Guidelines for Continuous Emission Monitoring Systems

CENTRAL POLLUTION CONTROL BOARD
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Note: Efforts have been made to include all available monitoring technologies/instrumentation in the document. In case any high end technology/ instrumentation is not covered or is introduced subsequently the details be forwarded to CPCB, so that the same can be incorporated while reviewing this document subsequently.

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1.0 BACKGROUND

Central Pollution Control Board vide its letter No. B-29016/04/06PCI-1/5401 dated 05.02.2014 issued directions under section 18(1) b of the Water and Air Acts to the State Pollution Control Boards and Pollution Control Committees for directing the 17 categories of highly polluting industries such as Pulp & Paper, Distillery, Sugar, Tanneries, Power Plants, Iron & Steel, Cement, Oil Refineries, Fertilizer, Chloral Alkali Plants, Dye & Dye Intermediate Units, Pesticides, Zinc, Copper, Aluminum, Petrochemicals and Pharma Sector, etc., and Common Effluent Treatment Plants (CETP), Sewage Treatment Plants (STPs), Common Bio Medical Waste and Common Hazardous Waste Incinerators for installation of online effluent quality and emission monitoring systems to help tracking the discharges of pollutants from these units. The directions envisage:

a) Installation of online emission quality monitoring system in 17 categories of highly polluting industries and in Common Hazardous waste and Biomedical waste incinerators for measurement of the parameters, Particulate Matter, NH_3 (Ammonia), SO_2 (Sulphur Dioxide), NO_X (Oxides of Nitrogen) and other sector specific parameters, not later than by March 31, 2015 and transmission of online data so generated simultaneously to SPCB/PCC and CPCB as well. The deadline was later extended to June 31, 2015.

b) Installation of surveillance system with industrial grade IP (Internet Protocol) cameras having PAN, Tilt, Zoom (PTZ) with leased line real time connection for data streaming and transmission of the same in case of industries claiming Zero Liquid Discharge (ZLD).

c) Ensure regular maintenance and operation of the online system with tamper proof mechanism having facilities for online calibration (onsite/ offsite; Remote).

Parameters required to be monitored in the stack emissions using Continuous Emission Monitoring system, are industry specific and are specified below:

a) Particulate Matter

b) HF (Fluoride)

c) NH_3 (as Ammonia)
d) SO_2 (Sulphur Dioxide)
e) NO_X (Oxides of Nitrogen)
f) Cl_2 (Chlorine)
g) HCl (Hydro Chloric acid) and HF (Hydro Fluoric Acid)
h) TOC (Total Organic Carbon) / THC (Total Hydro Carbon) / VOC (Volatile Organic Carbon)- C_nH_m
i) Process parameters: Carbon Monoxide, Temperature, Pressure, Flow, Moisture Content, O_2 (Oxygen), CO_2, etc.

2.0 GENESIS OF PROBLEM

The highly polluting industries such as Power, Cement, Iron & Steel, Chlor-alkali, Pharmaceuticals, Fertilizers, Refineries, Pesticides, Distilleries, Sugar, Pulp & Paper, Textile, Tanneries, and other categories of industries emit particulate matter and other gaseous pollutant into atmosphere. These industries also release pollutants through effluent discharge.

The SPCBs and PCCs have prescribed standards for various pollutants emitted/ discharged by the industries as notified under the Environment (Protection) Act,1986. The compliance monitoring needs to be strengthened to ensure that emissions/ effluent complying with the stipulated norms are only discharged by the industries.

With rapid industrialization, it is becoming a need and necessity to regulate compliance by industries with minimal inspection of industries. Therefore, efforts need to be made to bring discipline in the industries to exercise self-monitoring & compliance and transmit effluent and emission quality data to SPCBs/PCCs and CPCB on continuous basis.

For strengthening the monitoring and compliance through self-regulatory mechanism, online emission and effluent monitoring systems need to be installed and operated by the developers and the industries on, 'Polluter Pays Principle'.

Verification, validation and accuracy check of the values indicated by the online devices needs to be done. For proper interpretation of data measures need to be taken at the level of SPCBs/PCCs. For regulatory and for purpose of actions to be taken against non-complying industries/facilities, the existing method of sampling, analysis and related procedures under the existing statutes need to be continued, till further direction.

Various technologies are available for monitoring the particulate matter and gaseous emission from the stack of industries and common treatment facilities in terms of the parameters specified in the directions issued by CPCB. However, no guidelines on selection of the Continuous Emission Monitoring Systems (CEMS) are available. This guideline document has aimed to help industries and regulator for proper implementation of online emission monitoring system through proper selection, operation and data transfer in a transparent self-regulatory mechanism.

3.0 CONTINUOUS EMISSION MONITORING SYSTEM (CEMS)

In recent years Online Emission Monitoring Technology has received attention and interest in context of providing accurate and continuous information on particulate matter/ gaseous emission from stacks. There are already commercially available systems for monitoring parameters such as PM, HCl, HF, NH_3, SO_2, CO, O_2, CO_2, NOx, VOC, etc;.

3.1 Objectives of Continuous Emission Monitoring Systems

The Continuous Emission Monitoring (CEM) System comprises of the total equipment necessary to determine the concentration of gaseous emission and/or particulate matter concentration and/or emission rate using analytical measurements and a computer program to provide results in units of the applicable emission limits or standards. The data recorded/observed is gathered either through analog outputs to a recording system or send directly to a DAS (Data Acquisition System) for storage and onward transmission.

Data Acquisition System includes special modules for data treatment and further transmission to the Central Data Acquisition and Handling System in

SPCB/ CPCB central office. It is important to have properly engineered CEM systems.

i) Compliance with legislation

For any given process, limits have been imposed on the quantum of emissions that an industry is permitted to release to the atmosphere for a particular parameter/ pollutant. These limits are expressed as:-

- Maximum concentration in ppm or mg/Nm^3 (as specified in standards)
- Maximum mass emission (Kg/ Tonne or Kg/unit production)

For calculating maximum mass emissions i.e, Kg/ Tonne or Kg/unit production, values of flow and concentration are also required.

ii) Validity/ Availability of Measured Data

Quality assurance procedures shall be used to evaluate the quality of data produced by the CEMS required for determining compliance with the emission standards on a continuous basis as specified in the Indian regulation. Reference methods will be defined to substantiate the accuracy and precision of the CEMS.

Performance Specifications will be used for evaluating the acceptability of the CEMS at the time of or soon after installation and whenever specified in the Indian regulations. The CEMS has to include continuous quality check for Zero and for scale (Span) point, preferably without human intervention, to ensure continuous data validity and credibility.

Zero check on Gaseous CEMS must be achieved by using zero air supply (usually an inert gas like N_2) done automatically and periodically. Calibration check on Gaseous CEMS must be achieved by internal or external calibration gas supply, preferably using reference gases/ blends with concentration certified by external body. The use of Certified Zero & Span Test Gas Cylinders or Gas filled “Calibration Cuvetts/ Cells”, Certified by leading global Agencies like TUV/ MCERT are also acceptable for CEMS in India. The Cuvetts/ Cells and are known to have long term stability compared to cylinders. Ambient air not being a certified gas is not recommended for calibration.

iii) Basic Requirement

The major prerequisites of efficient Continuous Emission Monitoring System are:

a) It should be capable of operating unattended over prolonged period of time.

b) It should produce analytically valid results with precision/ repeatability

c) The analyser should be robust and rugged, for optimal operation under extreme environmental conditions, while maintaining its calibrated status.

d) The analyser should have inbuilt features for automatic sample matrix change adaptation.

e) The analyser should have inbuilt zero and calibration check capability

f) It should have data validation facility with features to transmit raw and validated data to central server.

g) It should have Remote system access from central server for provisional log file access.

h) It should have provision for simultaneous Multi-server data transmission from each station without intermediate PC or plant server.

i) It should have provision to send system alarm to central server in case any changes are made in configuration or calibration.

j) It should have provision to record all operational information in log file.

k) There should be provision for independent analysis, validation, calibration & data transmission for each parameter.

l) The instrument must have provision of a system memory (non-volatile) to record data for atleast one year of continuous operation.

m) It should have provision of Plant level data viewing and retrieval with selection of Ethernet, Modbus & USB.

n) Record of calibration and validation should be available on real time basis at central server from each location/parameter.

o) Record of online diagnostic features including analyzer status should be available in database for user-friendly maintenance.

p) It must have low operation and maintenance requirements with low chemical consumption and recurring cost of consumables and spares.

The analyzer must include the following features (typical characteristics):

a) Continuous measurements on 24X7 basis.
b) Direct Measurement of pollutant concentration.
c) Expression and display of measurements in ppm, mg/m^3 or volume % as specified in standards.
d) Display of the measurement values as well as all the information required for checking/maintenance of the analyzer.
e) Display of functional parameters.
f) Lower detection limit:< 0.5% Full Scale.
g) Zero & Span drift:< 1% Full Scale / week.
h) Linearity:< 1% FS.
i) Response time < 200 seconds.
j) Power supply compatible with utilities available on Indian industrial sites.
k) Digital communication with distant computer for data acquisition/recording/reporting.
l) RS232 / RS485 / Ethernet / USB communication ports.
m) Analog Outputs for transmission to Plant's supervision center.
n) Minimum lifetime of analyzers should be 10 years/
o) Type approved according Indian Certification Scheme (or by foreign accredited institutes such as TÜV, MCERTS or USEPA).

3.2 Merits of CEMS

The major advantages of CEMS over traditional laboratory based and portable field methods are:

a) CEMS provide continuous measurement of data for long periods of time, at the monitoring site of interest, without skilled staff being required to perform the analysis.
b) All the major steps in traditional analysis like sample collection,

transportation, conditioning, calibration and analysis procedures including QC are usually automated in on-line analyzers.

c) In case of sudden disturbance in the system, the on-line analyzers provide timely information for taking immediate corrective/preventive steps compared to conventional methods.

4.0 TECHNICAL OPTIONS FOR SAMPLING OF POLLUTANTS IN CEMS

The sampling technologies are summarized in **Figure1**. Two types of systems available for monitoring of particulate and gaseous pollutant are mentioned below:-

1) In-Situ Systems: - Folded Beam/ Point
- Cross Duct

2) Extractive systems: -
- Hot Extractive Systems with Heated Analyzer (Hot and Wet System)
- Hot Extractive Systems with Sample Cooling and Cold Analyzer (Cold and Dry System)
- Extractive dilution system (Instack and out stack)

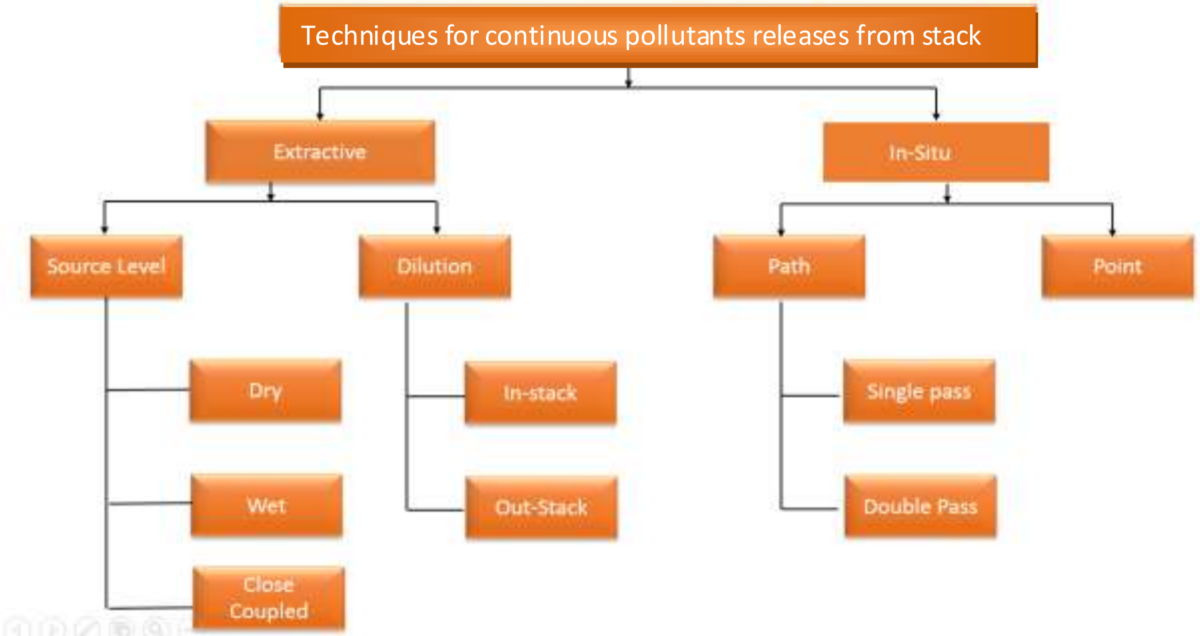
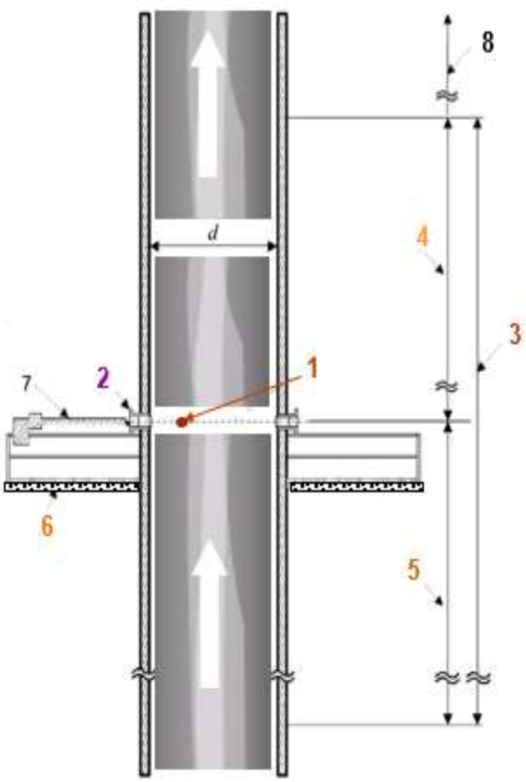


Figure 1: Techniques for Continuous Sampling Pollutant Releases from Stacks

The sampling location has major impact on the representativeness and accuracy of sample collected. Suitable measurement sites and sections are necessary to obtain reliable and comparable emission measurement results. Appropriate measurement sections and sites have to be planned while designing a plant.

Emission measurements in flue 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 pollutant being released in the waste gases can be determined. Emission measurements require appropriate sampling ports and working platforms. The installation of measurement ports and working platforms should be considered in the planning phase of a measurement section, refer **Figures 1.1 & 1.2**. Specifications of regulations along with official requirements if any, should be considered in selection and specification of measurement site and sections.



1. Measurement point
2. Measurement pot
3. Measurement section
4. Outlet (2D)
5. Inlet section (8D)
6. Working platform
7. Manual sampling train

(Note: D= Stack Diameter)

Figure 1.1: Measurement Site and Measurement Section

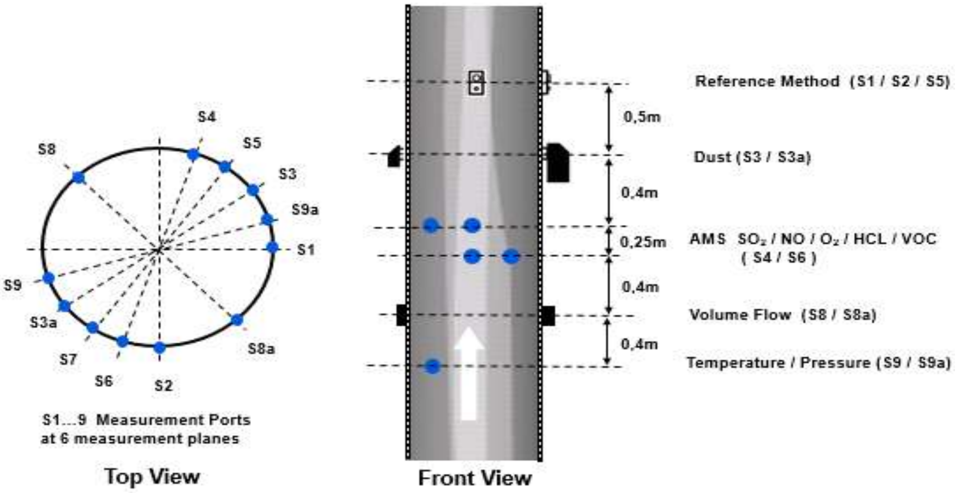


Figure 1.2 : Measurement Site and Measurement Section

The measurement site and measurement section for CEMS is based or EN 15259 criteria for selection of measuring point/ port locations and depends upon following conditions (For Details refer EN15259 Standards):

a) Whether to monitor concentration alone or gas flow also;

b) Whether the system requires periodic calibration using standard method or whether the CEMS can be calibrated by other means.

The influence of these factors in determining the positional requirements is shown in the decision tree in **figure 2**.

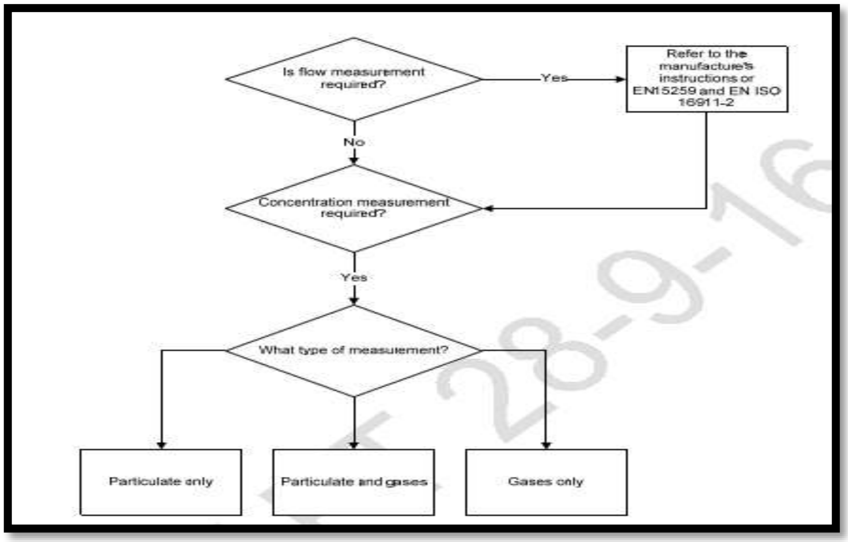


Figure 2: Selecting a sample location

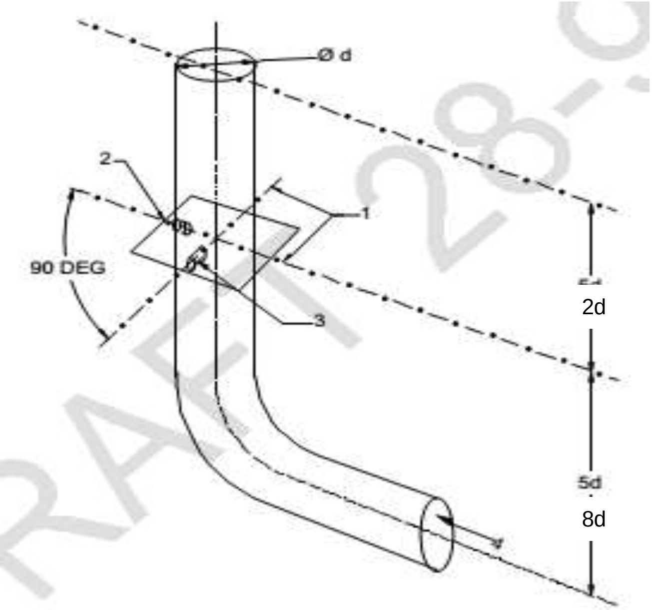
4.1 Sampling Location for Particulate Matter

The analyser/ systems installed for particulate matter monitoring require calibration performed by isokinetic sampling carried out to either BSEN 13284-1, IS : 11255 Part 1 (Particulate Matter) or EPA method 17 or EPA method 5 or BS ISO 9096:2003. The sampling location for the analyser must be in accordance with the appropriate standard.

The sampling ports for manual extractive sampling should be located approximately one hydraulic duct diameter or 500 mm upstream of the continuous monitoring port, whichever is the smaller, or alternatively the manufacturer’s guidance should be followed. The sampling position should be in a straight length of duct (**Figure 3**) where;

a) The angle of gas flow is less than 15^{o}
b) No local negative flow is present;
c) The minimum velocity is higher than the detection limit (3 m/ Sec) of the method used for the flow rate measurement (for Pitot tubes, a differential pressure larger than 5 Pa);
d) The ratio of the highest to lowest local gas velocities is less than 3:1.

If the above information cannot be verified e.g. on a new installation, then the above criteria is generally fulfilled by siting the ports in sections of duct with atleast eight hydraulic diameters of straight duct downstreams of the sampling plane and two hydraulic diameters upstream hydraulic diameters from the top of a stack.



1. Sampling line
2. Sampling plane
3. Access port
4. Flow

Figure 3: Sample Plane Requirement for Particulate Matter Measurement

4.1.1 Sampling location for systems with particulate matter and gas analysers

While selecting a location for installation of in-situ analysers in large ducts, the gas profile at the proposed sampling point must be checked for stratification. A stratification test is undertaken to confirm that the composition of the gas is homogenous. Typically, a surrogate gas such as oxygen or carbon dioxide is measured using a direct reading instrument in order to obtain information on the gas profile within the duct. The stratification test must take into account variations of gas composition with time. This can be achieved by using two continuous analysers each connected to sampling probes. One probe is placed at a fixed location in the duct; the other is used to obtain samples at grid locations across the duct. The two sets of data can then be compared in order to compensate for variations in concentration with time.

4.1.2 Sampling location for gas analysers

Selection of a sampling location for gas analysis alone is less difficult than for particulate measurement. A location in the duct where the gas is well mixed and therefore homogenous should be chosen.

4.2 Analysis of Measurement Techniques

4.2.1 In Situ system:

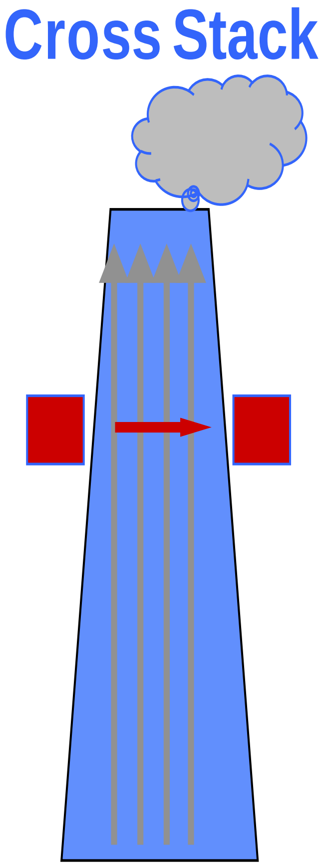
Non-extractive (in-situ) systems

In-situ type analyzers may be of two types: point in-situ type or cross stack type. These are explained below.

- Point in-situ

Point in-situ systems perform measurements at a single point in the stack, as do extractive system probes. In point in-situ systems the sensing optics are contained in a tube fitted with holes or filters to allow flow-through of stack gases. The sampling path will be relatively short compared to the stack or duct diameter, so the sampling location must be carefully chosen to ensure that the sample is representative of the flue gas.

In certain CEMS, the measurement length is extended over the length of a probe (say 500mm to 1m) to increase resolution and provide a more representative measurement.



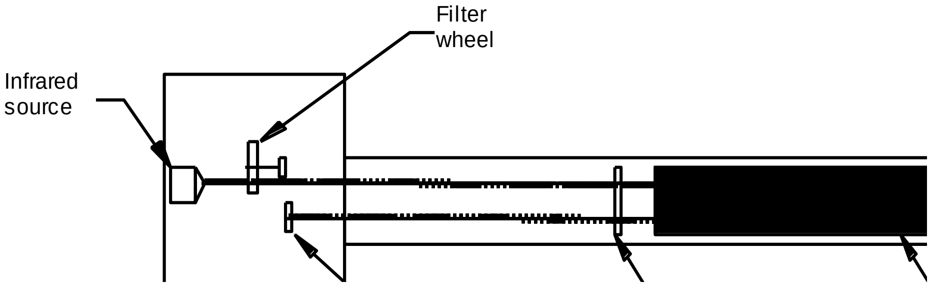


Figure 4.2.1 a: Point in-situ gas analyzer

Cross stack monitors

Cross stack monitors measure over the entire stack or duct diameter. They are based on a beam of a certain wavelength that crosses the duct and is attenuated proportionately to the concentration of the target compound. In some systems, a pipe may be used in the stack for support or calibration purposes, or to reduce the optical path lengths in very large stacks or ducts. There are two basic types of path systems: single pass and double pass where the beam is reflected back across the stack. These systems can be simpler than extractive systems, however there are additional challenges associated with making valid zero and span checks and minimizing interference from other pollutants.

Figure 4.2.1 b. Single pass transmissometer /opacity monitor

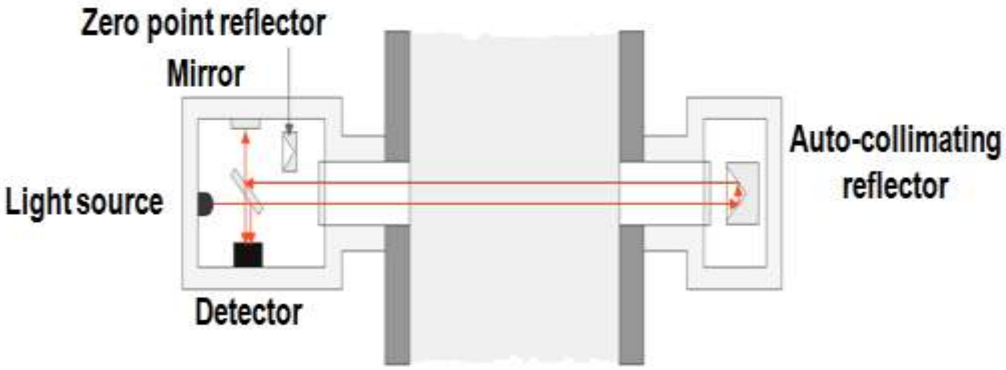


Figure 4.2.1 c. Double pass transmissometer /opacity monitor

Single beam and double beam principle- Single-beam configuration is simplest where one light beam from source is passed to receiver. Dual or double-beam configurations internally split the light emitted from the source into two beams – one becomes measurement beam and another becomes reference beam. The measurement beam is projected through the optical medium of interest and is referenced to the second (reference) beam, which is totally contained within the instrument. There can be common or separate detectors for both the beam.

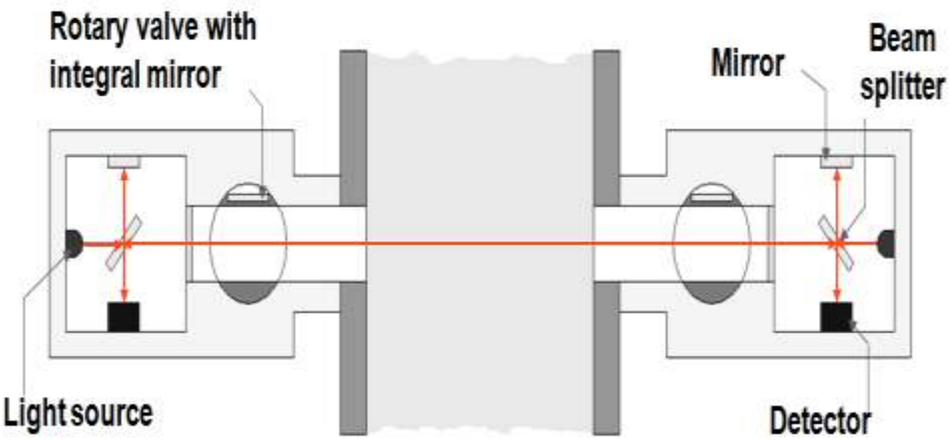


Figure 4.2.1 d: Double Beam Transmissometer (Measurement)

- **Benefits:**
  - ✓ Fast Response time
  - ✓ Reasonable cost
  - ✓ Process control
  - ✓ No sample conditioning required.

- **Limitations:**
  - ✓ Two flanges may be needed so an access to both side of stack is required.
  - ✓ Systems are subject to stack vibration and temperature variations
  - ✓ Sensitivity is limited due to the path length (critical for stacks with small diameters)
  - ✓ Limited quantity of gases can be monitored

- ✓ Analyzer is subject to cross interferences especially from Water (Moisture)/ Temperature / Pressure.
- ✓ In situ systems are installed outside at top of stack so inconvenient conditions for maintenance
- ✓ No absolute method of On Line Calibration using injection of span gases along the path length.
- ✓ Complete Calibration equipment to be installed with analyser on top of stack platform.
- ✓ Calibration checks / After readjustment the equipment has to be brought down to lab for calibration / validation checks.

4.2.2 Extractive system (Gaseous Pollutant)

Source-level extractive systems are those in which a sample of flue gases is continuously extracted and conveyed to the analyzer using a sampling line. Particulate matter may be removed from the gas, and it may be cooled and dried, but in all other respects the sample is not altered by the sampling process. Three types of source-level extractive systems are marketed commercially:

Hot and wet systems

Cool and dry systems with conditioning at the analyzer enclosure

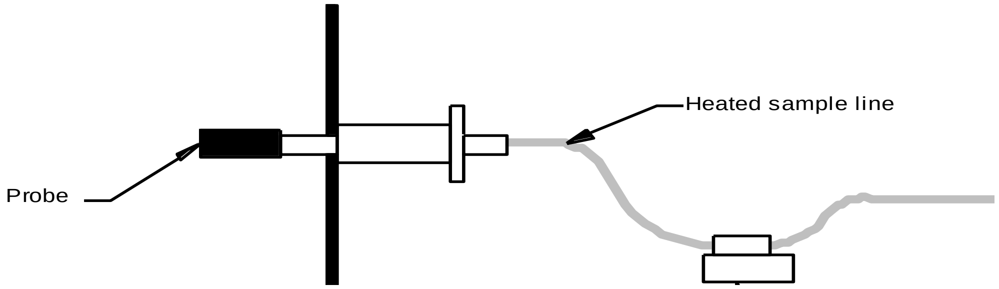


Figure 4.2.2 a: Hot and wet gas sampling system

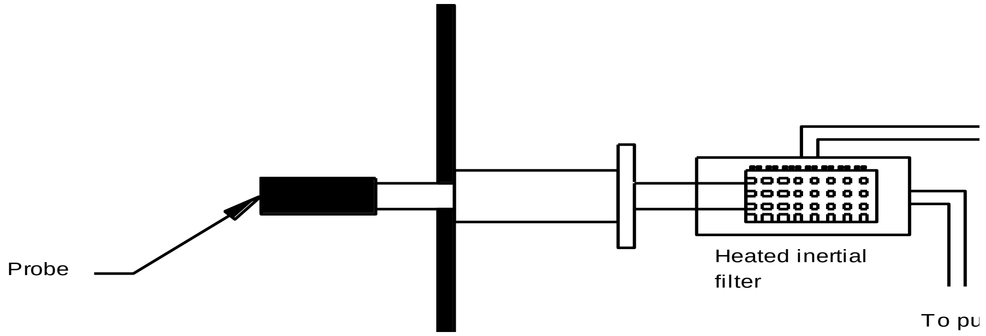


Figure 4.2.2 b: Close coupled gas analyzer

In some cases, a combination of these systems may be used, for example when there is a requirement to measure both highly reactive and less reactive pollutants concurrently.

A source-level extractive system consists of several basic components: probe, sample line, filters, moisture-removal system and pump. In some source-level systems the analyzer, for example IR analyzer, O_2 zirconia sensor or TOC Flame Ionization Detector (FID), is mounted on the stack or duct, after a short sample line. In this case, analyzer response times are very fast and apart from particulate filtering, sample conditioning is not required. These systems are known as close coupled.

- **Benefits**:
  - ✓ Sensitivity of the system is not related to stack diameter.
  - ✓ Varying stack temperature does not affect the measurements
  - ✓ Can be proven using reference calibration gases.

- **Limitations**
  - ✓ Longer response time, however meets the emission requirement.
  - ✓ The closed coupled systems are subject to stack vibration and temperature variations requiring higher maintenance as calibration also mounted on

stack, however extractive system (Hot-Wet or Dry Direct Extractive does not have this issue)

4.2.3 Dilution based extractive system

The need is to transport the sample hot, and to filter and dry relatively large volumes of flue gas. This problem can be largely avoided by using dilution systems, where gas is drawn into the probe at much lower flow rates than in a source-level system. Dilution systems are used in conjunction with ambient air level gas analyzers.

Oxygen must be measured separately for correction purposes (the diluted sample is 'swamped' by dilution air).

There are two types of commercially available dilution systems: **dilution probes**, where dilution of the sample gas takes place **in the stack**, and **out-stack dilution systems**, where dilution is carried out external to the stack. The latter is less sensitive to changes in stack gas temperature, pressure and density, however heated sample lines till out of stack dilution system.

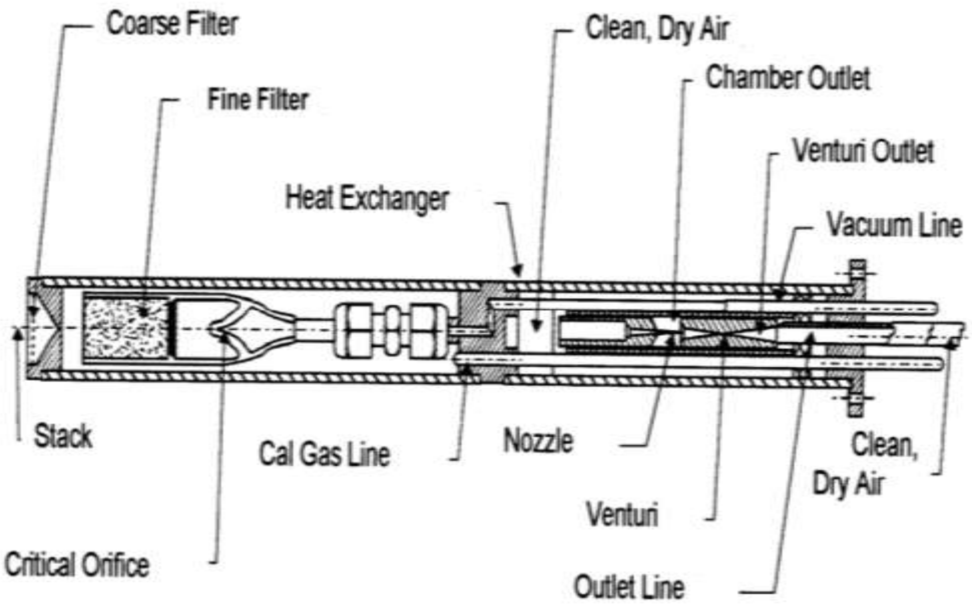


Figure 4.2.3 a: Typical in-stack dilution probe

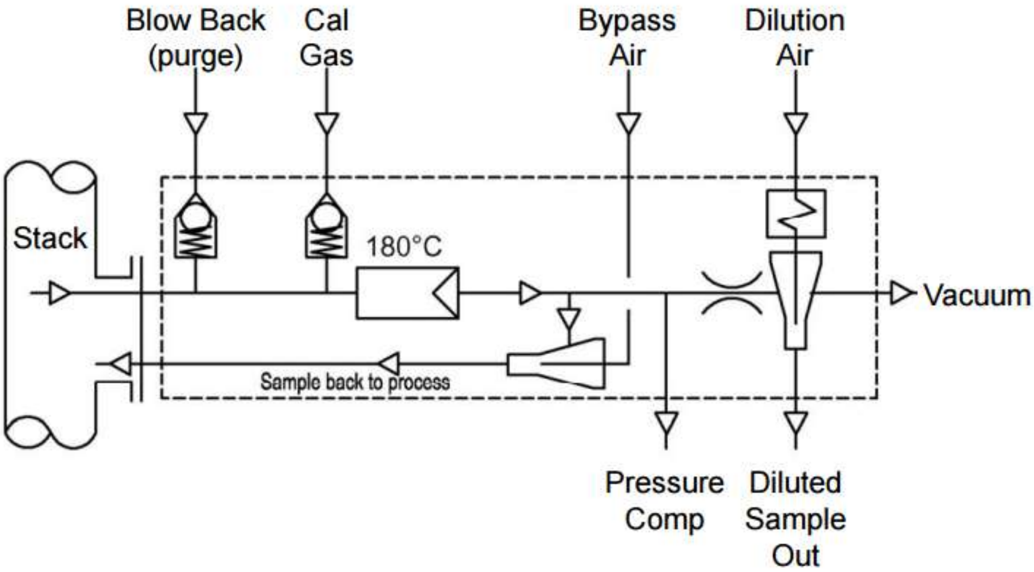
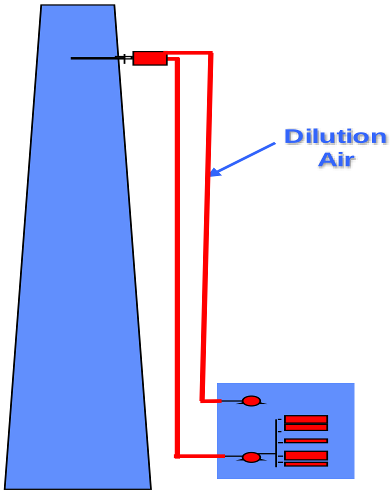


Figure 4.2.3 b: Typical out-stack dilution probe

Sample gas is extracted from the stack at a known flow rate, mixed with a known flow rate of dry air / dilutant.

- **Benefits:**
  - ✓ It can be used to reduce moisture content so no heated sampling components are required.
  - ✓ No power required at the probe so it can be used in hazardous areas.
- **Limitations:**
  - ✓ Flow rates are critical and need to be controlled to avoid varying dilution ratios.
  - ✓ Sample gas needs to be of high concentration to avoid analyzer sensitivity issues or use of air quality analyzers.
  - ✓ Cannot be used for all gases including oxygen.
  - ✓ Careful consideration of probe materials



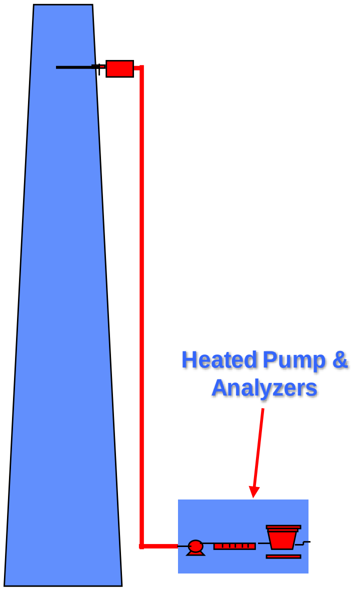
for high temperature and corrosive applications.

- ✓ Needs more maintenance due to presence of dust / ash \ sulfur presence which effect the micro critical orifice leading to erroneous measurements / higher maintenance.
- ✓ The ambient air type analyser technologies used here are not suitable for hazardous area and require elaborate care for installation like shelters for Installation & maintenance.

4.2.4 Hot Wet Extractive system with Heated Analyzer

Sample gas is extracted from the stack and transported to the analyzer using heated line and heated sampling components – filters, pumps etc., including the analyzer measurement cell.

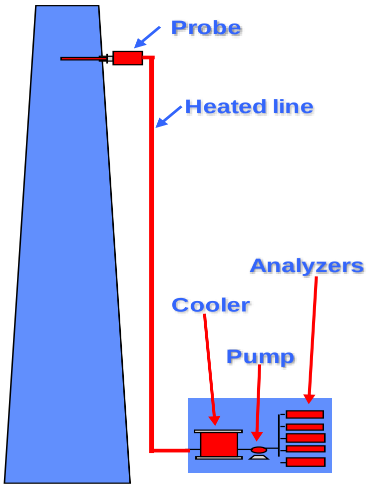
The temperature of all components in contact with the sample gas is typically at 180°C to avoid condensation and loss of soluble gases.



- ➢ **Benefits**
  - ✓ Sensitivity of the system is not related to stack diameter.
  - ✓ Varying stack temperature does not affect the measurements
  - ✓ Use technologies like FTIR that can measure most gases including NH_3, HF, HCl, VOC, H_2O and O_2.
  - ✓ Multi gases including specialty gases that are difficult to measure in other techniques.
- ➢ **Limitations**
  - ✓ Costly heated sample lines and components.
  - ✓ Heated lines not UPS protected due to power required- risk of condensation and damage.
  - ✓ More time required to maintain the system and heat stressed components.

- ✓ Online continuous H_2O measurement for online correction of moisture as normalization being a hot wet technique.

4.2.5 Hot Extractive System with Gas Cooler and Cold Analyzer



Sample gas is passed through a cooler to bring the sample gas temperature down to a low temperature and to remove water so sample is almost dry. Coolers are typically Peltier or Compressor type with outlet dew point 3°C.

- ➢ **Benefits**
  - ✓ Sensitivity of the system is not related to stack diameter.
  - ✓ Varying stack temperature does not affect the measurements
  - ✓ Multi gas measurement is possible with flexibility of different principle of measurements.
  - ✓ Can use analyzers operating at low/ambient temperatures so components are not heat stressed.
  - ✓ These analyser are versatile as suitable for harsh environments and can be placed in a clean, dry & temperature controlled environment, so more stable system and easier to maintain
  - ✓ Analyzers are running at low temperatures, so systems tend to be cheaper than heated systems and widely used concept.
  - ✓ These are also available in hazardous area installation.

- ➢ **Limitations**
  - ✓ It cannot be used on very soluble/corrosive gases.
  - ✓ Soluble gases (HCl, HF, NH_3) can be lost during the cooling.
  - ✓ Heated Sample gas line is required to maintain dew point.

5.0 MEASUREMENT TECHNIQUES FOR PARTICULATE MATTER AND GASEOUS POLLUTANT

5.1 Techniques / Instrumentation for Online PM Monitoring

Particulate Matter Continuous Emission Monitoring Systems (PM CEMS) measure a parameter (e.g. scattered light) which can be correlated to dust concentration by comparison to a gravimetric sample taken under isokinetic conditions rather than the mass concentration directly**.** The performance and suitability of any particulate monitor is therefore application dependent. A number of techniques are used in practice which provide a practical and robust solution for most industrial applications. There are two main types of Particulate Measurement Techniques:

a) In-Situ Systems for Dry Stacks
b) Extractive Systems for applications with entrained water droplets in the gas stream

1. In-situ systems

The main techniques used for Continuous Monitoring of Particulate Matter in dry stacks are: -

a) **Light Attenuation (Transmissiometry)**: In this method the amount of light absorbed by particles crossing a light beam is measured and correlated to dust concentration. In Opacity/Extinction instruments the amount of light reduction is measured directly, whereas in Ratiometric Opacity systems the ratio of the amount of light variation (flicker) to the transmitted light is measured.

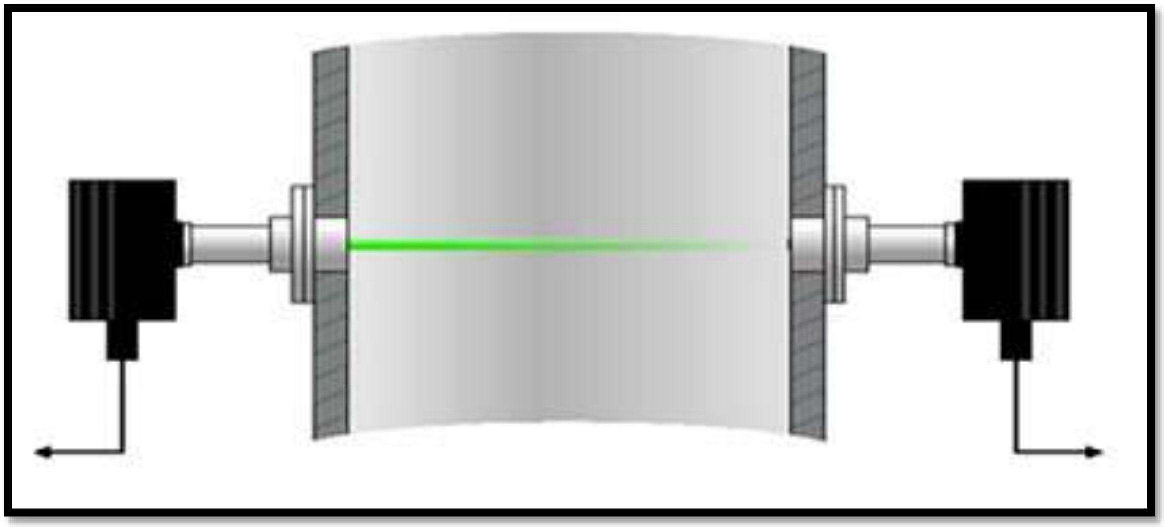


Figure 5.1 : Light Attenuation

As with in-situ path systems for monitoring gaseous pollutants, transmissometers may be single-pass or double-pass design. Double-pass types use a reflector on the opposite side of the stack or duct so that the light is transmitted twice through the flue gas. Some modern single-pass designs use two identical senders and receivers on each side of the stack to alternatively transmit and receive light in order to increase sensitivity and reduce the effects of fouling of the optical surfaces. The light sources use includes filament bulbs, light emitting diodes and lasers.

The simplest of the transmissometers will produce an opacity that can be correlated with a smoke colour scale, e.g. the Ringelmann scale. More sophisticated analysers that are equipped with on-line zero and span adjustment can be programmed to produce an output proportional to 1mg/m^{3}based on the results of calibration measurements.

Transmissometers are usually of the cross duct design with a sender and receiver on opposite sides of the stack, or with a reflector to pass the light through the flue gas twice. Point in-situ analysers have been developed in which the light source and detector are carried at opposite ends of a rigid tube. The tube contains a series of slots which allows the passage of PM-laden flue gas through the tube and hence between the light source and detector. This arrangement overcomes some of the problems associated with the cross duct systems with regard to alignment of sender and receiver and differential expansion caused by temperature variations, and stack vibrations.

Limitations of measurement: Transmissometry (Opacity monitors) is used extensively worldwide to monitor, “Opacity”. This is particularly true in the utility and power generation industries. Adoption of opacity monitors for particulate matter monitoring in stacks is less universal due to their inapplicability to the lower levels of particulate now found in industrial processes. Industries where Opacity monitors are still well accepted are the power, cement and steel industries due to their historical experience in satisfying opacity requirements. There are a number of Opacity instruments with TUV approvals for particulate measurement. Their limitations are widely accepted as follows:

- It cannot monitor particulate levels below 25mg/m^3 per meter path-length, since at low concentrations the reduction in the light beam caused by the particles is indistinguishable from the zero drift of the source/detector (i.e. variation in the intensity of the receiver with no dust conditions). This fundamental limitation makes the instrument unsuitable for many well abated emission applications (e.g. after a bag filter) as a result of the instrument requiring to measure a small reduction in a large baseline signal.
- The system is sensitive to dust contamination on the lens surfaces since it is not possible to distinguish between the reduction in light caused by dust in the stack and dust on the lenses. In practice a curtain of air (provided by a blower) is injected into the transmitter and receiver heads to keep the lens surfaces clean.
- Systems without retro-reflectors (i.e. non double-pass) are sensitive to misalignment between the transmitter and receiver.
- The calibration of the instrument changes with changes in the particle properties:

- Particle type and refractive index (mainly changes the amount of light scattering)
- Particle colour mainly changes the amount of light absorbed
- Particle size and shape (changes the amount of light scattering) manifests itself in requiring a number of regression curves to be calculated at differing process conditions and differing fuels used for combustion.

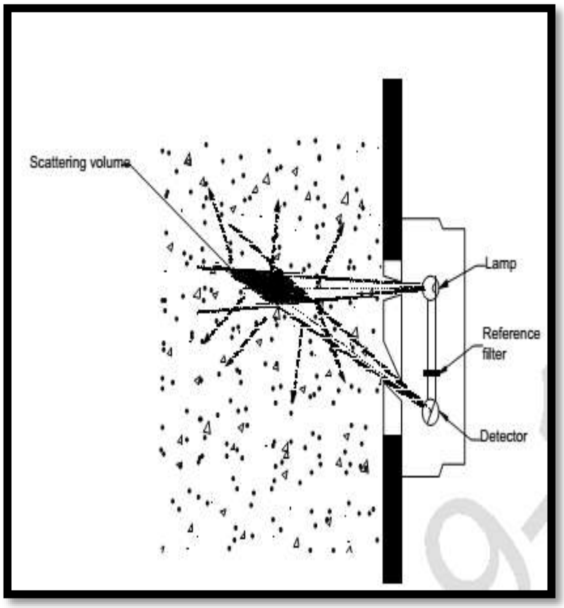
- Water vapour and water droplets absorb light over the light frequency range used by opacity monitors and therefore opacity instruments are not suitable for stacks with flue gas below dew point or containing water droplets from wet collectors. This makes opacity monitors unsuitable for monitoring particulate matter emissions from coal fired power plant applications where Flue Gas Desulphurization (FGD) plant is not fitted with stack reheat (wet FGD).

b) **Light scattering**: In this system the amount of light scattered by the particles in a specific direction is measured. Forward, side or back scatter are a function of the angle of scattered light that is measured by the detector. Light scattering techniques (especially forward scatter) are capable of measuring dust concentrations several magnitudes smaller than that measured by transmissometers.

When light is directed toward a particle, the particle may both absorb and scatter the light, deflecting it from its incident path. An opacity monitor or transmissometer measures the intensity of light that is not scattered. Other instruments have been developed to measure the scattered light. The intensity of the scattered light depends on the angle of observation, the size of the particle, its refractive index and shape, and the wavelength of the incident light. Both in-situ and extractive analysers of this type have been developed. A light beam is passed through the Particulate Matter (PM) laden flue gas. Absorption and scatter attenuate the light. Light scatter analysers measure the intensity of the scattered light at a predetermined angle to the beam direction. The amount of light scattered in any direction is dependent on the size distribution and shape of the dust particles. Variations in the intensity of the light source and sensitivity of the detector are compensated for by the use of a reference beam, in the opposite phase to the measuring beam, onto the photoelectric detector.

Scatter light measurement is a more sensitive measurement method for low dust loading. Opacity measurement at low loading is limited by the requirement to measure very small variations in the light received on the axis from the transmitter. Scatter light analysers measure only the scattered light and do not have to deal with the small variation in a large amount of transmitted light.

Instruments can be based on the forward scatter, side scatter or back scatter principles, and can be in-situ, point in-situ or extractive. This type of analyser scan claimed to be more accurate for measure low PM concentrations of upto 1mg/m^3

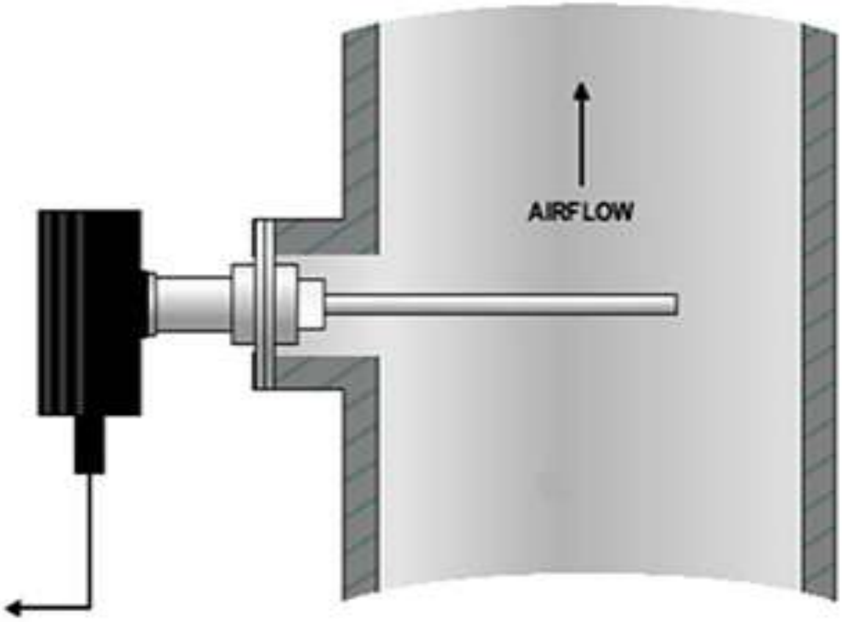


Limitations of technology: Side Scatter or Back Scatter instruments are used in low dust concentration applications, such as those found in Power plant, Lead Smelters and Incinerators equipped with bag house as pollution control systems. Their technical limitations are as follows:

- The calibration is affected by changes in particle size and type of particle. For example, with absorbing particles (such as black fly ash) the response of a Back Scatter device is reduced by a factor of 20% from peak response when the particle size changes from 0.8µm to 0.7µm. The peak response for non-absorbing particles is three times greater than for absorbing particles.

- Back and Side Scatter devices are less sensitive than Forward Scattering devices although can still provide sensitivity of less than $1 mg/m^3$.
- In-situ light scattering instruments cannot differentiate between water aerosols and solid particles

c) **Probe Electrification (Non-Optical)**: The electrical current produced by particles interacting with a grounded rod protruding across the stack/duct is measured and correlated to dust concentration. Charge induction (AC Tribolectric and Electro Dynamic) and DC Triboelectric instruments are types of probe electrification devices in which different signal and current analysis are performed. The Probe Electrification techniques are not all the same and should not be confused by each other. Electro Dynamic systems are used in Europe as Compliance devices due to their inherent reliability, repeatability and self-check capability.



Consideration should be taken when selecting Probe Electrification instruments. It should not be used after Electrostatic Precipitators as the action of the filter can affect the charge characteristics of the measured particulate causing errors in the instruments readings. Incase Tribo probe is mounted above ESP, then a Faraday Shield is placed around the entire probe length and grounded to negate the charge of flue gas particles emerging from the ESP field. All three techniques are highly sensitive and are responsive at low concentrations below 1mg/m^3. The stack diameter may be a limiting factor in probe electrification technique. The probe length shall cover atleast half diameter to make representative sampling.

Sticky, moist flue gases always pose threat to the performance, as the surface of the probe gets easily coated and restrict the charge exchange resulting in poor performance. Frequent cleaning and maintenance is required.

2. Optical Scintillation

Optical scintillation, like light extinction, utilizes a light source and a remote receiver that measures the amount of received light. The difference is that the scintillation monitor uses a wide beam of light, no focusing lenses, and the receiver measures the modulation of the light frequency due to the movement of particles through the light beam and not the extinction of light. The principles at work here are that the particles in a gas stream will momentarily interrupt the light beam and cause a variation in the amplitude of the light received (scintillation). The greater the particle concentration in the gas stream the greater the variation in the amplitude of the light signal received. The scintillation monitor must be calibrated to manual gravimetric measurements at the specific source on which it is installed. Little advance against opacity as it reduces zero and upscale drift with modulated light to eliminate effects of stray or ambient light. The transmitter and receiver are located on opposite sides of the duct; therefore, this instrument also measures across-stack PM concentration. The instrument response increases with PM concentration and can be correlated by comparison to manual gravimetric data.

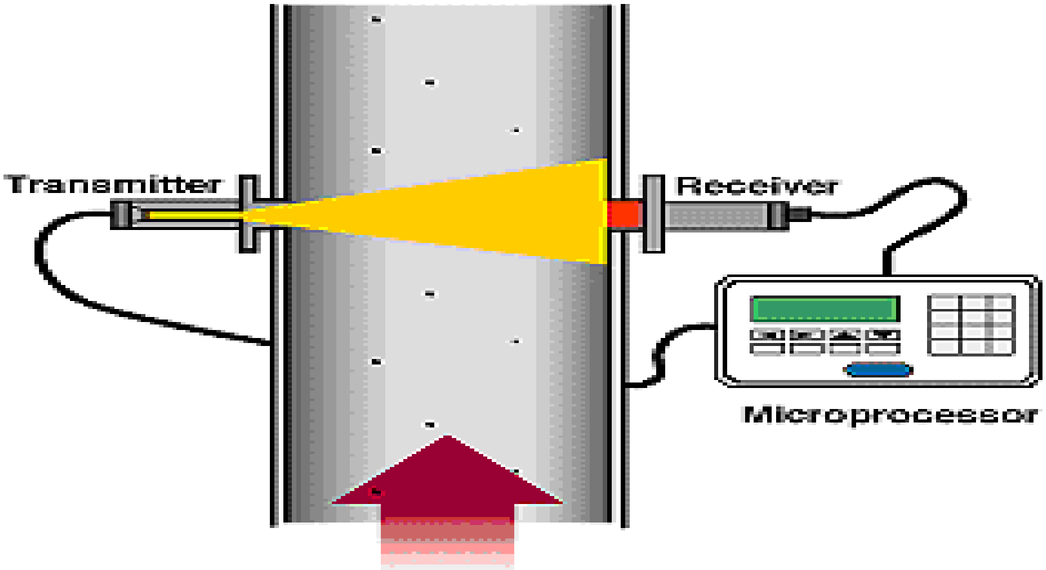


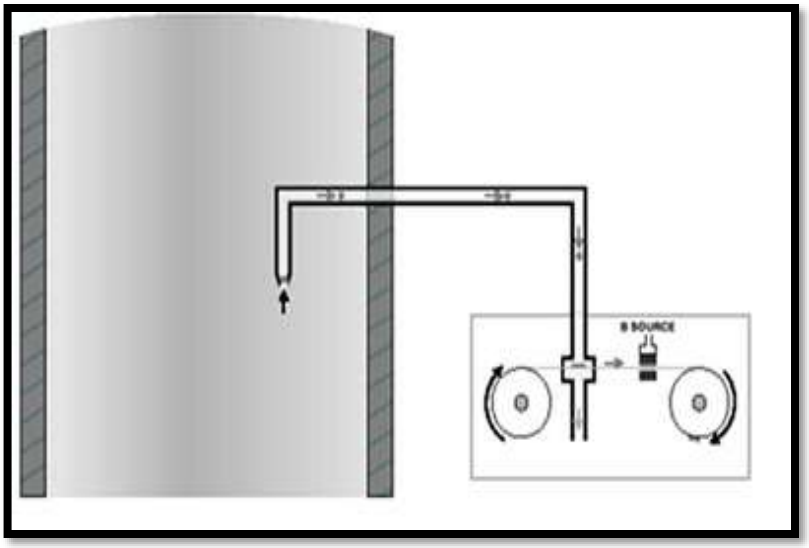
Table 3: The advantages and disadvantages Optical Scintillation

Advantages	Disadvantages
Low price	Measures secondary particles as PM
Easy to install	properties of PM Adversely affected by Particle size, density, shape change
Low maintenance	The cleaning of receiver in a dirty stack is an issue
Sensitivity to little high concentration	Not Sensitive to low PM concentration
Perform better in dry stack Moisture	Measures liquid drops as PM;

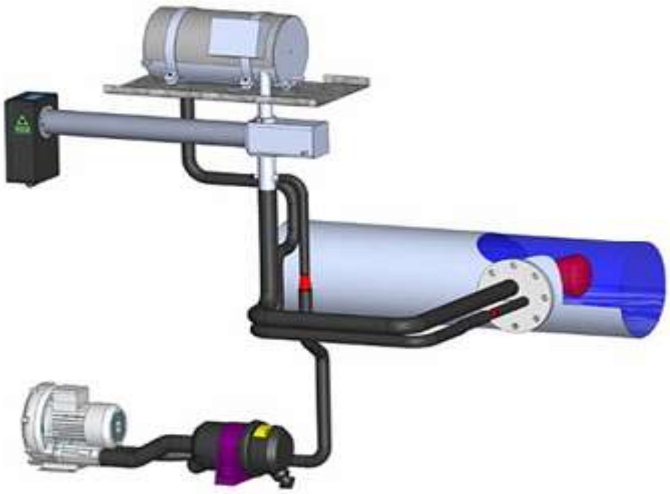
3. Extractive systems

The presence of water droplets in saturated gas streams below the dew point i.e., after wet collectors will affect the monitoring response of all in-situ technologies to an extent where calibrated results cannot be guaranteed. In these instances, extractive systems must be used. The two common methods for measuring in wet stacks are:-

a) Beta Attenuation: The moving gas stream is sampled and the particulate is collected onto a filter. The filter is advanced periodically (typically every 15 minuts) into a measurement chamber, so that radioactive Beta particles can be passed through the sample and the amount of Beta particles transmitted through the sample is measured. The advantage of this technique is that the absorption of radioactivity is not significantly affected by the type of particle (although particles with different Nucleonic density have different responses).



b) Extractive Light Scatter: The flue gas is extracted (recommended under isokinetic conditions) and then passed into a heater unit to evaporate any water or water vapour below dew point water before measurement in an external light scattering chamber. A Forward Light scattering technique is normally used in the chamber. Extractive systems have been designed to overcome the problematic issues of sample handling on a continuous basis.



5.1.1 Requirements of an efficient on-line PM CEMS

One of the fundamental issues in obtaining good results from particulate matter measuring instruments is to ensure that the instrument fits for purpose of the intended application. This means that the instrument: -

1. Must have a stable, reliable response, which can be directly correlated to dust concentration with limited cross interference from likely changes in process or flue gas conditions. Certified products provide guidance on the application suitability of different instruments. Manufacturers should be contacted for more detailed guidance on the application suitability of a specific type of instrument.
2. Can operate long term in the application without the need for maintenance or cleaning. The Maintenance Interval as stated in the certificate can provide guidance on servicing issues and longer duration tests and experience with an instrument are also very relevant.
3. The system has sufficient resolution for the intended application. The systems certificates state the ranges in mg/Nm^3 for the instrument which is the lowest dust range at which the instrument will still meet the required performance standards. Guidance should be provided on the factor allowed between the instrument certification range and Emission Limit Value (2.5 or 1.5 for low dust applications). The minimum detection level of the instrument should also be considered in relation to the normal operating condition of the plant to ensure a meaningful stable response from the instrument at normal plant conditions which can then be calibrated.
4. The operating technology should be suitable for the type of Filtration system (pollution control system) used, the diameter of the stack or duct, the dust loading and any other additional parameters (like corrosiveness, stickiness, moisture, etc.) that may affect the operation of the PM CEMS i.e. for applications with entrained water droplets an extractive PM CEMS which conditions the wet gas stream to remove the entrained liquid must be used to obtain quantitative results.

5.2 Techniques/ Instrumentation for Online Gaseous Pollutant Monitoring

The extractive type of emission gas analyzers available are:

1. Non Dispersive Infrared (NDIR)

Many gaseous pollutants absorb light energy in one or more regions of the spectrum. Sulphur dioxide / Nitric Oxide / Carbon Monoxide and a wide range of other gases absorb infrared radiation and ultra violet radiation. Each type of pollutant molecule absorbs light at a characteristic wave length, and therefore it can be distinguished from other pollutant species.

Continuous emission monitors using this principle apply the Beer-Lambert Law, which states that the transmittance of light (i.e, the ratio of the intensities of the transmitted and incident light) through a medium that absorbs it is decreased exponentially.

Heteroatomic gaseous molecules, which contain two or more dissimilar atoms in the molecule, display unique absorption characteristics in the infrared region of the spectrum. Homoatomic molecules containing only one type of atom within the molecule do not produce characteristic vibrations when exposed to light in the infrared region; therefore, they cannot be measured by this technique.

By using this principle an instrument can be designed to measure pollutant gas concentrations. Non-dispersive photometry analysers using infrared (NDIR) have been developed for monitoring a wide range of gases.

Simple non-dispersive infrared analysers use filters or other methods to measure the absorption of light over a relatively small range of wavelengths centered at an absorption peak of the molecule of interest. In a simple NDIR analyser, infrared light is emitted from a source such as a heated coil or other type of infrared radiator. The light is transmitted through two gas cells: a reference cell and a sample cell. The reference cell contains a gas such as nitrogen or argon that does not absorb light at the wavelength used in the instrument. A sample of the gas is passed through the sample cell of the instrument. As the infrared beam passes through the sample cell, pollutant molecules will absorb some of the light. As a result, when the light emerges from the end of the sample cell it has less energy than when it entered. It will also have less energy than the light emerging from the reference cell. The energy difference is detected by a detector. The ratio of the detector signals from the two cells gives the light transmittance, which can be related to the pollutant gas concentration.

Simple non-dispersive infrared analysers are still supplied for applications where only one gaseous species is to be monitored. They are relatively low cost, reliable and robust. A limitation of analysers based on this principle is that gases that absorb light in the same spectral region as the gas of interest will cause a positive interference in the measurement.

Water vapour are strongly absorbing in the infrared region and must be removed from the sample before the gas enters the analyser. One solution to this problem is to use absorption cells arranged in series, as in the Luft detector. The NDIR analysers combine with O_2 measurement for online continuous correction / normalization for any diluent of emission gases being measured by CEMS system.

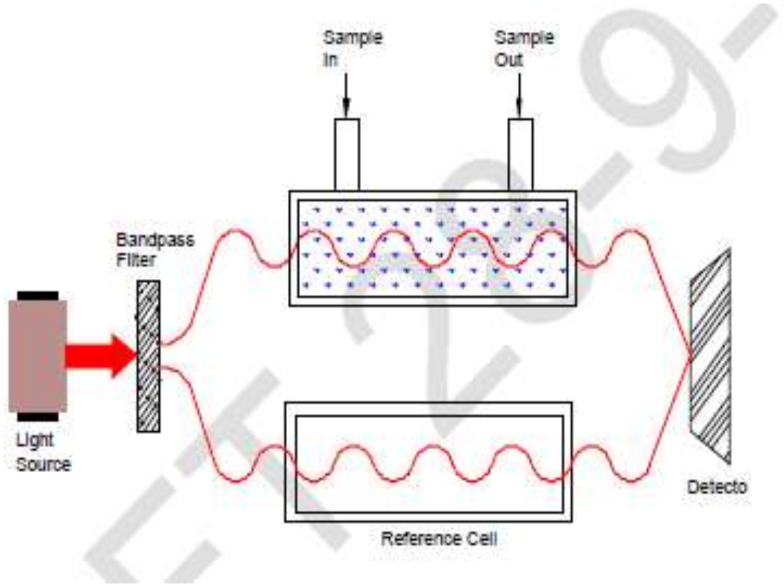


Figure 5.2 : NDIR System

2. Photoacoustic Detector

A variant of the pneumatic detector technique is the photoacoustic detector. Analysers based on this principle of operation monitor acoustic waves resulting from the absorption of chopped light by molecules in a sealed sample cell.

In a light-absorbing molecule, when vibrational-rotational energy dissipates absorbed light energy into kinetic energy, the pressure will increase in the sealed chamber in which they are confined. If the light beam is turned on and off, the pressure will alternately increase and decrease, producing a pressure pulse or acoustic signal. In practice this is achieved by placing a rotating chopper between the light source and the measurement chamber. When the chopper produces pulses between 20Hz and 20 KHz frequency, the pressure pulse can be detected by sensitive microphones.

By placing different optical filters in a carousel located between the chopper and measurement chamber, a range of organic and inorganic compounds can be measured at ppb levels. In the photoacoustic technique light absorption is measured directly, so if there is no absorbing gas in the measurement cell, no pressure pulse will be generated. If some gas is present, some sound will be generated and if more gas is present more sound will be generated.

The technique does not provide continuous analysis, as the sample must be sealed in the measurement chamber before the analysis sequence can begin. This cycle typically takes40 seconds to complete for five determinants.

3. Gas Filter Correlation (GFC) NDIR

A type of NDIR technique, which is widely used in in-situ monitors, is also applied to extractive system analysers. The gas filter correlation (GFC) technique uses a reference cell that contains a 100% concentration of the pollutant of interest, instead of the 0% concentration in the techniques discussed previously. Radiation from an infrared source passes through a filter wheel, which contains a neutral gas, such as N_2, in one cell and the gas of interest in the other cell. The light is then passed through a modulator that creates an alternating signal.

When the instrument is operating the filter wheel is continuously rotating. When light passes through the gas filter it will be attenuated. The gas filter contains enough of the target gas to remove most of the light at the wavelength where the target gas absorbs. The gases not absorbed at selected wave lengths are not removed and are passed on to the detector. The net result is reduction of light energy reaching the detector. When the light passes through the neutral cell its intensity is not reduced. If a sample of gas containing the target pollutant is introduced into the sample cell the molecules will absorb light energy at the absorption wavelength of the target gas. Because the gas filter was chosen to absorb energy at the same wavelengths, the absorption is already complete in the gas filter cell beam, and the detector will see the same signal as it did when the sample cell contained zero gas. The beam passing through the N_2 side however will carry less energy because light is absorbed by the target gas in the sample cell. The difference between the two beams is monitored, and can be related to the concentration of the gas of interest in the sample. Other gases having spectral patterns in the same regions as the target gas will not affect the measurement, as they do not correlate. Moisture has absorption and needs to be removed and adequate correction is required.

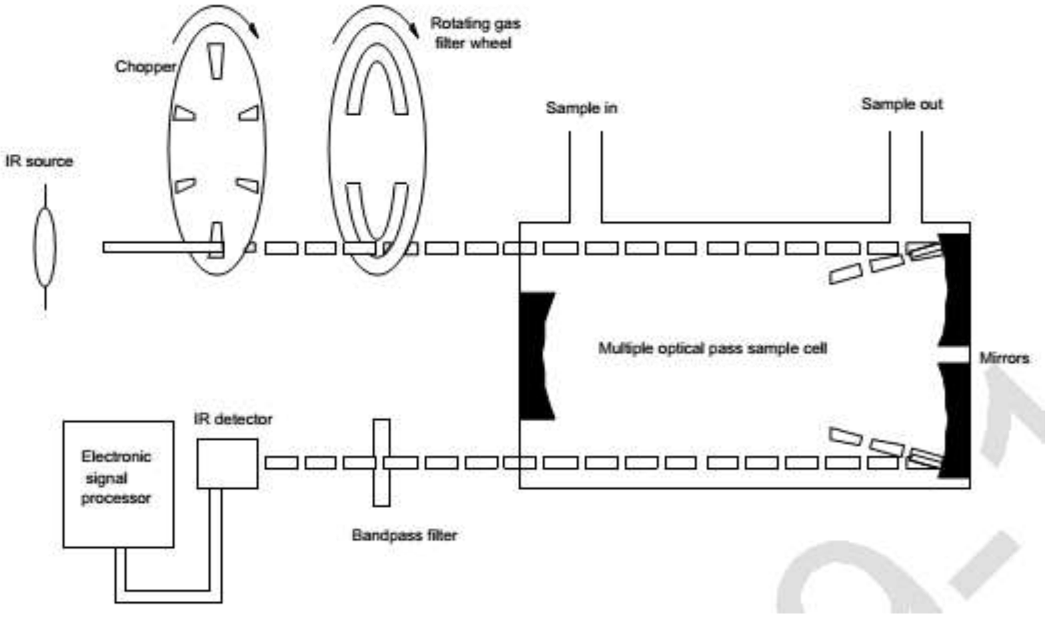


Figure 5.2.a : Gas Filter Correlation NDIR

4. Differential Optical Absorption Spectroscopy (DOAS)

Another non-dispersive method measures light absorption at different wavelengths, those at which the molecule absorbs energy and those that do not. In this system a reference wavelength is used instead of a reference cell.

This technology was initially developed for O_3 and NO_2 measurement in ambient air and extended to other ambient species. The technique, known as differential absorption spectroscopy or differential optical absorption spectroscopy (DOAS), is applicable to both extractive system analysers and in-situ systems. This open path method is used in ambient for Fence Line Ambient Air Quality monitoring over long distances; however, can be deployed as CEMS for selective monitoring.

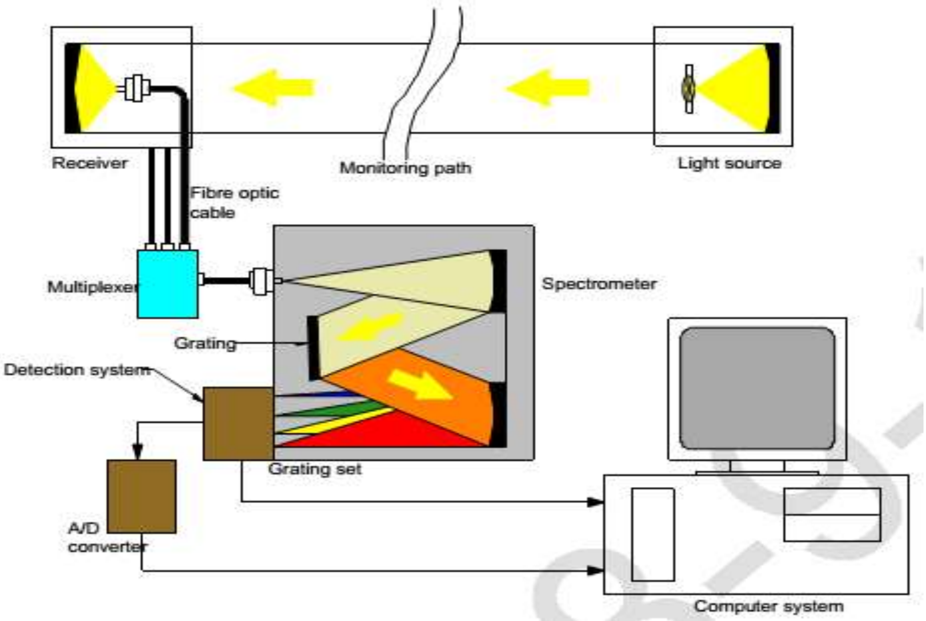


Figure 5.2.b : Differential Optical Absorption Spectroscopy

5. Fourier Transform Infrared Spectroscopy (FTIR)

Infrared-active gases, such as CO_2, CO, SO_2, NO, NO_2, HCl, HF, VOC, H_2O, can be measured simultaneously using Fourier transform IR spectroscopy (FTIR spectroscopy). Unlike in traditional spectroscopy, the absorption spectrum is not recorded by means of dispersive elements such as lattices or prisms, but using an interferometer arrangement.

Most FTIR spectrometers are based on the Michelson interferometer which has the function of a monochromator. The radiation hits a beam splitter which reflects 50 % of the radiation and transmits the remaining 50%. The reflected and transmitted beams hit two mirrors which are perpendicular to one another and are reflected back to the beam splitter. The beam splitter recombines the two reflected beams into one. The recombined beam is passed through a cell filled with the gas component to be measured and then focused on an IR detector.

Continuously shifting one of the mirrors opposite the beam splitter produces differences in the optical path length which the two beams have to cover on the way back to the beam splitter. This difference (path difference of the interferometer) produces interference in the recombined beam which results in the fundamental coding. The shifting makes the interference signal (local intensity distribution) variable (interferogram). This means the interferogram contains all the information about the spectrum in encrypted form. The absorption of the modulated IR radiation in the measurement cell means that the interferogram contains all the spectral information at the same time.

A mathematical Fourier transformation into the IR range (demodulation) is then applied to the interferogram recorded. By comparing the IR spectrum recorded to a reference spectrum, the FTIR spectrometer can quantitatively detect a number of IR-active measured objects, depending on the software version used. Once the instrument has been calibrated the calibration data are stored as a spectral library, which is stored as software. Essentially the FTIR technique provides a ‘signature’ of the total absorption spectrum of the sample gas over a broad spectral range. Instruments typically works in wavelength range from 2.5 to 25 µm.

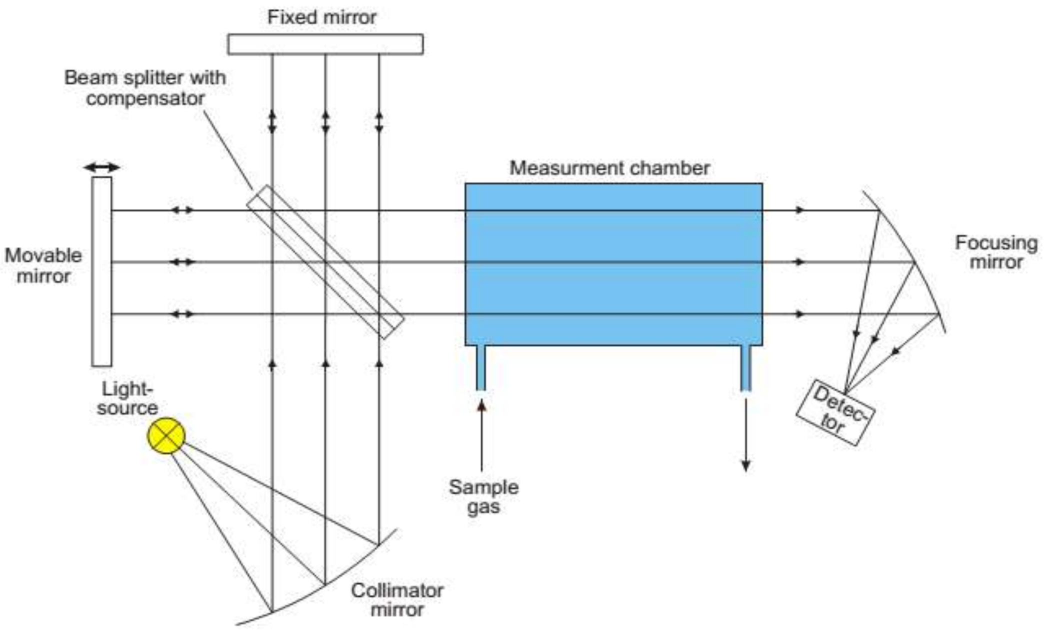
This FTIR is an advanced technology and works on Hot Wet Technique completely heated at 180ºCand has wide applications due to multi gas measurement over the IR spectrum of 2 to 25 µm and can measure CO, CO_2, SO_2,NO,NO_2, HCl,HF,NH_3, H_2O, VOC, etc. For monitoring of low concentration of NH_3, HCl and HF extractive system is preferred. Additional modules of O_2 &

VOC can also be integrated into the online measurement. Best suited for wet process with high moisture even as high as 50 – 60 Vol% in background eg. Waste Incineration, waste to power, process like Dry Cement, process using alternative fuels like pet coke, waste, bio mass, etc.

The minimum detection limit (MDL) is in parts per billion (10^{-9} ratio at atmospheres), when resolution is 0.5 cm^{-1} and optical path is 100m (**Table 1**).

Table 1: Minimum Detection Limit of FTIR Method for different compounds

Sl. No	Compound	Frequency (cm^{-1})	MDL (PPB)	Remarks
1.	Carbon Dioxide (CO_2)	2363	0.4	MDL is 0.4 ppb if no other CO_2 is present. In air, the minimum detectable change in CO_2 would be about 50 ppb
2.	Carbon Monoxide (CO)	2200-2100	2.0	Array of lines
3.	Hydrogen Chloride (HCl)	3050-2700	1.5	Array of lines
4.	Nitric Oxide (NO)	1920-1870	4.0	Array of lines
5.	Nitrogen Dioxide (NO_2)	2210	1.0	Array of Lines
6.	Sulfur Dioxide (SO_2)	1361	2.0	Spike; water must be carefully subtracted
7.	Water (H_2O)	1700-1400	5.0	MDL is 5 ppb if no other water is present. In Humid air, the minimum detectable change in water content would be 1000 ppb.



6. Non Dispersive Ultraviolet (NDUV)

The characteristics of light in the ultraviolet (UV) region of the spectrum (shorter wavelength, higher energy) lead to molecular electronic transitions when the light is absorbed. Absorption of ultraviolet photons excites the electrons of the atoms within the molecule to a higher energy state. The excited electrons quickly loose the energy by returning to the ground state by one of four methods; dissociation, where absorption of high-energy photons can cause the electron to leave the molecule completely, causing it to fragment; re-emission, where an identical photon is re-emitted as the electron decays back to its ground state; fluorescence, where a photon is emitted at a lower frequency than the original absorption as the electron decays back to its ground state, causing the gas to appear to glow.

Analysers that are designed to operate in the UV region typically employ the differential absorption technique. Analysers designed to measure SO_2 measure UV light absorption at a wavelength in the SO_2 absorption band centered at 285nm. This is then compared to the absorption at the wavelength region of 578nm where there is no SO_2 absorption.

Differential absorption NDUV instruments have proven to be very reliable in source monitoring applications and can also measure both NO & NO_2

simultaneously without need of NOX Converter. The technique has lower interferences but cannot measure other pollutants like CO / CO_2.

7. Ultraviolet Fluorescence

Ultraviolet fluorescence analysers for SO_2 are based on the absorption of UV light at one specific wavelength by the SO_2 molecules, and its re-emission at a different wavelength. Commercially available instruments contain either a continuous or pulsed source of UV radiation. Filters are used to produce a narrow waveband around 210nm. The light (photon) emitted from the exited molecules is passed through a filter and then to a detector photomultiplier tube. The amount of light received at the specific wavelength is directly proportional to the number of SO_2 molecules and is a measure of concentration in the measurement cell, provided the sample flow rate is tightly controlled. A problem with this measurement principle is the 'quench effect' caused by the capture of the emitted radiation from the SO_2 molecules by other molecules present in the gas e.g. CO_2, O_2, $N_{2,}$ etc. The quenching effect varies depending on the molecule involved and it is therefore very difficult to compensate for this effect when the matrix gas containing SO_2 has a time variable composition, eg. a boiler flue gas. This effect has limited the use of this type of analyser for emission monitoring purposes, however it has found wide application as an ambient air analyser for SO_2 where the matrix gas, i.e. ambient air, does not vary significantly in composition.

UV fluorescence analysers can be used for emission monitoring purposes at Large Combustion Plants (LCPs) if a high ratio dilution sampling system as described earlier is used. In case of measurement of SO_2 concentrations in the stack gases, the quality of the dilution air significantly affects the measurement result. Besides inability to measure components like O_2, CO, CO_2, etc. is its limitation compared to other techniques like NDIR/NDUV with capacity for multi gas measurements.

8. Flame Photometric

Flame photometric analysers are specified in Environment Agency Technical Guidance NoteM2 for the measurement of total sulphur. The technique is non-selective, and is not specific to SO_2. It is therefore rarely used for continuous monitoring, but is a popular technique for Total Sulfur measurement as an online ASTM Technique.

9. Chemiluminescence Analysers

Chemiluminescence is the emission of light energy that results from a chemical reaction. It was found in the late 1960s that the reaction of nitric oxide (NO) and ozone (O_3) produced infrared radiation from about 500 to 3000nm. It lost its status due to interferences / Quench Effect of CO_2/ Moisture and additional accessories like Ozone generators, pumps etc besides inability to measure measurement components like SO_2, CO, CO_2, etc. compared to other techniques like NDIR/NDUV which can do multi gas measurements.

Nitrogen dioxide (NO_2) does not participate in this reaction and must be reduced to NO before it can be measured by this method. Most commercial analysers contain a converter that catalytically reduces NO_2 to NO. The NO (converted from NO_2) plus the original NO in the sample is then reacted with O_3 as described above to give a total NO + NO_2 (NOx) reading.

Chemiluminescence monitors are well established for the monitoring of NOx. The method is also well established for ambient air monitoring. These monitors have very low detection limits (of around 0.1 ppm) and a wide range (up to 10,000 ppm), plus a short response time of a few seconds. This type of system has found wide acceptance in Ambient Measurement for very low concentration levels. In North America the system is used with conventional sampling systems and also with high ratio dilution samplers. For high concentration stack gases, the system is not popular in Europe as it requires dilution technique for diluting the high concentrations in Stack gas by extractive dilution system.

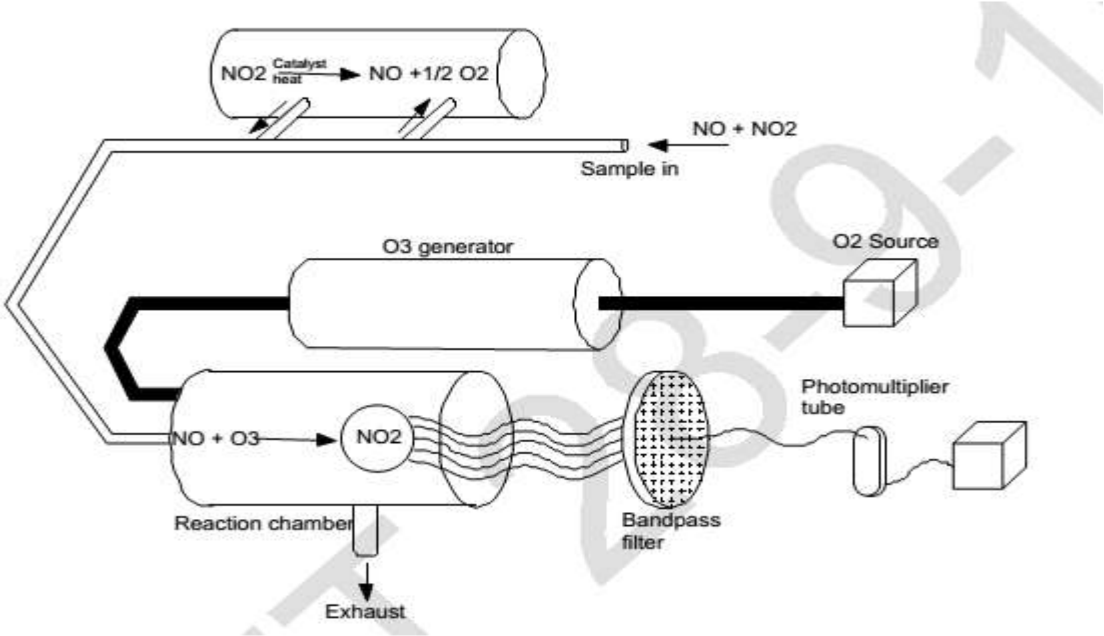


Figure 5.2.c : Chemiluminescence Analysis

10. Derivative/ Laser Spectroscopy

Derivative/LASER spectroscopy involves scanning a spectral absorption peak and obtaining its second derivative or higher derivatives with respect to wavelength at the peak maxima. The derivative peak is measured, and this has the effect of increasing the detection sensitivity of the measurement. In analysers using this technique either the originating light from the light source is modulated or the light seen at the detector is modulated. This modulation produces a signal at the detector that is dependent on the shape of the absorption curve of the molecules.

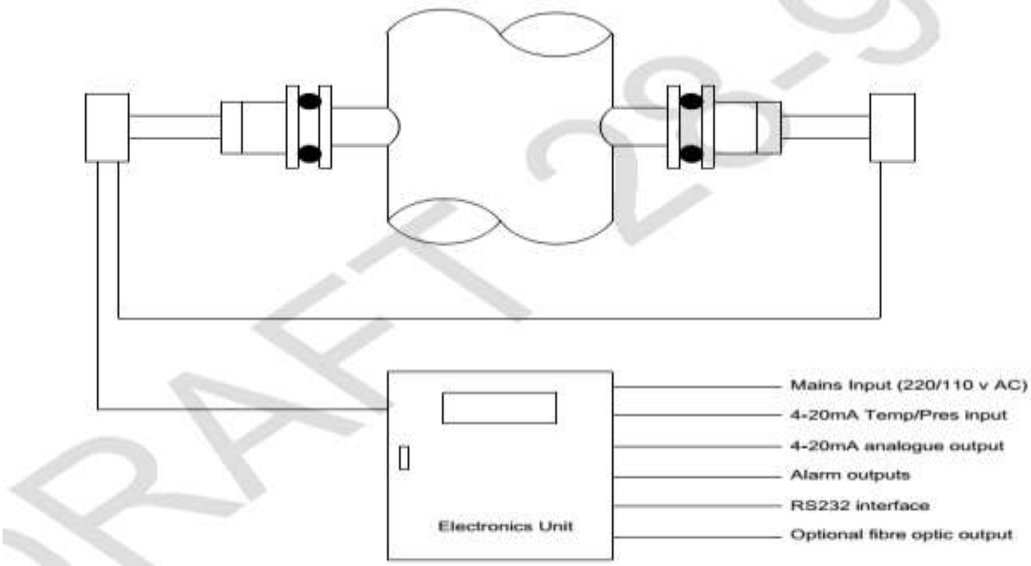
Scanning over the absorption spectrum produces harmonics of the absorption line. The second harmonic of the signal is usually used to measure the concentration of the absorbing gas. The amplitude of the second harmonic is proportional to the second derivative of the intensity with respect to the wavelength.

Tuneable diode lasers (TDL) have been used in extractive, path in-situ, point in-situ and close-coupled monitoring designs using second derivative detection techniques. A simple diode laser system can employ the differential absorption technique, tuning the laser to different wavelengths by changing the laser temperature or its driving current.

Large interferences of gases may influence the measured concentration. This is due to line broadening effect as a result of molecular collisions. Different types of molecule may broaden the absorption line differently. Modern TDL analysers automatically compensate for this effect using digital filtering techniques.

An interesting aspect of the technique is its ability to measure oxygen concentration. As mentioned previously, homoatomic molecules such as O_2do not exhibit unique absorption characteristics in the infrared region of the spectrum. By using the derivative spectroscopic technique, the spin of electron is modified can be detected.

If oxygen is to be monitored using this technique, it is important to use pure nitrogen rather than air to purge the sensor 'windows', as the presence of oxygen in the purge gas will interfere with the measurement. Alternatively, it may be possible to correct the interference introduced by the purge air by calculation. In this technique the total path length, the path length containing purge air, the path length containing flue gases and the temperature of the purge air and flue gases are measured, and the data are used to discriminate between oxygen present in the purge air and oxygen in the flue gases. Advance TDL techniques like CRDS (cavity ring down spectroscopy) or ICOS (Cavity Off-Axis Spectroscopy) are very stable at as low as ppb levels.



11. Flame Ionization Detector

The Flame Ionization Detector (FID) is the standard method for the measurement of Total Hydro Carbon (THC) / Total Organic Carbon (TOC)/ Volatile Organic Compounds/ carbon (VOC). The FID is capable of sensing most organic compounds and because of its relatively high sensitivity; it has become widely used in environmental applications.

In a typical FID the gas sample enters the base of a combustion chamber, where it is mixed with either hydrogen or a mixture of hydrogen or O_2 10% and helium. A mixture of hydrogen and helium is used in order to reduce oxygen synergistic effects; however, more fuel gas is required with this approach resulting in shortened operating times. An alternative technique employs ceramic material to construct the burner nozzle; in this case pure hydrogen may be used for the fuel gas. The mixture is burned in a jet with oxygen.

The flame produces ions and free electrons. A current is applied between the burner and a collector plate, and the ions and free electrons increase the current flow in the circuit, which is sensed by an electrometer. The current is approximately proportional to the number of carbon atoms entering the flame; as the response of the detector is slightly different for different types of organic compounds, the detector must be calibrated for the compounds being analysed to achieve the best accuracy.

The FID is selective and convenient to use in source sampling applications, since it does not respond significantly to other gases in the sample such as N_2, water vapour, CO, SO_2 and NO. However organic compounds that contain nitrogen, oxygen or halogen atoms may give a reduced response. The FID based system applicable for CEMS is hot- wet extractive, as a heated measurement.

12. Photo Ionisation Detector

In a photo ionisation detector (PID), a light in the UV region of the spectrum ionises organic molecules. The major components of the flue gas sample such as O_2, CO, N_2, CO_2 and water vapour are not ionised by the UV source. A typical

PID analyser consists of a UV lamp and a pair of electrodes to measure the current proportional to the concentration.

Different molecules require different energies to photoionise, and the frequency of the light used in the PID may not ionise all of the organic species present in the sample. UV lamps of varying intensities are used to monitor complex mixtures of organic compounds.

PIDs are used in conjunction with gas chromatographs, or alone as portable analysers, where the technique can be used to produce extremely rugged and compact instruments. However, as the PID technique can be non-selective, analysers of this type are usually used as screening devices.

13. Gas Chromatography

Gas Chromatography (GC) is used to isolate the individual components of a mixture of organic and inorganic compounds from each other for subsequent identification and quantitative analysis. GC is based on the selective distribution of compounds between a stationary phase and a mobile phase (carrier gas). In the process, the moving gas phase passes over a stationary material that is selected to adsorb the organic molecules contained in the sample gas depending on polarity. The stationary phase can be either liquid or solid, and is contained in a long thin tube, commonly known as a ‘column’. Columns are made from fused silica, glass or stainless steel.

In an ideal column operated under ideal conditions, each molecular species will exit the column at a different time depending upon molecular weight and polarity. Selecting the appropriate column and operating it under the appropriate temperature with a suitable carrier gas flow rate will enable separation of the gas sample into its individual components. It should be noted that the technique is not truly continuous.

The compounds separated in a chromatographic column must be detected and quantified. Many types of detectors are available; the most common by used in source monitoring applications are TCD, FID, PID, FPD, etc.

Analysers based on the principle of gas chromatography are complex and expensive. Although portable versions are available, they are not often used for the continuous measurement of organic compounds in emissions to atmosphere from LCPs and waste. Gas Chromatography techniques have been most popular technique in the Petroleum Refining/Petrochem industry for process measurements.

14. Zirconium Oxide (ZrO_2) Analyzer for Oxygen measurement

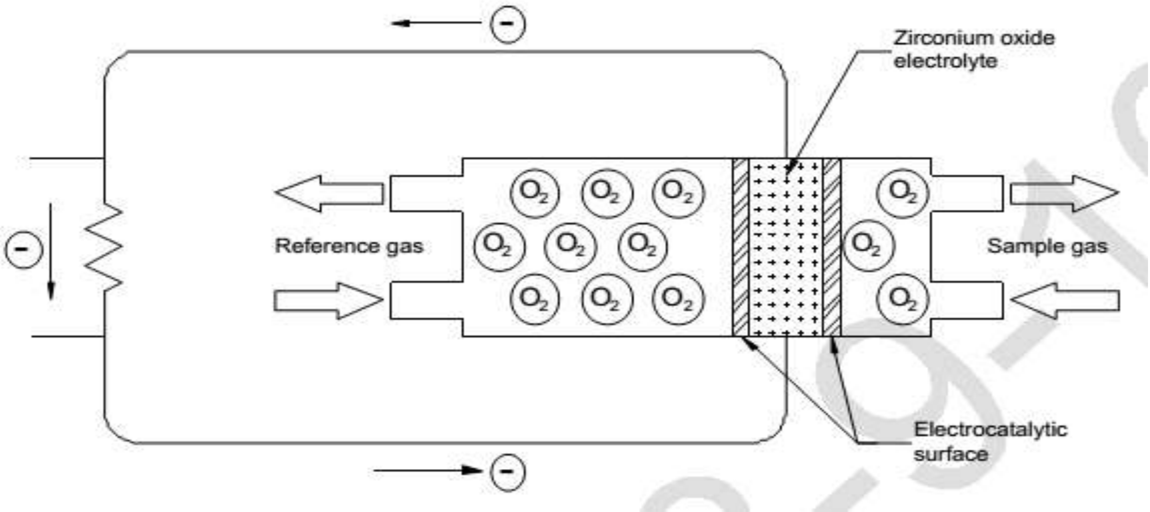
Analysers using ZrO_2 for the measurement of oxygen concentration in flue gases can either be in-situ, i.e, the measurement cell is in the stack; extractive on-stack, i.e, the cell is mounted on the stack with a sampling probe protruding into the flue gas; or extractive with the cell mounted in an analyser some distance from the stack.

In this method ceramic material, Zirconium Oxide (ZrO_2) coated with a thin layer of platinum, acts as an electrolyte to allow the transfer of oxygen from one side of the cell to the other. In the cell the oxygen concentration in the reference side is maintained at 21%. When the sample side of the cell is exposed to flue gases, the oxygen concentration in the sample side will be less than in the reference side. When ZrO_2 is heated to around 600°C, oxygen ions can migrate through the material, releasing electrons in the process. This results in the generation of an electromotive force, which is proportional to the difference in oxygen concentration between the two sides of the cell. If the reference oxygen concentration is known, the sample concentration can be calculated. The main characteristics of these analysers are:

- Very accurate and reliable measurement of O_2;
- A fast response time (for in-situ measurement) makes it ideal for process control applications;
- It is a well-understood technology with examples at most boiler plants (for combustion control);
- It has a low capital cost and low maintenance;

- The measurement is on a wet basis. The level of water vapour must be known to calculate the concentration on a dry basis.

It should be noted that the electrical output of the ZrO_2 cell is zero when both sides of the cell contain ambient air. The output of the cell increases as the oxygen content in the sample side of the cell is reduced. Thus it is normal practice to 'zero' ZrO_2analysers at the 'air point', i.e, 21% oxygen.



15. Paramagnetic Analysers for Oxygen measurement

These extractive type analysers make use of the paramagnetic properties of oxygen for the measurement of concentration. Oxygen has a relatively strong permanent magnetic moment, which can be used to influence flow patterns of sample gas within an analyser.

The general characteristics of the extractive paramagnetic analysers are:

- Accurate and reliable measurement;
- Measure on a dry basis as part of an extractive system, therefore providing correct reference values for other extractive systems;
- Can be installed in the same sampling train as other analysers making use of common components, e.g. coolers, filters etc. This also ensures that sample contamination by air in-leakage to the sampling system is taken into account; and

- Usually situated adjacent to other analysers, so can be part of an integrated monitoring package.

The types of paramagnetic analysers available are:

15.1 Paramagnetic Thermo-magnetic (Magnetic Wind) Analysers for Oxygen measurement

This method uses the temperature dependence of para-magnetism to generate a magnetically induced gas flow (magnetic wind), which is then measured. The sample gas to be analysed flows through a two-chamber system, consisting of sample and reference chambers. The two chambers hold temperature-dependent resistors that form part of a wheat stone bridge having thermodynamically identical conditions. The sample chamber is located in the field of a permanent magnet, while the reference chamber is not.

The bridge is connected to a constant current source. When oxygen-free gas flows through both chambers, the thermodynamic conditions in both chambers remain identical. If the gas in the sample chamber contains O_2, an enhanced circulatory flow proportional to O_2 content is established in the sample chamber. This disturbs the temperature dependent balance of the bridge circuit creating a DC signal proportional to O_2 content of the sample gas.

These analysers have a low maintenance requirement and are generally cheaper than other types of paramagnetic analysers. Because of the dependence of the principle on the thermal conductivity and specific heat of the sample gas, the composition of the background gas must be taken into account during calibration. The response time is also relatively slow.

15.2 Paramagnetic Automatic Null-Balance Analysers

The oxygen molecules in a flowing gas sample will establish a partial pressure gradient in a magnetic field. This gradient can be used to exert a force on a small dumbbell shaped body located within the field. The torque on the dumbbell causes a displacement that is detected by a mirror and photocell assembly, which measures its angular position. Compensation current produced as a function of this position results in an electromagnetic torque counteracting the measurement torque and tries to restore the dumbbell to its original position. This compensation current is proportional to the O_2 content of the sample gas.

This measurement principle can achieve high sensitivity and accuracy. Analysers of this type have become a standard for flue gas analysis and are also type approved for emission monitoring.

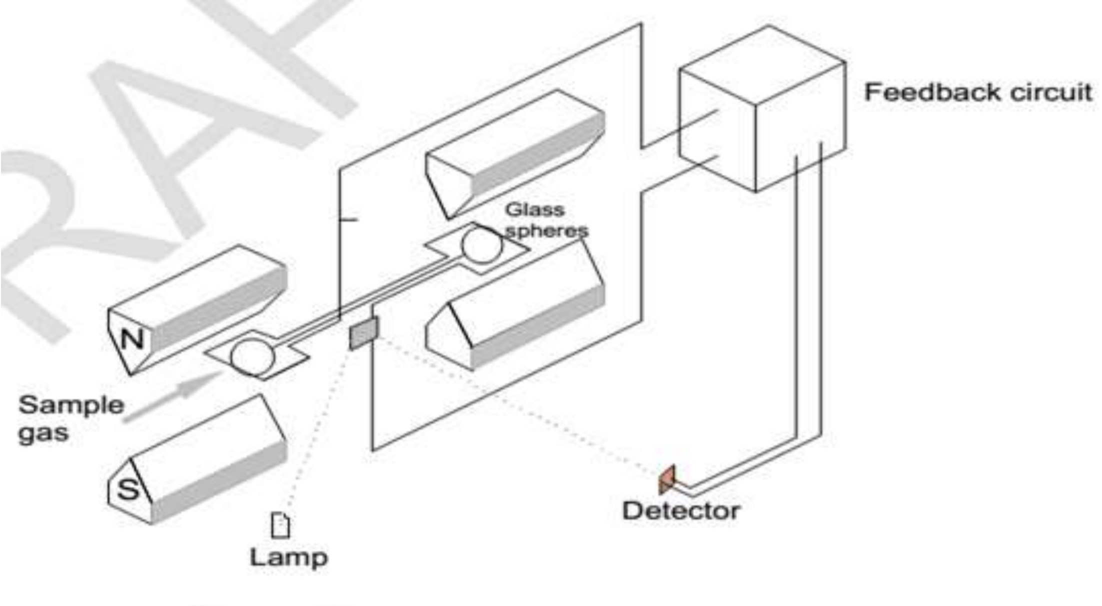


Figure 5.2.d : Magnetic Null-Balance Analysis

16. Electrochemical Fuel Cells for Oxygen Measurement

In recent years a wide range of portable flue gas analysers based on electrochemical fuel cell technology are available. In certain multi-component analyser applications, O_2measurement is made using these cells. A typical cell used for the measurement would be of the metal air battery type comprising an anode, electrolyte and an air cathode.

Reaction take place at the anode and cathode. During reaction, current is generated which is proportional to the oxygen content of the sample gas. The cross sensitivities of this cell are minimal and the use of gas filters, as used for CO or SO_2 measurement with electrochemical cells, is not normally required. Additionally, the problem of overloading (where the concentration is well above the measurement range) that causes problems for other sensors is not a problem for the O_2 cell due to the nature of the combustion process, as O_2 concentration in excess of 21 % are not possible.

Recent advances have led to O_2 cells designed for continuous use that have been incorporated into the continuous analysers discussed above. Measurement of O_2 would appear to be the most reliable and accurate measurement that can be made with flue gas alalyser using fuel cell technology. This is approved technique with TUV/MCERT for O_2 measurement for normalization of CEMS measurement as it does not monitor pollutant but O_2 as a diluant for normalization.

6.0 FLUE GAS FLOW / VELOCITY MONITORING TECHNIQUES

Most commercially available flue gas flow monitors operate using one of the five principles for measuring velocity and volumetric flow: ultrasonic pulse detection, differential pressure, thermal detection (convective cooling), audible acoustic detection and optical scintillation. The five varieties of flow monitors are stack or duct mounted and operate as a component (including a microcomputer, pressure transmitters, and temperature transmitters) of a system. Other types of flow monitoring systems are available:

6.1 Ultrasonic Flow Monitors

The volumetric flow rate of stack gas is measured by transmitting ultrasonic pulses across the stack in both directions. Ultrasonic flow monitors are also available in probe design with the instrument being installed on one side of the stack only, while having a shorter measurement length to cross stack instruments, these instruments have the advantage of not needing mounting and platforms at two different heights on the stack.

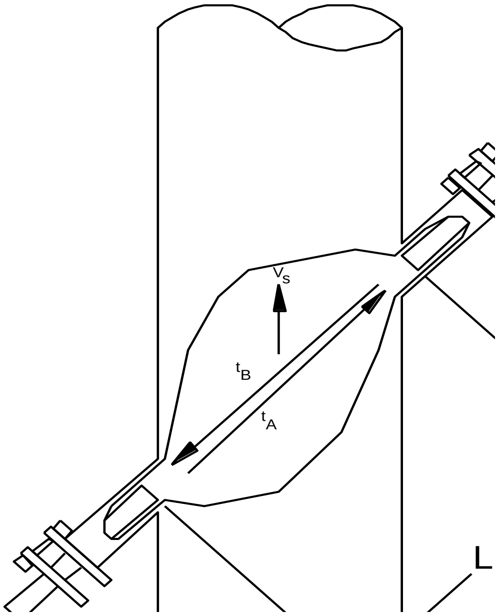


Figure 6.1: Ultrasonic Flow Monitor

The tone pulses are accelerated or retarded due to the gas velocity in the stack. The time required for traversing the distance of the stack with and against the flow is a function of the sound velocity and the effluent velocity. Stack flow can be calculated based on the difference in the time required to traverse the stack in both directions. The ultrasonic pulses must traverse the stack or duct at a minimum angle of 10 degrees; however, traverses between angles of 40 and 70 degrees tend to provide the best results, as long as the traverse path length is not so long that the ultrasonic pulses become difficult to detect.

6.2 Differential Pressure Flow Monitors

The S-type Pitot tube is designed as per the design of Stausscheibe or reverse type Pitot. The probe is constructed of two in-line tubes. The sampling point of the probe consists of two opposing open faces perpendicular to the traverse axis. A side view of the probe resembles two stacked tubes with the ends tapered away from one another and the openings planed parallel to the horizontal axis. The Fechheimer Pitot probe consists of flow sensors mounted on two multipoint averaging manifolds. The probe design consists of two manifolds (tubes) welded together with a truss plate. The truss maintains a distance between the manifolds in a plane perpendicular to the flow and the stack wall. One manifold averages multiple points of impact pressure, and the other averages multiple points of wake pressure. The impact and wake pressure averages are registered by the flow transmitter. This technology is used in numerous gas flow monitoring applications other than flue gas. Other types of noncontact flow monitors are also available in market.

6.3 Thermal Flow Monitors

Thermal flow monitors measure the electric power required to maintain a constant temperature of approximately 24 to 38ºC above the exhaust gas temperature in a flow sensor. The monitors are available for both single-point and multipoint analysis, and non- sensing components of the systems can be constructed from various corrosion- resistant metals.

6.4 Infrared Correlation

Light based noncontact devices are also suitable for velocity measurement in flue gas.

Table 2: Flow Meter Selection Matrix

Parameters	Types of Flow (Velocity meter)				
	Impact Differential Pressure (Pitot Tube)		Thermal anemometer[1]	Bi-directional ultrasonic	Infrared correlation
Irregular Flow	Single point	Multiport			
Wet stack	×	✓	✓	✓	✓
Max Flue Gas Temperature	Up to 1200°C	Up to 12000°C	200 – 300 ºC (model specific)	450° C - 850°C (model specific)	Up to 1000 ºC
Low speed	×	3 m/s	×	✓	✓
High Speed	×	35 - 50 m/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 aThermal 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.

7.0 ASSESSMENT OF MONITORING TECHNOLOGIES

The suitability of the technologies/instrumentation for monitoring the stack emission quality in different matrices, considering the limitations of the technologies, the varying Indian environmental conditions were assessed. Issues related to the utilities and maintenance required, operating costs, etc., wherever available were also considered. The comparative chart depicting working limitations, including, specifications of above said technologies for measurement of particulate matter and gaseous pollutant is depicted in **Table-3** and **4**.

Table-5 depicts the composition analysis of available technologies for measurement of particulate matter and gaseous pollutants, while **Table-6** depicts CEMS technologies suitable for different categories of Industries.

The prevailing industry specific emission standard and stacks in industries where CEMS are to be installed along with the CEMS options available for monitoring are presented in **Table-7**. Various technologies available and suitable for monitoring pollutants in specific matrices are given in **Table-8**.

Table 3: PM CEMS Technology Applications and Limitations

Measurement Technology		Technology	Stack Diameter (m)	Concentration (mg/m^3)		Filter Type	self-checks		Dry	Humid	Wet	Type of Dust		Velocity Dependant
				Min	Max		sensor contamination check	zero & span				Same	Changing	
Probe Electrification	Charge Induction (AC)	ElectroDynamic	0.2 - 4	0.05	1000	Bag, Cyclone, Drier, Scrubber (5) None (6)	✓ (7)	✓ (7)	✓	✓	x	✓	x	No (8)
	Contact Charge Transfer (DC)	DC Triboelectric	0.2 - 2	1	1000	Bag cyclone None (6) ESP (10)	x	x	✓	x	x	✓	x	Yes
	Combination AC & DC	Combination AC & DC / Tribo	0.2-2	1	1000	Bag, Cyclone None (6)	x	✓ (7)	✓	x	x	✓	x	Yes
Transmisometry	Ratiometric Opacity	DynamicOpacity	1 - 15 (1) (2) (7)	10 (3)	1000	Bag (1), Cyclone, EP, None	✓	✓ (7)	✓	x	x	✓	x	No
		Dynamic Detection Principle	1 - 10 (1) (2)	20	1000	Bag (1), Cyclone, EP, None	✓	x	✓	x	x	✓	x	No
	Opacity	Opacity	2 - 10 (1) (2)	30 (4)	1000	EP, None	✓	✓	✓	x	x	✓	x	No
		Non Comliance Transmittance	2 - 10 (1) (2)	30 (4)	1000	EP, None	x	x	✓	x	x	✓	x	No
Scattered Light	Scattered Light (Forward)	ProScatter	1 - 4 (2)	0.02	300	Bag, Cyclone, EP & none	✓	✓	✓	x	✓ (9)	✓	✓ (12)	No
		Other Forward Scatter	1 - 3 (2)	0.1	200	Bag, Cyclone, EP , none	✓	✓	✓	x	✓ (9)	✓	x	No
	Scattered Light (Back/Side)	Back/Side Scatter	1 - 4 (1) (2)	25	500	Bag (1), Cyclone, EP, none	✓	✓	✓	x	x	✓	x	No
		ProScatter	2 - 15	10	501	Bag (1), Cyclone, EP, none	✓	✓	✓	x	x	✓	x	No

Notes:

(1) Concentration dependant
(2) Representative Flow dependant
(3) Application specific
(4) Stack diameter dependant

(5) No water droplets
(6) No filter - not advised
(7) Model specific
(8) Varing velocity range 8-20m/sec

(10) Advised with Faraday Shield/ edge

All Transmisometry and Scattered Light Instruments Must be provided with constant clean air purge supply

This document is meant as a guide and reflects the majority of technology limitations of instruments currently commercially available, however specific models may offer decreased or increased capability the actual stack conditions will dictate instrument suitability

Table 4: Overview on Technical Selection & Suitability for Gaseous CEMS Technology

Technique	Type	Parameter(S) Measured	Comments& Limitations
Chimiluminescence	Extractive	NO, NO_x, NO_2*	*NO_2 calculated (NO_x -NO). - To operate it requires additional accessories like Ozone Generator, Pumps, Dilution Probes/ Assemblies, etc. - Quench Effect of CO_2/Moisture, etc. - Suitable for very low concentrations of NOx applications like Ambient Quality Monitoring in cleaner environment. - Inability to measure other emission components like SO_2, CO, CO_2, etc.as compared to other techniques which can do multi gas measurements.
UV Fluorescence	Extractive	SO_2, H_2S*, TRS* (Total Reduced Sulphur)	*Cannot be measured simultaneously with SO_2. - To operate it requires additional accessories Dilution Probes/ Assemblies, etc. - Quench Effect of CO_2/Moisture, etc. - Suitable for very low concentrations of SO_2. applications like Ambient Quality Monitoring in cleaner environment. - Inability to measure other emission components like NO_x, CO, CO_2, etc. compared to other techniques which can do multi gas measurements.
NDIR	Extractive	CO, CO_2, SO_2, NO_X, etc.	- A direct method for continuous monitoring of multiple gases suitable upto 4-5 gas measurements without any dilutions. - Popular for low SO_2/ NOx concentrations with moisture removal. - Used in cold Dry extractive technique to remove moisture to avoid background interference from moisture. - Uses Internal optical filters for removal of interferences. - Inability to measure other emission components like HF, Cl_2, H_2S, etc. compared to other techniques which can do multi gas measurements. - Issue of disolution and stripping of CO_2/ SO_2 can under estimate the measured concentration, in case calibration does not follow the same system of cooling.

Technique	Type	Parameter(S) Measured	Comments& Limitations
NDUV	Extractive	SO_2, NO NO_2, NH_3,Cl_2, CS_2, etc.	- A direct method for continuous monitoring of multiple gases suitable upto 2-3gas measurements without any dilutions. - Popular in harsh applications in wide spectrum of Industrial process. - Used in cold Dry extractive technique to remove moisture to avoid background interference from moisture. Hot Wet options available for soluble gases like NH_3. - Inability to measure other emission components like CO, CO_2, HCl, HF,etc. compared to other techniques which can do multi gas measurements.
Fourier Transformed Infra-Red (FTIR)	Extractive	CO, CO_2, SO_2, NO, NO_2, N_2O, (NH_3),(HF), (HCl), CH_4, Moisture (H_2O), VOC, etc.	- A direct method for continuous monitoring of multiple gases upto 5 - 12 gases using high end spectroscopy technique. - H_2O measurement in FTIR spectroscopy is necessary for moisture correction. - Uses Hot Wet Preferred technique for complex stack gas matrix like waste Incinerators or waste to power plants, alternative fuels fired Cement Plants, with high moisture and soluble gases. - High Price, however, with multi complex gases and integrated modules like VOC, O_2 makes it cost effective over all solution. - Ideal for very low concentration of NH_3, HF, HCl
Differential Optical Absorption Spectroscopy (DOAS)	Open Path Long Distance / Perimeter	CO, CO_2, SO_2, NO_2, (NH_3),(VOC), HCl, HF etc.	- Suitable of monitoring of multiple gases preferably more than 5, but has maintenance issues as it is suitable for open path fence line ambient quality monitoring - Suitable for trace measurements -Limitations in High Dust & Moisture applications - Indirect measurement technique having calibration challenges at site, as calibration needs to be done through a bench.
Flame Ionization	Extractive	Total HC (VOC)	-Very selective technique for Total HC/ TOC/ VOC. Requires H_2 gas for flame and carrier Gas. -Integrated with extractive Hot wet / cold dry techniques.
Tunable Diode Laser	Path	CO, CO_2, NH_3, Moisture (H_2O), HCl, HF, CH_4 etc. O_2 & H_2S	Usually selective laser techniques are not cost effective technique for single component, very expensive, for multi gas measurement.

Technique	Type	Parameter(S) Measured	Comments& Limitations
			- Limitation in measuring SO_2 and NO_x due to lack of selectivity. - Measurement of H_2O for moisture correction is necessary and available in recent analysers.
Electrochemical	Extractive	O_2, CO/CO_2, etc.	- Electrochemical sensor is a consumable and requires regular replacement and gets influenced by process stack background gas matrix. - Limitations Influenced by moisture, dust, temperature, etc. - Suitable for Ambient / LEL / Portable detection - Not suitable for online stack emission monitoring in Industries.
Zirconium Oxide / O_2Cell	In-situ	O_2	Widely used for boiler/ Stack O_2 correction/ Normalisation. Technology explained earlier. (both extractive and in-situ)
Paramagnetic	Extractive	O_2	Stable and accurate and the technology type explained in detailed earlier.

Notes:

(a) Based on requirement, CEM System must have Flow (Velocity) measurement device and direct measurement facilities for O_2, CO and CO_2 installed

(b) Any dilution extractive system must have CO_2 measurement facility at source and measuring point to prove the correctness of the selected dilution ratio.

Table 5: Comparative analysis of technologies available for measurement of Particulate matter and Gaseous pollutant

Type of Technology	Extractive NDIR	In-situ NDIR	DOAS (Differential Optical Absorption Spectroscopy)	DILUTION EXTRACTIVE
How it works	Gas is extracted from stack, transported to sampling system, gas is conditioned and analyzed with a multi-gas NDIR analyzer	Optical head is directly mounted on the stack, by measuring light absorbed the analyzer measures the gases	Emitter, Receiver mounted across the stack. Xenon lamp emits light, amount of light absorbed at receiver sent to analyser through Optic Fibre cable	Very small amount of gas Extracted (Diluted) from stack to the analyser. Analyser normally used for AQM can be used here.
Advantage	Very low levels can be measured, less failure because analyzer not exposed to outside conditions, easy to maintain because no need to climb tall stacks, also we can add any other analyzer at a later date to measure other gases, consumes less calibration gas and no water interference. Probe installation at lower height of even 3 to 4D possible.	Suitable for high levels of concentrations. The complete analyser system along with calibrtaion equipment needs to be installed on a height (8D)at the stack platform and would require adequate arrangement for maintenance and calibration by operator / vendor / Laboratory.	No sampling. Very less maintenance. Works very well in harsh conditions like High moisture. High Data capture rate. Single analyser can be used for multi stack measurements. This can be measured both ppm and %age. Usualy quaterly (3 month). Calibration is recommended or when any changes.	Low Intial Cost, Clean & dry sample. More time required for calibration as the calibration gases will pass the complete system from analyser till probe. The Critical Orifice is challanged in High Dusty process applications. Calibration gas consumption is very high, increases operation costs.
Limitations	Installation takes more time, slightly more expensive Its widely used technique in harsh process applications and same rugged technique has been adopted in emissions. Lower cost for multi gas	Cannot measure low levels, no expansion possible, difficult to maintain, consumes much more calibration gases, stack gas corrode the probe and optics easily, water interference is a problem	Optic Fibre cable limted to 25 mts. For CO, NO etc. High Initial cost	Individual analyser required for each parameter. Dilution ratio should be fixed as per actual flue gas condition.Readings can be tampered by changing dilution ration. Needs special care for installation as these are

Type of Technology	Extractive NDIR	In-situ NDIR	DOAS (Differential Optical Absorption Spectroscopy)	DILUTION EXTRACTIVE
				ambient air technologies.
List of gases that can be measured	CO, CO_2, NO. SO_2, CH_4, etc, Moisture (number of gases not limited because we can add analyzers)	CO, CO_2, NO, SO_2, CH_4, HCl, Moisture – but limited to any 3 or 4 gases in one system (Note insitu do not measure NO_2 only calculates)	UV analyser- SO_2, NO, NO_2 Phenol, Cl_2, Formaldehyde, Benzene IR analyser- CO, CO_2, HCL, HF, H_2O, SO_3, NH_3, N_2O, CH_4	SO_2, NOx, CO
Maintenance requirements	Easy as it is inside a building, less failure as sensitive analyzer is more protected	Difficult as one has to climb the stack, more failures as exposed to harsh conditions.	Very Very less as compared to any other analyser	More maintenance
Approvals	TUV / MCERT approvals and conforms to US EPA.	US EPA does not recommend Insitu because of high expectations in performance in the USA	TUV, MCERTS and meets USEPA calibration protocols	Only conforms to USEPA not approved / prefered by EU-TUV/MCERT
Multiplexing possible Y/N	YES	NO	NO	NO
Suited for which industries	All	Only low dust, low water vapor stacks	Hot Wet applications	Only those having very high concentrations.
Remote calibration Y/N	YES	YES	NO	NO
Online calibration Y/N	YES	YES	NO	YES
Effect of dust	-	Maximum	Maximum	Maximum
Effect of temperature	-	Limited Temperature	-	Less than 400°C

Categories of	Aluminium	Cement	Distillery	Chlor	Fertilizers	Iron	Oil	Petrochemical	Power	Zinc	Copper	Common	Common Bio

Type of Technology	Extractive NDIR	In-situ NDIR	DOAS (Differential Optical Absorption Spectroscopy)	DILUTION EXTRACTIVE
Effect of pressure	-	Limited Pressure	-	-
Effect of moisture	Nil as removed or Hot Wet	Very much affected, need to measure H2O online	If moisture over 40%, instrument effected	Very much affected
Calibration adjustment as per Protocol Calibration frequency	Refer Calibration references in this guidelines	Refer Calibration references in this guidelines	Refer Calibration references in this guidelines	Daily Calibration (big drawback)

Table 6: Suitability of Gas CEM Technologies for Different Categories of Industries

Industries				**Alkali**		**& Steel**	**Refinery**		**Plants**			**Hazardous Waste Incinerators**	**Medical Waste Incinerators**
Emission Gas Parameters as per CPCB requirements	HF	NOx, SO_2	-	Cl_2, HCl	HF, NH_3	SO_2	CO, NOx, SO_2	CO, NOx, SO_2	NOx, SO_2	SO_2	SO_2	HCl, **TOC**, SO_2, NOx, CO	HCl, NOx
Hot / Dry Extractive CEMS (with Gas Cooler)		**BRT**				**OPT**	**BRT**	BRT	**BRT**	**BRT**	**BRT**		
Hot / Dry Extractive CEMS (with Gas Dryer)		OPT				BRT						**OPT**	**OPT**
In-Situ CEMS	**OPT**			**OPT**	**OPT**								
Hot Extractive Systems with Heated Analyzers	**BRT**			BRT	**BRT**							BRT	BRT
Dilution Sampling + Ambient Analysers							**OPT**	**OPT**	**OPT**	**OPT**	**OPT**		

BRT = Best Recommended Technique

OPT = Other Possible Technique

Table 7: Parameter specific Emission Standards for industries need to install CEMS

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits			Options available for CEMS
1	Aluminum	Raw Material Handling	PM	PM 150 mg/NM^3			In situ PM CEMS NDIR for CO FTIR for CO DOAS for open Path /Perimeter (Fence) monitoring Flow measurement is essential
		Calcination	PM, CO	PM 250 mg/NM^3 and CO 1% (Max)			
		Green Anode Shop	PM	PM 150 mg/NM^3			
		Anode Bake Oven	PM and total fluoride (F)	PM 50 mg/NM^3 and0.3 Kg/MT of Al			
		Pot room	PM (as HF)	PM 150 mg/NM^3 and Total F 2.8 Kg/MT (Soderberg Tech.) 0.8 kg/MT (Pre-baked Technology)			
2.	Cement Plant (without co processing), Standalone Clinker Grinding Plant or, Blending Plant	Rotary Kiln –without co processing	Parameter	Date of Commissioning	Location	Concentration not to exceed, in mg/Nm3	PM CEMS Insitu FTIR based hot wet technique to measure CO, CO_2, SO_2, NO, NO_2, (HCl)*, (HF)*, (NH_3)*, VOC, H_2O, etc. (FID for THC) & O_2 Analysers can be added *in-situ laser based method may be preferred for lower concentration. Hot wet extractive gaseous CEMS Preferable as given above. Paramagnet for O_2 When NOx-SNCR implanted NH_3 must be measured on the stack preferably with TDLAS/ FTIR NDIR / NDUV/ FTIR for multigas analysis (SO_2, NO_x)
			PM in mg/NM^3	on or after the date of notification (25.8.2014)	anywhere in the country	30	
				before the date of notification (25.8.2014)	critically polluted area or urban centres with population above 1.0 lakh or within its periphery of 5.0 kilometer radius	30	

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits			Options available for CEMS
					other than critically polluted area or urban centres	30	
			Sulphur Dioxide (SO_2) in mg/Nm3	Irrespective of date of commissioning	Any where in the country	100, 700 and 1000 when pyritic sulphur in the limestone is less than 0.25%, 0.25 to 0.5% and more than 0.5% respectively	
			Oxides of Nitrogen (NOx) in mg/Nm3	After the date of notification (25.8.2014)	Anywhere in the country	(1) 600	
				Before the date of notification (25.8.2014)	Anywhere in the country	(2) 800 for rotary kiln with In Line Calciner (ILC) technology. (3) 1000 for rotary kiln using mixed stream of ILC,	

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits			Options available for CEMS
						Separate Line Calciner (SLC) and suspension preheater technology or SLC technology alone or without calciner.	
	Cement Plant with coprocessing of wastes	Rotary Kiln – with co-processing of Wastes	Parameter	Date of Commissioning	Location	Concentration not to exceed, in mg/Nm3	PM CEMS FTIR based hot wet technique to measure CO, CO_2, SO_2, NO, NO_2, (HCl)*, (HF)*, (NH_3)*, VOC, H_2O, etc. (FID for THC) & O2 Analysers can be added *in-situ laser based method may be preferred for lower concentration.
			Particulate Matter PM) (mg/NM^3)	on or after the date of notification (25.8.2014)	Anywhere in the country	30	

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits			Options available for CEMS
				before the date of notification (25.8.2014)	critically polluted area or urban centres with population above 1.0 lakh or within its periphery of 5.0 kilometer radius	30	Hot wet extractive gaseous CEMS Preferable as given above. Paramagnet for O_2 When NOx-SNCR implanted NH_3 must be measured on the stack preferably with TDLAS/ FTIR NDIR / NDUV/ FTIR for multigas analysis (SO_2, NO_x)
					other than critically polluted area or urban centres	30	
			SO_2 (mg/NM^3)	irrespective of date of commissioning	anywhere in the country	100, 700 and 1000 when pyritic sulphur in the limestone is less than 0.25%, 0.25 to 0.5% and more than 0.5% respectively	

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits			Options available for CEMS
			NOx (mg/NM^3)	After the date of notification (25.8.2014)	Anywhere in the country	(1) 600	
				Before the date of notification (25.8.2014)	Anywhere in the country	(2) 800 for rotary kiln with In Line Calciner(ILC) technology. (3) 1000 for rotary kiln using mixed stream of ILC, Separate Line Calciner (SLC) and suspension pre-heater technology or SLC technology alone or without calciner.	
			HClmg/NM^3	10 mg/Nm^3			
			HF mg/NM^3	1 mg/Nm^3			NA
			TOC (mg/NM^3)	10 mg/Nm^3			
			Hg and its compounds	0.05 mg/Nm^3			

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits	Options available for CEMS
			Cd +Tl and their compounds	0.05 mg/Nm^3	NA
			Sb+As+Pb+ Co+Cr+Cu+ Mn+Ni+V and their compounds	0.5 mg/Nm^3	
			Dioxins and Furans	0.1 ngTEQ/ Nm^3	
3	Distillery	Boiler Stack	PM	150 mg/NM^3	In Situ or cross duct / Triboelectric PM CEMS
4	Chlor Alkli	(Hyper tower) (HCl Plant)	Cl_2, HCl	Cl_2-15 mg/NM^3 *HCl vapour and mists-35 mg/NM^3	FTIR, TDLAS (Hot Wet) Cl_2- NDUV (Hot Wet)
5	Fertilizers	Phosphate	PM, Fluoride	PM-150 mg/NM^3 Total Fluorides-25 mg/NM^3	✓ In-situ or Cross Duct PM CEMS ✓ FTIR, TDLAS for HF/NH_3 gases (Hot Wet) ✓ Hot/wet extractive NDIR/ NDUV acceptable for NH_3
		Urea (Old Plants) before 01/01/1982	PM	150 mg/NM^3	In Situ or cross duct for PM
		Urea (New Plants) after 01/01/1982	PM	50 mg/NM^3	TDLAS in-situ would be preferred for HF, NH_3, NDIR / NDUV/ FTIR for multigas analysis (SO_2, NO_x)
6	Integrated Iron & Steel Plants	Coke oven plant New Batteries at GF sites Rebuild	PM SO_2 NO_x	50 mg/NM^3 800 mg/NM^3 500 mg/NM^3	In Situ or cross duct for PM NDIR / NDUV, FTIR for multigas analysis (SO_2, NO_x) CO Extractive due to high dust, coke+Tar present in the sample

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits		Options available for CEMS
		Batteries Existing Batteries				
		Sintering Plant	PM	150 mg/NM^3		
		Blast Furnace		Existing Units	New Units	
			PM	50 mg/NM^3	30 mg/NM^3	
			SO_2	250 mg/NM^3	200 mg/NM^3	
			NO_x	150 mg/NM^3	150 mg/NM^3	
			CO	1% (Max)	1% (Max)	
		Steel making shop-basic oxygen furnace				
		Blowing/lancing operation	PM	300 mg/NM^3	Should be with gas recovery	
		Normal operation	PM	150 mg/NM^3	Should be with gas recovery	
		Dedusting of desulphurisation	PM	100 mg/NM^3	50 mg/NM^3	
		Rolling mill	PM	150 mg/NM^3		
		Re-heating (reverberatory) furnaces		Sensitive area	Other areas	
			PM	150 mg/NM^3	250 mg/NM^3	
		Arc furnaces	PM	150 mg/NM^3		
		Induction furnaces	PM	150 mg/NM^3		

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits		Options available for CEMS
	Sponge Iron Plants	Cupola foundary	PM	Melting capacity less than 3 tonn/hr	Melting capacity 3 tonn/hr and above	
				450 mg/NM^3	150 mg/NM^3	
			SO_2	300 mg/NM^3, corrected at 12% CO_2		
		Calcination plant/lime kiln/ dolomite kiln	Parameter	Capacity upto 40 Tonne/ day	Capacity above 40 Tonne/ day	
			PM	500 mg/NM^3	150 mg/NM^3	
		Refractory unit	PM	150 mg/NM^3		
		Rotary Kiln	PM	100 mg/NM^3 (Coal based) 50 mg/NM^3 (Gas based)		
7	Oil Refinery	Furnace boiler and captive power plant gas based		Before 2008	After 2008	In Situ or cross duct PM CEMS preferably optical based technology NDIR (CO/SO2/NOx) / NDUV (NO_x, SO_2) Multi gas / UVF – SO_2/CLD – NO, NO_2 & CO by NDIR
			PM	10 mg/NM^3	5 mg/NM^3	
			SO_2	50 mg/NM^3	50 mg/NM^3	
			NO_x	350mg/NM^3	250mg/NM^3	
			CO	150mg/NM^3	100mg/NM^3	
			H_2S in fuel gas	150mg/NM^3	150mg/NM^3	
		Furnace boiler and captive power plant liquid fuel based		Before 2008	After 2008	In Situ or cross duct PM CEMS preferably optical based technology NDIR (CO/SO2/NOx) / NDUV (NO_x, SO_2) Multi gas / UVF – SO_2/ CLD – NO, NO_2 & CO by NDIR
			PM	100 mg/NM^3	50 mg/NM^3	
			SO_2	1700 mg/NM^3	850 mg/NM^3	
			NO_x	450 mg/NM^3	350mg/NM^3	
			CO	200 mg/NM^3	150 mg/NM^3	
			S content in weight %	1.0	0.5	

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits		Options available for CEMS
		Sulphur Recovery Unit		Existing SRU	New SRU	NDIR (CO/SO2/NOx) / NDUV (NO_x, SO_2)Multi gas / UVF – SO_2/ CLD – NO, NO_2 & CO by NDIR
			H_2S NO_x CO	15 mg/NM^3 350 mg/NM^3 150 mg/NM^3	10 mg/NM^3 250 mg/NM^3 150 mg/NM^3	
8	Petrochemical	Furnace, Boiler, Heater, Vaporizer Liquid Fuel based		Existing Plant	New/ Expansion	In situ or Cross Duct PM CEMS (Preferably optical) NDIR (CO/SO_2/NOx) / NDUV (NO_x, SO_2)Multi gas / UVF – SO_2/ CLD – NO, NO_2 & CO by NDIR
			PM SO_2 NO_x CO	100 mg/NM^3 1700 mg/NM^3 450 mg/NM^3 200 mg/NM^3	50 mg/NM^3 850 mg/NM^3 350 mg/NM^3 150 mg/NM^3	
		Furnace, Boiler, Heater, Vaporizer Gas based		Existing Plant	New/ Expansion	In situ or Cross Duct PM CEMS (Preferably optical) Gaseous analyser preferably be dilution extractive due to safety issues NDIR (CO/SO_2/NOx) / NDUV (NO_x, SO_2) Multi gas / UVF – SO_2/ CLD – NO, NO_2 & CO by NDIR
			PM SO_2 NO_x CO	10 mg/NM^3 50 mg/NM^3 350 mg/NM^3 150 mg/NM^3	5 mg/NM^3 50 mg/NM^3 250 mg/NM^3 100 mg/NM^3	
9	Power Plant	TPP Installed before 31/12/2003		Less than 500 MW	More than 500 MW	Cross Duct PM CEMS NDIR / NDUV for multigas analysis (SO_2, NO_x) CO NH_3 for DeNOx control as operating parameter with TDLAS/ FTIR due to low value expected after emission control Mercury Vapours – Hot extractive system with gold amahgamation chemical or Thermal desorption using Alomic Fluorosence technique for measurement Atomic Absorption with Zeemans
			PM SO_2 NO_x Hg	100 mg/NM^3 600 mg/NM^3 600 mg/NM^3 0.03 mg/NM^3	100 mg/NM^3 200 mg/NM^3 600 mg/NM^3 0.03 mg/NM^3	
		TPP Installed on &after 01/01/2004 upto 31/12/2016		Less than 500 MW	More than 500 MW	
			PM SO_2 NO_x Hg	50 mg/NM^3 600 mg/NM^3 300 mg/NM^3 0.03 mg/NM^3	50 mg/NM^3 200 mg/NM^3 300 mg/NM^3 0.03 mg/NM^3	

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits		Options available for CEMS
		TPP to be Installed from 01/01/2017	PM SO_2 NO_x Hg	30 mg/NM^3 100 mg/NM^3 100 mg/NM^3 0.03 mg/NM^3		correction
10	Zinc	Smelter, SRU		Existing unit	New unit	In Situ PM CEMS NDIR/ UVF/ NDUV for SO_2
			PM	100 mg/NM^3	75 mg/NM^3	
			SO_2	1370 mg/NM^3 (Upto 300) 1250 mg/NM^3 (Above 300)	1250 mg/NM^3 (Upto 300) 950 mg/NM^3 (Above 300)	
			Acis mist / sulphur trioxide	90 mg/NM^3 (Upto 300) 70 mg/NM^3 (Above 300)	70 mg/NM^3 (Upto 300) 50 mg/NM^3 (Above 300)	
11	Copper	Smelter, SRU		Existing unit	New unit	In Situ PM CEMS NDIR/ UVF/ NDUV for SO_2
			PM	100 mg/NM^3	75 mg/NM^3	
			SO_2	1370 mg/NM^3 (Upto 300) 1250 mg/NM^3 (Above 300)	1250 mg/NM^3 (Upto 300) 950 mg/NM^3 (Above 300)	
			Acis mist / sulphur trioxide	90 mg/NM^3 (Upto 300) 70 mg/NM^3 (Above 300)	70 mg/NM^3 (Upto 300) 50 mg/NM^3 (Above 300)	
12	Biomedical waste Incinerator	Incinerator Stack	PM $NO_{x,}$ HCl Total ****** dioxines and furans	50 mg/NM^3 400 mg/NM^3 50 mg/NM^3 0.1 ng TEQ/NM^3 (at 11% O_2)		In Situ PM CEMS FTIR, TDLAS, for gases (Hot Dry Extractive is preferable) Ideally system should be Hot-wet Extractive Type

S. No.	Industries/ Facilities	Units of Operation	Parameters Prescribed	Emission Limits	Options available for CEMS
			Hg Temp. P.C.C. Temp. S.C.C.	0.05 mg/NM^3 Combustion Efficency >99% 800 ^{o}C 1050 ± 50 ^{o}C	Cold/ dry extractive NDIR for HCl, NOx, CO, CO$_2$ (permeation drying) All monitored values shall be corrected to 11 % O$_2$on dry basis.
13	Common Hazardous Waste Incinerator	Incinerator Stack	PM HCl SO$_2$ CO TOC HF NOx Total ** dioxines and furans Cd, Th & its compounds Hg and its compunds Sb+ As+ Pb+ Cr+ Co+ Cu+ Mn+ Ni+ V ***	50 mg/NM^3 50 mg/NM^3 200 (30min); 100 mg/NM^3 (30 minutes) & 50 mg/NM^3 (24 hourly) 20 mg/NM^3 4 mg/NM^3 400 mg/NM^3 0.1 ng TEQ/NM^3 (Existing incinerator) 0.05 mg/NM^3 0.05 mg/NM^3 0.5 mg/NM^3	Recomended system should be Hot wet Extractive Type, In situ Optical based PM CEMS. FTIR type multigas analysis is best suitable NDIR & FID for multigas analyser FID based instrument for THC(VOC)/ TOC NDIR+FID+TDLAS+FTIR preferred for low level of NH$_3$, HF & HCl TDLAS preferred for low level NH$_3$, HF, HCl. Paramagnetic or Zirconum / NDIR for CO, CO$_2$
14	Sugar	Boiler	PM	150 mg/NM^3	

Note:

Alternative fuels like Petcoke, Waste, Sludge, Bio Mass, tyre, etc.

* Mist not possible by CEMS ** PCDDs/ FCDDs not possible by CEMS *** Metals not possible by CEMS

- Flue gas velocity, Temperature, Moisture, CO_2 and O_2 measurement are compulsory for all installations. Installation using dilution techniques must have CO_2 measurement facilities at stack and at the instrument end.
- All the data has to be corrected to mass/volume at STP (760mm Hg Pressure and 298 K temperature in dry condition).
- NOx values are required to be reported as NO_2mg/NM^3
  NOx = NO + NO_2 = NO X 1.53+ NO_2= NOx as NO_2 (to ensure no under reporting)
- De NO_x (SCR / SNCR)- Recommended to go for NO + NO_2 measurement for correct reporting as NO_2

Table 8: Suitability of Technologies for Different Matrices

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
SO_2	NDIR / NDUV	Extraction Cold Dry	Cement Power Iron & Steel, Oil, Refinery, Petrochemical, Zinc, Copper	Incinerators	Interfering Moisture is removed using Coolers and measure as dry basis.	H_2O	Removal of H_2O by sample gas coolers before measurement
	UV FLUORESCENCE	Dilution	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators, High Dust, Moisture and corrosive backgrounds ; eg. petcoke fired units.	Wet based measurement require continuous high purity instrument air	HC, Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	HC kicker inbuilt in the analyser
	UV DOAS	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Closed Path Length Stacks	Wet based measurement requires online measurement of H_2O, O_2, P, T, Flow. Limitation in high dusty stacks and smaller dia stacks due to lack of optical path length. Open path better suited for perimeter monitoring..	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	Separate moisture measurement to be done and moisture measurement to be calibrated and also, moisture to be compensated
	IR-GFC	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators / Dynamic Process stacks	Wet based measurement requires online measurement of H_2O, CO_2, O_2, P,T, Flow.	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	Separate moisture measurement to be done and moisture measurement to be calibrated and also moisture to be compensated
	IR	Extraction Hot Wet	Cement Power Iron & Steel Oil Refinery		Wet based measurement	H_2O	Separate moisture measurement to be

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
			Petrochemical Zinc Copper Incinerators				done online correction.
	UV	Extraction Hot Wet	Oil Refinery, Petrochemical, (SRU Incinerators Stacks)		Wet based measurement		
	NDIR	Extraction Cold Dry	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators	Wet based measurement	H_2O	Removal of H_2O by sample gas coolers before measurement
	Chemiluminescence	Dilution	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators	Wet based measurement require continuous high purity instrument air	HC, Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	HC kicker inbuilt in the analyser
	UV DOAS	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators	Wet based measurement requires online measurement of H_2O, O_2, P, T, Flow. Limitation in high dusty stacks and smaller dia stacks due to lack of optical path length. Usualy for ope path perimeter monitoring.	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	Separate moisture measurement to be done and moisture measurement to be calibrated also moisture to be compensated
NO_x	IR-GFC	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	High Dust, Moisture and corrosive backgrounds ; eg. petcoke fired units.	Wet based measurement requires online measurement of H_2O, CO_2, O_2, P, T, Flow. NO_2 cannot be measured is a limitation.	Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	Removal of H_2O by sample gas coolers before measurement

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
	IR	Extraction Hot Wet	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper Incinerators		Wet based measurement	H_2O	Removal of H_2O by sample gas coolers before measurement
CO	IR	Extraction Cold Dry	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators	Interfering Moisture is removed using Coolers and measure as dry basis.	H_2O	Removal of H_2O by sample gas coolers before measurement
	IR-GFC	Dilution	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators	Wet based measurement require continuous high purity instrument air	Hydrocarbons have high interferences	
	IR-GFC	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators	Wet based measurement requires online measurement of H_2O, CO_2, O_2, P, T, Flow. NO_2 cannot be measured is a limitation.	Hydrocarbons have high interferences, Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	NIL
	IR	Extraction Hot Wet	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper	Incinerators/ Wet process	Wet based measurement	NIL	NIL
NH_3	TDLS	In-Situ	Fertilizer	Hot wet required above due ≥180 Deg C.	Wet based measurement requires online measurement of H_2O, CO_2, O_2, P, T, Flow. Limitation in high dusty stacks and smaller dia stacks due to lack of optical	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	Hot Wet- H_2O measurement required

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
					path length.		
	NDUV	Extraction Hot Wet	Fertilizer		Wet based measurement	NIL	NIL
HF	TDLS	In-Situ	Aluminum Fertilizer	Hot wet required above due ≥180 Deg C.	Wet based measurement requires online measurement of H_2O, O_2, P, T, Flow. Limitation in high dusty stacks and smaller dia stacks due to lack of optical path length.	Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	Hot Wet- H_2O measurement required
	TDLS	Extraction Hot Wet	Aluminum Fertilizer	Hot wet required above due ≥180 Deg C.	Wet based measurement	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	Hot Wet- H_2O measurement required
	FTIR	Extraction Hot Wet	Aluminum Fertilizer	Hot wet required above due ≥180 Deg C.	Wet based measurement	H_2O	Hot Wet- H_2O measurement require
HCl	TDLS	In-Situ	Chlor Alkali	Hot wet required above due ≥180 ^{0}C.	Wet based measurement requires online measurement of H_2O, O_2, P, T, Flow. Limitation in high dusty stacks and smaller dia stacks due to lack of optical path length.	Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	Hot Wet- H_2O measurement require
	IR	Extraction Hot Wet	Chlor Alkali Incinerators	Cold dry not situable, hot	Wet based measurement	H_2O	Hot Wet- H_2O measurement

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
				wet ≥180 ^{0}C.			require
	FTIR	Extraction Hot Wet	Chlor Alkali Incinerators	Hot wet required above due ≥180 ^{0}C.	Wet based measurement	H_2O	Hot Wet- H_2O measurement require
PM	Transmissometry	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper		Not suitable for low level measurement (>100mg/NM^3) Not suitable for smaller dia stacks (>2M)	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	NIL
	Scatterd Light Based	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper		NIL	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	NIL
	DC Triboelectric	In-Situ	Cement, Power, Iron & Steel, Oil Refinery, Petrochemical, Zinc, Copper		Output available only in mass emission value (KG/HR) Frequent probe cleaning	Water droplets. Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	-
Flow	Ultrasonic	In-Situ	All industries	Dusty stacks need auto blow back for effective cleaning.	NIL	Stack Dynamics	NIL
	Thermal flowmeter	In-Situ Probe	Selective	Dusty stacks need auto blowback for effective cleaning.	Varying gas composition and wet gases contamination of probe	Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	
	Pitot tube	In-Situ	Selective	Dusty stacks	Plugging problem No	Stack	Back Air Purge for

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
				need auto blowback for effective cleaning.	mass flow measurement	Dynamics like T,P, Flow, Moisture, Vibration, etc.	periodic cleaning
H_2O	TDLAS	In-Situ			Calibration not possible at site Max. Range 0-30%	Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	Every time should be taken to factory for calibration
	FTIR	Extractive Hot Wet			External calibration unit to be used for calibration Max. Range 0-40%		
CO	IR	In-Situ Probe	All Combustion		Max. Temp. 400 ^{o}C Max. Dust 100g/m^{3}	Stack Dynamics like T,P, Flow, Moisture, Vibration, etc.	
	IR	In-Situ (Cross Duct)	All Combustion		Max. Temp. 400^{o}C Max. Dust 100g/m^{3}	Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	
	IR	Extractive Hot Wet	All Combustion		Larger response time		Shorter transportation lines
	IR	Extractive Cold Dry	All Combustion		Larger response time		Removal of H_2O by sample gas coolers before measurement
Oxygen	Zirconia	In-Situ	All Combustion			Stack Dynamics like T, P, Flow, Moisture, Vibration, etc.	

Parameter	Technology	Type	Industries where technology is applicable (17 category, Incinerators	Industries where technology can not be applicable	Limitations of Technology	Interfering substances	Interference removal mechanisms
	Paramagnetic	Extractive	All Combustion		Larger response time Measurement in dry basis		Removal of H_2O by sample gas coolers before measurement

* In case of wet based measurement, assessment of H_2O (moisture) is important to correct the results on dry basis.

8.0 SITE REQUIREMENT AND PREPARATION FOR MOUNTING OF CONTINUOUS EMISSION MONITORING SYSTEM

1. **Infrastructure and mounting**
    a. All measurement ports in the stack / duct, etc. will have to be made available as per CEMs system requirement and confirming the regulatory requirement
    b. CEMs analyser mounting flanges needs to be welded/grouted as per the mounting guidelines furnished by the vendor.
    c. Industry to ensure availability of permanent, strong & reliable platforms at CEMs analyser mounting location with safe approach ladders or stair case (spiral) or elevator. Vertical ladders if provided, should have back guard, stair case if provided, should be with proper hand rail, steps should be evenly distributed with adequate height, length & width. Monkey ladder is not preferred in case the height of platform is more than 30 meter from the ground.
    d. For ease of maintenance work, the stack platform width for metallic stacks should be 800mm minimum & for concrete stack platform width should be minimum of 1000mm. All platforms should have hand rails.
    e. All the power cables, signal cables, instrument air tubing's should be properly laid & clamped so that should not be an obstacle for personnel movements.
2. **Utilities**
    a. Uninterrupted power supply - single phase, 110/ 230 VAC as applicable should be supplied up to the analyser mounting location
    b. Power supply should be properly earthed; lightning arrestor wire line & earthing cable wire line should be separate.
    c. Instrument air connection – Clean and dry compressed air will have to be supplied by end user upto the analyser probe mounting location.
    d. Quality of instrument air shall depend upon the specific demand of parameter being measured.

3. Safety

With respect to instrument safety, all the instructions in the vendor specific CEMs manual shall be followed. All flanges, ports must be well supported and welded as per required standards. Mounting bolts, etc. must be fully tight before commissioning. All personnel safety standards and procedures for working at height must be adhered to at site.

a. If the approach to platform is by using vertical ladder's, then at every 10-12 mtrs landing should be provided. The entire length of ladder must have protective back guard/cage.
b. Ladder must continue through platform approach to some distance above such that landing on platform is easy.
c. Ladder must be well maintained with all fasteners rigidly fixed in the stack wall.
d. The completed ladder network and stack has to be regularly inspected for corrosion and must be painted periodically.
e. Platform railing must be rigid at least reach 1.2 mtr in height from platform surface.
f. If analyser mounting location is above 45meter elevation then for ease of maintenance and personnel safety, proper stair case or lift/elevator should be provided
g. Industry to ensure removal of bee hive from stack or stack nearby location before proceeding for any CEMs mounting/maintenance work on stack platform.

9.0 CALIBRATION, PERFORMANCE EVALUATION AND AUDIT OF CEMS

The calibration process for CEMS is well established in European Union and USA. The European Union follow EN 14181 which specifies procedures for establishing Quality Assurance level in terms of QAL 2, QAL 3 and Annual Surveillance Test (AST) for ***CEMS (CEMS is also called Automated Measurement Systems (AMS) in Europe)*** installed at industrial plants for determination of flue gas components and other glue gas parameters. In the UK QAL 1 procedures are covered by certification under MCERTS Scheme for Continuous Monitoring System. The suitability evaluation of CEMS and its measuring procedures are described in EN ISO 14956 (QAL 1), which subsequently became EN 15267-1.

The USEPA follows a different route by using Relative Accuracy Test Audit (RATA) for gases and Relative Response Assessment (RRA) for Particulate. The details of the RATA system are mentioned below:

1. A RATA is an audit in which data from a CEMS is compared to data from EPA reference methods of 40 CFR Part 60. CEMS accuracy is determined relative to the EPA reference method. Although the same EPA reference methods are used to determine emissions for compliance purposes (as in a stack test), the primary function of reference method data in a RATA is as the benchmark for comparison with the CEMS data. A RATA is initially conducted during the certification or performance specification testing period of each CEMS. After the initial certification had been completed the RATA performance audit must be conducted at least once every four calendar quarters.
2. A Relative Accuracy Audit is an abbreviated version of a RATA and was originally intended for auditing CEMS (3 out of 4 calendar quarters) which were not designed to accept Cylinder Gas Audits (CGA). Only three test runs are required for an RAA.

The difference between the European System and that followed in USA for Quality Assurance of CEMS is given in **Table 9**.

Table 9: Difference between the two QA systems followed in European Union &USA

	Selection of CEM	**Installation**	**Stability before calibration**	**Valid calibration**	**Ongoing instrumental stability**	**Ongoing calibration stability**
EU	QAL1 (EN15267 parts 1 to 3) with appropriate certification range	EN15259	QAL3	Functional test and QAL2	QAL3 plus annual linearity	Functional test and annual surveillance tests (AST)
USA	None but legal onus on the operator to provide valid data	Field Performance Test	7-day drift test	Correlation tests over 3 days	Zero and Span plus, quarterly linearity test	Annual correlation test and Relative Accuracy Test Audits (RATA) for gases and Relative Response Assessment (RRA) for particulate

The system for Quality Assurance followed in European Union as well as in EPA requires a well-established infrastructure for calibration of the systems, for uncertainty calculations and performance evaluation besides requiring skills and expertise to support each CEM, since the CEM is specifically characterized and calibrated for the individual application.

9.1 Recommended Instrumentation/Methodology for Monitoring

a. The USEPA TUV & MCERTS certified analysers *for emissions* alone are recognised for use as CEMS.

b. All indigenous and foreign Manufacturers of analysers/ instruments for real time monitoring of industrial emissions shall obtain certificate for their system within six months after the Indian certification system is in place.

c. Each manufacturer shall subject its product range to the verification for Conformity of Production (COP), every year. For this, the year shall mean the period from 01, April of a calendar year to 31st March of the succeeding calendar year.

d. CPCB will notify agency for COP.

e. If the COP verification report indicates non-compliance the manufacturer must stop the manufacturing immediately and recall back all the systems installed of the models observed non-complaint.

f. The testing shall be done as per the procedure and specifications laid down by CPCB.

g. The analysers/ instruments will not be considered for installation; in case their manufacturer fails to obtain the required certification from the Indian Certification Agency/ agencies within 12 months of the establishment of Indian Certification System.

h. The following parameters shall also be monitored: -

- Carbon Dioxide (CO_2)
- Carbon Monoxide (CO)
- Stack gas velocity
- Stack gas Volumetric Flow Rate
- Stack Gas Temperatures
- Stack Gas Parameters like Moisture
- Oxygen (O_2)

9.2 Acceptance of CEMS Until Indigenous Certification System is Placed

A CEMS to be used at installations covered by CPCB direction shall have to be proven suitable for its measuring task (parameter and composition of the flue gas) by use of the procedure equivalent to international standards (EPA PS or EN QAL Standards). It shall prove performance in accordance to the set performance characteristics during the field-testing.

The performance testing procedures involve all concerned including plant operator, vendor and testing laboratories. The Regulator has to inspect the installation and collect information. The comments on this information are essential tool to qualify the installation for further performance testing

Field-testing is a procedure for the determination of the calibration function and its variability and a test of the variability of the measured values of the CEMS compared with the data quality objectives specified. The performance tests are performed on suitable CEMS that have been correctly installed and commissioned. A calibration function is established from the results of a number of parallel measurements performed with a Standard Reference Method (SRM). The variability of the measured values obtained with the CEMS is then evaluated against the required criteria to satisfy the Data Quality Objective.

Table 10: Performance Specification for SO_2, NO_X and CO

S.No.	Specification	Tolerance ranges/values
1	Zero Drift /Weekly	≤ ± 1 % of Span
2	Span Drift /Weekly	≤ ± 1 % of Span
3	Analyzer's Linearity	≤ ± 1 % of Span from calibration curve
4	Performance Accuracy	≤ ± 10 % of compared Reference measurement

Table 11: Performance Specification for O_2, and CO_2

S.No.	Specification	Tolerance ranges/values
1	Zero Drift /Weekly	≤ ± 1 % of O_2
2	Span Drift /Weekly	≤ ± 1 % of O_2
3	Analyzer's Linearity	≤ ± 1 % of O_2
4	Performance Accuracy	≤± 10 % of compared Reference measurement or within 1% of O_2

Table 12: Performance Specification for PM CEMS

S.No.	Specification	Tolerance ranges/values
1	Zero Drift between two servicing intervals	≤ ± 2 % of Full Scale range
2	Reference point Drift between two servicing intervals	≤ ± 2 % of Reference value range
3	Analyzer's Linearity	The difference between the actual value and the reference value must not exceed ±2 percent of full scale (for a 5 point check).
4	Performance Accuracy	≤ ± 10 % of compared Reference measurement

Table 13: Specification for Analyser

S. No.	Specification	Tolerance ranges or values
1	Zero Drift /Weekly	≤ 1 %
2	Span Drift /Weekly	≤ 1 %
3	Analyzer's Linearity	< 1 % of full scale
4	Performance accuracy	≤ ± 10 % of compared reference measurement

The performance test procedures are repeated periodically, after a major change of plant operation, after a failure of the CEMS or as demanded by regulators.

9.3 Calibration of Air Analysers (Gaseous Parameter)

a. The instruments/ analysers for real time monitoring of gaseous emissions shall be calibrated with respect to their functioning, drift, linearity detection limit, output, operating temperature and other relevant parameters before installation.

b. It is advised to mention that calibration for certified CEMS and full performance demonstration of uncertified CEMS (which involves calibration) must be performed while being installed.

c. After six months of operation, the system shall be rechecked for its health and data accuracy and reliability, following multi point calibration (at least 03 span concentrations) using standard methods and certified reference materials.

d. The data comparison and calibration verification shall be done once in 06 months by empanelled laboratories following standard procedures and using certified reference standards.

e. The health of the instruments/analysers shall be assessed on daily basis at fixed time (10.00 a.m.) by checking the zero drift. No adjustment is allowed.

f. In case the daily zero drift is more than the acceptable limit as specified in the catalogue/brochure of the instrument/analyser manufacturer and persists continuously for five days, the instrument/ analyser shall be recalibrated following procedure laid down at point (d) above.

g. The instruments/ analysers shall be rechecked for zero and span drift every Friday at fixed time (10:00 a.m.) using standard methods and standard reference materials. The drift needs to be recorded and suitably incorporated in the data collected over the period.

h. For Differential Optical Absorption Spectroscopy (DOAS), Non Dispersive Ultra Violet (NDUV)/Non Dispersive Infra-Red lamp based systems, the calibration shall be revalidated once in 03 months, and after replacement of lamp. In-situ based TDLS/ DOAS needs to be brought down to lab for calibration.

i. The values of NDUV / NDIR based system will be compared with the standard methods using Standard Reference Material every Friday at fixed time (10.00 am) and Zero drift checked daily at fixed time (10.00 am).

j. The instrument/ analyser shall be recalibrated after any major repair/replacement of parts/lamps or readjustment of the alignment using standard methods and certified reference materials.

k. The instrument/ analyser system shall have provision of remote calibration, for verification of the system performance by SPCBs/PCCs whenever, felt necessary.

l. The intensity of the lamp shall be checked once every fortnight.

m. Data capture rate of more than 85% shall be ensured.

n. For FTIR Spectroscopy calibration once a year checks are acceptable or when major over haul as change in Lazer / Spectrometer.

o. Using Air for Zero/Span calibration is not acceptable, Zero / Span Gas / Gas filled Cuvette to be used with required certifications.

9.4 Calibration of Air Analysers (Particulate Matter)

The PM CEMS device is ready for calibration only after performing all of the required installation, registration, and configuration steps. Details of Particulate Matter CEMS calibration are given below.

a. The continuous Particulate Matter monitoring system (PM-CEMS) shall be calibrated at different operational loads against isokinetic sampling method (triplicate samples at each load) at the time of installation and thereafter, every six months of its operation.

b. The results from the Particulate Matter monitoring system shall be compared on fortnightly basis i.e. second Friday of the fortnight, at fixed time (replicate sample) starting 10.00 am. with standard isokinetic sampling method.

c. In case, deviation of the comparison values for 02 consecutive monitoring is more than 10%, the system shall be recalibrated at variable loads against isokinetic sampling method (replicate samples).

d. No adjustment of Calibrated Dust Factor (CDF) is allowed unless full-scale calibration is performed for PM CEMS. Change of CDF should be permitted only if it is approved by SPCB/ PCC.

e. After any major repair to the system, change of lamp, readjustment of the alignment, change in fuel quality, the system shall be recalibrated against isokinetic sampling method. (triplicate samples at each load)

f. The data capture rate of more than 85% shall be ensured.

g. The intensity of lamp shall be checked once every fortnight.

h. The data comparison/calibration verification shall be done by laboratories empanelled by CPCB using standard reference methods and at a frequency specified.

9.5 Emission Monitoring

a. To ensure laminar flow the Particulate Matter monitoring systems (CEMS) shall be installed at a distance at least at 8 times the stack diameter downstream and 2 times stack diameter upstream from any flow disturbance. (Extractive CEMS can be installed at 4 times of stack diameter downstream)

In rare cases the PM CEMS analyzer can be installed at a distance atleast 4 times the stack diameter downstream from any flow disturbance; however, correction for stratification shall be made. The calibration may be more difficult in these cases and the full scale calibration shall cover all working loads and atleast 12 (triplicate sample at 25%, 50%, 75% and 100% load) sampling shall be carried out for dust factor.

b. CEMS devices shall be installed at minimum 500mm below from the port hole designed for manual sampling.
c. All measurement ports into the stack shall be as per CEMS system requirement.
d. Particulate CEMS devices (Cross Duct) or probe shall be installed in horizontal plane;
e. Probe / sampling device for gaseous CEMS shall be installed protruding downwards with suction system facing the direction of flow of flue gases.
f. The construction of chimney shall adhere to CPCB publication, "Emission Regulation Part III" (COINDS/20/1984-85) unless otherwise specified by CPCB or SPCB/ PCC.

9.6 Data Consideration/ Exceedance for Violation

a. Any exceedance of values over the prescribed standards or norms shall be considered as violation. However, time average value (as decided by CPCB) will be used for compliance check.
b. Instantaneous elevated data i.e. spikes with duration less than one minute shall be dealt separately and not considered for data averaging.
c. In case of loss of data for more than 10 minutes per half hour, one half hourly value is lost and in case the loss is more than 5 half hourly data per day, a day's data is lost.
d. Any day in which more than three hourly average values are invalid due to malfunction or maintenance of the automated measuring system shall be considered lost date for the day 85% date capture in based on available daily average.
e. In the case of a breakdown of the RTMS, the operator shall reduce or close down operation if the problem is not rectified within 24 hours.
f. Operating hours – means the time expressed in hours during which the plant in whole or in part is operating and discharging emission into the air, excluding start up and shut down periods.

g. Any exceedance of the monitored values against the standards shall invite SMS & email to the industry from SPCBs/PCCs, requiring immediate feedback on the corrective action initiated/taken.

h. For any second failure of the industry to keep the emissions within the norms the industry shall immediately move towards closure of its operation under intimation to SPCBs/PCCs.

i. The values recorded during calibration or during preventive maintenance shall not be considered for exceedance and assessing the data capture rate.

j. Plant start-up or batch process starting emissions shall not be considered for averaging for the initial, 30 minutes' period in case of batch processes or small furnaces/ boilers not operating continuously.

k. Plant shut down period shall be excluded while calculating data capture rate.

9.7 Data Acquisition System (DAS)

a. DAS (Data Acquisition System) defines the logging of digital data from the analysers

b. The data shall be transferred directly from the analyser (no in between logic) to the server at CPCB/ SPCBs or PCCs via Data Acquisition System.

c. Data should be in encrypted format (tamper proof)

d. DAS to automatically and seamlessly transfer data to Data Acquisition & Handling System (DAHS).

e. Data dissemination to stakeholders from web server linked to DAHS.

f. The system shall operate on Open Application Programme Interface (API) protocol based on REST based technology.

g. The system shall record all the monitored values and transfer 30 min. average value to DAHS. The system shall have provision to assess the momentarily values as and when required.

h. Data validation protocol inbuilt with data quality codes to defined specification *in DAS/DATA LOGGER.*

i. Web server to meet the needs of local PCBs, Industry and CPCB.

10.0 DATA ACQUISITION, MANAGEMENT AND REPORTING

Considering the heterogeneity of real time monitoring systems industries are required to submit real time data through their respective instrument suppliers. This mechanism shall help in consolidating the data avoiding the complexity of different technologies and availability of monitored data in different data formats while involving the instrument suppliers in data transferring mechanism. The system enables two ways communication required to manage such real time systems.

The functional capabilities of such software systems shall include:

a. The system should be capable of collecting data on real time basis without any human intervention.
b. The data generation, data pick up, data transmission; data integration at server end should be automatic.
c. The submitted data shall be available to SPCBs/PCCs and CPCB for immediate corrective action.
d. Raw data should be transmitted simultaneously to SPCBs /PCCs and CPCB.
e. In case of delay in collection of data due to any reason, the data transmission should be marked delayed data and reports of delayed data should by displayed on the portal
f. At no point of time, manual data handling shall be permitted. Data validation should be permitted only through the administrator and data changes recorded with date and time stampings.
g. Configurations of the systems once set up (through remote procedure) and verified, should not be changed. In case any setting change is required it should be notified and recorded through the authorized representatives only.
h. The data submitted electronically shall be available to the data generator through internet, so that corrective action if any required due to submission of erroneous data can be initiated by the industry.

i. The software should be capable to verify the data correctness which means at any given point of time the regulatory authorities/data generator should be able to visualize the current data of any location's specific parameter.

j. A system for data validation shall be incorporated in the software with two stage/three stage validation and fixed responsibilities of stakeholders;
   - Data Generator
   - SPCBs/ PCCs
   - CPCB

k. Change Request Management: window for requesting data changes due to actual field conditions shall be provided by the industry in line to SPCBs/ PCCs to consider the request or not. The environmental conditions around the site surrounding shall also be recorded along with other environmental parameters, as these have the potential to affect the monitoring system adversely and corrupt the data generated.

l. System should have capability to depict data at the actual location of industry over the map. CPCB and or SPCBs/ PCCs shall develop a map based system for data integration at a single location.

m. The software should be capable of analyzing the data with statistical tools and shall have the following capabilities:
   - Statistical data analysis (customizable) for average, min., max., diurnal variation, RSD, correlation, covariance, etc.
   - Comparison of parameters of different locations in user selectable time formats i.e. in graphical and tabular formats compatible to MS Excel, MS Word, *.txt etc.
   - Capability of comparison of data with respect to standards/threshold values.
   - Auto report and auto mail generation etc.
   - Providing calibration database for further validation/correction of data.
   - Transmitting data to different locations as per EC, CTE/CTO, and other directives in force.

- Channel configuration for range, units, etc. as required for specific parameters and facility.
- Providing data in export format on continuous basis through central/station computer system to other system.

n. Data transmission through different media like GPS, CDMA, Normal phone line, Data-cards, Broadband, 3G etc. (at least any two media supported).

o. Data Storage for next five years.

p. System should be connected to a backup power source with adequate capacity to avoid any power disruption.

Considering the large volume of data required to be collated, compiled, processed and interpreted a software system will be developed in future at CPCB in consultation with all SPCBs/PCCs exploring common data format to collect data from different servers to a common server.

11.0 SUMMARY

a. The industries falling in 17 categories of highly polluting industries, Common Bio Medical waste and Common Hazardous waste incinerators have to install Continuous Emission Monitoring System.

b. The responsibility of data submission lies with the Individual units. The instrument supplier will facilitate data transmission on behalf of industries. Industry will ensure at least 85% data availability from the system installed.

c. The vendors/ instrument supplier shall install their server in SPCB/PCCs and CPCB for transferring data from the real time CEM systems.

d. CPCB in consultation with SPCBs/PCCs shall explore the possibility to identify a common protocol, so that the data from the real time systems can be transferred directly to the server installed by SPCBs/PCCs and CPCB in a compatible form.

e. The vendor/instrument supplier shall make provisions to provide data continuously at least at 04 locations in SPCBs/PCCs, RO/DO of SPCBs, CPCB, and industry directly from the analyzers.

f. The plausibility control of data received shall be done. The team members will be responsible for validating, interpreting and interpolation of data on periodic basis.

g. The vendor/instrument supplier will regularly cross check the data obtained from CEM system with that of the samples collected manually and analyzed using approved laboratory techniques and revalidate the calibration factor essential for generating better quality data.

h. The industries shall ensure that the monitoring systems are covered under Comprehensive Maintenance Contract with the vendors/ authorized Indian service partners of the instrument manufacturer for at least for 05 years after installation.

i. The authorized Indian service partner/instrument manufacturer shall ensure that any problem in monitoring system/data acquisition and transfer system does not persist beyond 72 hours.

j. The vendors / instrument manufacturers shall ensure availability of spare parts for at least 07 years after installation of the system.

k. As nearly all the Emission analyzers are manufactured abroad, the Indian Bidder has to provide copy of the authorization from the original instrument manufacturer for bidding on his behalf.

l. Role of manufacturers/supplier authorized Indian Service Partner:

    - Supply and install equipment suitable to monitor the emission in the available matrix
    - Supply all the supporting equipment, analyzers and software
    - Supply equipment/instruments capable of monitoring/ measuring the parameters identified in the range of occurrence in the industrial unit
    - Supplied software should establish two ways communication sending diagnostics of instruments on demand, with central servers at SPCBs/PCCs and CPCB

- The software should be capable of transmitting the data along with diagnostics of the instrument

m. CPCB empaneled laboratories shall only be engaged as third party agency for all activities related to assessment of installation, calibration of CEMS, validation of data, etc.

S. No.	References
1.0	**CPCB's CEMS related Documents** i) Direction for installation of CEMS and CWQMS in 17 Categories Industries, CETP, HWI, BMWI ii) Draft Notification on CEMS and CWQMS iii) Minutes of Meeting with Industries on Online Monitoring iv) List of Parameters for CEMS and CWQMS v) First hand information on list of suppliers vi) CPCB/e-PUBLICATION/2013-14 on "Specifications and Guidelines for Continuous Emissions Monitoring Systems (CEMS) for PM Measurement With Special Reference to Emission Trading Programs"
2.0	**USEPA Documents related to CEMS** a) Continuous Monitoring Manual b) 40 CFR Part 75: CEMS Field Audit Manual c) USEPA CEMS Performance Specification i) PS – 2 : Performance Specification for SO_2 and NO_x ii) PS – 3 : Performance Specification for O_2 and CO_2 iii) PS – 4 : Performance Specification for CO iv) PS – 4A: Performance Specification and Test Procedure for CO v) PS – 4B: Performance Specification and Test Procedure for CO and O_2 vi) PS – 6: Performance Specification and Test Procedure for Emission Rate vii) PS – 8A: Performance Specification and Test Procedure for Hydrocarbon (TOC) viii) PS – 11: Performance Specification and Test Procedure for PM CEMS ix) PS – 15: Performance Specification for Extractive FTIR CEMS x) PS – 18: Performance Specification for HCl – CEMS d) Quality Assurance (QA) Documents i) Procedure 1: QA Requirement for Gaseous CEMS ii) Procedure 2: QA Requirement for PM CEMS iii) Procedure 5: QA Requirement for Total Gaseous Mercury (TGM) CEMS and Sorbent Trap e) 40 CFR part 180 f) COMS (Continuous Opacity Monitoring System)
3.0	EN Documents i) EN 15267 – Part 1: Certification of AMS (CEMS) ii) EN 15267 – Part 2: Certification of AMS (CEMS) iii) EN 15267 – Part 3: Certification of AMS (CEMS) iv) EN 14181 – Quality Assurance of AMS (CEMS) v) EN 14884 – Test Method AMS (CEMS) for TGM
4.0	UK Documents a) RM:QG-06: Calibration of PM CEMS (Low Concentration) b) MCERTS : BS EN 13284: PM CEMS
5.0	Standard Operating Procedure for Compliance Monitoring using CEMS – Abu Dhabi