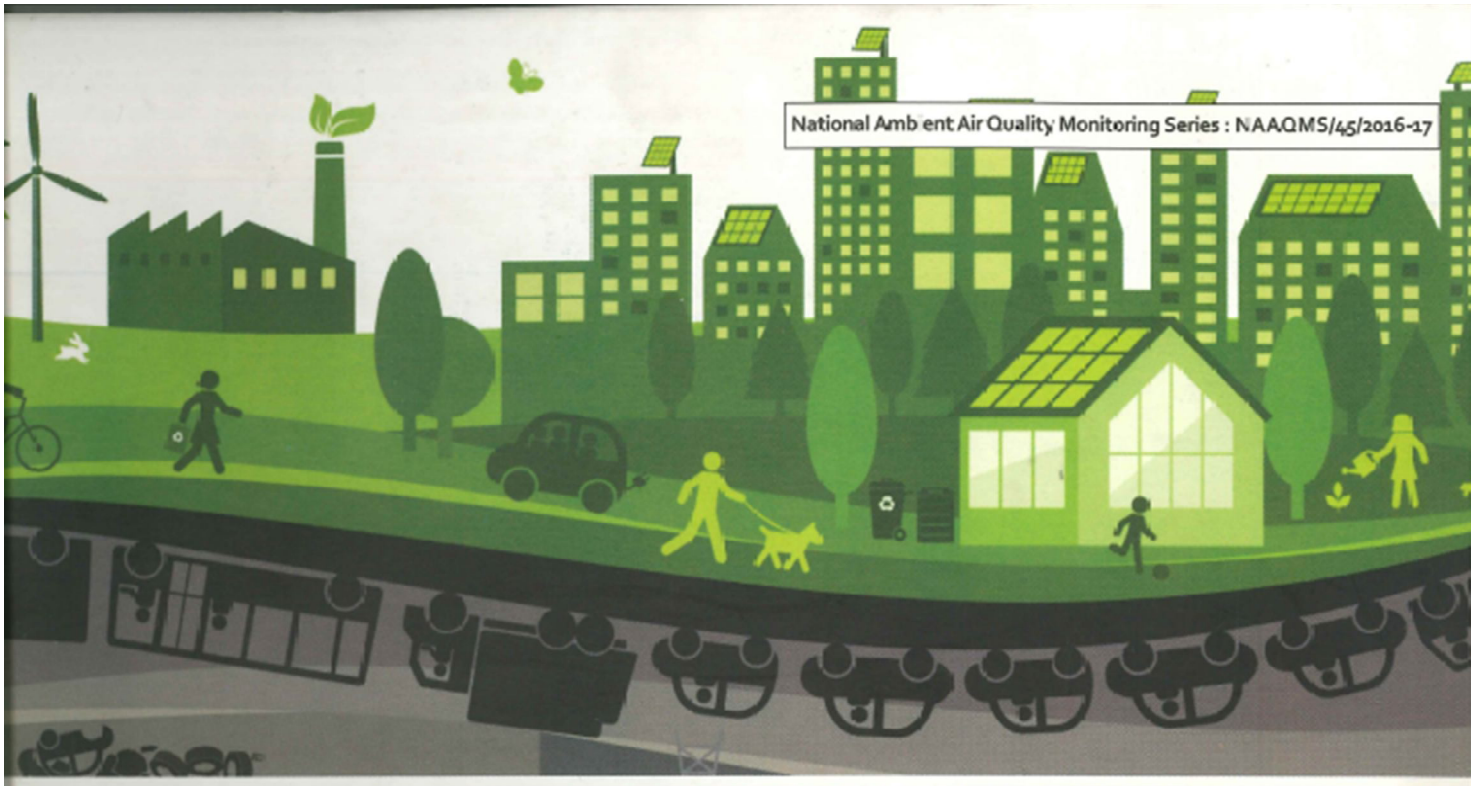

National Ambient Air Quality Monitoring Series : NAAQMS/45/2016-17

TECHNICAL HANDBOOK FOR INSTALLATION, MAINTENANCE, CALIBRATION, DATA CONNECTIVITY AND DATA QUALITY CHECK OF CONTINUOUS AMBIENT AIR QUALITY MONITORING SYSTEM (REAL TIME)

CENTRAL POLLUTION CONTROL BOARD
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE
www.cpcb.nic.in
August 2016

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FOREWORD

Under the provision of Air (Prevention and Control of Pollution) Act. 1981, the Central Pollution Control Board (CPCB) has been mandated to define the air quality standard for the country. In this direction, the 4th generation standard has been defined in National Ambient Air Quality Standards (NAAQS) 2009 for 12 parameters, of which 08parameters can be monitored for real time basis. Central Pollution Control Board (CPCB), State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) have already setup these systems on Million-Plus Cities, State Capitals, Religious and Historical Places under various operational mode like, O&M contract, Built-Own-Operate (BOO) System and Built-Own-Operate & Transfer (BOOT).

Taking the help of 07 parameter out of eight, on real time basis, CPCB has evolved National Air Quality Index (NAQI) to provide generic or first hand information on the air quality to the public. This has trigged the requirement for adoption of uniform monitoring protocol at national level. In this direction, CPCB had already published "Guidelines for Real Time Sampling &Analysis (NAAQM/97/2012-12)", however, to meet the objectives of quality operation, calibration, data generation, validation, data transmission, etc., CPCB team has prepared this document which also peer reviewed by the technical experts of NPL. IMD, IIT-Kanpur and CSE.

This handbook is prepared under the guidance and supervision of Dr. D. Saha Scientist 'E' and incharge. Air Laboratory and Sh. S. K. Sharma, Scientist 'C'. i shall like to ccmpliment the entire team for completion of this document. The contributions of peer reviewers for improvement of this document are also acknowledge . I hope this document will bring uniform operation of all CAAQMS in the country.

(Arun Kumar Mehta)

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Chapter-1
Overview of CAAQM System

1.1 Introduction

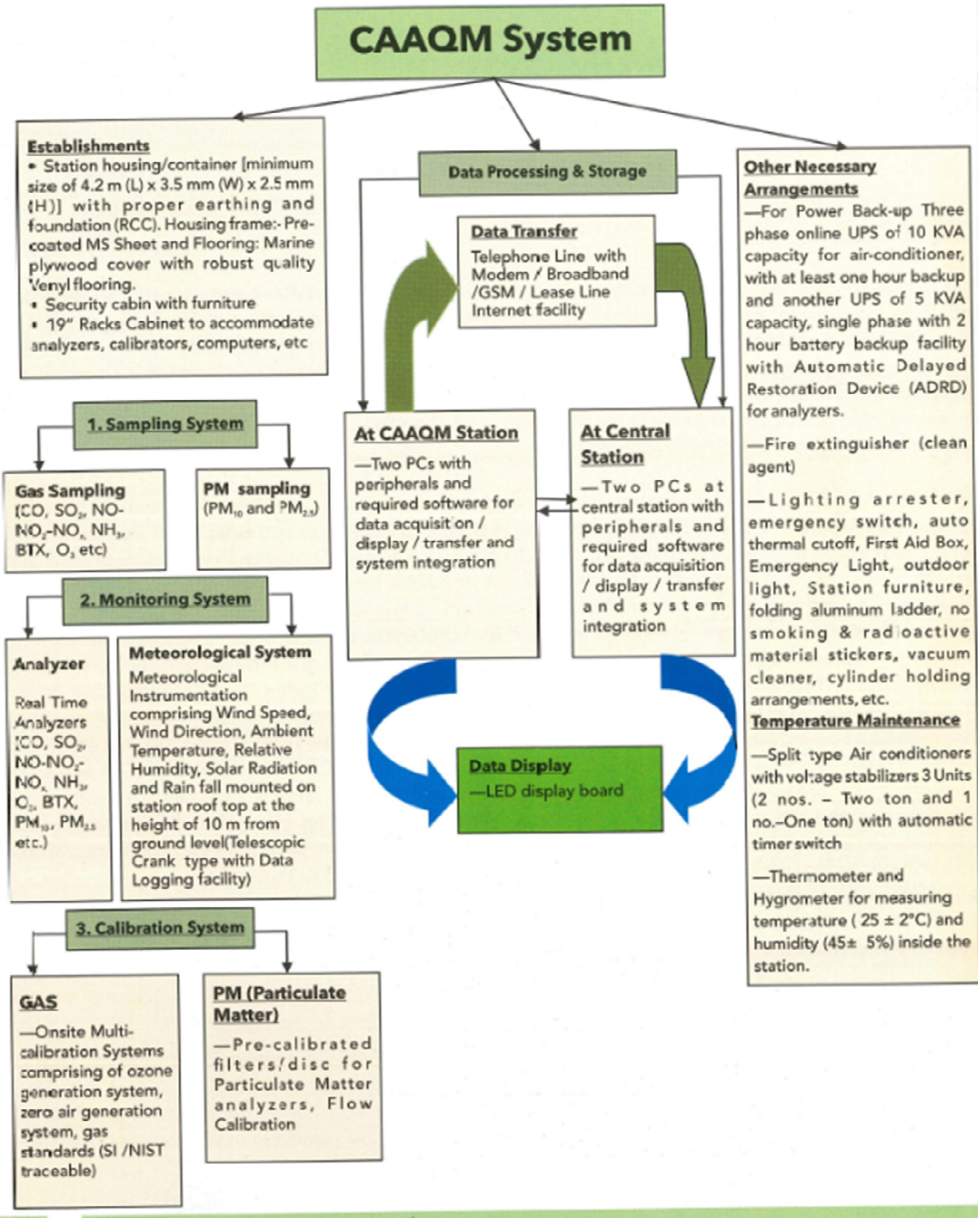
Due to rapid industrialization and urbanization, the air quality of our cities is deteriorating day by day and there is an urgent need to monitor the air quality of our cities. In parallel, there is also a need to have city-based action plan and time-bound review for curbing air pollution. Any air quality monitoring programme is likely to involve a significant investment of resources and this needs to be recognized at the outset. The correct selection of equipment and operational procedures is essential to ensure that these resources are not wasted and that the results obtained fulfill the original requirements of the monitoring exercise.

The Central Pollution Control Board has notified 4th version of National Ambient Air Quality Standards(NAAQS) in 2009 under the provision of the Air (Prevention and Control of Pollution), Act 1981 .The revision was made with the objective to provide a better air quality, irrespective of land-use pattern, across the country. In this revision, 12 set of health based parameters have been notified which are required to be monitored at National level with the notified methods. The present NAAQS required an integrated system of monitoring i.e. it is a combination of Continuous Ambient Air Quality Monitoring System (CAAQMS) and Manual monitoring system as the real time system can handle only 8 set of parameters. Since the inauguration of National Air Quality Index (NAQI) by Hon'ble Prime Minister, the real time system has taken place in India as the system demands instantaneous data dissemination towards public participation at large, besides review the regulatory issues time to time. There is a need to frame uniform methodologies for monitoring, calibration, data validation and data connectivity of these real time monitoring systems at National level. CPCB with its extensive experience in this field, has framed a Technical Handbook for setup of a CAAQM System, which describes all aspects (such as procurement, installation, calibration, maintenance, data acquisition and audit procedure with the help of flow chart and diagrams) related to this system.
Special emphasis has been given to make this Handbook simple and concise (not much technical specification has been discussed) so the personnels involved in this system integration, may acquire necessary information to understand the setup procedure and functioning of CAAQM System.

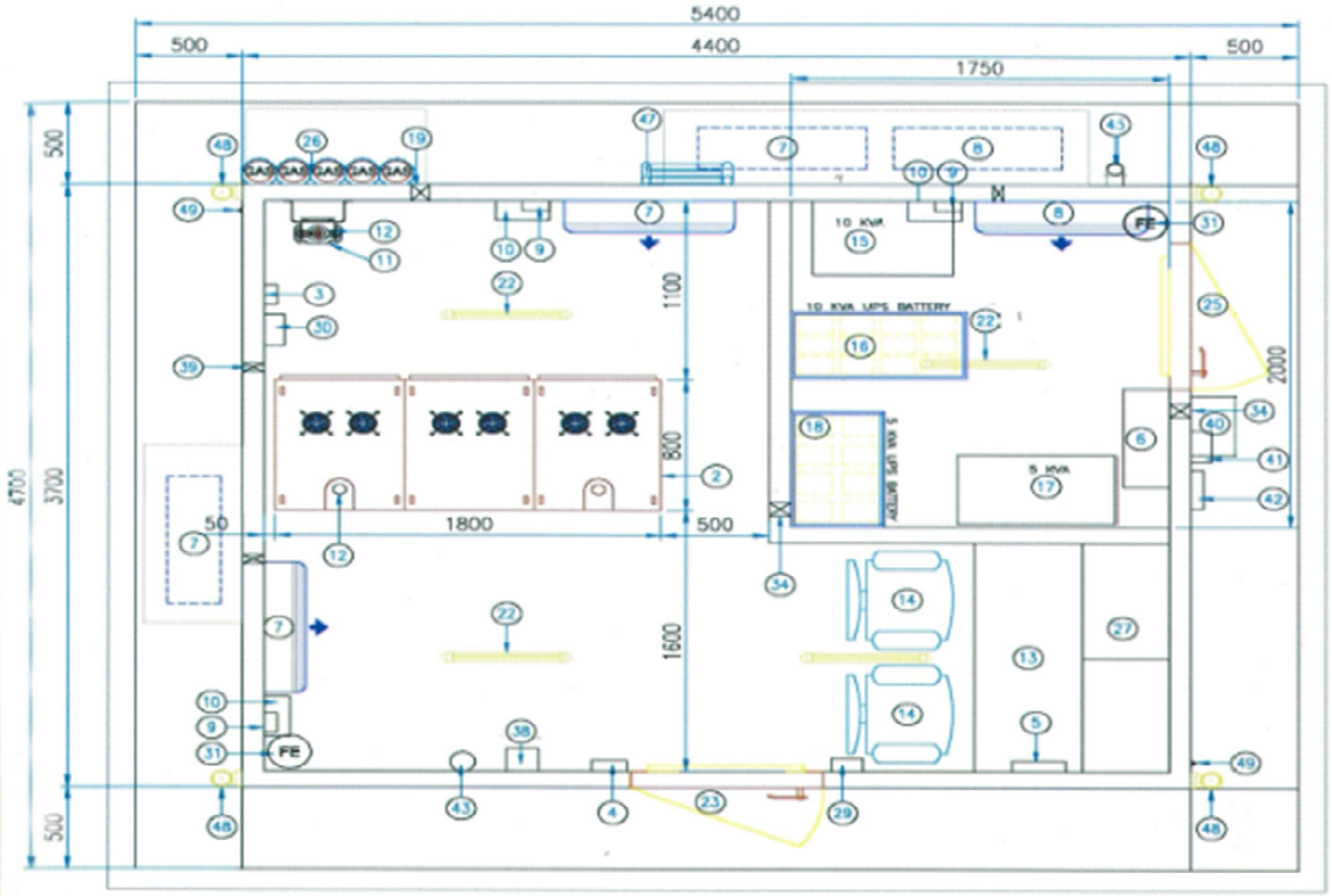
1.2 CAAQM SYSTEM

A Continuous Ambient Air Quality Monitoring System (CAAQMS) is a specialized system that is housed in a temperature controlled container and is equipped with all necessary analyzers, required for ambient air quality monitoring, calibration equipment, data acquisition (hardware and software) system with complete power backup facility. This system can be remotely managed and real time monitoring data can be accessed.

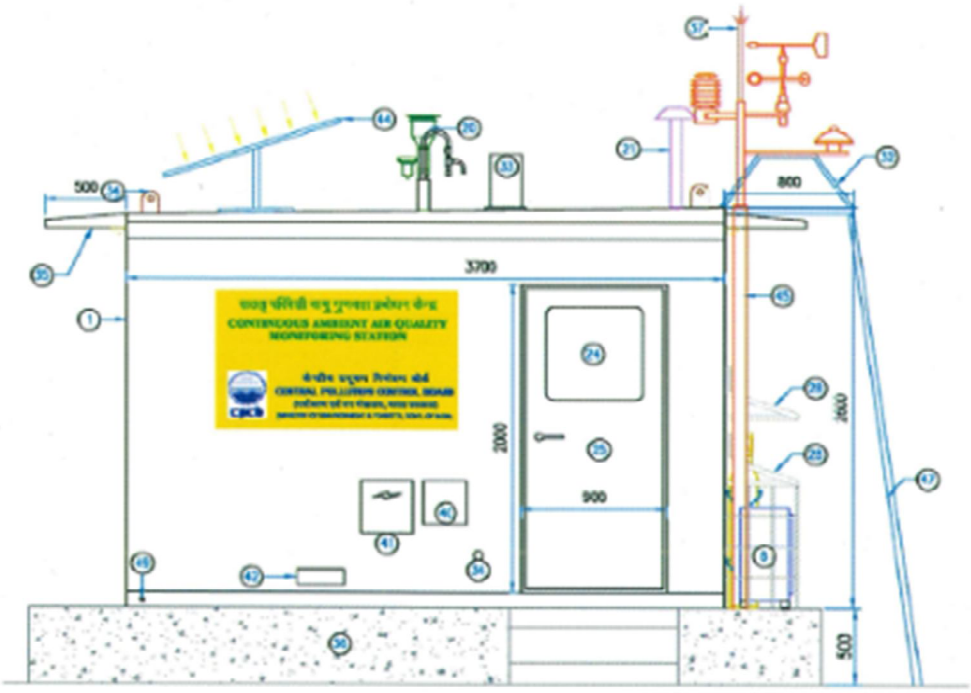
1.3 Components of a CAAQM System



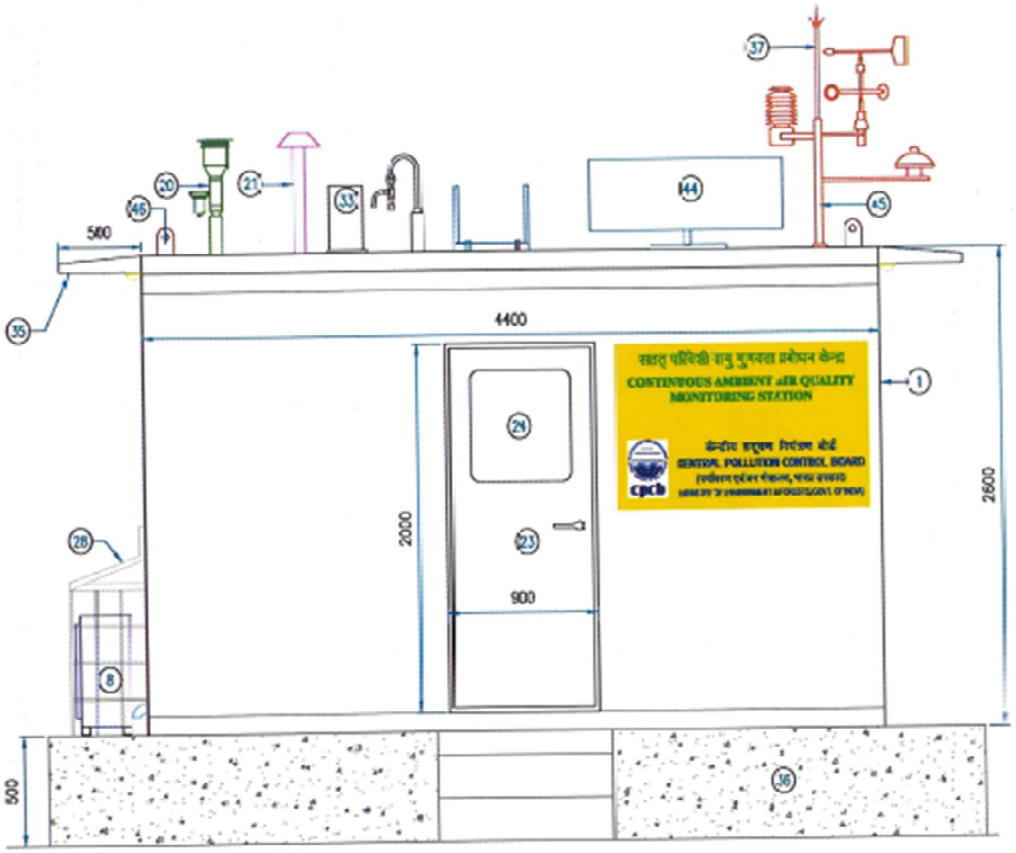
1.4 Model of CAAQM System Shelter



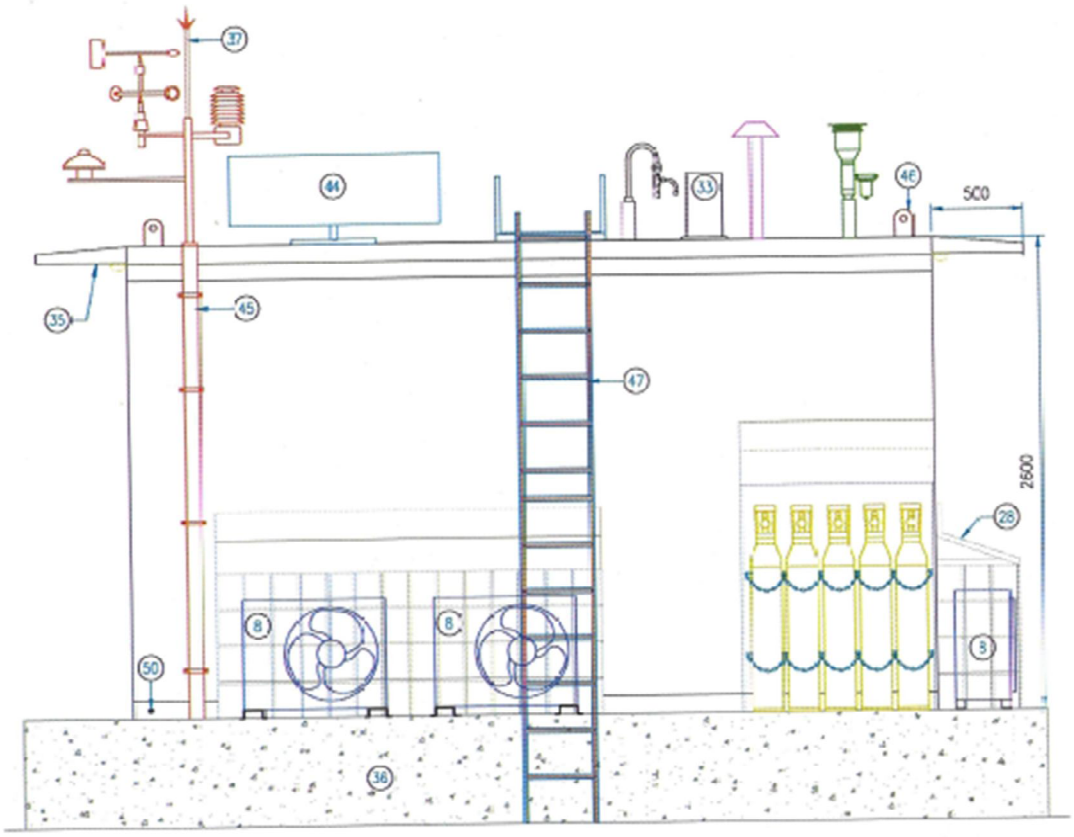
TOP VIEW



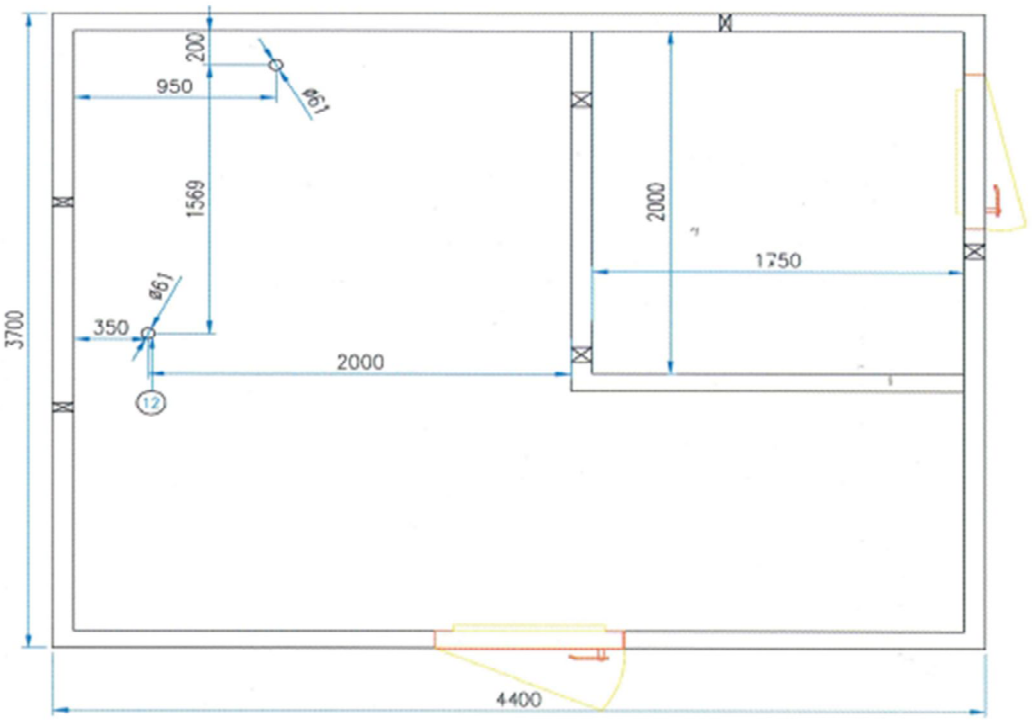
R.H.S. VIEW



FRONT VIEW



REAR VIEW



ROOF HOLES DETAIL LAYOUT

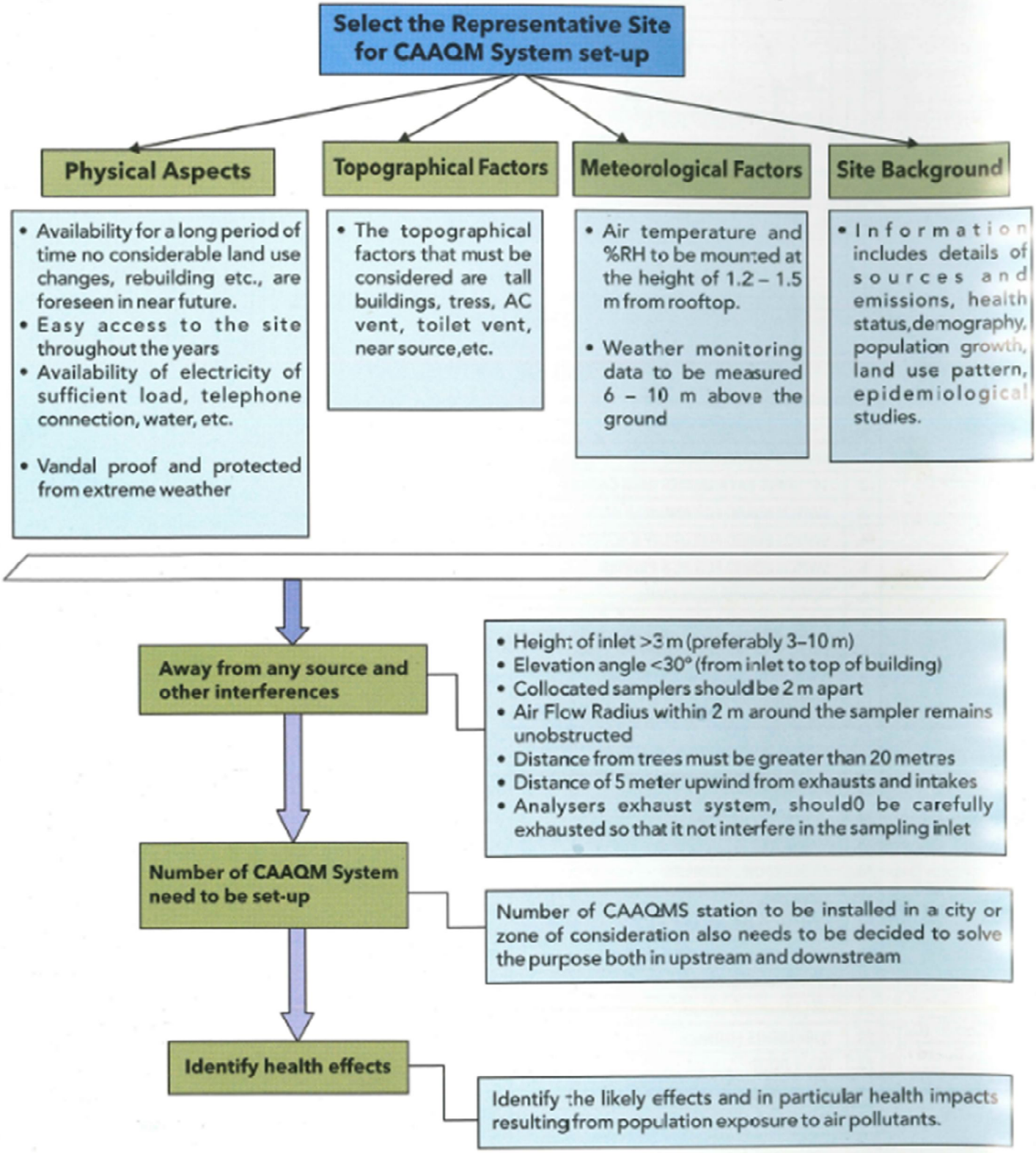
Sr. No.	Description
1.	AMBIENT STATION ROOM
2.	19" TRIPLE BAY ANALYZER RACK CABINET
3.	SWITCH BOARD FOR ANALYZER RACK
4.	SWITCH BOARD FOR UTILITY & ACCESSORIES
5.	SWITCH BOARD FOR PC & PRINTER
6.	POWER DISTRIBUTION PANEL
7.	2.0 TR SPLIT AIR CONDITIONERS - 2 NOS.
8.	1.0 TR SPLIT AIR CONDITIONERS - 1 NO.
9.	AIR CONDITIONER SWITCH BOARD
10.	STABLIZER FOR AC UNIT
11.	MOISTURE TRAP
12.	ROOF HOLE FOR MOISTURE TRAP, GAS/SPM SAMPLING HOOD
13.	WORKING TABLE
14.	OPERATORS CHAIRS
15.	10 KVA UPS
16.	BATTERY FOR 10 KVA UPS
17.	5 KVA UPS
18.	BATTERY FOR 5 KVA UPS
19.	CALIBRATION GAS TUBING ENTRY
20.	SPM SAMPLING HOOD
21.	GAS SAMPLING HOOD
22.	TUBE LIGHTS FITTINGS
23.	MAIN DOOR
24.	GLASS WINDOW FOR DOOR
25.	SIDE DOOR

Sr. No.	Description
26.	CALIBRATION CYLINDERS
27.	CUPBOARD
28.	SHADE FOR CYLINDERS/AC OD UNIT
29.	EMERGENCY SWITCH
30.	THERMOSTAT
31.	FIRE EXTINGUSHER
32.	ROOF PLATFORM
33.	RAIN GUAGE
34.	POWER CABLE ENTRY
35.	CANOPY
36.	FOUNDATION FOR SHELTER
37.	LIGHTING ARRESTER
38.	HYGROMETER
39.	EXHAUST FOR ANALYZER
40.	TELEPHONE JUNCTION BOX
41.	30 ENERGY METER
42.	EARTHING STRIP
43.	EMERGENCY LED CLUSTER LIGHT
44.	SOLAR PANEL
45.	METETOLOGICAL MAST - 10 MTRS.
46.	LIFETING HOOKS
47.	LADDER
48.	EXTERNAL LIGHTS
49.	BODY EARTH POINT
50.	LIGHTING ARRESTER EARTH

Chapter-2

Pre- requisite for Installation

2.1 Flow chart to select the representative site for set-up of CAAQM system



2.2 List of Requirements

The following instruments/equipments should be intended for one Continuous Ambient Air Quality Monitoring (CAAQM) system:

Brief Description	Qty. in Nos.
CAAQM SYSTEM – HOUSING/CONTAINER	
Housing/Container including sampling system(GAS and PM), internal, electrical and gas line fittings, instrument racks, tools (electrical & mechanical), etc.	1 Unit
SPLIT AIR CONDITIONER (AC)	
2 Ton Capacity	2 Units
1 Ton Capacity	1 Unit
ONLINE UNINTERRUPTED POWER SUPPLY (UPS)	
10 KVA, capacity (Three Phase I/P and Single Phase O/P, with 01 hours backup) for Air Conditioner	1 Unit
5 KVA, capacity (Single Phase I/P & Single phase O/P, with 02 hrs backup for Analysers)	1 Unit
CONTINUOUS AMBIENT AIR QUALITY MONITORING ANALYSER / SYSTEM	
Sampling System- For Gas & PM	1 Unit
19" Rack	3 Units
CONTINUOUS AMBIENT AIR QUALITY MONITORING ANALYSERS (GAS)	
SO_2 Analyser	1 Unit
NO-NO_2-NOx Analyser	1 Unit
NH_3 Analyser	1 Unit
CO Analyser	1 Unit
O_3 Analyser	1 Unit
BTX Analyser	1 Unit
CONTINUOUS AMBIENT AIR QUALITY MONITORING ANALYSERS (PM)	
Continuous PM_{10} Monitoring Analyser	1 Unit
$PM_{2.5}$ Monitoring Analyser	1 Unit
CALIBRATION SYSTEM	
Multi Point Calibrator comprising of calibration gas supply, zero air generation, ozone generator and automated calibration	1 Unit
Calibration Gas Cylinders (SI traceable)	
METEOROLOGICAL SYSTEM	1 Unit
Sensors for (A) Wind Speed, (B) Wind Direction, (C) Ambient Temperature, (D) Relative Humidity, (E) Solar Radiation & (F) Rainfall, mounted on (G) Telescopic Crank-up Meteorological Tower with (H) Barometric Pressure	
DATA ACQUISITION AND COMMUNICATION SYSTEM	1Unit
Station Computer with Data Logging facility(Station and Central)	1 Unit
Work Station Computer (for AQI Preparation) (Station and Central)	1 Unit
Managed CISCO Switch (Rack Mountable)	1 Unit
Access Point (AP) (Station and Central)	1 Unit
Unified Threat Management (UTM) device (Station and Central)	1 Unit
Connectivity for Data Transfer (Station and Central)	1 Unit
DAH Software (Station and Central)	1 Unit
Remote Monitoring Tool/Software (Station and Central)	1 Unit
42 U Industrial Rack (Central)	1 Unit
Rack Server (Central)	1 Unit
Display Board Data Transmission Device (Station and Central)	2 Units
Outdoor LED Data Display System (Station and Central)	2 Units

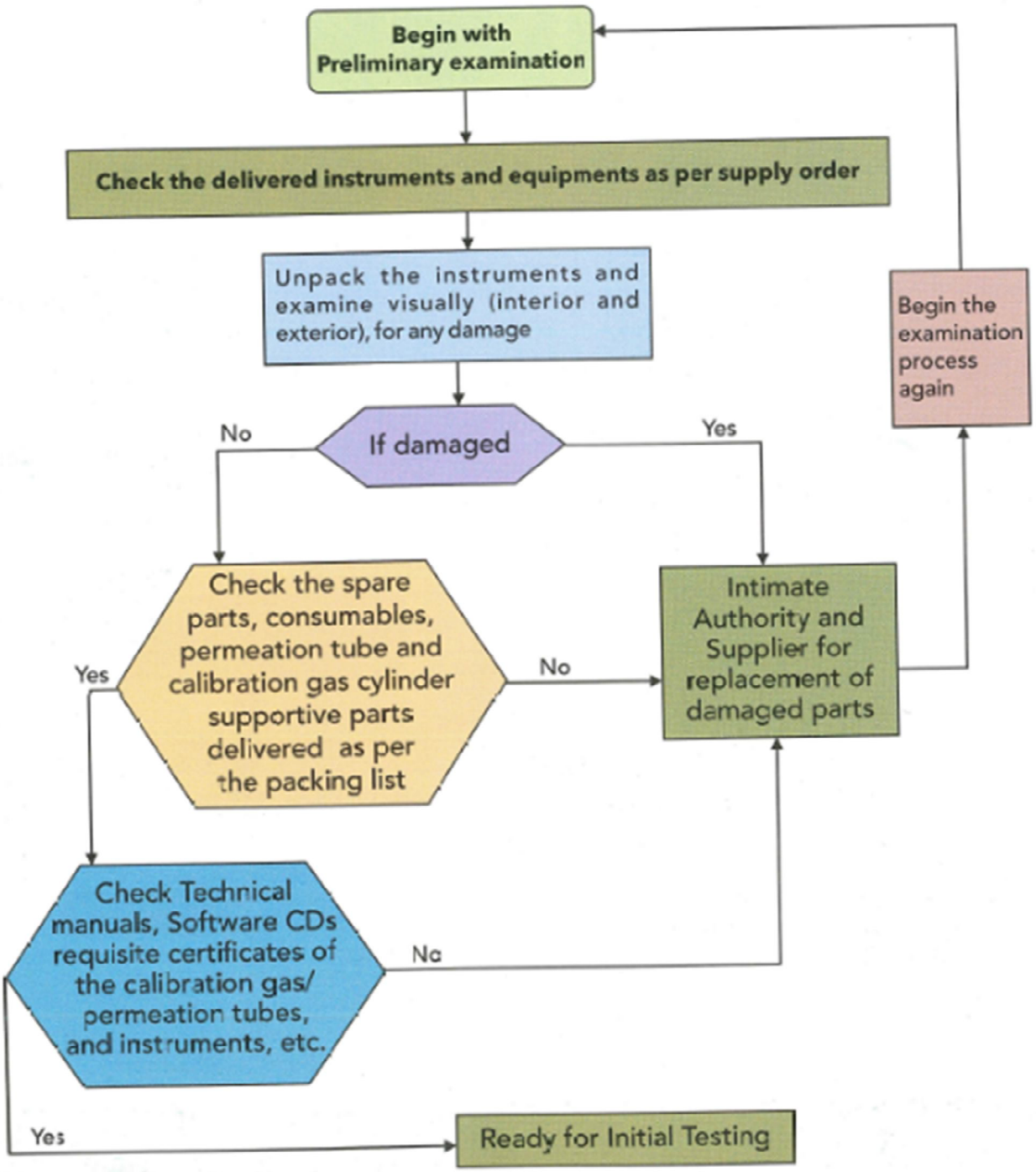
Note : For Detailed Specifications of above mentioned equipments and instruments, refer to separate document of CPCB (available on CPCB website i.e. www.cpcb.nic.in)

Chapter-3

Unpacking of Instruments/ Equipments

In this chapter, the procedure for unpacking of Instruments/Equipments at the time of its arrival and its physical examination for any damage and checking of supplied materials/items as per the list provided has been discussed.

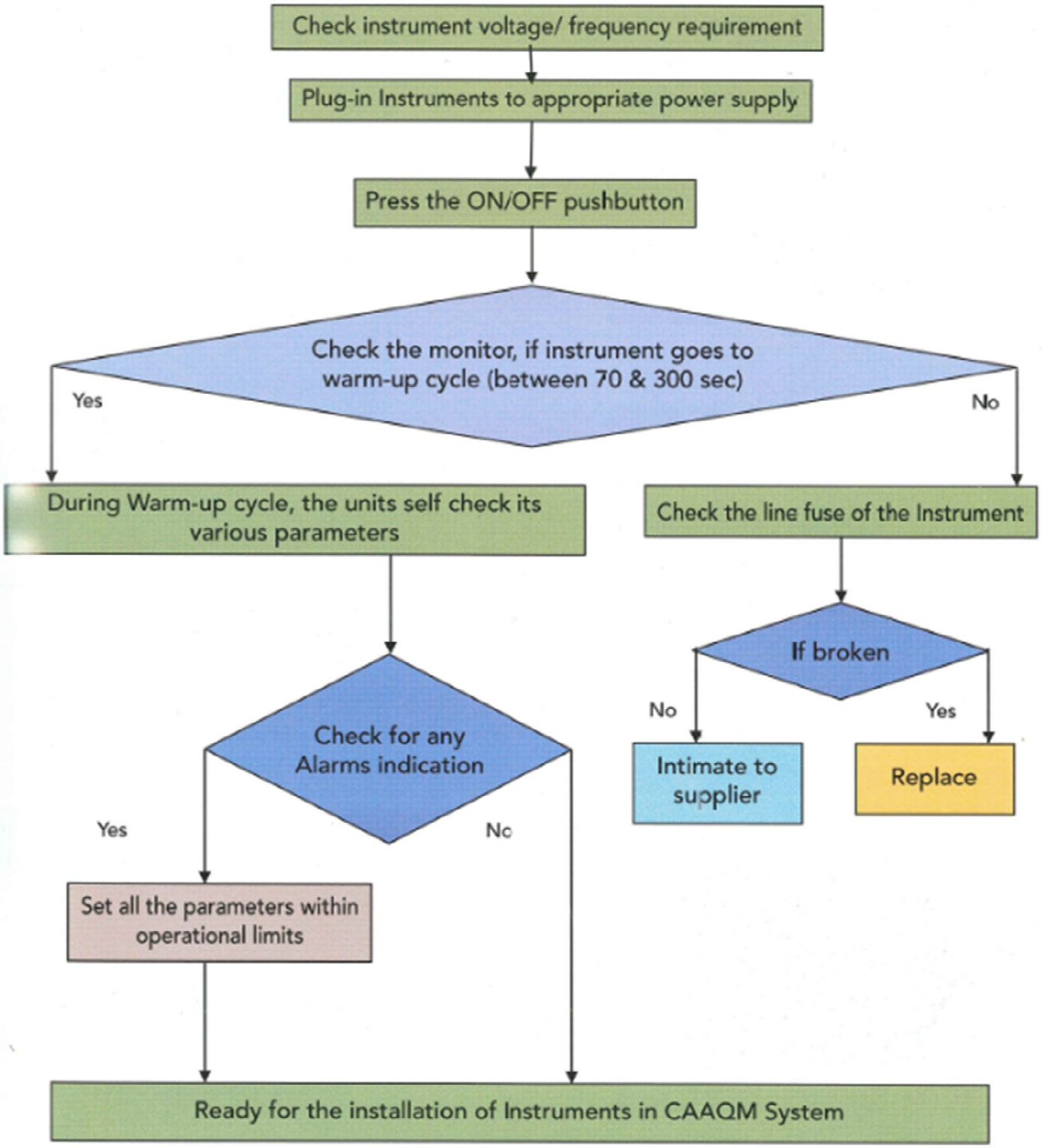
3.1 Flow chart of Preliminary examination (Visual/ Physical Inspection) of the components



3.2 Initial Testing

The components of the system need to be checked initially before going for their installation in the CAAQM System.

Flow Chart of Initial Testing

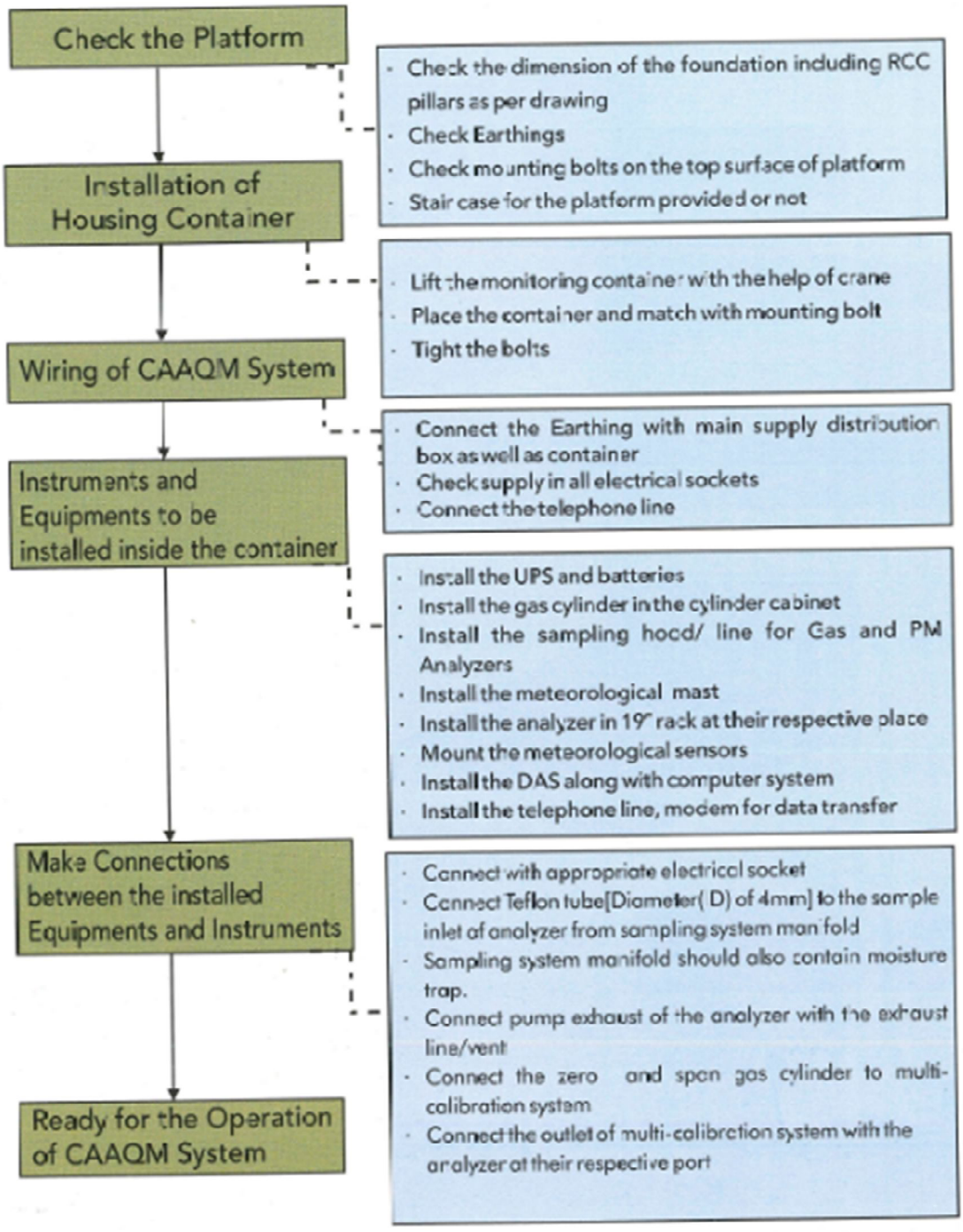


Chapter-4

Installation of Instruments and Equipments of CAAQM System

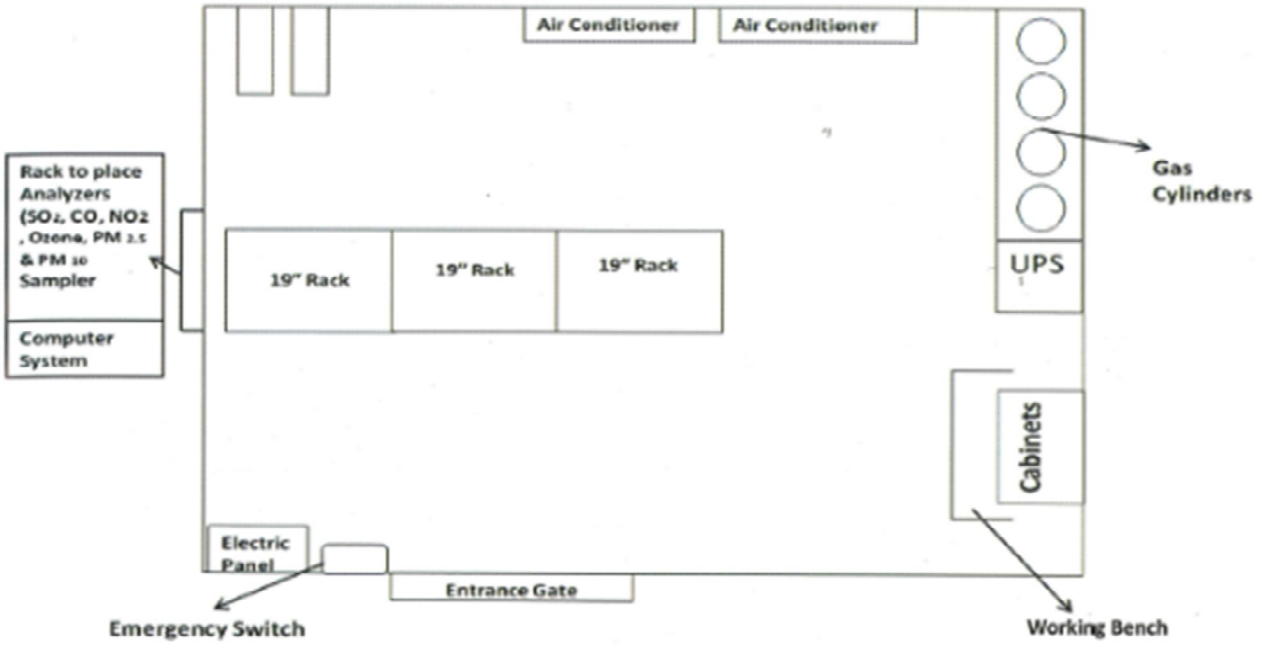
The various operations, required before installations of Instruments & Equipments of CAAQM System have been described in the following sections.

4.1 Flow chart of Installing Procedure



4.2 Floor Layout of CAAQM System

This floor layout shows the placing arrangement of main components of a CAAQM System.



4.3 Layout of CAAQM System

Figure 1.2 shows the arrangement of connections of sampling manifold with the respective analyzers and their outputs. The schematic drawing of sampling system as well as output of meteorological sensors with the Data Aquisition System is as shown in Figure 1.3.

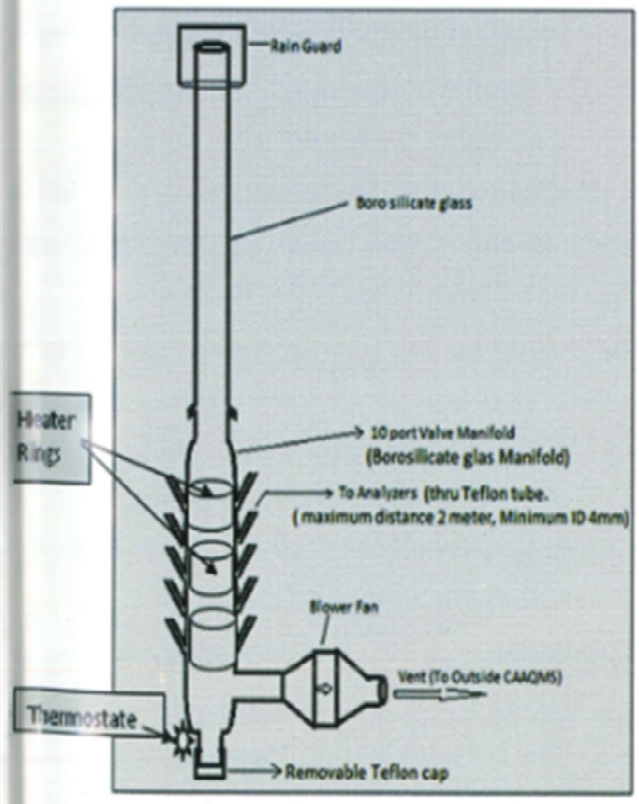


Figure 1.2 CAAQMS Sampling Manifold

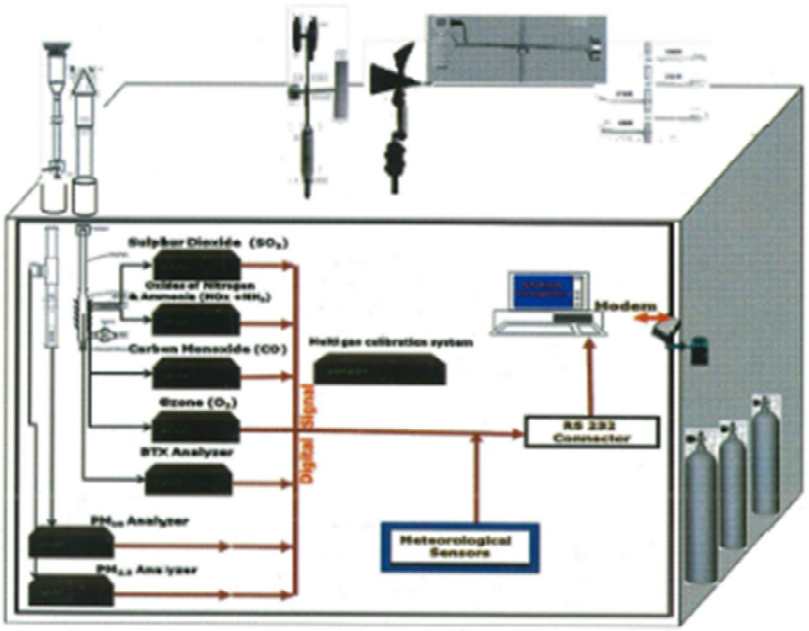
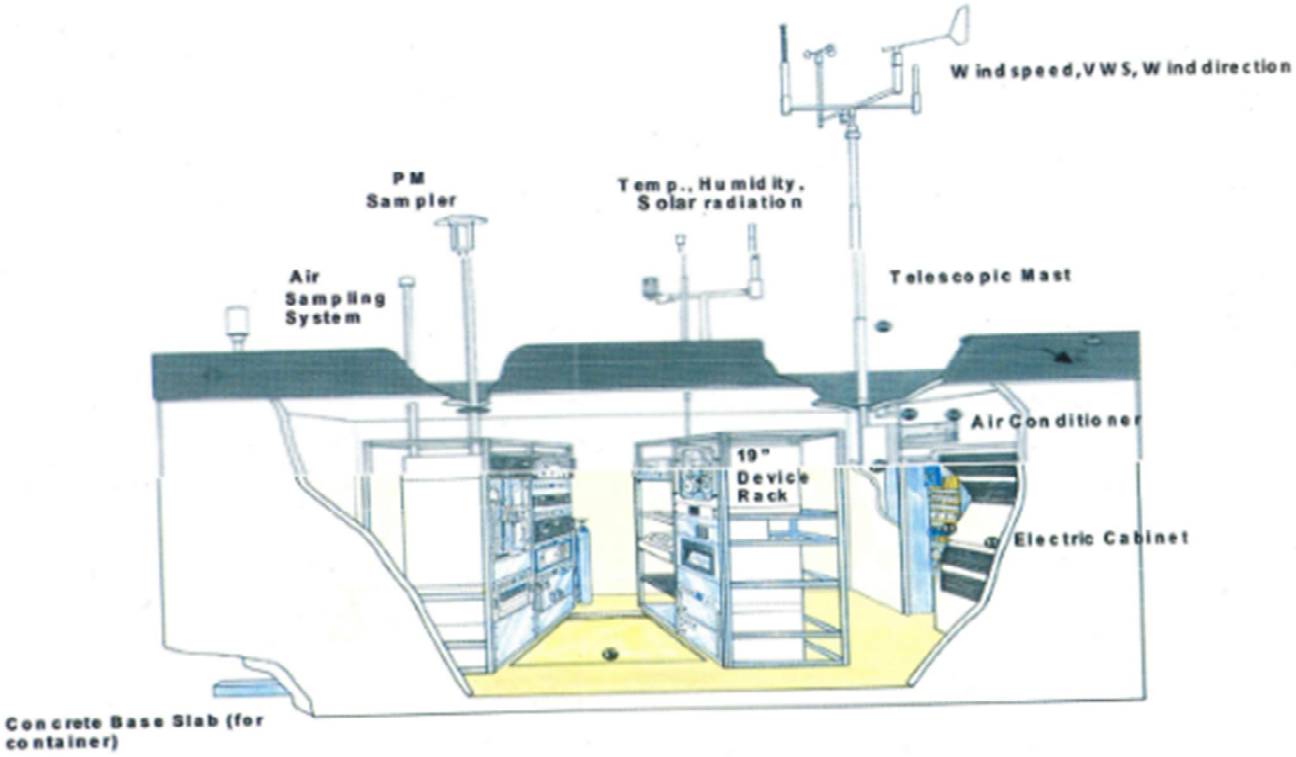


Figure 1.3 CAAQMS Sampling System

The following arrangements indicate the placing of different Meteorological Sensors and Samplin System on the roof top of CAAQM Housing/ Container.



4.4 Requirements - Prior to Operation and Calibration

(a) **Environment condition : -** The CAAQM System should be maintained neat and clean, free fro dust, chemicals, very high humidity, etc., for smooth functioning of any electronic analyzer systems.

(b) **Housing Temperature & Relative Humidity : -**The temperature inside the housing should b maintained at 25±2°C and relative humidity at 45±5% for better performance of analyzer as w quality of data.

(c) **Power back up : -** The power supply to the analyzer should be always through a rugged U (220V,50 Hz) with proper battery backup.

(d) **Earthing : -** Dedicated earthings are required for the complete system and should be proper tested before putting system in operation.

(e) **Other Checks**

The following checks are required to be performed prior to zero and span calibration procedu While performing these checks, the operator should also comply with the instructions of t manufacturer's operation manual.

- In case of PM analyzer, radiation source shall be inspected by an official supervision agency prior to initial start-up or setup by the authorized / supplier personnel.
- Initial inspections of the equipment and tightness tests on the sources
- Fitting with knurled knob for connection of the sampling head
- Check the air-outlet (pump outlet) for connection to the external vacuum pump
- Check the main power supply assembly of Analyzers
- Check electrical connections of equipments/analyzers
- Check ventilation system consists of a ventilation grid integrated in the rear panel for ventilation of the electrical and electronic circuits
- Check the associated equipment functioning
  - Sampling assembly (sampling head must be grounded)
  - Pump assembly
  - Records
- Selection and modification of programmable parameters
- Set internal real time clock
- Set the units of measurement and how the result will be presented
  - Surface density selection ($\mu g/cm^2$)
  - PM concentration selection($\mu g/m^3$)
  - Selection of unit of flow (LPM)
  - Set the range of measurements
  - Set cycle and period of duration
  - Validates and record all the selections
  - Flow test in different modes
- Alarm checks for detection and indication of malfunctions: temperature, pressure, flow rates, electric parameters, etc.

5 Main precautions before proceeding for calibration

a) Follow standard safety practices for the handling and storage of calibration gas cylinders and their installation.

b) Do not expose calibration gas cylinders to direct sunlight or excessive heat.

c) Maintain the same sample flow rate during sampling and calibration. (Use the same sample pump and flow meter/rotameter)

d) The standard gas mixtures must pass at the time of calibration through all filters, scrubbers, conditioners, and other components, those used during routine ambient sampling.

Chapter-5

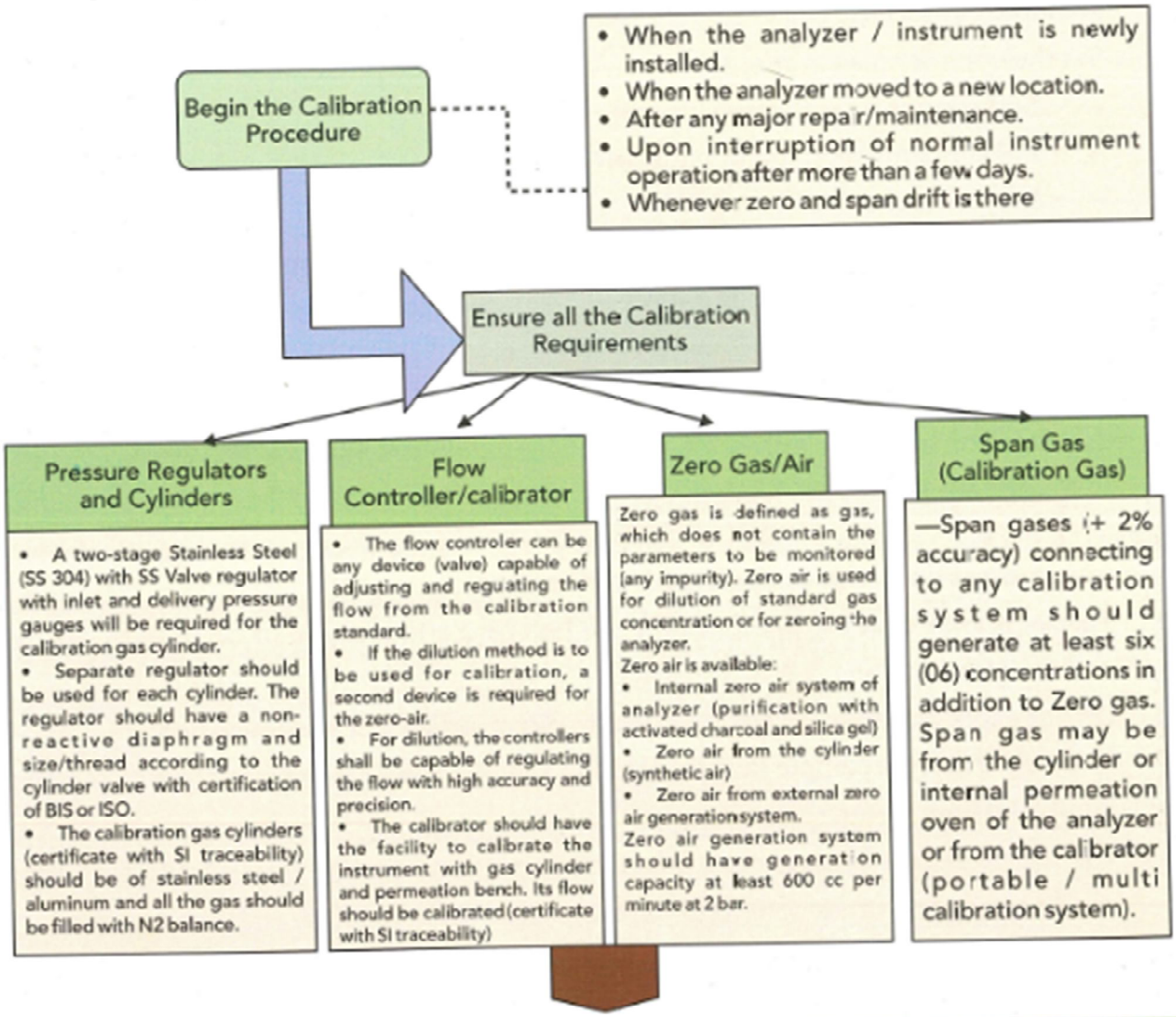
Initial System Start-up & Calibration

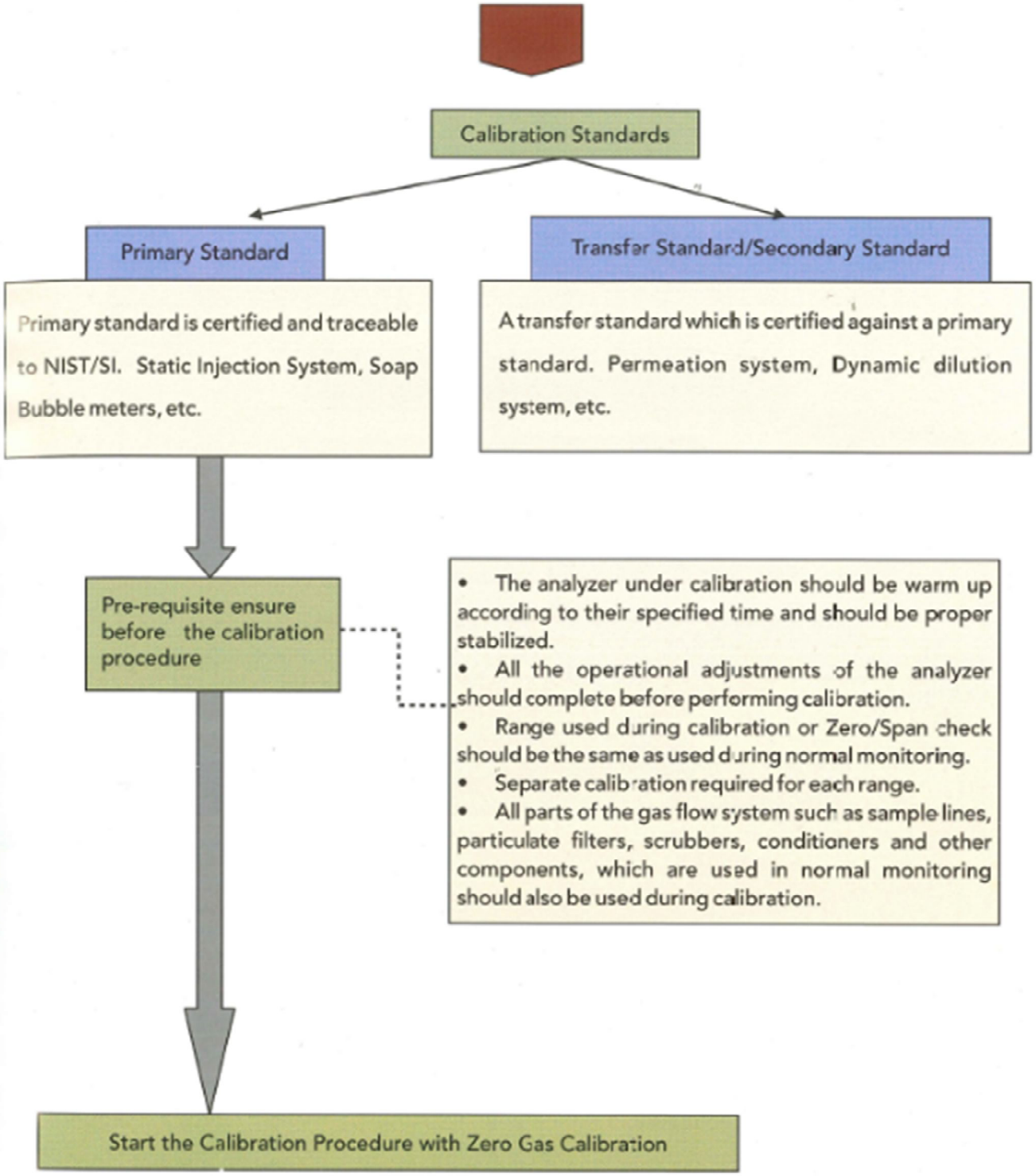
5.1 Introduction

When a new monitoring instrument/analyzer is installed, zero and span calibration should performed frequently, may be daily. After obtaining enough data on the drift performance of t analyzer, the calibration frequency can be adjusted accordingly. To facilitate the process determining calibration frequency, it is strongly recommended that control charts should developed and used to monitor the zero and span drift performance of each analyzer. If the d becomes excessive, then the corrective action has to be taken.

5.2 Flow Chart of Calibration procedure

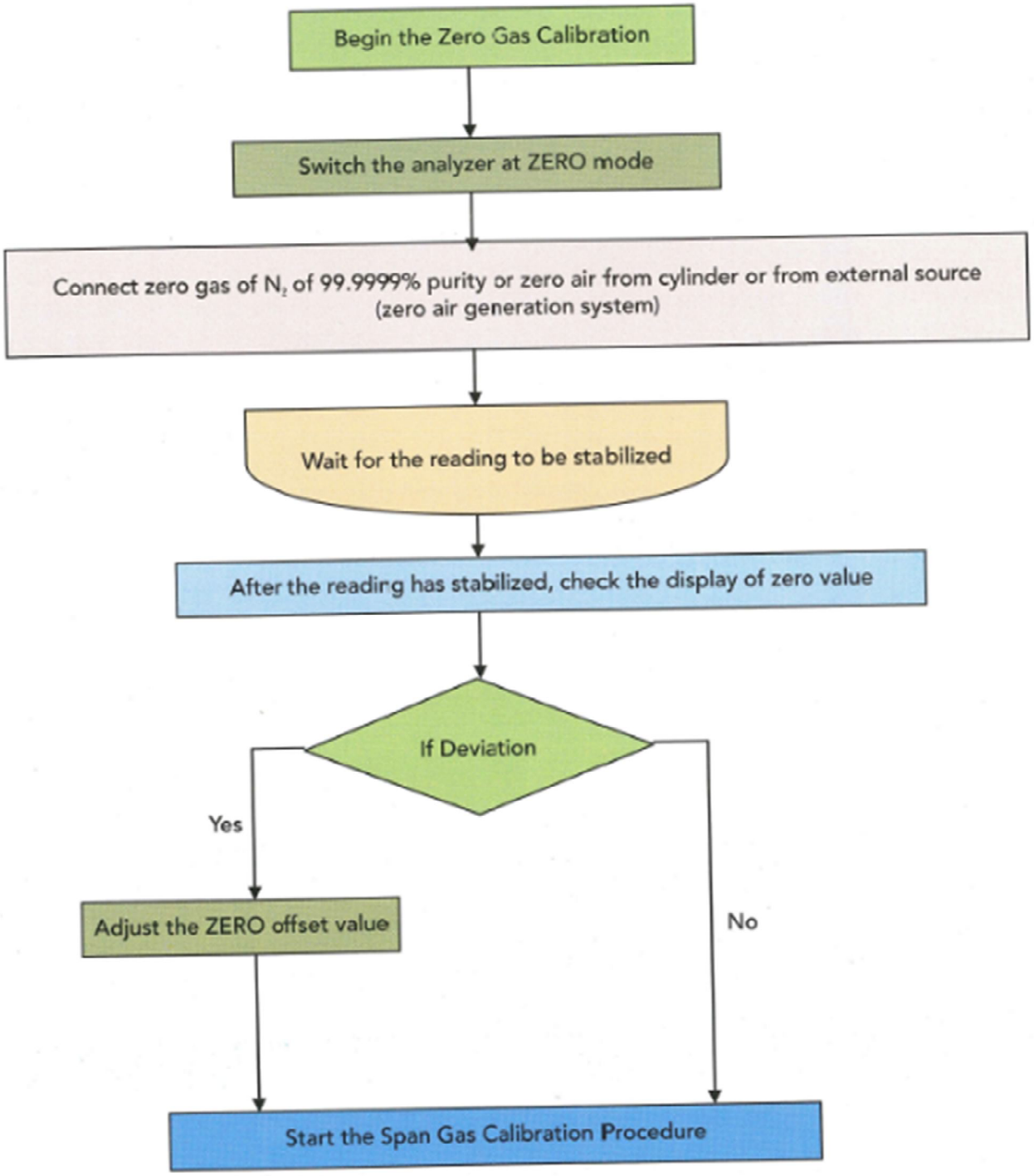
Calibration of a system is to check and adjust any scale, reading or value, digital or analog, comparison with an absolute standard. The calibration of any analyzer/system is very much requir to get the precise and accurate results. The calibrations of Gas analyzers as per the requirement a described sequentially in this flowchart.




Calibration Standards
Primary Standard
Primary standard is certified and traceable to NIST/SI. Static Injection System, Soap Bubble meters, etc.
Transfer Standard/Secondary Standard
A transfer standard which is certified against a primary standard. Permeation system, Dynamic dilution system, etc.
Pre-requisite ensure before the calibration procedure
• The analyzer under calibration should be warm up according to their specified time and should be proper stabilized.
• All the operational adjustments of the analyzer should complete before performing calibration.
• Range used during calibration or Zero/Span check should be the same as used during normal monitoring.
• Separate calibration required for each range.
• All parts of the gas flow system such as sample lines, particulate filters, scrubbers, conditioners and other components, which are used in normal monitoring should also be used during calibration.
Start the Calibration Procedure with Zero Gas Calibration

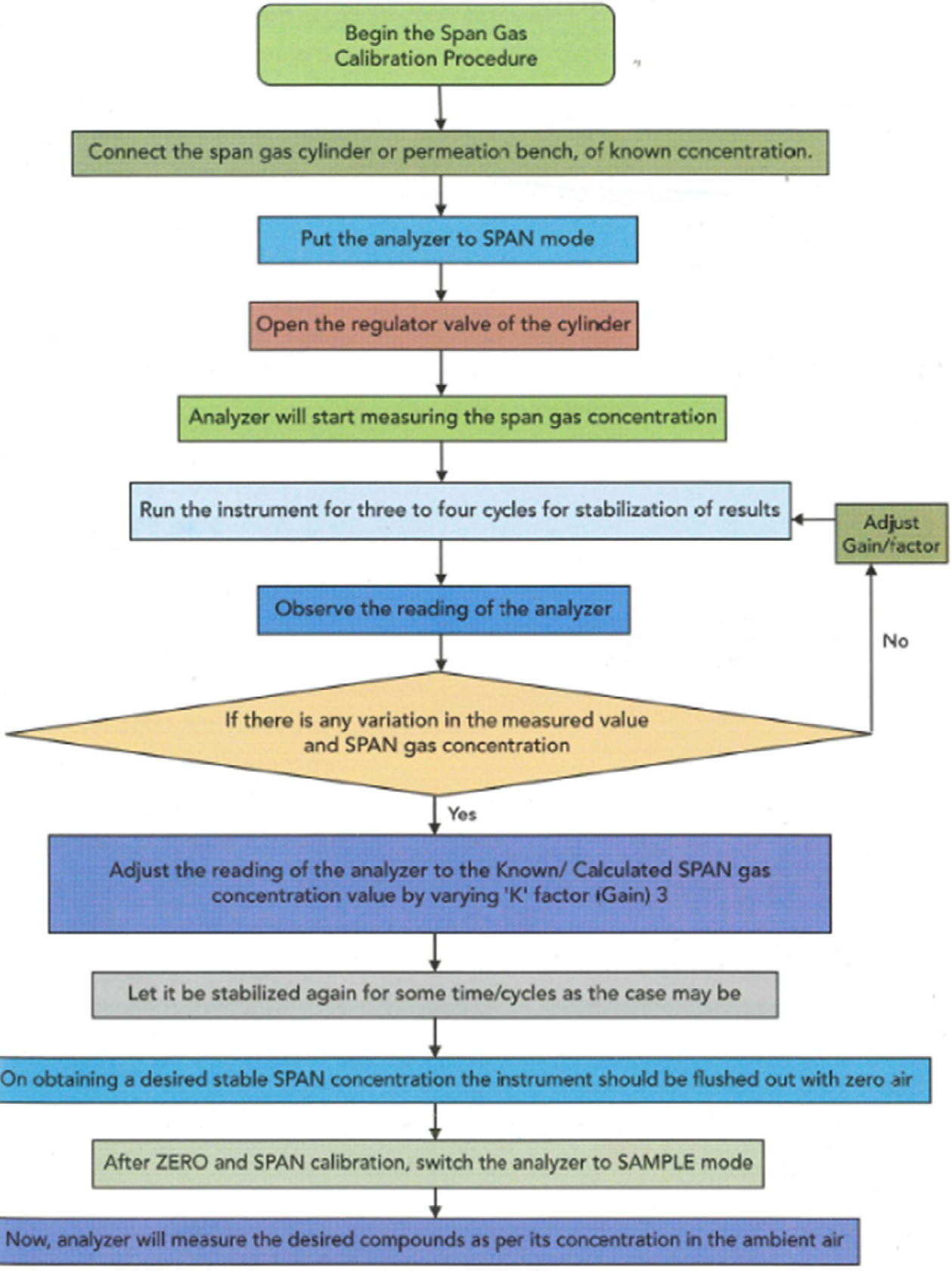
5.3 Flow chart of Zero calibration

The Analyzer calibration process starts first with zero calibration. Synthetic air, Nitrogen, etc., may be us for Zero calibration.



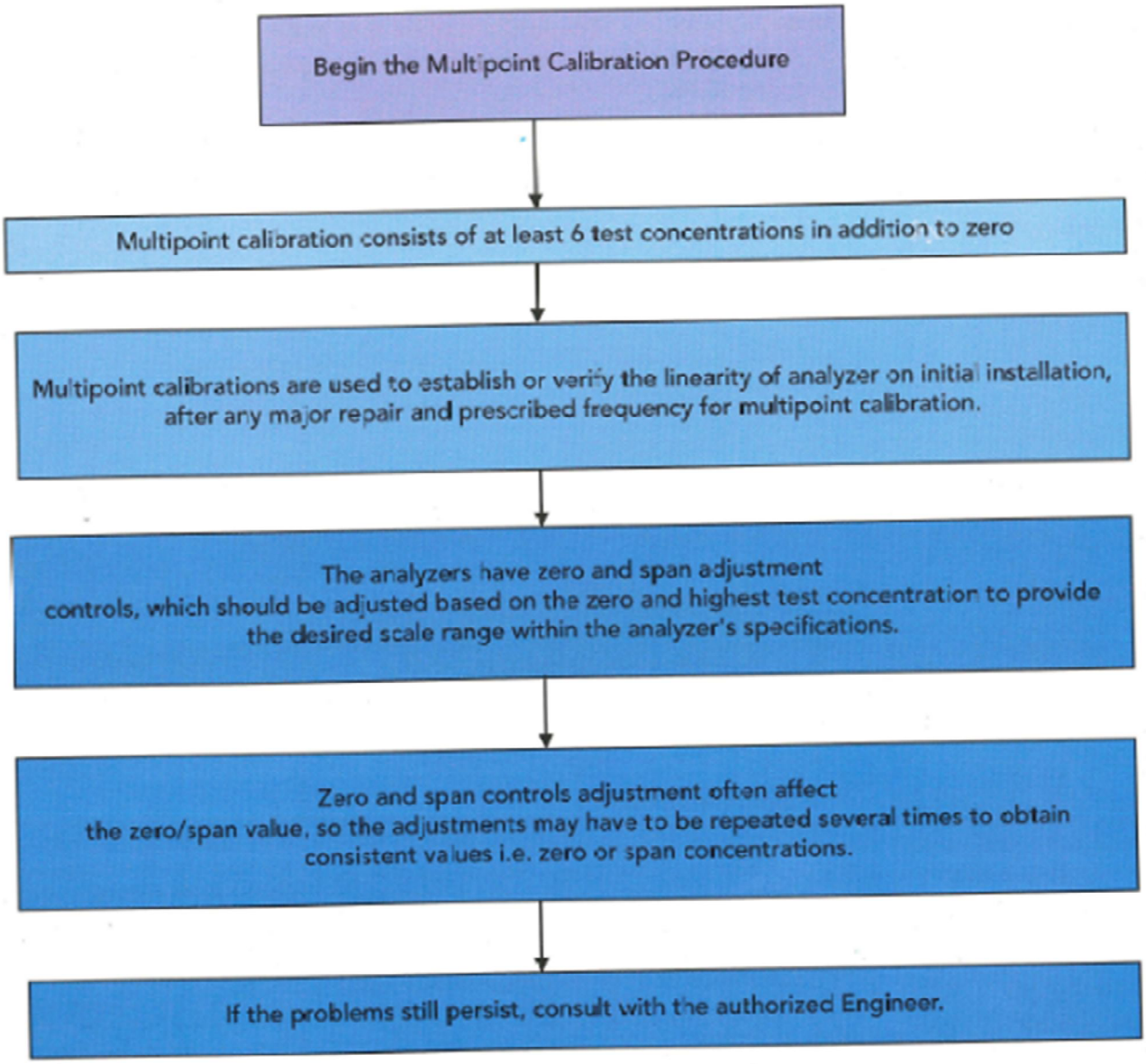
4 Flow chart of Span calibration

ter zero calibration, the span calibration should be performed. This calibration is carried out with
as mixtures, traceable to NIST/SI standards.

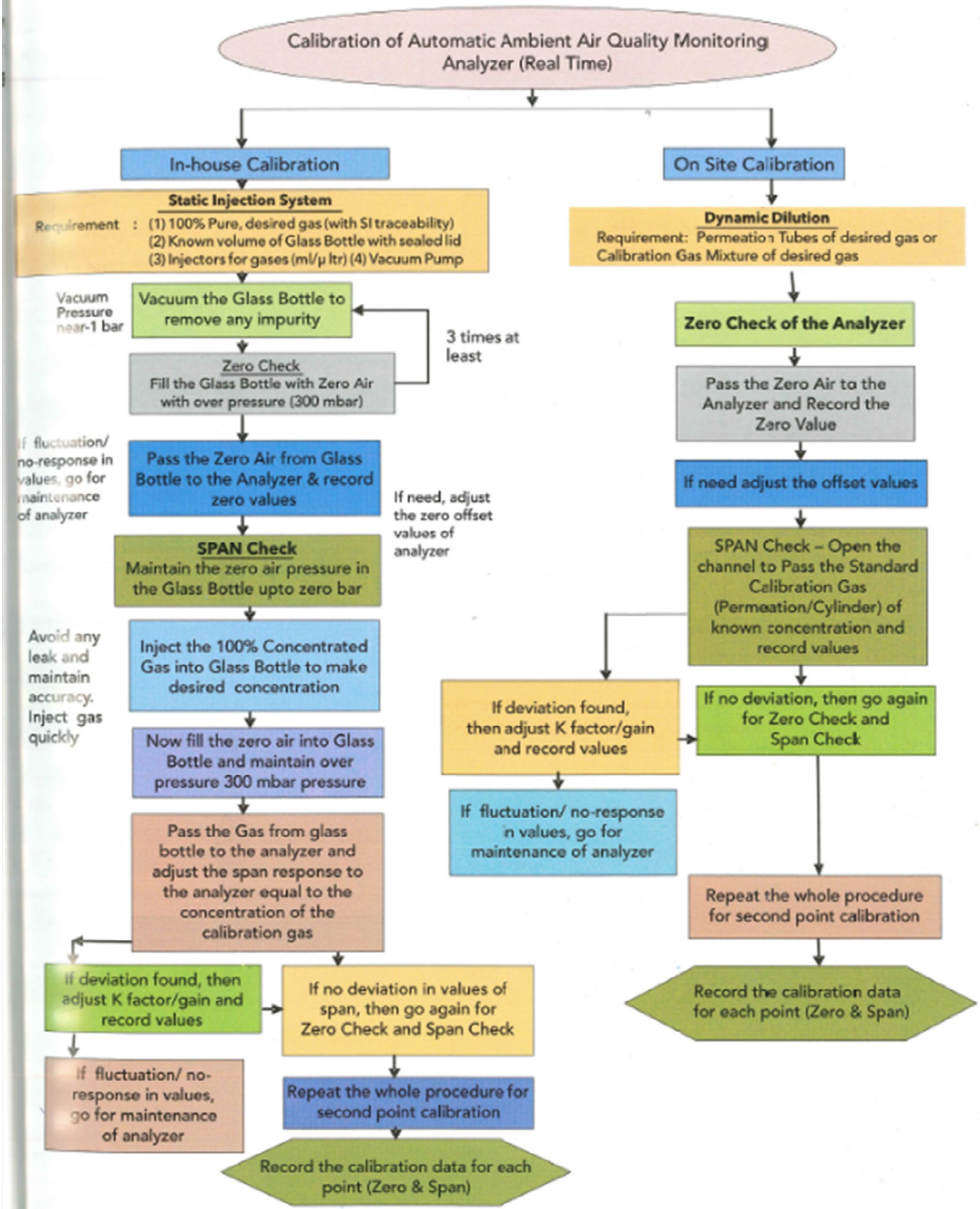


5.5 Flow chart of Multi-point calibration

Multipoint calibration is performed when new analyzer is installed or after any major breakdov /repair in the analyzer. Multipoint calibration procedure include the span calibration procedure wi different concentration values i.e. 15%, 30%, 45%, 60%, 75% and 90% of full scale (measuring rang for the parameter.



5.6 Flow Chart of Calibration with Primary and Secondary Standards



5.7 Calibration Frequency of Analyzers

S. No	Calibration	Description	Frequency/ Periodicity
1.	Zero and span check (Drift Check)	• Zero and span drift check without any adjustment in analyzer • Comparing the analyzer response for a zero air and a span point of the range used • This check can be performed using internal zero air and span.	Daily (once in 24 hrs in automatic cycle mode)
2.	Two-point calibration (Precision check)	Checking & correcting the response of the analyzer at zero & at a span point located at approximately 80% of the full scale of the range used.	Once in Ten days
3.	Multipoint calibration (linearity check)	• Complete check of the analyzer performance characteristics (linearity). • Multi calibration system/ calibration allowing the generation of 06 concentrations up to 80-90% of the upper range limit. • Six gas concentration (15%, 30%, 45%, 60%, 75%, & 90% of full scale of range used)	Once in three month or after any intervention to the analyzer

The following table describes the applicability of calibration i.e. Zero/ Span check, Two point and multipoint of different Analyzers:

Analyzer	Check Zero & span point (Daily)	2-point Calibration (Once in 10 days)	Multipoint Calibration (Once in 03 months)	Check of Convertor efficiency
SO_2	Yes	Yes	Yes	Not Applicable
NO-NO_2-NO_x	Yes	Yes	Yes	Yes (checking the convertor efficiency with GPT) Conv. Efficiency> 96%
NH_3	Yes	Yes	Yes	–
CO	Yes	Yes	Yes	–
O_3	Yes	Yes	Yes	–
BTX	Yes	Yes	Yes	–
PM_{10}/ $PM_{2.5}$	Zero calibration check automatically with every cycle of measurement	–	Span calibration with pre-calibrated filter/disc	–

Note : Mention certificate of cut-point with SI/NIST traceability for PM_{10} & $PM_{2.5}$ Analysers

5.8 Calibration frequency of Meteorological Sensors

S. No	Parameter	Description	Frequency
1.	Wind direction sensor	• Cardinal points. • North • East • South • West	Once in a Year
2.	Wind speed sensors	Wind Tunnel	Once in a Year
3.	Barometer pressure	By comparing with any reference barometer	Once in a Year
4.	Solar Radiation	Calibration with reference sensor	Once in a Year
5.	Air temperature & Humidity sensor	Calibration with reference sensor	Once in a Year

5.9 Summary of the entire process

A) Step-wise Operation of Gas Analyzers

- Ensure the connectivity of the Teflon tube from analyzer to the well cleaned glass manifold sampling system
- Ensure the main sampling pump in ON condition
- Replace Teflon dust Inlet Filter (PTFE) of the analyzer
- Power ON the analyzer and wait till Warm-up
- Configure the Date, Time, Language, Measuring Range and check for any Alarm message
- In alarm condition, check the MUX signals within acceptable limits & calibration oven temperature
- Select Zero mode for zero calibration
- Ensure that the fillers in Zero Bag Filter are in good condition
- Check Zero value and if any deviation, adjust the value
- Analyzer is zero calibrated
- Select Span mode (for Span calibration)
- Pass the Span Gas of Known concentration (source from internal Permeation Oven or external Gas cylinder)
- Check the Span value and adjust, if required
- Go to the K-factor for adjusting the span value
- Analyzer is calibrated
- Put the analyzer in Sampling mode
- Analyzer shows the instantaneous values
- Follow the protocol

B) Step-wise Operation of DUST Analyzers

- Check that the 'O' rings should be fitted properly between the sampling head and Monitor
- Check the connections of the sampling pump
- Fix the filter tape in the monitor
- Switch ON the Analyzer
- Set the Date, Time and sampling flow rate settings
- Proceed for the " SELF TEST" of the monitor to check the proper functioning of the monitor
- Periodic Calibrate the system with its internal calibration system (foil calibration) and correcti there is any deviation (foil should be traceable to NIST/SI standards)
- Every hour it gives a concentration value of $PM_{2.5}$/ PM_{10}
- In sampling 'ON' mode the analyzer will show the previous hourly value of PM2.5/ PM10.
- Put the analyzer in Sampling mode
- Analyzer shows the instantaneous values
- Prepare records/ data sheet

C) Safety Precautions during operation & calibration of Analyzers

- General safety precautions related to electrical hazards must be observed at all times whe working with electrical equipment. Electrical receptacles and equipment must be properl grounded. Use caution when servicing or operating electrical equipment in wet conditions, a frequently encountered at field monitoring sites. Electrical equipment should be switched o and disconnected prior to servicing of internal parts. (Note: Some internal adjustments ma require the equipment to be switched on)
- General safety precautions related to the handling and use of compressed gases must b observed during the calibration and QC procedures for continuous analyzers. Never attem to use the contents of a compressed gas cylinder without an appropriate pressure regulate Do not remove valve protector cap until ready to make connections. Keep valve pointed aw from yourself and anyone else. Vent valve briefly to clear opening of dirt and debris befo making connection. Never hammer on a cylinder valve or use excessive force in opening closing. After making connections, check for leaks with soapy water. Close cylinder valve a release all pressure from a device before disconnecting. Never apply oil to a compressed g valve or regulator. Never expose a compressed gas cylinder to a temperature above 52° Vent and use compressed gases only with adequate ventilation.
- Check that gas leak sensors (CO, SO_2, etc) are installed in the house/container. They shou work with alarm.
- Vent line and exhaust system should work properly.
- Fire safety gadgets, first aid box should be at the place.

Chapter-6

Data Acquisition of CAAQM System

All the outputs of Analyzers and Meteorological Systems are connected with the Data Acquisition System (DAS). The station software will capture data from all channels of the system and store in the Personnel Computer (PC) which is used for calibration and configuration of each channel.

6.1 Basic Requirements of DAS

- Availability of at least 85% data of a day and 90% and above in a month.
- Calibration is to be done at regular interval.
- Collect local information as much as possible which can impact collected data like storm, local firing, rain etc.
- Initial Data validation can be done by software automatically.
- DAS should reject data, if data crosses a certain predefined percentage range. But, this may not be correct always as it can ignore the impact of other external factor (Rejected Data should be stored separately for further analysis in manual data validation).
- Software validation should be performed and recorded.

6.2 Data Networking

1) Data of CAAQMS station should be transmitted uninterrupted to CPCB & SPCBs and it should be provided from the local station (Raw Data), not from central station.

2) For uninterrupted data connectivity; lease line and broad band connection with static IP address as a backup, should be available at each CAAQM System.

3) Data Acquisition System (DAS) should

Capable of transfer data to CPCB & SPCBs simultaneously and at least 85% data must be uploaded. Balance, 15% data may be considered lost due to calibration and breakdown of analyzers.

Have feature of displaying online diagnostics of analyzer and remote calibration of gaseous parameters.

Able to provide different report format

Have capability to provide data validation facility

Have capability to point out unusual data, and remind before use it for considering in report.

6.3 Flow Chart for Data Acquisition

Ensure or connect all the system with power supply assembly

Install Instruments/ Equipments to acquire data at station as per requirement to set up Data Acquisition System

Connect the port of Analyzers with RS-232 station computer to acquire data

Perform the Plausibility check of the Data acquisition system

Check the data of analyzer before storing into station system database

If a data value seems appropriate start acquiring or storing data in station computer system database

Check the acquire data at station computer before transmitting to central computer

Prepare the record of the data

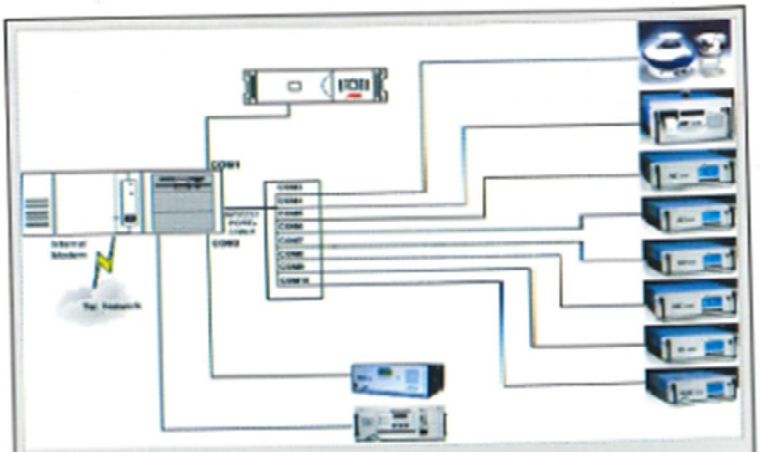


Figure Integration of Station Analyzers

Ideal working Instrument: Check that the instrument should operate in working condition. There should not be any leakage in the sampling line &the instrument should be free from any alarm signals. Flow of the sample should be proper &. MUX signals should be verified as per the manuals provided by the manufacturer. Zero and Span values should be checked.

Storage Device / Computer: Check the data values should be identical while transferring from Instrument to Computer. There should not be any deviation during transmittance of data.

Follow Measuring Range: Check that the data should be in the Measuring range of the instrument. If No, check the working instrument condition as above.

Calibration Factor Check: Check that the last calibration factor should not be disturbed. Check the Zero and Span values if deviation is more than +/- 5 % then remove the data.

No Negative Values : Check that there should not be any negative values on instrument. If yes, check the working instrument condition as above.

Follow Systematic Trend: The data values should be depicted in a trend w.r.t. time series. Difference in two subsequent values should not be very high. If there are any high peak values due to emergency/ local effect irrespective of the general trend, it should be removed.

- The trend of the curve of the collected data of the day be identified.
- The trend is to be compared with the trend of the previous day with the station specific observation.
- Identify the trend of a pollutant.
- Data of a parameter sometimes correlate with another parameter which is to be identified and checked*.
- Compare with the other pollutant with which a correlation exists*.
- If there is no other abnormalities and fluctuation then the data can be considered VALID.

***Note: Depends on the case by case, not always true.**

Check the recorded data

The data files contain 24 hours of data, usually from 6:00 AM to 6:00 AM as one hour averages. Check the data for the following:

a) Check all parameters have data.
b) Check the maximum, minimum, capture rate, average; zero and span are within the specified limits.

If there is any problem in acquired data

Yes

Repeat the plausibility check and take appropriate measures for proper functioning of the system

No

After initial validation of data at station, go for transmitting of Data on Real time basis to Central Server

Install the Data communication system to transmit data to central computer

Ensure the internet connectivity as per requirements

S.No.	Options	Comparison
1.	Dial up	Poor Quality of service Noise, Very Slow, Data transfer success rate 75%
2.	Broadband	Quality is good, breakdown time is high, (location specific) Success rate 80%
3.	GSM with Static IP	Unpredictable, signal strength low inside container, Success rate 90% .
4.	Leased Circuit.	99% sure, reliable, costly (recommended)

Begin the transmission of data to central computer

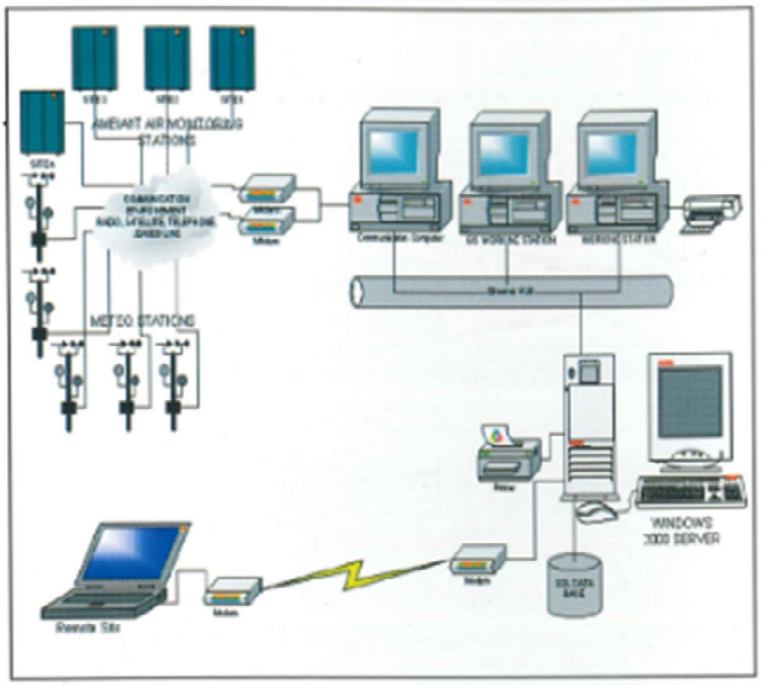


Figure Setup of Data Transmission

In case, there is no data at central computer

Yes

Take the required actions to ensure continuous availability of valid data

1) Visit the station
2) Check for communications breakdown (the modem/ logger may require resetting).
3) Check for loss of station power supply.
4) If steps 2 or 3 are the cause of the problem, then the service provider must be notifiec.
5) If only one instrument id Off-Line, then carry out the following:
(i) Check if the minimum data capture is greater than 80%
(ii) Use discretion to determine whether a station vis t is requirec.
6) If the zero or span falls outside the prescribed limits then carry out the following:
(i) Check the ambient data for unusual values as per the Data Screening Criteria.
(ii) Allow the system to run another automatic calibration before undertaking a station visit
7) In any emergency, if person at the central station unable to identify a problem, then the station operator for that station should be contacted.
8) All the problems should be logged and informed through Mail and phone tc the concerned authorities.

No

Record data at central server for Data Validation

Chapter-7
CAAQMS Data Management at Central

7.1 Data Validation

Data Validation is the routine process designed to ensure that the reported values meet the quality goals of the ambient data operations.

- Its purpose is to deduct and then verify any data values that may not represent actual Air Quality conditions of the sampling stations. These are completely independent of process of Initial Data collection.
- It can be done on the basis of successive data values since it is expected that one does not expect rapid changes of concentration of pollutants during 5 min or 1 hour period.
- When the difference between successive values increases more than predetermined values, the reading will be flagged with appropriate symbol for further verification.

7.1.1 Data validation Protocol for CAAQM system

- Constitute a team of experts for data validation.
- **System validation :-**

Check the data as per the logbook and calibration records maintained at the station and take a note, if any remarks are there.

- **Data validation:-**

Check for Negative values, Zero values, consistent values, diurnal variations, compare with earlier data. Also, note the episodial events, if any.

- Remove the invalid data from the Database
- **Statistical validation:-**

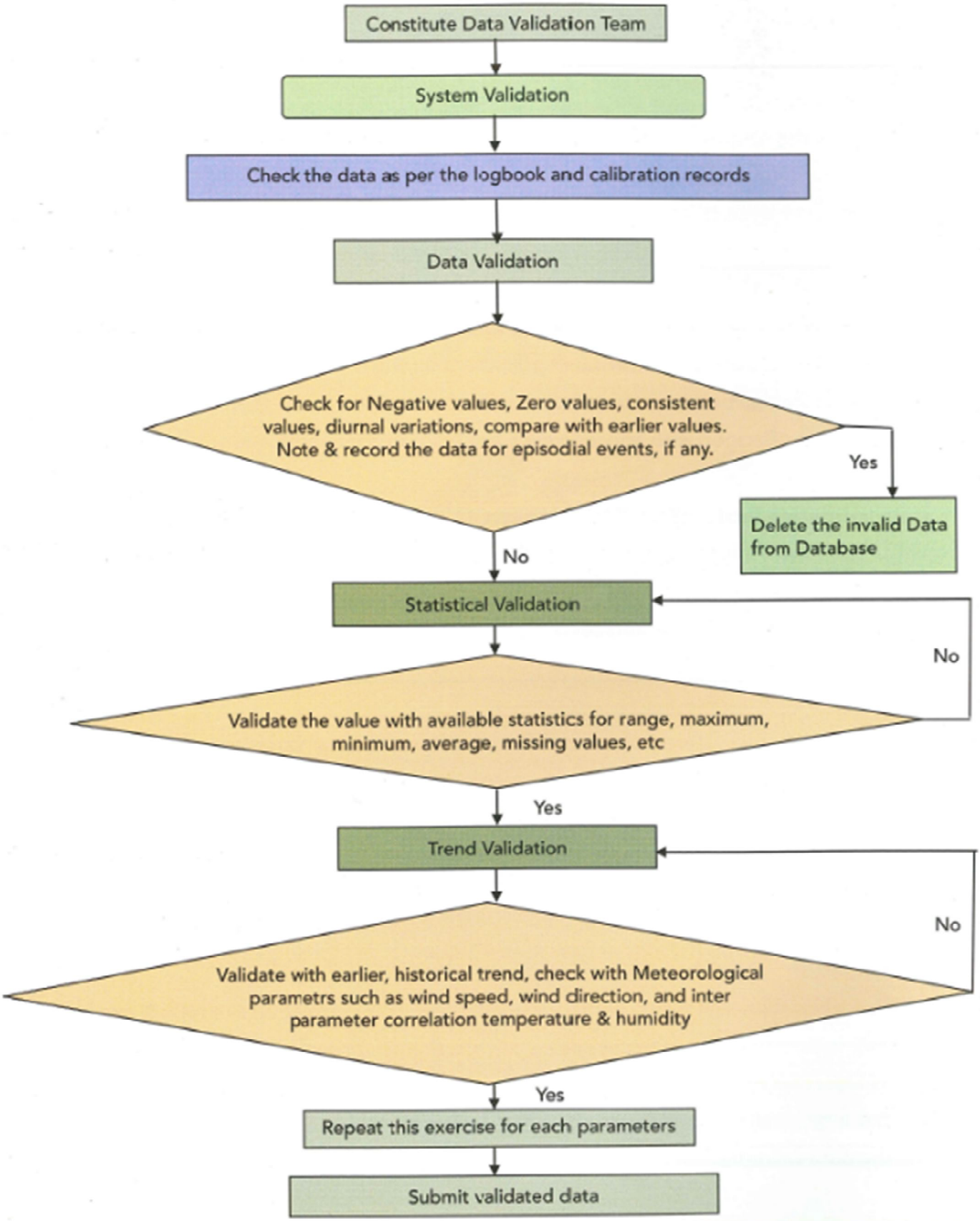
Validate the value with available statistics for range, maximum, minimum, average, missing values, etc.

- **Trend validation :-**

Validate with earlier, historical trend, carry out inter parameter correlation like NO_2 & ozone, etc, and also correlate with metrological parameters such as wind speed, wind direction, temperature, humidity and solar radiation.

- Repeat the similar validation process for each parameter in the above stated manner.
- Submit the data validation report and retain data base in safe custody.

7.2 Flow Chart of Data validation Protocol



7.3 Data Reporting

1. Daily data reporting (complete set inclusive of air pollutants and meteorological parameters) of each station either electronically or hard copy to be submitted.
2. Submission of calibration data regularly in the prescribed format which should be duly signed by the authorized person.
3. Monthly and quarterly report based on valid data generated in the desired format. The monthly reporting should also contain variances from the targeted correct data.
4. The daily data are required to be checked on regular basis by the concerned official and if any discrepancies found, the same shall be communicated to the Supervisor for immediate rectification.
5. Calibration values should be flagged at the station and should not be considered for the calculation of minimum, maximum, average values etc.
6. Data backup is required at the station as well as Central Station.
7. Captured data with Data Capture Rate (DCR - %age of validated and correctly recorded data) should be 85% and above.
8. The recording slots, consumed on a particular day for calibration purpose shall not be considered as a lost data but for maintenance or any other purposes shall be considered as lost data for DCR calculation.

7.4 Performance requirement of CAAQM DAS System

In order to ensure availability of validated data from the CAAQM System, following are the Performance Prerequisites of a CAAQM System:

(i) Capable of operating unattended over prolonged period of time

(ii) Produce analytically valid results with precision and accuracy

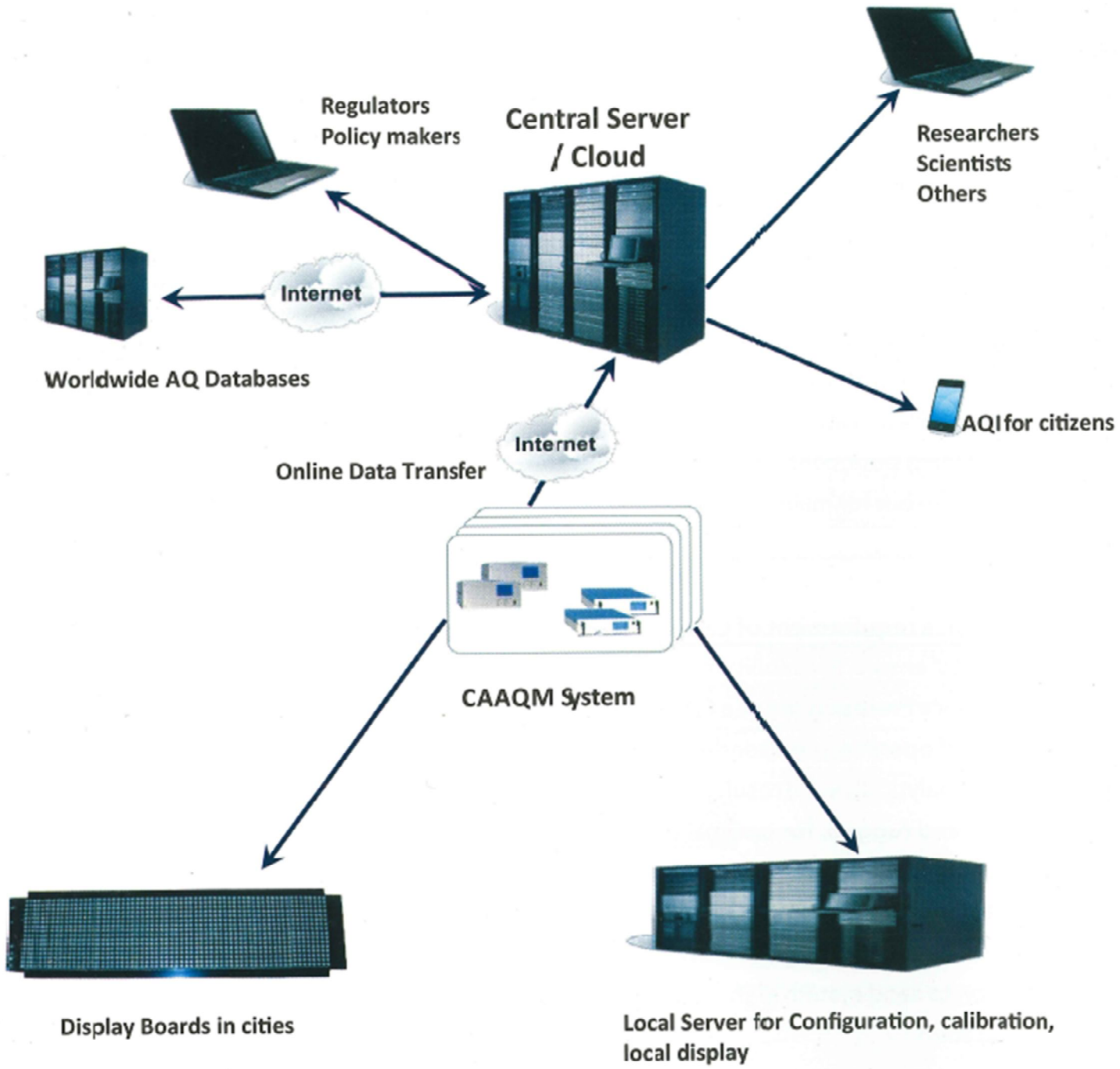
(iii) Robust and rugged, for optimal operation under the normal environmental conditions, while maintaining its calibrated status

(iv) Remote Access facility from Central Server with provisioning of log file access

(v) Provision for transmitting data to Multi-server from station

(vi) Provision to send system alarm to central server and any changes made in system configuration or calibration

7.5 CAAQM System Data Transmission Architecture



Chapter-8
Maintenance

There are two types of maintenance, one is called preventive and another is breakdown maintenance. The timely preventive/ periodic maintenance minimize the down time and prolongs the life of equipment whereas Breakdown maintenance is carried out in the emergent condition.

8.1 Preventive Maintenance

Preventive maintenance is performed while the equipment is still working, so that it does not break down unexpectedly. This tends to follow planned guidelines from time-to-time to prevent equipment and machineries breakdown. It involves systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects.

8.1.1 Physical Inspection of CAAQM System

A) Outside

- Physical check of sampling head and meteorological system installed on top
- Check the Sampling head and meteorological mast are in proper height as installed

B) Inside

- Look thoroughly for any burning/ sparking in the equipments
- Cleaning/ Dusting of racks and equipments is proper or not
- Check the Power supply
- Check if there is any alarms/ Fault status of Analyzers
- Check if there is any leakage of the gas
- Check the Data display on computer system
- Check the cooling of AC to maintain the temperature inside the station
- Check the temperature and RH data logger/ record to see station's environmental condition
- Clean the sampling line
- Change the inlet filter for proper sampling and flow
- Ensure that no moisture content is there
- Check the functioning of sampling pump
- Check the pressure of calibration gases
- Check the temperature and RH data logger/record to see room's environmental condition

8.1.2 Preventive Maintenance for Continuous Analyzers

1) For all analyzers, preventive maintenance should be performed according to the instructions in the instrument manual provided by the manufacturer.
2) For any preventive or remedial maintenance actions taken, the action should be recorded and kept on file. Documentation must include analyzer identification, analyzer location, date of maintenance, name of person who performed maintenance, and type of maintenance performed.
3) Sampling lines should be inspected every month and cleaned annually or when found to be in need of cleaning.
4) Sampling line filters should be inspected/ replaced at least monthly.
5) For analyzers using selective scrubbers/converters (SO_2, NH_3, H_2S), verify their efficiency periodically and replace when necessary.
6) The PTFE filter membrane of the analyzers should be changed once in a week, keeping in view the Indian climate condition.
7) All the permeation tube and gas mixture being used for calibration should be Certified /traceable to SI/NIST. The permeation tube(s) to be used for calibration should not be older than one year, (as per certificate).
8) Every three months, the permeation rate of the certified permeation tubes should be verified by the Gravimetric method and primary calibration system.
9) Calibration schedule should be followed as per the schedule mentioned in 5.7 and 5.8.
10) Maintain the log book for recording analyzers maintenance and breakdown with the status of all other peripherals installed at stations.

8.1.3 Routine Check-up during operation

1.	CAAQMS Room Cleaning
2.	DAS Data Check at Local Station
3.	AC Working Status (Keep Room Temp at 25°C to 27°C)
4.	UPS Back up check
5.	Power Fail Record
6.	Time Synchronization with Analyzer & logger
7.	Status of outside Environment
8.	Instrument Fault Status
9.	PM_{10}/$PM_{2.5}$ Sampling pipe heater check.
10.	Automatic Changeover of AC
11.	Cylinder Pressure Check
12.	Back Fan Filter
13.	PM_{10}, $PM_{2.5}$ Sample Inlet Cleaning
14.	AC Inlet Filter Cleaning
15.	Battery checkup
16.	Filter Checkup (Change, if Required)
17.	MUX Signal Record
18.	Analyzer calibration
19.	Cleaning Glass sample manifold (for gases), PM_{10} & $PM_{2.5}$ sampling hood.
20.	Flow check in PM_{10} / $PM_{2.5}$ Analyzer
21.	Hard disk Data back up
22.	GPT for NO_2 converter efficiency testing
23.	Multi point calibration in all analyzer
24.	Pump Checkup / maintenance
25.	Clean & change Pump Maintenance Kit, restrictor(if required)
26.	All documents/ manuals should be in place, register/log books/ calibration records are maintained/updated properly.

8.1.4 Precautions at the Stations

Don't Run in case of Heavy Rain or Lightening.	Switch off Station
Don't put UPS in by pass mode, if it is not working.	Don't run the station without UPS
Don't run CAAQMS if water is leaking from roof top	Repair immediately
Don't run Analyzer in case of alarm	Contact Service Engineer immediately
Don't run CAAQMS if earth pit not connected properly to analyzer rack.	Check earthing (pour water regularly)

8.2 Breakdown Maintenance

Issues leads to breakdown of CAAQM System are as follows:

1) Analyzers are not properly calibrated or malfunctioning but still generating data.
2) Non-availability of SI/NIST certified/traceable calibration gases and permeation tubes in the station.
3) Lack of skilled/technical trained manpower in each station (one Instrument/Electronic engineer & one Environmentalist Chemistry for data analysing is required).
4) Non-availability of sufficient inventory of spare parts as well as spare analyzer with O & M Firm.
5) Non-availability of Service Infrastructure including service engineer with O & M Firm.
6) Non-availability of Dedicated Lease line or broadband Connection for data transmission at each station.

8.3 Maintenance Schedule

Following tables specify the action/procedure required for Preventive maintenances, periodically.

8.3.1 ON-SITE (at the station)

Periodicity	Action/Procedure
Weekly	Check the alarms/faults status of analyzers and event logs.
	Record pressure of calibration gas cylinder and Nitrogen/Zero Air Gas cylinder.
	Check the room and analyzer rack temperature
	record the battery voltage and current of UPS.
	Station housekeeping and clean-up
	AC working status
	Power failure record
	Status of outside environment
	Dust analyzer (PM_{10}/$PM_{2.5}$) sampling pipe heater check
	Automatic AC changeover switch working status
	Check and adjust the zero air pressure at 200 kPa
	Check the calibration gas cylinder pressure (change cylinder if pressure is I<10 bar)
	Inspect the meteorological sensors and mast from the ground for physical damage
	Inspect gas sample inlet Teflon cap and clean it.
	Clean the Racks from dry cloth.
	Check and remove the water from water trap bottle

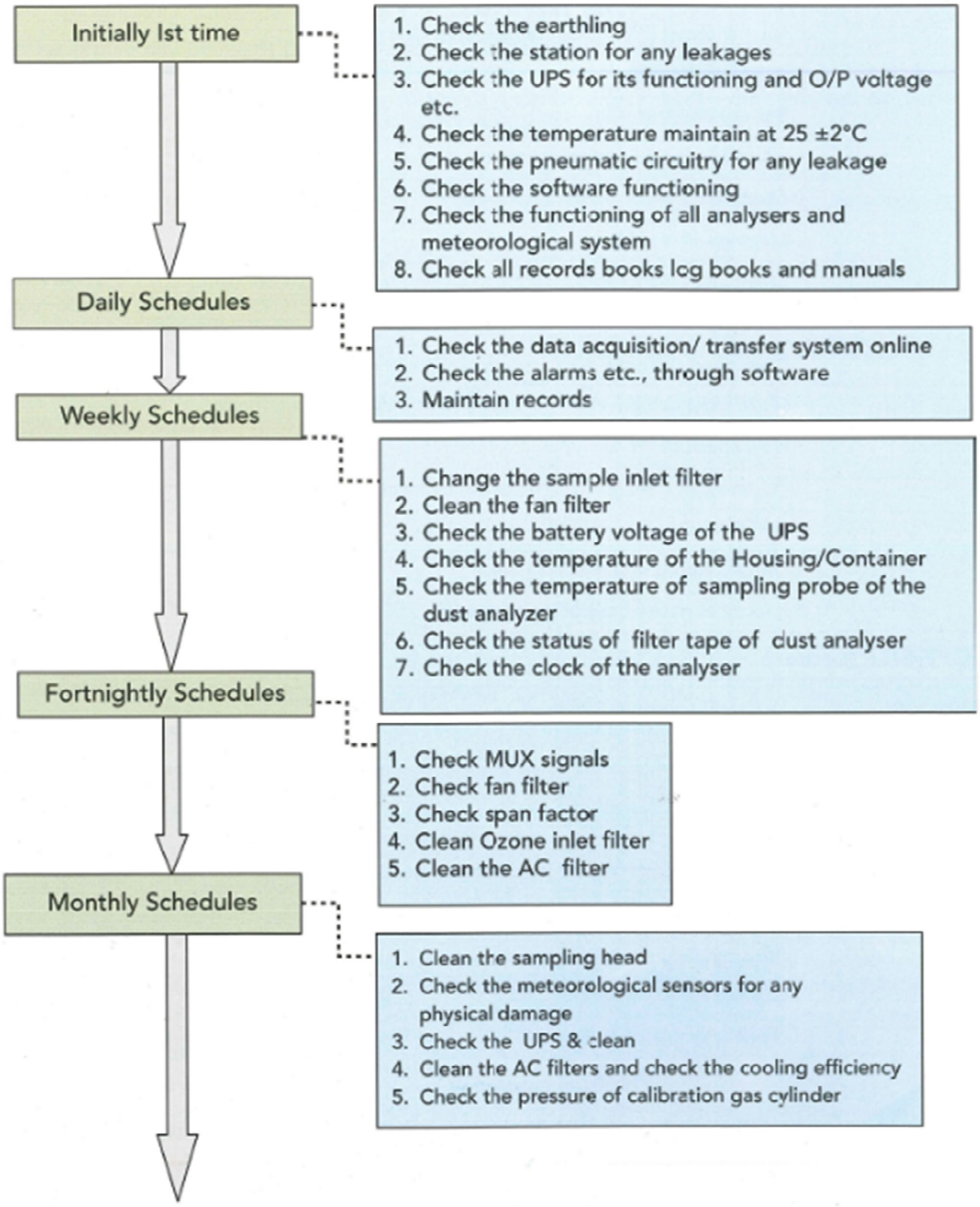
	Check NH_3 Convertor Temperature is at desired level, if not then adjust it.
	Back fan filter
	Dust analyzer (PM_{10}/$PM_{2.5}$) sample inlet cleaning
	AC filter cleaning
	Battery checkup
	Inlet filter checkup of analyzers
	Checking of MUX signals of analyzer
	Maintain all records
Monthly	Clean Instruments Racks, UPS and all instruments from dry cloth.
	Record pressure of calibration gas cylinder and Nitrogen gas cylinder.
	Check and clean the Air Conditioner Filters.
Quarterly	Clean glass sample inlet manifold and remove moisture, if any
	Flow check of PM analyzer
	PM analyzer (PM_{10}/$PM_{2.5}$) sample hood cleaning
	GPT for NO_2 convertor efficiency testing
	Pump checkup and maintenance
	Backup of data from station computer

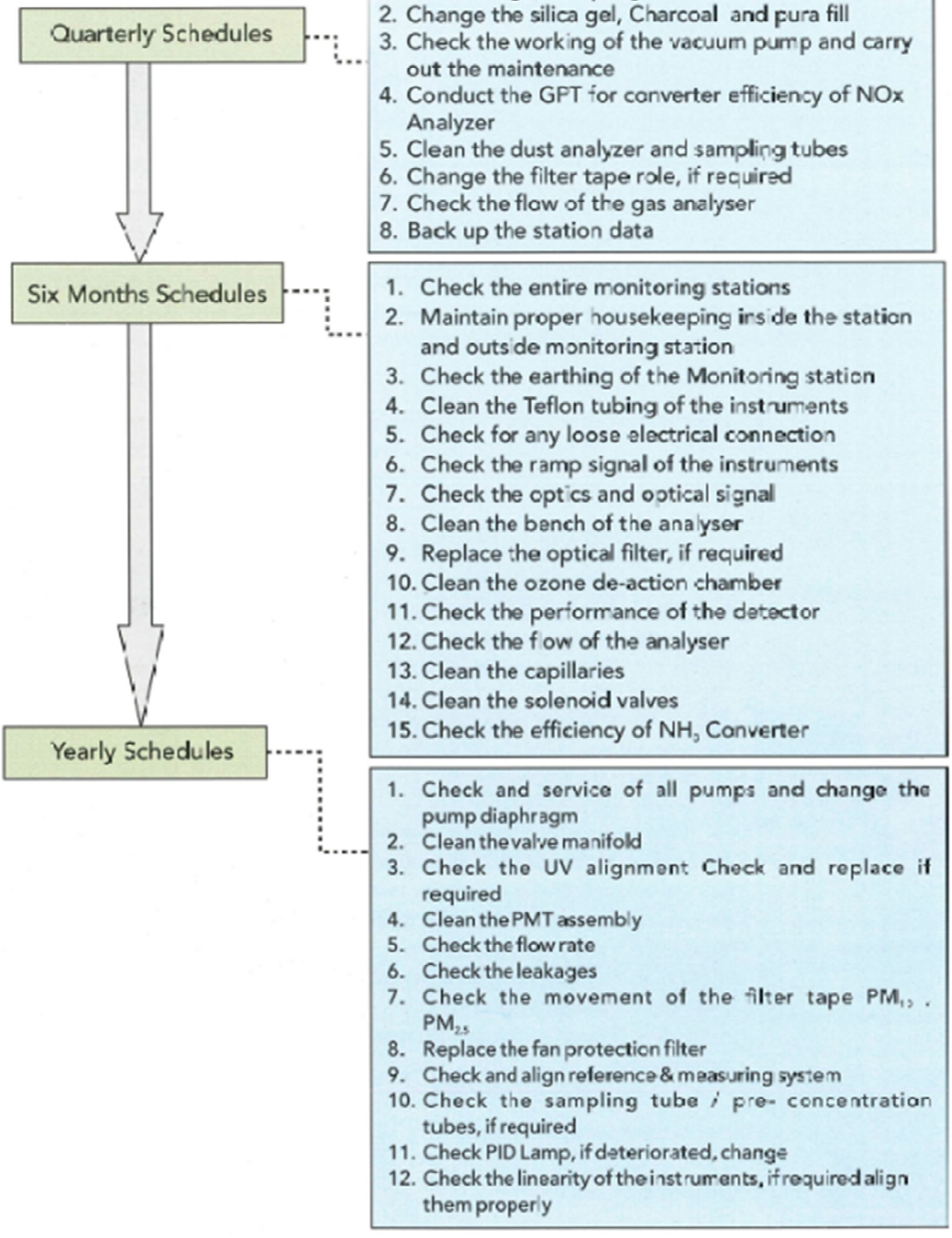
8.3.2 OFF-SITE (server)

Periodicity	Action/Procedure
Daily	Check Data Acquisition System / Data Logger is reading all parameters (online)
	Ensure proper operation of all analyzers
	Check the alarms/faults status of analyzers and event logs.
	Status of outside environment
	Prepare daily report of station data
Quarterly	Backup of Server data
	Quarterly report of data

**Note: Please refer to Operation and Maintenance manuals for details and specific maintenance schedule as advised by the manufacturer of the instrument.

8.4 Flow Chart of Periodic Maintenance Schedules




Quarterly Schedules
1. Clean the gas sampling inlet manifold
2. Change the silica gel, Charcoal and pura fill
3. Check the working of the vacuum pump and carry out the maintenance
4. Conduct the GPT for converter efficiency of NOx Analyzer
5. Clean the dust analyzer and sampling tubes
6. Change the filter tape role, if required
7. Check the flow of the gas analyser
8. Back up the station data
Six Months Schedules
1. Check the entire monitoring stations
2. Maintain proper housekeeping inside the station and outside monitoring station
3. Check the earthing of the Monitoring station
4. Clean the Teflon tubing of the instruments
5. Check for any loose electrical connection
6. Check the ramp signal of the instruments
7. Check the optics and optical signal
8. Clean the bench of the analyser
9. Replace the optical filter, if required
10. Clean the ozone de-action chamber
11. Check the performance of the detector
12. Check the flow of the analyser
13. Clean the capillaries
14. Clean the solenoid valves
15. Check the efficiency of NH_3 Converter
Yearly Schedules
1. Check and service of all pumps and change the pump diaphragm
2. Clean the valve manifold
3. Check the UV alignment Check and replace if required
4. Clean the PMT assembly
5. Check the flow rate
6. Check the leakages
7. Check the movement of the filter tape PM_{10}, $PM_{2.5}$
8. Replace the fan protection filter
9. Check and align reference & measuring system
10. Check the sampling tube / pre- concentration tubes, if required
11. Check PID Lamp, if deteriorated, change
12. Check the linearity of the instruments, if required align them properly

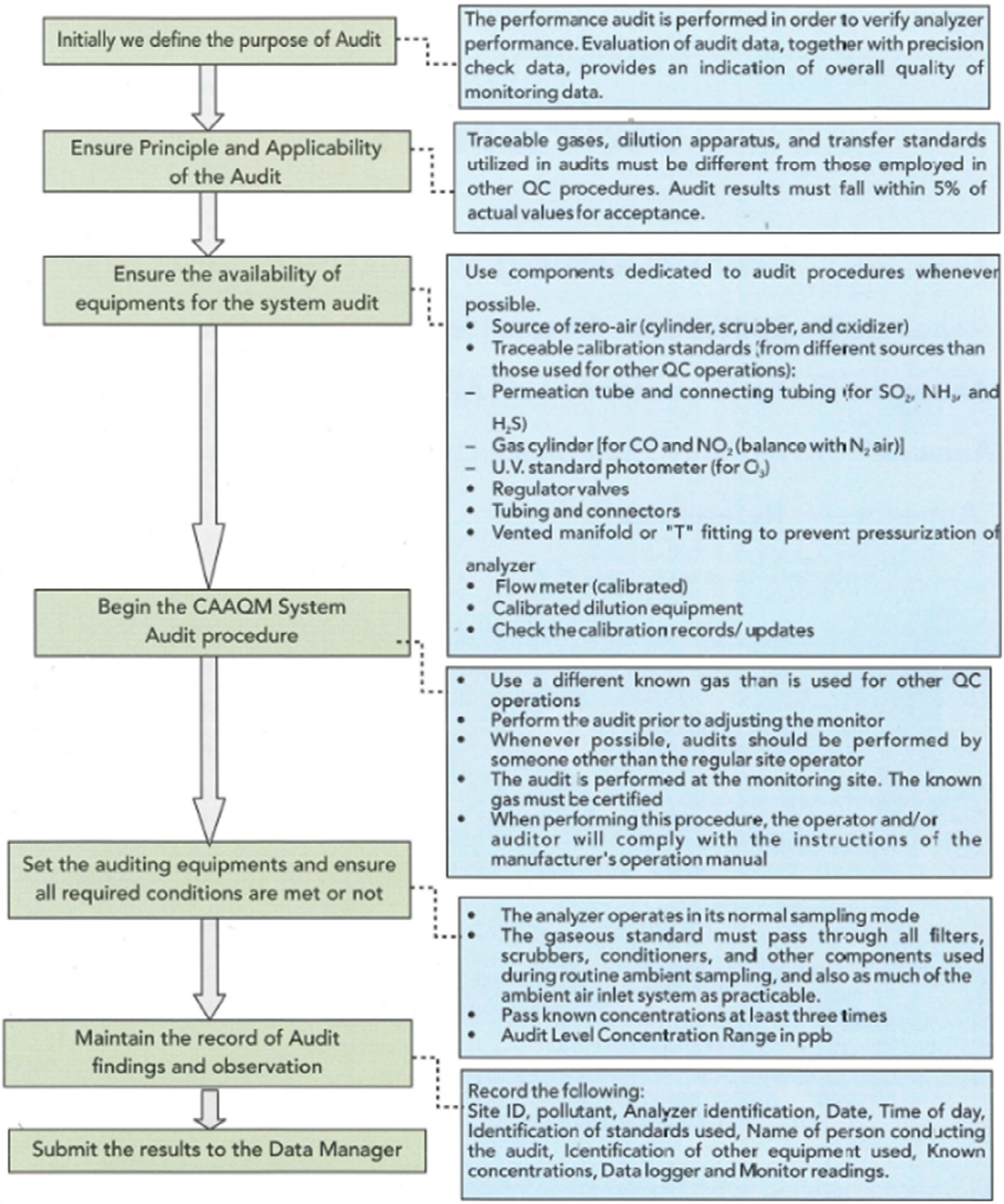
Chapter-9
Annual Audit of CAAQM system

9.1 Introduction

The Annual Audit is very much essential for each CAAQM system to ensure the proper functioning of the system in respect of proper operation of analyzers, their maintenance & calibration, data quality, operator skills, etc. The frequency of the system audit should be at least once in a year, by third party who should have accreditation of ISO 17025 and having expertise in the O&M of CAAQM System.

Audit definition	A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives
System audit	A systematic on-site qualitative review of facilities, equipment, training, procedures, record-keeping, validation, and reporting aspects of a total (quality assurance) system,to arrive at a measure of the capability and ability of the system.
Performance audit	An independent assessment of the performance of the instruments to determine if they are producing valid data. – Direct challenge using known inputs – Co-located Transfer Standard
Role of the auditor	The auditor must be independent of the monitoring operations – Guest at the site and of the monitoring program – Independent evaluation of the site operations – Mutual training exercise
Role of the auditee	The auditee should be the normal operator of the site – Responsible for day to day operations – Removal and reinstallation of site instrumentation – Answer questions about the site operations
Audit equipment	• Independent of the site instrumentation • Traceable to known standards • Of suitable accuracy to appropriately assess the site instrumentation performance
Audit frequency	Typical recommendations • System: Annual • Performance: Six months

9.2 Flow Chart for Performance Audit Procedure



APPENDIX

Annexure-I NATIONAL AMBIENT AIR QUALITY STANDARD (2009)

Annexure-II Calibration Protocol for CAAQM System

Annexure-III Performa for Annual Audit of CAAQM System

Annexure-IV Monthly Field Check List of CAAQM System

Annexure-V References

ANNEXURE - I

NATIONAL AMBIENT AIR QUALITY STANDARD (2009)

Pollutant	Time Weighted Average	Concentration in Ambient Air		
		Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Government)	Methods of Measurement
SO_2, µg/m³	Annual*	50	20	• Improved West and Gaeke • Ultraviolet fluorescence
	24 hours**	80	80	
NO_2, µg/m³	Annual*	40	30	• Modified Jacob & Hochheiser (Na-Arsenite) • Chemiluminescence
	24 hours**	80	80	
PM_{10}, µg/m³	Annual*	60	60	• Gravimetric • TOEM • Beta attenuation
	24 hours**	100	100	
$PM_{2.5}$, µg/m³	Annual*	40	40	• Gravimetric • TOEM • Beta attenuation
	24 hours**	60	60	
O_3, µg/m³	8 hours**	100	100	• UV photometric • Chemiluminescence • Chemical Method
	1 hour**	180	180	
Lead (Pb), µg/m³	Annual*	0.50	0.50	• AAS/ICP method after sampling on EMP 2000 or equivalent filter paper • ED-XRF using Teflon filter
	24 hours**	1	1	
CO, mg/m³	8 hours**	2	2	• Non Dispersive Infra Red (NDIR) spectrosopy
	1 hour**	4	4	
Ammonia (NH_3) µg/m³	Annual*	100	100	• Chemiluminescence • Indophenol blue method
	24 hours**	400	400	
Benzene	Annual*	5	5	• Gas chromatography based on continuous analyzer • Adsorption and Desorption followed by GC analysis
Benzopyrene (BaP) - particulate phase only, ng/m³	Annual*	1	1	• Solvent extraction followed by HPLC/GC analysis
Arsenic (As), ng/m³	Annual*	6	6	• AAS/ICP method after sampling on EMP 2000 or equivalent filter paper
Nickel (Ni), ng/m³	Annual*	20	20	• AAS/ICP method after sampling on EMP 2000 or equivalent filter paper

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 8 hourly or 1 hourly monitored values, as applicable, shall be compiled with 98% of the time in a year.2% of the time, theymay exceed the limits but not on two consecutive days of monitoring.

Note - Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

ANNEXURE-II

CALIBRATION PROTOCOL FOR CAAQM SYSTEM

NAME OF CAAQM SYSTEM ..... DATE: .....

S. No.	Parameter	Status	Zero Value		Zero Offset		Span Calibration			K Factor (Span)		%age of Deviation
			Pre	*Post*	*Pre*	*Post*	Span Source	*Pre*	*Post*	*Pre*	*Post*	
1.	CO Analyzer	OK	0.0	0.0	0.0	0.0						
2.	SO_2 Analyzer	OK	0.0	0.0	0.0	0.0						
3.	NO_x Analyzer	OK										
	NO		0.0	0.0	0.0	0.0						
	NO_2		0.0	0.0	0.0	0.0						
	NOx		0.0	0.0	0.0	0.0						
4.	O_3 Analyzer	OK	0.0	0.0	0.0	0.0						
5.	VOC Analyzer	OK										
	Benzene											
	Toluene											
	E-benzene											
	M+P Xylene											
	O-Xylene											
6.	PM_{10}/$PM_{2.5}$ Analyzer	OK										
7.	**Meteorological Parameter**											
	Temperature	OK										
	Humidity	OK										
	Wind Speed	OK										
	Wind Direction	OK										
	Vertical Wind Speed	OK										
	Solar Radiation	OK										
	Barometric Pressure	OK										
8.	**Computers**											
9.	**UPS / ACs / Others**	Not ok										
10.	**Data Display Board**	OK										
	Maintenance Details/ Requirement											
	Specific Observation(s)											

System Maintained By..... System supervised by .....

ANNEXURE-III

MONTHLY FIELD CHECK LIST OF CAAQM SYSTEM

NAME OF CAAQM SYSTEM ..... DATE: .....

S. No.	Description	Status	Remarks
1.	Date of Visit		
2.	Availability of SOP		
3.	Environmental Concition (Housing)		
4.	Working of Analyzers		
5.	Working of Metecrological Sensors		
4.	Availability of Calibration Protocol		
5.	Availability of Calibration Gas (NIST Traceable)		
6.	Availability of Permeation Tube (NIST Traceable)		
7.	Two point Calibration (Precision check)		
8.	Full Calibration (Multipoint Calibration check)		
9.	Validity of Insurance (CAAQM System)		
10.	Electricity Bill Paid		
11.	Telephone Bill Paid		
12.	Payment of Security Services		
13.	Servicing of ACs Installed		
14.	Data Display Board Working		
16.	Name of the Engineer Deputed/Present		
18.	Log-Book maintained and observation entered		
19.	Data Received (Daily / Monthly)		
20.	Name of the visiting Official		
21.	Special Remarks, if any		

System Maintained By..... System Visited by .....

PERFORMA FOR ANNUAL AUDIT OF CAAQM SYSTEM

(PERFORAMANCE EVALUATION)

Name & Location of CAAQM System: _____ **Date:** _____

01. Status of Analyzers:

S.No.	Analyzer/Monitor	Year of installation	Working / Not working	Dates of last three calibrations			Remarks
				(I)	(II)	(III)	
1.	SO_2						
2.	$NO\text{-}NO_2\text{-}NO_x$						
3.	NH_3						
4.	CO						
5.	O_3						
6.	BTX						
7.	HC						
8.	Dust ($PM_{10}/PM_{2.5}$)						
9.	Calibrator						
10.	Computer system						

02. Calibration Gases:

S.No.	Available Calibration Gas Cylinder	Date of manufacturing /refilling	Date of validity/ Shelf-life	Certificate		Not certified
				NMI	Traceable to SI/NIST	
1.	SO_2					
2.	NO					
3.	CO					
4.	NH_3					
5.	Methane					
6.	Benzene					
7.	Synthetic Air/N_2					

03. Permeation Tubes:

S.No.	Present Status	Date of manufacturing	Date of validity/ Shelf-life	Certificate		Not certified
				NMI	Traceable to NIST/SI	
1.	SO_2					
2.	NO_2					
3.	Benzene					
4.	Toluene					
5.	Xylene					
6.	O-xylene					
7.	M & p-xylene					

04. Status of Meteorological Parameters:

S.No.	Meteorological Parameter Status	Working / Not Working	Calibrated / Not calibrated	Date of last calibration	Remarks
1.	Temperature				
2.	Relative Humidity				
3.	Wind Speed				
4.	Wind Direction				
5.	Vertical Wind Speed				
6.	Atmospheric Pressure				
7.	Solar Radiation				

03. Status of Gas Sampling System: Cleaned / Not Cleaned
04. System for vent out of exhaust gases of Analyzer: Available / Not Available
07(a) Status of UPS : Working/Not working

(b) Date of installation of batteries: _____

08 Status of Air Conditioner: Working / Not working

09(a) Data Display Board: Working/not working

(b) Observation:

10. Availability of data transfer facility:

11. Frequency of visit:

12. Frequency of joint calibration:

13. Maintenance of Log Book: Yes/No

14. Availability of spare parts and consumables: Yes/No

15. Details of Analyzers not working continuously for more than 3 months:

16. Whether temperature of the housing is maintained: Yes/No

17. Status of Thermal switch: working/not working

18. Whether any sticker pasted outside the system for any radioactive material /equipment: Yes/No

19. Condition of furniture/ fixtures:

20. Availability of:

(i) Fire extinguisher : Yes / No
(ii) Emergency Light : Yes / No
(iii) First Aid Box : Yes / No

21. System for data submission: Daily / Weekly / Monthly

22. Periodicity of Report submission: Monthly / Quarterly / Yearly

23. Condition of Housing/ Container:

24. No. of persons deputed for O&M:

25. Any other information:

Note : - **Strike off / Tick Mark as applicable**

Name & Signature of Engineer
(Maintaining the System)

Name & Signature of System Incharge

Name & Signature
(Performance Audit Team)

Name & Signature
(Performance Audit team)

ANNEXURE-V
References

The following referenced documents based on European standards are indispensable for the preparation of this Handbook.

EN 14211, Ambient air quality — Standard method for the measurement of the concentration of nitrogen dioxide and nitrogen monoxide by chemiluminescence

EN 14212, Ambient air quality — Standard method for the measurement of the concentration of sulphur dioxide by ultraviolet fluorescence

EN 14625, Ambient air quality — Standard method for the measurement of the concentration of ozone by ultraviolet photometry

EN 14626, Ambient air quality — Standard method for the measurement of the concentration of carbon monoxide by nondispersive infrared spectroscopy

EN 14907, Ambient air quality — Standard method for the measurement of the concentration of particulate matter

EN 14662-3, Ambient air quality — Standard method for measurement of benzene concentrations — Part 3:Automated pumped sampling with in situ gas chromatography

EN 45011, General requirements for bodies operating product certification systems (ISO/IEC Guide 65:1996)

EN ISO 9001, Quality management systems — Requirements (ISO 9001:2000)

EN ISO/IEC 17021, Conformity assessment — Requirements for bodies providing audit and certification of management systems (ISO/IEC 17021:2006)

EN ISO/IEC 17025, General requirements for the competence of testing and calibration laboratories (ISO/IEC 17025:2005)