APCD Selection & Case Study

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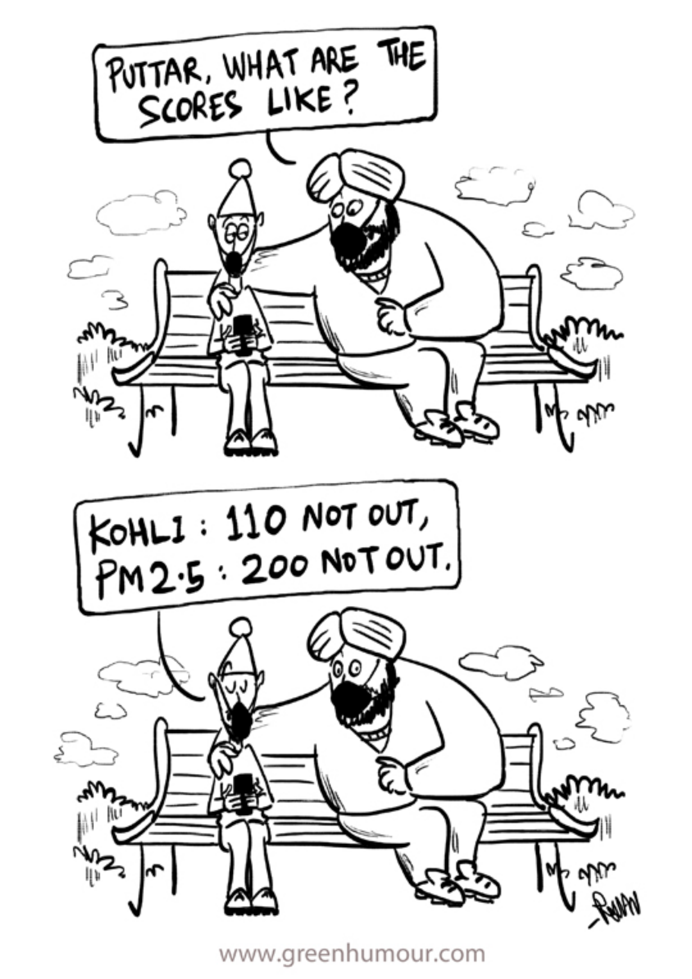
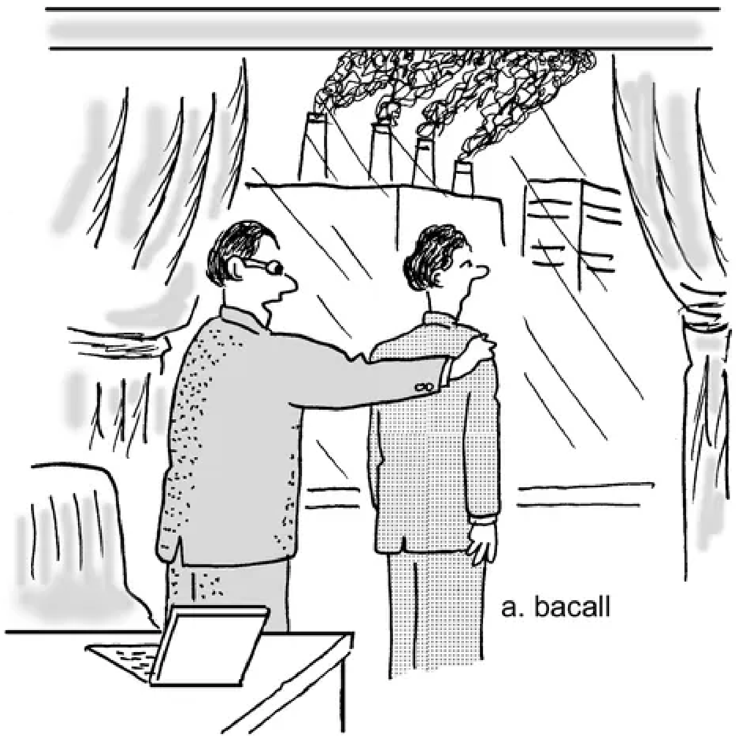


"Let's close the shades before you bring the environmental regulators in."

A Picture Is Worth a Thousand Words



"Someday son, all this will be yours to argue with the Environmental Protection Agency over."

"THERE'S GOOD CHOLESTEROL, GOOD BACTERIA... WE HAVE TO COME UP WITH SOME GOOD POLLUTION."

A Picture Is Worth a Thousand Words

Agenda

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Introduction

02
Factors for Selection

03
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04
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01

Introduction

Introduction

Selection and installation of Air Pollution Control Equipment (APCE) more difficult than before due to rapid industrialization with growing population and promulgation of stricter air emission regulations

The protection of public health and welfare are primary reasons for installation of APCE and is further administered by a host of environmental laws and regulations

Introduction

Engineering profession responds to this challenge of Selection, Design and Installation of APCE mainly on three principal considerations:

Legal obligations imposed for protecting public welfare and wealth;

Social obligations imposed by the community wherein the source of pollution is or will be located;

Economic obligations imposed by market constraints.

Introduction

The air pollution control strategy for optimum environmental impact mostly emphasizes on five alternatives whose purpose would be either to reduce or to eliminate air emissions which are:

- Elimination of the entire or part of the process operation
- Process modifications
- Shifting of the process operation from one place to the other
- Introducing appropriate pollution control technology
- Suitable combination of any of the above

02

Factors for Selection

Factors for Selection

A variety of factors are necessary to be considered before a particular piece of air pollution control hardware is being selected, designed and installed. These factors can be grouped into three categories :

Environmental

Engineering

Economic

Environmental Factors

Availability of space in the plant

Ambient conditions

Permissible emission limits (e.g., air pollution regulations),

Wastewater generation and land pollution stemming from air pollution control systems

Location of the equipment

Availability of utilities & support facilities like common waste treatment and disposal facility, transportation, etc.

Aesthetic considerations (i.e., visible steam or water vapor plume, etc.)

Contribution to the noise level within the plant as to the surroundings from the operation of air pollution control device

Engineering Factors

Pollutant characteristics

- physicochemical properties, pollutant concentration, particle shape and particle size distribution, corrosivity, abrasiveness, chemical reactivity, toxicity, carcinogenicity, etc.

Characteristics of gas stream

- volumetric flow rate, pressure, temperature, humidity, composition, density, viscosity, combustibility, corrosivity, reactivity, toxicity, carcinogen city, etc.

Design and performance characteristics of the particular pollution control system

- dimensions, weight, target efficiency curves, mass transfer and/or contaminant destruction capability—in the case of gases or vapors, pressure drop, turn down ratio, temperature limitations, reliability, utility requirements, maintenance requirements, flexibility to meet more stringent air emission regulations, etc.

Economic Factors

- Capital Cost (equipment, installation, engineering, etc.)
- Operating Cost (utilities, maintenance, etc.)
- Expected life and salvage value of the equipment

Other Considerations

Check certified test report on its performance operated under similar situation. Ask for performance information and design specifications

If certification is not available then pilot scale model can be used for evaluating its performance under existing conditions

Specifications should be meticulously prepared

Process and economic fundamentals should be careful reviewed

Operation and maintenance costs should be given high priority on the list of equipment selection factor

Spare parts of the equipment intended to be purchased should be readily available

Typical Factors

The design, procurement, installation and startup problems can be further complicated by the following factors either alone or in combination:

- Quacks are doing air pollution control engineering
- New fabricators with unproven device
- Absence of emission standards in some industrial activity
- Verbose specification of device that is being put into the market
- Problems associated with the process unreliability
- Weak guarantees for the new control device
- Unreliable delivery schedules
- Tight compliance schedules
- New / changing air emission standards from stationary point sources

03

Review of Design Process

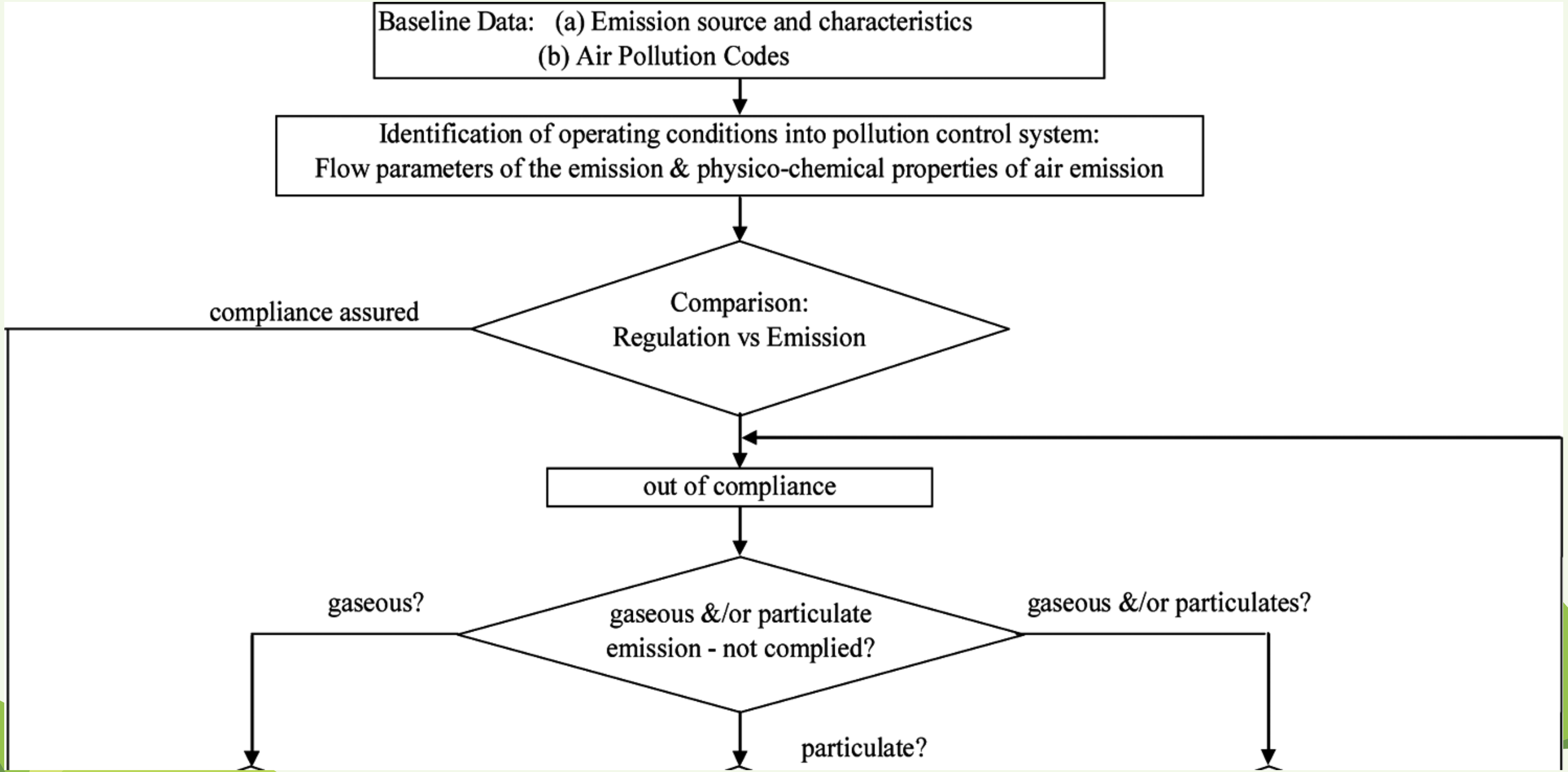
Necessity

Design reviews for APCE are necessary :

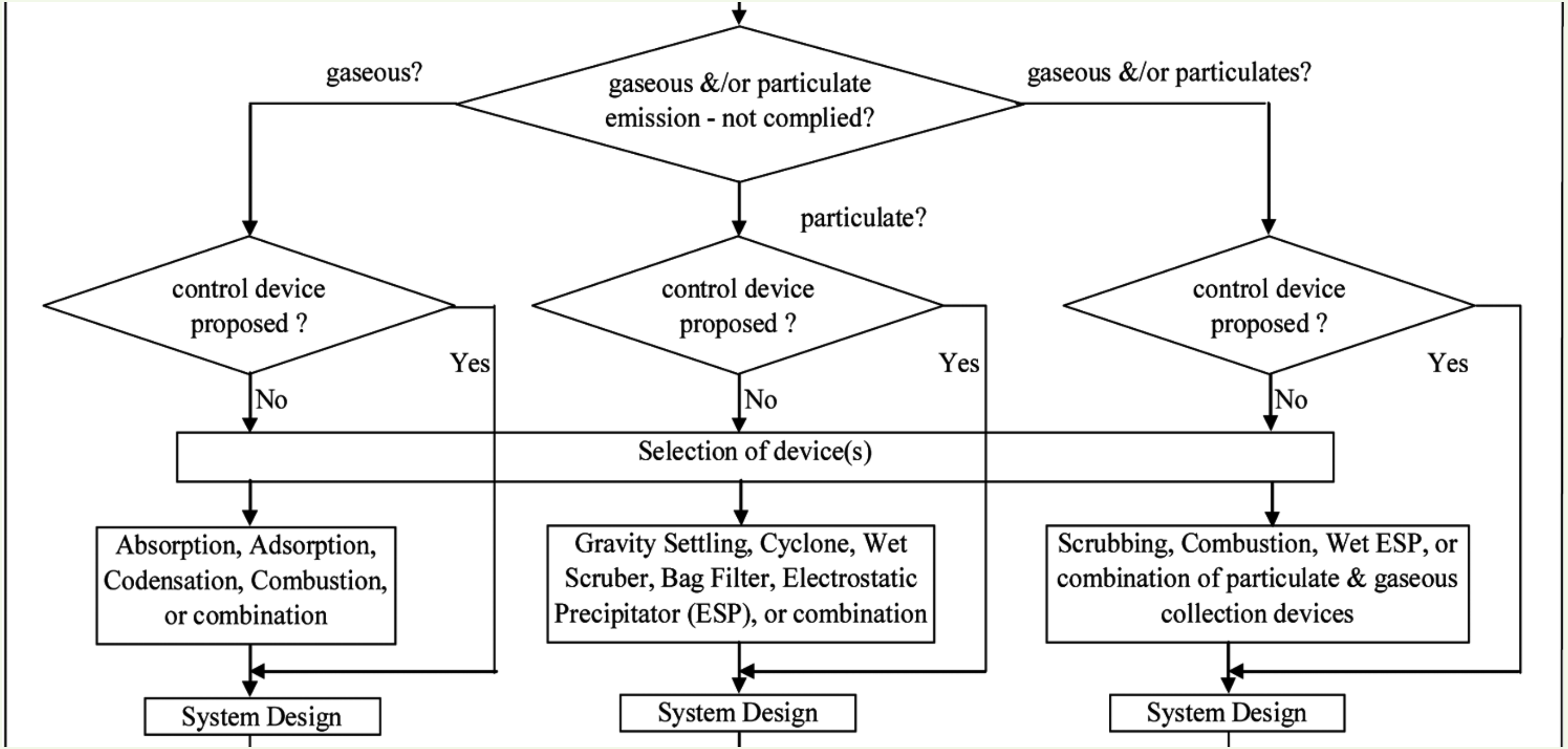
- To study the compliance with applicable air emission standards
- To assess the performance of existing control device
- To evaluate the feasibility of a proposed device
- To assess the effect of process modifications on the control device

A typical generalized design review approach is presented in succeeding slides. The design review investigation is an activity generally performed early in the evaluation stage.

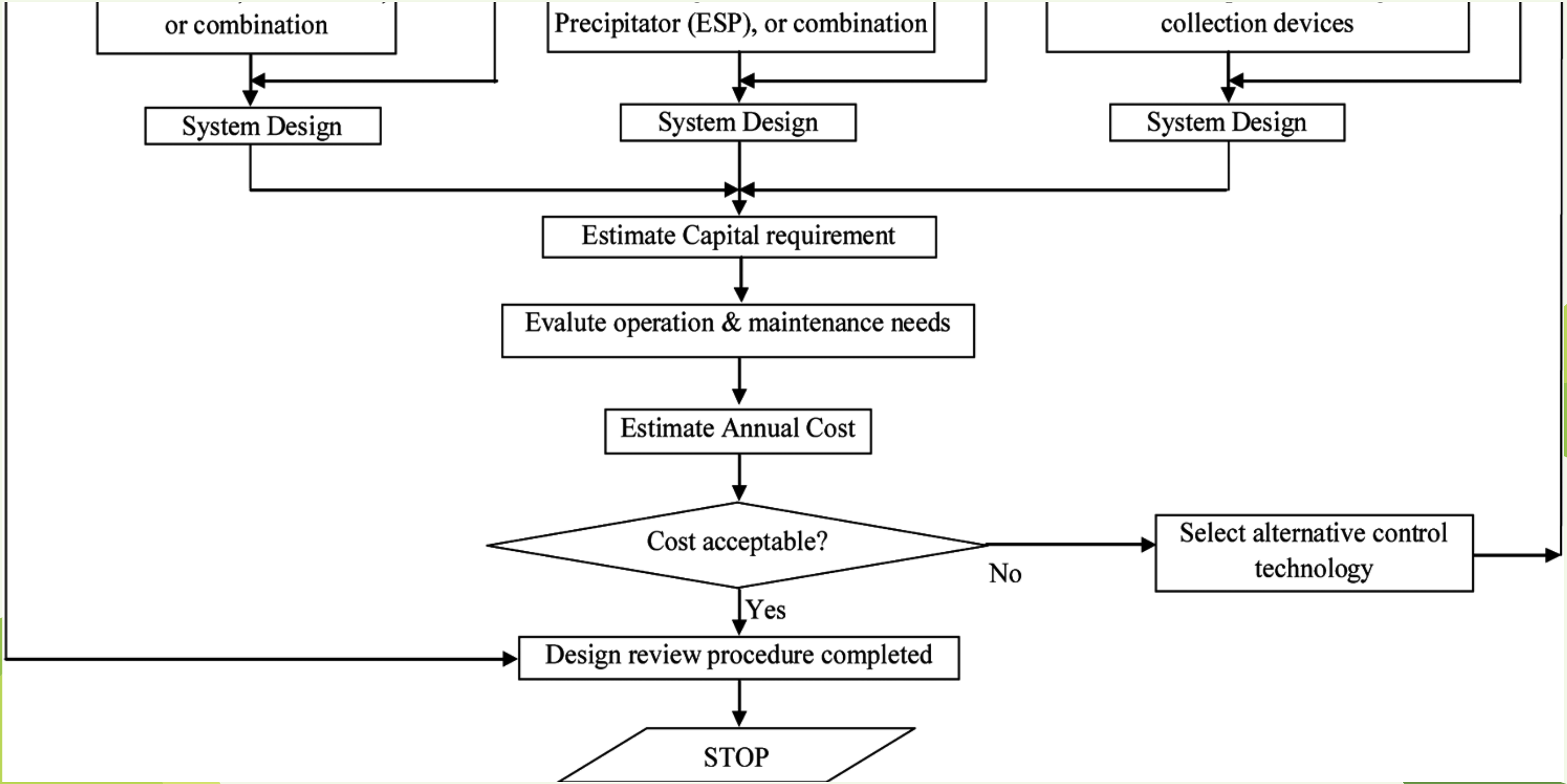
Typical design review approach



Typical design review approach



Typical design review approach



04

Suggestions for APCD

Suggestions

The final choice in the selection of the appropriate air pollution control device is usually dictated by the device capable of achieving compliance with the emission standards set forth by the regulatory authority at the lowest uniform, annual cost

To compare the specific air pollution control device alternatives, a fair amount of knowledge of the specific application and site is essential.

The critical aspects of selecting the air pollution control device can be described based on particulate collection device as well as gaseous emission control device

Suggestions

All of the control methods exhibit maximum control efficiency when the inlet concentration is high

All of the methods are also sensitive to the gas stream temperature

Absorption, adsorption, biological treatment, and condensation work best at low temperatures, while oxidation and reduction systems operate in narrowly limited high temperature ranges

Absorption processes are often effective for the removal of multiple contaminants, although a sophisticated separation process is required if each contaminant needs to be recovered individually.

Suggestions

Incineration can generate products of incomplete combustion or otherwise undesirable by products that may often require additional controls.

At gaseous pollutant concentrations of more than about few hundred parts per million, carbon adsorption has been found to offer a 99% efficiency or greater

Removal efficiencies can exceed 95% at higher concentrations (>1000 ppm)

The knowledge of the capabilities of the various control options coupled with the common sense, will simplify the overall selection procedure

Criteria for selection

Criteria for the selection of particulate removal equipment	
Particulate/career gas-specific criteria	**Equipment specific criteria**
• Particulate concentration • Particle size distribution • Particle density • Abrasiveness • Gas temperature • Tendency for agglomeration and incrustation • Chemical reactivity • Inflammability and explosiveness • Toxic properties • Odorous properties • Optical properties • Foaming properties • Wettability • Price	• Fractional collection efficiency • Security of operation • Availability • Size • Adaptability to varying operating conditions • Pressure drop • Maintenance and repair • Simplicity of design • Sensitivity to erosion, corrosion and foam formation • Water requirement • Electricity requirement • Operating cost • Investment cost

Advantages and Disadvantages

Advantages and disadvantages of particulate removal devices	
Advantages	Disadvantages
Inertial or impingement (cyclone) separators	
• Low capital cost • Relative simplicity and few • maintenance problems • Low pressure drop • Dry collection and disposal • Relatively small space requirements	• Offer low particulate collection efficiencies especially for particulate sizes below 5 mm • Inability to handle sticky materials

Advantages and Disadvantages

Advantages and disadvantages of particulate removal devices	
Advantages	**Disadvantages**
Wet scrubbers	
• No secondary dust as residuals • Relatively small space requirement • Ability to remove gases as well as particulates (especially "sticky" ones) • Ability to handle high temperature, high humidity gas streams • Low capital cost • Insignificant pressure drop • High collection efficiency of fine particulates and gaseous emission	• Potential water disposal/effluent treatment problem • Corrosion problems (more severe than with dry systems) • Potentially objectionable steam plume opacity or droplet entrainment • High pressure drop (~25 cm w.c.) for some units • Relatively high maintenance costs for systems with column internals

Advantages and Disadvantages

Advantages and disadvantages of particulate removal devices	
Advantages	**Disadvantages**
Fabric filter systems (Bag Houses)	
• Very high collection efficiency (99.9%) for both coarse and fine particulates • Relative insensitivity to gas stream fluctuations and large changes in inlet dust loadings (for continuously cleaned filters) • Recirculation of filter outlet air • Dry recovery of collected material for subsequent processing and disposal • No corrosion problems	• Requirement of costly refractory mineral or metallic fabric at temperatures in excess of 290ºC • Need for fabric treatment to remove collected dust and reduce seepage of certain dusts • Relatively high maintenance requirements • Explosion and fire hazard of explosive dusts

Advantages and Disadvantages

Advantages and disadvantages of particulate removal devices	
Advantages	**Disadvantages**
Fabric filter systems (Bag Houses)	
• Simple maintenance, flammable dust collection in the absence of high voltage • High collection efficiency of submicron smoke and gaseous contaminants through the use of selected fibrous or granular filter aids • Relatively simple operation	• Shortened fabric life at elevated temperatures and in the presence of acid or alkaline particulate or gas constituents. Potential crusty caking or plugging of the fabric, or need for special additives due to hygroscopic materials, moisture condensation, or tarry adhesive components • Respiratory protection requirement for fabric replacement • Medium pressure-drop

Status of the applicability

Status of the applicability of gaseous emission control techniques

Control technique	General applicability	Typical concentration range	Typical gas temperature range	Applicable for control of: Multiplec contaminants?	Applicable for control of: Gas laden with particulate matter?
Absorption	Acid gases & organic compounds	<1 ppm to >100,000 ppm[a]	<150°F[b]	Yes[g]	Yes
Adsorption		<1 ppm to 25% of LEL[a]	<130°F[b]	Yes[g,h]	Often require pretreatment
Biological Treatment	Organic compounds	<1 ppm to ~1000 ppm	<110°F[c]	Yes	
Oxidation		<1 ppm to 25% of LEL[a]	600°F to 2000°F[d]	Yes	Often require pretreatment
Reduction	NO and NO_2	<100 ppm to 1000 ppm[a]	550°F to 2000°F[e]	Yes[i]	Yes
Condensation	Organic compounds	>100 ppm[a]	–320°F to 80°F[f]	Yes[g,h]	Often require pretreatment

Notes:

[a]Maximum removal efficiency usually occurs at maximum contaminant inlet concentration.
[b]Gas stream precooling is needed in some applications to reduce operating temperatures.
[c]Gas stream precooling and humidification are needed in some applications to reduce operating temperatures and to increase gas stream humidity.
[d]Catalytic systems operate in the 500°F–1000°F range. Thermal oxidizers and flares operate in the 1200°F–2000°F range.
[e]SCR systems operate in the 550°F–750°F range. SNCR systems operate in the 1600°F–1900°F range.
[f]Cryogenic systems operate in the –100°F to –320°F range. Refrigeration systems operate in the –50°F to –150°F range. Water condensers operate in the 40°F–80°F range.
[g]Multiple compound separation and recovery can be difficult in some applications.
[h]Generally used for systems having one to three organic compounds in the gas stream.
[i]Used for control of nitric oxide (NO) and nitrogen dioxide (NO_2).
LEL: Lower Explosive Limit.

PM Control Techniques

Technique	Description	Advantages	Disadvantages	Application
Gravitational Settling	It uses gravity and reduced the velocity of the gas stream so that particles get settled down inside the chamber	Low initial cost, simple technique, continuous disposal of particles	Only large particles of size greater than 70μm can be collected	Used as a pre-cleaner in industries like food and metallurgical industries
Cyclone Separator	Uses centrifugal force to separate out particles from the gas inside the chamber	Low-pressure drop, low initial cost, continuous disposal of particles	Efficiency decreased for low particle concentration, low collection efficiency for smaller particles	Used in industries to reduce fly ash emissions, cement industries, textile industries

PM Control Techniques

Technique	Description	Advantages	Disadvantages	Application
Scrubbers / Wet Collectors	Remove particles from dirty air or gas stream by the action of liquid droplets	Applicable for high-temperature installations, can remove particles as well as gas	High maintenance cost, high power consumption for better efficiency	Used where hot gas must be cooled, waste-water treatments
Fabric filter	Blocks and collects the particles over the fabric layer and allows the air to pass through it	High collection efficiency for smaller particulates, simple construction	High maintenance and fabric replacement, block the fabric after a period of time	Used in flour mills, chalk and lime plants, foundries, brickworks, cement industries and so on

PM Control Techniques

Technique	Description	Advantages	Disadvantages	Application
Electrostatic Precipitator	Uses electrostatic force to remove the particulates of much smaller sizes from the gas stream	Highest collection efficiency, low-pressure drop, negligible treatment time, low maintenance	High initial cost, needed more space, insulation must be more	Used in paper and pulp mills, chemical industries, cement industries, steel plants, and electricity industries

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Case Study 1

Introduction

A study of Particulate Matter reduction was done in two food industry units and a detergent manufacturing unit.

Industry	Fuel	Air Pollution Control Device
Food Industry 1	Coal	Multi - Cyclone
Food Industry 2	Rice Husk	Bag Filter
Detergent Industry	Wood	--

Introduction

- ✓ Samples were drawn from the stacks of the industries
- ✓ Samples were taken from the inlet and outlet of Air Pollution Control device so as to find out the efficiency of the control device
- ✓ Samples were taken after every 1 h for 24 h/8 h, so as to take into consideration different aspects of the manufacturing process and heat load desired at that particular time

Food Industry 1

- Samples from inlet and outlet of the APCD are taken
- APCD installed is multicyclone and the fuel used is coal
- Perusal of results of the inlet and outlet samples indicates that the multicyclones are working very effectively
- Efficiency of the multicyclone is also worked out to be around 80-82%
- Reason for such a high efficiency of multicyclone installed is the fuel used
- Unburnt coal particles being heavier, the velocity of these particles is slowed down by the multicyclone and these are settled here

Food Industry 2

- The fuel used is rice husk. the control device installed by the industry is bag filters which are more effective pollution control device
- The rice-husk being light, the combustion rate is very low but this fuel is a cheaper one and hence the industry is using it keeping in view the economics
- When burnt, being light the suspended particulate matter is very high
- If the pollution control devices are not used, such a high concentration particulate matter may be emitted to environment causing damage
- Emission results obtained after APCD : bag filter are very low
- Rice husk ash contains silica, Al_2O_3, Fe_2O_3, CaO, MgO, etc. Such inorganic components in ash requires the most effective device is installed and bag filters are the best one for such emissions

Detergent Industry

- This is a small scale industry and is engaged in soaps and detergents manufacturing
- Industry is producing sodium silicate within its own premises from sand using wood as fuel
- For the formation of sodium silicate high temperature about 1100 K is needed
- Wood being highly combustible, the contents are the lowest
- Result of the suspended particulate matter (SPM) is very low, meeting the standards prescribed

Conclusion

1
- Fuel determines the type of air pollution control device needed

2
- For fuel like rice husk ash pollution, bag-filters are most suitable

3
- For fuel like coal, multicyclones are effective devices

4
- Wood being highly combustible, its combustion is complete and if used as fuel may not need any control device and the results may meet the prescribed limits

06

Case Study 2

Introduction

- Fly ash with a density of (689 Kg/m^3), Coal dust with a density of (841 Kg/m^3) and Lime stone with a density of (1914 Kg/m^3) was subjected to removal by air cyclone separator for various particle sizes and various velocities

Results

- With increase in velocity, the removal efficiency was observed to increase continuously for each particle size and various velocities
- However this increase in efficiency was found to be less significant in case of higher particles (>50μm) when compared to those lesser particles (<50μm)
- But there was a limitation in handling less particle sizes (< 20 μm)
- Higher efficiencies were observed with lime stone compared to coal dust and fly ash

Results

- It is evident due to the fact that the higher density particles have greater tendency to settle down compared to the lower ones
- Hence in the cyclone separator, higher density particles can be easily removed compared to the lower density particles.

S. No.	Range of particle size (µm) that are collected	Range of collection Efficiency (%)
1	3.34-7.01	<50
2	20-40	65-85
3	40-50	85-92
4	>50	>92

Conclusion

- If the size of the PM is more than 50µm, the collection efficiency is almost same for any sample
- With an increase in density of the sample, collection efficiency increases linearly
- For the same velocity (or for the same power consumption), highly dense particles are removed with higher collection efficiency compare to low dense particles
- At high velocities, the efficiency decreased instead of increasing due to carry over solid particles along with the exit gas.

“Earth provides enough to satisfy every man's need, but not every man's greed.”

— **Mahatma Gandhi**

Thanks!

Do you have any questions?

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