confidence interval of the ELV. Refer to TGN M20 for further information.

(ii) Cases where the emissions are not sufficiently high enough to derive a calibration function using SRM data

If the emissions are less than the 95% CI of the daily average ELV and the scatter of data points means that it is not possible to derive a valid calibration function, then:

- The CEM may be calibrated using reference materials.

- The SRM data is used to verify that the emissions are well within the ELV and that the CEM is responding with an acceptable degree of accuracy and precision to low levels of emissions.

Note 1: The readings are acceptable if the average of the CEM and SRM results do not differ by more than the 95% confidence interval of the daily average ELV.

Note 2: Refer to TGN M20 for guidance on dealing with low levels of emissions; this is described as Method C.

6.6 Calculation of variability

Refer to EN 14181 for an example calculation. Note that the daily average ELV is applied.

STA document QGN001, Revision 1, provides additional guidance on calculation of uncertainty.

6.7 Test of variability

Refer to EN 14181 for an example calculation. Note that the daily average ELV is applied. Appendix 3 contains k_v values for three to 30+ pairs of data.

6.8 QAL2 report

(i) The QAL2 report

The QAL2 report submitted to the Environment Agency shall be at least summary and a full report shall be submitted if required, where the full report shows all the raw data. Appendix 2 shows a template which specifies the minimum requirements for QAL2 and AST reports. The QAL2 report shall be retained by the operator and test laboratory.

Note: The raw data means the short-term averages, e.g. half-hourly or hourly averages.

Furthermore:

- The operator and the test laboratory shall retain all raw data for a period of at least five years.
- Operators and test laboratories shall have quality assurance provisions to assure the traceability of data.

(ii) Recommendations and statements in the QAL2 report

Test laboratories should state any actions that the operator needs to perform. For example, some functional tests may have been omitted before the parallel reference tests; or the QAL3 procedure might be incomplete.

Test laboratories may recommend when to apply the calibration function. For example, if there is not a significant difference between the standard SRM values and standardised CEM values before applying the calibration function, then test laboratories may recommend that it may not be necessary to apply the calibration function. There are two important factors to note in such cases:

The differences between the standardised SRM and standardised CEM results (before applying the calibration function) are not significant if the CEM and SRM results do not differ by more than half the allowable confidence interval at the ELV.

The operator needs to consult the local Environment Agency Regulatory Officer to determine if not applying the calibration function is acceptable.

7. Ongoing quality assurance during operation (QAL3)

7.1 General

The QAL3 procedure is the responsibility of the operator. However, during QAL2 and AST exercises, the test laboratory shall check whether there is a QAL3 procedure in place, and whether there is data

to show that the operator has implemented the QAL3 procedure. Then the test laboratory shall report their findings in the QAL2/AST report

The main points to note are that:

- The CEM must be able to indicate negative values.
- The operator shall decide which type of control chart or procedure is to be used.
- When using Shewhart charts, no adjustment of the zero and span figures should be made.

Note: Whilst auto-corrections before the CEM drifts out of the control range are not recommended, such auto-corrections may take place so long as the CEMs still meet the QAL1 specification for zero and span drift.

- If the CEM has been calibrated over an expanded range, (refer to sections 6.5 of this document and EN 14181), then the zero and span checks will be over this set range.

7.2 Procedure to maintain ongoing quality

EN14181 gives two examples of maintenance of the ongoing quality. However, the CEMs supplier can implement any procedure within the CEM that will confirm that the precision and drift, as specified in QAL1, has remained in control. Data values must be stored for audit purposes at the next AST.

Note: For regulatory purposes, the allowable drift and precision is based on the QAL1 specification. However, operators may choose to use the actual QAL1 performance of the CEMs as a benchmark.

7.3 Calculation of the standard deviation

Refer to TGN M20 for an example of a calculation.

7.4 Documentation of control charts

No additional requirements; refer to TGN M20 for examples.

8. Annual Surveillance Test (AST)

8.1 Functional tests

The functional tests are a mandatory requirement within EN 14181. Annex A specifies the requirements for the functional tests. Either the test laboratory, process operator or CEMs supplier may perform the functional tests. However, the process operator is responsible for ensuring that the functional tests are performed. The test laboratory has three responsibilities with regard to the functional tests:

- The test laboratory shall inform the process operator that the functional tests are a mandatory requirement within EN 14181, and that the functional tests must be performed before the parallel reference tests specified within the QAL2 and AST requirements of EN 14181. Additionally, the test laboratory needs to inform the process operator of the risks associated with not performing the functional tests. The risks of not performing the functional tests before a QAL2 or AST include regulatory enforcement action, and a failure of the QAL2 and AST

- The test laboratory shall report the results of the functional tests, using the pro forma in Appendix 1 of this MID.

- If the functional tests are not performed, then the test laboratory needs to include the reasons for this in the QAL2 or AST report.

The functional tests need to be performed no more than one calendar month before the parallel reference measurements with SRMs. If the functional tests are performed earlier than one month before the parallel reference measurements with SRMs, then the test laboratory shall inform the operator that the operator needs to provide verifiable evidence to demonstrate that the results of the functional tests are still valid. This evidence shall include at least performance tests to demonstrate that the performance of the CEM has not changed between the functional tests and the parallel reference measurements. Such tests would include at least zero and span data for the entire sampling system (applicable) and analyser.

Functional tests are required for oxygen-measuring CEMs, and for moisture-monitoring CEMs if these are present. The criteria for the tests shall be based upon the requirements of the MCERTS performance standards.

Note: Moisture-monitoring CEMs means those CEMs which typically measure one or more gaseous stack-gases on a hot, wet basis.

Whilst anyone may perform the functional tests, Annex A of EN 14181 specifies which tests are required, and where applicable, includes details on how the functional tests are to be performed. TGN M20 provides an elaboration of the requirements of Annex A of EN 14181. We recommend that test laboratories, process operators and CEMs service-providers all include documented provisions for the functional tests, within their management systems. Annex A of EN 14181 and the requirements of TGN M20 should be used as a basis for these documented procedures.

8.2 Parallel measurements with a SRM

(i) Application of the SRMs

In general the provisions of Section 6.3 of this MID also apply to the SRMs performed during the AST.

Only suitably qualified testing laboratories may perform the SRMs required for the AST (see section 5.1 above).

It must be noted that five tests are a minimum and the test laboratory is advised to carry out a greater number in case any tests are deemed invalid. Additionally, the length of the sampling day should not compromise safety. Therefore the length of the sampling day should balance the requirements for representative data against the requirements for safety.

If the test laboratory is using instrumental methods for SRMs, then the SRM monitoring system may be operated continuously over the entire duration of the AST. Zero and span checks of the monitoring systems shall take place at the start and the end of the sampling period, and at least once every 24 hours. Test laboratories shall state in their Site Specific Protocol the time intervals between the start-time of each pair of measurements. Furthermore, test laboratories shall demonstrate that the interval between each pair of data provides representative samples, taking into account any process variations. Test laboratories shall have a procedure for dealing with outliers in the data. Once the test laboratory has eliminated any outliers, then all the remaining data pairs shall be used.

Monitoring systems used within SRMs must meet the performance standard of the relevant EN standard. A instrument certified under MCERTS will meet these requirements, whilst certified systems must be certified to the appropriate determinands and ranges..

(vi) Low level clusters

A low level cluster of data values is defined as a spread of data which is less than the 95% confidence interval of the daily average ELV, and where the resultant SRM and CEM data does not provide a good line of best fit. An R^2 value of less than 0.9 for gases, for example, indicates a poor fit. In such cases, a calibration function may be unreliable. Therefore the test laboratory may use the SRM data to confirm that the CEM is responding to even low emissions, that the process is compliant with the ELVs, and linearity data may be used to calibrate the CEM.

Note: As a guideline, when there are low level clusters, the difference between the average of the CEM and SRM data should not be more than the 95% confidence interval of the daily average ELV.

TGN M20 provides further guidance on dealing with low-level clusters of data.

8.3 Data Evaluation

Data from the AST may be used to extend the valid calibration range if:

- The range is not extended more than 1.5x the maximum value of the calibration range from the original QAL2.
- The AST data is within the 95% CIs of the calibration range.

8.4 Calculation of variability

Refer to EN 14181 for example of pass-fail criteria. Note that the daily average ELV is applied.

8.5 Test of variability and validity of the calibration function

Refer to EN 14181 for example calculations. Note that the daily average ELV is applied. Appendix 3 contains k_v values and t-factors for three to 30+ pairs of data.

8.6 AST report

The AST report submitted to the Environment Agency shall be at least summary and a full report shall be submitted if required, where the full report shows all the raw data. Appendix 2 shows a template which specifies the minimum requirements for QAL2 and AST reports. The AST report shall be retained by the operator and test laboratory.

Furthermore:

- The operator and the test laboratory shall retain all raw data for a period of at least five years.
- Operators and test laboratories shall have quality assurance provisions to assure the traceability of data.

9. Documentation

No additional requirements to EN 14181.

Annex A
(normative)
QAL2 and AST functional tests of CEMs

A.1 General

Scope of the functional tests.

Activity	QAL2		AST	
	Extractive CEM	**Non-extractive CEM**	**Extractive CEM**	**Non-extractive CEM**
Alignment and cleanliness		✓		✓
Sampling system	✓		✓	
NOx converter efficiency	✓		✓	
Documentation and records	✓	✓	✓	✓
Serviceability	✓	✓	✓	✓
Leak test	✓		✓	
Zero and span check	✓	✓	✓	✓
Linearity			✓	✓
Interferences			✓	✓
Zero & span drift (audit)			✓	✓
Response time	✓	✓	✓	✓
Report	✓	✓	✓	✓

Note 1: The lead organisation for the functional tests is the MCERTS accredited test laboratory. This applies whether the test laboratory is performing the tests or not, i.e. if the test laboratory is not performing the tests, then the test laboratory still makes the operator aware of the requirements of the functional tests, and then reports the results of the functional tests in the QAL2 or AST report.

Note 2: Anyone performing the functional tests should be suitably trained and competent in the applicable procedures, e.g. through training provided by the manufacturer or supplier of the CEMs.

Note 3: The organisation conducting linearity tests must have access to approved surrogate reference materials for the particulate analyzer

Note 4: All parts used for repairs must be covered by the instrument's QAL1 certificate, i.e. the parts must meet the same performance specifications as those used within the CEM during its QAL1 testing and approval.

A.2 Alignment and cleanliness

No additional requirements to EN 14181.

A.3 Sampling system

If the CEM is equipped with a NOx converter, then the efficiency of this converter must be tested at least annually, and not at longer intervals than those specified by the supplier of the NOx converter. Additionally, the efficiency of the converter shall not fall below 95%.

A.4 Documentation and records

Training records refer to the process operator's employee's records on training for the CEM system. The test laboratory needs to check for the presence of the following, but not assess the actual documentation; procedures for the management, maintenance and calibration of CEMs, and; maintenance records

A.5 Serviceability

A list of recommended reference material(s), tools and spare parts must be supplied by the CEM manufacturer / supplier and cross-checked with availability on site or by supply agreement.

A.6 Leak test

No additional requirements to EN 14181.

A.7 Zero and span check

Refer to original QAL1 tests regarding ranges of reference materials. Data to be supplied by the manufacturer / supplier.

A.8 Linearity

No additional requirements. The data for zero readings is treated in the same way as other data points.

A.9 Interference

MCERTS certification of CEMs will show which interferents can have a measurable effect on the CEMs response to stack gases other than the target determinand. Therefore, if there is a failure of the QAL2 or AST tests, then the test laboratory shall refer to the MCERTS testing data, and determine whether any significant interferents are likely to be present in the stack which could result in a failure of the QAL2. If so, then the test laboratory shall determine the extent to which such interferents may introduce a bias into the measurements from the CEM.

Note 1: Test data on potential interferents should be available from the CEM manufacturer or supplier.

Note 2: In reality, the interferent test will be very rarely required. The Environment Agency knows of very few examples of this test being required.

A.10 Zero & span drift (audit)

No additional requirements to EN 14181. The test laboratory shall assess whether the operator has a QAL3 procedure in place, and whether the operator has applied this procedure. The evidence would comprise (i) a documented procedure, (ii) zero and span data, (iii) control charts.

A.11 Response time

The response time is specified in the MCERTS performance standards for CEMs.

A.12 Report

No additional requirements to EN 14181.

Annex B
(normative)
Test of linearity

Refer to TGN M20 for a detailed explanation.

Annex C
(normative)
CUSUM Control Chart

Refer to TGN M20 for detailed explanation.

Annex D
(informative)
Documentation

No additional requirements to EN 14181.

Annex E
(informative)
Example of calculation of the calibration function and performance of the variability test

Refer to EN 14181 and EN 13284 Part 2 for examples.

Annex F
(informative)
Example of calculation of the standard deviation σ_{CEM} of the CEM at zero and span level

Refer to EN 14181 and EN 13284 Part 2 for examples.

Annex G
(informative)
Example of using the calibration function and performance of the variability test in the AST

Refer to EN 14181 and EN 13284 Part 2 for examples.

Annex H
(informative)
CUSUM charts field form (drift)

Refer to TGN M20 for an explanation

Appendix 1: Pro-forma for assessing and reporting the results of the functional tests

Requirement	✓	Notes
1. Alignment and Cleanliness		
A visual inspection, with reference to the CEMs manuals, shall be carried out on the following when applicable:		
• Internal check of the CEM		
• Cleanliness of the optical components		
• Flushing air supply		
• Obstructions in the optical path		
• After re-assembly at the measurement location at least the following shall be checked		
• Alignment of the measuring system		
• Contamination control (internal check of optical surfaces)		
2. Sampling Systems		
A visual inspection of the sampling system shall be performed, noting the condition of the following components, when fitted:		
• Sampling. probe		
• Gas conditioning systems		
• Pumps		
• All connections		
• Sample lines		
• Power supplies		
• Filters		
• NOx converters – if the sampling system contains a NOx converter, then the test laboratory shall record when the last efficiency-test was performed, and the result of this test.		
• The sampling system shall be in good condition and free of any visible faults, which may decrease the quality of data		
3. Leak testing		
• Leak testing shall be performed according to the CEMs manuals. The test shall cover the entire sampling system.		
4. Zero and Span check		
• Reference zero and span materials shall be used to verify the corresponding readings of the CEM.		
• In case of non-extractive CEM, zero and span checks shall be performed using a reference-path free of flue gas before and after readjustment and after re-assembly of the CEM at the measurement location.		
5. Linearity		
• During the calibration/linearity tests the applied concentrations should be logged onto the DCS to		

Requirement	✓	Notes
prove the complete system i.e. concentration applied to the instrument is represented by the instrument output and identical to the value logged on the DCS. DCS logged values should be included in the instrument service report. • The linearity of the CEM's response shall be checked using five different reference materials, including a zero concentration.		
• The reference material with zero concentration, as well as the reference materials with four different concentrations, shall have a verifiable quantity and quality.		
• In case of gaseous reference materials, these four reference materials can be obtained from different gas cylinders or can be prepared by means of a calibrated dilution system from one single gas concentration.		
• The reference material concentrations shall be selected such that the measured values are at approximately 20 %, 40 %, 60 % and 80 % of the range of two times the emission limit. It is necessary to know the values of the ratios of their concentrations precisely enough so that an incorrect failure of the linearity test does not occur. The dry test reference material shall be applied to the inlet of the CEM.		
The individual CEMs are tested using the following concentrations applied in a randomised sequence:		
• Reference material with zero concentration;		
• Reference material concentration approximately 20 % of 2 times the emission limit;		
• Reference material concentration approximately 40 % of 2 times the emission limit;		
• Reference material concentration approximately 60 % of 2 times the emission limit;		
• Reference material concentration approximately 80 % of 2 times the emission limit;		
• Reference material with zero concentration;		
After each change in concentration, the first instrument reading shall ordinarily be taken after a time period equal to at least three times the response time of the CEM. At each reference material concentration, at least three readings shall be made, six readings shall be taken at zero. The time period between the start of each of the three readings shall be separated by at least four times the response time. The test-laboratory may apply a risk-based approach to linearity testing in order to reduce the time for the tests. For example, the readings may be taken after less than 3x the response time; however, if the CEM fails the linearity test, then the test laboratory shall repeat the linearity test and wait at least 3x the response time as stated above. Alternatively, the number of repetitions of the test may be reduced if the CEM passes the required performance criteria by a factor of at least 2 (i.e. half the allowable residual). Increasing the waiting time to 5x the response time, for example, may be a means of meeting this requirement. Where no other method is possible, the linearity can also be performed with the aid of reference		

Requirement	✓	Notes
materials such as grating filters or gas filters. The linearity shall be calculated and tested using the procedure as given in EN 14181 annex B. If the CEM does not pass this test, then the problem shall be identified and rectified.		
6. Interferences		
• A test shall be undertaken if the process gases to be monitored contain components that are known interferences, as identified during QAL1 and there is a failure of the QAL2 or AST which could be due to interferents.		
7. Zero and Span drift (Audit)		
• The test laboratory shall assess whether the operator has a QAL3 procedure in place, and whether the operator has applied this procedure. The evidence would comprise (i) a documented procedure, (ii) zero and span data, (iii) control charts.		
8. Response Time		
• The response time of the CEM shall be checked. This can be performed, if appropriate, by feeding of the reference material at the end of the sampling probe. The response time shall not exceed the performance requirement applied during the QAL1 tests.		
9. Service Report		
As a minimum requirement the service report should include the following:		
• Document reference for work instruction for the type of work being undertaken		
• Instrument manufacturer		
• Instrument type		
• Instrument model		
• Instrument Serial No		
• Operating principle		
• Operating range		
• Certification details		
• Compliance with MCERTS (including certificate no.)		
• Location		
• Date and time work was undertaken		
• Equipment used – type, serial no's, calibration dates		
• Gases used – certificate numbers, expiry dates, binary / mix		
• NOx converter efficiency test, if applicable		
• Calibration and linearity data as required by EN14181		
• Logged data for period of calibration and linearity		

Requirement	✓	Notes
Note: There may be gaps in the data, however, for various reasons; for example, if the CEMs are removed from the stack for the linearity test. In such cases, the test laboratory shall state why there are gaps in the data.		
• Name and signature of service engineer		

Appendix 2: Template for a report for QAL2/AST

Foreword

This template specifies the minimum requirements for reports for QAL2 and ASTs, as required by EN 14181. It is a specification for both the contents of a report, and the order of the contents. Test laboratories may include additional information, and also present much of the information specified below within tables. However, additional information should be within the annexes, in order to keep the main body of the report as short as possible. As a guideline, the main body of the report should be between 20 and 40 pages long for an installation with one multi-gas CEM. The full data and supplementary information should be included in annexes.

The template is based on Microsoft Word but a test house can use any programme they wish providing the minimum requirement set out in this template are included.

This template is divided into six core sections and supporting Annexes, which are:

- Section 1 – Executive summary/title page
- Section 2 – Information about the regulated installation, and its provisions for monitoring
- Section 3 – Information about the monitoring that the test laboratory performs
- Section 4A – Data and calculations – QAL2
- Section 4B – Date and calculations - AST
- Section 5 – Results of the functional tests, and who performed the tests.

Annexes

- Any supporting data which the test laboratory decides to include in the Annexes
- Any supporting information about the test laboratory, e.g. a copy of the scope of accreditation

We have designed this template with flexibility in mind. Therefore so long as test laboratories include all the specified contents and in the order of sections given in this template, variations are permitted. The template can also be amended based on the experience of test laboratories and feedback.

Section 1 – Executive Summary/title pages

Section 1A – a table to include the following:

- The name, address, and primary contact for the process operator
- The type of process/installation name
- The permit number
- The dates of the tests
- The date and version of the report
- The name, address, telephone number, email address and UKAS reference for the test laboratory
- The report author
- The name of the person approving the report

Section 1B - a table to include the following:

- Whether the test is an AST or a QAL2
- The stack designation
- The determinands
- Value for a in the calibration function
- Value for b in the calibration function
- The valid calibration range based on calibrated CEMs data from the QAL2
- The valid calibration range based on calibrated CEMs data from the AST
- The extrapolated range based on reference materials
- A statement of a pass or fail for the variability test (QAL2 and AST)
- A statement of a pass or fail for the calibration test (AST)
- A firm statement that the calibration function, once applied, only remains valid so long as there are no adjustments made to the CEMs. For example, small, manual adjustments to the gain and offset after regular zero and span checks.

Section 1C – a table to include the following:

- If there any are deviations from the SRMs, and reasons for this.
- If there any are deviations from EN 14181, and reasons for this.
- Any impacts on the results.
- Any actions required.

Section 2 – Information about the Regulated Installation

2.1	**Regulatory information**			
2.1.1	**Name of the operator**			
2.1.2	**Name of the installation**			
2.1.3	**Address of the installation**			
2.1.4	**Sector for the installation**			
2.1.5	**Permit number**			
2.1.6	**Date of the last QAL2/AST**			
2.1.7	**Regulated determinands and emission limit values**			
Determinand	Emission point	Short-term ELV	Daily average ELV	Uncertainty requirement
Notes	*These will be specified in the permit*	*This will typically be a 30-minute average or a 1 hour average, but may differ for LCPD installations.*	*This will typically be a daily average, but may be a 48-hour average for some types of LCPD installation*	*This will be expressed as a 95% confidence interval within the WID or LCPD*
2.2	**Operational Information and site monitoring-provisions**			
2.2.1	**Process type and variations in emissions.** • Continuous or batch process - describe the operating phases. Indicate the percentage of the load of normal runs and expected variations of emissions. • Explain how the expected emissions and variations in the emissions influence the sampling times and duration, in order to capture a representative set of samples. • Include any other factors which would affect the monitoring results e.g. automatic zero and span operations, or low-emissions values. • It is also essential to check historical data beforehand, to check if the emissions are at or near zero and to report these. • If the check reveals that the emissions are at or near zero, then include provisions to deal with these low emissions. • If the CEM is reading zero then investigate to ensure that the CEM is working. An agreement with the client that the implications are understood and that these discussions and findings are documented.			
2.2.2	**Type of fuel** • Describe what types of fuels and their proportions during the QAL2/AST and during a normal operating year, and whether multiple calibration-functions are required.			

	• If the process is co-incineration, then what types and proportions of fuels were used?
2.2.3	**Abatement** • Type of abatement plant and how this affects emissions.
2.3	**Monitoring provisions at the installation – periodic monitoring**
2.3.1	**Stack and sampling ports** • Rectangular or round stack/duct • Dimensions/diameter of stack • Location of the sampling ports • Number of sampling ports • Include a diagram (and preferably photographs) of the emission point, platform and location.
2.3.2	**Monitoring platform and site-provisions** Record the following: • The extent to which there is a safe and clean working environment with sufficient space and weather protections. • Whether there is easy and safe access to the CEM, • Whether there are adequate supplies of reference materials, tools and spare parts, • Whether there are facilities to introduce the reference materials for gaseous-monitoring systems, both at the inlet of the sampling line (where present), and at the inlet of the CEM. • The degree of compliance with the requirements of MID 15259.
2.3.2	**Sample – how representative is it?** • Grid measurements – compliance with MID 15259 • Ratio of highest to lowest flow-rates.
2.4	**Continuous Emission Monitoring Systems (CEMs) at the installations**
2.4.1	**Types of CEMs for each main determinand, oxygen and moisture** • Type, e.g. cross-duct, in situ, or extractive • Brand • Model • Certification range

	• Principle • Location of sampling/measurement • Statement of QAL1 compliance • Statement whether moisture is by measurement or calculation
2.4.2	**Types of monitoring for peripheral determinands** • Monitoring for temperature and pressure, and a statement whether temperature and pressure are recorded.

Section 3 – Information about the monitoring campaign

3.1	**Test laboratory staff**						
Name	MCERTS Registration Number	Certification level with expiry date					
		L1	L2	TE1	TE2	TE3	TE4
3.2	**Standard Reference Methods (SRMs)** - include the following, e.g. in a table. • Determinand • SRM standard applied • Type and principle • Operational range • Certification range of any instrumental methods used • Uncertainty • UKAS accreditation						

Section 4A – Data and calculations – QAL2

Section 4A – Monitoring data and calculations	
This section specifies the minimum number of tables and charts, and the minimum requirements for each table. Test laboratories may combine tables where data would be repeated, e.g. in Table 1 and 2, where it is necessary to convert data to standard conditions in order to determine whether Method A or Method B is to be used.	
A4.1	**Table 4.1 - Raw monitoring data** • Start and end times of each pair of data • Raw CEM results • Stack/CEM peripheral determinands for temperature, pressure, oxygen and moisture (if measured) • Raw SRM results • SRM peripheral determinands for temperature, pressure, oxygen and moisture • SRM results expressed under the same conditions as the CEM results
A4.2	**Table 4.2 – standardised monitoring data** • Standardised CEM results (STP) • Standardised SRM results (STP)
A4.3	**Plot 1 – mandatory** • Time series of standardised CEM versus standardised SRM data
A4.4	**Calculation and procedure – Elimination of outliers**
A4.5	**Calculation – determination of Method A or Method B**
A4.6	**Table 4.3 – data used to determine the calibration function** • SRM results expressed under the same conditions as the CEM results • Raw CEM results
A4.7	**Calculation – determination of the calibration function**
A4.8	**Table 4.4 – Calculation of calibrated CEM values** • Raw CEM values • Calibrated CEM values, at stack conditions • Peripheral determinands for CEMs • Calibrated CEM values, standardised

Section 4A – Monitoring data and calculations	
A4.9	**Plot 2 – mandatory** • x-y plot of CEM versus SRM data, both at conditions measured by the CEM, and not standardised • Calibration function, including R^2 value for Method A
A4.10	**Table 4.5 – Data used for the variability test** • Calibrated CEM values, standardised • SRM values, standardised • Difference between each pair of values • Difference minus the average of the differences • Difference minus the average of the differences, squared
A4.11	**Calculation - the variability test** • The calculations, as set out in EN 14181 • The variability test • Statement of the results
A4.12	**Plot 3 – Mandatory** • x-y plot of calibrated, standardised CEM data versus standardised SRM data, • Indication of the valid calibration range • Extrapolation of the valid calibration range, using surrogates • Parallel lines above and below the regression line through the standardised, calibrated CEM values and standardised SRM values. The parallel lines should be at the allowable 95% confidence intervals of the daily average ELV (sometimes called 'tramlines')

Section 4B – Data and calculations - AST

Section 4B – Monitoring data and calculations	
This section specifies the minimum number of tables and charts, and the minimum requirements for each table. Test laboratories may combine tables where data would be repeated, e.g. in Table 1 and 2, where it is necessary to convert data to standard conditions in order to determine whether Method A or Method B is to be used.	
B4.1	**Table 4.1 - Raw monitoring data** • Start and end times of each pair of data • Raw CEM results • Stack/CEM peripheral determinands for temperature, pressure, oxygen and moisture (if measured) • Raw SRM results • SRM peripheral determinands for temperature, pressure, oxygen and moisture • SRM results expressed under the same conditions as the CEM results
B4.2	**Table 4.2 – standardised monitoring data** • Standardised CEM results • Standardised SRM results
B4.3	**Plot 1 – mandatory** • Time series of standardised CEM versus standardised SRM data
B4.4	**Calculation and procedure – Elimination of outliers**
B4.5	**Table 4.3 – data used to calculate calibrated values** • Raw CEM values • The original calibration function from the previous QAL2 • Calibrated CEM values, at stack conditions • Peripheral determinands for CEMs • Calibrated CEM values, standardised • Standardised SRM values
B4.6	**Table 4.5 – Data used for the variability test** • Calibrated CEM values, standardised • SRM values, standardised • Difference between each pair of values

Section 4B – Monitoring data and calculations	
	• Difference minus the average of the differences • Difference minus the average of the differences, squared
B4.7	**Calculation - the variability test and the acceptance test** • The calculations, as set out in EN 14181 • The variability test • The acceptance test • Statement of the results
B4.8	**Plot 2 – Mandatory** • x-y plot of calibrated, standardised CEM data versus standardised SRM data • Indication of the valid calibration range • Parallel lines above and below the regression line through the calibrated, standardised CEM values and standardised SRM values. The parallel lines should be at the allowable 95% confidence intervals of the daily average ELV (sometimes called 'tramlines') • Extrapolation of the valid calibration range, using surrogates, if applied

Section 5 – Results of the functional tests

Appendix 3
k_v values and t-factors
Table A4.1

Number of parallel measurements N	$k_v(N)$	$t_{0.95}(N-1)$
3	0.8326	2.353
4	0.8881	2.920
5	0.9161	2.132
6	0.9329	2.015
7	0.9441	1.943
8	0.9521	1.895
9	0.9581	1.860
10	0.9629	1.833
11	0.9665	1.812
12	0.9695	1.796
13	0.9721	1.782
14	0.9742	1.771
15	0.9761	1.761
16	0.9777	1.753
17	0.9791	1.746
18	0.9803	1.740
19	0.9814	1.734
20	0.9824	1.729
25	0.9861	1.711
30	0.9885	1.701

Ordinarily between 3 and 8 pairs of data are required for an AST, and at least fifteen measurements for a QAL2. If there are more than 8 pairs of data for an AST, or more than 30 for a QAL2, then it is advisable to choose the applicable k_v and $t_{0,95}$ values for the next lowest value. For example, if there are 37 pairs of data points, then k_v and $t_{0,95}$ values for 30 data pairs can be safely used.