

GENERAL STANDARD
FOR
AIR POLLUTION CONTROL

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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 value 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.

1. SCOPE

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

2. REFERENCES

Throughout this Standard the following Standards and Codes are referred to. The editions of these Standards and Codes that are in effect at the time of publication of this Standard shall, to the extent specified herein, form a part of this Standard. The applicability of changes in Standards and Codes that occur after the date of this Standard shall be mutually agreed upon by the Company and the Vendor/Consultant.

IPS (IRANIAN PETROLEUM STANDARD)

IPS-E-PR-810	"Process Design of Furnaces"
IPS-E-PR-460	"Process Design of Flare and Blowdown System"
IPS-E-SF-860	"Engineering Standard for Air Pollution Control"
IPS-E-ME-210	
IPS-E-PR-770	

Publications:

Louis Theodore, Anthony J. Bounicore, Air Pollution Control Equipment, Prentice-Hall, Inc. 1982.
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.

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.

3.2 Adsorption

A physical process in which the molecules of a gas of dissolved substances or of liquids, adhere in extremely thin layers to the exposed surface of solid substances with which they come into contact.

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 Cleaning

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

3.6 Cyclone

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

3.7 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".

3.8 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 200/ μm .

3.9 Droplet Separator

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

3.10 Dust

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

3.11 Dust Separator

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

3.12 Capture

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

3.13 Filter

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

3.14 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.

3.15 Grit

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

3.16 Impaction

The action of particles entering into contact with a surface.

3.17 Mist

A suspension of droplets in a gas.

3.18 Particle

A small discrete mass of solid or liquid matter.

3.19 Pollutant; Contaminant

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

3.20 Porous Layer

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

3.21 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.

3.22 Purification

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

3.23 Threshold Limit Values (TLVs)

Refer to air borne 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.

3.24 Site

Works or plant where sampling is to be carried out.

3.25 Sampling Point

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

3.26 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), except where otherwise specified.

5. SITE AND PROCESS MEASUREMENT OF AIR POLLUTION

5.1 General

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

- Part 1: Fixed Type Measurement
- Part 2: Portable Type Measurement

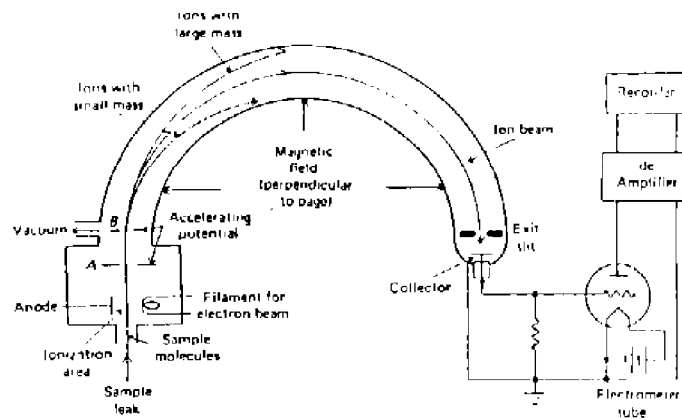
5.2 Fixed Type Measurement

5.2.1 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.

5.2.2 Material

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

5.2.3 Construction

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.

5.2.4 Operation and performance

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

5.2.5 General requirements

All requirements should be according to supplier's advise such as electrical power carrier gas, standard gas, water supply, safe place, drainage, test equipment and test run.

5.2.6 Calibration of instrument

Calibration of instrument should be according to operation manual book and this could be monthly or weekly. All items for the calibration should be supplied by manufacturers.

5.2.7 Process monitoring apparatus

Another fix type apparatus which is normally used in industry is SO₂, NO_x and O₂ measuring analyzer.

5.2.7.1 Material

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 SO₂ and NO_x. It could provide direct measurement of NO and NO₂ simultaneously.

5.2.7.2 Construction

Construction and installation of instrument should be according to supplier's recommendations. It could be installed even 305 m (1000 feet) away for continuous emission monitoring. All requirements should be according to manufacturer's advise.

5.2.7.3 Operation and performance

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

5.2.7.4 General requirements

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

5.2.7.5 Calibration of instrument

Calibration of instrument should be based on supplier's manual operation booklet.

5.3 Portable Type Measurement

The apparatus are used for measurement of:

- a) Toxic gas detection
- b) Hydrocarbon gas detection
- c) CO₂, CO and O₂ detection

5.3.1 Toxic gas detection

This apparatus is used for detection of H₂S, HCN, Cl₂, CO₂, SO₂, NH₃, HF, HCl, NO₂, H₂, CO, F₂, Br₂, AsH₃, PH₃, SiH₄, B₂H₆ and GeH₄.

5.3.1.1 Material

The basic principle of system is electrochemical diffusion sensors.

5.3.1.2 Construction

There is no need for installation. It could be operated from -40°C to +40°C (-40°F to 104°F). There are different types of sensors for each gas to be measured and used.

5.3.1.3 Operation and performance

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

5.3.1.4 Calibration of instrument

In general, this type of instrument is factory calibrated and in case of failure it should be returned to the manufacturer or alternatively only the user's competent personnel of instrument control may calibrate the instrument as per the instructions given in the supplier's manual operation.

5.3.2 Hydrocarbon gas detection

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.

5.3.2.1 Material

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

5.3.2.2 Construction

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

5.3.2.3 Operation and performance

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

As for performance, the F.I.D will locate gas leaks down to 1/ppm for early warnings of potentially dangerous conditions.

5.3.2.4 Calibration of instrument

In general this kind of instrument is factory calibrated. In case of failure the instrument should be returned to the manufacturer or may be calibrated by competent personnel of user's instrument control in accordance with the guide lines given by the manufacturer.

5.3.3 CO₂, CO and O₂ measurements

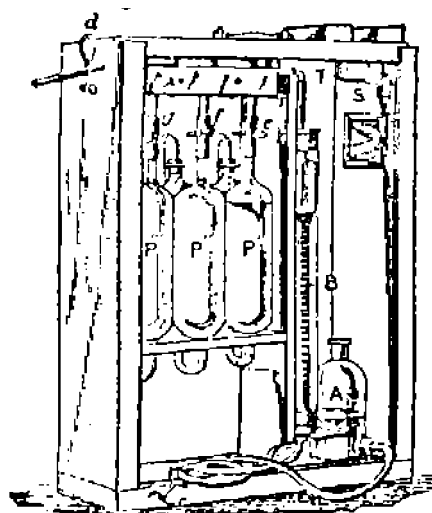
The Orsat apparatus is used for easy measurement of CO₂, CO and O₂ gases. For more details see Wilfred W. Scott, Standard Methods of Chemical Analysis, Vol. 2, 1989.

5.3.3.1 Material

There are three bottles with glasses and one burette. Bottle P' is filled with Potassium or Sodium Hydroxide solution. Bottles P', P'' are filled with Potassium Pyrogallate and Cuprous Chloride solutions respectively. Inquiries should be made from manufactures in respect of material specification before ordering.

5.3.3.2 Construction

The basic structure of instrument is shown in Fig. 2:



BASIC STRUCTURE OF INSTRUMENT
Fig. 2

5.3.3.3 Operation and performance

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.

5.3.3.4 Calibration of instrument

Instrument should be calibrated with a mixture of known gases. The instructions given by the Manufacturer in the calibration of instrument shall be considered.

6. LABORATORY MEASUREMENT

6.1 Sampling and Calibration of Gaseous Pollutants

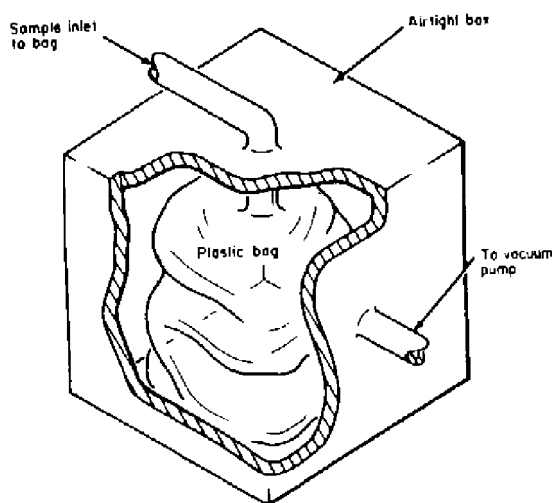
6.1.1 sampling

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 required.

6.1.1.1 Material

The containers are usually made from flexible plastics, 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 is in working order.

SAMPLING AND CALIBRATION OF GASEOUS POLLUTANTS



A PLASTIC BAG BEING USED FOR GRAB SAMPLING
Fig. 3

6.1.1.2 Construction

The basic principal structure of grab sampling is shown in Fig. 3.

6.2 Adsorption Sampling

Adsorbents are used to isolate a variety of pollutant gases.

6.2.1 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.

6.2.2 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.

6.3 Absorption Sampling

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

6.3.1 Bubblers and impingers

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

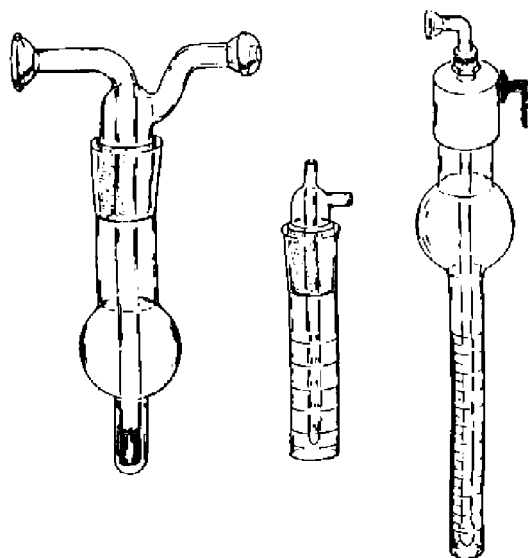
6.3.2 Material

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 100/ μm holes).

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

6.3.3 Construction

A number of designs for bubblers and impingers are shown in Fig. 4.



TYPICAL BUBBLER AND IMPINGER SAMPLING EQUIPMENT

Fig. 4

6.4 Cryogenic Sampling

The cryosampling technique is designed to preconcentrate chemical or called cold trapping.

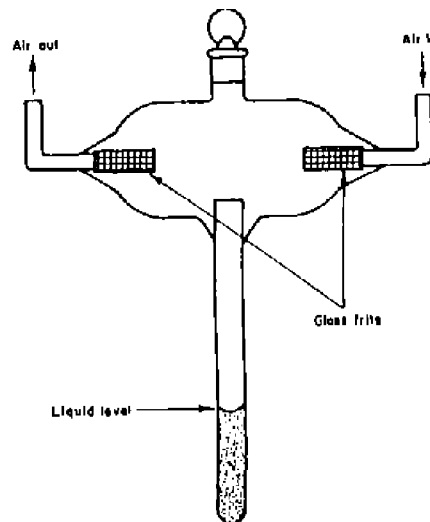
6.4.1 Material

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.

6.4.2 Construction

The basic structure for cryo-sampling is shown in Fig. 5.



DIFFUSION CELL
Fig. 5

6.4.3 Inspection

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

The oil level in pumps should be checked weekly and the system cleaned before each run.

7. 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 recently have been used, in addition, other methods in ASTM could be used.

7.1 NDIR

Nondispersive Infrared (NDIR) analyzer is the instrument for monitoring carbon monoxide.

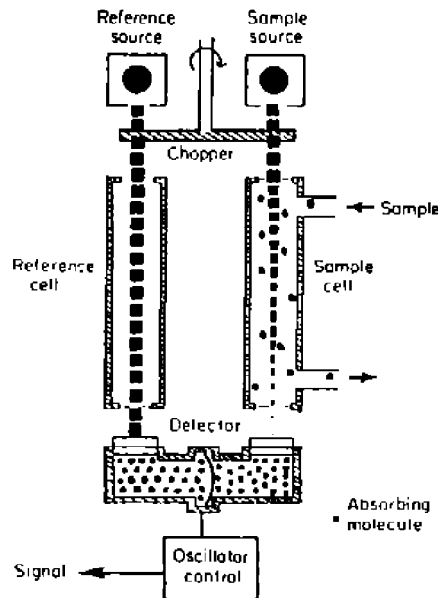
7.1.1 Material

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.

7.1.2 Construction

The basic structure of instrument is shown in Fig. 6. 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. 6

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

7.2 Gas Chromatography

Gas chromatography method is used for measurement of total Hydrocarbons, Methane and Carbon Monoxide (CO).

7.2.1 Material

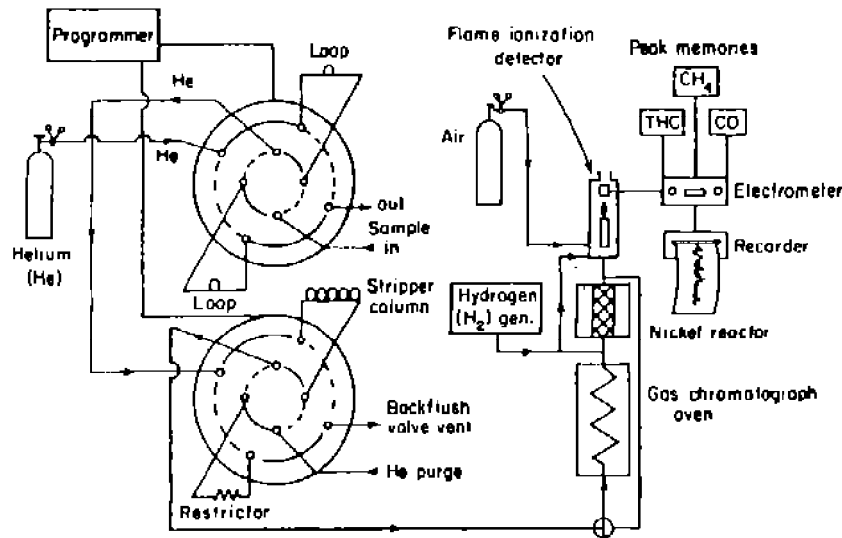
Carrier gas which is Helium carries gas through column. Column which is packed with different material cause separation of gases.

These gases after separation reach to detector and with using F.I.D. Flame Ionization Detector, the different component 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.

7.2.2 Construction

The basic principle of instrument is shown in Fig. 7.



GAS CHROMATOGRAPHIC ANALYZER FOR TOTAL HYDROCARBONS (THC), METHANE (CH₄), AND CARBON MONOXIDE (CO)
Fig. 7

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

7.2.3 Operation and performance

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

7.2.4 General requirements

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

7.2.5 Calibration of instrument

Calibration of instrument should be according to supplier's manual operation booklet.

7.3 Colorimetric Analyzers

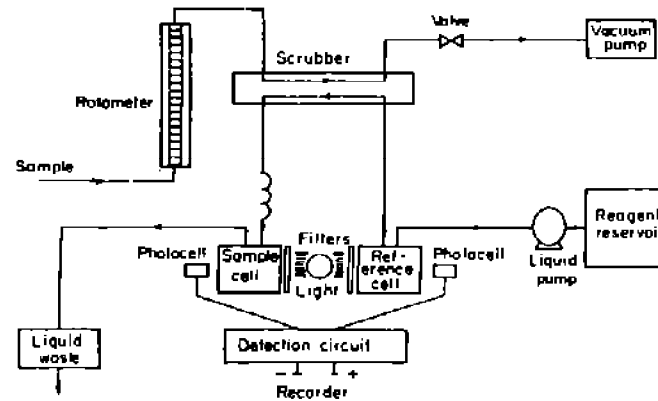
This method of instrumental chemical analysis is used for gaseous air contaminants. Operation is based on absorption of the air contaminant in a liquid reagent with subsequent formation of a colored reaction product which is determined by measurement of light absorbance in a flow colorimeter.

7.3.1 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 these equipment, required specification should be obtained from manufacturers.

7.3.2 Construction

The principal structure of instrument is shown in Fig. 8. All requirements should be based on mutual agreement between Purchaser and Manufacturer.



COLORIMETRIC ANALYZER
Fig. 8

7.3.3 Operation and performance

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

7.3.4 General requirement

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

7.3.5 Calibration of instrument

Calibration of instrument should be according to supplier's manual operation booklet.

8. 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.

8.1 Sulfur Dioxide SO_2

8.1.1 Colorimetric methods

The material and construction of instrument has been described in Clause 7.

8.1.2 Wet chemical methods

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

8.1.3 Conductivity method

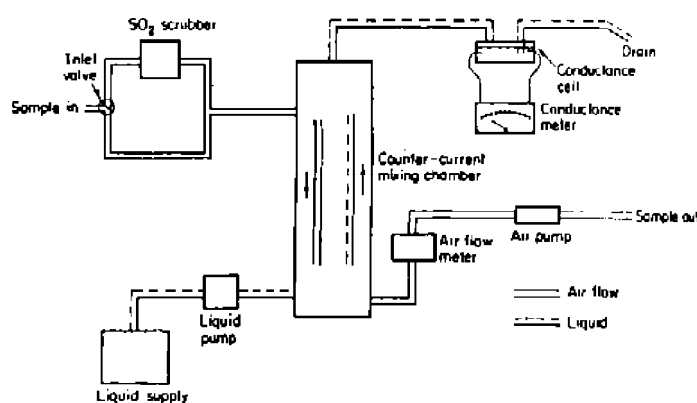
In this method the sample gas passes through the solution and ionize within it, decreasing the electrical resistance (increasing conductance) this method is for continuous monitoring.

8.1.3.1 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.

8.1.3.2 Construction

The basic of conductimetric analyzer is shown in Fig. 9.



COUNTER-CURRENT TYPE SULFUR DIOXIDE CONDUCTIMETRIC ANALYZER
Fig. 9

8.1.3.3 Operation and performance

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

8.1.3.4 General requirement

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

8.1.3.5 Calibration of instrument

Calibration of instrument should be according to supplier's manual operation booklet.

8.2 Hydrogen Sulfide

8.2.1 Wet chemical methods

For Analysis of hydrogen sulfide by wet chemical methods see ASTM Volume 11.03, Section 11, 1989.

8.2.2 Multifunctional instrumental methods

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

8.2.2.1 Fluorimetry

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

8.2.2.2 Coulometry

For material and construction reference is given in Clause 8.2.3.

8.2.2.3 Gas chromatography

Described in Clause 7.2.

8.2.2.4 Mass spectrometry

Described in Clause 5.2.

8.2.2.5 Flame photometric method

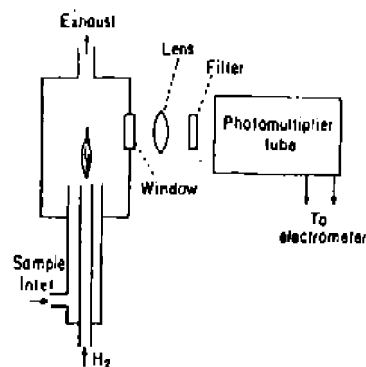
The flame photometric method operates on the measurement of light emitted from an element when burned in a hydrogen flame.

8.2.3 Material

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

8.2.4 Construction

The basic element of instrument is shown in Fig. 10.



FLAME PHOTOMETRIC DETECTOR

Fig. 10

8.2.5 Performances, general requirements and calibrations are as specified in Clauses 7.2.3, 7.2.4 and 7.2.5 respectively.

8.2.6 Electro-Chemical transducers

Basic of this measurement is described in Clause 5.3 but for detail see Arthur C. Stern, Air Pollution, Vol. III, Academic Press, 1976.

8.2.7 Solid state detector

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

9. NITROGEN COMPOUNDS AND OXIDANTS

9.1 Wet Chemical Methods

Detailed in ASTM Volume 11.03, Section 11, 1989.

9.2 Colorimetric Analyzers

Described in Clause 7.3.

9.3 Gas Chromatography

Described in Clause 7.2.

9.4 Chemiluminescent Method

Reference is made to Arthur C Stern, Air Pollution III, Academic Press, 1976 for details.

10. SAMPLING 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, filtration, impingement, centrifugation, or by electrostatic or thermal precipitation. For more detail refer to ASTM Vol. 11.03, Section 11, 1989.

10.1 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.

10.1.1 Atomic absorption method

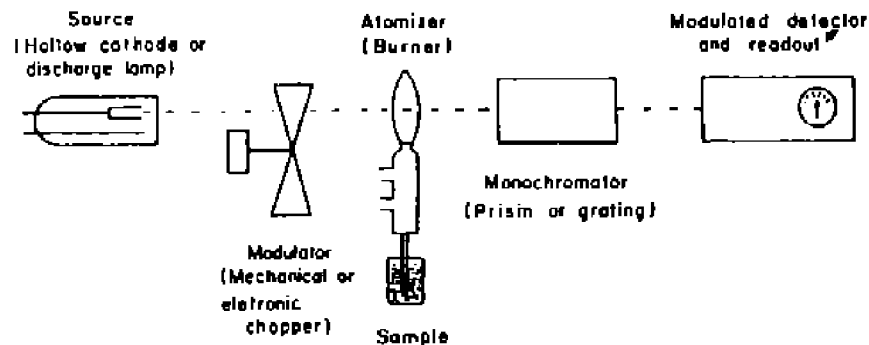
In an atomic absorption analysis the element being determined must be reduced to the elemental state, vaporized, and imposed in the beam of radiation from the source.

10.1.2 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.

10.1.3 Construction

The basic element of instrument is shown in Fig. 11.



SCHEMATIC DIAGRAM OF ATOMIC ABSORPTION SPECTROMETER
Fig. 11

10.2 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.

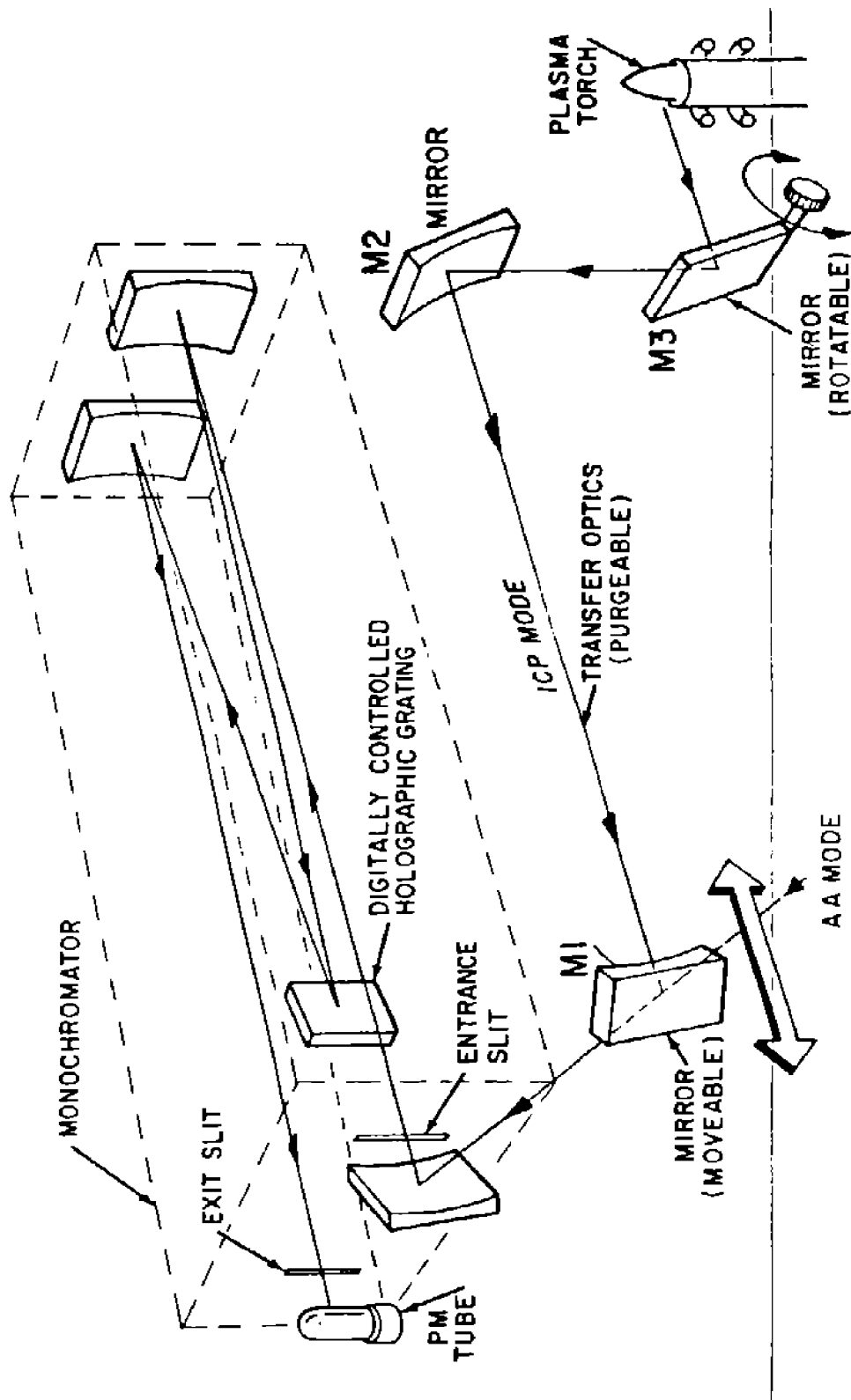
10.2.1 Material

An instrument has components as a spectrophotometer. These include a plasma source, a monochromator, 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).

10.2.2 Construction

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

10.2.3 Performance, general requirement and calibration are the same as given in Clauses 7.2.3, 7.2.4 and 7.2.5 respectively.



ICP OPTICAL SCHEMATIC
Fig. 12

10.3 Other Methods

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

11. CLEANING EQUIPMENT

11.1 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).

11.1.1 Mechanical collector

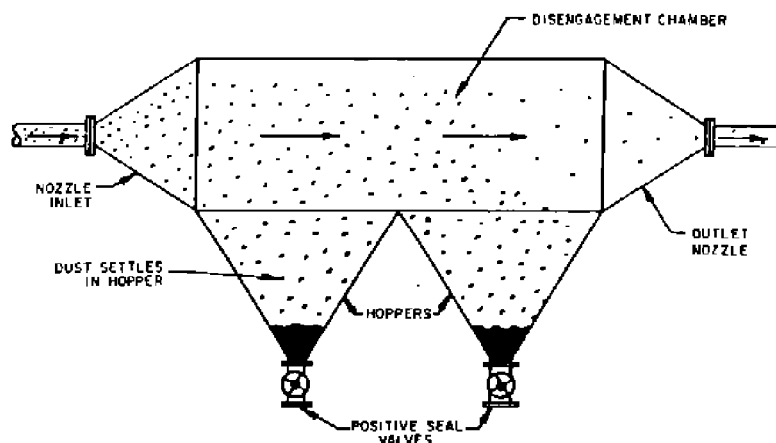
11.1.1.1 Gravity settling chamber

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 include pneumatic pumps, nozzles, hoppers, electrical power. Specification can be obtained from manufacturers.

b) Construction

A typical gravity settling chamber is shown in Fig. 13. This type of mechanical collector has very low collection efficiencies on fine and moderately fine dusts.



EQUIPMENT FOR PARTICULATE REMOVAL (GRAVITY SETTLING CHAMBER)

Fig. 13

c) Installation and inspection

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

11.1.1.2 Recirculating baffle collector

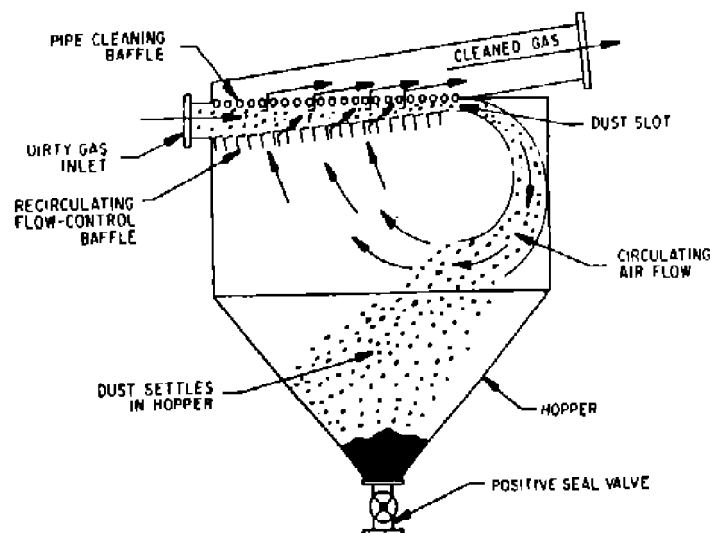
This type of collector where the gas to be cleaned is introduced at high velocity under a horizontal baffle.

a) Material

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

b) Construction

A typical recirculating baffle collector is shown in Fig. 14. 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. 14

c) Installation and inspection

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

11.1.1.3 High efficiency cyclones

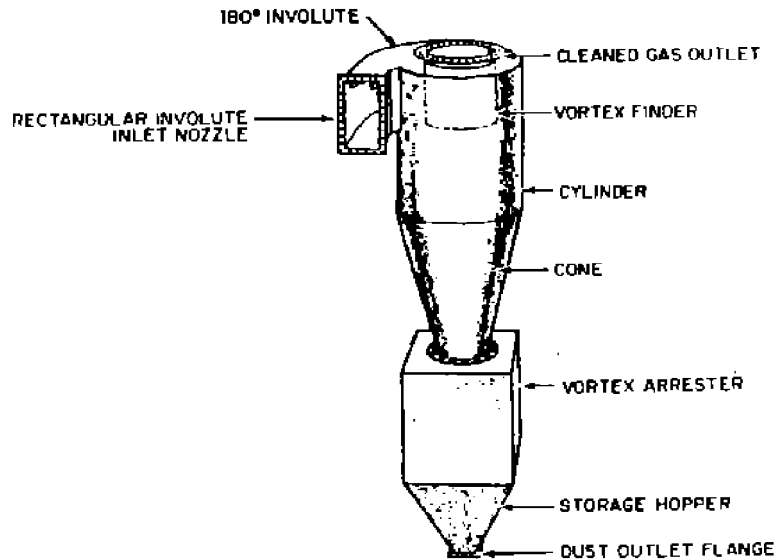
Inertial separators which employ a rotating flow. The particles are separated under the effect of centrifugal forces from the gaseous flow and are released in a radial direction.

a) Material

Cyclone collector can be manufactured from a wide range of materials including mild steel, low-alloy steel, 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. 15.



SINGLE HIGH-EFFICIENCY INVOLUTE CYCLONE

Fig. 15

c) Installation and inspection

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

11.1.2 Fabric filters

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

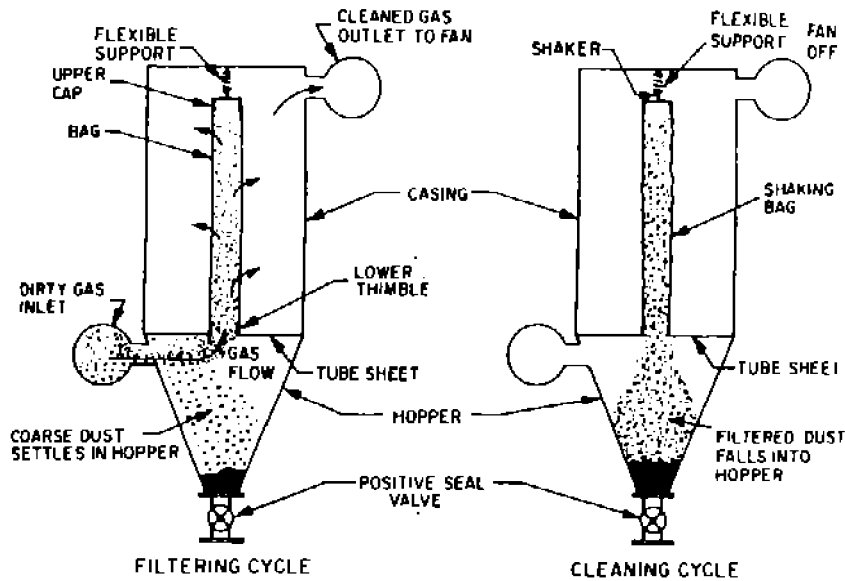
11.1.2.1 Fibrous filter separators

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. 16.



INTERMITTENT BAGHOUSE WITH MANUAL OR POWERED SHAKING
Fig. 16

c) Installation and inspection

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

11.1.3 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.

11.1.3.1 Bubble washers or packed bed scrubbers

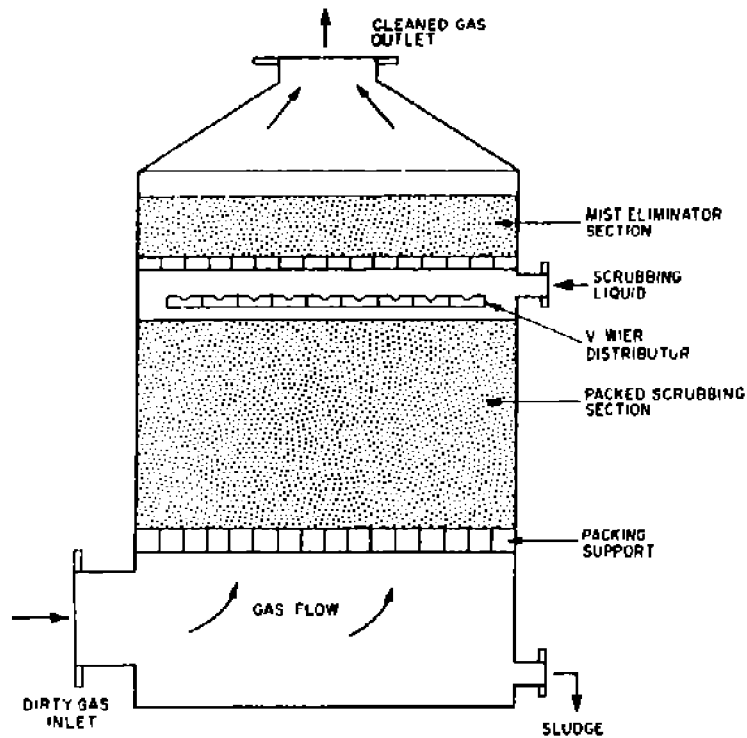
In this type of scrubber, the dirty gas is passed upward through the tortuous instertices formed by a thin or thick bed of small packing wetted by the counter flowing wash liquid.

11.1.3.2 Material

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

11.1.3.3 Construction

A typical single-bed scrubber is shown in Fig. 17.



COUNTER-CURRENT FLOW SCRUBBER

Fig. 17

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

11.1.3.4 Installation and inspection

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

11.1.4 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).

11.1.4.1 Material

In general the body of scrubbers are made from mild steel.

11.1.4.2 Construction

Basic principle of this type scrubber is shown in Fig. 18 which includes, dust cycle, demist section and water cycle.

Dust cycle

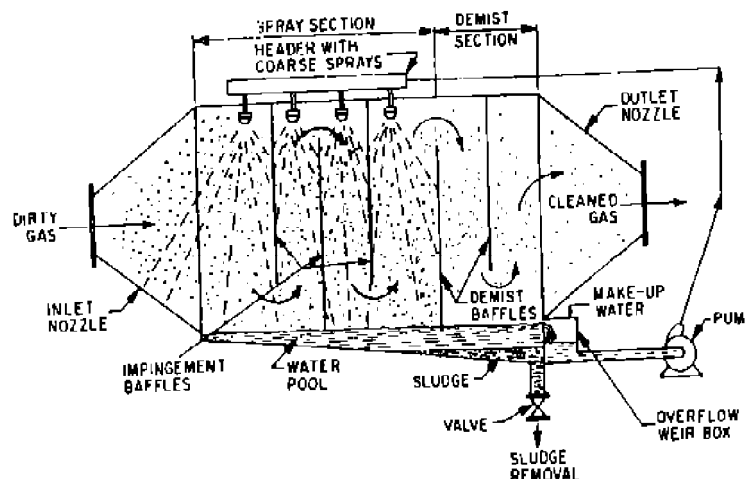
Captured wetted dust particles settle as droplets under the influence of gravity to the surface of the water pool.

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 cu.m (1,000 cu.ft) of gas cleaned.



WETTED IMPINGEMENT BAFFLE SCRUBBER

Fig. 18

11.1.4.3 Installation and inspection

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

11.1.5 Restricted flow scrubbers

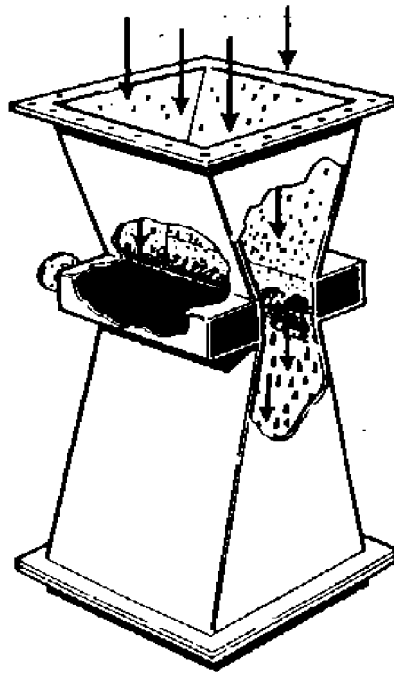
Wet separators in which the particles are brought into contact with the washing liquid in a restricted zone which causes a change in pressure or velocity conditions in the flowing gas line venturi, or orifice scrubbers and induced gas scrubbers (see also ISO 6584).

11.1.5.1 Material

This type of scrubber is made by different kind of steel described in Clause 11.1.3.2.

11.1.5.2 Construction

Construction of vertical downward gas flow venturi scrubber is shown in Fig. 19 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. 19

11.1.5.3 Installation and inspection

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

11.1.6 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.

11.1.6.1 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:

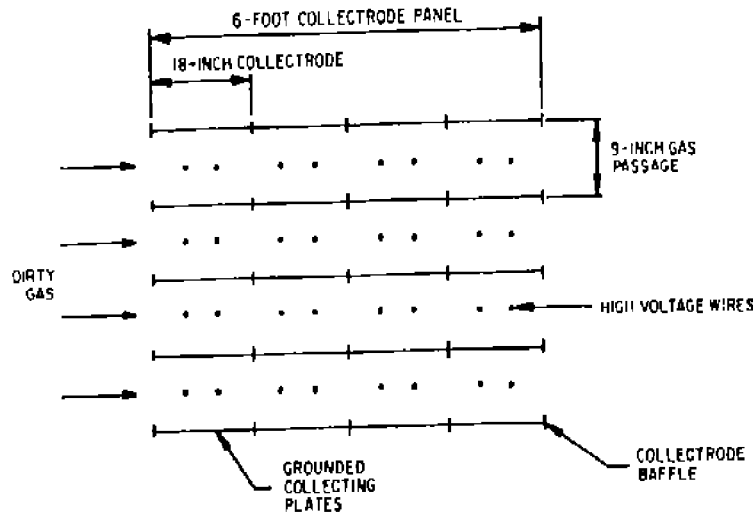
Gas-tight casing including:

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

11.1.6.2 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. 20.



CROSS SECTION OF FOUR-GAS-PASSAGE COLLECTRODE MODULE
Fig. 20

11.1.6.3 Installation and inspection

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

12. EQUIPMENT FOR GASEOUS WASTE DISPOSAL

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

12.1 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.

12.1.1 Material and construction

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

12.1.2 Absorption

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

- a) Packed columns;
- b) plate columns;
- c) spray towers;
- d) high-energy scrubbers and;
- e) gas-solid absorption.

12.2 Packed Columns

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

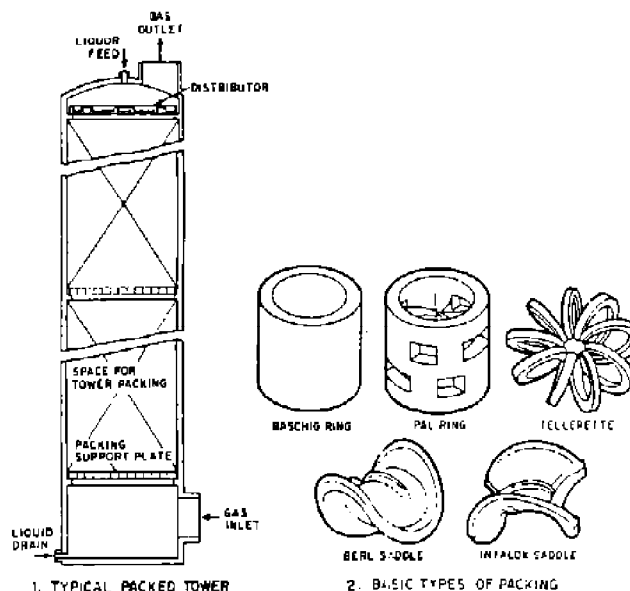
12.2.1 Material

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.

12.2.2 Construction

A typical lay-out of packed column is shown in Fig. 21. 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.



TOWER PACKING
Fig. 21

12.2.3 Installation and inspection

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

12.3 Plate Columns

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

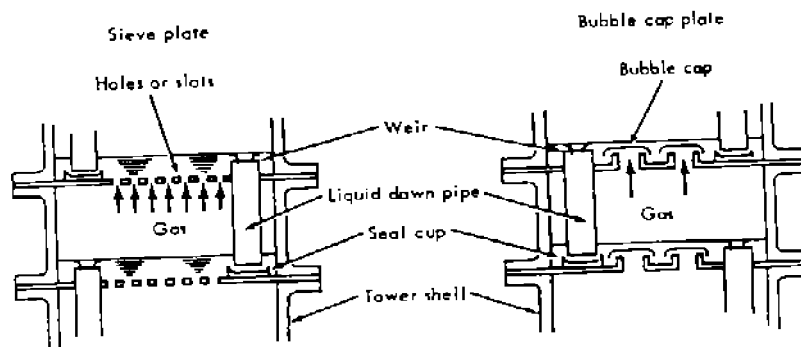
12.3.1 Material

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.

12.3.2 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. 22.



TYPES OF PLATES
Fig. 22

12.3.3 Installation and inspection

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

12.4 Spray Tower

See Clause 11.1.4.

12.5 High Energy Scrubbers

See Clause 11.1.5.

12.6 Gas Solid Absorption

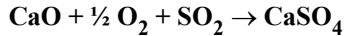
In dealing with high gas flow rates containing substantial quantity of pollutant, gas-solid absorption method should be used.

12.6.1 Material

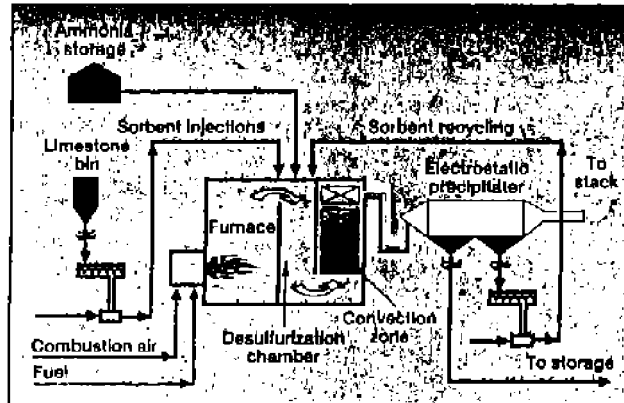
There are variety of solid absorbent with different processes for removal of pollutant gas. Information can be obtained from R.D. Ross, Air Pollution and Industry, Van Nostrand Reinhold, 1972, hydrocarbon processing, environmental processes 93, (August 1993).

12.6.2 Construction

Typical lay-out of processes for removal of SO_2 show in Fig. 23 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:



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



GAS SOLID ABSORPTION

Fig. 23

12.6.3 Installation and inspection

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

13. 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.

13.1 Material and Construction

For both material and construction see IPS-E-PR-770.

13.2 Installation and Inspection

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

14. COMBUSTION

Destruction of a waste gas or vapor by a combustion process is called incineration. There are three types of incineration:

- a) Direct flame;
- b) Thermal;
- c) Catalytic.

14.1 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.

14.1.1 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.

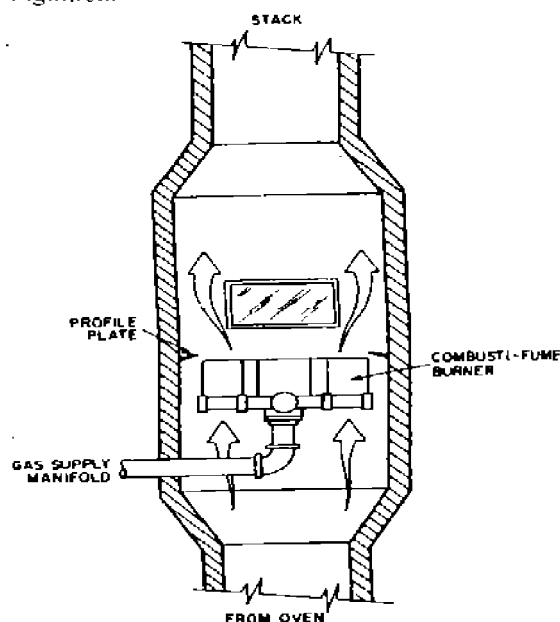
14.2 Thermal Incineration

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

14.2.1 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. 24.



DUCT TYPE FUME BURNER
Fig. 24

14.2.2 Installation and inspection

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

14.3 Catalytic Incineration

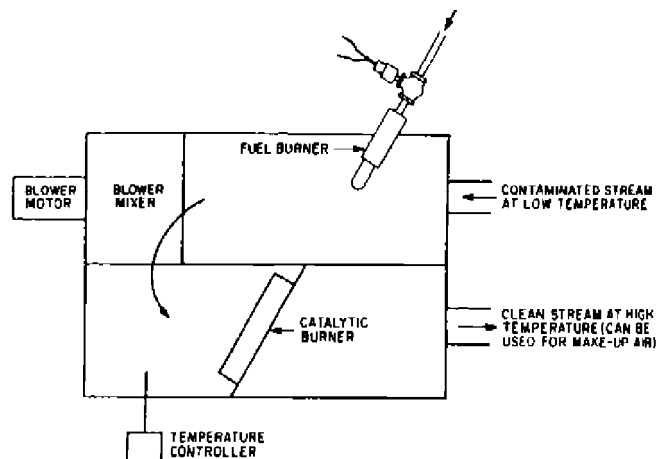
Catalytic incineration should be considered for gaseous wastes containing low concentration of combustible materials and air.

14.3.1 Material

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

14.3.2 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. 25.



CATALYTIC INCINERATOR
Fig. 25

14.3.3 Installation and inspection for catalyst poison

As recommended by the Manufacturer.

15. 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.

16. 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.

17. 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.

18. 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.

19. WARRANTY

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

20. 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 - SUMMARY OF COLD BATH SOLUTIONS

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	-147
Isopentane slush	-160.5
Liquid oxygen	-183
Liquid nitrogen	-196