CEM 2014 - International Conference and Exhibition on Emissions Monitoring

Predictive Emission Monitoring (PEM): Suitability and Application in View of U.S. EPA and European Regulatory Frameworks

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Abstract

Predictive Emission Monitoring (PEM) represents a novel and cost-effective approach for continuous monitoring of source emissions as alternative to Continuous Emission Monitoring Systems (CEMS). In order to be accepted as full compliance solution, PEM needs to be strictly in line with applicable regulations for source monitoring.

PEM Systems are software-based. Consequently, they do not need gas analyzers and associated hardware like sample conditioning or shelters. Interfaced with plant control systems, PEMS utilize process inputs to offer continuous, real-time monitoring of pollutants, e.g. NO_x, SO_2, CO, HC or diluents like O_2. PEMS are generally suitable for all gas- and oil-fired emission sources in lieu of Continuous Emission Monitoring Systems (CEMS), providing equal accuracy and data quality. The models are built with quality assured emissions training data along with paired, time-synchronized data of process parameters with correlation to emissions.

PEMS are typically packaged with Data Acquisition and Handling Systems (DAHS) to result in self-sufficient compliance solutions. Applications exist for utilities, petrochemical, chemical, steel and other industrial plants or municipal sites. PEMS offer significant cost benefits with lower capital expenditures as well as much lower operational and maintenance cost than CEMS. PEMS and DAHS require for operation very little or no plant manpower.

To become a certifiable, accepted equivalent to CEMS, however, PEMS need to be based on a sound regulatory framework and has to obey the requirements of a demonstrable, stringent quality assurance scheme. U.S. Environmental Protection Agency (EPA) has stipulated the Performance Specification (PS) 16 within 40 CFR Part 60 or Subpart E of 40 CFR Part 75 to certify PEMS as alternative monitoring method in lieu of CEMS. Europe is presently drafting a standard within CEN / TC 264 “Air Quality” that considers the relevant European norms EN14181 and EN15267. The major part of this paper shall detail the regulatory framework conditions and describe various performance requirements.

At present, PEMS is mainly applied in countries following U.S. EPA regulations, because these standards are in place for some years already and demonstration programs have been executed. Consequently, the technology already gained significant interest not only in the U.S. but in the Middle East and parts of Asia. PEMS installations exist as stand-alone compliance solutions or as part of an integrated environmental monitoring approach capable to address multiple sources in one plant. One prerequisite is seamless integration of PEMS and DAHS and integration in the plant-wide IT and communication networks. An additional benefit is that a PEMS-DAHS package is a viable diagnostic tool to lower emissions and improve combustion efficiency.

1. Introduction

PEM(S) or Predictive Emissions Monitoring (Systems) can be considered as alternative or back-up to automatic monitoring devices (Continuous Emission Monitoring System – CEMS, in Europe usually Automated Measurement Systems - AMS) for demonstrating regulatory compliance of source emissions. Just as CEMS, PEMS qualify for continuous determination of emissions according to prevailing regulations and quality assurance requirements. PEMS may be used as an alternative to CEMS for all gas or oil-fired plants (turbines, boilers, heaters etc.) for components like NO_x, SO_2, CO, O_2, CO_2, but also for NH_3, H_2S, HC, VOC etc. Nevertheless, additional applications shall not be excluded as long as they demonstrate that they are suitable for PEMS. PEMs exhibit similarities, but also differences to source measurements with gas analyzers. They feature, however, some distinct advantages, which will foster a widespread application in future. In addition, PEMS can also serve as supplement to CEMS for plant-wide monitoring networks of large facilities like refineries or chemical plants, where part of the sources can utilize PEMS, but others have to rely on CEMS.

PEMS define the relationship between a number of characteristic process parameters of an emission source and the corresponding emission concentration. PEMS provide a reasonable alternative to CEMS (AMS), where a reliable and predictable correlation exists between plant operating conditions and emissions. By employing historical paired emissions and selected process data (e.g. load, fuel composition, flow, pressure and temperature data, environmental conditions; turbine and boiler settings) a model is generated, which allows determining the actual plant emissions for compliance purposes. The used process inputs are selected for the model according to their significance for influencing plant emissions.

These so-called empirical PEMS (in contrast to parametric PEMS) have been tested and evaluated with positive results within the frame of corresponding programs by the US Environmental Protection Agency (US EPA) in the last decade. Special emphasis has been put on quality assurance of the results. PEMS can be applied in lieu of CEMS according to title 40 C(ode) (of) F(ederal) R(egulations) Part 60[1] (especially Performance Specification 16[2]) and 40 CFR Part 75[3] (Subpart E[4]). PEMS is used at multiple plant sites, particularly in the U.S., but also in the Middle East and partly in Asia. In Europe PEMS so far is common only in a few countries. Consequently, most of the deliberations in the following sections will address the regulatory framework for PEMS as per relevant U.S.EPA standards.

A strong motivation to replace CEMS with PEMS results from cost savings due to lower capital expenditures as well as much lower operational and maintenance cost. This motivation is based on the fact that PEMS can accomplish equal accuracy and quality of emissions data compared to CEMS.

Suitable sources for PEMS monitoring are e.g.

- Generally gas- or liquid-fired emission sources
- Boilers
- Turbines
- Reciprocal Internal Combustion Engines (RICE)
- Biogas Plants
- Duct Burners
- Dryers
- Chemical Oxidizers

- Regenerative Thermal Oxidizers (RTOs)
- Process Heaters
- Olefin Furnaces
- Crude Heaters
- Kilns
- Ships

As examples for applications, where PEMS usually are not suitable, the following can be listed (acceptable applications may depend on regional regulations):

- Solid, moisture absorbing fuels
- Waste Incinerators
- Restricted suitability for coal-fired sources

In the following chapters, an overview of pertinent regulations for PEMS application, minimum requirements that can be derived from the standards as well as implications for quality assurance are given.

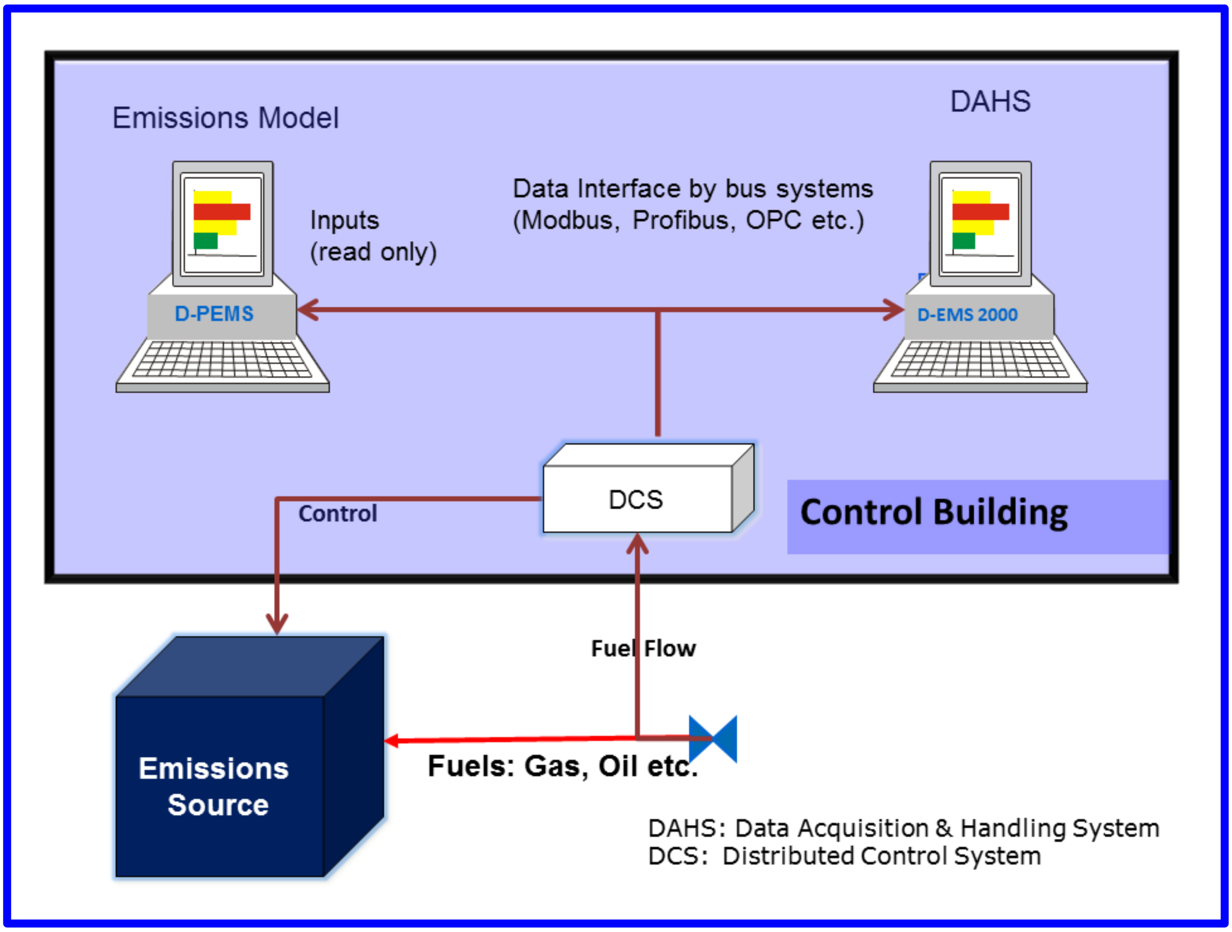

Figure 1: Generic PEMS configuration. Please note that PEMS and Data Acquisition Software typically reside on one computer, which is preferably located close to the plant control system in the control building. Two separate computers are shown only for illustration.

2. Regulatory Framework

As all environmental monitoring methods, also PEMS for compliance determination of emissions is subject to regulations that describe requirements, application and quality assurance. The major regulatory frameworks for environmental monitoring are constituted by the U.S. Environmental Protection Agency (EPA) and the European Union. Many countries outside the USA and Europe have basically adopted these standards, e.g. Middle East countries very closely follow U.S. EPA.

2.1. U.S. EPA

CEMS as well as PEMS in the USA and countries following US Environmental Protection Agency (EPA) regulations are mainly governed by 40 C(ode)F(ederal)R(regulation) Part 60 (Part 63[5]) and 40 CFR Part 75. PEMS specifically is addressed in Part 60 Performance Specification PS-16 and Subpart E Alternative Monitoring Methods. Important subparts to these two main standards can be found below.

In a nutshell, essential elements of Part 60 and Part 75 are:

Part 60:

- New Source Performance Standard - NSPS, promulgated first 1971;
- There are subparts for each type of source with e.g. subpart D covering boilers, GG covering stationary gas turbines and J Petroleum Refineries;
- Applicable to Industrial Units >100 mmBTU (about 29 MW), in some case also to smaller sources (e.g. Subpart Dc covering small industrial boilers);
- Requires Continuous Monitoring of Primary Pollutants (NO_x, SO_2, CO, Opacity and VOC);
- Part 60 is flanked by a series of test methods for emission measurements and 16 Performance Specifications (http://www.epa.gov/ttn/emc);
- PEMS permitted based on Performance Specification (PS-) 16;
- Certification with an initial Relative Accuracy Test Audit (RATA) followed by quarterly Relative Accuracy Audits (RAAs) and annual RATA's (Section 8 and 9 of PS-16).
- Quality Assurance Procedures as per Part 60 Appendix F;
- Portable analyzer application as Standard Reference Method for QA audits as per ASTM Method D6522-00[6]

Part 75

- Originally published in January, 1993;
- The purpose was to establish Continuous Emission Monitoring (CEM) and reporting requirements under EPA's Acid Rain Program (ARP), which was instituted in 1990 under Title IV of the Clean Air Act;
- ARP regulates electric generating units (EGUs) that burn fossil fuels and that serve a generator > 25 megawatts;
- It requires continuous monitoring and reporting of SO_2 mass emissions, CO_2 mass emissions, NO_x emission rate, and heat input;
- It also requires a complete data record for each affected unit. Emissions data must be reported for each unit operating hour, without exception;
- Each CEMS or PEMS must be equipped with an automated DAHS;
- PEMS is permitted based on subpart E (Alternative Monitoring Methods).

Others standards that are significant for PEMS are e.g.

- Reciprocating Internal Combustion Engines (RICE) Rule, RICE NESHAP[7] or the
- National Emission Standards for Hazardous Air Pollutants for Major Sources[8]: Industrial, Commercial, and Institutional Boilers and Process Heaters, December 2012 ("Boiler MACT – Maximum Achievable Control Technology").

2.2. EU

Essential European Directives for application of CEMS (and PEMS) are

- the Large Combustion Plant Directive LCPD (2001/80/EC)[9] and
- the Waste Incineration Directive WID (2000/76/EC)[10].
- These directives are now consolidated in the DIRECTIVE 2010/75/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 24 November 2010 on industrial emissions (integrated pollution prevention and control) – IED directive[11]

For Europe, the Working Group (WG) 37 within the European Committee for Standardization (CEN) Technical Committee 264 "Air Quality" has been established end of 2012. This WG37 shall draft a European PEMS Standard (EN) "*prEN 264153 Predictive Emission Monitoring Systems (PEMS) – Applicability execution and quality assurance"* starting out with the

- Netherlands technical agreement NTA 7379 Guidelines for Predictive emission monitoring systems (PEMS) - Execution and quality assurance[12]

This EN will also incorporate the applicable elements of EN 14181: *Stationary source emissions - Quality assurance of automated measuring systems* (EN 14181:2004[13]) and EN15267, Parts 1-3[14, 15, 16].

A detailed assessment of performance criteria as presented in EN15267 Part 3 with respect to their applicability for PEMS can be found in the final report of TÜV Rheinland[17] for a R&D project entitled "*Evaluation of the application of Predictive Emissions Monitoring Systems (PEMS) in Europe taking into account the boundary conditions of the Standards EN 14181 and EN 15267"* that was generously funded by VGB Power Tech. This project was conducted at two combined cycle power plants in Germany and had the major objective to compare PEMS with the plant CEMS and the results of a QAL2 conducted by an independent, accredited stack tester.

WG37 has the specific task to accommodate in the draft standard the one-of-a-kind characteristic of PEMS, which always features plant and emission source related singularities. This is even the case, if PEMS is applied to the same gas turbine type. This is a particular challenge for dealing with EN15267 Part 3 and the array of questions concerning type tests. U.S. EPA Part 60 and PS-16 focus primarily on a certification for a specific plant (initial RATA).

Another working group, WG 9 "Quality assurance of automated measuring systems (Amendment to EN14181:2004)" within CEN TC 264 is related to WG 37, as it is working on a draft of data acquisition and handling systems (DAHS).

To address communication and digital interfaces, a quite significant issue also for PEMS and their integration in plant-wide IT networks, the Association of German Engineers VDI has published a series of guideline documents as VDI 4201, Part1-4[18, 19, 20, 21].

3. PEMS Practical Minimum Requirements / Performance Criteria

From the above given standards one can deduce practical minimum requirements for achieving a PEMS performance that makes it an accepted alternative to CEMS. Below some of the key requirements are briefly addressed with reference made to the pertinent standard to which the requirements need to be in line with.

3.1. Model

There are various ways and methods, how to build a good and robust PEM model and to fulfill the regulatory challenges. Commonly used approaches are e.g.

- Neural network,
- Statistical Hybrid,
- Linear Models,
- First Principle,
- Hybrid Models (Combination of Neural Network - First Principle – Linear Models - Statistical Hybrid);

Parametric monitoring (Continuous Parametric Monitoring Systems – CPMS) is typically excluded from the above list, because they are not covered by PS-16. According to PS-16, parametric monitoring systems serve as indicators of compliance and have parametric limits but do not predict emissions to comply with an emissions limit. Hence, these are not included in the PEMS definition. CPMS are covered by PS-17[22] (proposed rule). Also systems that use fewer than 3 process variables do not qualify as PEMS unless the system has been specifically approved by an administrator for use as a PEMS.

Regardless the model type, the performance has to live up to minimum performance requirements as stipulated in the PEMS standards to become suitable for compliance monitoring.

3.2. Units

PEMS must be able to report results in any unit wanted by the operator or stipulated by the relevant environmental regulation (ppm, mg/Nm^3, for reference oxygen concentration, g/GJ, etc.).

3.3. Measurement Frequency and Response Time

As minimum five seconds refresh rate, but preferably one second shall be accomplished. When building a PEMS that generates data in real time, the response time of the process data and the emission data shall be taken into account. 99,9 % of the final value shall be reached in less than one sec. For a computer-aided system, such response time shall not be a critical requirement.

3.4. Zero and Span

Even though daily zero and span determination is mandatory for CEMS according to U.S. EPA (Part 60 Subpart A §60.13 “Monitoring Requirements”), PS-16 overrides it. PS-16 requires the more rigorous sensor validation system instead (see below 3.10). Span and zero cannot be tested as with gas analyzers, since the PEMS has no possibility of supplying test gases to it.

3.5. Accuracy / Precision / Bias / Drift

Certified PEMS can demonstrate equal accuracy as well maintained CEMS. PEMS must meet the accuracy requirements of the applicable regulations. It shall be able to demonstrate compliance, when tested during QA audits against Standard Reference Methods. According to PS-16, it is required to meet a Relative Accuracy (RA) of

- 10 percent for measurements over 100 ppm or 0,2 lbs/mmBTU,
- 20 percent for measurements between 10 (0,05 lbs / mmBTU) and 100 ppm, and
- within 2 ppm for measurements under 10 ppm.

For diluent PEMS, an alternative criterion of ± 1 % absolute difference between the PEMS and RM may be used if less stringent.

Since the PEMS itself does not exhibit any drift, the drift of the input parameters sensors needs to be considered.

PEMS data is considered biased and must be adjusted if the arithmetic mean is greater than the absolute value of the confidence coefficient in the corresponding equations of PS-16. In such cases, a bias factor must be used to correct the PEMS data.

3.6. Uncertainty

For PEMS uncertainty budgets and expanded uncertainty has to be determined for performing QAL1 and QAL2 (EN14181) following ISO 14956[23]. Uncertainty is often split into three (independent) levels:

- the uncertainty of the relationship found ('Lack-of-Fit, a measure to indicate how far the values that the PEMS generates correspond with the values that are measured during the stack testing campaign');
- the uncertainty due to deviations in the input parameters used;
- the uncertainty due to parameters not included in the PEMS.[12]

These independent uncertainties are then converted via the error progression law to a total uncertainty. Detailed descriptions, how to determine uncertainty can be found in [16].

3.7. Extrapolation

Extrapolation of a PEMS outside the range for which modelling has been carried out is mathematically possible. To limit a possible extrapolation error, extrapolation may be carried out to a maximum of 100 % + 10 % of the minimum value and the maximum value for the input parameter. This is similar to the scope of a calibration function according to QAL2 of EN 14181. The range used shall preferably lie within the historical range of the input parameters (operating envelope of the PEMS).

Extrapolation may be reasonable where[12]

- the relationship between input parameter and the PEMS value in the extrapolation area is monotonous,
- the effect is reducing from a mathematical point of view, and
- the calculated concentration is not higher than 10 % of the calibration interval.

PEMS must incorporate ways to detect and notify the operator of operating envelope exceedances. Emission data collected outside the ranges of the sensor envelopes will not be considered quality assured. PS-16 allows an extrapolation inside the operating envelope.

3.8. Monitoring Uptime

Data capture of PEMS shall typically be > 99,5 %. Redundancy for critical process parameters shall be built in the model, where possible in order to have an additional countermeasure in case of process input failures. An important aspect to be considered when developing PEMS is to make the models most resilient to input failures.

3.9. Ranges

Ranges shall only be limited by the used analyzer data for the training data set. Model development shall be able to incorporating data from multiple analyzers and multiple ranges. Ranges must be fully adjustable.

3.10. Sensor Validation

A Sensor Validation System is an inevitable element of a PEMS and must demonstrate the ability of the PEMS to detect excessive sensor failure modes that would adversely affect emission determination. This includes obvious sensor failure or sensor drift. According to PS-16, a PEMS must be designed to perform automatic or manual determination of defective sensors on at least a daily basis. Recommended is, however, to do this minimum once per hour or better, once per minute or once per prediction cycle.

This sensor evaluation system may consist of a sensor validation sub-model, a comparison of redundant sensors, a spot check of sensor input readings at a reference value, operation, or emission level, or other procedure that detects faulty or failed sensors. A sensor evaluation system may generate substitute values (reconciled data) that are used when a sensor is perceived to have failed[2]. PS-16 requires that one has to obtain prior approval before using reconciled data. A model can then accurately predict emissions regardless of sensor failures and interruptions. The sensor validation system shall include an alarm to inform the operator when sensors need repair and when the PEMS is out-of-control. All sensors must be calibrated as often as needed but at least as often as recommended by the manufacturers.

The final selection of the best suitable process parameter shall be done in a dialogue between model developer and plant engineers to determine, which inputs on one hand have the best correlation to emissions levels and on the other hand exhibit the best reliability and minimal maintenance interventions. Not the best correlating input is always the best in case the corresponding sensor is prone to failure or exhibits instabilities.

The capability of a Sensor Validation System to use information from remaining sensors to reconstruct the values of a failed sensor results in a particular advantage of PEMS, its resilience to input failures. Even if a few sensors fail or drift, the PEMS results remain valid as long as relative accuracy does not fall below a certain value according to the applicable regulation. This usually gives the operator more time to replace defective sensors without impairing data availability and monitoring uptime.

3.11. Model Adaptation

Model adaptation (re-training) may be needed, once significant changes occur in the related plant process. Improvement of model performance and extension of model operating envelope by adding additional historical emissions or stack test data can also be achieved. This data addition capability shall be useable to improve ranges and accuracy. All such interventions or modifications need to be automatically and immutably logged as countermeasure for preventing emissions record manipulation. Once model re-training needs to be conducted, the PEMS has subsequently to be re-certified using the tests and procedures as e.g. given in PS-16 or 40 CFR Part 75 Subpart E. For example, if one initially developed PEMS for a plant operating at 80–100 % of its range, one would have performed the initial test under these conditions. If the unit operates at 50–100 % of its range later on, a further RA test and statistical tests are conducted, as applicable, to verify that the new conditions of 50–100 % of range are correctly covered by a re-trained PEMS model. It has to provide acceptable data, also if new PEMS parameter(s) are included. One may only use the PEMS under the source-specific operating conditions it was certified for.

3.12. Model and Data Protection

Measures against model and data manipulation need to be implemented. Regular checking shall comprise scrutiny if the model or data was changed or manipulated. Procedures could e.g. be

- The collected raw data is stored in an immutable manner;
- Any modification of the model files that is made will automatically generate a new revision number (e.g. original number 123456 Rev.0, after modification 123456 Rev.1 and so on);
- Model functionality is tested with input data from an audit representing the input values at selected process conditions. The results generated should be very close to the reference method values at the latest audit (RATA, QAL2 or AST) and they should not change. This shall demonstrate that model, database and the results have not been corrupted;
- Model files shall be encrypted.

3.13. Hardware and Interfaces

No special hardware shall be needed. PEMS shall be executable on topical standard sever and workstation hardware. PEMS software shall be executable with standard operating systems. Standards shall be used to interface with DCS, PI, PLC or other data loggers. All conceivable standard interfaces have to be addressed as reasonably practical, in particular

- OPC DA and UA. OPC is gaining increasing significance
- ModBus RTU and TCP,
- Profibus DP and PA,
- Fieldbus,
- Serial communication,
- Others, as needed.

Details can be found e.g. in VDI 4201, Part 1-4, as referenced on above page 6.

PEMS installations can exist as stand-alone compliance solutions. In many instances, however, they are part of an integrated environmental monitoring approach capable to address multiple sources in one plant. One prerequisite is a seamless interaction of PEMS and Data Acquisition and Handling Systems (DAHS) and integration in plant-wide IT and communication networks. An additional benefit is that a PEMS-DAHS package provides a viable diagnostic tool to lower emissions and to improve combustion efficiency by surveillance of both, emission variations and associated changes in plant process conditions.

4. Quality Assurance

For establishing an appropriate quality assurance scheme, one should consider that the functionality and performance of PEMS is very similar to a continuous gas analyzer. Consequently, Predictive Emission Monitoring Systems must abide by the same quality assurance (QA) schemes as analyzer based systems to guarantee equivalent results with equivalent accuracy and precision. According to PS-16, the following QA elements have to be conducted and incorporated in a QA plan beyond the initial PEMS certification test:

- For the initial certification of a PEMS that is used for continual compliance according to PS-16, one must perform a minimum 27-run, 3-level (9 runs at each level) relative accuracy test. Additionally, the data must be evaluated for bias, by F-test and correlation analysis. One has to conduct the specified number of RM tests at the low (minimum to 50 % of maximum), mid (an intermediary level between the low and high levels), and high (80 % of maximum) key parameter operating levels, as practicable. If these levels are not practicable, one must vary the key parameter range as much as possible over three levels[2];
- Daily Sensor Evaluation Check. A sensor evaluation system must check the integrity of each PEMS input at least daily. It is recommended to perform this once per minute;
- Quarterly Relative Accuracy Audits (RAAs). In the first year of operation after the initial certification, a RAA has to be conducted consisting of at least three 30-minute portable analyzer or reference method (RM) determinations each quarter a RATA is not performed. The average of the three portable analyzer or RM determinations must not differ from the simultaneous PEMS average value by more than 10 percent of the analyzer or RM value or the test is failed. If a PEMS passes all quarterly RAAs in the first year and also passes the subsequent yearly RATA in the second year, one may elect to perform a single mid-year RAA in the second year in place of the quarterly RAAs. This option may be repeated, but only until the PEMS fails either a mid-year RAA or a yearly RATA. When such a failure occurs, one must resume quarterly RAAs in the quarter following the failure and continue conducting quarterly RAAs until the PEMS successfully passes both, a year of quarterly RAAs and a subsequent RATA.[2]
- Yearly Relative Accuracy Test Audit (RATA). Perform a minimum 9-run RATA at the normal operating level on a yearly basis in the quarter that the RAA is not performed.[2]

For PEMS used at plants subject to 40 CFR Part 75, Subpart E requires the plant applying for approval of an Alternative Monitoring System (AMS) to perform a 720 operating hour (minimum) demonstration showing that the AMS has the same or better precision, reliability, accessibility, and timeliness (PRAT) as a CEMS. One needs to provide valid paired AMS and CEMS data for at least 90 % of the minimum 720 operating hours. Regarding reliability, it requires the unit to demonstrate that the PEMS is capable of providing valid one-hour averages for minimum 95.0 % of unit operating hours over a one-year period.

Three statistical tests must be passed, i.e., a linear correlation analysis (r-test), an F-test, and the one-tailed t-test for bias with other plot / reports required to be turned in. Each monitoring system must be equipped with an automated Data Acquisition and Handling System (DAHS).

The sensor validation system shall include an alarm to inform the operator when sensors need repair and when the PEMS is out-of-control. In setting up the alarm system, a demonstration shall be performed at a minimum of four different PEMS training conditions, which must be representative of the entire range of expected operating conditions. Ongoing semi-annual or annual RATAs shall be performed at the normal operating level. Monthly, 3-run (minimum) relative accuracy audits (RAAs), shall be performed in every calendar month of the year in which the unit operates for at least 56 hours, except for a month in which a full 9-run RATA or PEMS recertification is performed. A detailed description of Part 75 PEMS quality assurance can e.g. be found in [24].

For countries following European regulations, a comparable PEMS QA can likely be conducted based on EN 14181 with the QA elements QAL 1 (calculation of the uncertainty budget according to EN ISO 14596), QAL 2, QAL 3 (regular checking of input parameters and sensors) and Annual Surveillance Test (AST). A suitability test as per EN15267-3 might not be feasible due to the one-of-a-kind nature of PEMS. The precise way how to address PEMS QA on the basis of EN 14181 and EN15267 has yet to be specified in the standard, WG37 has to accomplish (see page 6).

Table 1: Overview of important and applicable QA measures for PEMS

PEMS is an analyzer!	
Measure	**Frequency**
Sensor Validation	Once per minute, minimum daily
Relative Accuracy Audit RAA	Quarterly / Monthly
Relative Accuracy Test Audit RATA	Annual
EN 14181 QAL1	Uncertainty. PEMS Model Building
EN 14181 QAL 2	Initial calibration
EN 14181 QAL 3	Periodic checks at regular intervals
EN 14181AST	Annual

5. Summary and Comparison PEMS – CEMS

As set out above, PEMS can be an alternative for continuous compliance monitoring of emissions if they conform to specific standards and are subject to stringent quality assurance procedures. In particular, the U.S. Environmental Protection Agency is permitting PEMS on the basis of established standards. For Europe and the EU such standards have yet to be drafted and promulgated apart from some countries that have such standards already in place (e.g. The Netherlands). CEMS and PEMS and their minimum performance requirements exhibit a lot of commonalities, however, there are a few distinct differences.

Below table summarizes substantial commonalities as well as differences of PEMS versus CEMS.

Table 2: Characteristic common features and differences of PEMS versus CEMS

Common Features	**CEMS / PEMS**	
Continuous	Both methods can be used for continuous emissions monitoring.	
Plant Types	For all oil- and gas-fired sources.	
Accuracy / Precision	Accuracy and precision are comparable provided that the same quality assurance i applied.	
Quality assurance	Securing data quality with procedures of EN14181 / requirements of EN 15267 (EU as well as Part 60 / Part 75 RATA / RAA (USA).	
Data Acquisition	For data representation and reporting of monitoring results, use of data acquisition and handling systems.	
Differences	**CEMS**	**PEMS**
Hardware	• Gas Analyzers • Accessories like probes, heated lines, racks, shelters etc. needed	• Standard server hardware with means fo data back-up and securing data integrity
Application	CEMS more universally applicable: • Plants fired with variable solid fuels • Components like particulate matter and Hg	• Basically not suitable for solid, moisture absorbing fuels • Not applicable at e.g. waste incinerators • Restricted for coal-fired plants
Cost	• Capital cost: Approximately 50 % of a comparable CEMS. In case of model transferability or for ex-proof areas, cost difference may even be much higher • Operations and maintenance: Approximately 10-20 % of CEMS cost • Quality assurance: No cost difference	
Quality assurance	• EU: Type approval • U.S. Daily Zero and Span check (Part 60)	• EU: EN15267-3 may not reasonably applicable due to the plant specific, one-of-a-kind characteristic of PEMS • U.S. Sensor Validation System (PS-16, Subpart E). Resilience to input failures.

6. References

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[3] U.S. Code of Federal Regulations, 40 CFR PART 75—CONTINUOUS EMISSION MONITORING

[4] U.S. Code of Federal Regulations, 40 CFR Part 75, Subpart E. "Alternative Monitoring Systems", Federal Register, Subpart E

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