RM-QG6 – Calibrating particulate-monitoring continuous emission monitoring systems (CEMs), especially for low concentrations of particulate matter

Quick guide RM-QG6 **Issued** September 2009 **Review due by** September 2010

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 matter.

2. Practical Guidance

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 to increasing concentrations of uniform particulate, 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 Cases where there are low-level clusters of particulate emissions

These are very common. If the emissions during a calibration exercise are low, i.e. less than 30% of the daily average ELV, then it is likely 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 this is practicable. Although surrogates can be used to calibrate CEMs for gases if the SRM data is insufficient for calibration, this may not be the case with particulate monitors. Therefore if the SRM data is not sufficient enough to calibrate particulate monitoring CEMs and the surrogates are not valid, then a different approach is needed (see section 2.7).

2.5 Using surrogates

Surrogates typically have three roles when applied to particulate monitors:

- Testing the response time.
- Testing the linearity
- Determining stability through zero and span tests.

There may be occasions when surrogates can be used to calibrate particulate monitors, but such cases are rare.

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.

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.

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.
- If the applicable legislation does not specify a 95% confidence interval, then apply a value of 30% of the daily-average or similar applicable average ELV.

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

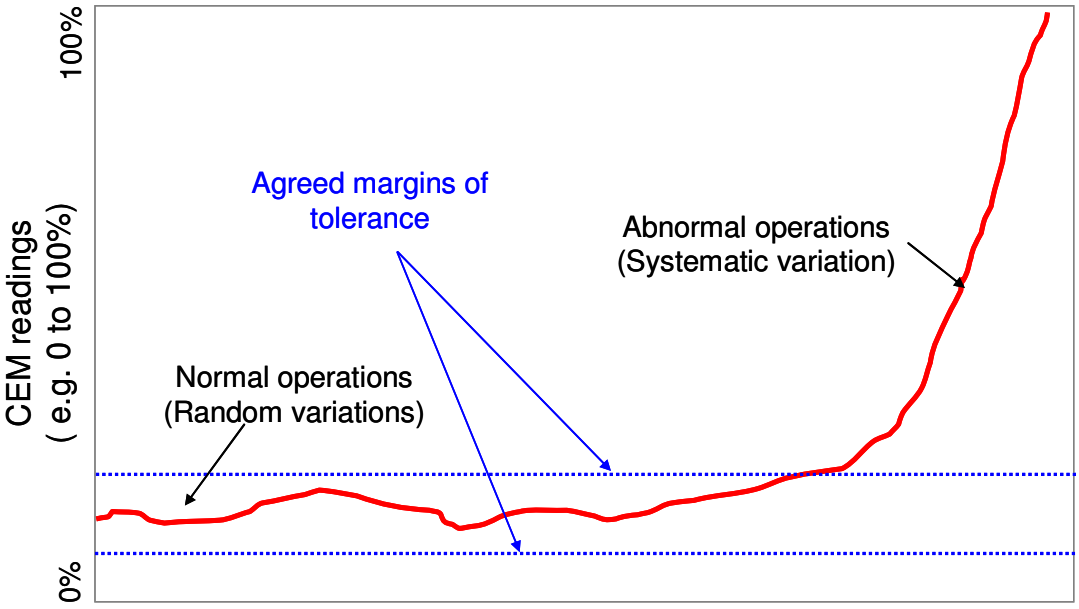
If a test report states that a particulate monitor cannot be calibrated due to very low emissions, then the output of the CEM will be qualitative. Whilst it may be possible to intuitively set the reading of the CEM to provide an output in $mg.m^{-3}$, such readings will be an approximation at best, with a strong likelihood of high levels of uncertainty. Unless it is possible to produce higher, representative emissions from the process, such readings should be disregarded for regulatory purposes when compared to an ELV, even if there is an apparent breach of the ELV.

However, the output from the particulate monitor can demonstrate whether the process is under control or not. Therefore such outputs should be regarded as an indicative trend, which can then demonstrate if there is a significant change in the process resulting in an increase in emissions that requires attention as soon as possible. Hence an operator must have operational procedures in place to respond appropriately to such changes indicated by the particulate monitors.

Figure 1 demonstrates how such a procedure could work, applying the following steps.

- A set of three to five repetitions of a SRM must show that the emissions are controlled and well below the ELV.
- The SRMs also show that the CEM responds – albeit with a high uncertainty – to low levels of particulate, and therefore provides an indication of low emissions, if not accurate and precise measurements.
- The operator notes the representative output that the CEM produces when the emissions are low and well controlled. It is recommended that the output is in units other than $mg.m^{-3}$.
- The operator plots the emissions on a chart, and includes upper and lower margins of tolerance to allow for random, but acceptable variations in the outputs of the CEM. These upper and low margins of allowable variations are agreed with the Environment Agency.
- If the output from the CEM changes and rises above the upper margin of error, then the operator takes immediate action to investigate the causes of the change in the output of the CEM, and then takes appropriate action to ensure that the readings return to within the margins of tolerance as quickly as practicable.
- When reporting emissions for annual emissions inventories, the operator may apply two approaches:
  - ♦ Using an average based on the results of periodic monitoring, or:
  - ♦ Reporting a result which states that the emissions are not more than a result based on the allowable uncertainty of the daily average ELV – or similar medium-term average ELV - expressed as a 95% confidence interval.

Figure 1 – Using control charts for indicative monitoring.



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 Quick Guides

- 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.