

Emerging trends in the design of pollution control system for metallurgical industries

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ABSTRACT

The paper discusses the emerging trends in the design of pollution control systems for both air as well as water pollution. Recent trends in the design of high efficiency cyclones have been touched upon. In the area of water pollution, the application of bio-technology for mitigation of water pollution have been stressed.

INTRODUCTION

Globally the Governments of various countries are clamping down on industries generating pollution through stricter legislations. Thus all types of industries including metallurgical industries are waking up to this call of pollution control at source. New industries and old industries under modernisation are setting up latest pollution control systems. Under the circumstances, manufacturers of pollution control equipment can not get away with their obsolete and substandard equipments. The manufacturers of equipment are looking into their product design and going for improvement to meet the stringent environmental regulations. They are even going for new collaboration to import new high technology design of equipments to satisfy the norm. In the sixties and seventies industries in India used to install cyclones as the air pollution control equipment. But now we have whole new sets of equipments for air pollution control like pulsejet bag filter, electrostatic precipitator etc. which can guarantee any emission level at a price. In India we are still generally speaking of 150 mg/Nm^3 of permissible dust level from stack. In developed countries this ranges between 30 mg/Nm^3 to 50 mg/Nm^3 . Even in India such norms are clamped on some units of metallurgical industries such as the norm for coke oven is 50 mg/Nm^3 .

For water pollution control also in addition to the prevalent unit processes for treatment of effluents, modified secondary/tertiary treatment consisting of biological, membrane separator, ultrafiltration etc. have been introduced to meet the ultimate effluent standards.

Air Pollution Control Equipments

In metallurgical industries, generally air pollution control requires removal of particulates. The equipment for controlling air pollution is selected based on characteristics of particulate. The physical and chemical characteristics of particulate affect the ease with which particles can be collected. Therefore, it is important to know the particulate characteristics before choosing a control equipment.

Some of the important characteristics of particulates are : (a) Concentrations, (b) Chemical composition, (c) Size and particle size distribution, (d) Density, (e) Tendency to agglomerate, (f) Solubility, (g) Corrosive characteristics, (h) Electric properties, (i) Hygroscopicity, (j) Flowability, (k) Flammability, and (l) Nature of carrier gas, humidity, temperature etc.

Evolution of Air Pollution Control Equipments

First generation equipment

Centrifugal Separators : Centrifugal separators are basically inertial separators. The most common type of centrifugal separator is the cyclone collector in which the velocity of the entering gas provides the energy to form and maintain a double vortex within the cyclone. As the gas enters, it spirals downwards forming the outer vortex, then spirals upwards through the inside forming the inner vortex.

Settling Chambers: In this mechanism low gas velocity causes gravitational settling. Here the equipment operates below the terminal settling velocity of the particle. Advantages are : effective pre-cleaner, simple construction, low initial and operating cost., dry dust disposal, no problems with abrasive materials etc.

Momentum Separators : Here the inertia of the particles cause them to move from the body of the gas towards the collection area. These operate at low efficiencies and are used as pre-collectors.

Wet Scrubbers : Scrubbers are collection devices in which particles are brought in contact with a liquid surface; captured into the liquid and then removed with the liquid. Different types of scrubbers are : Spray tower, Cyclone scrubber, Packed scrubber, Impingement scrubber. The scrubbers give good collection efficiency upto 5 micron dust particles.

e) Bag filters (Shaking and reverse air type) : One of the oldest and positive

means of removing particulate matter from gas streams in through filtration. Properly designed and suitably applied, these are capable of achieving highest degree of removal. The predominant collection mechanism is impaction and interception and also electrostatic and diffusion.

A bag filter closely resembles a household vacuum cleaner. The dirty air passes across a filter media, deposits the pollutant and the clean air comes out. Filter media is in the shape of a tube or a flat pocket.

The filter tubes are mounted inside a metal housing. The dirty gas is fed to the metal housing and the gas either deposits the cake on the outside or on the inside surface of the filter cloth depending on design. The deposited material is either removed by shaking or by reverse air flow from a compressor.

These are low ratio bag filters and uses woven cloth. These bag filters are getting phased out due to their big sizes, lower efficiency and maintenance problem due to moving parts.

Second generation equipment

Under this category the following equipments are called second generation. These are in vogue and are highly efficient and widely used. The first generation equipment described earlier are used as precollector or in a system where dust characteristics warrant their use.

Multiclone : This is improvement on large diameter cyclones. Multiclone uses small dia cyclones in a cluster. The cyclones range from 40 mm to 250 mm. Efficiency of multiclone is higher than large diameter cyclones.

Venturi scrubber : Venturi scrubber is highly efficient. The major collection mechanism is the impingement of the particles from high speed gas stream into water drops. Efficiency of removal increases with the increase in number of droplets formed by atomization. The energy for atomization is provided by gas. The design is free from moving parts but the disadvantage would be the high energy consumption.

Pulse jet bag filter : This is an improvement on earlier type of bag filters viz shaking and reverse air type. These are high ratio bag filters and occupies less space and is compact in size.

These bag filters use high pressure blast of air to clean dusty bags. Non-woven cloth are used and these have long life. The deposited material is either removed during the filter operation (called on-line cleaning) or a portion of the

bag house is taken out of service and cleaned (called offline cleaning). These bag filters are widely used in metallurgical industries.

Electrostatic Precipitators (ESP) : The collection of particulate matter in electrostatic precipitators is through the movement of charged particles in an electric field. Following steps are involved in collection of dust inside the ESP.

- Production of corona (electric field)
- Charging the dust
- Migration of charged dust to plate of opposite polarity.
- Giving off the charge by dust
- Rapping out the collected dust.

The ESP consists of two sections

- Ionization section
- Collection plate section

Ionization section consists of corona from discharge electrode. This imparts necessary charge to the dust particle, which migrates to collection plate which is grounded and rapped out.

The ESP has small gas-side pressure loss and is very efficient for sub-micron sizes of dust. Resistivity of dust should be optimum so that it can be charged.

Advantages of electrostatic Precipitator

- High particulate removal efficiency
- Low gas side pressure loss
- Relatively low power consumption
- Efficiency depends on resistivity of dust

However, the disadvantage of such system lie in their high initial cost.

Future Trends in Air Pollution Control

For particulate removal, high efficiency cyclones are being developed

having efficiency as high as 99.9% + when operated properly within the envelope of its specification. For particles of size 5 microns and specific gravity less than 1, the efficiency is of the order of 99 % + . The design and operation of such cyclones depends strongly on correctly specifying the properties of gas, particulates and shape of cyclone. The modification in the original design consists of :

- Addition of vortex breaker with air lock.
- Emphasis on efficient design based on accurate measurements of its inlets, body cone, discharge, vortex finder, vortex breaker etc. (Ref. : Tips for selecting highly efficient cyclone — Chemical Engg. May 1995). For increasing efficiency of ESP, the conditioning of particulates by moisture addition/sulphuric acid addition for ash etc. are practised.

The recent regulations may call for reduction of SO_2 and NO_x in emission as being practiced in developed countries. Although many methods for SO_2 control are available, lime and lime stone scrubbing is generally in vogue all over the world. However, secondary pollutant generated in the form of sludge calls for costly conversion processes for manufacture of saleable products such as gypsum and their allied products. The process technology modifications reduces NO_x emissions. However, control technology for NO_x emissions are grouped into either combustion modifications including low NO_x burners or post combustion methods which rely on eliminating NO_x species with a reducing agent, which is ammonia or ammonia forming materials such as urea.

Hot gas cleaning based on ceramics candle filter, absorbent beds/filters have been introduced for entrainment of particulates from hot gases upto 1000°C including removal of NO_x and SO_x (Ref. : Gas cleaning comes out of the bag — Chemical Engg. July 1994).

In metallurgical plants the major problem lies in disposal of collected dust from various dedusting system. In Indian Steel Plants still no major solution has been found for its utilisation apart from accumulation in storage ponds/dumps creating secondary pollutants. The present trend is to go for mini-pelletiation or briquetting and utilise the same for further extraction of valuable components.

Water Pollution

There are a number of water quality parameters, for which statutory values have been fixed to maintain the effluent water quality. In the metallurgical

plants particularly the following key parameters are usually chosen to which all other parameters are linked : COD - Chemical Oxygen Demand, BOD5 - Biological Oxygen Demand after 5 days, SS - Suspended solids, Hydrocarbons, Toxic substances : Heavy metals - Ammonia ions, H^+ or OH^- ions, Cyanide, Phenols, etc. The following Table-1 shows the extent of water pollution potential from the integrated steel plants (Ref : UNEP-Environmental Aspects of Steel Industry, 1983)

Table-1: Extent of water pollution potential from steel plant, kg/t of finished steel

Units	Quality Parameters				
	COD	BOD5	HC	Toxic substances	SS
Sintering plant, Pellet plant	-	-	-	Ore impurity Zn, As, F, S	0.01 - 0.14
Coke Oven	1-3	-	-	NH_4^+ 0.4-2.5 Phenol 0.4-0.8 CN 5×10^{-5}	0.32
Blast Furnace	0.6	-	-	CN: 0-2	1.2-6
BOF	0.06	<0.1	-		3-40
Continuous casting & Hot Rolling Mill	0.05-0.1	10	0.1-0.4		0-30
Pickling	0.5	20		H^+ 2-3 mols/t	7-9
Cold Rolling	0.1-0.2		0.1-1		0.2

Industrial Waste Water Treatment Processes

The waste water treatment processes can be categorised in the following manner to meet water pollution control norms.

1) Base level technology (Primary) : Coagulation, flocculation and sedimentation; Solid liquid separation; Precipitation and filtration; Emulsion breaking , Neutralisation and Aeration Degasification,

ii) Stage-I Technology (Secondary): Biological digestion, Bio-degradation, Control of microbial activity, Adsorption

iii) Stage-II Technology (Tertiary): Ion exchange, Membrane separation, Evaporation

Physical and Chemical Treatment Methods

These treatment methods are mainly used for removal of non-biodegradable pollutants present in waste waters. These methods do not suffer the limitations of : (i) sensitivity to temperature, (ii) feed concentration changes. Many of the physical and chemical techniques include adsorption, chemical reaction, filtration, ion exchange, reverse osmosis, electro-dialysis, etc.

Adsorption

Activated carbon is most popular medium for commercial adsorption. In this process, powdered activated carbon is directly added to the waste water feed in the aeration tanks. Typical carbon regeneration and sludge incineration use a multihearth furnace.

Chemical reaction

Some of the most common chemical treatment processes are chemical coagulation, neutralisation, and chlorination. Ozonation is becoming more attractive and is a substitute for chlorination.

Membrane processes

These include reverse osmosis, ultrafiltration and electro-dialysis: (i) Reverse osmosis :When a dilute solution is separated from a concentrated solution by an ideal semi permeable membrane. Solvent molecules from dilute side pass through the membrane by the osmotic pressure in the concentrated side. Flow of solvent molecules will occur in the reverse direction, i.e. from concentrated to the dilute side. This is known as reverse osmosis.

Reverse osmosis is applied for demineralisation of sea water and for reduction of total dissolved solids from waste water. The process is costly, needs stringent operational conditions and the brine or concentrated pollutant disposal creates secondary pollution.

(ii) Ultra filtration :This employs porous membranes which have potential to separate large, dissolved, organic molecules from waste waters.

Biotechnology for water pollution control : In recent years biotechnology has been increasingly adopted for the industrial production of chemicals and biochemicals. The application for pollution control has gained importance as it appears to be the only technology which is environmentally compatible and economically viable. The concept of biotechnology in waste treatment is not new, since it is based on natural purification processes that occurs in soil and water. The development of biotechnology for pollution control rests on the selection of appropriate groups of microorganisms, either from natural population or by providing active degraders and retaining their potential through engineering principles. Significant success has been claimed in structuring micro-organisms for degrading chloro-aromatic compounds, pesticides and herbicides. Mutated cultures have also been isolated and developed for degrading toxic pollutants such as phenols, cyanides, pesticides and petroleum hydrocarbons. The biotechnological approach for pollution control currently adopted in India is based on : (i) The use of heterogenous natural microbial culture as such or after suitable acclimatisation. (ii) The isolation of hyper detoxification of hazardous pollutants and (iii) The optimisation of reactor design to provide compact units with resource recovery potential.

Recent trends in water pollution control : Various type of membrane are being developed and patented for removal of hydrocarbon/other pollutants present in waste water. The membrane basically consists of cellulosic filters, that are 400 μm in dia. These membrane separation technique requires working pressure of around 50 psig as compared to 100-1000 psig required for reverse osmosis process. Electrolysis, i.e. proper designed electro chemical processes are developed which can remove heavy metals and allow recovery of valuable chemicals from water streams. Fluidised bio-reactors have been developed to remove waste water phenols. (Ref. : Remove waste water phenol in a less costly way - Chemical Engg. Progress - Aug. 1992).

CONCLUSION

The first part of the article deals broadly with air and water pollution control equipment of yester-years which are low in efficiency but simple in design and of low cost. These equipments are called first generation equipments. Second generation equipments are in vogue now. They are sophisticated, costly but highly efficient. They can meet the strict stipulated norms. Constant research at high cost, particularly in USA is going on for modifying the second generation equipment/processes to suit the more stringent norms being introduced by the regulating authorities. Some of the recent developments on air and water pollution control are discussed.