Revision to the Quality Assurance Standard of Automated Measuring Systems EN14181

It is just over 10 years since EN14181 was first published [1] and the power industry subsequently highlighted areas in which the standard needed further development [2]. A CEN Technical Report, EN/TR 15983 [3], was issued in order to provide further guidance on implementation. A new version of EN14181 was published in November 2014 in order to consolidate and extend the additional interim guidance which is to be withdrawn. Note that Continuous Emissions Monitoring (CEM) systems are referred to as Automated Measuring Systems (AMS) within the standard and throughout this article.

"The linearity test range is at 'least the short term ELV' rather than being 'two times the emission limit', thus providing greater flexibility in the concentration range that can be considered in relation to concentration excursions."

Regulatory Framework for Combustion and Incineration Plant

The regulatory framework for large combustion plant defines Emission Limit Values (ELV) which are of key importance when implementing EN14181. The Industrial Emissions Directive (IED), published in December 2010 [4], replaces numerous European Directives that govern the environmental regulation of process plant and this requires the application of Best Available Techniques (BAT). The IED applies, in entirety, to new large combustion plant (>50 MW net thermal input) permitted from 7 Jan 2013 and to existing plant from 1 Jan 2016, subject to a number of temporary derogations not described here. Incineration and co-incineration plant are fully regulated under the IED from 7 January 2014.

All plant have to comply with the general permitting and BAT provisions in Chapter II of the IED. Large Combustion Plant (>50 MW thermal input) must comply with Chapter III and Annex V of the IED. ELV are defined for SO_2, NO_x and dust for large combustion plant fired by solid and liquid fuels and also CO for gas fired plant (Table 1). ELV are also defined for gas turbines (Table 2). ELV apply during normal operation only for all plant types (excluding start-up and shut-down). The tabulated ELV apply as Monthly averages and a Daily ELV is also specified as 110% of these Monthly ELV. Peripheral measurements, that are required to correct the emission concentration to reference conditions, must also be measured continuously where applicable: oxygen, water vapour (not required if the pollutant is measured on a dry basis), temperature and pressure.

Table 1 Large Boiler ELV

IED Annex V (>300 MW thermal input)

	Existing Plant (Part 1)			New Plant (Part 2)		
	Solid fuel	Liquid fuel	Natural gas	Solid fuel	Liquid fuel	Natural gas
SO_2	200	200	35	150	150	35
NO_x	200	150	100	150	100	100
Dust	20	20	5	10	10	5
CO	-	-	100	-	-	100
REF. $O_{2\ dry}$	6%	3%	3%	6%	3%	3%

Continuous monitoring is required for large combustion plant with a rated thermal input higher than 100 MW, although there are specific derogations for SO_2 and dust that instead require six monthly periodic monitoring, noting that mercury shall also be measured at least once per year for coal and lignite fired plant. However, alternative procedures can be proposed in place of periodic monitoring of the main pollutants, e.g., calculation of SO_2 from fuel sulphur content.

The IED strengthens the importance of Best Available Techniques (BAT) and permit conditions must comply with BAT Conclusions, drawn from the BAT Reference note (BREF) for each industrial sector, within four years of publication. Effectively, tighter ELV and a wider range of pollutants and additional monitoring requirements may be defined within the sectoral BREF. The Large Combustion

BREF is under revision and is likely to introduce substantially lower ELV and a wider range of continuously monitored species than the IED. This has been widely commented on and the final version should be published in 2015 when the requirements will be clarified.

Table 2 Gas Turbine ELV

IED Limits Gas Turbines (>50 MW thermal input)

	Existing Plant (Part 1)		New Plant (Part 2)	
	Natural gas	Liquid fuel	Natural gas	Liquid fuel
NO_x	50	90	50	50
CO	100	100	100	100
REF. $O_{2\ dry}$	15%	15%	15%	15%

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Air Monitoring

Incineration plant must comply with Chapter IV and Annex VI of the IED. Additional species are regulated and monitored continuously for incineration plant: CO, Total Organic Carbon (TOC), HCl and HF, with various derogations from continuous monitoring for HCl and HF which must instead then be monitored periodically along with trace metals, dioxins and furans.

The IED defines a confidence interval (CI) to account for measurement uncertainty. The confidence interval is subtracted from the reportable hourly average concentration for combustion plant and the half-hourly average for incineration plant. The CI is also used as the basis for many of the subsequent QA assessments described below. The defined confidence intervals are given in Table 3.

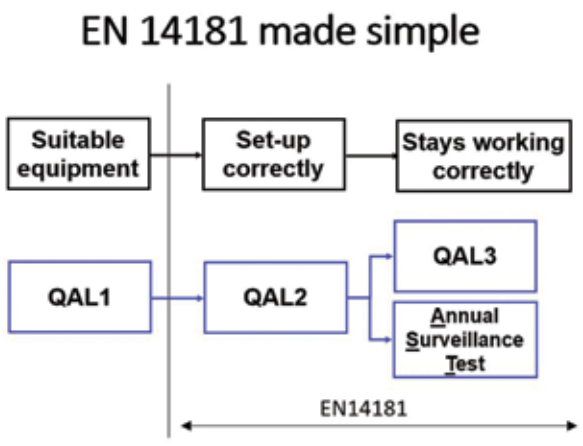
Table 3 IED Confidence Intervals

Species	Confidence interval (95%)
SO_2	20%
NO_X	20%
Dust	30%
CO	10%
TOC	30%
HCl	40%
HF	40%

Both combustion plant and incineration plant will be regulated with a Daily ELV that is used when applying the QA requirements described below. The reduction in the absolute value of the Daily ELV is the main regulatory impact on the QA requirements, as discussed below.

3 Over-view of EN14181

This section provides an over-view of EN 14181 which defines three Quality Assurance Levels - QAL1, QAL2 and QAL3 - and an Annual Surveillance Test (AST). The basic structure of the QA process is shown in the flow diagram.



Quality Assurance Levels (QAL)

The Operator has the following general responsibilities:

- Installation of compliant equipment (QAL1)
- In-situ calibration of AMS using an accredited test laboratory (QAL2)
- Annual check of the in-situ calibration using an accredited test laboratory (AST)
- Performing ongoing Quality Assurance based on regular zero and span checks (QAL3)
- Submission of QAL2, QAL3 and AST reports and ongoing maintenance of records
- Checking of hourly averages against the valid calibration range (weekly)

QAL1 requires an assessment of the suitability of the AMS equipment. New analysers should be certified and the certification field trial should be carried out on a similar process to that under consideration. The monitoring equipment must also be placed so that a representative reading can be obtained.

QAL2 requires calibration of the monitors against analytical methods - standard reference methods (SRM) - applied by a Test Laboratory accredited to ISO 17025. The straight line calibration relationship between the AMS and the SRM test data is established by taking at least 15 pairs of measurements obtained across at least 3 days of operation. Any scatter in the data comparison is assumed to be caused by the plant monitor

and this scatter (variability) must be below a threshold in order to pass.

Prior to a QAL2 calibration, various functional tests must be performed. As a minimum, the Test Laboratory must audit the functional tests. The Operator must also perform a weekly check of the reported emissions data to determine if this lies outside the Valid Calibration Range (VCR) established during the test campaign.

QAL2 is intended to take account of any bias caused by the specific monitoring equipment or the sampling location and must be conducted every 5 years or following a significant change to the process, the fuel mix or the AMS.

AST are intended to validate the calibration established under QAL2 by, again, employing an accredited test laboratory to take a reduced number of parallel measurements. The tolerance applicable to the data scatter is widened and an additional test compares the mean deviation from the calibration line with the 95% confidence interval mentioned above.

QAL3 is intended to provide an audited check of ongoing performance by conducting regular zero and span checks of the monitors and comparing the measured drift against pre-defined warning and action limits using a control chart approach.

Visit STA web site, http://www.s-t-a.org/en14181/ .

4 Changes to EN 14181

4.1 General Provisions

Appendix K of EN 14181:2014 describes the main technical changes between the first and second editions of the standard.

The main purpose of the amended standard remains the same, that is, the AMS meets the regulatory uncertainty requirements, now specified in the Industrial Emissions Directive for combustion and incineration plant. The IED confidence interval, evaluated at the Daily ELV, is now referred to as the Maximum Permissible Uncertainty (MPU) within EN 14181:2014. All of the uncertainty requirements within the standard are replaced by the MPU. As an example, for a plant with a Daily ELV of 100 mg/m^3 NO_x, MPU is 20% of 100 mg/m^3, i.e., 20 mg/m^3.

All QAL2/AST testing shall be conducted by a test laboratory that is accredited, under ISO 17025, to make the measurements or one that is approved directly by the Competent Authority. The measuring range of the AMS can now be selected to match the anticipated maximum short term (hourly or half-hourly) ELV.

4.2 Quality Assurance Level 1

A normative reference to the EN 15267 series of standards [5,6,7] for the certification of CEMs has been added. This means that new AMS installations must be certified to EN 15267 as demonstration of QAL1 compliance. For large combustion plant, the certification range should be below 2.5*ELV and for incinerators below 1.5*ELV. The QAL1 uncertainty should be less than 75% of the IED confidence interval. In the above example, less than 75% of 20 mg/m^3, i.e., 15 mg/m^3.

Existing uncertified AMS installations may be approved by the Competent Authority, e.g., on the basis that the remaining QA requirements are satisfied (QAL2, AST and QAL3), noting that the pass criteria become more stringent as the Daily ELV is reduced.

Existing certified instruments that cannot meet the formal uncertainty requirements due to a reduction in the ELV, e.g., due to new IED requirements, may be approved by the Competent Authority, e.g., on the basis that the remaining QA requirements are satisfied (QAL2, QAL3, AST).

For existing instruments that do not formally meet the certification requirements, the Operator should consider measures to reduce the measurement uncertainty, e.g., air conditioning the AMS shelter.

Normative reference to EN 15259 [8] has been added. Representative sampling points for AMS & SRM must be defined and there must be no interference or disturbance between the AMS & SRM.

In some cases, the existing duct work may be horizontal and readily accessible. The standard does not address the problems at existing plant where it can be impractical to meet the full requirements of EN 15259 with regards to sample ports and sampling platforms and the Operator will then need to agree alternative provisions with the Competent Authority, noting that the IED (Article 38) requires the Competent Authority to 'determine the location of the sampling or measurement points'.

4.3 Quality Assurance Level 2 and the Annual Surveillance Test

Functional Tests

Functional tests are now identical for both QAL2 and AST testing and are also recommended for peripherals (O_2, H_2O). It is recommended that functional checks are carried out not more than one month prior to the QAL2 or AST. Functional testing must be performed by an experienced testing laboratory that has been recognised by the Competent Authority.

The linearity test range is at 'least the short term ELV' rather than being 'two times the emission limit', thus providing greater flexibility in the concentration range that can be considered in relation to concentration excursions.

The response time of the AMS must continue to meet the EN 15267-3 performance criterion, rather than the historic actual QAL1 result, that is, degradation of the instrument in-service is now recognised, along with the need to remove in-situ analysers from the stack to conduct a zero and span check. Documentation must now include details of the AMS certification

QAL2/AST Testing

An AST may replace a repeat QAL2 provided that the AST measured values and at least 95% of the AMS short term averages, reported since the previous AST, are both less than MPU. There is a recommendation that QAL2 can be applied to peripherals (O_2, H_2O). However, the standard does not point out that there may be genuine differences between peripheral measurements at two locations so it may not be appropriate or necessary to apply QAL2 factors under these circumstances.

Water vapour values from a calibrated AMS or a calculated water vapour (for wet abatement systems) can be used to correct SRM measurements to a wet or dry basis as required.

Excluded outliers must be identified, reported and retained in data tables and calibration graphs, noting that the assessment method, and the justification for excluding outliers, are to be documented in the QAL2/AST report. It is recommended that additional test points, beyond the minimum requirements, are obtained to allow for outliers.

Exclusion of invalid data from the initial data set, prior to the outlier analysis, must also be justified in the QAL2/AST report, e.g., it is easy to justify the exclusion of start-up or transient data but all stable operating data during normal operation should usually be included.

QAL2 Calibration Function

There is a requirement that the QAL2 calibration shall be implemented within six months, rather than it simply being reported within six months. However, it is noted that the member states may allow the continued use of the previous calibration function if it can be proven by use of a specified statistical procedure that the new calibration function does not significantly differ from the previous one.

A new analysis procedure is defined for the treatment of low level data clusters (Method C). (This is based on Option 4 from B.3 of Annex B of EN/TR 15983 [3].) A calibration function is derived from a combination of data from the parallel reference tests and reference materials. Two reference points (at Zero and close to ELV) are added to the QAL2 data set prior to deriving the calibration function. However, the reference points are not included in the variability test. If appropriate reference materials, e .g., test gases, are not available, an alternative procedure can be approved by the Competent Authority and this must be fully documented in the QAL2 report.

The criterion for selecting the calibration procedure (Method A, B or C) has changed. This was previously based on the SRM test data range (max – min) being less than 15% of ELV. It is now based on the data range being less than MPU.

Valid Calibration Range (VCR)

The VCR established under QAL2 continues to be defined as the highest, calibrated, AMS QAL2 concentration, at standard reporting conditions, plus 10%. If the emissions data, reported subsequently, lie outside of this range, for more than a specified proportion of the time, a repeat QAL2 is required. Industry has long argued that this range extension is insufficient to cover normal process variability. The VCR can now be extended using the highest AST data point (plus 10%) provided that the extension is less than 50% of ELV. The VCR can always now be extended to 20% of ELV (minimum VCR).

As before, reference materials, e.g., test gases, can be used to improve confidence in data that lie beyond the VCR, although

the emphasis is placed on concentrations close to the ELV rather than a wider extrapolation. The agreement between the high test gas concentration and the calibration line must be within the MPU. The agreement between the Zero point and the calibration line must be within 10% of ELV. The Competent Authority must therefore determine if reference materials can be used to actually extend the VCR in addition to improving confidence. An extension to the short term ELV would be reasonable since this is the range across which the plant is expected to operate during normal operation.

Weekly data inspection (Monday to Sunday), to check that reported data are within the VCR, can now be based on the most recent operational hours (168 hours), rather than a calendar week, when the plant is not run continuously. Also, exceedances of VCR caused by plant failures do not now trigger a QAL2.

4.4 Quality Assurance Level 3

QAL3 requires Operators to have a procedure that describes the requirements for a) measuring zero and span values; b) plotting these values in control charts and c) using the control charts to determine if there is a systematic deviation (drift).

There is an enhanced description of QAL3 requirements including the selection and use of control charts and the execution of zero and span measurements. Three examples of control chart are described in detail in Annex C of the standard: Shewhart and CUSUM (included in EN 14181:2004) and an

additional Exponentially Weighted Moving Average (EWMA) approach. In all cases, including dust monitors, alternative reference materials can be used, such as optical filters, provided that these are certified as being QAL3 compliant under EN 15267-3.

There is a new general requirement on the Operator to ensure that AMS internal checks or compensation systems are active and operational and that AMS alarms are received by plant personnel so that corrective action can be taken at all times. Any type of manual or automated control chart can be used. Built-in procedures are allowed as an alternative to an external QAL3, provided that the data is available to the Operator to allow for annual auditing of the QAL3 data.

The required frequency is at least once per maintenance interval and at least once per month for uncertified AMS. For maintenance intervals greater than one month, justify with internal checks and, for multi-component analysers, a monthly span check of at least one gas component is required.

Hot spares (fully independent back-up AMS) can be used to extend QAL3 to an annual check provided that an alarm is raised when the difference between the two AMS is > 5% of the short-term ELV for more than five consecutive measurements.

Control chart limits can be based on the MPU rather than a detailed uncertainty assessment. The Alarm limit cannot be higher than 50% of MPU. The Warning limit may be set at 25% MPU.

For audit purposes, QAL3 documentation must include a history of the checks and the actions taken when exceeding control chart limits. Control charts should be stored for five years.

5 Concluding Remarks

The amendment of EN 14181 clarifies and improves the applicability of this Quality Assurance standard and this is a positive development that is welcomed by industry. There are a few remaining issues, that have been identified previously, that have not been addressed and that will require approval by the relevant Competent Authority for specific industrial sectors. These include: i) not applying QAL2 calibration factors if the agreement between AMS and SRM is acceptable; ii) extending the Valid Calibration Range beyond the Daily Emission Limit Value using reference materials; iii) simplification of linearity test requirements for multi-component analysers. It should be noted that the progressive reduction of Emission Limit Values increases the difficulty of passing each of the QA requirements. Further details can be found in a related conference paper [9].

6 References

1. EN 14181, Stationary source emissions. Quality assurance of automated measuring systems.
2. Graham D P et al (2009), European Power Industry Experience of EN14181, CEM 2009: 9th International Conference on Emissions Monitoring, 23-25 September 2009, Stresa, Italy.

3. PD CEN/TR 15983:2010, Stationary source emissions. Guidance on the application of EN 14181:2004.
4. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). Official Journal of the European Union, L 334/17 to 119, 17/12/2010.
5. EN 15267-1:2009, Air quality. Certification of automated measuring systems. General principles.
6. EN 15267-2:2009, Air quality. Certification of automated measuring systems. Initial assessment of the AMS manufacturer's quality management system and post certification surveillance for the manufacturing process.
7. EN 15267-3:2007, Air quality. Certification of automated measuring systems. Performance criteria and test procedures for automated measuring systems for monitoring emissions from stationary sources.
8. EN 15259:2007, Air quality. Measurement of stationary source emissions. Requirements for measurement sections and sites and for the measurement objective, plan and report.
9. Graham D, Faniel N, et al, Changes to the Quality Assurance Standard EN14181, CEM 2014 International Conference on Emissions Monitoring, Istanbul, May 2014.

The Source Testing Association

The Source Testing Association (STA) was established in 1995 the membership comprises representation from process operators, regulators, equipment suppliers and test laboratories. The STA is a non-profit making organisation.
The STA is committed to the advancement of the science and practice of emission monitoring and to develop and maintain a high quality of service to customers.

Its aims and objectives are to:
(i) contribute to the development of industry standards, codes, safety procedures and operating principles;
(ii) encourage the personal and professional development of practicing source testers and students;
(iii) maintain a body of current sampling knowledge;
(iv) assist in maintenance of a high level of ethical conduct;
(v) seek co-operative endeavours with other professional organisations, institutions and regulatory bodies, nationally and internationally, that are engaged in source emissions testing.

The Associations headquarters are based in Hitchin, Hertfordshire with meeting rooms, library and administration offices.
The Association's offers a package of benefits to its members which include:

- Technical advice relating to emission monitoring
- Conference and exhibition opportunities
- Seminars and training on a variety of related activities
- Representation on National, European and International standards organisations
- Training in relation to many aspects of emission monitoring
- Liaison with regulators, UK and International, many of whom are members.

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Mascots AwiBUB and AwiBOB also travelled to faraway places recently as well and supported Awite's partner ESCEM Ltd. at the IFAT Eurasia in Ankara. Awite are very pleased that their partner ESCEM received both of them so well and wish to thank ESCEM sincerely for it.

Has your curiosity been stirred? Learn more by visiting Awite at Agritechnica from 10– 4 November 2015, or simply give them a call.

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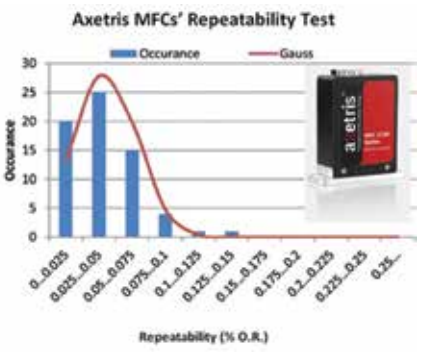

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Repeatability is a standardised term often used with reference to measurement instruments, and adopted by ASTM and other standardisation organisations. This performance criterion is associated with the precision of measurements generated on the same material using the same test method under specific conditions.

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