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SPECIFICATIONS AND GUIDELINES FOR CONTINUOUS EMISSIONS MONITORING SYSTEMS (CEMS) FOR PM MEASUREMENT WITH SPECIAL REFERENCE TO EMISSION TRADING PROGRAMS

cpcb

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PREFACE

Emission Trading using Particulate Matter as marker pollutant from industrial point sources has been taken up first time in the country. The activity involves use of Continuous Emissions Monitoring Systems (CEMS) for real time assessment of emission concentration vis-à-vis emission load. This initiation would help to gather real time information on pollution load from the stationary sources, which in turn put all the stake holders including regulators on step forward to plan regulatory reforms and keep vigil and ensure the implementation of the regulation more transparently and effectively.

The Ministry of Environment and Forests has initiated an important project to design and evaluate a pilot emissions trading scheme (ETS) for particulate matter from stationary sources, being launched in three states: Gujarat, Maharashtra and Tamil Nadu wherein the Central Pollution Control Board is working as Nodal Agency for overall implementation of the program. This report presents specifications and guidelines for the use of Continuous Emissions Monitoring Systems, including technique for calibration of CEMS along with QA-QC objectives for data quality. The document also describes and demonstrates the CEMS selection and guiding principles for smooth and easy operation of systems in a uniform & systematic way.

These guidelines have been carefully prepared after expensive consultations, workshops and interaction meets with CEMS suppliers and a thorough international peer review process. The document has been designed to provide support for the proposed regulatory system for implementation of ETS in India.

Sincere acknowledgement is also expressed for peer review experts: Mr. Alan Leonard of Ricardo-AEA (UK), Dr. Laura Diaz Anadon (Harvard University) and Dr. Richard Schmalensee (Massachusetts Institute of Technology). We express our gratitude to Ms. Mira Mehrishi, former Chairman, CPCB & Mr. Ajay Tyagi, Chairman, CPCB for encouraging support. Thanks are expressed to all concerned Member Secretaries: Mr. J. S. Kamyotra, CPCB; Mr. Hardik Shah, GPCB; Mr. Rajeev Mital, MPCB and Dr. S. Balaji, TNPCB (Retd.) for their support in this endeavor. Thanks are expressed to Dr. R. Hasan, Advisor (CP) & Mr. R.N. Jindal, Scientist-E, MoEF for initial conceptualization of the project in India. The efforts of members of the Technical Committee led by Dr. D. Saha, Scientist-D & I/c- Air Laboratory of CPCB, the Coordinator of the entire activity, for their respective support in this endeavour are sincerely acknowledged.

This guideline document would not only assist State Pollution Control Boards, Industries and CEMS manufacturers in India and abroad in ensuring high quality information from PM CEMS installations but will also enable us to move towards a cleaner environment and better air quality through implementation of "Polluter Pays Principle".

Continuous Emissions Monitoring Systems

and

Pilot Emissions Trading Scheme (ETS) for Particulate Matter from Stationary Sources (Stack) in India (Market Friendly Emissions Trading Scheme)

COLLABORATIVE PILOT PROJECT AMONG:

Ministry of Environment and Forests
GOVERNMENT OF INDIA

Gujarat Pollution Control Board

Maharashtra Pollution Control Board

TNPCB
Tamil Nadu Pollution Control Board

IFMR Research
ABDUL LATIF JAMEEL POVERTY ACTION LAB

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EXECUTIVE SUMMARY

The purpose of this document is to serve as a technical specification for accurate, reliable measurement of particulate matter using Continuous Emissions Monitoring Systems (CEMS) with reference to their use to support an emissions trading scheme. While measurement and regulation of particulate matter is a concern worldwide, this specification is unique, primarily because it is also designed to measure total load (equivalently average mass flow rate) over an extended period of time, as opposed to only mass concentration of particulates at any instant of time.

1. Continuous Emissions Monitoring Systems for Measurement

The term CEMS refers to the instrumentation and software required to measure emissions from a stationary source on a practically continuous basis. Unlike for carbon dioxide emissions or energy consumption, input-based methods of measurement are not reliable for particulates, since particulate emissions is a complex function of combustion conditions and abatement technology. Emission measurement and monitoring by CEMS has been in practice across the globe since the 1960s.

Different technologies have been developed to make quantitative measurements of particulate matter concentrations or load in smoke stacks. A characteristic that is common to all of these technologies (with the exception of beta attenuation, an extractive method) is that they are based on indirect measurement principles and therefore require *calibration* to smoke stack conditions before use. Thus calibration of a particulate CEMS device is a central part of all performance specifications including this one. This calibration in all cases involves a comparison of the continuous emissions monitoring device to standard gravimetric sampling techniques that are in use all over the world today. In a sense therefore, PM CEMS can be viewed as an extension of existing manual sampling techniques where technology is used to move from a one-time measurement of particulate matter pollutants in the stack, to a continuous measure.

Continuous measurement of PM emissions confers a number of benefits relative to manual stack sampling:

- Real time information: Emissions may vary quite widely in real time as a function of operating processes, the operational status of air pollution control devices (APCD), and fuel type and quality. Therefore CEMS readings provide a more accurate record of emissions over time.

- Transparency and Openness: The use of PM CEMS technologies presents industries, regulators and potentially the public with high quality, on-going information on emissions from each source so equipped. In turn, this means that regulation based on this data is also transparent and clear, industries can predict and be aware of the costs of compliance and plan accordingly.

- Load standards and Market Based Regulatory Mechanisms: PM CEMS data enables the use of load standards instead of concentration standards as the basis for regulating stationary source emissions. This is advantageous because health and environmental concerns are normally influenced by the mass or volume (in the case of effluents) of pollutants emitted. Additionally, total mass load of emissions is the critical quantity involved in emissions trading schemes.

CEMS have been used for monitoring of pollutants other than particulate matter in the first major emissions trading program, the acid rain program in US, and CEMS for PM have been used for monitoring of concentration based requirements in other settings. In this context, the Ministry of Environment and Forests has initiated an important project to design and evaluate a pilot emissions trading scheme (ETS) for particulate matter from stationary sources, in collaboration with three states – Gujarat, Maharashtra and Tamil Nadu, with the Central Pollution Control Board as nodal agency for overall implementation of the program. This has been initiated as a way forward towards reduction of Particulates in the ambient air. Therefore, the role of CEMS is to measure the total load of particulate matter (PM) coming from each stationary source. Total emissions can then be reconciled against permit holdings in the trading scheme.

2. Components of the Monitoring Framework

The technical framework of the PM-CEMS based monitoring system for ETS consists of a network of hardware devices and software programs that interlink regulated industries to the regulator in a manner that allows emissions data to be securely transmitted at regular intervals. The process begins with the collection of continuous PM mass flow data from an industry's stack, and moves through a secure and automated storage and transfer process to servers based at Data Acquisition and Handling Centres, where a number of functions ranging from analytics to data validation occur. The ultimate result is a set of reliable and accurate emissions data which serve as the foundation upon which the PM ETS rests.

The hardware components required at each industry site consist of (i) a PM CEMS device for mass flow measurement (and a volumetric flow meter, if required), (ii) a Data logger unit for saving the CEMS data (if not inbuilt in PM CEMS Device), and (iii) a Data Acquisition System (DAS), which is a PC with fast, reliable and dedicated broadband internet connectivity.

The software components at each industry site will consist of two software programs, both installed on the DAS: (i) the CEMS vendor software provided by either the CEMS device manufacturer or a third party software vendor (modified as needed for compatibility with ETS requirements) and (ii) the ETS Bridge software which acts as the interface between the CEMS vendor software residing on the same machine and the DAHC server software at the SPCBs and CPCB.

3. Roles and Responsibilities

The monitoring regime proposed is based upon CEMS but not limited to the instrumentation and associated software itself; rather, it encompasses a complete institutional and technical ecosystem for ensuring high-quality emissions data.

The most important roles are those of regulated industry and the state pollution control board (SPCB). It is the responsibility of regulated industry to comply with the specifications outlined in this and other applicable documents; and to ensure that high quality and reliable data is transmitted to the state board. Conversely it is the responsibility of the SPCBs to oversee the monitoring regime, clearly outline expectations from all parties, and implement the regulatory framework that uses the PM CEMS information. Other parties such as accredited labs, CEMS vendors and CEMS working groups in each industry cluster play essential support roles.

4. PM CEMS Standard Operating Procedures

The standard operating procedures (SOPs) for the selection, installation, calibration, and maintenance of PM CEMS devices underpin the functioning of the whole system. These procedures form the linkages between responsibilities of the various stakeholders and the specifications and standards required for smooth implementation of the monitoring framework for ETS.

The first step for adopting CEMS is to select a device (or combination of devices if flow meter is required) optimally suitable for the stack characteristics at the industry. Important considerations include stack diameter, flue gas temperature, and air pollution control devices (APCDs) installed, among others.[1] In parallel, industries will also need to select a CEMS vendor from which to purchase the equipment, subject to the vendor and any devices purchased meeting all requirements as outlined in these guidelines. Then, following the necessary setup procedures to install the required hardware and software, the SPCB will indicate whether the industry can proceed to calibration of the device and the test each CEMS device must pass to be in compliance with ETS performance standards.

In order to verify that the CEMS calibration meets the minimum performance requirements, it must undergo the Post-Calibration Performance Test. The SRM (Standard Reference Method) for measuring and calibrating PM emissions is through iso-kinetic sampling. The same iso-kinetic samples used for calibration are used for the CEMS Post-Calibration Performance Test. To ensure that the calibrated CEMS readings are valid under differing operational conditions, PM emissions should be varied as much as possible (by changing load or the operating conditions of the APCD or both) within the normal operations of the plant during calibration.

Software at the DAHC Server (SPCB) performs the Post-Calibration Performance Test and informs the industry if it passes or fails. This test checks that initial calibration is done sufficiently well, but, it does not exempt the industry from the requirement to carry out periodic quality control tests. Another post-calibration test must be carried out during the CEMS audit, required at least once in a year, while re-calibration of the same is to be taken up once in six months as per the standard operating procedure defined.

The performance standard and calibration protocol is intended to assure that CEMS estimates for total emissions load over a compliance period (typically 12 months) in the pilot ETS should be extremely reliable. For a well-calibrated CEMS (where the relationship between CEMS readings and true emissions is linear within the calibration range), the sum of these random errors would be expected to average out to zero, over a 3-month to 12-month of compliance period, allowing precise estimates of total emissions load for trading.

While this document primarily describes how to use PM CEMS in order to support a market based regulatory mechanism (emissions trading scheme) targeting total particulate load, the guidelines and specifications provided here will also enable the use of PM CEMS to strengthen existing systems of monitoring concentration standards.

[1] An overview of the selection process for both PM CEMS and flow meters is found in Appendix A.

Contributions

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Figures and Tables

Abbreviations

APCD	Air Pollution Control Device
CEMS	Continuous Emissions Monitoring System
CEPI	Comprehensive Environmental Pollution Index
CPCB	Central Pollution Control Board
CVS	CEMS Vendor Software
DAHC	Data Acquisition and Handling Centre
DAHS	Data Acquisition and Handling System
DAS	Data Acquisition System
DSS	DAHC Server Software
DVP	Data Validation Protocol
EBS	ETS Bridge Software
EPA	Environmental Protection Agency (US)
ETS	Emissions Trading Scheme
GPCB	Gujarat Pollution Control Board
MoEF	Ministry of Environment & Forests, Government of India
MPCB	Maharashtra Pollution Control Board
NAAQS	National Ambient Air Quality Standards
PM	Particulate Matter
SPCB	State Pollution Control Board
ToC	Type of Configuration
TNPCB	Tamil Nadu Pollution Control Board

1. INTRODUCTION

1.1 Continuous Emissions Monitoring – Systems and Benefits

Emission measurement and monitoring by Continuous Emissions Monitoring Systems (CEMS) has been in practice across the globe for a long time. The CEMS is basically an electronic device, which is capable of capturing electronic signals, e.g. in milliamps (mA), and they are collected and stored in a data logger. CEMS have been used for pollutants other than particulate matter in the first major emissions trading program, the acid rain program in US, and CEMS for PM have been used for monitoring of concentration based requirements in other settings. However this specification focuses on the use of PM CEMS with reference to the use of this data as the basis for an emissions trading scheme. Thus attempts have been made to document issues and aspects of Particulate Matter CEMS (PM-CEMS) in stationary industrial sources.

Introduction to PM CEMS

The technology behind continuous emissions monitoring systems for particulate matter (PM CEMS) has been developed since the 1960s when PM CEMS were first used in Germany. In the 1970s, the use of PM CEMS became a federal requirement in Germany, and particulate matter concentrations began to be correlated to opacity meter readings in the United States. Since that time, various regulatory standards for PM CEMS have been developed in different countries, each of which has been designed for the specific needs and objectives of the regulator. Nevertheless all these standards share a common broad protocol designed to ensure that the underlying objective of reliable emissions monitoring is achieved. Some of these standards include the US EPA performance specification (PS-11), various European specifications including the BS-EN 14181 and BS-EN 14182, and country standards by the TUV (Germany) and MCERTS (United Kingdom).

PM CEMS Technology

Concurrent with their increasing use in various regulatory and industrial contexts, different technologies have been developed to make quantitative measurements of particulate matter concentrations or load in smoke stacks. Different physical principles are commonly used as the basis of measurement today and these include (i) light scattering, (ii) probe electrification, (iii) light extinction and (iv) optical scintillation. A less common technology that is sometimes used in special conditions is (v) beta attenuation.

Light scattering, extinction and scintillation based devices rely on changes in the optical properties of stack gas as the concentration of particles increases. Probe electrification relies on changes in generated charge in a probe due to moving particles in the gas stream. Over the years, multiple studies have been carried out on the performance and characteristics of all these technologies and some of this history is available from the references to this document (USEPA, 2000).

A characteristic that is common to all of these technologies (with the exception of beta attenuation) is that they are based on indirect measurement principles and therefore require *calibration* to smoke stack conditions before use. Thus calibration of a particulate CEMS device is a central part of all performance specifications including this one. This calibration in all cases involves a comparison of the continuous emissions monitoring device to standard gravimetric sampling techniques that are in use all over the world today. For this same reason, the process of calibration is largely technology independent. In a sense therefore, PM CEMS can be viewed as an extension of existing manual sampling techniques where technology is used to move from a one-time measurement of particulate matter pollutants in the stack, to a continuous measure.

Benefits of PM CEMS

There are many clear benefits to continuous recording of particulate emissions as opposed to manual stack sampling at specified intervals. These include:

Real Time Information

Manual stack sampling provides no information on particulate emissions in the intervals between monthly monitoring. However actual emissions may vary quite widely in real time as a function of operating processes, the operational status of air pollution control devices (APCD), fuel type and quality, and so on. For this reason it is impossible to accurately estimate total emissions from any given industry (or group of industries) in a region from occasional stack sampling. This is a major drawback especially in critically and severely polluted areas where even small increases in pollutant load can be a major health concern.

Load Standards

PM CEMS data enables the use of load standards instead of concentration standards as the basis for regulating stationary source emissions. In many situations, load standards have a number of important advantages over concentration standards, especially because health and environmental concerns are normally influenced by the mass or volume (in the case of effluents) of pollutants emitted and not directly by the concentration. A higher pollution load will normally translate into higher ambient concentrations while a limit on concentration of emissions may still allow for a high total load to be emitted (through an increase in operating hours, stack volume or the number of stacks in an area).

In addition, while load standards often make more environmental sense than concentration standards, they also increase the number of options industry has available in order to comply with regulation. For instance, total load can be reduced by decreasing operating hours. However this is not a helpful option for an industry attempting to comply with concentration standards.

Transparency and Openness

The use of PM CEMS technologies presents industries, regulators and potentially the public with high quality, on-going information on emissions from each source so equipped. In turn, this means that regulation based on this data is also transparent and clear, industries can predict and be aware of the costs of compliance and plan accordingly, and the public at large obtains the best possible information on environmental performance of regulated units and the total emissions load in an area (from regulated stationary sources).

Market Based Regulatory Mechanisms

PM CEMS can enable implementation of market based regulation, by providing an accurate record of emissions over time. Market based regulatory mechanisms such as emissions trading provide a number of benefits to industry. The principal advantage is that emission reductions can be made at lower cost. Under cap and trade for instance (a form of emissions trading), only the total emissions load from a number of industries is fixed but individual units are free to trade emission permits amongst each other such that reductions are undertaken by those units for whom it is cheapest to do so. This flexibility can significantly reduce overall costs. In addition, since a cap and trade is based on a load standard the benefits of regulating load vs. concentration also carry over to industry.

Perhaps the most important of these advantages is the ability of PM CEMS to enable the accurate measurement of total mass load of emissions which is the critical quantity involved in emissions trading schemes. Indeed, it would be reasonable to argue that to use PM CEMS *only* as a support to concentration standards is to severely underutilize the information content of time series data. An important opportunity that is opened up for regulators using PM CEMS is the ability to measure and therefore regulate total mass emitted over a period of time, a quantity that cannot be reliably estimated using one time stack sampling. This document primarily describes how to use PM CEMS in order to support a market based regulatory mechanism (emissions trading scheme) targeting total particulate load. Nevertheless the guidelines and specifications provided here will also enable the use of PM CEMS to strengthen existing systems of monitoring concentration standards.

1.2 Pilot Emissions Trading Scheme for Particulate Matter

Introduction to Emissions Trading

Emissions trading schemes (ETS) have been applied to a variety of pollutants around the world in order to guarantee environmental outcomes while minimizing compliance costs. In an ETS, the regulator sets the overall quantity of emissions for a specified area but does not decide what any particular source will emit. Industrial plants and other polluters, rather than being prescribed a fixed emissions limit or concentration standard as an individual unit, face a price for their emissions and choose how much to emit, subject to the overall limit set by the regulator, taking this price into account. Under ETS, firms have the flexibility to design their own compliance strategy—emissions reduction through technology adoption or upgradation, or allowance purchases/sales—to minimize their compliance costs.

The five main areas for the successful implementation of ETS are:

1. **Setting the Cap.** The target for aggregate emissions from the sector where trading is introduced must be set to produce reasonable prices and emissions reductions.

2. **Allocating Permits.** The permits to emit must be distributed in an equitable way to build support for the scheme.

3. **Trading.** Permits are based on the total quantity of emissions rather than concentrations and have a time duration that is set by the regulator.

4. **Monitoring.** The quantity of emissions from each industrial plant must be reliably and continuously monitored with high integrity recognized by all sides.

5. **Compliance.** The regulatory framework must make industries confident that buying permits is the only reliable way to meet environmental obligations.

Global Experience with ETS

The US EPA pioneered such trading under the Clean Air Act to limit a variety of common air pollutants beginning in 1974 (Stavins, 2003). The landmark Acid Rain program applied the cap-and-trade model to sulphur dioxide pollution, achieving sharp reductions in emissions at lower than expected costs. In recent decades, environmental trading programs have proliferated in the European Union, Canada and increasingly in developing Asia. China has a nascent sulphur dioxide market as well as a trading market in CO_2 and has been testing market-based policies jointly with the US EPA since 1999 (Yang and Schreifels, 2003; Schreifels, Fu and Wilson, 2012). Indian industries trade in Renewable Energy Certificates and, via the Clean Development Mechanism, Certified Emissions Reductions (CER) for Carbon Dioxide. In 2012, the Indian government's Bureau of Energy Efficiency (BEE) launched a trading scheme based on energy consumption to encourage greater efficiency in energy-intensive industrial sectors.

In this context, the Ministry of Environment & Forests, the Central Pollution Control Board and the State Pollution Control Boards of the states of Gujarat, Maharashtra and Tamil Nadu have come together to design and pilot an emissions trading scheme for particulate matter air pollution from industrial point sources. Particulates are the most severe air pollution problem in India, with most major cities and many industrial areas out of compliance with the National Ambient Air Quality Standards for SPM (NAAQS) (CPCB, 2010; CPCB 2011). The model of industrial development in tightly-clustered industrial estates results in industrial combustion being the key source of particulate pollution in many areas, though transport emissions have also grown rapidly (CPCB, 2009; CPCB 2011). The emissions trading scheme (ETS) will be piloted in several such large industrial areas to reduce emissions and to provide a working example of emissions trading in India for a critical local air pollutant.

The Role of PM CEMS in the ETS pilot

As noted above, a solid monitoring framework to provide reliable and high quality emissions data forms the foundation of any successful trading program. It is worth noting that in an ETS there are two aspects of data quality that are of key importance.

<u>Measurement accuracy</u>

For emissions trading, it is important to have an accurate measurement of the *quantity of interest*, in this scheme total load of PM emissions over a set period of time. Some existing ETS have utilised input-based methods for estimating total emissions load for pollutants ranging from carbon dioxide to particulate matter; however there are significant drawbacks to this method. For instance, input-based methods of measurement are not reliable for particulates because PM emissions are a complex function of combustion conditions and abatement technology. Accordingly, such estimation methods would not reflect emissions reductions that occur after the inlet, such as improved maintenance of abatement equipment, which can be a low-cost means of achieving reductions for industry. Therefore it is critical for a trading scheme in PM to measure the particulate emissions at the outlet of a stack, necessitating the use of a monitoring technology such as CEMS.

Measurement frequency

Although in theory it is possible to extrapolate total emissions from periodic manual checks, the variations that exist in industry processes and conditions imply that these measures are highly unreliable as a basis for trading. Therefore having the time series of emissions readings provided by CEMS technology is necessary to form a more robust and complete measure of total emissions load, the quantity required for ETS and that ultimately influences ambient air quality.

ETS schemes implemented to date have monitoring protocols that use some combination of input-based methods of estimation, CEMS, and/or periodic site audits in order to determine compliance with the scheme. However even in schemes where CEMS are used, they are often not mandated for all regulated entities and the continuous emissions readings at the industry site are reported to the regulator on a periodic basis (e.g. quarterly) rather than in real-time. Implementation difficulties in early programs highlight the importance of having both accurate and high frequency data on emissions.

Building upon this experience, this document outlines a unique performance specification and set of guidelines for the use of continuous emissions monitoring of particulate matter to support load monitoring for an emissions trading scheme. In so doing, this document breaks new ground in the use of modern monitoring technology to support innovative market based regulations. This combination represents a significant advance not just in the Indian context, but globally.

1.3 The PM CEMS Monitoring Framework for ETS

The purpose of this document is to outline the technical and operational requirements of a PM CEMS-based monitoring framework that provides reliable and accurate data as a foundation for the pilot particulate matter emissions trading scheme.

The document is broadly divided into three sections that correspond to the key building blocks of such a system:

- Section 2 discusses the **technical components**, referring to the hardware and software components that form the basis of the monitoring framework. It also describes the technical specifications and performance standards that apply to the same.

- Section 3 describes the various **stakeholders** and their **roles and responsibilities** within the monitoring framework.

- Section 4 then outlines the **standard operating procedures** that underpin the functioning of the whole system. These procedures form the linkages between responsibilities of the various stakeholders and the specifications and standards required for smooth implementation of the monitoring framework for ETS.

These components and linkages are illustrated in Figures 1 and 2 which follow.

Figure 1: Monitoring Framework Components and Linkages

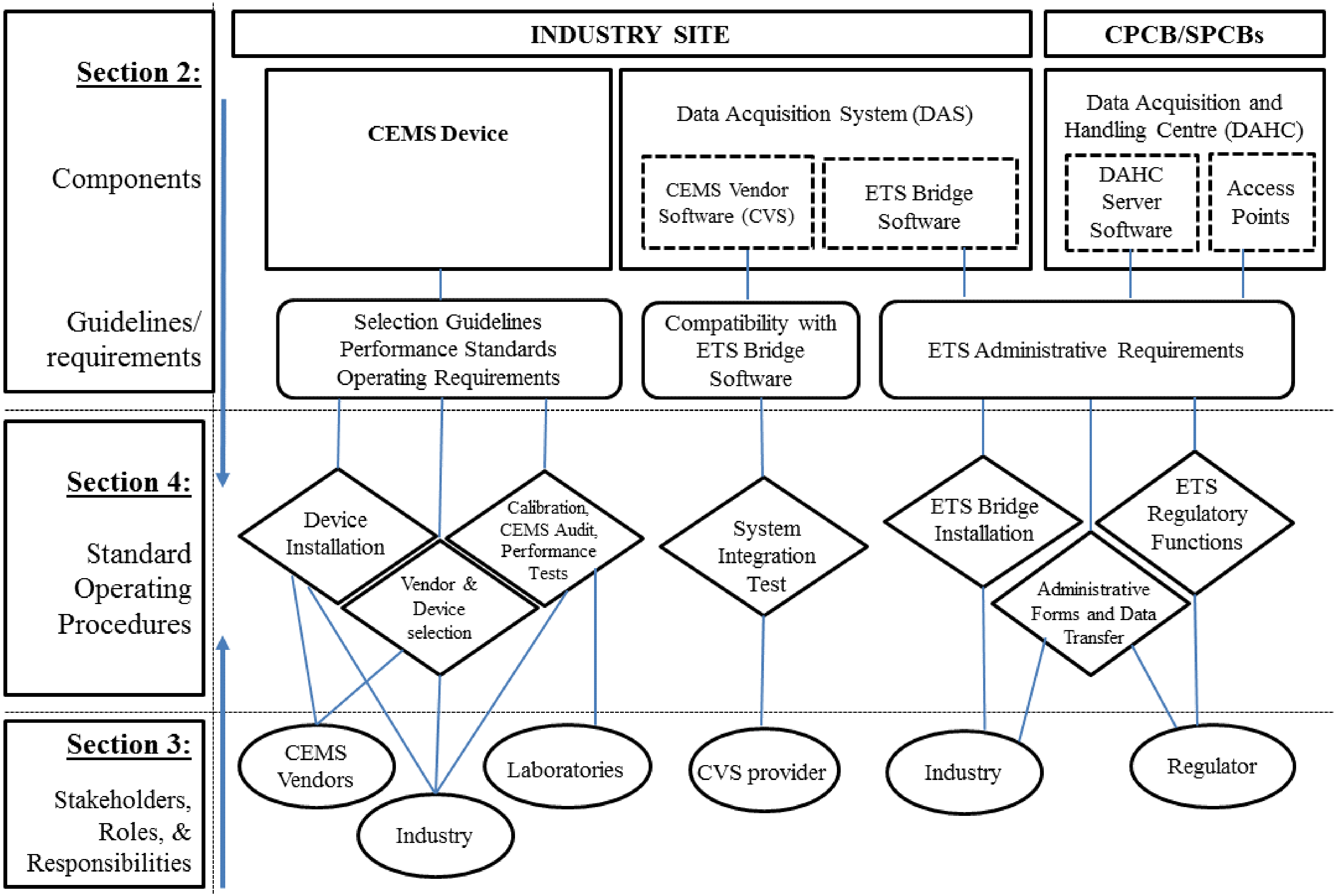
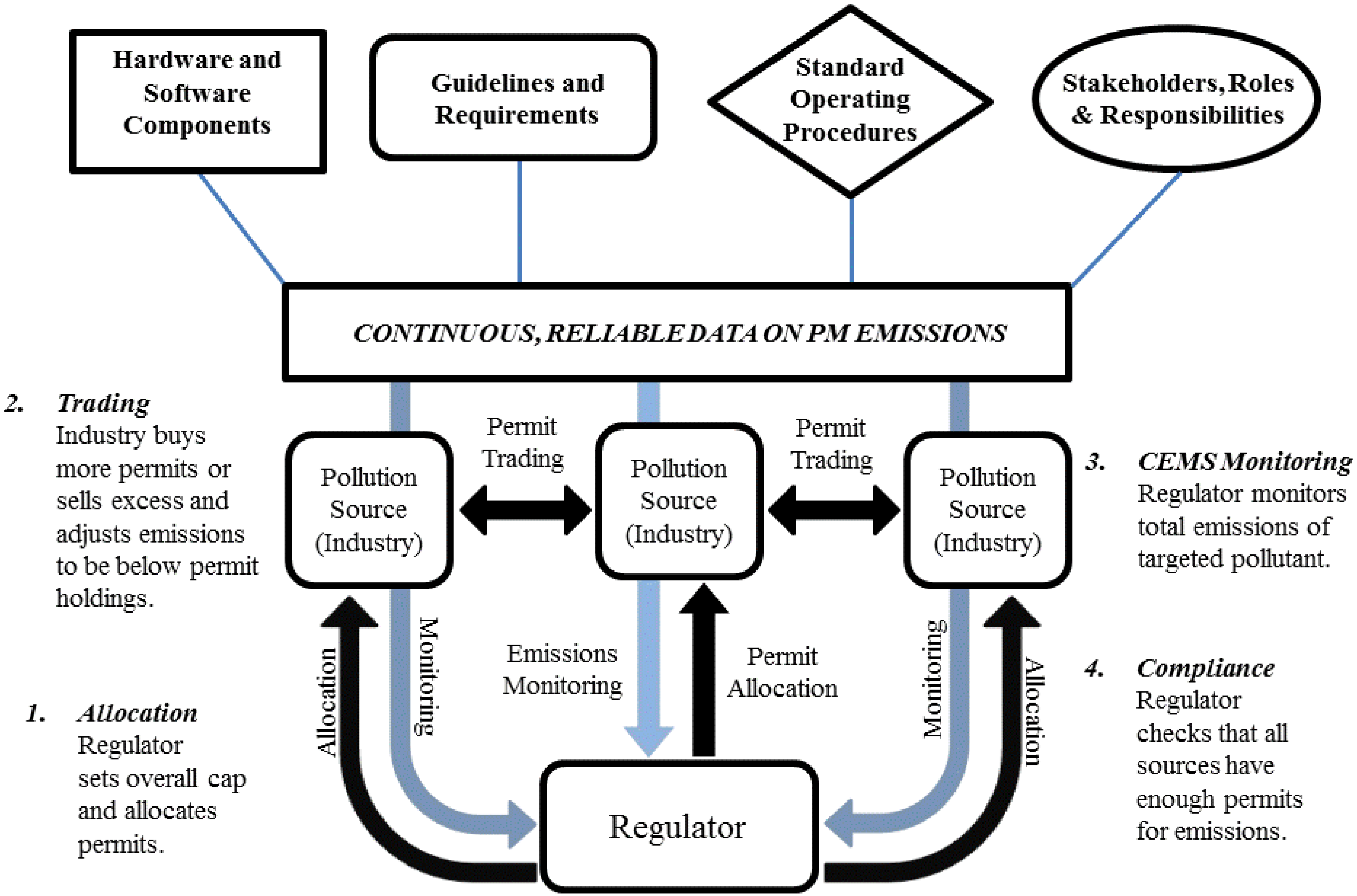


Figure 2: Role of PM CEMS Framework in ETS



2. COMPONENTS AND REQUIREMENTS OF THE CEMS MONITORING SYSTEM

The technical framework of the PM-CEMS based monitoring system for ETS consists of a network of hardware devices and software programs that interlink regulated industries to the regulator in a manner that allows emissions data to be securely transmitted at regular intervals. The process begins with the collection of continuous PM mass flow data from an industry's stack, and moves through a secure and automated storage and transfer process to servers based at Data Acquisition and Handling Centres, where a number of functions ranging from analytics to data validation occur. The ultimate result is a set of reliable and accurate emissions data which serve as the foundation upon which the PM ETS rests.

The hardware components required at each industry site consist of the following three devices:

- A PM CEMS device for mass flow measurement (and a volumetric flow meter, if required)
- A Data logger unit for saving the CEMS data (even when PC fails) for at least 7 days (if not inbuilt in PM CEMS Device)
- A Data Acquisition System (DAS), which is a PC with fast, reliable and dedicated broadband internet (minimum 256 Kbps) with 24/7 connectivity.

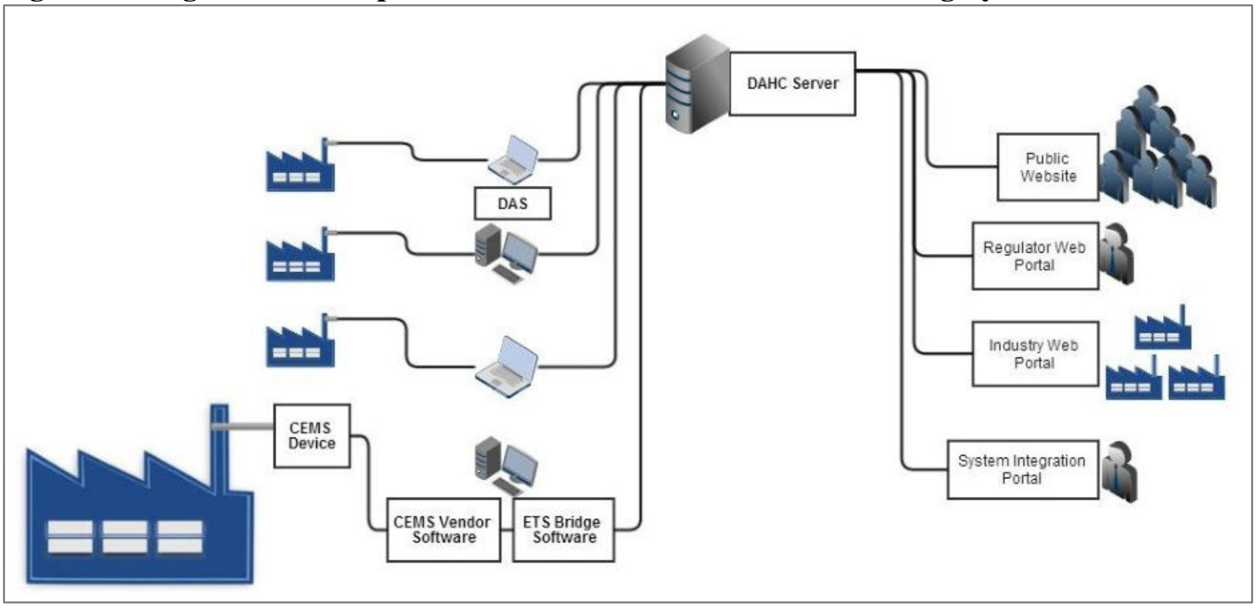
The software components at each industry site will consist of two software programs, both installed on the DAS:

- The CEMS vendor software provided by either the CEMS device manufacturer or a third party software vendor (modified as needed for compatibility with ETS requirements)
- ETS Bridge software which acts as the interface between the CEMS vendor software residing on the same machine and the DAHC server software at the SPCBs and CPCB.

These components are described in more detail in the sections that follow. While the requirements of the hardware devices (e.g. DAHC server) and software programs that reside with the regulators have also been developed by the Technical Committee, they are beyond the scope of this document.

Figure 3 below provides an illustration of how these hardware and software components combine to form the complete PM CEMS monitoring system.

Figure 3: Diagrammatic Representation of the PM CEMS Monitoring System



2.1 PM CEMS Device Options

Several PM CEMS measurement technologies are available through a number of equipment vendors, and this section provides general guidance on the selection and use of PM CEMS for the measurement of particulate matter mass flow in stationary sources (stacks). It is intended to ensure the reliability and accuracy of emissions data generated by an industry with a PM CEMS installation.

Acceptable Types of PM CEMS Technology Configurations for ETS

Acceptable technology configurations for meeting the PM mass flow rate continuous monitoring standards can be broadly divided into two categories: 1) mass flow based and 2) mass concentration based. Concentration based CEMS can be further divided into two configurations with and without volumetric flow meters installed. For the purpose of this pilot emissions trading program, concentration based technology without a volumetric flow meter is not valid. Without a flow meter, unrealistic assumptions must be made to estimate PM load, undermining the pursuit of high data quality. The diagram below illustrates the different CEMS configuration types.

Figure 4: Types of Technology Configurations

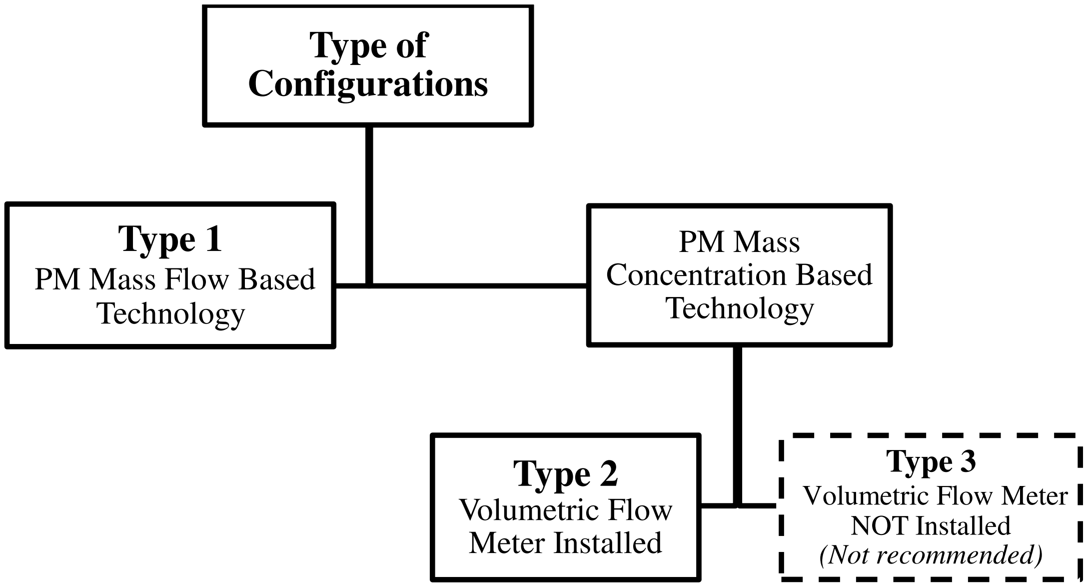


Table 1: Technology Configuration Characteristics

	Technology	Description	Calibration detail	Final Measurement
Type 1	**PM Mass Flow Based Technology**	Consists of a PM CEMS device that directly measures PM mass flow (e.g. triboelectric probe)	CEMS device is calibrated for PM mass flow using iso-kinetic sampling	Provides mass flow data directly.
Type 2	**PM Mass Concentration Based Technology with Volumetric Flow Meter**	Consists of a PM CEMS device that measures mass concentration and a separate flow meter that measures volumetric flow of the flue gas. Examples of mass concentration based CEMS devices are opacity meters and light-scattering devices	Each device must be calibrated separately.	Multiplication of readings from PM CEMS device and volumetric flow meter; Performance tests for the initial calibration, re-calibration and CEMS Audits will be conducted on CEMS device output
Type 3 (Not recommended)	**PM Mass Concentration Based Technology without Volumetric Flow Meter**	This configuration consists of a PM CEMS device that measures PM mass concentration only, and volumetric flow is assumed to be constant and equal to the maximum of: (i) the volume measured during calibration; (ii) the volume measured during the time of calibration or CEMS Audit; or (iii) the volume corresponding to the maximum ID fan output. However, this configuration is not generally valid for ETS because the assumptions made for substituting volumetric flow are unrepresentative and undermine data quality.		

Selection of PM CEMS Device

The first step for adopting CEMS is to select a device (or combination of devices if flow meter is required) optimally suitable for the stack characteristics at the industry. Important considerations include stack diameter, flue gas temperature, and air pollution control devices (APCDs) installed, among others.[2] In parallel, industries will also need to select a CEMS vendor from which to purchase the equipment, subject to the vendor and any devices purchased meeting all requirements as outlined in these guidelines.

The tables that follow are intended as *guidance* to industry to help select an appropriate CEMS technology and flow meter if necessary. However, regardless of technology choice, all CEMS devices must be calibrated and pass the performance tests described in Section 4 and Appendix D. Accordingly industry should select technologies after site examination by CEMS suppliers who may then undertake to guarantee that instruments will clear these performance criteria.

Calculating Total PM Load

Total PM load is calculated by the summation of continuous PM mass flow measurements over a specified compliance period. PM Mass flow values will vary for the different technology configurations (as explained in the table above), because individual mass flow measurements deviate slightly from true emissions (manual sampling). In the long run, these deviations will not affect total PM load (summed) since the average value of the difference between CEMS readings and true emissions (random noise remaining in a properly calibrated setup) would converge toward zero over the length of the compliance period. It is this characteristic of CEMS which serves to heighten data accuracy and support the emissions trading program with reliable emissions estimates.

[2] An overview of the selection process for both PM CEMS and flow meters is found in Appendix A.

Table 2: Stack Characteristics Matrix: PM CEMS Technology

Parameter	DC Tribo Mass Flow Monitor	AC Tribo Mass Concentration Monitor	Electrodynamic	Light Scatter Technology	Opacity Monitor	Wet Extractive Technology
Measured Value	Direct in g/s, kg/hr	mg/m^3	mg/m^3	mg/m^3	mg/m^3	mg/m^3
Velocity Monitor Required	X	✓	✓	✓	✓	✓
Duct < 1m Diameter	✓	✓	✓	✓	X	✓*
Duct >1m to 4m Diameter	✓	✓	✓	✓	✓	✓*
Duct > 4m Diameter	X	X	X	X	✓	✓*
Electrostatic Precipitator	X	X	X	✓	✓	✓
Stack Gas Temperature > 500°C	✓***	✓***	✓***	✓	✓	✓
Wet Scrubber with Stack Temperature <70°C or water condensate present	X	X	X	X	X	✓
Large particles> 20um	✓	✓	✓	X	✓	X
Dust> 100 mg/m^3	✓	✓	✓	✓****	✓	X
Varying gas velocity	✓^	X	✓	✓	✓	✓**

* Although this technology will work on any duct diameter, the size of the sampling nozzle diameter in relation to the duct diameter means that the sample is very unlikely to be representative of the particle size distribution of the whole area. This technology is only used where others cannot be used, primarily wet stacks.

** This technology is only appropriate in slowly varying velocity conditions

*** At high temperatures only specially designed instruments such as ceramic body probes will be suitable

**** Scatter light principle can measure readings up to 300 mg/m^3

^ Requires a monitor with mass response that is velocity independent within the range of stack velocity. Recommended for settings with limited velocity variation.

It is crucial to note that only quantitative CEMS designed to measure emissions are recommended for the ETS program, and qualitative / indicative technologies—such as Broken Bag Detectors—cannot be used as a substitute.

Table 3: Stack Characteristics Matrix: Flow Measurement Technology

Type	Impact Differential Pressure (Pitot Tube)		Thermal anemometer [1]	Bi-directional ultrasonic	Infrared correlation
	Single point	Multiport			
Irregular Flow	X	✓	✓[2]	✓[2]	✓
Max Flue Gas Temperature	Up to 550°C	Up to 550°C	200 – 300°C (model specific)	450° C - 850 °C (model specific)	Up to 1000°C
Wet stack	X	X	X	✓	✓
Low speed	X (minimum 5 m/s)		✓	✓	1 m/s – 50m/s
High Speed	✓	✓	✓	Up to 40 m/s (model specific)	1 m/s – 50m/s
Calibration	Factory / Site	Factory / Site	Factory / Site [3]	Factory / Site	Factory / Site

1 Pressure Transmitter (PT) and Temperature Transmitter (TT) are not installed with a Thermal Anemometer as it directly measures Mass Flow which is usually the required quantity. However, for the purpose of ETS in Type 2 CEMS configuration, Volumetric Flow is required and hence PT and TT are necessary to calculate density and convert mass flow calculated by the anemometer to volumetric flow.

2 Can be accounted for by using multiple probes/sensors

3 Calibration depends on physical properties (thermal conductivity, specific heat) of the gas whose flow is to be measured. Thus variation in properties of stack gas from factory calibrated values can result in inaccurate measurement.

2.2 PM CEMS Device Requirements

Beyond simply conforming to one of the configuration types, a further set of CEMS requirements is laid out to provide a final safeguard for data quality. These can be broadly categorized as hardware requirements and performance requirements.

PM CEMS Device Hardware Requirements

Once the particular configuration of the CEMS device is selected, following additional four requirements must be met:

a) The device should ideally measure and report both the **calibrated and uncalibrated** data to the DAS, if possible. The calibration equation will be applied later by the DAS to uncalibrated values. For devices which cannot send uncalibrated data, the device should register a calibration factor of ‘1’ and the calibration settings should be password protected.

b) PM CEMS device and flow-meter should be tamper-proof as far as possible.

c) The selected CEMS device (hardware) and flow meter must meet following specifications of key operating parameters such as: physical deviation in measurement, response time, minimum detection limit (for flow meters), security measures to prevent unauthorized maladjustment, and inclusion of diagnostic flags. The following table specifies the key operating parameters and their values to which CEMS devices and flow meters must conform. In addition, regardless of technology choice, all CEMS installations must pass the independent performance standards detailed in this document.

Table 4: Hardware Requirements - Key Operating Parameters

Name of Parameter	Specifications	
	PM CEMS Device	**Flow Meter**
Measurement range	User defined	User Defined
Instrument detectable concentration	10 mg/Nm^3 or less	1 m/s (minimum detectable limit)
Data acquisition	1 minute	1 minute
Data transmission	1 minute	1 minute
Deviation in the raw reading	< 5% of measurement range	<2% of measurement range
Drift	< 1% per month	Overall zero & span drift should be < 1% per month
Power supply	220 +/- 10 V at 50 Hz	
Data Availability	90% or higher under normal operation	90% or higher under normal operation
CEMS Hardware Certification: The PM CEMS device and flow meter should also have test results / certification / conformance from an accredited agency or a recognized standard viz US EPA PS-11, MCERTS or TUV covering basic operational and technical principles.[3]		

In addition to the above it is strongly recommended that automatic zero and span check facility be present in the CEMS hardware device. In the absence of such, it is required to carry out these checks on a weekly basis to ensure instrument performance.

PM CEMS Device Performance Standard

Once the hardware is finalized, the remaining safeguard for data quality is a performance standard all installed PM CEMS devices must meet. As opposed to physical device characteristics, the performance standard is a statistical test aimed at ensuring that calibrated emissions readings measured by the CEMS device are as close as possible to the true value.

The performance standard first involves passing a rigorous Performance Test after the device is calibrated (called the Post-Calibration Performance Test). This test acknowledges that

[3] At present US EPA has no device-specific certification for PM CEMS. However instrument manufacturers can declare conformance against the PS-11 standard.

initial calibration is done sufficiently well, but, it does not exempt the industry from the requirement to carry out periodic quality control tests. Another post-calibration test must be carried out during the CEMS audit, required at least once per year, and CEMS re-calibration which must occur at least once every six months and under conditions defined in the PM ETS standard operating procedures. These tests compare readings from the calibrated CEMS device to manual samples taken during the same time period to ensure the CEMS readings are within an acceptable range of the standard reference method (iso-kinetic stack sampling). Only if the device passes the post-calibration test(s) can it be deemed in compliance with ETS requirements. If the device accuracy is not in line with the performance standard, it must be re-calibrated and then tested again.

Details behind these calibration procedures and performance tests follow in Section 4 of this document under CEMS operating procedures.

2.3 Data Acquisition and Handling System (DAHS)

The Data Acquisition and Handling System (DAHS) comprises of software and hardware components that are designed to ensure the integrity of emissions data by providing a continuous record for supporting industry operations and regulatory reporting. The DAHS is responsible for collecting data, converting it into a common format, storing it, validating it, and performing post-validation activities such as report generation and analytics.

Note that although CEMS devices are designed to generate and store continuous emissions data, it is not a necessary requirement to have continuous reporting (real-time data transfer to DAHC Server at the regulatory agency) in a load-based ETS regime. For a scheme based on mass emissions caps, a cumulative account of mass emissions is required to reconcile permit holdings after the compliance period, but this can be done by summing up emissions data which is not necessarily continuous. As long as continuous data is being collected and stored on-site by the DAHS, data can technically be reported over larger intervals, subject to rigorous verification (in the U.S. Acid Rain Program, emissions are reported quarterly).

However, given the limited experience with PM CEMS devices in India, especially for measurement of particulate mass load, it is important to receive data more frequently in order to identify and address potential issues such as missing data, out of range data, outliers, etc. Thus, for the pilot ETS in India, the DAHS will transfer data on a continuous basis to DAHC Servers (at SPCB and CPCB offices).

DAHS Architecture

The proposed DAHS architecture forms a well-defined network of data collection and transfer which together protects data quality and provides a record of accurate data to support the pilot scheme. In the proposed system, the PM CEMS device sends emissions data to the CEMS Vendor Software which is installed on the DAS. Among other parameters, the CEMS device will send raw emissions measurements (uncalibrated data), diagnostics parameters such as the status and health of the instrument (called diagnostic flags), flow measurement reading, and temperature measurement reading.[4] Upon accepting emissions data from the CEMS device,

[4] Further details on parameters are outlined in Appendix C

the CEMS Vendor Software immediately converts it into the prescribed format, after which the ETS Bridge Software reads the data, stores it locally, and sends it to the SPCB and CPCB server where it is validated and analysed.

The PM CEMS device should ideally measure and report both calibrated and uncalibrated data to the DAS if possible. The CEMS Vendor Software will then apply the calibration factor and send the calibrated data to the SPCB server via the ETS Bridge Software. In the event that the CEMS device is not able to send uncalibrated data, the device should input the calibration factor as '1' and be password protected.

The hardware and software elements that form the full DAHS architecture are listed in Table 5, and descriptions of these components follow.

Table 5: DAHS Components

S.No.	Component
1.	**PM CEMS Device installed at industry**
2.	**Data Acquisition System (DAS) setup at the industry site**
2.1	CEMS Vendor Software will be installed in the DAS
2.2.	ETS Bridge Software will be installed in the DAS
3.	**Data Acquisition and Handling Centre (DAHC) located at Central and State Pollution Control Boards (CPCB and SPCBs)**
3.1	DAHC Server Software (DSS) will be installed on the Server at DAHC.
4.	**Access Points (e.g. web portals) from which the CEMS data can be viewed and analysed with various features by different users and stakeholders.**

From the starting point of the PM CEMS device installed on an industry stack, where emissions data are acquired, they are then handled by the following hardware and software components of the DAHS:

a) Data Acquisition System

The Data Acquisition System (DAS) is a PC on which a vendor-designed CEMS Vendor Software (CVS) and an application called the ETS Bridge Software (EBS) have been installed. The former is designed to accept incoming data from the CEMS device, convert it into a standard format, and store it in a defined folder, while the latter is designed to read the data converted in the standard format and send it to the SPCB server. A reliable and fast internet connection is required so that the ETS Bridge Software can send data to the server continuously. Data from the PM CEMS device should be sent directly to the DAS and can be concurrently sent to a distributed control system (DCS) of the industry.

b) CEMS Vendor Software

CEMS Vendor Software is the software provided by the vendor (or third party software firm) to capture the data from the CEMS device and further communicate with the ETS Bridge Software on a file-based protocol to send the data.[5] Each CEMS vendor participating in the pilot ETS project must incorporate this interface into their CEMS software package and pass the System Integration Test to ensure compatibility with ETS Bridge Software.[6] This software can be bought off the shelf or can be outsourced to another IT firm, but it has to be compatible with ETS Bridge software interface and must pass the System Integration Test.

c) <u>ETS Bridge Software</u>

ETS Bridge Software is a standalone application that will reside on the DAS at each industry. This software has a standard interface for receiving real-time data from (or communicating with) the CVS residing on the same machine. It will thus, collect measurement data of collected by CVS from the CEMS Device and further send it to the DAHC Server at the concerned SPCB (and to CPCB server in a parallel) in a secure and reliable manner. It also stores this data locally for a user-specified period.

d) <u>Data Acquisition and Handling Centre</u>

Each SPCB and the CPCB have a DAHC which is where emissions data from industry-installed CEMS are sent. Once received, a number of regulatory functions can be performed, including data validation, analysis, report generation, etc.

e) <u>Access Points</u>

Access points such as web portals linked to the DAHC Server Software will allow different stakeholders to access various functionalities of the software. Different levels of access are set for industry, regulator, and vendors as and when required.

Software Requirements

The PM CEMS device must be equipped with software, either designed by the CEMS vendor or by a third party software firm, which has successfully completed the System Integration Test to ensure compatibility with the ETS Bridge Software. Responsibility for passing the System Integration test rests with each CEMS Vendor or software firm, as applicable. The CEMS Vendor software must also be password protected.

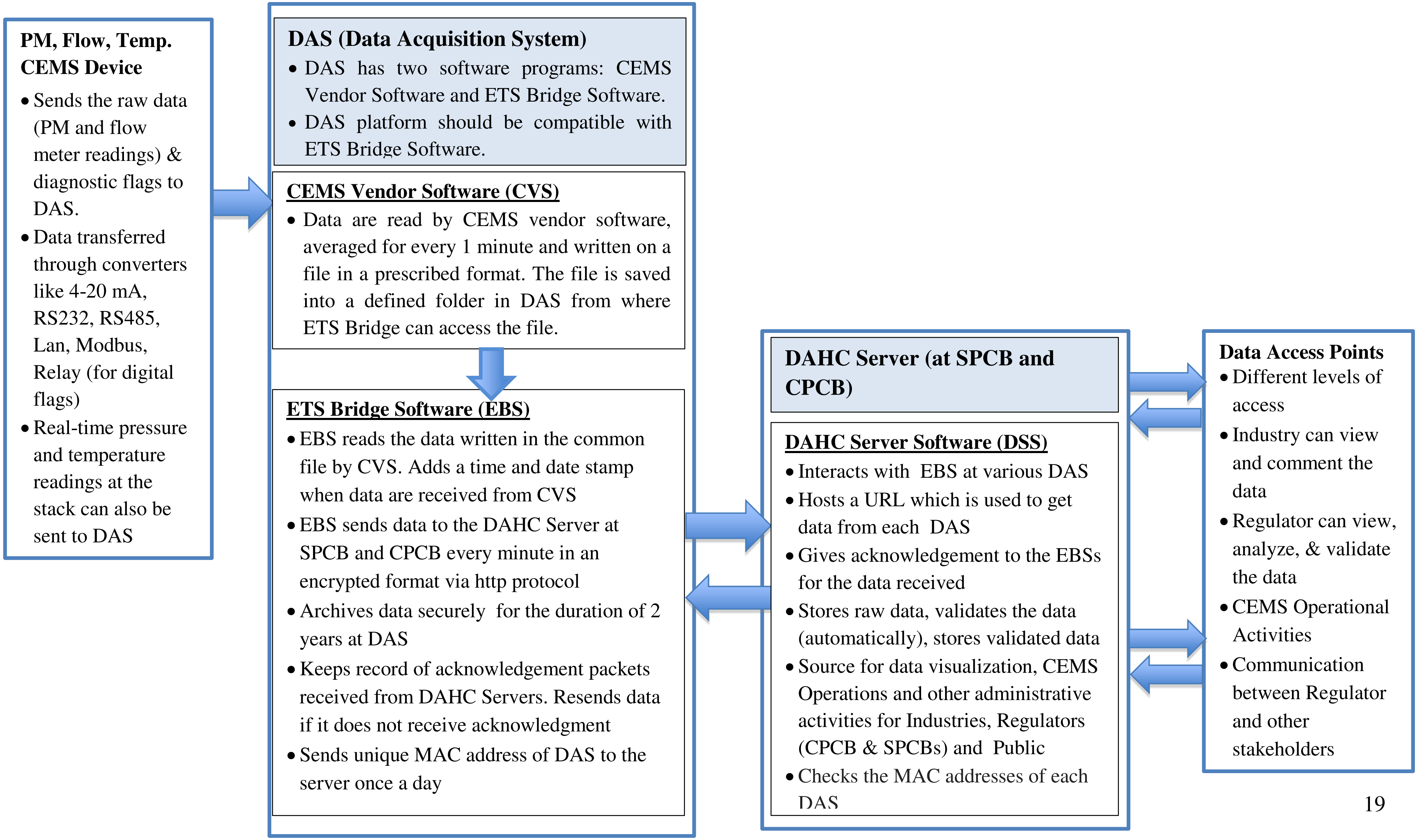
Additionally, the industry must download and install the ETS Bridge Software, which will be made available free of charge, for data transfer to the SPCB and CPCB server. An overview of the types of data transmitted by the DAHS is outlined in Table 6 below, and Figure 5 that follows summarizes the components and functions of the DAHS.

[5] Further details on the ETS Bridge Interface are found in Appendix F
[6] The procedure for the System Integration Test is detailed in Appendix F

Table 6: Overview of Data Categories Handled by DAHS

S.no.	Variable	Name	Source/Access Level
1.0	**Administrative Data**		
1.1	Industry Details (Industry registration form)		Manual data collection at SPCB
1.2	CEMS Registration Form		Accessible by Industry
1.3	CEMS Installation Checklist		
1.4	CEMS Functional Checklist		
1.5	Isokinetic Sampling Reporting Form		
1.6	Comments on validated data		
1.7	Administrative action (accept or reject) of Industry comments on validated data		Accessible by Regulator
2	**Configuration Data**		
2.0	Type of Pollutant	ToP	Accessible by Industry
2.1	Type of Configuration	ToC	
2.2	Comp. ID	CompID	Calculated by the DSS
2.3	Stack Dimension	Type of stack Length/Breadth Dia	Accessible by Industry
3	**Calibration Data**		
3.1	Average Pressure during Sampling	Pres_smpl	1) Accessible by Industry 2) Calculated by the DSS
3.2	Average temp. during sampling	Temp_smpl	
3.3	Calibration factor (m)	CF_m	
3.4	Calibration factor (c)	CF_c	
4	**Measurement Data**		
4.01	Date and Time Stamp	DTS	1) CEMS Vendor Device 2) CVS 3) EBS
4.02	Pressure at stack	Pres	
4.03	Temp. at stack	Temp	
4.04	PM CEMS raw Uncalibrated average	PM_uncal	
4.05	PM CEMS Calibrated average	PM_cal	
4.06	Velocity	Velocity	
4.07	Normalized Flow	N_flow	
4.08	PM mass	PM_mass	
4.09	Mode of the PM CEMS device	PM_DM	
4.10	Power Status of PM CEMS device	PM_PS	
4.11	Alarm of PM CEMS device	PM_Alrm	
4.12	Maintenance Alarm of PM CEMS device	PM_M_Alrm	
4.13	Mode of the flow-meter	F_DM	
4.14	Power Status of flow-meter	F_PS	
4.15	Alarm of flow-meter	F_Alrm	
4.16	Maintenance Alarm of flow-meter	F_M_Alrm	

Figure 5: Schematic of DAHS Data Flow and Activities



3. KEY STAKEHOLDERS, ROLES, AND RESPONSIBILITIES

A number of different parties are involved in implementing a monitoring regime built around a continuous emissions monitoring system. The most important roles are those of regulated industry and the state pollution control board (SPCB). It is the responsibility of regulated industry to comply with the specifications outlined in this and other applicable documents; and to ensure that high quality and reliable data is transmitted to the state board. Conversely it is the responsibility of the SPCBs to oversee the monitoring regime, clearly outline expectations from all parties, and implement the regulatory framework that uses the PM CEMS information. Other parties such as accredited labs, CEMS vendors and CEMS working groups in each industry cluster play essential support roles.

3.1 Central Pollution Control Board

The CPCB is the apex statutory organization for prevention and control of pollution and the R&D wing of MoEF. The organization is responsible for setting the overall standards at the national level including their revisions from time to time. They also play the responsible role for framework working of associated regulations and its modifications as and when necessary, as has been taken up for emission trading in this case.

3.2 State Pollution Control Boards

The SPCBs are the implementing agency for various prevention and control of pollution Acts and regulations notified from time to time at respective state levels. In this case the concerned SPCBs have been made responsible for implementation of the CEMS monitoring regime and any other associated regulatory framework such as emissions trading. In order to utilize PM CEMS data effectively it is necessary that the SPCBs provide information to the industries on how such data is to be generated and transmitted (the purpose of this document) and informs them about the applicable penalties in case of non-compliance. In order to oversee a network of stationary sources equipped with PM CEMS device, SPCBs have to be equipped with:

- Necessary infrastructure to receive and utilize real time emissions data
- Trained staff capable of interpreting and analysing this information
- CEMS field teams to conduct random back-checks on PM CEMS installations in regulated units
- CEMS field teams to evaluate installed PM CEMS in cases where transmitted data is unsatisfactory

3.3 Regulated Industries

It is the responsibility of regulated industry to comply with mandates to install PM CEMS device where applicable and follow the specifications outlined for the same. It is the responsibility of the industry to make sure that CEMS device passes the post-calibration tests (performance tests). Because ultimate responsibility for compliance lies with industry, it is strongly recommended that they specify terms of technical support, data quality expectations, maintenance and availability of spares, and delivery and installation timelines when placing the orders with vendors. Industry may also choose to sign annual maintenance contracts and other on-going quality control measures with vendors to ensure their PM CEMS devices remain reliable and accurate[7].

3.4 Local Industry Associations and CEMS Working Groups

A switch to continuous emission monitoring and its application to regulatory frameworks such as emission trading can bring many advantages to industry, regulators and the public. However there is also a learning curve involved. Industry associations can play a critical role at the cluster and national level in providing information and guidance to regulated units, liaising between regulators, industries and CEMS.

Additionally, CEMS working groups may be set up in each regulated cluster to provide additional support to industries in the regular maintenance of PM CEMS device installations. These groups may also provide local expertise on calibration methods and protocols. If determined by the appropriate pollution control board these working groups may also be accredited to undertake some or all of the calibration and Performance Testing required by this specification.

3.5 Accredited Labs

Labs currently accredited to perform manual stack sampling for PM measurement have an important role to play in providing the independent technical expertise necessary to implement the specifications outlined in this document.

3.6 CEMS Vendors

Vendors of PM CEMS technology are primarily responsible for producing and supplying analysers. Vendors are also responsible for provision of spare parts, warranty covered repairs, and ongoing maintenance and cleaning in cases where an Annual Maintenance Contract is signed. For this reason it is important for all PM CEMS vendors, especially those providing analysers to industry participating in the pilot particulate ETS, to ensure sufficient availability of spare parts and technically trained personnel.

Only CEMS Vendor Software which passes the System Integration Test will be approved to send data to the ETS Bridge Software, and thus participate in ETS.[8] For the most part ETS Compatible CEMS Vendor Software can be provided to the industry by CEMS vendors themselves; however independent software firms may also be contracted.

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[7] Details of the guidelines on preventive maintenance are in Appendix B

[8] Details of the System Integration Test are outlined in Appendix G

4. PM CEMS STANDARD OPERATING PROCEDURES

To outline the PM CEMS monitoring framework operational requirements, this section details the full sequence of steps involved in setting up the PM CEMS device at an industry site. These steps are split into several categories of activities:

1) PM CEMS device Installation, Registration and Configuration
2) Parallel Measurements by Standard Reference Method
3) Calibration and Post-Calibration Performance Test
4) CEMS Audit and CEMS Audit Performance Test, with Recalibration if required

The flow charts below show the general interaction of different stakeholders involved in the pilot ETS program and the detailed process of work flow among them, through which data quality from CEMS is maintained at the highest level.

Figure 6: Overview of CEMS Operations and Responsibilities

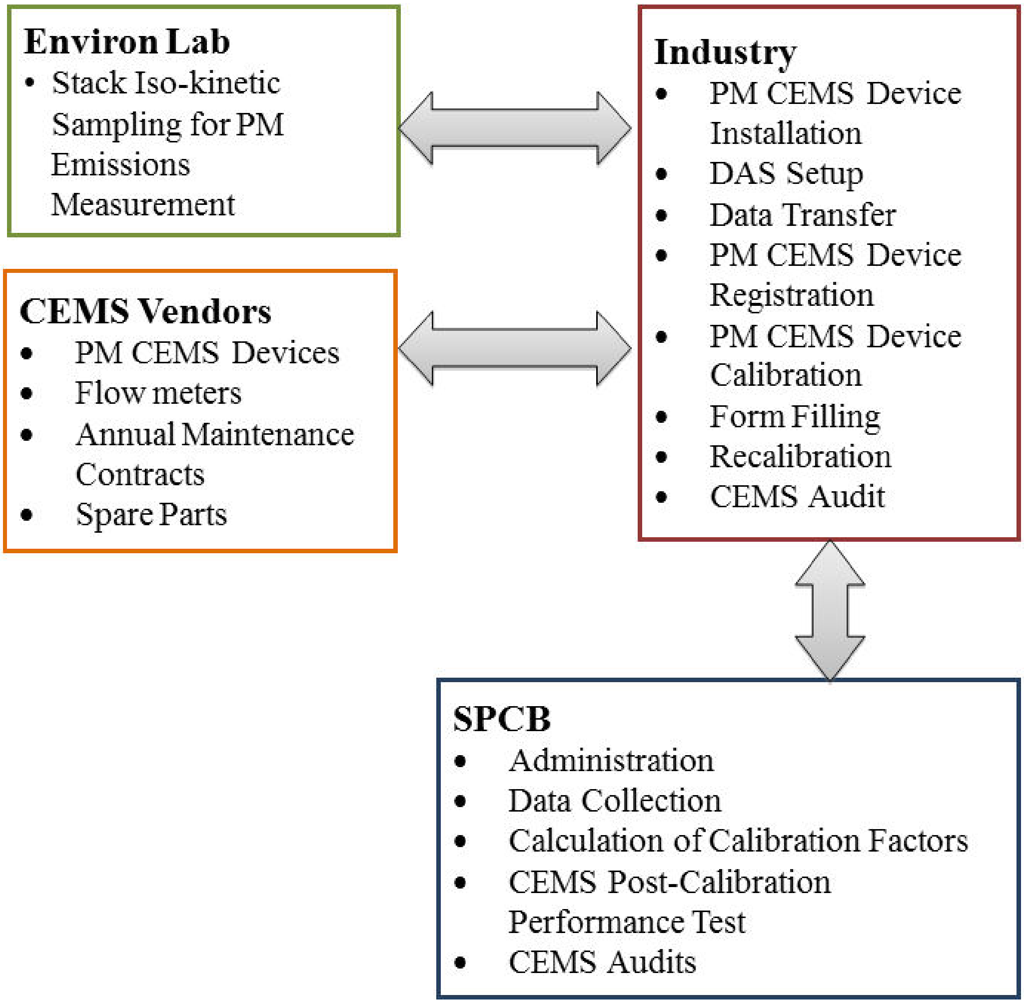

Figure 7: CEMS Operational Flow Details

Accredited Lab

PM CEMS Post-Calibration Performance Test

Conducts iso-kinetic sampling.

Submits the reports in the standard format to the industry.

External Factors Triggering Re-Calibration

Change in Process, Fuel, APCD or the PM CEMS Device

PM CEMS operating outside Valid Calibration Range

Failure in CEMS Audit

Industry

PM CEMS: Installation, Registration and Configuration

PM CEMS device installation and DAS setup.

Registration of PM CEMS Device in DAHC (SPCB).

Getting Configuration and Composite ID from DAHC (SPCB)

Installing ETS-Compatible CEMS Vendor Software.

Submission of Installation and Functional Test Checklists to DAHC (SPCB)

System ready for Calibration

PM CEMS Post-Calibration Performance Test

Asks accredited labs to conduct so-kinetic sampling as per the protocol.

Submits the results to the SPCB via DAHC Server Software.

Gets reports from the DAHC Server Software on the PM CEMS Calibration and Post-Calibration Performance Test

Test Passed	**Test Failed**
If Post-Calibration Performance Test passed, feeds the Calibration factors and other details to CEMS Vendor Software	Go for Recertification

PM CEMS Re-Calibration Performance Test

Asks accredited labs to conduct iso-kinetic sampling as per the protocol. Submits results to the SPCB via ETS Bridge Software. Gets reports from SPCB Server on the Post-Calibration Performance Test

SPCB

PM CEMS: Installation, Setup and Configuration

Checks PM CEMS registration data and sends the approval to industry.

Sends the Unique Composite ID (for each stack) and other configurations to the industry.

Accepts the Self-Attested Installation and Functional Test Checklist from industry

PM CEMS Post-Calibration Performance Test

Accepts the iso-kinetic reports from industry.

Does Post-Calibration Performance Test.

Calculates & reports the Calibration Factors and Valid Calibration Range.

4.1 PM CEMS Installation, Registration and Configuration

The first activity to be performed after selection of the most appropriate vendor and technology is setting up the PM CEMS device. Following installation of the CEMS device and flow meter (if applicable), a number of steps must be taken to ensure the device(s) meet the hardware and software requirements of this monitoring protocol.

These steps include:

- Setup of the Data Acquisition System (DAS), which consists of a PC with an internet connection, ETS compatible CEMS Vendor Software (which has passed the System Integration Test), and installation of the freely downloadable ETS Bridge Software. [9]
- Registration and configuration of the CEMS device
- Installation and functional test checklists

Following these steps, the SPCB will indicate whether the industry can proceed to calibration of the device and the test each CEMS device must pass to be in compliance with ETS performance standards.

4.2. Parallel Measurement by Standard Reference Method

The SRM (Standard Reference Method) for measuring and calibrating PM emissions is through iso-kinetic sampling. CPCB and EPA have both developed guidelines for effective PM sampling from stationary sources (stacks). The approved methods for PM iso-kinetic sampling are:

- CPCB Publications: Emission Regulation Part III and “Guidelines on Methodologies for Source Emission Monitoring” (2013)
- US EPA Method 17
- US EPA Method 5

Labs should submit to industry the detailed sampling sheet to document key measurements during the sampling process.

A SRM shall be used to sample the emissions at a sampling plane in the duct, which is close to the CEMS, such that the presence of the equipment specified in the SRM shall not significantly influence or disturb the CEMS measurements. The sampling time for each of the parallel measurements shall be 30 min or 1 hour. If the average level of particulates is lower than 10mg/m^3 in concentration, the sampling time must be 1 hour. Each of the sampling pairs: 1) CEMS device output (averaged over the measurement period) and 2) SRM value, must cover the same time period.

[9] Details of the System Integration Test are found in Appendix G; details on the ETS Bridge software interface are found in Appendix F.

Only labs with the following credentials are authorised to conduct iso-kinetic sampling for calibration of the CEMS device:

1. NABL certified lab
2. MoEF accredited EIA lab
3. Labs otherwise approved by CPCB/ SPCB

4.3. Calibration and Post-Calibration Performance Test

The PM CEMS device is ready for calibration only after performing all of the required installation, registration, and configuration steps. In order to verify that the CEMS calibration meets the minimum performance requirements, it must undergo the Post-Calibration Performance Test. The same iso-kinetic samples used for calibration are used for the CEMS Post-Calibration Performance Test. Software at the DAHC Server (SPCB) performs the Post-Calibration Performance Test and informs the industry if it passes or fails.

Details of CEMS calibration, including calculations required and pass/fail criteria are provided in Appendix E for the reference of vendors and industry. Here we summarize the basic concepts involved.

CEMS Calibration for ETS

The calibration procedure involves regressing CEMS readings against manual sample measurements and estimating a linear equation of a line through the points. The line would take the form of $y = mx + c + \hat{e}$ where the Standard Reference Method (SRM) and CEMS readings are on the y and x axes respectively. ê is a measure of how far each point is from the estimated line and is randomly distributed.

The post calibration relationship between PM CEMS calibrated readings can be described by the equation $\hat{y} = mx + c + e$, where x is the un-calibrated CEMS reading and $\hat{y}$ is the estimated post-calibration CEMS reading. Here, **m** and **c** are estimated calibration parameters whose values are equal to the slope and intercept of the estimated line relating CEMS readings to gravimetric sampling values. **e** represents residual instantaneous noise after applying the calibration equation. For applications such as an emissions trading scheme, where the relevant requirement involves using the PM CEMS device to measure *total mass emitted* and not concentration at any instant of time it is necessary to use estimates of either average concentration over the period T (which would need to be multiplied by average flow) or average mass flow rate (multiplied by the length of time T).

The performance standard and calibration protocol is intended to assure that CEMS estimates for total emissions load over a compliance period (typically 12 months) in the pilot ETS should be extremely reliable. For a well-calibrated CEMS (where the relationship between CEMS readings and true emissions is linear within the calibration range), the sum of these random errors would be expected to average out to zero, over a 3-month to 12-month of compliance period, allowing precise estimates of total emissions load for trading.

$$\bar{\hat{y}} - \bar{y} = \left(\frac{\sum_t \hat{y}_t}{T} - \frac{\sum_t y_t}{T}\right) = \frac{\sum_t (e_t)}{T} = 0$$

$$\bar{\hat{y}} = \bar{y}$$

Thus, Long term average of the CEMS estimated load = long term average of true load

As is evident, the long term average of the difference between calibrated CEMS readings and the true value will converge to its mean, i.e. 0, when the calibration is carried out using the prescribed method of a linear fit between SRM and CEMS readings. It is this long term average that is of interest when determining accuracy of the PM CEMS device as a monitoring technology to underpin the pilot emissions trading scheme for particulate matter. For more on statistical inference in environmental monitoring see Watson and Downing (1976), Bertheoux and Brown (2002), Gilbert (1987), Guttorp (2006), Barnett and O'Hagan (1997) and Kinney and Thurston (1993).[10]

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[10] Appendix E provides further detail on the necessary background calculations

Figure 8: Calibration and Post-Calibration Performance Test Overview

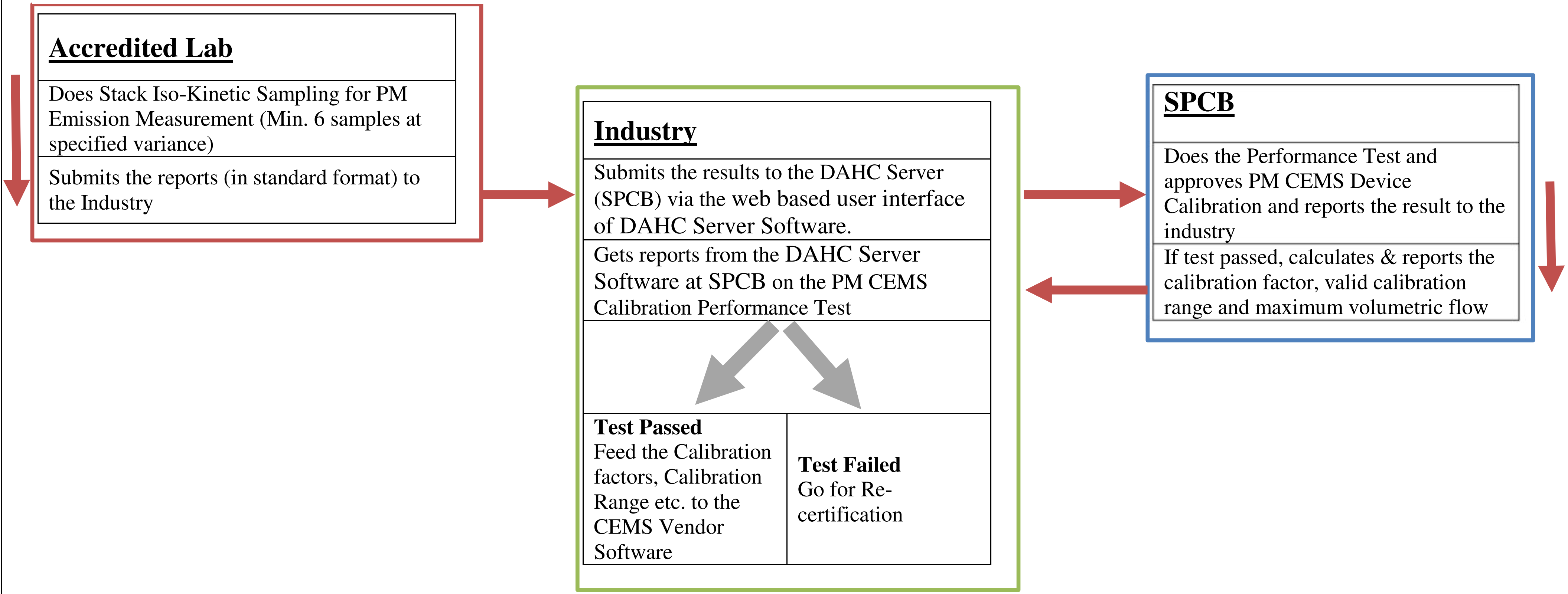

Table 7: Calibration and Post-Calibration Performance Test Steps

Step 1	PM emission measurement samples are taken according to Standard Reference Method for iso-kinetic sampling
Step 2	PM Samples are taken at different load conditions and emissions levels to ensure the calibrated CEMS device readings are valid under different operating conditions, as described in the section that follows. During iso-kinetic sampling for calibration, data availability from CEMS device should be at least 95%, otherwise the sample is considered invalid.
Step 3	Accredited labs fill the results of the iso-kinetic sampling along with other details in the sampling form provided give to the industry operator.[11]
Step 4	Industry submits relevant details from the sampling form to the DAHC Server at SPCB via the web based user interface of DAHC Server Software. Details asked are: a. Iso-kinetic sampling results b. Start and End time of the sampling c. Iso-kineticity d. Other standard parameters such as temperature, etc. In addition to the data availability requirement stated in Step 2, the sample will be considered invalid if either of the conditions below are not met: 1) Iso-kineticity of the sampling should be in the range of 0.9-1.1 2) Volumetric flow measured during iso-kinetic sampling is in ± 20% of the average flow meter reading during sampling [Note: Industry should keep the original copy of the Sampling Report submitted by the accredited lab along with the field data details for records.]
Step 5	Once the DAHC Server at SPCB receives the sampling results electronically, the DAHC Server Software performs the Post-Calibration Performance Test and calculates the factors. The DAHC Server Software then notifies the industry of the Calibration Factors, Valid Calibration range and maximum volumetric flow.[12]
Step 6	If the Post-Calibration Performance Test is passed, the industry feeds the calibration factors in the ETS-Compatible Vendor CEMS Software and starts sending the data.
Step 7	If the Post-Calibration Performance Test is failed, the industry must re-calibrate the device.

[11] Sample forms are available in Appendix D
[12] Detailed background calculations are included in Appendix E

Required Variation in PM Emissions level during Calibration

To ensure that the calibrated CEMS readings are valid under differing operational conditions, PM emissions should be varied as much as possible (by changing load or the operating conditions of the APCD or both) within the normal operations of the plant during calibration.

The failure to vary the range of conditions adequately will result in a narrower Valid Calibration Range, which defines the range of data that is considered valid by the SPCB. The Valid Calibration Range is calculated as the range from zero to 120% of the maximum mass flow that occurred during the Post-Calibration Performance Test.

The number of PM samples required will depend on whether a given industry has the ability to vary emission levels through means such as variation of load, feed rate, turning off ESP cells, or other methods. For taking parallel measurements at near zero load, either the emission source should be shut down, or otherwise the device can be operated outside the stack (no need to do isokinetic sampling in this case).

The industry is recommended to obtain a minimum of 9 measurements for calibration with variation in the emission levels as follows (7 isokinetic samples excluding 0 load):

- 2 point at zero load (no load)
- 4 points in the 75-100% emission range
- 3 points in the 25-75% emission range

However in situations where above mentioned scenario is not possible or very difficult, 6 measurements as per the following load variation will suffice (4 isokinetic samples excluding 0 load):

- 2 point at zero load (no load)
- 4 points at 75% - 100% emission range

Post-Calibration Performance Test

The post calibration performance test is a measure of the average deviation (expressed as a Root Mean Square Percentage Error) between estimated mass flow rate or concentration based on the CEMS calibration equation and isokinetic values. The CEMS calibration equation is derived using the best linear fit between CEMS raw readings and isokinetic readings. Appendix D details how to calculate the CEMS calibration equation using ordinary least squares as well as the average RMSPE. A calibration test is failed when the RMSPE is greater than 30%.

Frequency of Calibration of PM CEMS Device

Calibration of the PM CEMS device must be performed every 6 months. The frequency of calibration will be reviewed based on data-observation vis-à-vis cross verification/actual physical monitoring / deviations within the acceptable limits.

4.4. CEMS Audit and CEMS Audit Performance Test

To protect the integrity of emissions data underpinning the pilot emissions trading program, the PM CEMS Device requires ongoing maintenance and quality control.

For this pilot, **a CEMS Audit must be performed at least once in a year.**

Table 8: CEMS Audit Steps

Step 1	**Functional Test Checklist**[13]**:** CEMS vendor performs functional test and submits checklist to industry operator. The components of the functional test are: a. Visual inspection b. Leak testing c. Zero and span check d. Serviceability
Step 2	Industry enters functional test checklist information into corresponding form on the web based user interface of DAHC Server Software and submits it to the DAHC Server at SPCB. Staff from SPCB will review the checklist and send confirmation to industry.
Step 3	**Iso-kinetic Sampling:** Environmental lab will take 4-6 iso-kinetic samples following Standard Reference Method procedures
Step 4	**CEMS Audit Performance Test:** Using the same calibration equation derived for the initial calibration and Post-Calibration Performance Test, the CEMS Audit Performance Test is performed using the iso-kinetic sampling data as the standard reference method for at least 4 samples points at different load conditions. After industry submits the iso-kinetic sampling data to SPCB using the ETS Bridge Software, the DAHC Server Software does the CEMS Audit Performance Test and informs the industry. In case an instrument fails the CEMS Audit Performance Test, the industry has to recalibrate the device with sample points at different load conditions. If an instrument passes the test, 4 points used for doing the CEMS Audit Performance Test can be used for the purpose of calibration.[14] The CEMS Audit performance test is based on a criterion similar to the post-calibration test i.e. it is an RMSPE test.

4.5 Re-calibration of CEMS Device

Re-calibration of CEMS is required whenever the device begins to show high deviations, potentially due to changes in external or internal factors. The re-calibration guidelines are classified into two types: A and B.

Type A Re-calibration: In this case previous samples can be considered for the Calibration and Post-Calibration Performance Tests.

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[13] See Appendix D for sample forms
[14] For calculation details see Appendix E

Type B Re-calibration: In this case previous samples cannot be considered for the Calibration and Post-Calibration Performance Tests. All the iso-kinetic samples taken should be new.

Table 9: Situations Triggering Re-Calibration

Situation	**Type of Re-calibration**	**Remarks**
PM CEMS device operating out of range. This is defined as either: • 10% or more, of the 45-minute-moving average of calibrated CEMS device output, in a week are outside the Valid Calibration Range for five weeks or more. • 40% or more, of the 45-minute-moving average of calibrated CEMS device output, in a week are outside the Valid Calibration Range for one week or more.	Type A	1) Industry should take at least 2 more iso-kinetic samples above the valid calibration range. 2) Calibrate and conduct Post-Calibration Performance Test of the PM CEMS device with the previous sampling points and new sampling points according to ETS guidelines
PM CEMS device (hardware) changed but the model and manufacturer are same	Type B	Calibrate and conduct Post-Calibration Performance Test of the PM CEMS device according to ETS guidelines
Recalibration after every 6 months	Type B	Same as above
Change in fuel or process	Type B	Same as above
Major changes in the APCD which might change the profile of the PM emissions or flow	Type B	Same as above
Failure in a CEMS audit	Type B	Same as above. However, some or all samples taken for the CEMS Audit Performance Test can be used for recalibration

4.6. Commenting on CEMS Data

In case an industry wishes to provide comments on the CEMS data submitted by them they may do so through a web based user interface of DAHC Server Software. The industry should comment on submitted data within 15 days of submission (or within time limits intimated by the relevant board) or else comments will no longer be valid for review. The period can be revised later stage based on the actual observations over a period of time. The final decision on the course of action to take on the CEMS data will be made by the SPCB.

GLOSSARY OF TERMS

Acid Rain:	Acidic precipitation in form of rain, snow, fog or mist, due to incorporation of acid chemicals in the atmosphere which react with water molecules to produce acid. It is caused by the emissions of sulphur dioxides and nitrogen dioxides, products of many fuel combustion and industrial processes
APCD:	Air Pollution Control Device
Calibrate:	To check, adjust, or determine by comparison with a standard (the graduations of a quantitative measuring instrument). In the context of this document, it is the activity of calibrating the PM CEMS device.
Calibration Drift:	The difference between the instrument response and a reference value after a period of operation without recalibration.
CEMS:	Continuous Emissions Monitoring System
CEMS Audit:	Audit performed every six months to make sure CEMS device are performing as per the standard. Under the activity of CEMS audit, CEMS-Audit Performance Test is conducted.
CEMS Requirements:	Set of Hardware, Software and Performance Standards defined for the CEMS installed by the participating industry.
CEMS Vendor Software:	CEMS Vendor Software is the software installed by the vendor at the DAS that takes the data form the CEMS device and saves in a prescribed format, so that the ETS Bridge Software can read it. This software needs to pass the System Integration Test to test its compatibility with the ETS Bridge Software.
CEPI:	The Comprehensive Environmental Pollution Index (CEPI) is a pollution index created and maintained by the Central Pollution Control Board. It is calculated taking into consideration the various pollutants, their ambient air concentration, its impact on people and ecology, the level of exposure, affected population, etc.
Cluster:	A cluster is a collection of industries in the same geographic region designated by the State Pollution Control Board to participate in the pilot Emission Trading Scheme.
Combustion:	Burning. Many important pollutants, such as sulphur dioxide, nitrogen oxides, and particulates are often by

products of the burning of fuels such as coal, oil, gas, and wood.

Compliance: A unit that has abided by all the regulations of the Emissions Trading Scheme is said to be in compliance.

Compliance Period: The compliance period refers to the time period over which one emission permit is valid. All units under the Emissions Trading Scheme must have enough permits to cover all emissions during each compliance period at the end of the period.

Concentration of pollutant: Concentration of a pollutant is defined as mass of pollutant per volume of air. For the stack emissions, it is defined as mass of pollutant emitted from stack per volume of exhaust air from the stack. Pollution boards have set acceptable pollution levels at certain concentrations for various pollutants.

CPCB: Central Pollution Control Board. The Central Pollution Control Board, a branch of the Ministry of Environment and Forests, is primarily a standards-setting and technical body. It sets environmental and technical standards as along with running national monitoring and enforcement programmes.

DAHC: Data Acquisition and Handling Centre is the Centre located at the CPCB and SPCBs which collects data from the industry.

DAHS: Data Acquisition and Handling System

DAHC Server: Data Acquisition and Handling Centre Server is the server set up at the regulator's (CPCB and SPCB) DAHC.

DAHC Server Software: Data Acquisition and Handling Centre (DAHC) Server Software is the software installed at the DAHC Server for data collection, data storage, data visualization, administration, and other features.

DAS: Data Acquisition System is a PC at the participating industry which has two software programs: (i) CEMS Vendor Software and (ii) ETS Bridge Software installed. It takes the data from the CEMS device and sends it to the DAHC Server

EPA: The United States Environmental Protection Agency

ETS: Emissions Trading Schemes (ETS) are a regulatory tool used to reduce pollution emissions at a low overall cost. In such a scheme, the regulator sets the overall amount of emissions but does not decide what any particular source will emit.

Industrial plants and other polluters, rather than being told a fixed emissions limit or concentration standard, face a price for their emissions and choose how much to emit, within reasonable limits, taking this price into account. The cost placed on the emissions makes it costly to operate with high pollution and thus gives polluters an incentive to cut back the pollution levels.

ETS Bridge: Free Software or Freeware provided by the CPCB and SPCBs to be installed at the DAS (industry site). It acts as a bridge and transfers the data from CEMS Vendor Software to the DAHC Server.

Functional Test: Tests used to assure that CEMS device has been installed and is operating correctly.

Flue Gas: The gas exiting to the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases from a fireplace, oven, furnace, boiler or steam generator. Quite often, the flue gas refers to the combustion exhaust gas produced at the industrial units.

Mass flow standard: An emission standard expressed in terms of total mass emitted in a specified period of time. Concentration standards can be translated to a Mass flow standard using a flow rate value.

Moving Average: A moving average is a type of finite impulse response filter used to analyse a set of data points by creating a series of averages of different subsets of the full data set. A moving average is commonly used with time series data to smooth out short-term fluctuations and highlight longer-term trends or cycles.

Parameter Specification: List of parameters measured by the CEMS device and calculated at the DAS for data transmission to the DAHC Server.

Performance Requirements: Once CEMS is installed and calibrated, set of requirements (must) to be fulfilled by the participating industry with respect to the performance of the CEMS device. It consists of a Post-Calibration Performance Test and CEMS Audit Performance Test.

Permits: Each emission permit operates as a license to emit one kg of particulate matter during the compliance period for which that particular permit is valid. For instance, an industry holding 500 PM permits is allowed to emit a total of 500 units of PM within the time frame for which the permit is valid.

PM: Particulate Matter (PM) are tiny pieces of solid or liquid matter associated with the Earth's atmosphere. Particulate Matter, also known as Total Suspended Particulate Matter (TSP) or Suspended Particulate Matter [SPM], generally have aerodynamic particle sizes from 0.01-100 micrometres and larger. The term PM places no restriction on particle size.

Point Sources: Specific points of origin where pollutants are emitted into the atmosphere such as factory smokestacks.

Random Error: The non-systematic deviation experienced in any step of an analytical procedure that can be estimated by standard statistical techniques.

Re-calibration: Calibrating the PM CEMS device again to override the previous calibration equation. This can be triggered because of various conditions.

Standard Reference Method: A sampling and/or measurement method that has been officially specified by an organization as the method meeting its data quality requirements.

Sector: Category of Industrial units defined by the production of same or similar products, such as chemicals, textiles and the like.

Software Requirements: Set of requirements on the software installed on the DAS that need to be met.

SPCB: State Pollution Control Board. State Pollution Control Boards are the primary bodies responsible for enforcement of environmental regulations in India.

Source: Point of emissions of particulate matter into the ambient air, such as a boiler stack or process stack, also used to refer to the utility or process connected to such a stack where appropriate.

Stack: A chimney, smokestack, or vertical pipe that discharges used air.

Systematic Error: A consistent deviation in the results of sampling and/or analytical processes from the expected or known value. Such error is caused by human, instrumental or methodological bias.

System Integration Test: A test performed on the CEMS Software to determine if it is compatible with the ETS Bridge Software

Unit: Single industrial plant (industry), which may contain multiple sources (stacks).

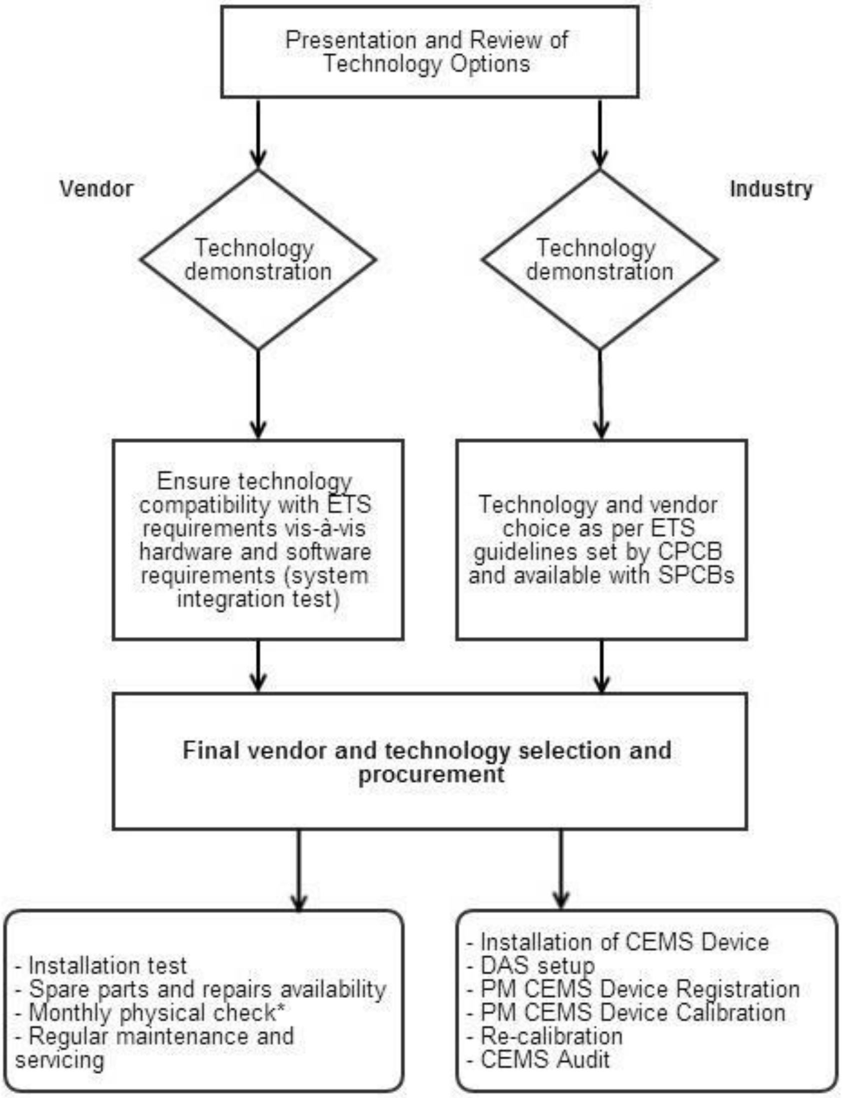
Valid Calibration Range: Defined as the range from zero to 120% of the maximum PM emission mass flow rate or PM emission mass concentration (whichever is applicable) that was observed during an initial calibration or recalibration

Zero Drift: The change in instrument output, over a stated time period of non-recalibrated continuous operation, when the initial input concentration is zero; usually expressed as a percentage of the full scale response.

APPENDIX A: DEVICE SELECTION PROCESS

A1. Overview Flow Chart for PM-CEMS Selection

Figure 9: Selection Process



APPENDIX B: INSTALLATION AND MAINTENANCE GUIDELINES

B1. Selection of CEMS Installation & Sampling Points

Measurements in flowing gases require defined flow conditions in the measurement plane, i.e. an ordered and stable flow profile without vortexing and backflow so that the velocity and the mass concentration of the measured component in the flue gas can be determined.

The installation point for the PM CEMS and flow meter should be such that flow is fully developed at that point. As a general rule, the port hole should be at least **five stack diameters downstream** and **two diameters upstream** from any flow disturbance such as a bend, expansion, or contraction in the stack. The device should be installed such that it is **accessible for regular maintenance**.

Appropriate choice of CEMS Technology in consultation with the vendors and technical plant team should be followed by selection of suitable measurement sections and measurement sites to obtain reliable and comparable emission measurement results. For instance, the measurement section should be clearly identified and labelled, and be in a location where a suitable working platform may be erected.

More detailed installation guidelines can be found in BS EN 15259:2007.

B2. Preventive Maintenance Guidelines for PM CEMS Device and Flow-meter

In general, the maintenance interval of any instrument depends on the nature of the measured medium, the conditions relating to system pressure, general ambient conditions (e.g. climatic conditions at the point of measurement), etc. In this section, recommended preventive maintenance steps for different types of device have been outlined.

Table 10: Preventive Maintenance Guidelines by Device

PM CEMS Device– Transmissiometry Type	
Components	**Preventive Maintenance**
Instrument Air	• Confirm if the instrument air is passing at the receiver and transmitter side. • Instrument air should be free from dust, water vapour and oil mist. • Air filters or regulators (if any) connected to the air-line must be drained regularly.
Transmitter & Receiver	• Remove the transmitter from the flange and check if laser /LED is emitting properly from the transmitter. • Check if any dust particles are deposited on the glass window of the transmitter. • Clean the dust on the glass window with soft cloth or IPA solution such that all dust is removed from the glass window. (Note: Care should be taken not to form any scratches on the glass window.) • The transmitter unit should always align with the instrument; i.e.100% the light should pass to the opposite side (receiver unit).
Zero and Span Check	• Perform the Zero Check and Span Check of the device regularly.
Maintenance Alarms	• Check the maintenance alarms of the device for contamination, misalignment or any other maintenance check
Others	• Visual inspection and cleaning of the external device parts (for corrosion, damaged seals and gaskets, colour alterations on the housings, etc.) • Regular Inspection and check of catches, locks and screw connections
PM CEMS Device – Scatter-light Type	
Components	**Preventive Maintenance**
Instrument Air	• Confirm if the instrument air is passing at the receiver and transmitter side • Instrument air should be free from dust, water vapour and oil mist. • Air filters or regulators (if any) connected to the air-line must be drained regularly.
Transmitter & Receiver	• Remove the transmitter/receiver from the flange and check if any dust particles are deposited on the optics. • Clean the dust on the glass window with soft cloth or IPA solution such that all dust is removed from the glass window. (Note: Care should be taken not to form any scratches on the glass window.)
Maintenance Alarms	• Check the maintenance alarms of the device (if any).

Others	• Visual inspection and cleaning of the external device parts (for corrosion, damaged seals and gaskets, colour alterations on the housings, etc.) • Regular Inspection and check of catches, locks and screw connections.
PM CEMS – Triboelectric and Electrodynamic Type	
Components	**Preventive Maintenance**
Cleaning	• Regular cleaning of prober, insulator and stub pipe. To be done at least once in 3 months
Drift Check	• To be done 6 month drift check
Maintenance Alarms	• Check the maintenance alarms of the device (if any).
Others	• Visual inspection and cleaning of the external device parts (for corrosion, damaged seals and gaskets, colour alterations on the housings, etc.) • Inspection and check of catches, locks and screw connections
Flow meter – Cross-duct Type	
Components	**Preventive Maintenance**
Instrument Air	• Confirm if the instrument air is passing at the receiver and transmitter side • Instrument air should be free from dust, water vapour and oil mist. • Air filters or regulators (if any) connected to the air-line must be drained regularly.
Transmitter & Receiver	• Remove the transmitter/receiver from the flange and check if any dust particles are deposited on the transducer. • Clean the dust on the glass window with soft cloth or IPA solution such that all dust is removed from the sensor. (Note: Care should be taken not to form any scratches on the sensor)
Maintenance Alarms	• Check the maintenance alarms of the device for contamination, misalignment or any other maintenance check
Others	• Visual inspection and cleaning of the external device parts (for damages such as corrosion, damaged seals and gaskets, colour alterations on the housings, etc.) • Regular Inspection and check of catches, locks and screw connections.
Flow meter – Probe Type	
Components	**Preventive Maintenance**
Cleaning	• Regular cleaning of prober, insulator and stub pipe. To be done at least once in 3 months
Maintenance Alarms	• Check the maintenance alarms of the device (if any)
Others	• Visual inspection and cleaning of the external device parts (for corrosion, damaged seals and gaskets, colour alterations on the housings, etc.) • Regular Inspection and check of catches, locks and screw connections.

APPENDIX C: PM CEMS DATA PARAMETER SPECIFICATIONS

The list of parameters that can be sent out from a site depends on the instrument used and to an extent on the vendor specific software functionality. For the purpose of the pilot ETS, a standardized set of parameters has been detailed. All CEMS Software are required to output data for each parameter, and provide N.A. if the value is not applicable for a certain CEMS device type.

Table 11: PM CEMS Data Parameter Details

Parameter Details		
Type of Parameter	**Transferred/Submitted during**	**When will it change**
Configuration data	This data is specific to a stack and instrument. It is submitted by industry at the time of registration of the CEMS device in the DAHC Server DAHC Server communicates the Configuration ID of the stack to the industry	When the PM CEMS device is changed (to a new device from a different vendor or of a different make)
Calibration data	This data is specific to the calibration of the PM CEMS device. Iso-kinetic sampling details submitted by the industry to the DAHC Server DAHC Server software calculates calibration factors and informs industry.	When new calibration is done When CEMS Audit is performed
Measurement data	This is the real time data which is continuously measured or calculated and then transferred to the server on real time basis. Submitted by the CEMS Vendor Software to the DAHC Server via ETS Bridge Software on real time basis	Real time data

C1. Configuration Data

Type of Pollutant (ToP):

ToP indicates the type of the pollutant for which the data is transmitted. For example, TOP = 1 for Particulate Matter (PM). A complete list of codes for various pollutants will be published later.

Type of Configuration (ToC):

Code to indicate the type of technology configuration

Table 12: Type of Configuration (ToC) Codes

Code	Type of Configuration
0	No data being sent
1	Type 1: PM Mass Flow Based Technology
2	Type 2: PM Mass Concentration Based Technology with Volumetric Flow Meter

Composite ID (CompID):

The Comp ID pinpoints a particular stack, in a particular industry, in a particular region. CompID is a fixed-width string containing 14 characters:

Table 13: Composite ID Characters

Position	Count	Meaning
1-2	2	State code
3-5	3	District code
6-10	5	5 digit Industry Code
11-12	2	Specific stack number in particular industry
13	1	Type of Pollutant
14	1	Instrument No.

i. Industry name code and stack number to be configured on server

ii. Instrument number is added to distinguish between multiple instruments installed at the same stack

iii. Type of Pollutant is added to distinguish the type of pollutant for which the file is generated

iv. For instance, an industry called Sri Ramesh Chemicals in Jalna has 5 digit unique ID ‘21908’ with one PM CEMS device in each of the three stacks would have following Composite IDs, one for each stack:

MHJLN219080**1**11

MHJLN219080**2**11

MHJLN219080**3**11

‘1’ at the last of each Composite ID refers to the instrument number. If one more PM CEMS device is installed at Stack no. 1, its composite ID will be MHJLN21908011**2**. SPCBs will release the 5 digit unique ID for each industry.

Stack Dimensions:

Type of stack and internal dimensions of the stack where the PM CEMS is installed (i.e. length and breadth, or diameter). Cross-sectional area of the stack can be calculated using these parameters.

C2. Calibration data

This data is specific to the calibration of the PM CEMS device.

Iso-kinetic sampling data:

This refers to the data of the iso-kinetic sampling done by the lab.

Average Pressure at the Stack during sampling (Pres_Smpl):

The average of the pressure reading at the stack during various isokinetic sampling points. The unit of this parameter should be kPa. This is required to normalize the PM Calibrated data with pressure if pressure measuring device is installed.

Average Temperature at the Stack during sampling (Temp_Smpl):

The average of the temperature reading at the stack during various isokinetic sampling measured in degree Celsius. This is required to normalize the PM Calibrated data with temperature if temperature measuring device is installed.

Calibration Factor (CF_m):

Dust parameter 'm' obtained from the calibration curve (y=mx+c) obtained through a linear regression of isokinetic sampling data and CEMS device data. It is generally reported in a numerical format to 3 decimal places.

Calibration Factor (CF_c):

Dust parameter 'c' obtained from the calibration curve (y=mx+c) obtained through linear regression of isokinetic sampling data and CEMS device data. It is generally reported in a numerical format to 3 decimal places.

[Note: To track which calibration factors are used, the DAHC Server Software saves all the previous calibration factors and also the start and end time of each set of calibration factors.]

C3. Measurement Data

CEMS vendor software sends one set of measurement data as per averaging interval (at present 1 minute) to the ETS Bridge Software which is further sent to the DAHC Server. All values must be read every minute or faster and averaged every 1 minute. Below is a list of parameters.

Date and Time Stamp (DTS):

DTS data is mandated to be formatted in such a way that data is reported also at every one minute interval. The format of DTS is yyyymmddHHMMSS using a 24 hour clock. CEMS vendor software takes the time from the system clock of the DAS.

For instance, the DTS for the average of observations taken between the interval 15:29 and 15:30 on the 14th of December, 2012 would be reported as <20121214153000>, and subsequent observations would therefore be recorded <20121214153100> and so on.

Pressure at the Stack (Pres):

The average of the pressure reading at the stack. The unit of this parameter should be kPa. In case a pressure measuring device is not installed, the average of the pressure measured during the iso-kinetic sampling (Pres_Smpl) will be taken as proxy for pressure and data should indicate'NA'.

Temperature at the Stack (Temp):

The average of the temperature reading at the stack measured in degree Celsius. In case a temperature transmitter is not installed, the average of the temperature measured during the iso-kinetic sampling (Pres_Smpl) will be taken as proxy for temperature and data should indicate'NA'

PM CEMS Raw Uncalibrated Output Average (PM_Uncal):

The average PM CEMS device measurement reading. It is the non-calibrated output averaged across the 1-minute interval.

PM CEMS Calibrated Average (PM_Cal):

The average (across 1 minute) of the Particulate Matter (PM) concentration or mass flow obtained after calibrating the device (using the mx+c equation to convert uncalibrated data to calibrated data and normalizing it, if required).

ToC	Units	Formula
1	Kg/hour	$PMCal = (CF\_m) * (PMUncal) + (CF\_c)$
2	mg/Nm^3	$PM\_Cal = \{(CF\_m) * (PM\_Uncal) + (CF\_c)\} * \{\left(\frac{273 + Temp}{T_{STP}} * \frac{P_{STP}}{Pres}\right)\}$

Velocity (Velocity):

The average of the flow speed in the stack across the 1 minute interval. The unit of this parameter should be m/s.

Velocity		
TOC	**Units**	**Formula**
1	NA	NA
2	m/sec	Direct flow meter reading

Normalized Flow (N_Flow):

The average of the volumetric flow in the stack across the 1 minute interval. The unit of this parameter should be Nm^3/s.

Normalized Flow Formula		
ToC	**Units**	**Formula**
1	NA	NA
2	Nm^3/sec	$N\_Flow = Velocity * A * \left(\frac{T_{STP}}{273 + Temp} * \frac{Pres}{P_{STP}}\right)$

where,
A = Stack Cross Sectional Area

PM Mass (PM_Mass):

The average mass flow through the stack during the 1 minute interval. The unit of this parameter should be kg/hour. The method of calculation is different for different types of configuration.

Formula to calculate PM Mass		
TOC	**Units**	**Formula**
1	Kg/hour	$PM\_Mass = PM\_Cal$
2	Kg/hour	$PM\_Mass = PM\_Cal * N\_Flow * \frac{3600}{1{,}000{,}000}$

Diagnostic Flags (DF):

This is the flag to indicate the health of the PM CEMS device or its availability to measure and send data. Each PM CEMS vendor has to report this and they can make these flags a function of the diagnostic features of their device. These are not averaged over 1 minute interval, but values at the end of every 1 minute interval. Diagnostic flags consist of 8 types of parameters (4 for PM CEMS device and 4 for flow-meter). Details are mentioned in table below.

Table 14: Diagnostic Flag Details

<table>
<tr><td colspan="3">Note: For all the alarms, apart from below mentioned codes, two following code apply:
- Error in updating device status – 9
- Feature not available – NA</td></tr>
<tr><th>S.No.</th><th>Details</th><th>Variable Name</th></tr>
<tr><td rowspan="2">1.</td><td>Device Mode of PM CEMS device</td><td>(PM_DM)</td></tr>
<tr><td colspan="2">Indicates current status of PM CEMS device. Valid values are –
Current Status — **Valid Value**
Normal operation — 0
Calibration — 1
Maintenance — 2
Warming up — 3
System Error – 4 — 4</td></tr>
<tr><td rowspan="2">2.</td><td>Power Status of PM CEMS device</td><td>(PM_PS)</td></tr>
<tr><td colspan="2">• Power on – 0
• Power off – 1</td></tr>
<tr><td rowspan="2">3.</td><td>Alarm for PM CEMS Device</td><td>(PM_Alrm)</td></tr>
<tr><td colspan="2">• No Alarm – 0
• Alarm – 1. If the data send is not valid or fault alarm is on.</td></tr>
<tr><td rowspan="2">4.</td><td>Maintenance Alarm for PM CEMS Device</td><td>(PM_M_Alrm)</td></tr>
<tr><td colspan="2">• No Alarm – 0
• Maintenance Alarm – 1. Maintenance Alarm for PM CEMS Device. This corresponds to the status of the overall status of the maintenance.</td></tr>
<tr><td>5.</td><td>Device Mode of flow-meter</td><td>(F_DM)</td></tr>
<tr><td></td><td colspan="2">Indicates current status of the flow-meter. Valid values are –
Current Status — **Valid Value**
Normal operation — 0
Calibration — 1
Maintenance — 2
Warming up — 3
System Error – 4 — 4</td></tr>
<tr><td rowspan="2">6.</td><td>Power Status of flow-meter</td><td>(F_PS)</td></tr>
<tr><td colspan="2">• Power on – 0
• Power off – 1</td></tr>
<tr><td rowspan="2">7.</td><td>Alarm for flow-meter</td><td>(F_Alrm)</td></tr>
<tr><td colspan="2">• No Alarm – 0
• Alarm – 1. If the data send is not valid or fault alarm is on.</td></tr>
<tr><td rowspan="2">8.</td><td>Maintenance Alarm for flow-meter</td><td>(F_M_Alrm)</td></tr>
<tr><td colspan="2">• No Alarm – 0
Maintenance Alarm – 1. Maintenance Alarm for PM CEMS Device. This corresponds to the status of the overall status of the maintenance.</td></tr>
</table>

C4. Parameters transferred to ETS Bridge Software

Table 15: Parameters Transferred to ETS Bridge Software (according to ToC)

Parameter	Optional / Mandatory	Type 1	Type 2
CompID	Mandatory	Pre-assigned Unique ID of a Stack and CEMS instrument	
ToC		1	2
CF_m		Calibration factor ‘m’	
CF_c		Calibration factor ‘c’	
Pres_Smpl		Average pressure reading during isokinetic sampling	
Temp_Smpl		Average temperature reading during isokinetic sampling	
PM_Uncal		Raw reading of the PM CEMS Device	
PM_Cal		PM Calibrated reading. Units= kg/hour	PM Calibrated reading. Units=mg/Nm^3
Velocity	Mandatory only for Type 2.	Not Applicable	Velocity reading from the Flow Meter
N_Flow	Mandatory only for Type 2.		Normalized Flow Meter Reading
PM_Mass	Mandatory	PM Calibrated reading Units = kg/hour	PM Calibrated reading Units = kg/hour. PM_Mass=PM_Cal*N_Flow*(3600/1000000)
Pres	Optional	Pressure Reading	
Temp		Temperature Reading	
PM_DM		Mode of the PM CEMS device	
PM_PS		Power Status of PM CEMS device	
PM_Alrm		Alarm of PM CEMS device	
PM_M_Alrm		Maintenance Alarm of PM CEMS device	
F_DM		NA	Mode of the flow-meter
F_PS			Power Status of flow-meter
F_Alrm			Alarm of flow-meter
F_M_Alrm			Maintenance Alarm of flow-meter

APPENDIX D: SAMPLE FORMS

Appendix D1. CEMS Registration Form

The purpose of this form is **to register the device via the DAHC Server** after CEMS device installation and before device calibration. It needs to be **filled out by the industry,** and it must be **submitted to the SPCB.**

<table>
<tr><th>S.No.</th><th colspan="4">Details</th></tr>
<tr><th>1.</th><th colspan="4">Unit Information</th></tr>
<tr><td>1.1.</td><td>Industry Name</td><td colspan="3"></td></tr>
<tr><td>1.2.</td><td>Industry Address (Factory Address)</td><td colspan="3"></td></tr>
<tr><td>1.3.</td><td>District and Pin Code</td><td colspan="3"></td></tr>
<tr><td>1.4.</td><td>Industry Sector</td><td colspan="3"></td></tr>
<tr><td>1.5.</td><td>Name of Industry Contact Person</td><td colspan="3"></td></tr>
<tr><td>1.6.</td><td>Position of Contact Person</td><td colspan="3"></td></tr>
<tr><td>1.7.</td><td>Phone no. and Email of Contact Person</td><td colspan="3"></td></tr>
<tr><th>2.</th><th colspan="4">Stack Information</th></tr>
<tr><td>2.1</td><td>Name of the stack (how stack is identified by the industry)</td><td colspan="3"></td></tr>
<tr><td>2.2.</td><td>Emission Source (Boiler/Cement mill etc.)</td><td colspan="3"></td></tr>
<tr><td>2.3.</td><td>Stack height (in meters, from ground level)</td><td colspan="3"></td></tr>
<tr><td>2.4.</td><td>Stack Shape and Internal stack dimensions in meters (length/breadth/diameter)</td><td colspan="3"></td></tr>
<tr><td>2.5.</td><td>APCDs attached to the Stack (including make and model)</td><td colspan="3"></td></tr>
<tr><td rowspan="3">2.6.</td><td rowspan="3">Fuel(s) used in the attachment – indicate % if multiple fuels</td><td>Fuel Name</td><td>Used % of Time</td><td>Amount /Year</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><th>3.</th><th colspan="4">CEMS Device Information</th></tr>
<tr><td>3.1.</td><td>Manufacturer and Model of the PM CEMS Device</td><td colspan="3"></td></tr>
<tr><td>3.2.</td><td>Technology Principle of the PM CEMS Device</td><td colspan="3"></td></tr>
<tr><td>3.3.</td><td>Instrument provider of the PM CEMS Device</td><td colspan="3"></td></tr>
<tr><td>3.4.</td><td>Type of PM CEMS Device</td><td colspan="3">a. Concentration based instrument
b. Mass flow based instrument</td></tr>
<tr><td>3.5.</td><td>Span and Range of Detection</td><td colspan="3"></td></tr>
<tr><td>3.6.</td><td>Foreign Certification of this PM CEMS (if any)
Indicate certification type and country</td><td colspan="3"></td></tr>
<tr><th>4.</th><th colspan="4">Flow Meter Information (Not Applicable, if not installed)</th></tr>
<tr><td>4.1.</td><td>Manufacturer and Model Flow Meter</td><td colspan="3"></td></tr>
<tr><td>4.2.</td><td>Flow Meter Principle</td><td colspan="3"></td></tr>
<tr><td>4.3.</td><td>Instrument provider of the Flow meter</td><td colspan="3"></td></tr>
<tr><th>5.</th><th colspan="4">ETS Compatible CEMS Vendor Software Information</th></tr>
<tr><td>5.1.</td><td>Software Provider Name</td><td colspan="3"></td></tr>
<tr><td>5.2.</td><td>Software Name and Version No.</td><td colspan="3"></td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="5">Disclaimer by industry: I hereby declare that, to the best of my knowledge and belief, the information given above is true.</td></tr>
</table>

Appendix D2. Installation Checklist

The purpose of this form is **to document the installation checklist.** It needs to be **filled out by the Industry,** and it must be **submitted to the SPCB.** It must be filled after CEMS device installation, before device calibration, and must be submitted as part of the **CEMS Installation Procedure**.

No.	Guidelines For Measurement Planes	Meets Criteria (Please tick as appropriate)		If Deviation : Please Record
1.	What is the distance (in meters) of CEMS from the nearest upstream bend?	____	meter(s)	
2.	What is the distance (in meters) of CEMS from the nearest downstream bend?	____	meter(s)	
3.	Is the measurement plane located at the position of the duct with uniform cross section and shape?	Yes / No		
4.	Are there gases from multiple processes entering into the flue gas duct?	Yes / No		
5.	Is there an aerodynamic system (such as fan, vane, special duct design) to ensure mixing of the different gases entering the duct?	Yes / No		
6.	Is there a necessary working platform and appropriate infrastructure to access the measurement section and ports?	Yes / No		
7.	Is the measurement section and measurement port clearly labelled and identifiable?	Yes / No		
8.	Has a traverse velocity study been performed by the vendor or the facility in-charge before installation?	Yes / No		
9.	What is the ration of the highest and lowest velocity as per the velocity traverse test which was conducted?	Yes / No		
10.	Is there a negative flow indication in the velocity traverse test reports?	Yes / No		
Disclaimer by industry: I hereby declare that, to the best of my knowledge and beliefs, the information given above is true.				

Appendix D3. Functional Test Checklist

The purpose of this form is **to document the functional checklist.** It needs to be **filled out by the industry** and it has to be **submitted to the SPCB.** The Functional Test required in the Installation process and the CEMS Audit should be conducted, and the results should be recorded in this form. It must be filled after CEMS device installation and before device calibration as part of the **CEMS Installation Procedure**.

Date of Functional Test :		
Details of Person performing the Functional Test		
Name :		
Position and Company :		
Contact Number and Email :		
FUNCTIONAL TEST FORM		Mark "OK" or write down comments
1.	**Alignment and Cleanliness (Visual Inspection)**	
1.1.	Internal check of the PM CEMS Device	
1.2.	Cleanliness of the probe and/or optical components	
1.3.	Flushing air	
1.4.	No obstructions in the optical path	
1.5.	Proper alignment of the measuring system	
1.6.	Power supply connection present	
1.7.	All connections	
1.9.	Internal check of flow meter	
2	**Leak testing**	
2.1.	Were there any leaks observed in the purge air or instrument air system of the PM CEMS Device?	
2.2.	Were there any leaks observed in the purge air or instrument air system of the Flow Meter?	
3	**Zero Check**	
3.1.	Perform a zero check for the PM CEMS Device. Indicate the method used and fill the result.	
3.2.	Perform a zero and span check for Flow Meter. Indicate the method used and fill the result.	
4	**Serviceability**	
4.1.	Safe and clean working environment of the CEMS Device, with sufficient space and weather protection	
4.2.	Easy and safe access to the CEMS	
4.3.	Availability of tools and spare parts for maintaining CEMS Device in case of breakdown or malfunction	
Disclaimer by industry: I hereby declare that, to the best of my knowledge and beliefs, the information given above is true.		

[Note-In case of the PM emissions mass flow based device, mention NA for questions related to flow meter]

Appendix D4. Iso-kinetic Sample Reporting Form

The purpose of this form is **to report the iso-kinetic sampling results to the SPCB.** It needs to be **filled out by the industry,** and it must be **submitted to the SPCB.**

Standard Reference Method (SRM) Used:	
Lab which performed the sampling:	

1	2	3	4	5	6	7	8	9	10
Sample No.	t_0	t_1	T_{Sample}	P_{Sample}	$Velocity_{Sample}$	N_PM_{Sample}	Total gas passed	K	% load on the process/ emissions
Units			(°C)	(kPa)	(m/s)	(mg/Nm^3)	(litres)		(m/s)
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									

Where,
t_0 = Start time of sampling
t_1 = End time of sampling
k = Isokineticity
T_{Sample}= Temperature measured during sampling as per SRM (°C)
P_{Sample}= Pressure measured during sampling as per SRM (kPa)
$Velocity_{Sample}$= Flue gas velocity measured during sampling as per SRM (m/sec)
N_PM_{Sample} = Normalised PM Mass Concentration during sampling as per SRM (mg/Nm^3)

Disclaimer by industry: I hereby declare that, to the best of my knowledge and belief, the information given above is true.

APPENDIX E: BACKGROUND CALCULATIONS

Appendix E1. Commonly used formulae

Table E1.1 : Formulae used on CEMS Data

Equation No.	Parameter	TOC=1	TOC=2
1	PM_Cal= (Calibrated PM)	Kg/hour	mg/Nm^3
		$(CF\_m) * (PM\_Uncal) + (CF\_c)$	$\{(CF\_m) * (PM\_Uncal) + (CF\_c)\} * \{\left(\frac{273 + Temp}{T_{STP}} * \frac{P_{STP}}{Pres}\right)\}$
2	Velocity= (Velocity from Flow meter installed)	NA	m/sec
		NA	Direct flow meter reading
3	N_Flow= (Normalized volumetric flow from flow meter)	NA	Nm^3/sec
		NA	$Velocity * A * \left(\frac{T_{STP}}{273 + Temp} * \frac{Pres}{P_{STP}}\right)$
4	PM_Mass= (PM Mass Flow from CEMS device)	Kg/hour	Kg/hour
		PM_Cal	$PM\_Cal * N\_Flow * \frac{3600}{1{,}000{,}000}$
5	U_PM_Cal= (Un-normalized Calibrated PM. For ToC=2 only)	NA	mg/m^3
		NA	$\{(CF\_m) * (PM\_Uncal) + (CF\_c)\}$

Table E1.2 : Formulae used on Iso-kinetic Sampling Data

Equation No.	Parameter	TOC=1	TOC=2
6	N_Flow_{Sample} = (Normalized volumetric flow during sampling)	Nm^3/sec	Nm^3/sec
		$(Velocity_{Sample}) * (A) * \left(\frac{T_{STP}}{273 + T_{Sample}} * \frac{P_{Sample}}{P_{STP}}\right)$	$(Velocity_{Sample}) * (A) * \left(\frac{T_{STP}}{273 + T_{Sample}} * \frac{P_{Sample}}{P_{STP}}\right)$
7	U_PM_{Sample}= (Un-normalized Mass Concentration during sampling)	NA	mg/m^3
		NA	$(N\_PM_{Sample}) * \left(\frac{T_{STP}}{273 + T_{Sample}} * \frac{P_{Sample}}{P_{STP}}\right)$
8	PM_Mass_{Sample}= (PM Mass Flow measured during sampling)	Kg/hour	NA
		$(N\_PM_{Sample}) * (N\_Flow_{Sample}) * \frac{3600}{1{,}000{,}000}$	NA

where,		
Relevant to Table E1.1	CF_m	Calibration factor m
	CF_c	Calibration factor c
	PM_Uncal	Raw reading of the PM CEMS Device
	PM_Cal	Calibrated PM readings (kg/hour for ToC=1 and mg/Nm^3 for ToC=2)
	U_PM_Cal	Un-normalized and Calibrated PM readings (mg/m^3). For ToC=2 only
	PM_Mass	Mass flow of PM through the stack measured using CEMS device (kg/hour)
	Temp	One minute average temperature reading at stack from temperature transmitter (°C)
	Pres	One minute average pressure reading at stack from pressure measurement device (kPa)
	Velocity	Flue gas velocity in the stack measured by the flow meter (m/sec)
	N_Flow	Average of the volumetric flow in the stack measured by flow meter (Nm^3/sec)
Relevant to Table E1.2	T_{Sample}	Temperature measured during sampling as per SRM (°C)
	P_{Sample}	Pressure measured during sampling as per SRM (kPa)
	$Velocity_{Sample}$	Flue gas velocity measured during sampling as per SRM (m/sec)
	N_Flow_{Sample}	Normalized volumetric flow during sampling as per SRM (Nm^3/sec)
	N_PM_{Sample}	Normalised PM Mass Concentration during sampling as per SRM (mg/Nm^3)
	U_PM_{Sample}	Un-normalized Mass Concentration during sampling as per SRM (mg/m^3)
	PM_Mass_{Sample}	PM Mass Flow measured during sampling as per SRM (kg/hour)
Relevant to both the tables	A	Stack Cross Sectional Area (m^2)
	T_{STP}	Temperature at Standard Temperature Pressure Condition (Kelvin)
	P_{STP}	Pressure at Standard Temperature Pressure Condition (kPa)
Note: All formulae in Appendix E.2, E.3 refer the equations provided in this table		

Appendix E2. Calibration Factors & Post-Calibration Performance Test

Steps to determine the calibration factors and conduct the post-calibration performance test consist of the following:-

1) **Get SRM (Iso-kinetic manual stack sampling) data.**

2) **Obtain CEMS raw (uncalibrated) readings and flow meter readings (if applicable)** for the time period corresponding to each manual sample taken. Calculate the average readings for each device. The average CEMS raw reading is used to determine the calibration factors, and the average flow meter reading is used in the criteria to determine sample validity for ToC=2.

3) **Determine the number of valid samples** based on isokineticity, data availability, and, for ToC=2, volumetric flow criteria. For calibration at least 4-7 valid iso-kinetic samples are required (in addition to two at zero load).[15]

4) Once the required number of valid samples has been taken, **calculate the calibration factors** 'm' and 'c' using Ordinary Least Squares regression (best linear fit) between the CEMS raw readings and SRM readings.

5) Determine the calibrated CEMS values by applying the calibration factors to each raw CEMS reading. Use these values to **calculate the Root Mean Squared Percentage Error (RMSPE)**, a statistical measure of the average deviation between the calibrated CEMS readings and the SRM readings. **If RMSPE is < 30%, the device passes the Post-Calibration Performance Test.[16]**

6) If the device passes, **calculate the Valid Calibrated Range** (defined as 0 to 120% of the maximum calibrated CEMS reading from Step 5).

7) **Results of the test are sent to the industry**. If the device has passed, then the calibration factors and valid calibrated range are also provided to industry. If the device has failed, then it needs to be checked and recalibrated before repeating the Post-Calibration Performance Test.

Details of each are as follows:-

Step No.	Details
1.	<u>**Get SRM (Iso-kinetic manual stack sampling) data:**</u> Get the results of manual stack sampling (done as per Standard Reference Method) from the Iso-kinetic Sample Reporting Form[17] and fill them in the relevant columns (column 2) in Table E2.
2	<u>**Obtain and calculate the average readings from devices:**</u> Calculate the average of the PM CEMS Raw (uncalibrated) reading and Flow meter reading for DTS (Date and Time Stamp) corresponding to the SRM Sampling. Fill the average PM CEMS Raw (PM_Uncal) in Column 2 of Table E3. Fill the average Flow meter reading in Column 4 of Table E2 (For ToC=2 only and not for ToC=1) (Note: These values are sent by the ETS Bridge to the DAHC Server).

[15] Number of valid samples required will depend on industry characteristics – see Section 4.3 for further details.
[16] With the exception of very low PM stacks (all SRM readings < 10 mg/Nm^3), for which the test is passed for any level of RMSPE
[17] Appendix D4. Iso-kinetic Sample Reporting Form

3

Select valid samples:

Table E2 : Determine Valid and Invalid SRM Samples					
1	2	3	4	5	6
Sample No.	K	Normalized Volumetric Flow during sampling	Avg. of Normalized Volumetric flow from flow meter	% Raw CEMS data available during sampling	Valid Sample (Yes/No)
		N_Flow_{Sample}	Avg. of N_Flow		
Units	%	Nm^3/sec	Nm^3/sec	%	
1					
2					
10					

Column 3: Normalized Volumetric Flow during sampling as per SRM (N_Flow_{Sample})

For the calculation of N_Flow_{Sample}, refer to equation No. 6 in Table E1.

Column 4: Calculation of the Average of Normalized Volumetric Flow from flow meter (N_Flow)

Take the average of the normalized volumetric flow (from flow meter) for the corresponding SRM. For calculation of N_Flow, refer to equation No. 3 in Table E1.

Column 6: Valid Sample (Yes/No)

Valid Sample as 'Yes' if following conditions are satisfied, else fill 'No'.

- Isokineticity value between 90% and 110%
- Data availability from the CEMS device corresponding to the isokinetic sampling duration is at least 95%
- Normalized volumetric flow measured during iso-kinetic sampling is in $\pm$ 20% of the average normalized volumetric flow meter reading during sampling (Applicable for ToC=2 and not ToC=1)

4

Calculate Calibration Factors:

For valid samples from Table E2 (value of column 6 'Valid Sample' = 'Yes'), fill Table E3 with SRM reading and raw CEMS device reading.

Table E3 : Calibrate CEMS Device against SRM Readings					
1	2	3	4	5	6
Sample No.	Avg. PM CEMS Raw Reading	Normalized Mass Conc. during sampling	Un-normalized Mass Conc. during sampling**	Normalized Volumetric Flow during sampling	PM Mass Flow during sampling*
	Avg of PM_Uncal	N_PM_{Sample}	U_PM_{Sample}	N_Flow_{Sample}	PM_Mass_{Sample}
i	x_i		** (y_i) for ToC= 2		* (y_i) for ToC=1
Units		mg/Nm^3	mg/m^3	Nm^3/sec	kg/hour

	Column 2: As explained in step-2 **Column 3:** Normalised PM Mass Concentration during sampling as per SRM (N_PM_{Sample}) Column 7 of the Iso-kinetic Sample Reporting Form[18] **Column 4:** Un-normalized Mass Concentration during sampling as per SRM (U_PM_{Sample}) For calculation of U_PM_{Sample}, refer to equation No. 7 in Table E1. **Column 5:** Average Normalized Volumetric flow during sampling as per SRM (N_Flow_{Sample}) Column 3 of Table E2 for the valid samples **Column 6:** PM Mass Flow during sampling as per SRM (PM_Mass_{Sample}) For calculation of PM_Mass_{Sample}, refer to equation No. 8 in Table E1. Calibration factors 'CF_m' and 'CF_c' of the linear regression equation {y=(CF_m)*x + (CF_c)} fitted over CEMS and SRM readings can be calculated using the formula below :- • $CF\_m = \frac{\sum_{i=1}^{n} x_i y_i - n\bar{x}\bar{y}}{\sum_{i=1}^{n} x_i^2 - n\bar{x}^2}$ • $CF\_c = \bar{y} - m\bar{x}$ where:- ○ For ToC = 1, y_i is the PM Mass Flow during sampling as per SRM (PM_Mass_{Sample}) measured in kg/hour i.e. Column 6 of Table E3. ○ For ToC = 2, y_i is the Un-normalized Mass Concentration during sampling as per SRM (U_PM_{Sample}) measured in mg/m^3 i.e. Column 4 of Table E3. For all ToC, x_i is the Avg. PM CEMS Raw Reading i.e. column 2 of Table E3.
5	**Calculate RMSPE and Perform Post-Calibration Performance Test:** For valid samples from Table E2 (value of column 6 'Valid Sample' = 'Yes'), fill Table E4 with SRM reading and raw CEMS device reading.

Table E4: Calculate RMSPE

1	2	3	4	5
Sample number	PM_Mass_{Sample} or U_PM_{Sample}	Avg. of PM_Cal or U_PM_Cal	(Percentage Errors) $\mathbf{D_i = (y_i - \hat{y}_i) * \frac{100}{y_i}}$	(Square of Percentage Errors) $\mathbf{D_i * D_i}$
i	y_i	$\hat{y}_i$	D_i	
1				
2				
10				
Sum				

[18] Appendix D4. Iso-kinetic Sample Reporting Form

Column 2: PM_Mass_{Sample} (ToC=1) or U_PM_{Sample} (ToC=2)

- If ToC=1, fill PM_Mass_{Sample} (PM Mass Flow during sampling as per SRM)
  Column 6 of Table E3. (Units=kg/hour)
- If ToC=2, fill U_PM_{Sample} (Un-normalized Mass Concentration during sampling as per SRM).
  Column 4 of Table E3. (Units=mg/m^3)

Column 3: Average of PM_Cal (ToC=1) or U_PM_Cal (ToC=2)

- If ToC=1, fill PM_Cal (Calibrated PM readings).
  Use equation 1 of Table E1 for the corresponding sampling as per SRM. (Units=kg/hour)
- If ToC=2, fill U_PM_Cal (Un-normalized and Calibrated PM readings)
  Use equation 5 of Table E1 for the corresponding sampling as per SRM. (Units=mg/m^3)

Column 4: Percentage errors

- Calculate the percentage errors (using the formula mentioned).

Column 5:. Square of errors

- Square the percentage errors (using the formula mentioned).

Grey box:

- Calculate the sum of values in Column 5 of Table E4 and place in the grey box in last row.

Insert the value from the grey box (**Sum of** D_i*D_i) into the following equation to calculate:

$$RMSPE=\sqrt{\frac{1}{N}\times \text{Value from grey box (i.e. Sum of } (D_i * D_i))}$$

Where, N is the number of valid samples

Thus, RMSPE =

Is RMSPE is lesser than the allowable limit (30%) (Tick one) : Yes / No

If RMSPE < 30 % Then CEMS Device PASSES the Post-Calibration Performance Test
Else
CEMS Device FAILS the Post-Calibration Performance Test

** For very low PM stacks (all the Iso-kinetic PM emission mass concentrations reading less than 10 mg/Nm^3), Post-Calibration Performance Test is deemed Pass for any level of RMSPE.*

Hence, Write test result here (Tick one): **PASS/ FAIL**

If the CEMS device fails the Post –Calibration Performance test, it needs to be checked and recalibrated, and the Post-Calibration Performance Test needs to be redone.

6	**Calculate Valid Calibrated Range:** If the CEMS device has passed the above mentioned test, calculate 120% * the highest "Calculated PM emission rate" i.e. $$\text{Valid Calibration Range} = 1.2 * (m * (\max\{\text{Avg. PM CEMS Raw Reading}\}) + c)$$ *Where;* Avg. PM CEMS Raw Reading (PM_Uncal) is Column 2 of Table E3. If the Valid Calibration Range value is higher than the previous value of the Valid Calibration Rang then write the new value below, otherwise, the previous value. This Industry's Updated Valid Calibration Range is : 0 to ____________
7	**Inform industry:** Following parameters should be informed to the industry depending on the result of the Post-Calibration Performance Test (step 5)

Parameters	Passed	Failed
Post-Calibration Performance Test Result	Passed	Failed
Calibration factor 'm'	CF_m from step 4	Not Applicable
Calibration factor 'c'	CF_c from step 4	Not Applicable
Valid Calibration Range	Valid Calibration Range from step 6	Not Applicable

Appendix E3. CEMS Audit Performance Test

Steps to conduct the CEMS Audit Performance Test consist of the following:-

1) **Get SRM (Iso-kinetic manual stack sampling) data**

2) **Obtain CEMS readings and flow meter readings (if applicable)** for the time period corresponding to each manual sample taken. Calculate the average readings for each device. The average CEMS readings are used to calculate RMSPE, and the average flow meter reading is used in the criteria to determine sample validity for ToC=2.

3) **Determine the number of valid samples** based on isokineticity, data availability, and, for ToC=2, volumetric flow criteria. For CEMS audit at least 4 valid iso-kinetic samples are required (in addition to two at zero load).

4) **Calculate RMSPE**, a statistical measure of the average deviation between the CEMS readings and the SRM readings. **If RMSPE is < 40%, the device passes the CEMS Audit Performance Test.**[19]

5) **Results of the test are sent to the industry.** If the CEMS device fails the CEMS Audit Performance test, it needs to be checked, recalibrated, and must then pass the Post-Calibration Performance test. Some or all of the iso-kinetic samples taken for the CEMS audit may be used for recalibration.

Details of each are as follows:-

<table>
<tr><th>Step No.</th><th>Details</th></tr>
<tr><td>1.</td><td><u>Get SRM (Iso-kinetic manual stack sampling) data</u>
Get the results of manual stack sampling (done as per Standard Reference Method) from the Iso-kinetic Sample Reporting Form[20] and fill them in the relevant column (column 2) in Table E5.</td></tr>
<tr><td>2</td><td><u>Select the valid samples:</u>
<table>
<tr><th colspan="6">Table E5 : Determine Valid and Invalid SRM Samples</th></tr>
<tr><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td></tr>
<tr><td>Sample No.</td><td>K</td><td>Normalized Volumetric Flow during sampling</td><td>Avg. of Normalized Volumetric flow from flow meter</td><td>% Raw CEMS data available during sampling</td><td>Valid Sample (Yes/No)</td></tr>
<tr><td></td><td></td><td>N_Flow_{Sample}</td><td>Avg. of N_Flow</td><td></td><td></td></tr>
<tr><td>Units</td><td>%</td><td>Nm^3/sec</td><td>Nm^3/sec</td><td>%</td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>10</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>
<u>Column 3:</u> Normalized Volumetric Flow during sampling as per SRM (N_Flow_{Sample})
For the calculation of N_Flow_{Sample}, refer to equation No. 6 in Table E1.</td></tr>
</table>

[19] With the exception of very low PM stacks (all SRM readings < 10 mg/Nm^3), for which the test is passed for any level of RMSPE

[20] Appendix D4. Iso-kinetic Sample Reporting Form

	Column 4: Calculation of the Average of Normalized Volumetric Flow from flow meter (N_Flow) Take the average of the normalized volumetric flow (from flow meter) for the corresponding SRM. For calculation of N_Flow, refer to equation No. 3 in Table E1. **Column 6: Valid Sample (Yes/No)** Valid Sample as 'Yes' if following conditions are satisfied, else fill 'No'. o Isokineticity value between 90% and 110% o Data availability from the CEMS device corresponding to the isokinetic sampling duration is at least 95% o Normalized volumetric flow measured during iso-kinetic sampling is in ± 20% of the average normalized volumetric flow meter reading during sampling (Applicable for ToC=2 and not ToC=1)
3	**Calculate RMSPE and Perform CEMS Audit Performance Test:**

Table E6: Calculate RMSPE

1	2	3	4	5
Sample number	PM_Mass_{Sample} or U_PM_{Sample}	Avg. of PM_Cal or U_PM_Cal	(Percentage Errors) $D_i = (y_i - \hat{y}_i) * \frac{100}{y_i}$	(Square of Percentage Errors) $D_i * D_i$
i	y_i	$\hat{y}_i$	D_i	
1				
2				
10				
Sum				

Column 2: PM_Mass_{Sample} (ToC=1) or U_PM_{Sample} (ToC=2)

- o If ToC=1, fill PM_Mass_{Sample} (PM Mass Flow during sampling as per SRM)
  For calculation of PM_Mass_{Sample}, refer to equation No. 8 in Table E1. (Units=kg/hour)
- o If ToC=2, fill U_PM_{Sample} (Un-normalized Mass Concentration during sampling as per SRM).
  For calculation of U_PM_{Sample}, refer to equation No. 7 in Table E1. (Units=mg/m^3)

Column 3: Average of PM_Cal (ToC=1) or U_PM_Cal (ToC=2)

- o If ToC=1, fill PM_Cal (Calibrated PM readings).
  Use equation 1 of Table E1 for the corresponding sampling as per SRM. (Units=kg/hour)
- o If ToC=2, fill U_PM_Cal (Un-normalized and Calibrated PM readings)
  Use equation 5 of Table E1 for the corresponding sampling as per SRM. (Units=mg/m^3)

Column 4: Percentage errors

Calculate the percentage errors (using the formula mentioned)

Column 5:. Square of errors

- o Square the percentage errors (using the formula mentioned)

	Grey box: o Calculate the sum of values in Column 5 of Table E6 and place in the grey box in last row. Insert the value from the grey box (**Sum of** D_i*D_i) into the following equation to calculate: $$RMSPE=\sqrt{\frac{1}{N}\times \text{Value from grey box (i.e. Sum of } (D_i*D_i))}$$ Where, N is the number of valid samples Thus, RMSPE = [ ] Is RMSPE is lesser than the allowable limit (**40%**) (Tick one) : Yes / No **If RMSPE < 40 % Then CEMS Device PASSES the CEMS Audit Performance Test** **Else** **CEMS Device FAILS the CEMS Audit Performance Test** ** For very low PM stacks (all the Iso-kinetic PM emission mass concentrations reading less than 10 mg/Nm^3), CEMS Audit Performance Test is deemed Pass for any level of RMSPE.* Hence, Write test result here (Tick one): **PASS/ FAIL** If the CEMS device fails the CEMS Audit Performance test, it needs to be checked, recalibrated, and must then pass the Post-Calibration Performance test. Some or all of the iso-kinetic samples taken for the CEMS audit may be used for recalibration.
4	**Inform industry** Industry should be informed about the result of the CEMS Audit Performance Test mentioned in step 3.

APPENDIX F: ETS BRIDGE INTERFACE

F1. Interface Overview

The ETS Bridge Software has to collect and send data from the CEMS device to the SPCB and CPCB server. Hence it is imperative that there is a standard interface for the communication between the CEMS Software and the ETS Bridge Software. All CEMS vendors should ensure that their software provides the required data as per the ETS Bridge interface.

F2. Interface Details

The ETS Bridge Software has a '**File based Interface**'. This means that a file in the prescribed format is generated by the CEMS Software and read by the ETS Bridge Software. This is to ensure that all vendors can easily incorporate any required changes in their software to comply with this interface.

Interface Configuration

The following items need to be configured for the interface between the CEMS Vendor Software and ETS Bridge Software, i.e. both of them must refer to the same file. This configuration file will be stored in the same folder as the ETS Bridge, will be named ETSBridge.ini, and will contain following information:

1. Folder where data files will be generated by CEMS vendor software
2. Archive folder where data files will be moved after a file is completely processed by ETS Bridge Software
3. Averaging interval in seconds (which is 60 seconds as of now)

The format of this configuration file will be like an .ini file with a single section called [Config] and name=value pairs under it:

Format	Example
[Config] DataFolder=<data folder path> ArchiveFolder=<archive folder path> AvgInterval=<averaging interval in seconds>	[Config] DataFolder=C:\\ETS\data ArchiveFolder=C:\\ETS\archive AvgInterval=60

CEMS Software should create data files in the ETS data folder that has to be "C:\\ETS\data".

F2.1 Data File Naming and Creation

A separate data file will be created for each date for each CEMS device connected to the DAS. The data file will be stored in the folder specified in interface configuration file (.ini file).

Format	Example
<Creation date>_<CompID given in configuration data section>.csv	The data file for stack 001 at Sri Ramesh Chemicals in Jalna (having unique code 21908) created on 14th Dec 2012
<yyyymmdd>_<CompID>.csv	**20121214_ MHJLN219080111.csv**

Whenever the CEMS Vendor Software runs, it will look for the data file with the current date for each instrument in the ETS data folder. If found, it will open and append new data to this file, otherwise it will create a new file. It will also create a new file for each instrument when the date changes. The CEMS Vendor Software should always open the file in such a way that ETS Bridge Software is able to open same file simultaneously and read data from it.
[Note: The new day starts at 00:00 hours.]

F2.2. File Format

Each file will have a header row, calibration data row, multiple number of data rows (ideally 1440 rows: 1 per minute) and a footer row. For the file, first 2 rows won't be repeated. From 3rd row onwards, a row of data will be added every minute.

Section	Format	Example
Header	The **1st** row of the file will always be a header row.	
	<ToP,ToC,CompID>	1,1,**MHJLN219080111**
Calibration data row	The **2nd** row of the file will contain the calibration data.	
	<CF_m,CF_c,Pres_Smpl, Temp_Smpl>	5.1,0.024,100.324,310.1
Data Rows	Subsequent rows in the file will contain measurement data Note: – Comma is used as a delimiter between parameters – No spaces should be used at any point in the file – If a parameter is not applicable for the given instrument, write NA in place of value – If there is an error in the instrument / DAS while reading a parameter, write 'err' in place of value – Each row must end with a CRLF (carriage return/line feed) character	
	<DTS,PM_Uncal,PM_Cal,Velocity,N_Flow,PM_Mass,Pres,Temp,PM_DM,PM_PS,PM_Alrm,PM_M_Alrm,F_DM,F_PS,F_Alrm,F_M_Alrm>	20121214153000,10.1,55.6,NA,NA,55.6,99.21,150.2,0,0,0,0,0,0,0,0<CRLF>
Footer	Footer row indicates that CEMS vendor software has completed writing this file and the next data set will be written in a new file. This is always the last row in the file.	
	Eof	**Eof**

Some examples of valid and invalid data rows –

Data	Result
20121214153000,10.1,55.6,NA,NA,55.6,99.21,150.2,0,0,0,0, NA,NA <CRLF>	Valid
20121214223100,9.0,50.1,NA,NA,50.1,97.122,err,0,0,0,0,0,0 ,0,0<CRLF>	Valid Error in reading temperature
20121214153000,10.1,55.6,NA,,55.6, 99.21,150.2,0,0,0,0,0,0,0,0<CRLF>	Invalid - Space after comma - Empty instead of NA
20121214153000,10.1,55.6,NA,NA,55.6,99.21,150.2,0,0,0,0, 0,0,0,0**20121214153100,5,5.1,10.1,55.6,NA,NA,55.6,99.21,1 50.2,0,0,0,0,0,0,0,0<CRLF>**	Invalid - No CRLF after 1st row and hence 2nd row (red) in continuation with 1st row
20121214153000,5,5.1,10.1,55.6,NA,NA,55.6,99.21,150.2,2, 0,0,0,0,0,0,0<CRLF>	Invalid PM CEMS device in Maintenance Mode
20121214153000,10.1,55.6,NA,NA,55.6,99.21,150.2,0,0,0,0, 0,1,0,0<CRLF>	Invalid Flow-meter power is off
20121214153000,5,5.1,10.1,55.6,NA,NA,55.6,99.21,150.2,0, 0,1,0,0,0,0,0<CRLF>	Invalid PM Alarm 'On' i.e. Fault mode of device or data invalid indicated by device (though device is in normal operation mode)
20121214153000,5,5.1,10.1,55.6,NA,NA,55.6,99.21,150.2,0, 0,0,1,0,0,0,0<CRLF>	Valid Maintenance Alarms from PM CEMS Device On. Device needs maintenance.

F3. Data Exchange Process

1. Whenever the CEMS Vendor Software starts, it will look for the file with the current date for each instrument connected to it. If found, it will open this file, otherwise it will create a new file. It will also create a new file for each instrument when the date changes.
2. When the ETS Bridge Software starts, it will load information about the number and type of CEMS instruments connected to the DAS via the CEMS vendor software. This information will be obtained from the DAHC server.
3. Then ETS Bridge Software will look for files from each instrument and open these files for reading.
4. It will read all new rows already existing in the file since last reading.
5. Then it will wait for new data rows to arrive in the file. As soon as a new row is appended to the file, the ETS Bridge Software will read that row.
6. ETS Bridge Software will add one more date and time stamp at the beginning of each data row. This time stamp specifies when ETS Bridge Software read the row. If difference between the ETS Bridge Software time stamp and CEMS Software time stamp is more than a threshold, the server will add a 'late' flag for this row. This indicates that the data was not received by the ETS Bridge Software in real time.
7. ETS Bridge Software will send the data to the DAHC servers at SPCB and CPCB, every minute as soon as it is read from file. In case data cannot be sent to one or both servers, ETS Bridge will keep the data locally and send to server(s) as soon as possible. The bridge will keep track of rows sent to each server and ensure that there is neither data loss nor data duplication.
8. ETS Bridge Software will also store all data locally in a different folder in encrypted format.
9. ETS Bridge Software will also generate an error file logging all errors encountered.

10. When the date changes, the CEMS Software will write a footer row in the previous day's file and close that file. After this, the CEMS Software cannot write any new data in this file.
11. After encountering a footer row in a file, the ETS Bridge Software will close that file and move it to an archive folder specified in the configuration file.

If the CEMS Software cannot read data in real time from an instrument due to whatever reason, it MUST read this data later and write it to the appropriate files before a footer row is written. This is to ensure that there is no data loss. In this case, all this data will be treated as 'late' by the server. However, this must be done before the CEMS Software starts writing real time data to the current file. Thus, the CEMS Software cannot keep an older file open while writing data in a newer file.

APPENDIX G: SYSTEM INTEGRATION TEST FOR VENDOR SOFTWARE

G1. Rationale for System Integration Test

The ETS Bridge Software supports a file-based interface for communication with CEMS Vendor Software at the industry. Each CEMS vendor participating in the pilot ETS project must incorporate this interface into their CEMS software package and pass the System Integration Test to ensure compatibility with ETS Bridge Software. It is necessary to carry out this test for the following reasons:

1. It will ensure parity in data transfer among different vendors participating in the project.
2. It will ensure that CEMS Vendor Software follows data transfer guidelines established for ETS. The software should transfer the required parameters in prescribed format and carry out underlying calculations appropriately.
3. It will establish that timely, uncorrupted and secure data transfer takes place from CEMS Vendor Software to DAHC Server via ETS Bridge Software.

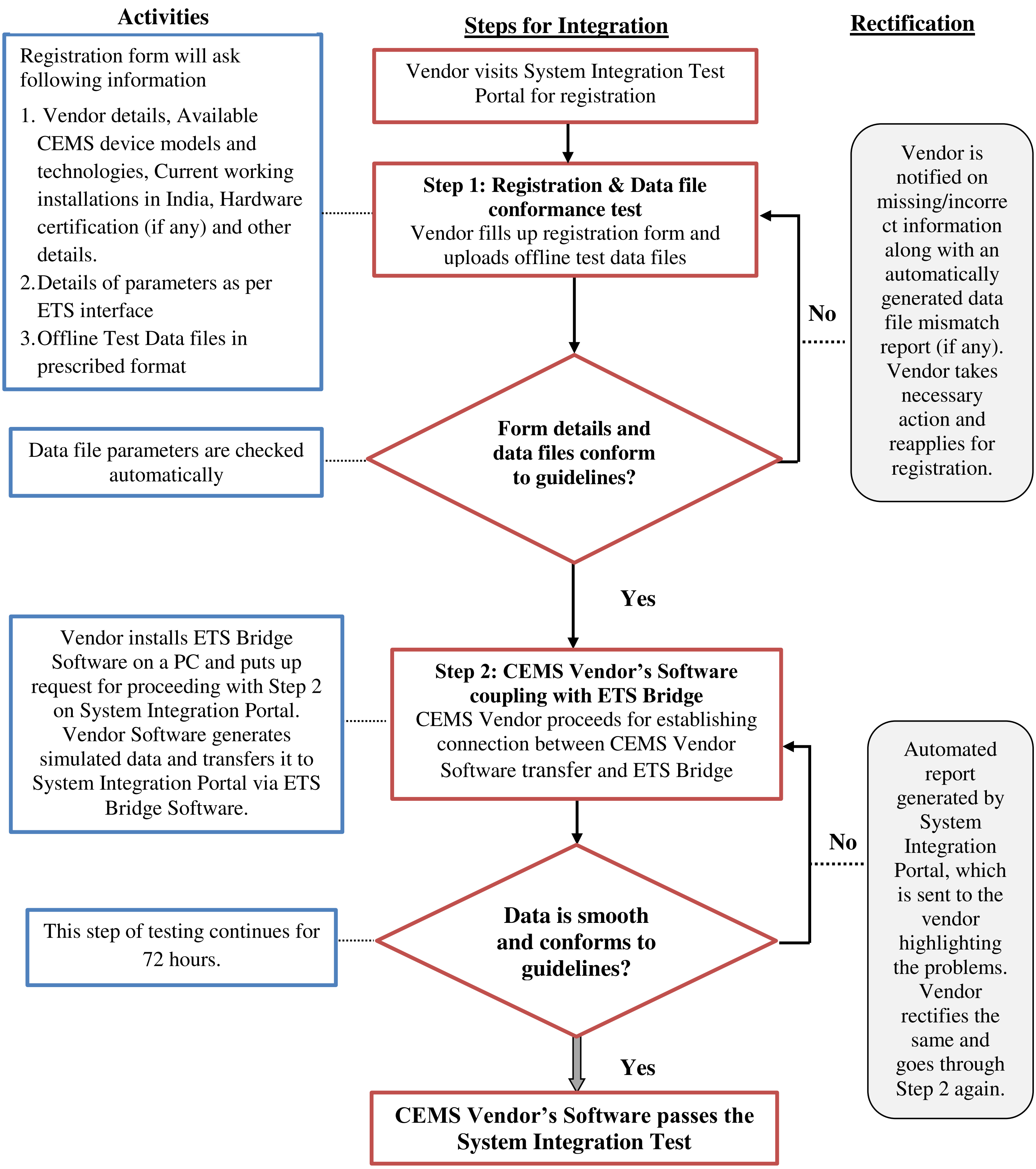
Passing the System Integration Test will be the responsibility of the CEMS Vendor.

G2. Procedure for System Integration Test

A web-based portal hosted by the Central Pollution Control Board (CPCB) will be made available to vendors for carrying out the steps required for the System Integration Test. Each CEMS Vendor will register on the portal, following which a user-ID and password would be provided to them for carrying out further integration tasks. The portal will have sections for uploading required data files and documentation and will be capable of carrying out automated checks on the conformance of transferred data with data transfer guidelines. Additionally, a feature will be made available for generating reports on mismatched data. Vendors can go through the automated reports and rectify the mismatches to proceed with software testing procedure.

The procedure for the system integration test of CEMS Vendor Software has been divided in two broad steps. The flow chart below outlines the overall procedure:

Figure 10: System Integration Test Process



Step 1: Registration and Data File Conformance Test

To begin the system integration test, the vendor must register on the System Integration Portal and upload the required documents, which include test data files. The System Integration Registration Form will ask general vendor details, available CEMS device models and technologies, present working installations in India, hardware certification information and other details. For the file conformance test, automated checks on data files are carried out and a report of mismatches (if any) is generated. The vendor is intimated about the required rectification steps. Once the registration details are accepted and the data file conforms to the guidelines, the vendor can move ahead to Step 2.

The activities and respective responsibilities under Step 1 are as follows:

S.No.	Activity	Responsibility
i.	Vendor visits the System Integration Portal and registers	Vendor
ii.	Vendor fill up System Integration Registration Form and uploads the test data files in the prescribed format	Vendor
iii.	Uploaded Test Data files are checked automatically and success/failure report citing the mismatches (if any) is generated and CEMS vendor is notified accordingly	Portal
iv.	Vendor rectifies the details/documents/data files as reported by the portal and reapplies for the test (skip if no rectification required)	Vendor
v.	Step 1 complete	

Step 2: CEMS Software Coupling with ETS Bridge Software (Offline Testing)

Step 1 registers the vendor and confirms that the data file generated by the CEMS Vendor Software follows the ETS guidelines and specifications. Step 2 of the integration process ensures proper coupling of CEMS Vendor Software with the ETS Bridge Software. In other words, this step checks whether the data file generated by vendor software is in the correct format, that calculations performed are correct and that it is read smoothly by ETS Bridge Software.

The activities and respective responsibilities under Step 2 are as follows:

S.No.	Activity	Responsibility
i.	Vendor downloads and installs ETS bridge on a PC and puts up request on portal for proceeding with Step 2 of integration process specifying the time when portal should start checking the data	Vendor
ii.	Vendor Software generates simulated data and transfers it to the portal via ETS bridge for 72 hours	Vendor
iii.	Various parameters of data transfers are checked automatically by the portal	Portal
iv.	A report on success/failure of the offline coupling trial along with reasons for failure (if any) is generated and shared with vendor	Portal
v.	Vendor rectifies the problems and goes through (ii) to (iv) again. (Skip this step if (iv) succeeds)	Vendor
vi.	Step 2 complete	

The following checks would be carried out by the System Integration Portal during offline coupling trial:

a. Date and Time Stamp should meet and data transfer should take place every minute.
b. File format should be as per the ETS data transfer guidelines.

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