RM-QG6 – Calibrating particulate-monitoring continuous emission monitoring systems (CEMs)

1. Scope

This note describes the procedures for calibrating particulate monitors according to the requirements of BS ISO 10155, and BS EN 14181 (as supplemented by BS EN 13284-2), especially for low concentrations of particulate

2. Practical Guidance

Applying BS EN 14181, BS EN 13284-2 and BSI ISO 10155 at low particulate concentrations

2.1 Background

ISO 10155 and BS EN 14181 (supplemented by BS EN 13284-2) specify that a test laboratory shall calibrate continuous emission monitoring systems (CEMs) for particulate matter (PM) using parallel measurements with a specified number of repetitions of a standard reference method (SRM), as given in Table 1. These two standards are based on the premise that CEMs have a linear response, when using reference materials or methods. In order to derive a reliable calibration function, these standards require the following:

- A good spread of data, or medium to high-level clusters (including some values at or near zero for all cases) in situations where EN 14181 applies.
- An acceptable level of accuracy and precision for the SRM or reference materials.
- A regression line which passes through zero, or near to zero.

If the correlation co-efficient (R^2) of the regression line for the CEM and SRM data is 0.9 or more, then the calibration function will most likely be valid. However, there are two common conditions where it is not possible to apply the above requirements:

- Low-level clusters of data – this is very common for emissions of PM, especially when the industrial process is equipped with bag filters.
- When the R^2 value is under 0.9.

Whenever there are low-level clusters of data, the uncertainty of the SRM will be proportionally greater with respect to the measured emissions. In such cases, there will be a greater degree of relative scatter of data points, which is reflected by a low R^2 value. In such cases, the test laboratory cannot produce a reliable calibration function using SRM data.

This Quick Guide provides guidance on calibrating PM CEMs where there is a spread of data, medium to high-level clusters, or low-level clusters.

2.2 Cases where there is a spread of data

There is a spread of data when the measurements can range from zero up to the ELV, and where the difference of the highest and lowest readings is more than 15% of the ELV. In such cases, calibrate particulate monitors as follows:

- Apply EN 14181 and EN 13284-2 for sites falling under the incineration and large-combustion plant Directives.
- Apply ISO 10155 for other types of installation
- Ensure that there are values near or at zero.
- Take the number of repetitions of the SRM, as specified in Table 1.

2.3 Cases where there is a medium to high-level cluster of data

There is a medium to high-level cluster of data when the measurements are above 30% of the ELV, and when the difference of the highest and the lowest readings is not more than 15% of the ELV. In such cases, calibrate particulate monitors as follows:

- Apply EN 14181 and EN 13284-2 for sites falling under the incineration and large-combustion plant Directives.
- Apply ISO 10155 for other types of installation, following the provisions in 2.9 of this document.
- Ensure that there are values near or at zero.
- Take the number of repetitions of the SRM as specified in the standards in Table 1.

2.4 Low-level clusters of particulate emissions

These are very common. If the emissions during a QAL2 exercise for EN 14181 are low, i.e. less than 30% of the ELV, then it is unlikely that the R^2 value will be below 0.9. The R^2 value is likely to fall when the cluster of emissions is closer to zero. In such cases, the test laboratory should use surrogates to calibrate the CEM. If the CEM is sufficiently precise and the test laboratory minimises the uncertainty of the SRM as far as practicable, then the R^2 value will be higher.

2.5 Roles of the SRM

The SRM has two roles; the first is to verify that the sweep of emissions reported by the CEM is valid. The second role is to determine a calibration function if this is required.

2.6 Procedure for calibrating particulate CEMs when either SRM data or surrogates are valid

- If the R^2 value of the regression line for the SRM and CEM data is more than 0.9, then the test laboratory shall determine a calibration function and apply this to CEM.

- If the R^2 value is less than 0.9, then the test laboratory shall use surrogates to calibrate the CEM if this is possible.

The test laboratory may find that it is not possible to determine a meaningful calibration function; for example, when most or all of the reported PM values are at or near zero. If

so, then the test laboratory shall do the following instead of the variability test specified in EN 14181:

- Determine an average and standard deviation for the CEM data and SRM data.
- Compare the averages of the CEM data and SRM by using the 95% confidence interval specified in applicable Directives.
- The results are acceptable if both averages lie within the 95% confidence interval.

Using surrogates

Surrogates have two roles:

- Calibrating CEMs if this is possible
- Determining stability through zero and span tests.

Although surrogates for PM CEMs are limited and can be inaccurate, they are the best practicable option available if there is insufficient SRM data to calibrate a CEM, but only when the response of the CEM to the surrogate is proportional to a known particulate concentration. However, because of the nature of PM, this is rare.

2.7 Setting up CEMs if surrogates cannot be used to calibrate the CEM

There will be situations when calibration is impossible, due to:

- Low clusters of emissions, meaning that the data does not meet the requirements of BS EN 13284-2 or ISO 10155.
- Surrogates may be useful for zero, span and linearity tests, but the resultant data cannot be meaningfully related to concentrations of particulate.

In such cases, the particulate monitor cannot be used as a quantitative monitor for particulate, but can serve as a qualitative indicator. Therefore if the emissions are consistently low, we recommend that:

- The SRM is used to verify that the emissions are low.
- Surrogates are used to check the linearity, and zero and span settings of the monitor.
- The monitor is set on its most sensitive range, in order to alert the operator that the control devices for particulate may need attention if an increase in emissions is observed.

2.8 Requirements of BS EN 14181

BS EN 14181 has two requirements which require the use of surrogates and related procedures:

- Linearity tests. The test laboratory can also use the results of this test as an alternative means of calibration if there is insufficient SRM data.
- Zero and span tests.

If the design of the CEM does not provide for conventional zero and span tests, then the operator may use an alternative procedure that reflects the response of the CEM, if it were measuring the target determinand.

If the design of the CEM does not provide for linearity and drift checks at all, once the CEM is operating on an industrial process, then the operator will not be able comply with BS EN 14181.

2.9 Applying ISO 10155 – medium to high-level clusters

ISO 10155 describes a procedure for calibrating PM CEMs using repetitions of the SRM. This standard is based on the premise that the emissions will vary, or can be varied. Then the test laboratory repeats the SRM three times at three different concentrations, therefore producing nine SRM measurements.

ISO 10155 therefore provides for cases where there is a spread of data, but not for clusters. In order to determine calibration factors for PM CEMs at installations where the emissions are not low (i.e. above 30% of the ELV), but occur as medium to high-level clusters, use the following procedure.

- Ensure that the CEMs read zero when the emissions are zero.
- Take at least five SRM measurements when the process is operating normally.
- Take an average of the SRM measurements and the CEM measurements, and then use these averages to determine a calibration factor.

There is no need to perform the statistical tests specified in ISO 10155, as these tests apply to cases where linear regression can be applied, i.e. when there is a spread of data.

2.10 Functional tests

All the applicable standards for PM CEMs include functional tests. These are mandatory for installations which require operators to apply EN 14181 and EN 13284-2. We strongly recommend that operators ensure that functional tests are performed on PM CEMs in cases where ISO 10155 applies.

2.11 Regulation when particulate monitors cannot be calibrated

If a test report states that a particulate monitor cannot be calibrated, then the output will be qualitative. This means that even if the output is in $mg.m^{-3}$, such readings should be disregarded for regulatory purposes, even if there is an apparent breach of the ELV. However, the output from the particulate monitor should be regarded as an indicative trend, which can then indicate if there is a:

- A significant change in the process, that requires attention as soon as possible.
- The operator should have operational procedures in place to respond appropriately to such changes indicated by the particulate monitors.

2.12 Summary of procedures

Table 1 shows the conditions for CEMs providers and test laboratories to choose the most applicable procedure.

3. Further Information

3.1 Mini Guidance Notes

- RM-QG-01 Selecting continuous emission monitoring systems (CEMs)
- RM-QG-03 Application of EN 14181

3.2 Technical Guidance Notes and MIDs

- TGN M2 – Monitoring of stack emissions to air
- TGN M20 – Quality assurance of continuous emissions monitoring systems
- MID EN 13284-1

4. Feedback

Any comments or suggested improvements to this note should be e-mailed to Richard Gould at richard.gould@environment-agency.gov.uk or internally to Gould, Rick.

Table 1 – Procedures for calibrating particulate-monitoring CEMs

Process	Spread of data (Spread > 15% of ELV)	Medium to high-level cluster (Emissions higher than 30% of daily average ELV)	Low-level cluster (Emissions not more than 30% of daily average ELV; linear regression produces R^2<0.9))
WID/LCPD (QAL2)	Apply EN 14181 • Functional tests • Verify CEMs read zero at zero emissions • 15+ SRM repetitions over 3+ days • Calibration function plus statistical tests	Apply EN 14181 • Functional tests • Verify CEMs read zero at zero emissions • 15+ SRM repetitions over 3+ days • Calibration function plus statistical tests	Apply most of EN 14181 • Functional tests • Verify CEMs read zero at zero emissions • 5+ SRM repetitions over one • Perform variability test to determine acceptability • Do not apply a calibration function from SRM data. • Calibrate with surrogates if possible; if not, then set the CEMs gain-factor to respond to process changes.
WID/LCPD (AST)	Apply EN 14181 • Functional tests • Verify CEMs read zero at zero emissions • 5+ SRM repetitions over 1+ days • Calibration function plus statistical tests	Apply EN 14181 • Functional tests • Verify CEMs read zero at zero emissions • 3 to 5+ SRM repetitions over 1+ days • Calibration function plus statistical tests	Apply most of EN 14181 • Functional tests • Verify CEMs read zero at zero emissions • 3 to 5+ SRM repetitions over one • Perform variability test to determine acceptability • Do not apply a calibration function from SRM data. • Calibrate with surrogates if possible; if not, then set the CEMs gain-factor to respond to process changes.
Other PPC/EPR permits	Apply ISO 10155 • Functional tests • Verify CEMs read zero at zero emissions • 9+ SRM repetitions over 2+ days • Calibration function plus statistical tests	• Functional tests as specified in ISO 10155 • Verify CEMs read zero at zero emissions • 5 SRM repetitions over 1 day • Average of SRM and CEM data to derive a calibration factor	• Functional tests as specified in ISO 10155 • Verify CEMs read zero at zero emissions • 3 SRM repetitions over 1 day • Calibrate with surrogates if possible; if not, then set the CEMs gain-factor to respond to process changes.