GENERAL STANDARD

FOR

AIR POLLUTION CONTROL

ORIGINAL EDITION

JULY 1997

This standard specification is reviewed and updated by the relevant technical committee on Dec. 2003(1) and Nov. 2014(2). The approved modifications are included in the present issue of IPS.

FOREWORD

The Iranian Petroleum Standards (IPS) reflect the views of the Iranian Ministry of Petroleum and are intended for use in the oil and gas production facilities, oil refineries, chemical and petrochemical plants, gas handling and processing installations and other such facilities.

IPS is based on internationally acceptable standards and includes selections from the items stipulated in the referenced standards. They are also supplemented by additional requirements and/or modifications based on the experience acquired by the Iranian Petroleum Industry and the local market availability. The options which are not specified in the text of the standards are itemized in data sheet/s, so that, the user can select his appropriate preferences therein

The IPS standards are therefore expected to be sufficiently flexible so that the users can adapt these standards to their requirements. However, they may not cover every requirement of each project. For such cases, an addendum to IPS Standard shall be prepared by the user which elaborates the particular requirements of the user. This addendum together with the relevant IPS shall form the job specification for the specific project or work.

The IPS is reviewed and up-dated approximately every five years. Each standards are subject to amendment or withdrawal, if required, thus the latest edition of IPS shall be applicable

The users of IPS are therefore requested to send their views and comments, including any addendum prepared for particular cases to the following address. These comments and recommendations will be reviewed by the relevant technical committee and in case of approval will be incorporated in the next revision of the standard.

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GENERAL DEFINITIONS:

Throughout this Standard the following definitions shall apply.

COMPANY:

Refers to one of the related and/or affiliated companies of the Iranian Ministry of Petroleum such as National Iranian Oil Company, National Iranian Gas Company, National Petrochemical Company and National Iranian Oil Refinery And Distribution Company.

PURCHASER:

Means the “Company” where this standard is a part of direct purchaser order by the “Company”, and the “Contractor” where this Standard is a part of contract documents.

VENDOR AND SUPPLIER:

Refers to firm or person who will supply and/or fabricate the equipment or material.

CONTRACTOR:

Refers to the persons, firm or company whose tender has been accepted by the company.

EXECUTOR:

Executor is the party which carries out all or part of construction and/or commissioning for the project.

INSPECTOR:

The Inspector referred to in this Standard is a person/persons or a body appointed in writing by the company for the inspection of fabrication and installation work.

SHALL:

Is used where a provision is mandatory.

SHOULD:

Is used where a provision is advisory only.

WILL:

Is normally used in connection with the action by the “Company” rather than by a contractor, supplier or vendor.

MAY:

Is used where a provision is completely discretionary.

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APPENDICES:

0. INTRODUCTION

The effects of air pollution on human health, on plants and animals are well known. To ensure that all important methods of emission reduction have been considered, this Standard is prepared to provide information which will be of values to all concerned with measurements of general pollution of the air and involved in reducing to a realistic minimum the emission from industrial processes.

It is an advantage that there are accepted methods for the measurement so that a sound comparison of all results could be made.

In this standard, some of the subjects are adapted from the following specifications and handbooks:

- Air pollution control technology handbook / Karl B. Schnelle, Jr. and Charles A. Brown. by CRC Press, 2002
- Quality Assurance Handbook for Air Pollution Measurement Systems Volume II, by EPA, 2013
- Emission Testing Methodology for Air Pollution, Version 2, by EPA , August 2012
- Hand book of Air pollution Prevention Control. Nicholas P. Cheremisinoff, Ph.D.N&P Limited. 2002
- Environmental engineering dictionary and directory / Thomas M. Pankratz.p. cm. Lewis Publishers. 2001
- Mass Spectrometry, Peter M. van Organic Chemistry Department Nijmegen University, September 2005
- Louis Theodore, Anthony J. Bounicore, Air Pollution Control Equipment, Prentice-Hall, Inc. 1994.
- V.A. Fassel, Quantitative Elemental Analysis by Plasma Emission Spectroscopy, Science, 1978.
- Douglas A. Skoog, Donald M. West. Principles of Instrumental Analysis, Holt Rinehart and Winston, Inc., 1971.
- Hydrocarbon Processing Environmental Control, (August 1990).
- Wilfred W. Scott, Standard Methods of Chemical Analysis, Vol. 2, 1989.
- Arthur Cstern, Air pollution III, Academic press. 1976.
- R.D. Ross, Air pollution and Industry, Van Nostran Reinhold 1972.

1. SCOPE

This Standard specifies the minimum requirements for material, operation, tests, inspections and covers site and process measurements, calibration and installation of instruments.

Note 1:

This standard specification is reviewed and updated by the relevant technical committee on Dec. 2002. The approved modifications by T.C. were sent to IPS users as amendment No. 1 by circular No. 216 on Dec. 2002. These modifications are included in the present issue of IPS.

Note 2:

This standard specification is reviewed and updated by the relevant technical committee on Nov. 2014. The approved modifications by T.C. were sent to IPS users as amendment No. 2 by circular No. 434 on Nov. 2014. These modifications are included in the present issue of IPS.

2. REFERENCES

Throughout this Standard the following dated and undated standards/codes are referred to. These referenced documents shall, to the extent specified herein, form a part of this standard. For dated references, the edition cited applies. The applicability of changes in dated references that occur after the cited date shall be mutually agreed upon by the Company and the Vendor. For undated references, the latest edition of the referenced documents (including any supplements and amendments) applies.

ASTM (AMERICAN SOCIETY FOR TESTING AND MATERIAL)

ASTM D 1607 – 91 "Standard Test Method for Nitrogen Dioxide Content of the Atmosphere"

ASTM D 1608 – 98"Standard Test Method for Oxides of Nitrogen in Gaseous Combustion Products"

ASTM D 2010/D 2010M – 98 "Standard Test Methods for Evaluation of Total Sulfation Activity in the Atmosphere by the Lead Dioxide Technique"

ASTM D 4323 – 84"Standard Test Method for Hydrogen Sulfide in the Atmosphere by Rate of Change of Reflectance"

ASTM D 4185 – 96"Standard Practice for Measurement of Metals in Workplace Atmosphere by Flame Atomic Absorption Spectrophotometry"

ASTM D3685/D3685M – 13 "Standard Test Methods for Sampling and Determination of Particulate Matter in Stack Gases"

ASTM D 3162 – 94 "Standard Test Method for Carbon Monoxide in the Atmosphere"

ASTM D 2914 – 01 "Standard Test Methods for Sulfur Dioxide Content of the Atmosphere"

ASTM D 5438 – 05 "Standard Practice for Collection of Floor Dust for Chemical Analysis"

ASTM D 4913 – 00"Standard Practice for Determining Concentration of Hydrogen Sulfide by Direct Reading, Length of Stain, Visual Chemical Detectors"

IPS (IRANIAN PETROLEUM STANDARD)

IPS-E-PR-810 "Engineering Standard for Process Design of Furnaces"

IPS-E-PR-460	"Engineering Standard for Process Design of Flare and Blow down Systems"
IPS-E-SF-860	"Engineering Standard for Air Pollution Control"
IPS-G-ME-210	"General Standard for Flare Details for General Refinery and Petrochemical Service"
IPS-E-PR-771	"Engineering Standard for Process Requirements of Heat Exchanging Equipment"

ISO (INTERNATIONAL ORGANIZATION FOR STANDARDIZATION)

ISO 6584	"Cleaning Equipment for Air and other Gases-Classification of dust Separators"

3. DEFINITIONS AND TERMINOLOGY

3.1 Absorption

A physico-chemical process in which a substance associates with another to form a homogeneous mixture presenting the characteristics of a solution. Process by which pollutants are collected in a sampling or control device by reaction with a collection medium.

3.2 Adsorption

Removal of a pollutant from air or water by collecting the pollutant on the surface of a solid material.

3.3 Air Pollutant

Any material emitted into the atmosphere either by human activity or natural processes and adversely affecting man or the environment.

3.4 Air Pollution

Usually the presence of substances in the atmosphere resulting either from human activity or natural processes, present in sufficient concentration, for a sufficient time and under circumstances such as to interfere with comfort, health or welfare of persons or the environment.

3.5 Ambient Air

The air occurring at a particular time and place outside of structures. Often used interchangeably with “outdoor air”.

3.6 Cleaning

The removal of the deposit of solid or liquid particles, which has produced clogging.

3.7 Combustion

Combustion can be termed as the process of establishing self-sustained fire using fuel and oxidizer, in a controlled manner. It is basically a chemical process in which fuel is burnt in the presence of oxidizer.

3.8 Cyclone Collector

Control device used to collect large particles by inertial separation.

3.9 Cyclone

A dust (and grit) or droplet separator utilizing essentially the centrifugal force derived from the motion of the gas.

3.10 Dispersion

An operation as a result of which solid particles or liquid particles are distributed in a fluid. Also applied to a two-phase system in which one phase, known as the "Dispersed Medium" is distributed throughout the other, known as the "Dispersion Medium".

3.11 Droplet

A liquid particle of small mass, capable of remaining in suspension in a gas. In some turbulent systems, for example clouds, its diameter can reach 200µm.

3.12 Droplet Separator

An apparatus for separating liquid particles from a gas stream in which they are suspended.

3.13 Dust

Small solid particles conventionally taken as those particles below 75µm in diameter which settle out under their own weight but which may remain suspended for some time.

3.14 Dust Separator

An apparatus for separating solid particles from a gas stream in which they are suspended.

3.15 Capture

The extraction of solid particles-liquid particles or gases close to their sources.

3.16 Filter

An apparatus for separating solid or liquid particles from a gas stream in which they are suspended.

3.17 Fog

A general term applied to a suspension of droplets in a gas. In meteorology, it refers to a suspension of water droplets resulting in the visibility of less than 1 km.

3.18 Grit

Airborne solid particle in the atmosphere or flues, (in the United Kingdom: of size greater than 75 çm).

3.19 Impaction

The action of particles entering into contact with a surface.

3.20 Mist

A suspension of droplets in a gas.

3.21 Particle

A small discrete mass of solid or liquid matter.

3.22 Pollutant; Contaminant

Any undesirable solid, liquid or gaseous matter. A gaseous or liquid medium.

3.23 Porous Layer

A permeable layer of solid material in any form having interstices of small size, generally known as "pores".

3.24 Precipitation

An operation in which particles are separated from a gas stream in which they are suspended, by the action of an electrical field or a thermal gradient.

3.25 Purification

The total or partial removal of unwanted constituents from a gaseous medium.

3.26 Threshold Limit Values (TLVs)

Refer to airborne concentration of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse healthy effects.

3.27 Site

Works or plant where sampling is to be carried out.

3.28 Sampling Point

A specific location on a sampling line at which an individual sample is extracted.

3.29 Particulates

Solid mater, in a Gas stream, that is solid at normal temperature and pressure.

4. UNITS

This standard is based on international system of units (SI), as per IPS-E-GN-100 except where otherwise specified.

5. MONITORING SYSTEMS

Oil, Gas and Petrochemical industries usually have many combustion units such as fired heaters and boilers that emit SOx, NOx, CO, CO_2, and particulates, as well as trace quantities of unburned fuel, metals, and other organic compounds.

Since refineries and chemical plants handle large quantities of volatile organic compounds, they will usually have emissions of these compounds. The largest sources of VOCs are valves, flanges, pumps, compressors and other piping components. VOC emissions also come from storage tanks, loading operations and wastewater treating. VOCs and other air pollutants are also of interest due to their potential to cause annoying odors in the communities surrounding process plants.

Air pollution monitoring is conducted to determine either emission concentration or ambient air quality. Air quality data may be obtained through the use of mobile or fixed sampling networks and the use of integrated samplers or continuous monitors. Decisions regarding these monitoring techniques constitute the first important steps in design of a monitoring network. In fact there are many type of monitoring systems and a wide variety of instrumentation used to measure the concentration of gaseous compounds, particulate matter and physical properties in a waste gas stream. (*Air pollution control technology handbook / Karl B. Schnelle, Jr. and Charles A. Brown. by CRC Press, 2002*)

The development of a monitoring network of sites for a specific pollutant requires:

1. Understanding the monitoring objective(s).
2. Identifying the spatial scale most appropriate for the monitoring objective(s).
3. Identifying the general locations where the monitoring site(s) should be placed in order to collect a representative pollutant measurement.
4. Identifying specific monitoring sites. (*Quality Assurance Handbook for Air Pollution Measurement Systems Volume II, by EPA, 2013*)

6. SITE AND PROCESS MEASUREMENT OF AIR POLLUTANT

Site and process measurement is divided in two parts as follows:

Part 1: Fixed Type Measurement

Part 2: Portable Type Measurement

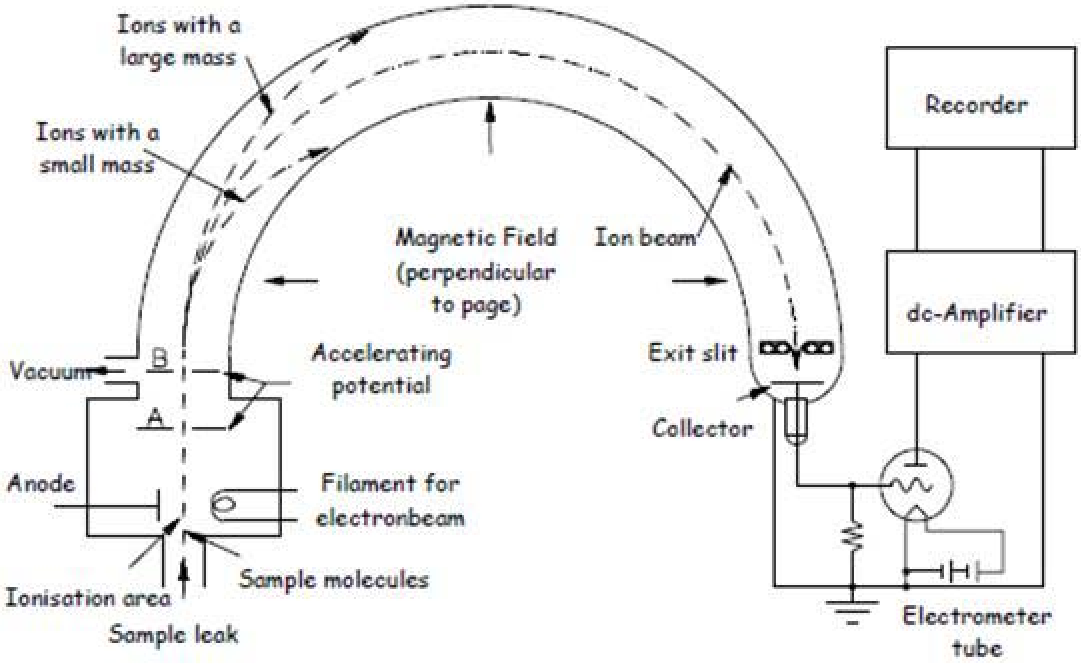
6.1 Fixed Type Measurement

6.1.1 Fixed type or on-line monitoring

One of the fastest and easiest process analyzer for petrochemical, refinery and environmental monitoring is mass spectrometer. In general this kind of instrument is designed for measurement of ionisable gas. Sampling system is bleed solenoid valve. This method is based on ion mobility separation is based on the ratio of the mass of the load.

6.1.1.1 Mechanism

In mass spectrometry the sample should be converted into positive ions which are then separated and characterized. Fig. 1 shows schematically the essential parts of a typical analytical mass spectrometer.



SCHEMATIC DIAGRAM OF AN ANALYTICAL MASS SPECTROMETER

Fig. 1

(*Mass Spectrometry, Peter M. van Organic Chemistry Department Nijmegen University, September 2005*)

6.1.1.2 Construction and operation

Construction and installation of instrument should be according to manufacturer's advise and purchase requirement but in general it should be in safe place with all necessary items such as electrical power, gas and water supply. Also it should be away from contaminated gas, shock, vibration, ignition of flammable gas. Operation of instrument after test performance should be according to manufacturer's manual operation booklet.

6.1.2 Process monitoring apparatus

Another fix type apparatus which is normally used in industry is SO_2, NO_x and O_2 measuring analyzer.

6.1.2.1 Mechanism

The principle of this instrument is based on split beam photometric analysis. In this instrument the process diode array is used as detector for monitoring SO_2 and NO_x. It could provide direct measurement of NO and NO_2 simultaneously.

6.1.2.2 Construction and Operation

Construction and installation of instrument should be according to supplier's recommendations. All requirements should be according to manufacturer's advice.

Operation of instrument after test performance should be according to manufacturer's manual operation booklet.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 6).

6.2 Portable Type Measurement

The apparatus are used for:

a) Hydrocarbon gas detection

b) CO_2, CO and O_2 detection

c) Toxic and other gas detection

6.2.1 Hydrocarbon gas detectors

This system is provided for detection of hydrocarbon gases such as natural gas, Ethylene, Propane and Butane, as well as low concentration of Chlorinated Compounds.

6.2.1.1 Mechanism

Detection of system is flame ionization detector (F.I.D), which has been used widely in Gas Chromatography Fig. 2.

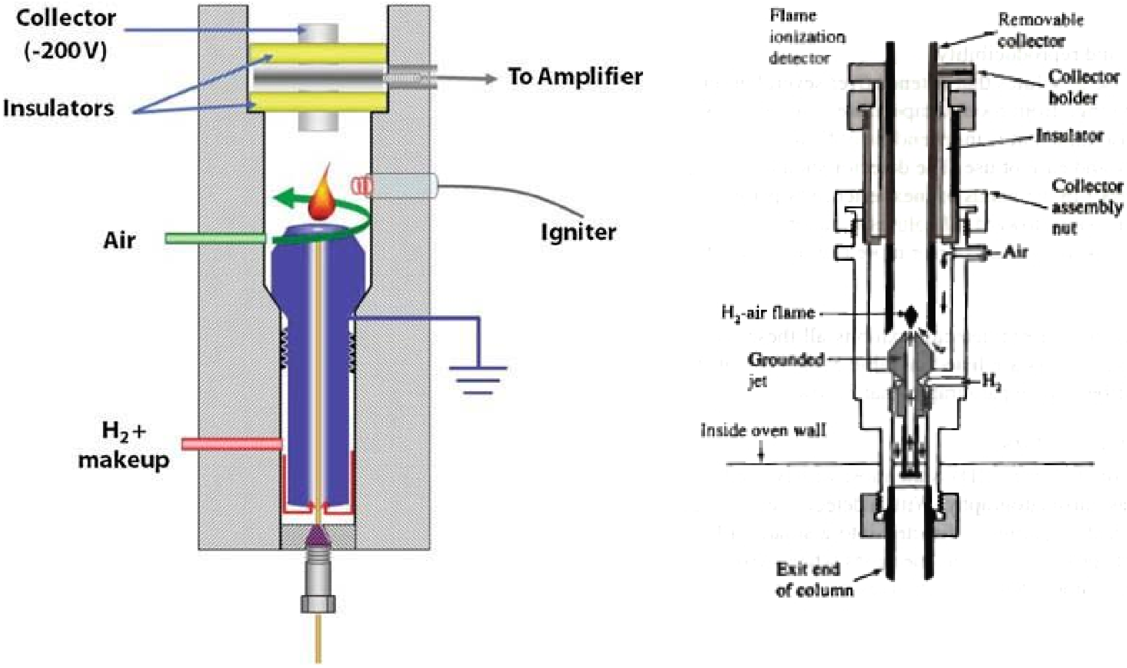
6.2.1.2 Construction and Operation

There is no need for installation, but for each gas different devices have been used.

Operation of instrument after test performance should be in accordance with manufacturer’s manual operation booklet.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 6).



FLAME IONIZATION DETECTOR (FID) FOR THE DETECTION OF HYDROCARBON

Fig. 2

(*Gas Chromatography Instruction, Tabriz Oil Refinery Company, 2009*)

6.2.2 CO_2, CO and O_2 measurements

The Orsat apparatus is used for easy measurement of CO_2, CO and O_2 gases. For more details see Wilfred W. Scott, Standard Methods of Chemical Analysis, Vol. 2, 1989.

6.2.2.1 Mechanism

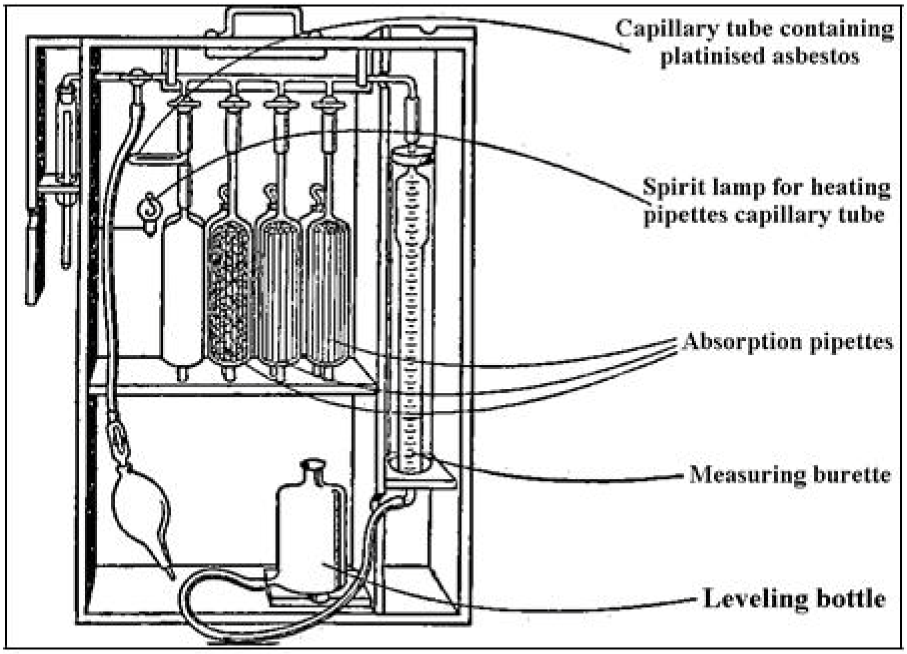
There are three bottles with glasses and one burette. One bottle is filled with Potassium or Sodium Hydroxide solution and other bottles are filled with Potassium Pyrogallate and Cuprous Chloride solutions respectively.

6.2.2.2 Construction and operation

The basic structure of instrument is shown in Fig. 3, Operation of this apparatus should be performed according to the supplier’s manual operation booklet, but all solutions should be prepared in time of use.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 6).



BASIC STRUCTURE OF INSTRUMENT

Fig. 3

6.2.3 Toxic and other gas detection

This apparatus is used for detection of H_2S, HCN, Cl_2, CO_2, SO_2, NH_3, HF, HCl, NO_2, H_2, CO, F_2, Br_2, AsH_3, PH_3, SiH_4, B_2H_6 and GeH_4.

6.2.3.1 Mechanism

The basic principle of system is electrochemical diffusion sensors.

6.2.3.2 Construction and operation

There is no need for installation. It could be operated according to environments conditions. There are different types of sensors for each gas to be measured and used.

Operation of instrument after test performance should be according to supplier's manual operation booklet.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 6).

7. LABORATORY MEASUREMENT

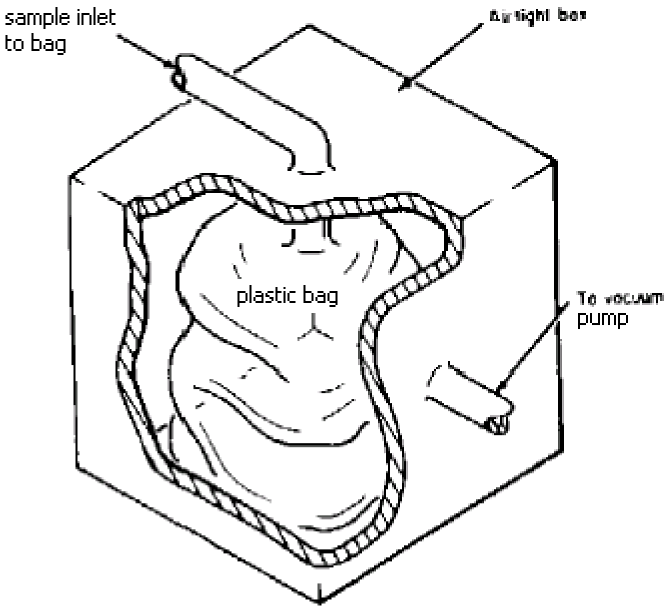
7.1 Sampling and Calibration of Gaseous Pollutants

7.1.1 Sampling

One of easiest way of sampling which should be used is grab sampling. Grab sampling is a technique commonly used in air pollution investigation. In this type of test a volume of air that can later be analyzed is taken as a sample.

7.1.1.1 Material

The containers are usually made from flexible plastics material could be also latex, rubber, steel, glass, or hypodermic syringes. Further specifications should be obtained from manufacturers before ordering. Care shall be taken in the selection of the syringe material to prevent contamination of gaseous samples. Repeated preconditioning treatments are necessary to avoid irreversible adsorption of the pollutant. Before using the syringe, the performance should be inspected to make sure it statement to be it is working in order.



a)

b)

Optional gauge

- Quickly confirm vacuum or pressure inside canister.
- Monitor pressure changes.
- Fully protected by canister frame.
- Can be heated to 90°C during cleaning.

Enhanced valve and canister bracket
Canister holder and valve bracket protect canister, tube stub, and valve.

2 or 3 Port high quality valve
Metal-to-metal seal, 2/3 turn with stainless steel diaphragm.

Your TO-Cans™ and SilcoCans™ are an investment! We offer check-ups and reconditioning when needed.

Serial-controlled label
For quick, sure identification.

c)

A PLASTIC BAG BEING USED FOR GRAB SAMPLING

Fig. 4

7.1.1.2 Construction

The basic principal structure of grab sampling is shown in Fig. 4.

7.2 Adsorption Sampling

Adsorbents are used to removed a variety of pollutant gases.

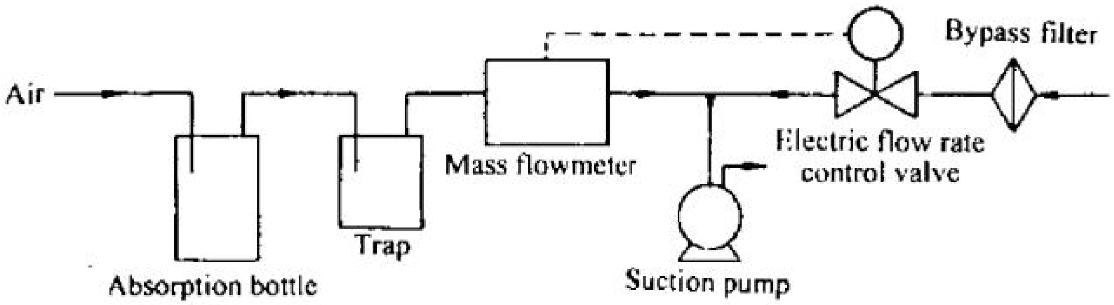
7.2.1 Material

The material, which should be used as adsorbent are Activated Aluminas, Silicagel, Molecular Sieve, Charcol and Celite. Further specifications should be obtained from manufacturers for purchaser consideration.

7.2.2 Construction

The sample should be drawn through a container with the adsorbent maintained at ambient or sub-ambient temperatures. Adsorbed material can be removed by heating or washing with suitable solvent.

If water vapor is present in the sample stream the adsorbent can be deactivated. Because of the nature of certain gases and adsorbents, it is not always possible to remove the adsorbed gas without decomposition. In addition, certain adsorbents are known to cause isomerization. Adsorption process scheme to be given in Fig. 5.



ADSORPTION PROCESS SCHEME FOR GAS ADSORPTION

Fig. 5

7.3 Absorption Sampling

Absorption is the process of transferring one or more gaseous components into a liquid medium in which they dissolve.

7.3.1 Bubblers and impingers

This is a kind of equipment to trap specific atmospheric gases in a solution which should later be analyzed.

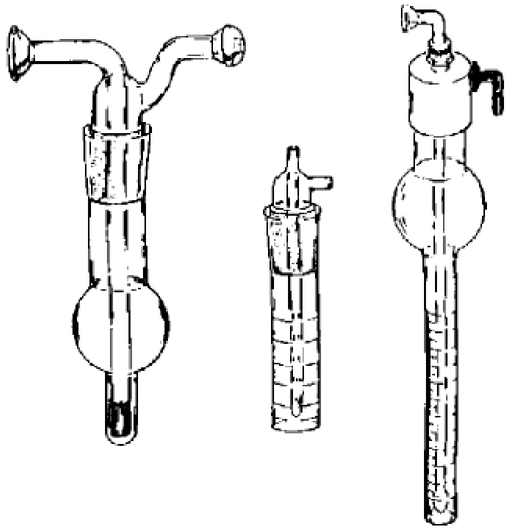
7.3.2 Material

The gas to be analyzed is drawn through a tube, the downstream end of which should be blown to the surface of a liquid. The dispersion tube should be an open-ended tube or one with a frit (material with many 50 to 100µm holes).

Frits should be; glass, plastic and ceramic. For further material specifications, inquiries should be made from manufacturers before ordering.

7.3.3 Construction

A number of designs for bubblers and impingers are shown in Fig. 6.



TYPICAL BUBBLER AND IMPINGER SAMPLING EQUIPMENT
Fig. 6

7.4 Cryogenic Sampling

The cryosampling technique is a method of concentration involves freezing out toxic species from polluted air at temperatures significantly lower than boiling points of sample substances.

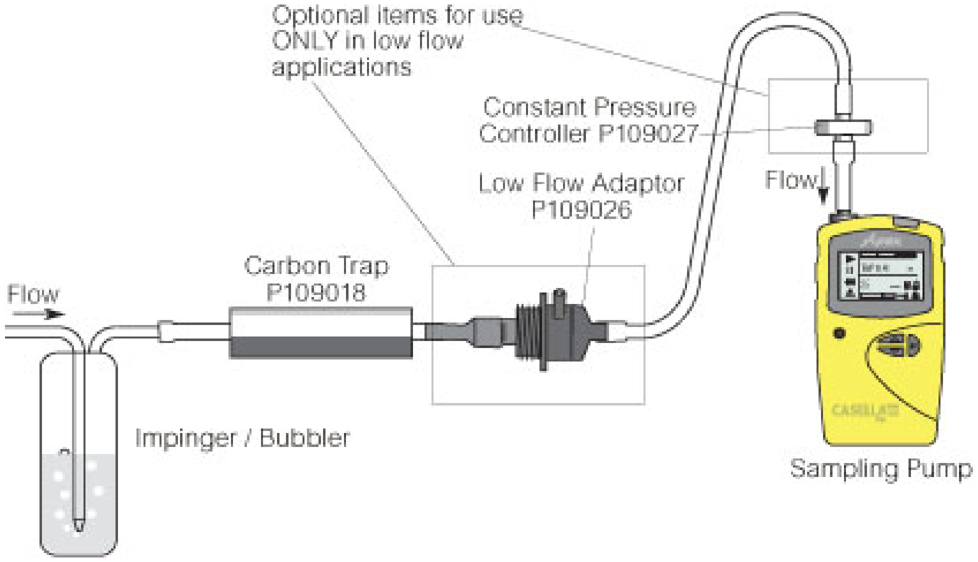
7.4.1 Material

Coolants frequently used for the trap are ice water, solid carbon dioxide, isopropyl alcohol, liquid oxygen, liquid nitrogen and liquid helium. A more complete selection of solution and their equilibrium temperatures are shown in Appendix A.

Other equipment for this kind of sampling are pumps, sequential samplers and operating power. Material specification should be obtained from manufacturers for purchaser consideration.

7.4.2 Construction

The basic structure for cryo-sampling is shown in Fig. 7.



DIFFUSION CELL

Fig. 7

7.4.3 Inspection

Liquid of instead for trapping samples must be checked since the diffusion rate is dependent on temperature.

The inspection of cryogenic air sampling should be done according manufacturer inspection and test manual.

8. HYDROCARBON AND CARBON OXIDES

Carbon oxides are air pollutant, which the Threshold Limit Values (T.L.V) were given in IPS-E-SF-860. For measurement of these gases in laboratory, new instrumental technique can be used; in addition, other methods in ASTM could be used.

8.1 NDIR

Nondispersive Infrared (NDIR) analyzer is the instrument for monitoring carbon monoxide, Carbon dioxide and hydrocarbon.

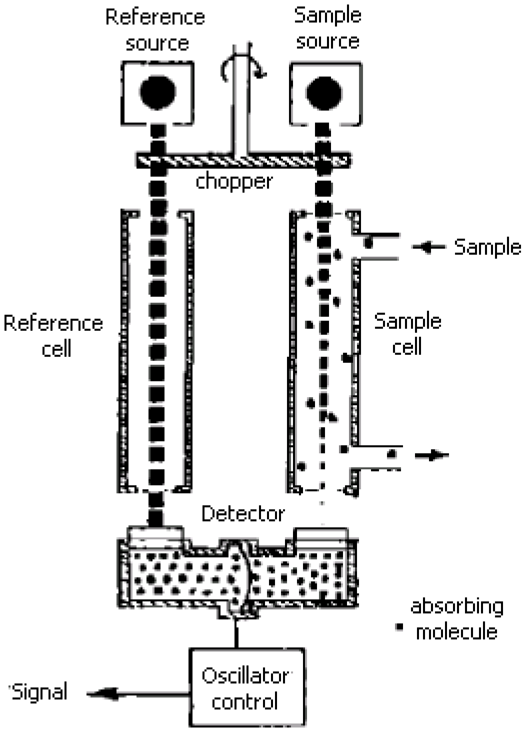
8.1.1 Material

Nondispersive infrared analyzer is based on the absorption of infrared energy by the contaminant gas.

This instrument consists of a sample cell and reference cell, two infrared sources, and detector cell. Reference cell is sealed and contains a gas transparent to infrared wavelengths. Further specification should be obtained from manufacturers for purchaser consideration.

8.1.2 Construction

The basic structure of instrument is shown in Fig. 8. An optical chopper alternately interrupts the infrared source for each cell to provide a pulse of energy through each cell. Reference cell passes almost all of the infrared energy on to the detector cell, while the air sample in the sample cell will absorb some of the energy.



NONDISPERSIVE INFRARED (NDIR) ANALYZER

Fig. 8

Refer to: (Daniel A. Vallero, Fundamentals of Air Pollution, 4th Edition, Academic Press of Elsevier, 2008)

Water vapor is interference in carbon monoxide analysis, it is necessary to dry the sample by refrigeration or the use of drying agents.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 8).

8.2 Gas Chromatography

Gas chromatography method can be used for measurement of total Hydrocarbons, Methane and Carbon Monoxide (CO). (US-EPA, Method 8000B, Determinative Chromatographic Separation, 1996).

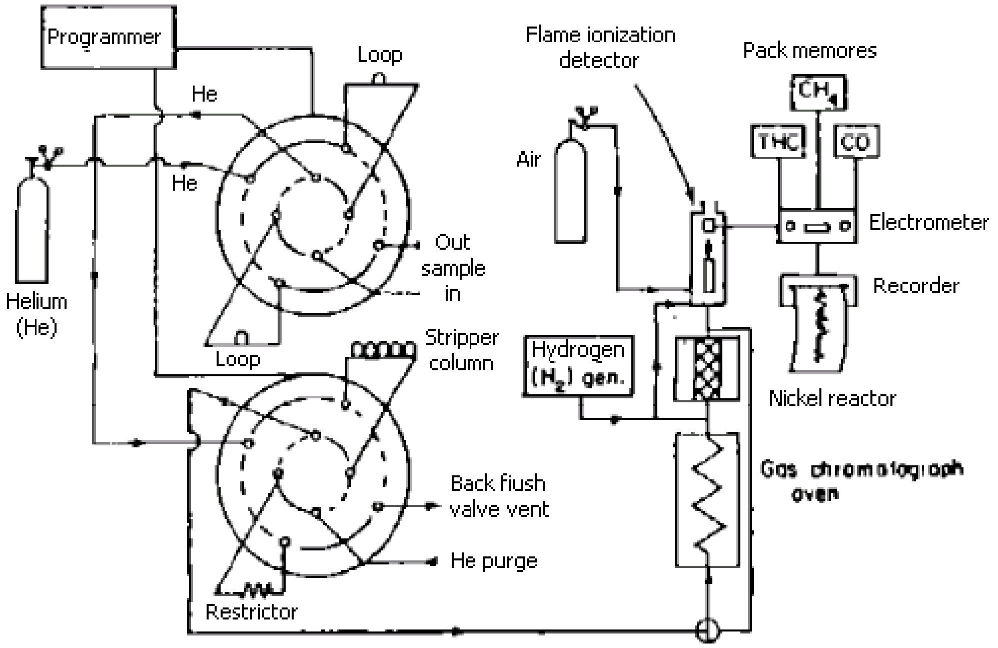
8.2.1 Material

Gas Chromatography achieves separation by passing a mobile phase which is an inert gas, usually Helium, over a stationary phase which is generally a silicone oil or similar material.
The *sample injected into* the Gas Chromatograph (G.C.) is carried by a carrier gas (e.g. Helium) through a lengthy column (which is in two types: Capillary or Packed) then, different components of the sample are separated. Separated components then, reach to a detector, usually Flame Ionization Detector (F.I.D.) for Hydrocarbon gas detection, and could be analyzed.
Various carrier gases and detectors could be used which depends on method of analysis. Further material specifications should be obtained from manufacturers for purchaser consideration.

(US-EPA, Method 8000B, Determinative Chromatographic Separation, 1996).
(Harold M. McNair and James M. Miller; “Basic gas chromatography” John Wiley and Sons, Inc, Publication, 2nd edition, 2009).

8.2.2 Construction

The basic principle of instrument is shown in Fig. 9.



GAS CHROMATOGRAPHIC ANALYZER FOR TOTAL HYDROCARBONS (THC), METHANE (CH_4), AND CARBON MONOXIDE (CO)

Fig. 9

Construction and installation of instrument should be according to supplier’s recommendations.

8.2.3 Operation and performance

Operation of instrument after test performance should be according to supplier’s manual operation booklet.

8.2.4 General requirements

All requirements should be according to supplier’s advice, such as electrical power, carrier gas, standard gas, test equipment and test run.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 8).

8.3 Colorimetric Analyzers

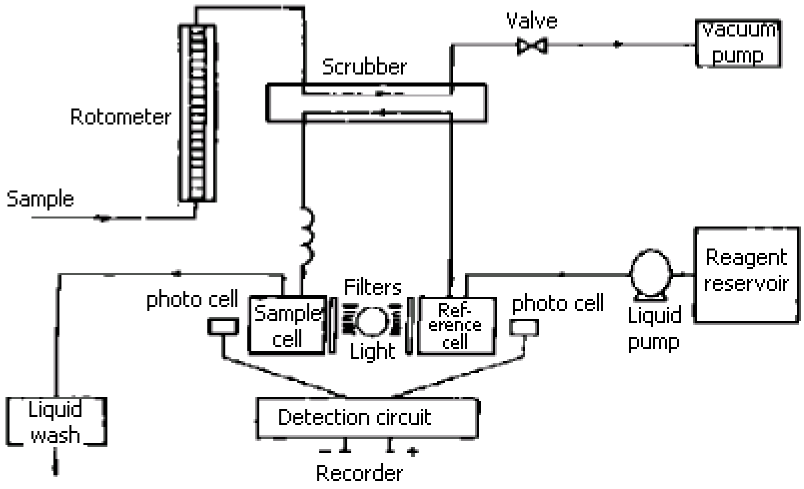
This method of instrumental chemical analysis is used for gaseous air contaminants. Operation is based on absorption of the air contaminant in a liquid reagent with subsequent formation of a colored reaction product which is determined by measurement of light absorbance in a flow colorimeter.

8.3.1 Material

The sample air passes into a scrubber, where it comes into contact with the liquid absorbent. There are different scrubber chamber including continuos bubblers, counter-current flow columns, co-current flow columns and spray chambers. For this equipment, required specification should be obtained from manufacturers.

8.3.2 Construction

The principal structure of instrument is shown in Fig. 10. All requirements should be based on mutual agreement between Purchaser and Manufacturer.



COLORIMETRIC ANALYZER

Fig. 10

8.3.3 Operation and performance

Operation of instrument after test performance should be according to supplier’s manual operation booklet.

8.3.4 General requirement

All requirements should be according to supplier’s advice, such as electrical power, carrier gas, standard gas, water supply, test equipment and test run.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 8).

9. SULFUR COMPOUNDS

Sulfur compounds are air pollutants, which the T.L.V were shown in IPS-E-SF-860. For measurement of these gases in laboratory several methods and techniques have been used which could be divided in the following parts.

9.1 Sulfur Oxide(s) SOX

9.1.1 Colorimetric methods

The material and construction of instrument has been described in Clause 8.

9.1.2 Wet chemical methods

For analysis of sulfur dioxide with wet chemical methods see ASTM Volume 11.03, 1989.

9.1.3 Conductivity method

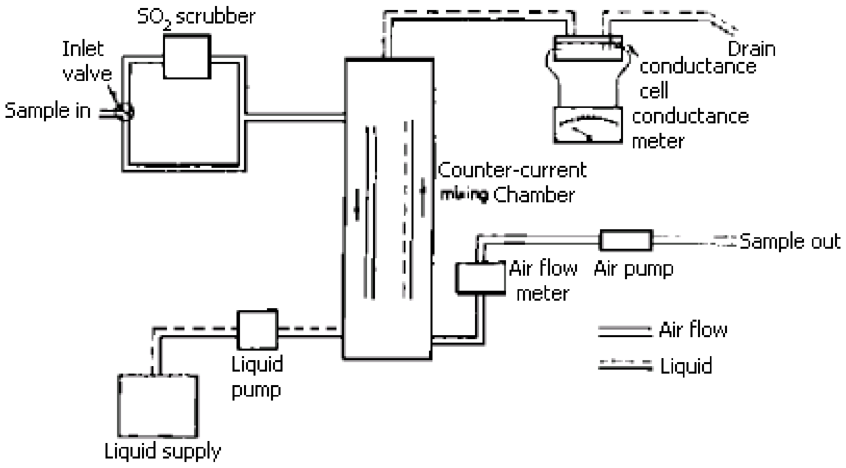
In this method, the sample gas passes through the solution and ionize within it, decreasing the electrical resistance (increasing conductance) this method is for continuous monitoring.

9.1.3.1 Material

Absorbing solution is dilute mixture of hydrogen peroxide in weak sulfuric acid, or deionized water. Detail of material specification should be obtained for Purchaser consideration.

9.1.3.2 Construction

The basic of conductimetric analyzer is shown in Fig. 11.



COUNTER-CURRENT TYPE SULFUR DIOXIDE CONDUCTIMETRIC ANALYZER

Fig. 11

9.1.3.3 Operation and performance

Operation of instrument after test performance should be according to supplier's manual operation booklet.

9.1.3.4 General requirement

All requirements should be according to supplier’s advice, such as electrical power, carrier gas, standard gas, water supply, test equipment and test run.

Note:

Calibration of instruments should be according to operating manual, all requirements should be according to supplier advice such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run (This is rule for all part of section 9).

9.2 Hydrogen Sulfide

9.2.1 Wet chemical methods

For Analysis of hydrogen sulfide by wet chemical methods see ASTM Volume 11.03, Section 11, 2007.

9.2.2 Multifunctional instrumental methods

There are several instrumental methods which could be used for this measurement as follows:

9.2.2.1 Fluorimetry

For material and construction, reference is made to Douglas A. Skoog, Donald M. West, Holt, and principles of instrumental analysis, Holt, Rinehart and Winston, Inc. 1971.

9.2.2.2 Coulometry

For material and construction reference is given in Clause 9.2.3.

9.2.2.3 Gas chromatography

Described in Clause 8.2.

9.2.2.4 Mass spectrometry

Described in Clause 6.1.

9.2.2.5 Flame photometric method

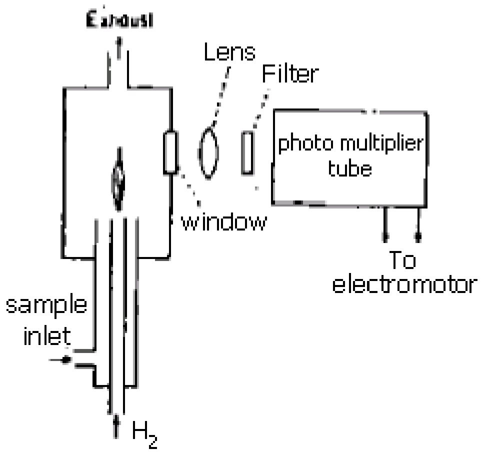
The flame photometric method operates on the measurement of light emitted from an element when burned in a hydrogen flame.

9.2.3 Material

Detector consists of a hydrogen burner and a photomultiplier tube. Specification can be obtained from manufacturers for Purchaser consideration.

9.2.4 Construction

The basic element of instrument is shown in Fig. 12.



FLAME PHOTOMETRIC DETECTOR

Fig. 12

9.2.5 Performances, general requirements and calibrations are as specified in Clauses 8.2.3, 8.2.4 and 8.2.5 respectively.

9.2.6 Electro-Chemical transducers

Basic of this measurement is described in Clause 6.2 but for detail see Arthur C. Stern, Air Pollution, Vol. III, Academic Press, 1986.

9.2.7 Solid state detector

For more information reference is made to Arthur C. Stern, Air Pollution, Vol. III, Academic Press, 1976.

10. NITROGEN COMPOUNDS AND OXIDANTS

10.1 Wet Chemical Methods

Detailed in ASTM Volume 11.03, Section 11, 2007.

10.2 Colorimetric Analyzers

Described in Clause 8.3.

10.3 Gas Chromatography

Described in Clause 8.2.

10.4 Chemiluminescent Method

Reference is made to Arthur C Stern, Air Pollution III, Academic Press, 1986 for details.

11. ANALYZING OF PARTICULATE MATTER

Airborne particulates or aerosols consist of either liquid or solid particles ranging in diameter from

0.01 µm or less, up to 100 µm. These should be isolated by sedimentation, filteration, impingement, centrifugation, or by electrostatic or thermal precipitation. For more detail refer to ASTM Vol. 11.03, Section 11, 1989.

11.1 Analysis of Inorganic Particulates

After sampling of particulate matter for measurement of inorganic element, there are several methods to be used. In this Section two important methods are described. For other methods reference is made to ASTM Vol. 11.03, Section 11, 1989.

11.1.1 Atomic absorption method

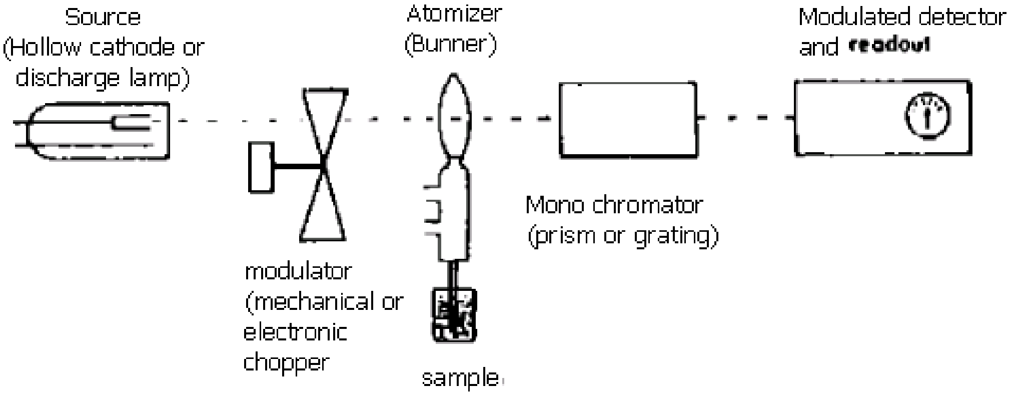
In an atomic absorption analysis the element being determined must be reduced to the elemental state, vaporized, and imposed in the beam of radiation from the source.

11.1.2 Material

An instrument has components as a spectrophotometer. These include a source, a monochromator, a sample container, a flame, a detector, and an amplifier indicator. Detail of specification can be obtained from manufacturers for purchaser consideration.

11.1.3 Construction

The basic element of instrument is shown in Fig. 13.



SCHEMATIC DIAGRAM OF ATOMIC ABSORPTION SPECTROMETER

Fig. 13

11.2 Inductively Coupled Argon Plasma Emission Spectroscopy

Gaseous ions or molecules, when thermally or electrically excited, emit characteristic radiation in the ultraviolet and visible regions. Emission spectroscopy is concerned with the characterization of the wave lengths and the intensities of radiation produced in this manner.

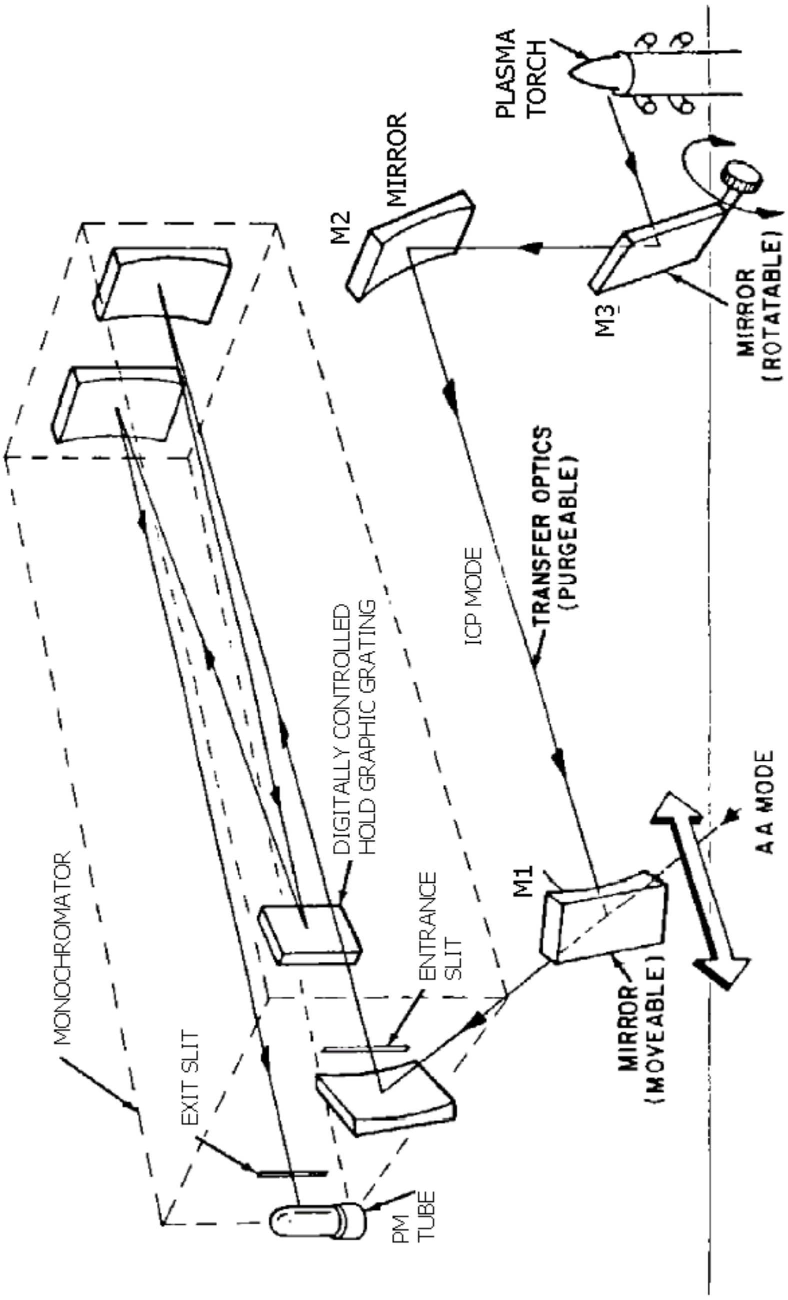
11.2.1 Material

An instrument has components as a spectrophotometer. These include a plasma source, monochromatic, a sample container, a detector, and an amplifier indicator. For more detail reference is made to V.A. Fassel, "Quantitative Elemental Analysis by Plasma Emission Spectroscopy", Science 202, 183 (1978).

11.2.2 Construction

The basic structure of instrument is shown in Fig. 14.

11.2.3 Performance, general requirement and calibration are the same as given in Clauses 8.2.3, 8.2.4 and 8.2.5 respectively.



ICP OPTICAL SCHEMATIC

Fig. 14

11.3 Other Methods

There are several other methods for analysis of inorganic particulate which are given in ASTM Volume 11.03, Section 11, 1989.

12. CLEANING EQUIPMENT

12.1 Selection of Equipment for Particulate Removal

Particulate matter (Dust and Grit) comes in great varieties of size, grain loading, shape, chemical composition, specific gravity, etc. In general there are four basic types of equipment available for particulate removal:

a) Mechanical collectors;

b) Fabric filters;

c) Wet scrubbers; and

d) Electric precipitators (see also ISO 6584).

12.1.1 Mechanical collector

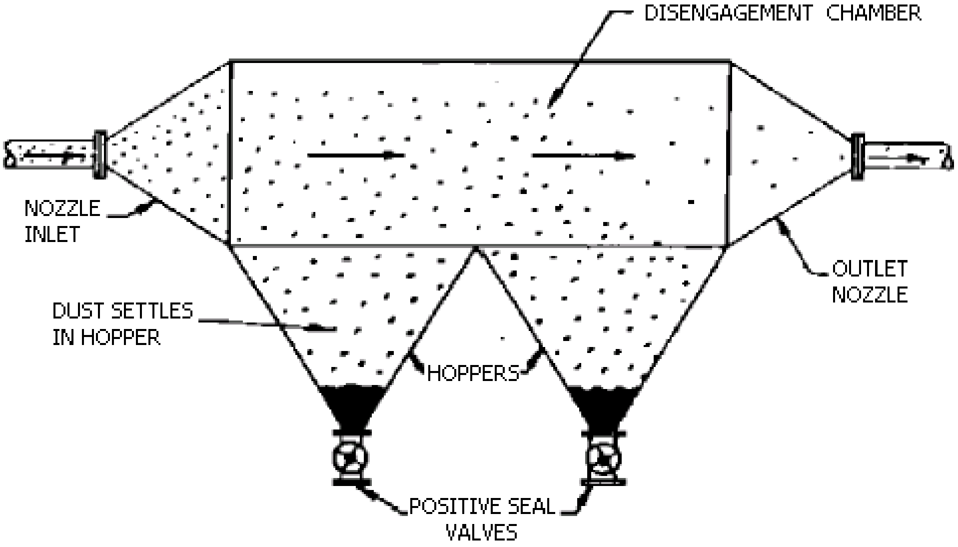
12.1.1.1 Gravity settling chamber

This collector slows the gas from conveying velocities to settling velocities. Dust could be settled under influence of gravity.

a) Material for this kind of collector includes pneumatic pumps, nozzles, hoppers, electrical power. Specification can be obtained from manufacturers.

b) Construction

A typical gravity settling chamber is shown in Fig. 15. This type of mechanical collector has very low collection efficiencies on fine and moderately fine dusts.



EQUIPMENT FOR PARTICULATE REMOVAL (GRAVITY SETTLING CHAMBER)

Fig. 15

c) Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

12.1.1.2 Recirculating baffle collector

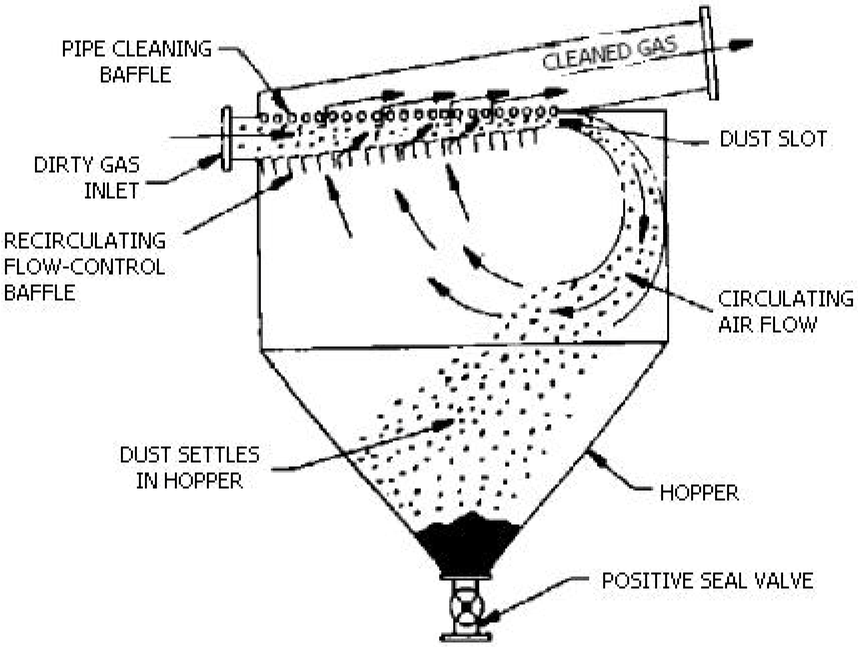
This type of collector where the gas to be cleaned is introduced at high velocity under a horizontal baffle.

a) Material

Material for this kind of collector include pneumatic pumps, pipe cleaning baffle, recirculating flow-control baffle, dust slot, hoppers, and electrical power.

b) Construction

A typical recirculating baffle collector is shown in Fig. 16. In this type of collector gas is introduced at high velocity under a horizontal baffle made up of rods spaced at 12.5 mm (half-inch) apart. The circulating flow is controlled at a nominal velocity by the expanding dust slot and the circulating flow control baffle.



RECIRCULATING BAFFLE COLLECTOR

Fig. 16

c) Installation and inspection

Installation and inspection should be as specified by the manufacturers in their manual books.

12.1.1.3 High efficiency cyclones

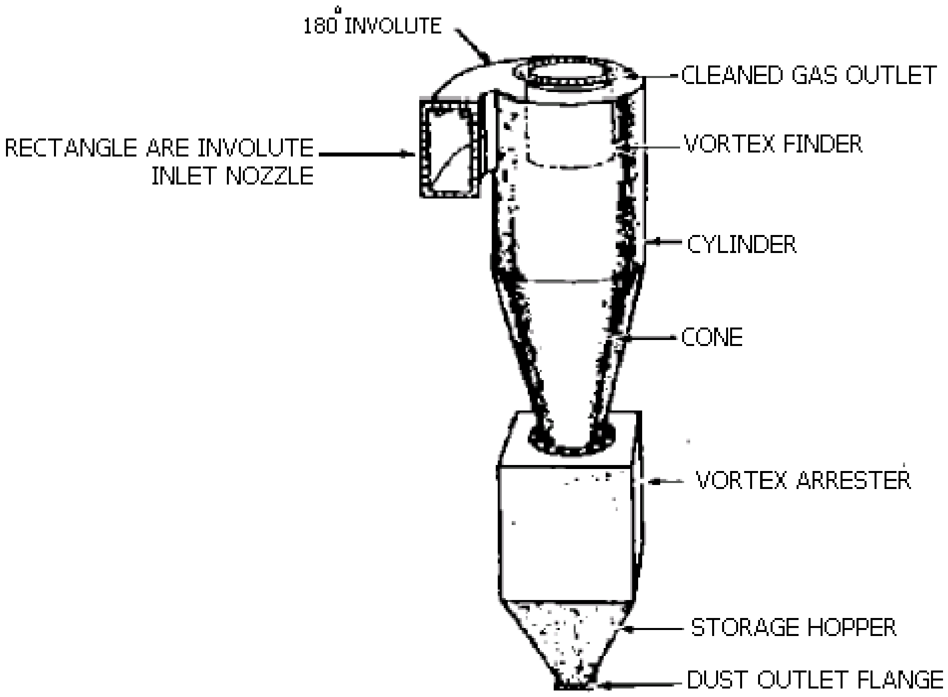
Inertial separators which employ a rotating flow. The particles are separated under the effect of centrifugal forces from the gaseous flow and are released in a radial direction.

a) Material

Cyclone collector can be manufactured from a wide range of materials including mild steel, low-alloy steel, and stainless steel. For corrosive services cyclones can be lined with soft natural rubber, Neoprene or PVC.

b) Construction

There are several types of cyclones, but a typical single high efficiency cyclone is shown in Fig. 17.



SINGLE HIGH-EFFICIENCY INVOLUTE CYCLONE

Fig. 17

c) Installation and inspection

Installation and inspection should be as specified in the manufacturer’s manual book.

12.1.2 Fabric filters

Separators in which the gas passes through a porous layer, which retains the particles.

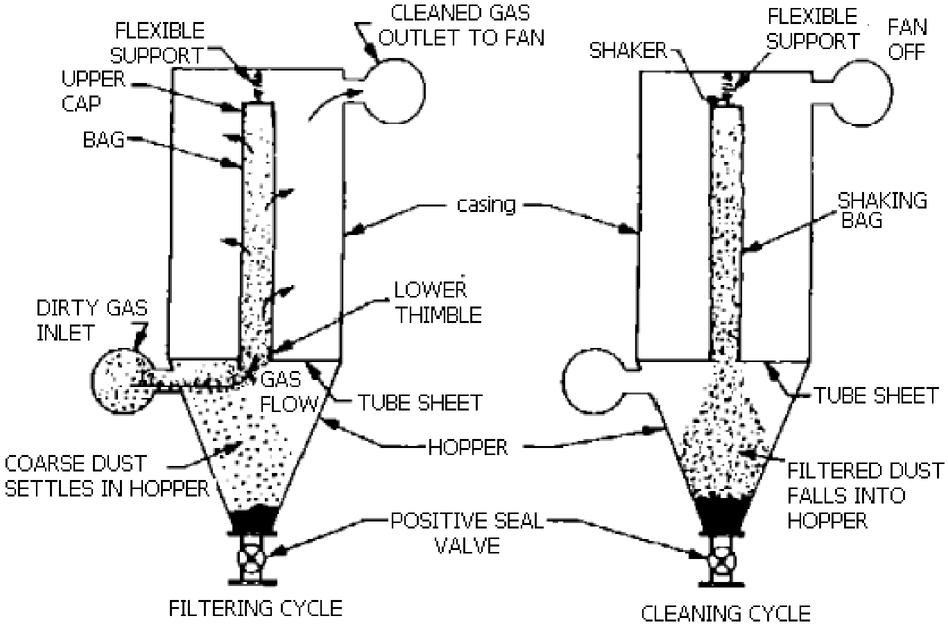
12.1.2.1 Fibrous filter separators

a) Material

Filtering separators where the particles are separated by means of a medium consisting of natural, mineral, synthetic or metallic fibers which constitute a woven or an unwoven material. These filtering media are generally in the form of bags or pockets.

b) Construction

A typical fibrous filter separator is shown in Fig. 18.



INTERMITTENT BAGHOUSE WITH MANUAL OR POWERED SHAKING

Fig. 18

c) Installation and inspection

Installation and inspection should be as specified in the manufacturer’s manual book.

12.1.3 Wet scrubbers

Separators in which forces are applied to promote the transfer of particles from a gaseous flow to a liquid phase is later removed from the gaseous flow by other mechanisms.

12.1.3.1 Bubble washers or packed bed scrubbers

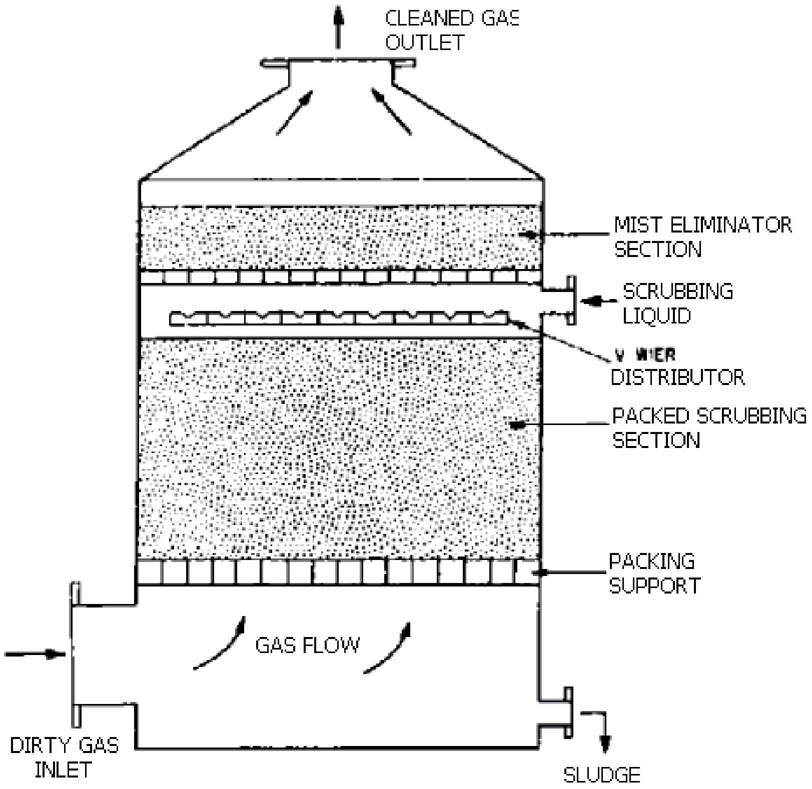
In this type of scrubber, the dirty gas is passed upward through the tortuous instertices formed by a thin or thick bed of small packing wetted by the counter flowing wash liquid.

12.1.3.2 Material

A great variety of packing could be used including glass, plastic spheres, raschig rings, berl saddles, tellerettes, partitioned rings.

12.1.3.3 Construction

A typical single-bed scrubber is shown in Fig. 19.



COUNTER-CURRENT FLOW SCRUBBER

Fig. 19

The packed scrubbing section could be thin, thick, or multiple. Multiple bed, with redistribution of water between them.

12.1.3.4 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

12.1.4 Spray washers

In this type of scrubbers' fine water sprays, wash the gas with water and settle the dust as sludge in the sludge tank (see also ISO 6584).

12.1.4.1 Material

In general, the body of scrubbers is made from mild steel.

12.1.4.2 Construction

Basic principle of this type scrubber is shown in Fig. 20 which includes, dust cycle, demist section and water cycle.

Dust cycle

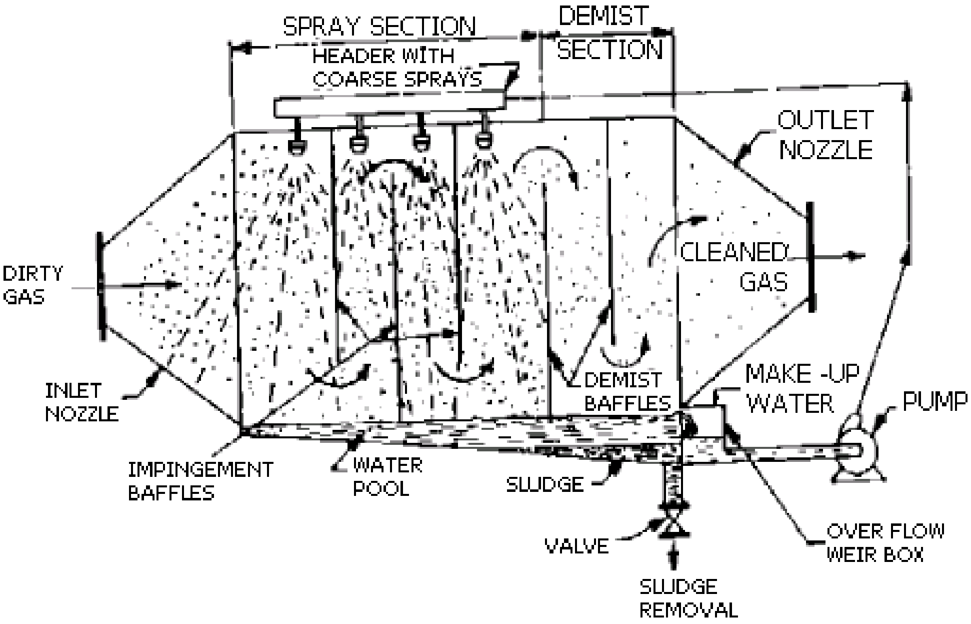
Captured wetted dust particles settle as droplets under the influence of gravity to the surface of the water pool.

Demist Section

Encourage settling of the droplets by reversing the direction of gas flow over the water pool.

Water Cycle

Water is recycled at a rate of 3.78 to 37.8 L/min (2 to 10 gal/min) for every 28.32 m^3 (1,000 ft^3) of gas cleaned.



WETTED IMPINGEMENT BAFFLE SCRUBBER

Fig. 20

12.1.4.3 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

12.1.5 Restricted flow scrubbers

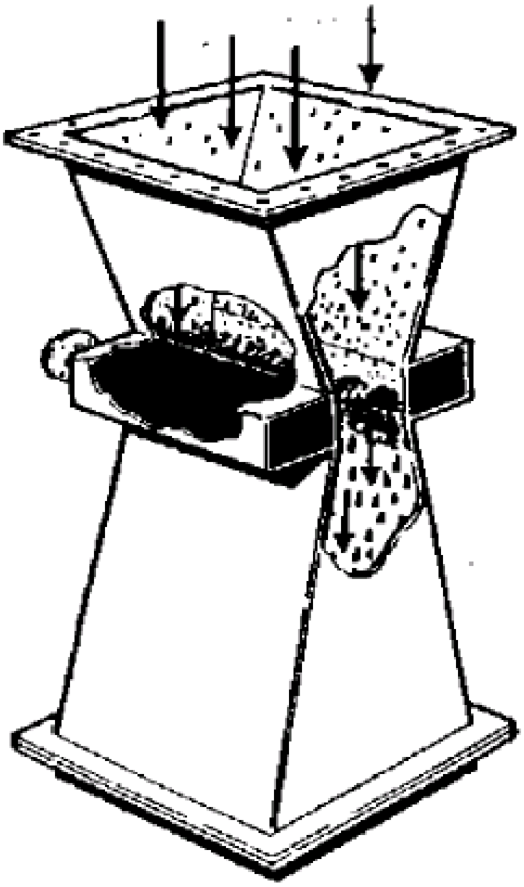
Wet separators in which the particles are brought into contact with the washing liquid in a restricted zone which causes a change in pressure or velocity conditions in the flowing gas line venturi, or orifice scrubbers and induced gas scrubbers (see also ISO 6584).

12.1.5.1 Material

This type of scrubber is made by different kind of steel described in Clause 12.1.3.2.

12.1.5.2 Construction

Construction of vertical downward gas flow venturi scrubber is shown in Fig. 21 in which scrubbing liquid is introduced into the tapered inlet section of the venturi by overflowing a circular weir. Liquid is fed tangentially into the weir through a pipe, thereby eliminating nozzle plugging. This design could use water containing large quantities of solids.



VERTICAL DOWNWARD GAS FLOW VENTURI SCRUBBER

Fig. 21

12.1.5.3 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

12.1.6 Electric Precipitators

An electric precipitator separates entrained particulate matter from a gas stream by first charging the dust to a negative voltage, precipitating it onto grounded collecting electrodes.

12.1.6.1 Material

In this type of precipitator, grounded collecting electrodes which electrically insulated should be used. High voltage wires (50,000 V) could be used for this purpose. The major components consist of:

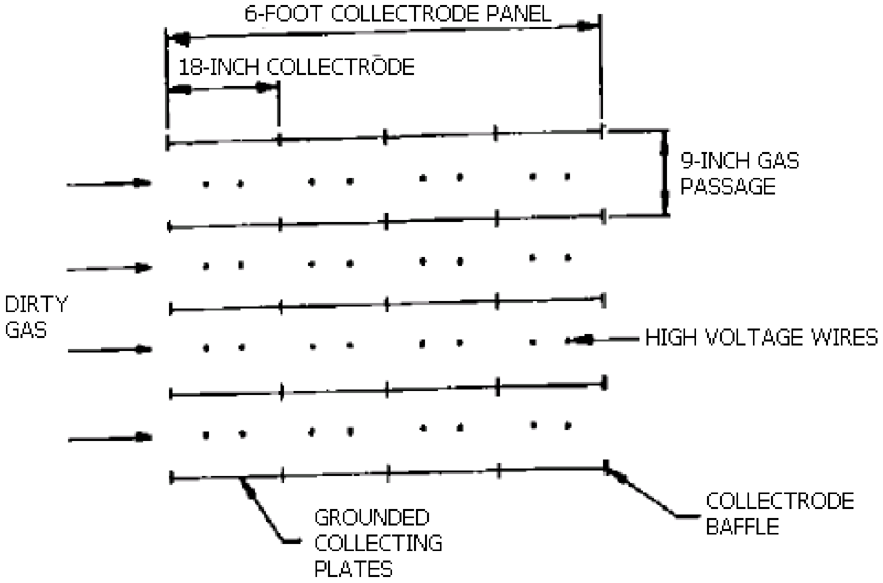
Gas-tight casing including:

- **a)** Hoppers.
- **b)** High-voltage discharge electrode system.
- **c)** Grounded collectrode system (cold-rolled steel).
- **d)** High-voltage supply (silicon diode power packs).

12.1.6.2 Construction

The basic structure of electric precipitator is gas ionization, dust charging, dust precipitation, dust layer builds, collectrode rapping and dust fall into hopper. Reference should be made to R.D. Ross, Air Pollution and Industry, Van Nostrand Reinhold, 1972 (for further information).

A typical cross section of a four-gas-passage collectrode module in electric precipitator, is shown in Fig. 22.



CROSS SECTION OF FOUR-GAS-PASSAGE COLLECTRODE MODULE

Fig. 22

12.1.6.3 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

13. EQUIPMENT FOR GASEOUS WASTE DISPOSAL

In this Section equipment suitable for elimination of gaseous pollutant will be discussed. See ISO 6584.

13.1 Dispersion with Stacks

A simple method of removal of pollutants is dispersion. In this method gas can be dispersed through stack or chimney and is diluted in the air when directly vented into the atmosphere (fog dispersion). When the gas is measured, it should correspond with TLV figures listed in IPS-E-SF-860.

13.1.1 Material and construction

Small-diameter stacks or chimneys are constructed entirely of metal (steel, stainless steel). Further information can be obtained from IPS-G-ME-210, IPS-E-PR-460.

13.1.2 Absorption

Absorption can take place either with or without chemical reaction. Gas absorbers for wasting processes consist of five types of apparatus:

a) Packed columns;

b) Plate columns;

c) Spray towers;

d) High-energy scrubbers and;

e) Gas-solid absorption.

13.2 Packed Columns

Packed columns should be designed of material resistant to the corrosion of the absorbed gas-liquid mixture.

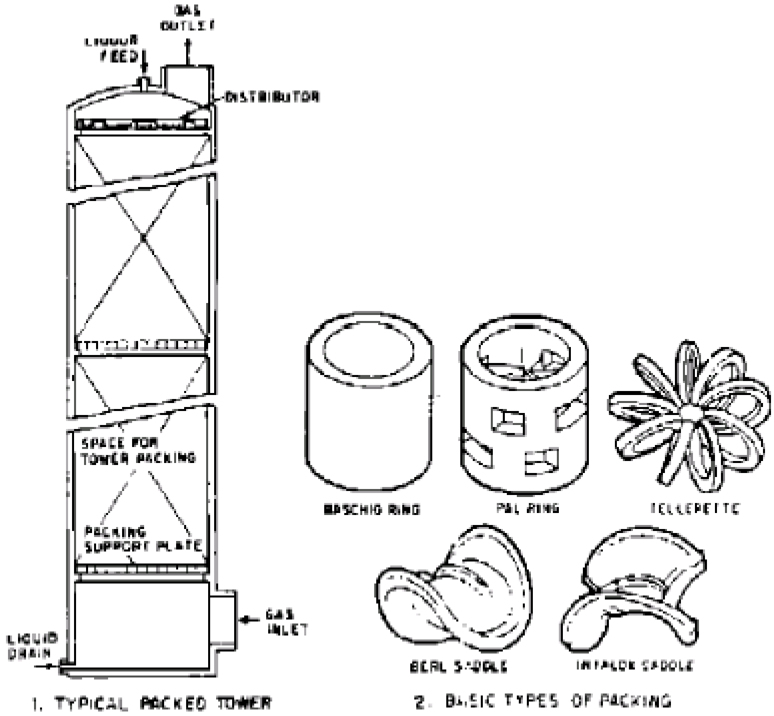
13.2.1 Material

Material for packing section could be ceramic metal, or plastic which provide a large amount of surface area per unit volume.

A distributor should be used to distribute the liquid phase over the packing.

13.2.2 Construction

A typical lay-out of packed column is shown in Fig. 23. Recycling in one or more packed section should increase the concentration of the absorbed gas. The gaseous effluent will exit from the top of tower.



1. TYPICAL PACKED TOWER

2. BASIC TYPES OF PACKING

TOWER PACKING

Fig. 23

13.2.3 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

13.3 Plate Columns

Plate Columns should be used for the absorption of gases, and vapors when low liquid rate are desirable.

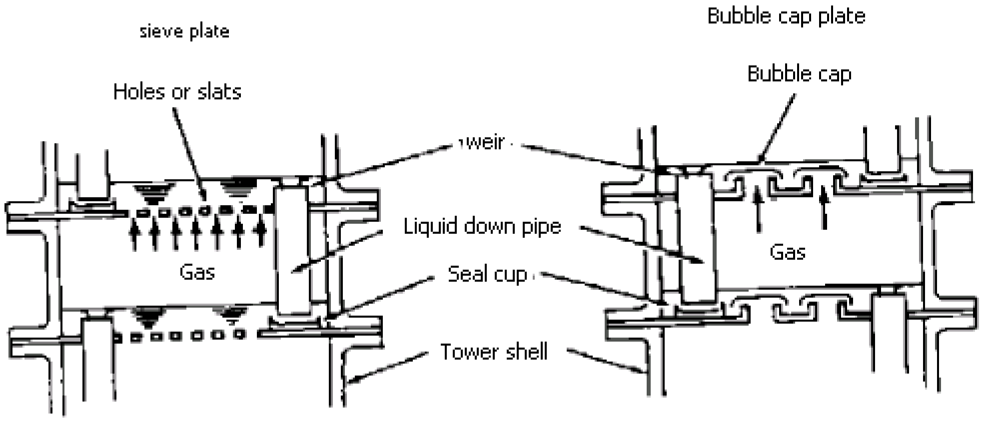
13.3.1 Material

Plate columns could be used in a variety type of standards as, bubble cap, bubble trays and sieve trays. Further specifications should be obtained from manufacturers.

13.3.2 Construction

In the plate column, because of the distribution mechanism, smaller quantities of liquid solvent could be used for the absorption of small quantities of vapor gas solute.

A typical lay-out of plate column is shown in Fig. 24.



TYPES OF PLATES

Fig. 24

13.3.3 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

13.4 Spray Tower

See Clause 12.1.4.

13.5 High Energy Scrubbers

See Clause 12.1.5.

13.6 Gas Solid Absorption

In dealing with high gas flow rates containing substantial quantity of pollutant, gas-solid absorption method should be used.

13.6.1 Material

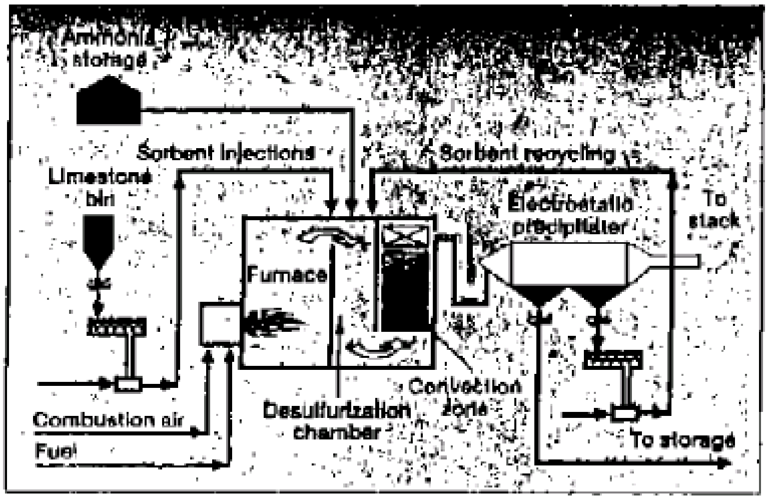
There are varieties of solid absorbent with different processes for removal of pollutant gas. Information can be obtained from R.D. Ross, Air Pollution and Industry, Van Nostrand Reinhold, 1972, hydrocarbon processing, environmental processes 93, (August 1993).

13.6.2 Construction

Typical lay-out of processes for removal of SO_2 show in Fig. 25 in which SO_2 is removed from the flue gases by a powdery sorbent (lime or limestone) fed into the intake of the desulfurization chamber. The basic reaction is:

$$\mathbf{CaO + ½ O_2 + SO_2 \rightarrow \ddot{} CaSO_4}$$

Because of the sorbent's small particle size (1 to 10 Microns) and the optimum temperature 850°C to 1100°C more than 80% of the sulfur could be captured.



GAS SOLID ABSORPTION

Fig. 25

13.6.3 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

14. CONDENSATION

Condensation could be considered when the waste gas has substantial quantities of a condensable material such as air which is saturated with water or other vapor. The equipment, which should be used for this process, are:

- **a)** Tubular surface condenser,
- **b)** Tubular air cooled condenser,
- **c)** Direct contact condenser.

14.1 Material and Construction

For both material and construction, see IPS-E-PR-771.

14.2 Installation and Inspection

Installation and inspection should be as specified by manufacturers in their manual books.

15. HEALTH AND SAFETY PRECAUTIONS

The risks associated with air emission testing must be carefully assessed prior to commencement. Appropriate risk management steps must be put in place to ensure that HSE obligations are fulfilled. Risks may arise from any number of hazards associated with the tasks to be done and the prevailing physical conditions. Some of the hazards involved include but are not limited to:

☐ working at height or on temporary platforms

☐ exposure to toxic gases

☐ electrical hazards

☐ trip hazards

☐ noise and vibration or heat from plant equipment

☐ objects falling from work platforms

☐ flammability

☐ environmental (eg sun, temperature, rain).

When the test laboratory is not the license, site management should be notified of impending tests and information sought on the site's safety policy and details of:

☐ requirements for safety work permits

☐ location of emergency equipment and safety signs

☐ location of refuge areas or muster points

☐ reporting procedures in the event of safety problems.

(*Emission Testing Methodology for Air Pollution, Version 2, EPA, August 2012*)

16. COMBUSTION

In combustion process, fuel and oxidizer are main ingredient, which are mixed and burnt while to produce heat energy. Combustion can occur either in flame or none-flame (smoldering/flameless) mode. But in most of the practical combustion systems, flames are formed during the combustion process.

Destruction of a waste gas or vapor by a combustion process is called incineration.

a) Direct flame;

b) Thermal;

c) Catalytic.

Incineration, like carbon adsorption, is one of the best known methods of industrial gas waste disposal. Unlike carbon adsorption, however, incineration is an ultimate disposal method in that the objectionable combustible compounds in the waste gas are converted rather than collected.

16.1 Direct Flame

Direct flame should be used when handling of gaseous waste materials are at or near their lower combustible, limit when mixed with air. Also it could be used when the waste gas itself is a combustible mixture without the addition of air.

16.1.1 Material and construction

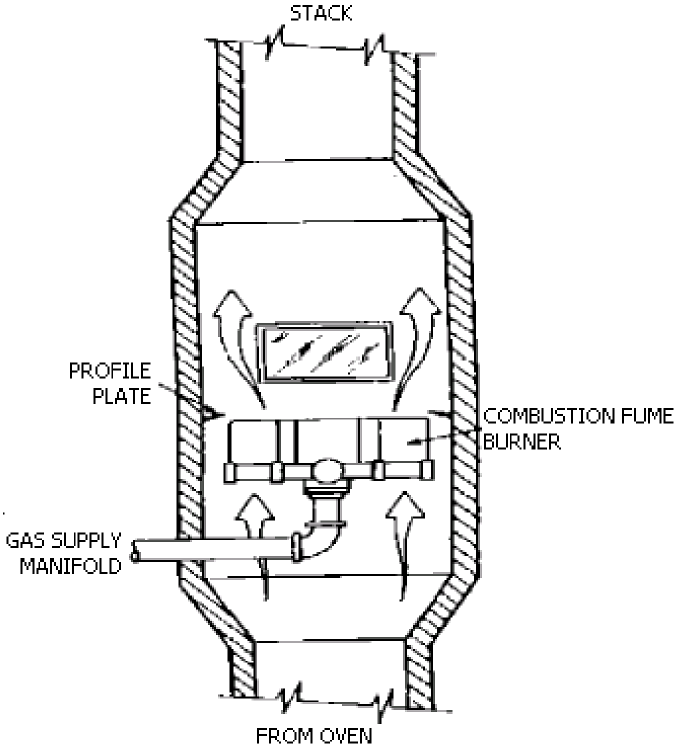
The equipment for direct flame incineration should be burner or combustor firing into some enclosure or into the open, which is called flare. For more detail see IPS-E-PR-460.

16.2 Thermal Incineration

In this method waste gas should be injected directly through a burner along with auxiliary fuel such as natural gas.

16.2.1 Material and construction

Typical type could be line burner in which a gas pipe with a number of holes which inject a fuel such as natural gas into the waste gas stream at the point of ignition. This type could be seen in Fig. 26.



DUCT TYPE FUME BURNER

Fig. 26

16.2.2 Installation and inspection

Installation and inspection should be as specified by manufacturers in their manual books.

16.3 Catalytic Incineration

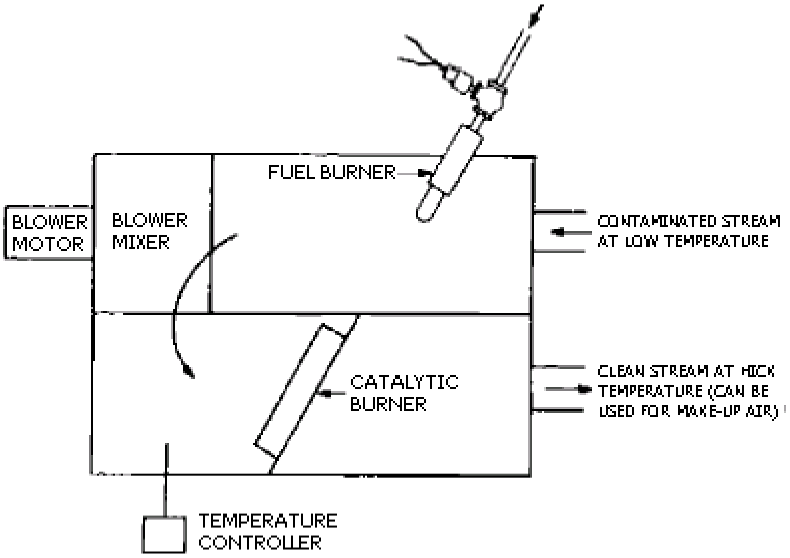
Catalytic incineration should be considered for gaseous wastes containing low concentration of combustible materials and air.

16.3.1 Material

There are different types of catalysts, but in general they may be nubble metals such as platinum or palladium dispersed on catalyst support which is alumina.

16.3.2 Construction

In this method the gas is preheated to a temperature to cause the reaction to occur on the surface of the catalyst. A typical sketch of equipment is shown in Fig. 27.



CATALYTIC INCINERATOR

Fig. 27

16.3.3 Installation and inspection for catalyst poison

As recommended by the Manufacturer.

17. MARKING

Each equipment shall be marked using stamp and cast figure or metal name-plate with letters not less than 8 mm in height.

1) Name of Manufacturer or identifying symbol,

2) Distinctive catalogue designation,

3) Date of Manufacture.

18. SHIPMENT

Shipment of all equipment should be under warranty and unpacking must be within this period (time of insurance for shipment).

It must be supplied and rapped in moisture proof material and also it shall bear in a clearly visible manner, with appropriate instruction, for storage.

19. SPARE PARTS

Packaging list should be with instrument which include, instrument + spare parts and two manual books.

Spare parts must be supplied for at least two years.

20. PRE-INSTALLATION AND INSTALLATION

Pre-installation and installation will be done by Manufacturer or representatives of supplier and purchaser (Upon request by purchaser).

Representatives should witness tests carried out for installation and commissioning of equipment.

21. WARRANTY

The instruments should be under warranty for at least one year after test run.

22. SERVICE AND INSPECTION

The instruments should be inspected by qualified persons assigned by the Manufacturer or user according to letter of agreement.

APPENDICES

APPENDIX A

TABLE 1 - Coolants used for cryogenic trapping of air contaminants

COOLANT	TEMPERATURE (°C)
Ice and water	0
Ice and NaCl	-21.0
Carbon tetrachloride slush	-22.9
Chlorobenzene slush	-45.2
Chloroform slush	-63.5
Dry ice and acetone	-78.5
Dry ice and cellosolve	-78.5
Dry ice and isopropanol	-78.5
Ethyl acetate slush	-83.6
Toluene slush	-95
Carbon disulfide slush	-111.6
Methyl cyclohexane slush	-126.3
N-Pentane slush	-130
Liquid air	-183
Isopentane slush	-160.5
Liquid oxygen	-183
Liquid nitrogen	-196