STANDARDS FOR CONTINUOUS EMISSION MONITORING

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Summary.

Continuous measurement of emissions has never been more important than it is today. There are two major EU Directives; The Large Combustion Plant Directive, and The Waste Incineration Directive, which contain specific reference to air emission limits values in terms of continuous measurement. Furthermore, the directives go so far as specifying that the continuous emission monitors to be used, must be calibrated and must meet certain performance criteria. To support these directive requirements are a range of CEN standards, some of which are still in the development stage. The paper will describe the methods available, the practical implications of their use, and the importance of consistency throughout Europe.

1. Legislation.

The two principle pieces of legislation that have had a major impact on the development of CEN standards are the Large Combustion Plant Directive (LCPD)[1] and the Waste Incineration Directive (WID)[2] and its predecessors (Hazardous Waste Incineration Directive[3] and Municipal Waste Incineration Directives[4] [5]). They have been the cornerstone in prescribing the use of CEN standards to comply with the Emission Limit Values set in the directives. Some concern the use of manual methods, such as for Dioxins, while others require Continuous Emission Monitors (CEM's) for Oxides of Sulphur and Nitrogen. Where CEM's are required the legislation has been quite prescriptive in some circumstances. It has not only prescribed the principle of the method to be used but also the quality (uncertainty) of the instrument to be used when installed(ie the minimum 95% Confidence Interval). Furthermore these instruments would be regarded as essential to the operation of the process, and where limits are exceeded for extended periods may be required to shut down the process.
The use of CEM's as a regulatory tool has been growing over the years, and should eventually replace existing manual methods, where good traceability can be established. They not only provide a continuous record of releases, but enable this information to be read remotely, where telemetry is available. For CEM's to be used effectively however, they must be fit-for-purpose, properly installed and calibrated, and have provision for ongoing quality control.

2. Essential aspects of standardisation

The production of standards has now become a complicated business. Whereas in the past, groups of experts got together to produce national standards of experimental accuracy, nowadays, standards have to be well researched, take into account many different national standards, and have to provide information on the uncertainty of the method. It wasn't until 1990 that CEN/TC 264 - Committee for Air Pollution Measurement Methods, was formed, a body

essentially brought about to produce standards, which would satisfy the requirements of the Hazardous Waste Incineration Directive.
It is not only necessary for experts to be selected from at least five participating European countries, but also for there to be a leader(Convenor) who can organise and plan the production of the final document. These experts are unpaid and give up their time with the co-operation and good-will of employers. Concensus has to be reached between the experts on all aspects of the standard, from the most appropriate method or methods and best instruments(fit-for-purpose) to be used, through to the laboratory and field trials to be undertaken. The outline of the method should be drafted at an early stage, in order that the most appropriate trials can be undertaken. It is essential that field trials are undertaken, not only to validate the instrument(s) to ensure that they are comparable, but to check that the method(s) are practicable. Secondly, laboratory and field trials have to be carried out to evaluate the uncertainty of the method(s). All these trials are expensive to undertake, but vital if the standard is to be used for regulatory purposes. Funding has been sought, and provided by the European Commission. This enables any standards produced by CEN to contain advice and information about the uncertainty of the measurement method. Once approval has been given by the member bodies of CEN (eg, AFNOR, BSI, DIN, etc), then the standard can be published as a European Standard (eg, EN 14181) and as a national standard (eg, BS:EN 14181). This process can take up to over five years, depending on any difficulties encountered during the trials, and/or technical complications.

3. Standards produced by CEN/TC 264

Since 1990 CEN/TC 264 has produced seven manual methods for the measurement of pollutants in stacks, and two for the continuous measurement of pollutants in stacks. These are shown in the tables below. Many manual methods were produced initially, because there was a lack of comparable standards within Europe, and there was a need for such standards to satisfy the requirements of European environmental legislation.

Number	Description of published standards [6]
EN 1948 pts 1-3	Stationary Source Emissions - Determination of the mass concentration of PCDD/PCDF (Dioxins & Furans)
EN 1911 pts 1-3	Stationary Source Emissions - Determination of the mass concentration of Hydrogen Chloride (HCl)
EN 13725	Stationary Source Emissions - ODOUR Concentration by dynamic dilution
EN 12619 pts 1 & 2	Stationary Source Emissions - Determination of TOC at low concentration - FID method (manual and continuous)
EN 13526	Stationary Source Emissions - Determination of TOC at high concentration - FID method.
EN 13649	Stationary Source Emissions - Determination of individual organic components
EN 13284	Stationary Source Emissions - Determination of low mass concentration dust pt1 - manual gravimetric method.
EN 13211	Stationary Source Emissions - Determination of the mass concentration of Mercury.
EN 14181	Stationary Source Emissions - Quality Assurance of an Air Emission Automatic Monitoring System
PrEN 14385	Stationary Source Emissions - Determination of total emission of As, Cd, Co, Cr, Cu, Mn, Pb, Sb, Tl, and V.

Since those early days CEN has been able to concentrate on continuous monitors, and has produced a generic one, EN 14181, for the assessment of the performance characteristics of CEMs, their calibration and their on-going quality assurance. This standard has been one of the most complex that we have produced and has taken many years to complete. The difficulties were principally due to differences in approach from member bodies, the practical difficulties of ensuring that the there was the correct spread of results over the emission limit value, and a pragmatic interpretation of the statistics involved. The statistics were in fact extremely complex, which required the provision of a separate explanatory memorandum (still under preparation). However the finished product will enable member countries to carry out continuous measurement in a more consistent manner.

4. Standards under development.

CEN has a number of standards under development, principally to satisfy the requirements of the Large Combustion Plant Directive(LCPD). The LCPD has set emission limit values in terms of mean values, whether it be 48-hourly or monthly means, emissions could not be monitored without properly calibrated CEMs. So standards are at an advanced stage of development for SO2, NOx, CO and O2, as shown in the table below.
CEN is also embarking on standard for the determination of flow in ducts. This will be a two part standard, firstly a manual method and secondly a method for continuous measurement of flow. There is an ISO standard (ISO 10780), but this does not contain any validation data or definitive guidance on uncertainty. Because of the need to be able to trade in combustion gases (Emissions Trading Directive [7]), and because it is a requirement of the IPPC Directive [8] to be able to report annual emissions of pollutants to air, there is a pressing need for such a standard. However to date no funds have been made available from the EC for the validation work.

Number	Description of Method
prEN 14789	Stationary Source Emissions - Determination of volume concentration of oxygen(O_2) - Reference method-Paramagnetism
prEN 14790	Stationary Source Emissions - Determination of water vapour in ducts
prEN 14791	Stationary Source Emissions - Determination of mass concentration of Sulphur Dioxide - Reference method
prEN 14792	Stationary Source Emissions - Determination of mass concentration of Nitrogen Oxides(NO_x) - Reference method
Not yet assigned	Stationary Source Emissions - Determination of mass concentration of Carbon Monoxide - Reference method
PrEN 14884	Stationary Source Emissions - Determination of total mercury - Automated measuring systems.
PrEN 13284-2	Stationary Source Emissions - Determination of low range mass concentration dust, pt 2 - validation of continuous emission monitors.
Not yet assigned	Stationary Source Emissions - Determination of Volumetric Flow measurement.
Not yet assigned	Minimum requirements for a European air quality Automated Measuring System Certification scheme.

Similarly, the standard for the continuous measurement of fine dust is nearing completion. Another difficult standard, because of the varying properties of different types and sizes of dusts.

Another standard that has been many years in preparation, is that for heavy metals. The major challenges were digestion problems, finding suitable traceable standards and the low level of metals found in some emissions. This has recently been published.
Finally there is a method being developed for the certification of stack monitors, similar to the TA Luft and emCERTS schemes. This is a vitally important standard in that it will safe duplication of work for manufacturers. Once the standard is completed, manufacturers will no longer have to entertain the costs of complying with both schemes, or other European national schemes.

5. Applicability of CEMs.

It is all very well that CEN has developed high quality standards for the continuous measurement of pollutants in ducts and stacks, but as mentioned earlier, it is vital that the instruments to be used are fit for purpose. This means ensuring that they can perform the desired function. A CEM may be quite capable of measuring NOx in an air stream, but it may not be so capable if there are a number of interferents present, which compromise the resolution of the instrument. Furthermore, there may also be present substances that will cause other practical difficulties, such as monomers that are likely to polymerise and "gum" up the works, or highly acidic substances that corrode away essential operating parts of the instrument. These problems are not necessarily insurmountable, but operators need to provide full information to manufacturers for them to make the correct choices and to make appropriate adaptations to their equipment.
Secondly the position of the installation of the CEM is vital, if it is going to have any chance of providing accurate information. The same sort of criteria applies as that used for siting sampling ports for manual testing. Striated flow, bends and obstructions should be avoided; instruments should be sited, preferably in straight vertical ducts that are free from droplets or aerosols, and be provided with suitable access via a platform.
When installing a CEM, it is important to be aware of the nature of the process being monitored, whether it is batch or continuous, or whether it has a large turn-down ratio, which affects the range of concentration of pollutants emitted. Also the type of abatement used is important, especially if it is after electrostatic precipitators. Flue gases can become highly charged, which may affect instruments, and is definitely a safety consideration.
Companies may request the fitting of several alarms to warn them of incorrect operation or malfunctions. It is important that these are both audible and visual, especially in noisy or complex plant. Instruments may need to be linked to the operation of abatement plant, or interlocked for plant shut-down. It is vital that such instruments have good ongoing quality control.
Finally, there may be the need to meet certain legal requirements, such as providing emission data in the form of 10minute, half-hourly or daily means. Most modern equipment have no problem with providing such data, and often have in-built quality checks.
By way of illustration the photograph below shows a vertical stack, which should provide a good location for the CEM. There is good access, but this is restricted for taking any manual samples and appears to be in poor repair, even though it is protected from the weather.

6. Challenges to standardisation of continuous monitoring

In order that field trials can be undertaken to ensure comparability of instruments/methods, it is necessary to find industries and plant that have the facilities to accommodate several instruments in the same sampling plane. Also it is necessary to find plant that can operate close to the emission limit value. On occasions these two criteria have been hard to meet. Either there aren't enough sampling ports to fit instruments, or the emission is at such a low concentration for the pollutant in question, that establishing comparability, when they are approaching the limit of detection of the method, is nigh on impossible. In most instances these difficulties were overcome, but for heavy metals in stacks, this made establishing uncertainty levels very difficult.

One of the greatest challenges to the production of good CEM standards is the understanding of the uncertainty of measurement. It has taken several years for this to be considered as a fundamental part of standardisation. Most experts are aware of this concept, but not all are fully conversant with GUM, The Guide to the Estimation of Uncertainty in Measurement [(9)]. It is absolutely vital that this is understood from the outset. To enable the correct laboratory and field investigations and trials to be undertaken, experts have to have a clear plan as to those aspects of the measurement process that have the biggest effect on the uncertainty of measurement. That is they need to have an uncertainty budget. Without this the trials would be fruitless, and any uncertainty estimation contained in the standard, meaningless.

Once the uncertainty of the measurement process has been established, the standard agreed across Europe and published, a certified CEM has been chosen and it's applicability to the job in question has been evaluated, then the instrument has to be calibrated in situ. This is to verify that any identified interferents or peculiarities of the process to be monitored, do not unduly affect the operation of the CEM. This is covered in the CEN standard, EN 14181, for incinerators and large combustion plant. Instruments have to meet strict criteria, based on 95% confidence statistics, which is prescribed in the Annexes to these directives. It is a complex standard to follow, but one that should be followed if we are going to ensure consistency of operation throughout Europe. It may also

have application outside these industries, but this would be determined by national regulators.

The Waste Incineration Directive has even more challenges. CEMs have to ensure a minimum data capture, in that plants may not operate for longer than 4 hours, if the CEM is inoperable. This requires a very thorough maintenance contract or duplication of instrumentation. Either way, this can be quite expensive for operators. It tends to force operators to use the most reliable CEMs.
Another aspect of the standard, EN 14181, is that there must be ongoing quality assurance checks, both at regular intervals throughout the year, but also through an annual surveillance test. Many instrument manufacturers are now simplifying the regular checks by in-built calibration checks. This obviates the need for expensive technicians to come out for regular physical checks.
The legislation is now requiring some substances to be monitored to be able to give 10 minute and half hourly means. Older instruments may not be able to satisfy this requirement, but there is available a wide range of software capable of doing so.

7. **Conclusions.**

Increasingly, European legislation requires the use of CEN standards to prove that ELVs have been met. In some instances this is in the form of spot measurements, but recent legislation has required the use of CEMs, which provide continuous records of releases to atmosphere, based on averaging periods as low as 10 minutes. Not only must these CEMs be fit-for-purpose(certified), but must be fully calibrated in the field to CEN standards, and must be of reliable design, which provides ongoing reliability.
CEN standards have been produced for both spot sampling and continuous measurement for a wide range of pollutants. They have good provenance, have known quality (uncertainty), and should provide greater consistency throughout Europe if properly installed and maintained.
To produce these high quality standards, CEN has to rely on the provision of funds from the European Commission, so that laboratory and field trials can be undertaken. Without this funding, standards would not have the necessary information on uncertainty, which is vital for consistent regulation.

References.

1. Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001, ***on the limitation of emissions of certain pollutants into the air from large combustion plants****. (Large Combustion Plant Directive).*
2. Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000, ***on the incineration of waste.*** (Waste Incineration Directive).
3. Directive 1994/67/EC of the European Parliament and of the Council of 16 December 1994, ***on the incineration of hazardous waste.*** (Hazardous Waste Incineration Directive).
4. Council Directive 1989/369/EEC of the European Parliament and of the Council of 8 June 1989, ***on the prevention of air pollution from new municipal waste incineration plants.*** (Waste Incineration Directive).
5. Council Directive 1989/429/EEC of the European Parliament and of the Council of 21 June 1989, ***on the prevention of air pollution from existing municipal waste incineration plants.*** (Waste Incineration Directive).
6. CEN website -www.cenorm.be.boss

7. Council Directive 2003/87/EC of the European Parliament and of the Council, ***on the greenhouse gas emission trading scheme.*** (Emission Trading Directive).
8. Council Directive 1996/61/EC of the European Parliament and of the Council, ***on integrated pollution prevention and control.*** (IPPC Directive).
9. The Guide to the Estimation of the Uncertainty of Measurement, EN 13005.