

U.S. Environmental Protection Agency

Air Pollution Training Institute

COURSE SI:422

3rd Edition

AIR POLLUTION CONTROL

ORIENTATION COURSE

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Unit 5

Control Techniques for Gaseous and Particulate Pollutants

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Air

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# **APTI**

## **Course SI:422 3rd Edition**

### **Air Pollution Control Orientation Course**

#### **Unit 5**

#### **Control Techniques for Gaseous and Particulate Pollutants**

Prepared By:  
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Office of Air Quality Planning and Standards  
Research Triangle Park, NC 27711



This is one of nine self-instructional units in the  
Air Pollution Control Orientation Course SI:422.

This unit consists of a cassette tape and this flip-  
book, which you will use simultaneously.

Turn the page and read the tips on effective use  
of this material.

## Tips for Effective Use of This Material

1. Listen to the recorded script while you go through this flipbook. The recorded portion is coordinated with the flipbook. Wait for the tape to finish the details of one point before studying the next point on the page.
2. When you hear a “beep” on the tape, direct your attention to the next page in the flipbook.
3. Pay attention to both words and pictures—they both convey important information. The flipbook will usually summarize main points or give examples.
4. Stop the tape at any point if you wish to spend more time reading a page in the flipbook. Rewind the tape if you wish to review a portion of the script.
5. Review the lesson objectives before answering the questions at the end of each lesson. Ask yourself whether you have mastered the information indicated in the objectives.
6. Answer the questions. They will help you assess your progress in mastering the course materials.
7. Check your answers. The correct responses can be found on the page(s) following the questions.
8. If you answer a question incorrectly, review the flipbook material covering the subject matter. Now Turn On the Tape Recorder and Begin Lesson I.

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# Lesson I: Control Techniques Not Requiring Control Devices

## Objectives

1. Name the two physical forms of air pollutants.
2. Identify four techniques for reducing pollutant emissions that do not require the use of emission control devices.

# Two Forms of Air Pollutants



Gaseous



Particulate

2



## Primary Gaseous Pollutants

- sulfur oxides
- acid gases
- nitrogen oxides
- odors
- carbon monoxide
- hydrocarbons

## Common Particulate Pollutants

- cement dust
- smoke
- acid mists
- metal fumes
- fly ash

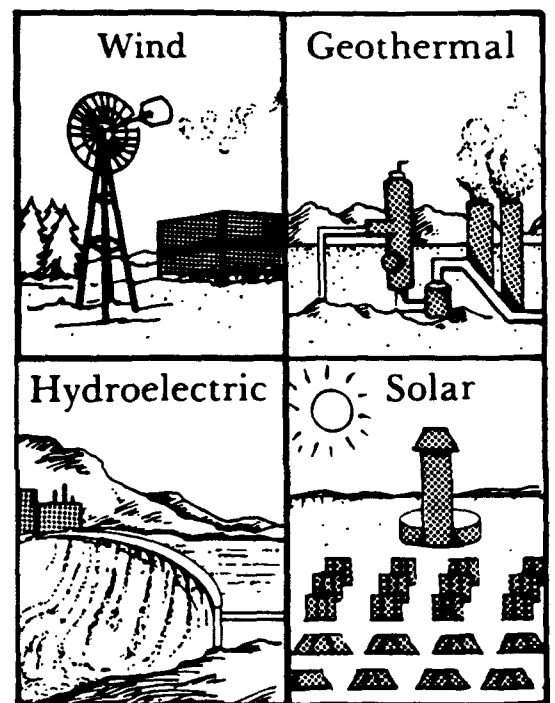
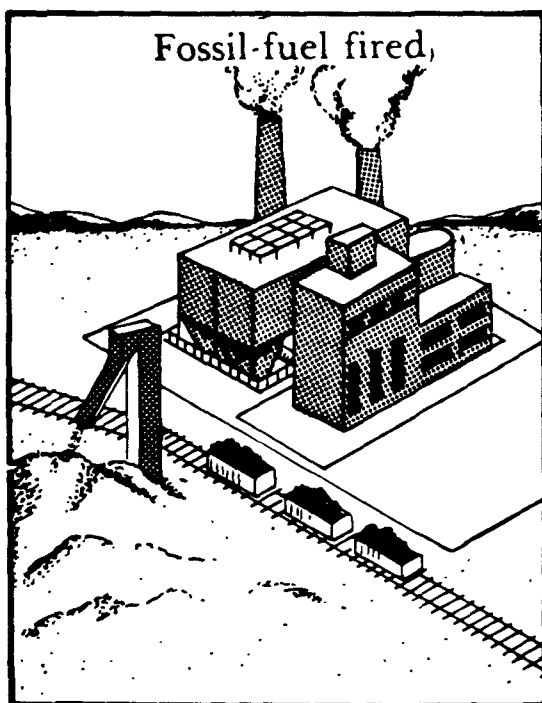
# Emission Reduction Techniques Not Using Emission Control Devices

- Process change
- Change in fuel
- Good Operating practices
  - good housekeeping
  - maintenance
- Plant shutdown

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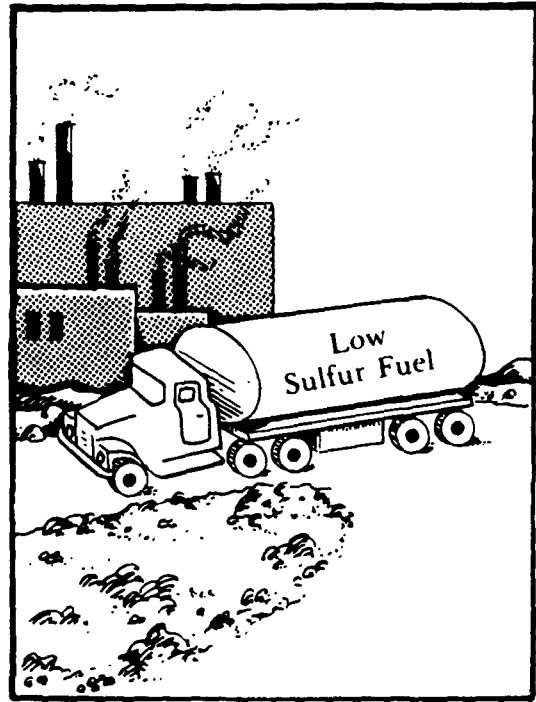
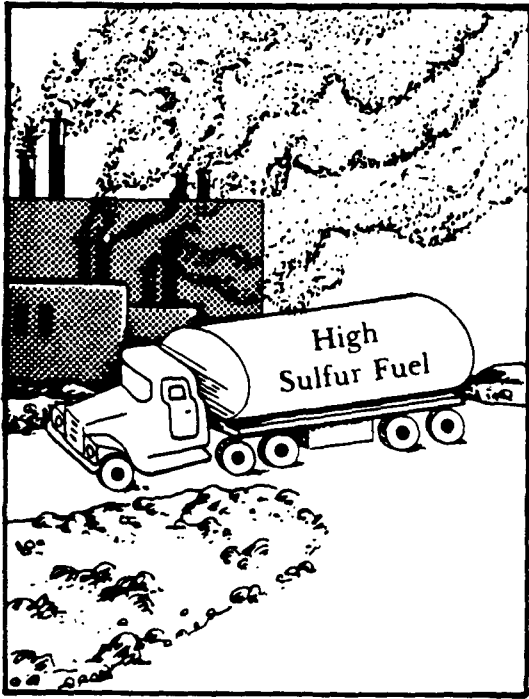


## Process Change



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# Change in Fuel

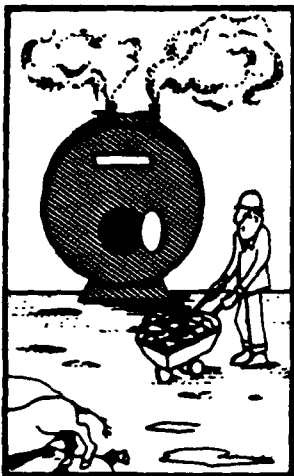


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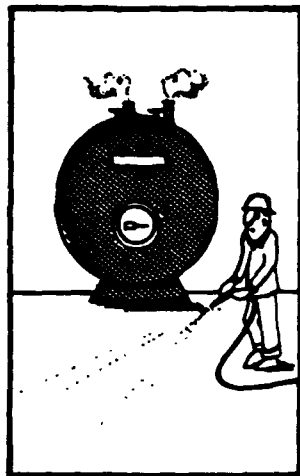


# Good Operating Practices

Bad

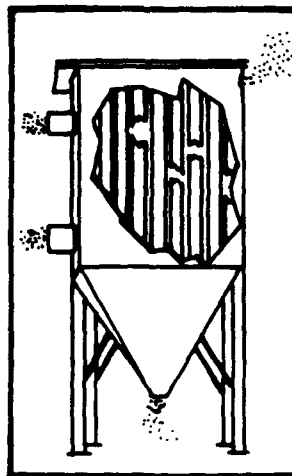


Good

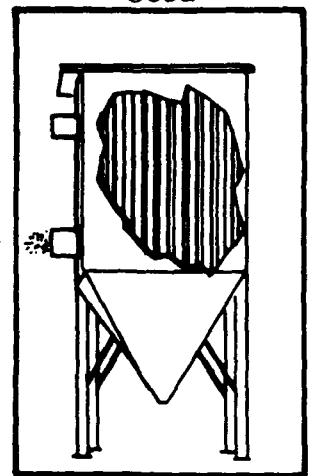


Good Housekeeping

Bad



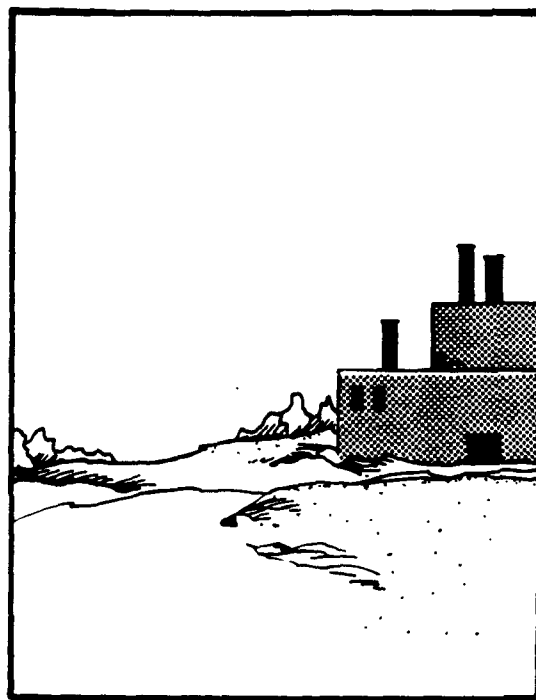
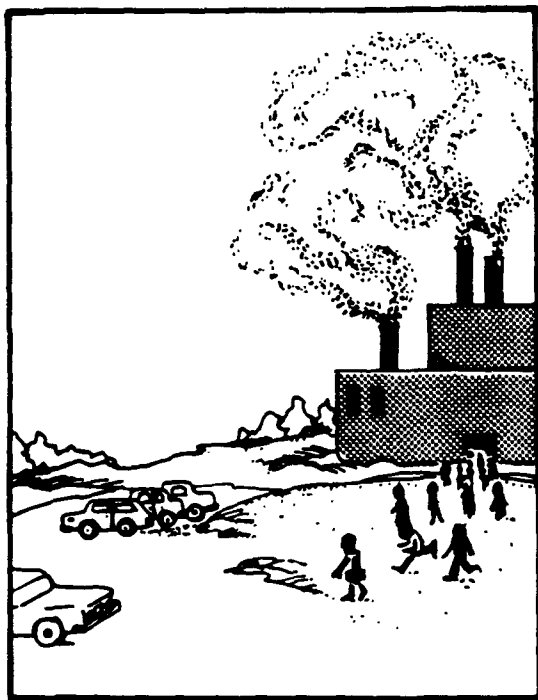
Good



Maintenance

7

# Plant Shutdown



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## National Emission Estimates 1970-1977

(Millions of metric tons/year)

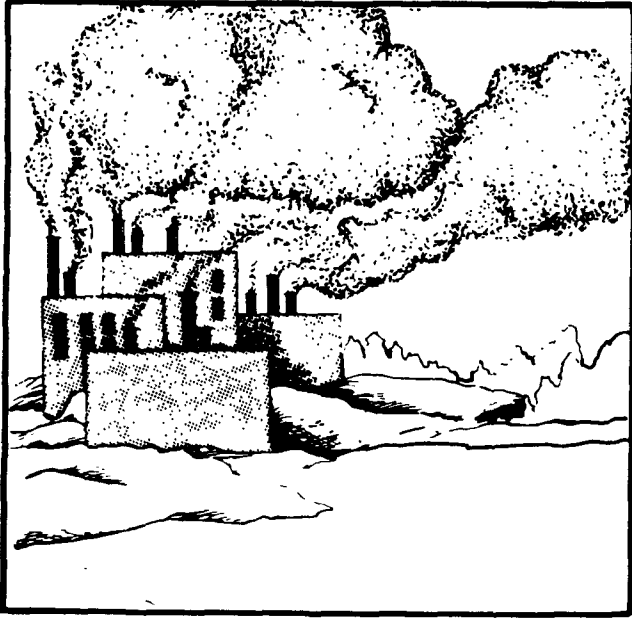
Year	TSP(a)	SO <sub>x</sub> (a)	NO <sub>x</sub> (a)	VOC(b)	CO
1970	22.2	29.8	19.6	29.5	102.2
1971	20.9	28.3	20.2	29.1	102.5
1972	19.6	29.6	21.6	29.6	103.8
1973	19.2	30.2	22.3	29.7	103.5
1974	17.0	28.4	21.7	28.6	99.7
1975	13.7	26.1	21.0	26.9	96.9
1976	13.2	27.2	22.8	28.7	102.9
1977	12.4	27.4	23.1	28.3	102.7

(a) TSP - Total Suspended Particulate matter in the case of emissions, just particulate matter

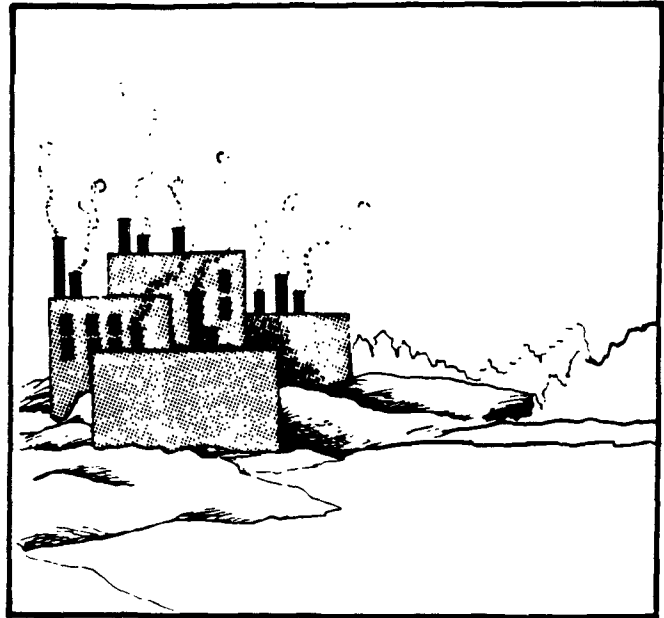
SO<sub>x</sub> - Sulfur Oxides

NO<sub>x</sub> - Oxides of Nitrogen

(b) VOC - Volatile Organic Compounds hydrocarbons etc.



Gray or black emissions from smoke stacks are easily seen by everyone



— but no one sees the gaseous emissions.

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## Lesson I Questions

1. Name the two forms of air pollutants.
2. Four of the following are methods of pollutant reduction that do not require the use of emission control devices. Which one is not?
  - a. tall chimneys
  - b. plant shutdown
  - c. good operating practices
  - d. change in fuel
  - e. process change

*Answers on next page.*



## **Lesson I Answers**

1. gaseous, particulate
2. a. tall chimneys

*After checking your responses, please turn on the tape recorder.*

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## **Lesson II: Control Techniques for Gaseous Emissions**

### **Objectives**

1. Name the four main techniques used in devices that control gaseous emissions.
2. Identify the definition of each of the following terms: absorption, adsorption, condensation, and combustion.
3. Given a diagram of a control device (as it appears in this flipbook), name the control device and tell whether it is of the adsorption, absorption, condensation, or combustion type.
4. Identify the factors that must be considered when choosing a device for the control of gaseous emissions.

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# Control Techniques for Gaseous Emissions

- Adsorption
- Absorption
- Condensation
- Combustion

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## Adsorption

The removal of a gaseous pollutant from a gas stream by allowing the pollutant molecules in the gas stream to become attached to a solid surface.

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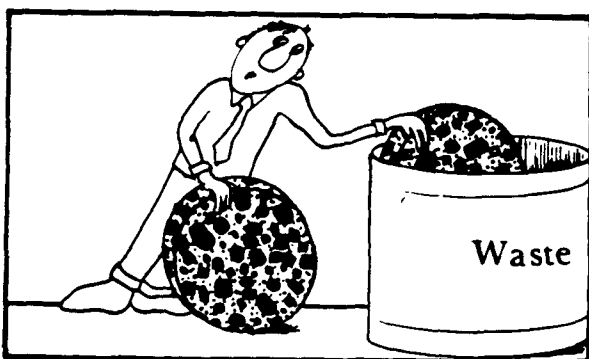
# Adsorption Design Factors

- Nature of the contaminant
- Surface area of adsorbent
- Temperature and pressure
- Nature of adsorbent

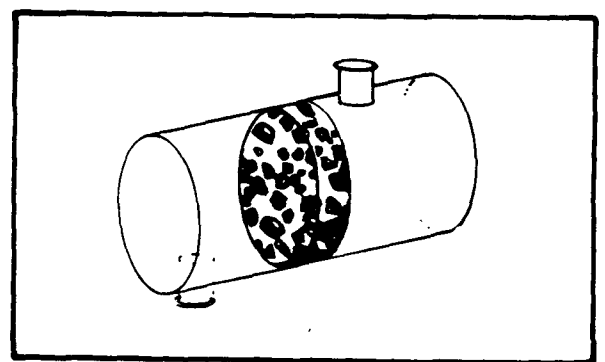
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## How do we dispose of adsorbents?



Dispose of both the pollutant and the adsorbent together



Remove the pollutant from the solid surface and re-use adsorbent bed (regeneration)

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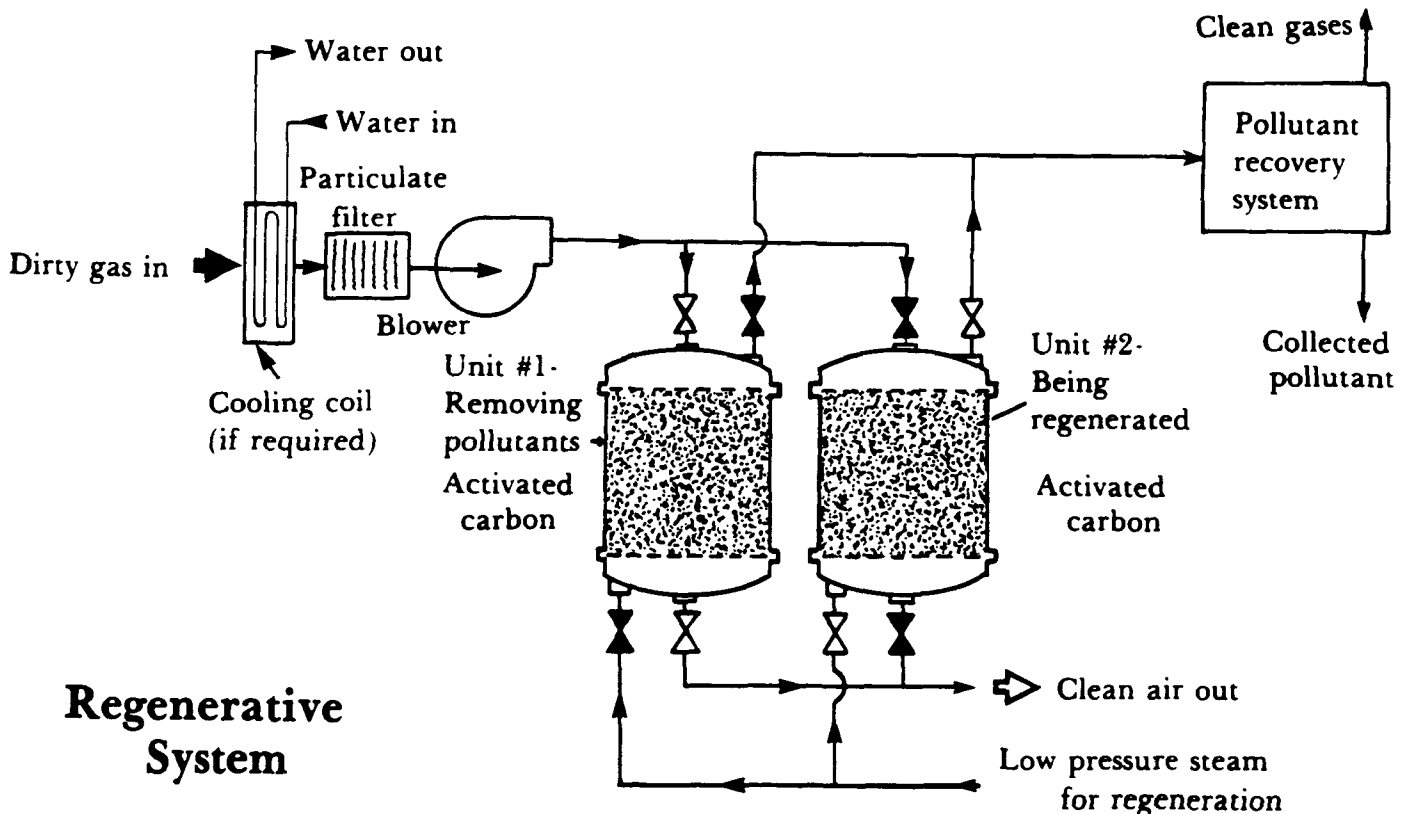
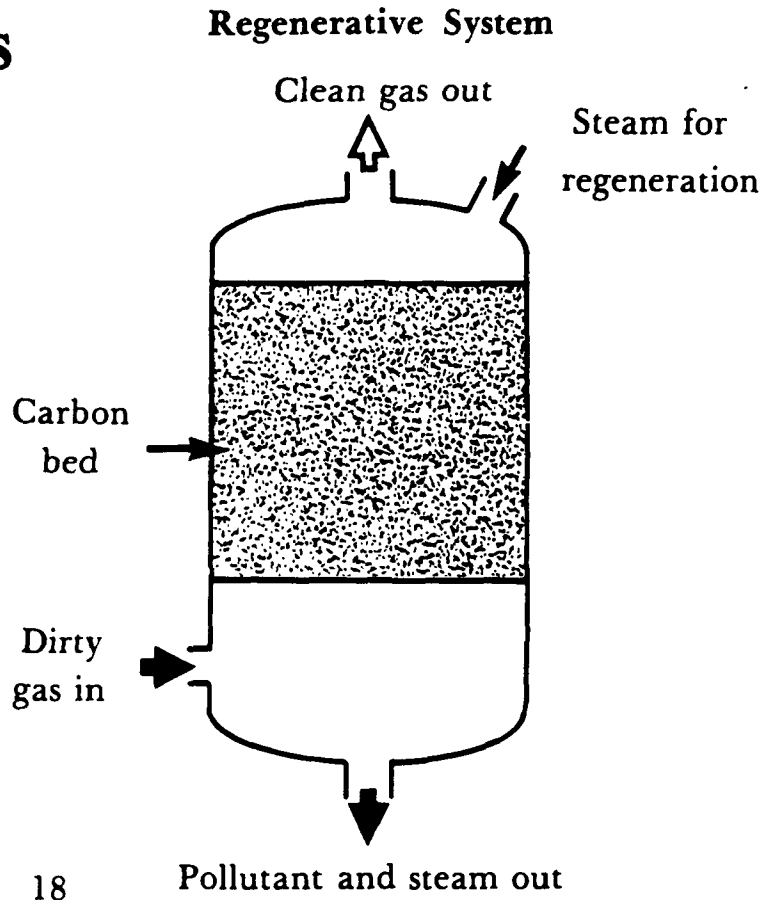
# Adsorption Systems

## Nonregenerative

- Have thin beds
- Commonly used where there are low concentrations of pollutants in a gas stream

## Regenerative

- Have thick beds
- Used for solvent or hydrocarbon recovery



# Absorption

The dissolving of a gaseous pollutant in a liquid solvent

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## Factors Affecting Absorption

- Type of pollutant
- Type of solvent
- Temperature of system
- Pressure on system

With absorption equipment we try to get as much gas-liquid mixing as possible.

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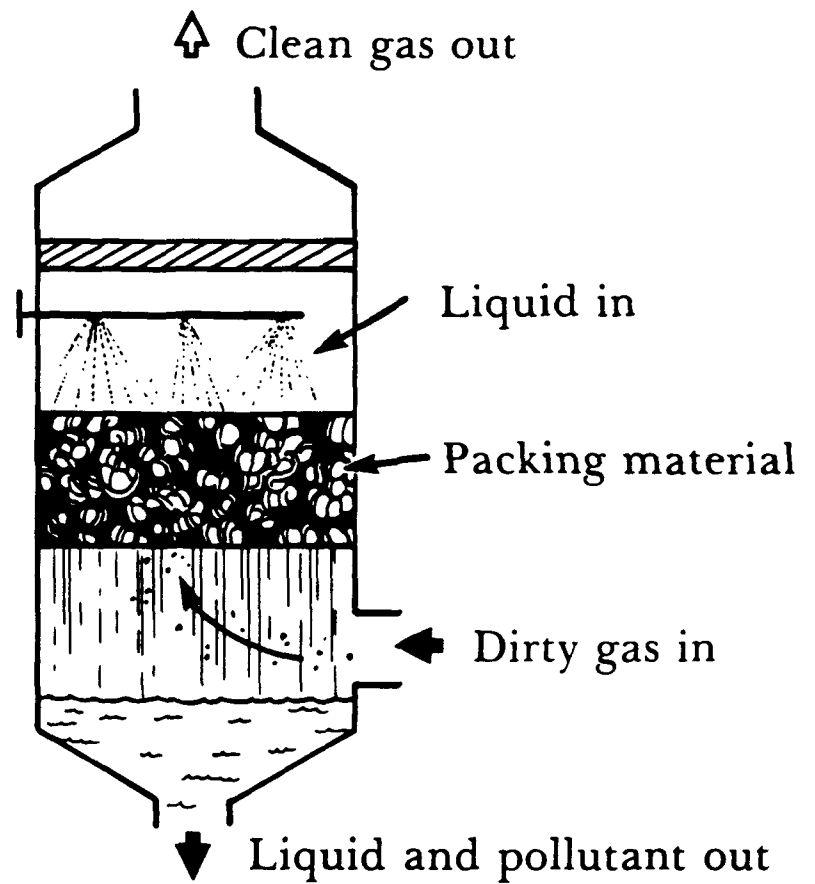


## Absorption Equipment

- Spray tower
- Spray-chamber
- Venturi scrubber
- Packed column

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# Packed Column



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**Condensation occurs when:**

- Pressure increased
- Heat extracted from a system (the most economical method is temperature reduction)

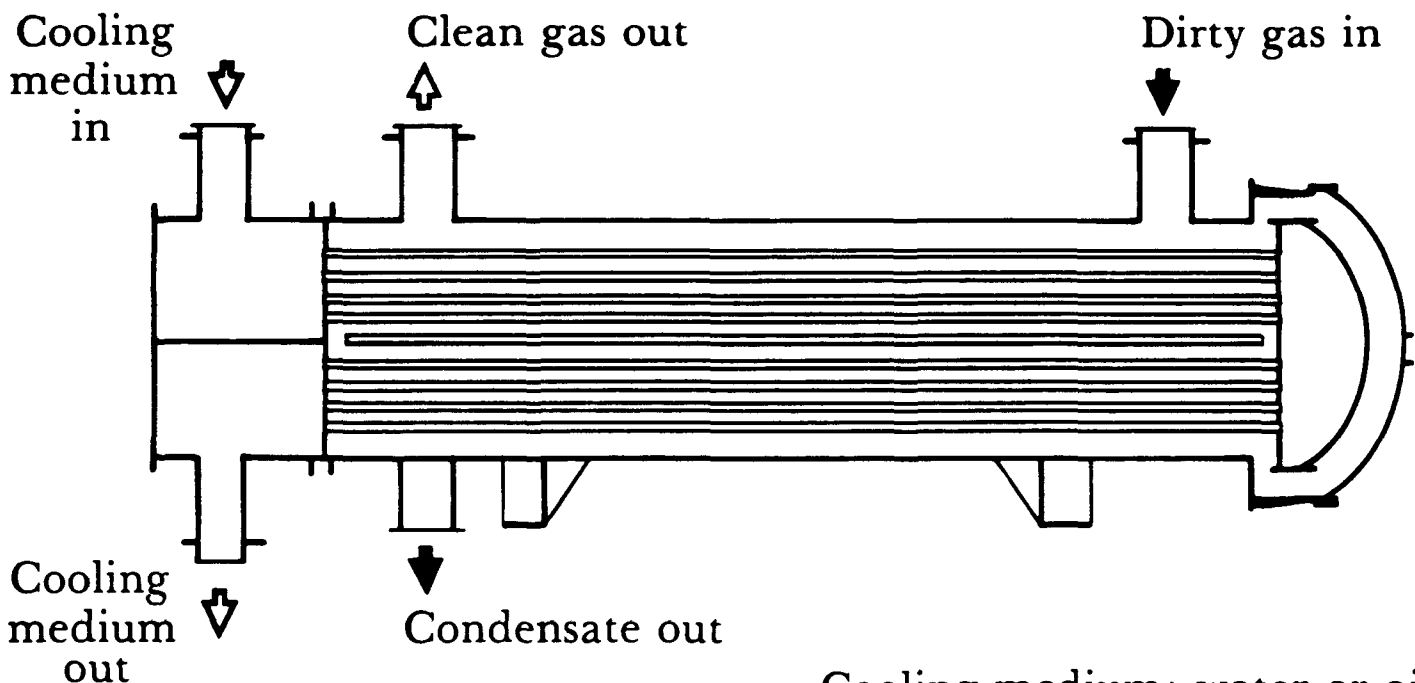
# Condensers are usually used in conjunction with:

- afterburners
- absorbers
- adsorption units

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## Surface Condenser (Temperature Reduction)

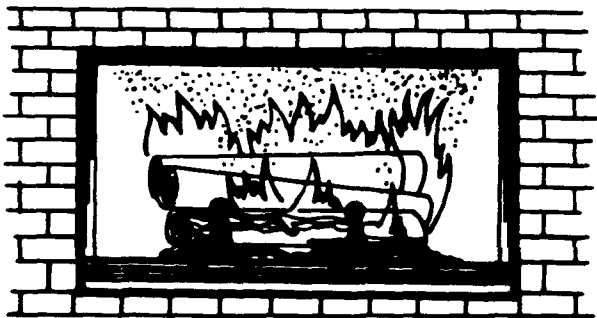
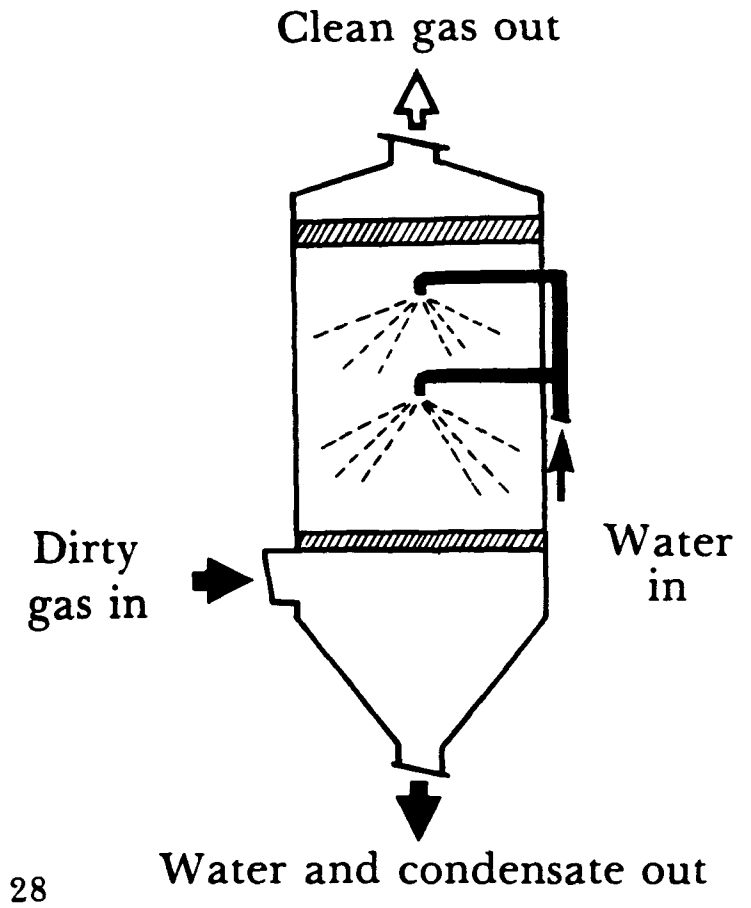


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Cooling medium: water or air



# Contact Condenser (Temperature Reduction)



# Combustion

The result of the combination of oxygen with a combustible material, usually accompanied by heat and light

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Combustion is commonly used as a control technique for hydrocarbon emissions.

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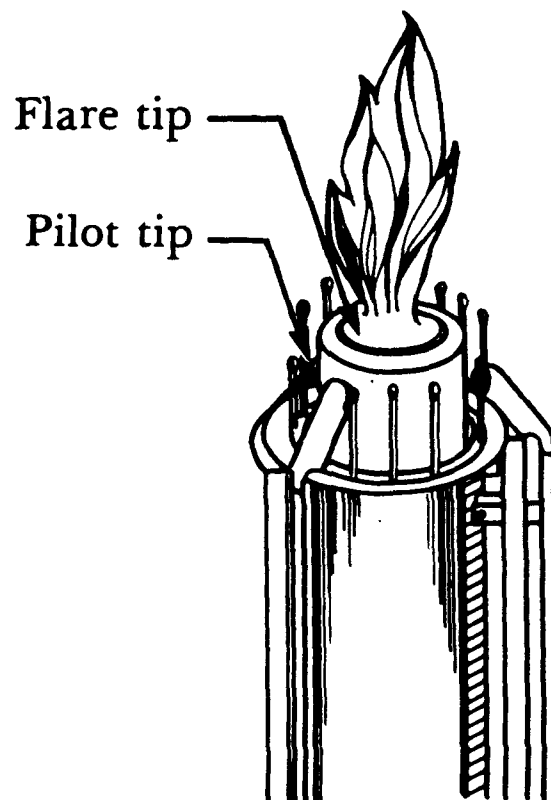


## Combustion Equipment

- Flare
- Thermal incinerator
- Catalytic incinerator

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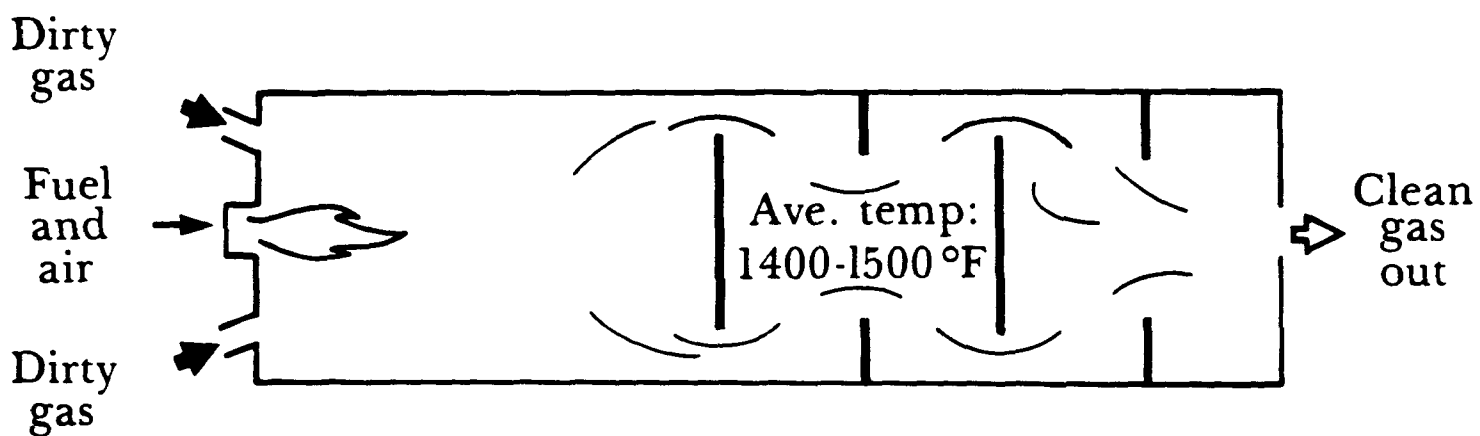
# Flare



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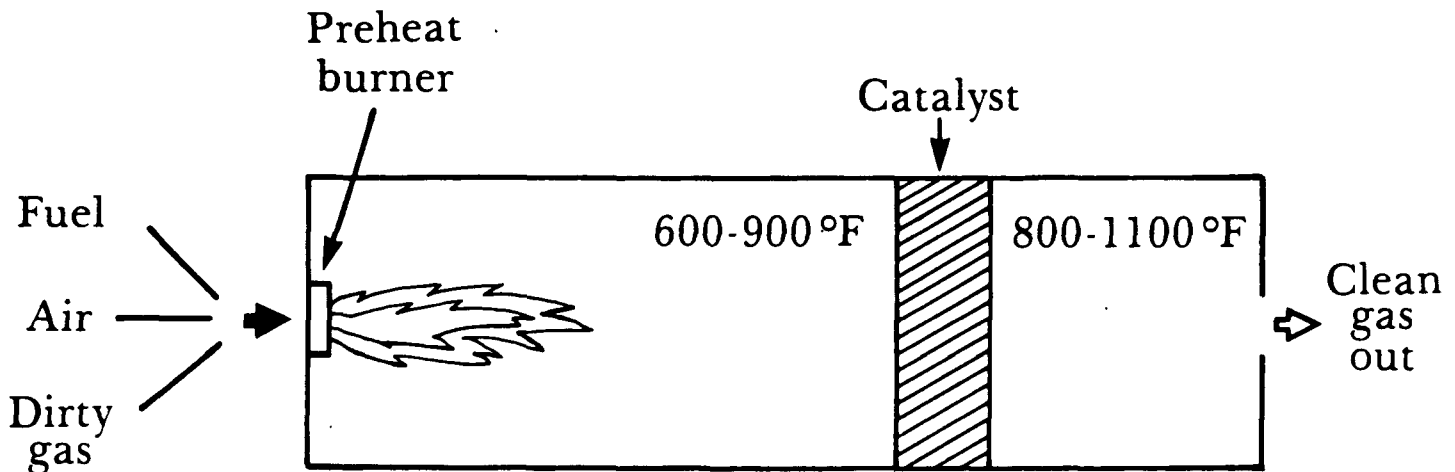


# Thermal Incinerator (Afterburner)



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# Catalytic Incinerator



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## Choice of Control Technique

Some questions to consider:

1. Will the pollutant burn?
2. Is the product of combustion a pollutant?
3. Is the pollutant soluble in water or another solvent?
4. Can the pollutant be easily condensed?
5. Is carbon adsorption applicable?
6. What is the age of the plant?
7. Is re-use of pollutant desirable?
8. What is the impact of control cost on selling price of the product?
9. What are equipment costs?
10. What are utility requirements?

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## Lesson II Questions

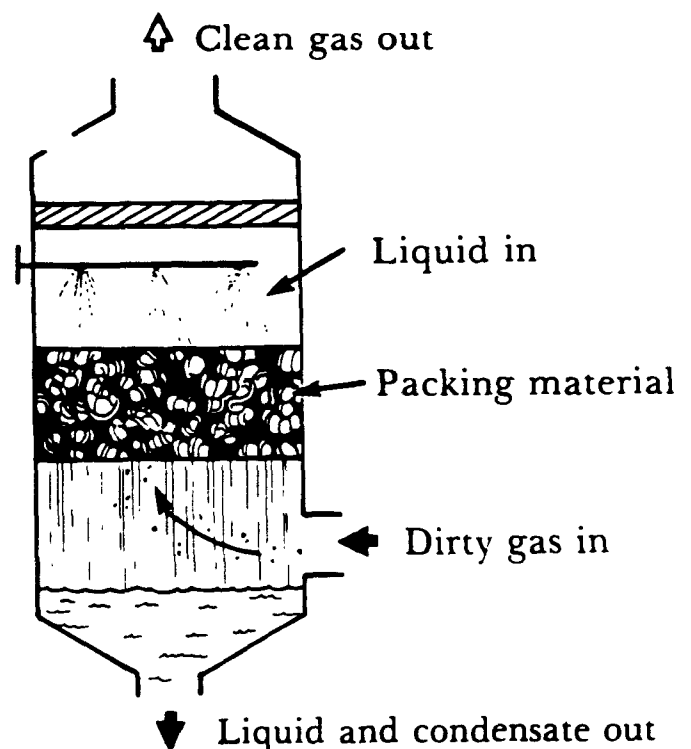
1. Name the four main techniques used in devices that control gaseous emissions.
2. The phrase, "the removal of a gaseous pollutant from a gas stream by allowing the pollutant molecules to become attached to a solid surface" defines which of the following terms?
  - a. condensation
  - b. absorption
  - c. combustion
  - d. adsorption
  - e. evaporation
  - f. none of the above

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3. The diagram at the right depicts which of the following type of control device?

- a. adsorption
- b. absorption
- c. combustion



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4. The device depicted in question No. 3 is a:
- a. flare.
  - b. surface condenser.
  - c. catalytic incinerator.
  - d. regeneration adsorber.
  - e. contact condenser.
  - f. packed column.

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5. Which of the following is not a factor to consider when choosing a device for the control of gaseous emissions?
- a. color of the pollutant
  - b. equipment costs
  - c. whether or not the pollutant will burn
  - d. age of the plant
  - e. whether or not the pollutant can be reused
  - f. solubility of the pollutant

*Answers on next page.*

## Lesson II Answers

1. adsorption, absorption, condensation, and combustion
2. d. adsorption
3. b. absorption
4. f. packed column
5. a. color of the pollutant

*After checking your responses, please turn on the tape recorder.*

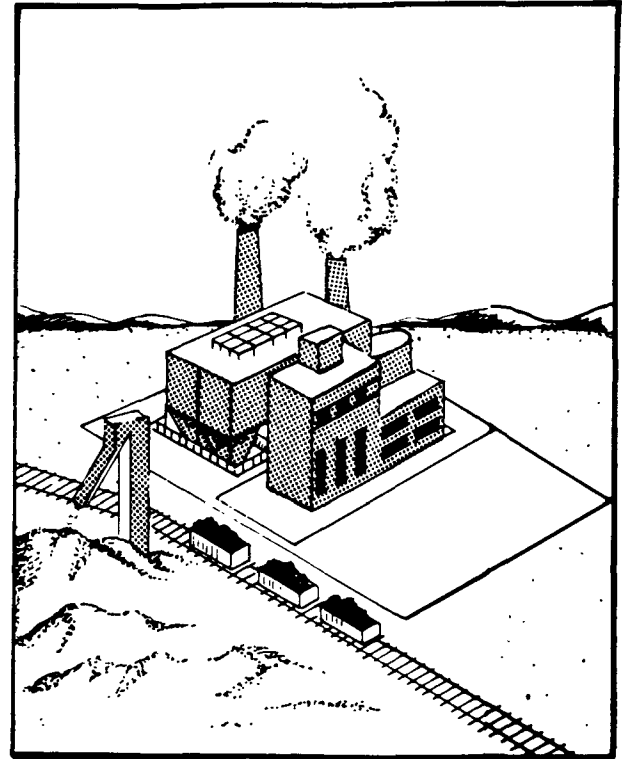
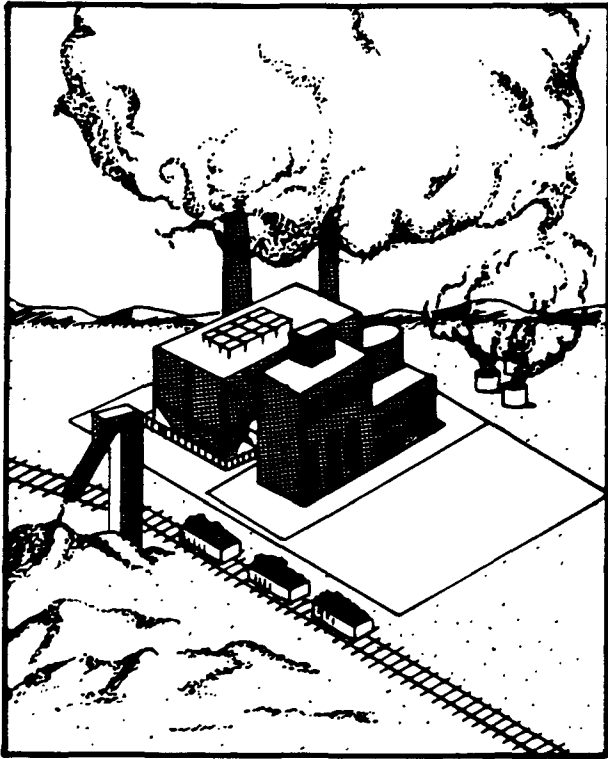
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## Lesson III: Control Techniques for Particulate Emissions

### Objectives

1. Name the 4 types of particulate matter.
2. Categorize each of the 4 types of particulate matter as either solid or liquid.
3. Identify the factors that must be considered before choosing a particulate control device.
4. Name the 5 main types of particulate control devices.
5. Given a diagram or picture of a control device (as it appears in this flipbook), name the control device.
6. Describe, briefly, the ideal solution to the problem of collected particulate matter disposal.



## Common Terms Used to Describe Particulate Matter

### Solid

- Dust
- Smoke
- Fumes

### Liquid

- Mist



# Information Needed About Gases and Particles

- Particle size
- Gas flow rate
- Temperature
- Moisture content
- Type and concentration of particles in gas stream
- Significant characteristics of particles — abrasive, explosive, flammable, acidic, etc.

## Degree of Control Desired (i.e. efficiency)

$$\text{Efficiency} = \frac{\text{weight of particles entering} - \text{weight of particles leaving}}{\text{total weight entering control equipment}}$$

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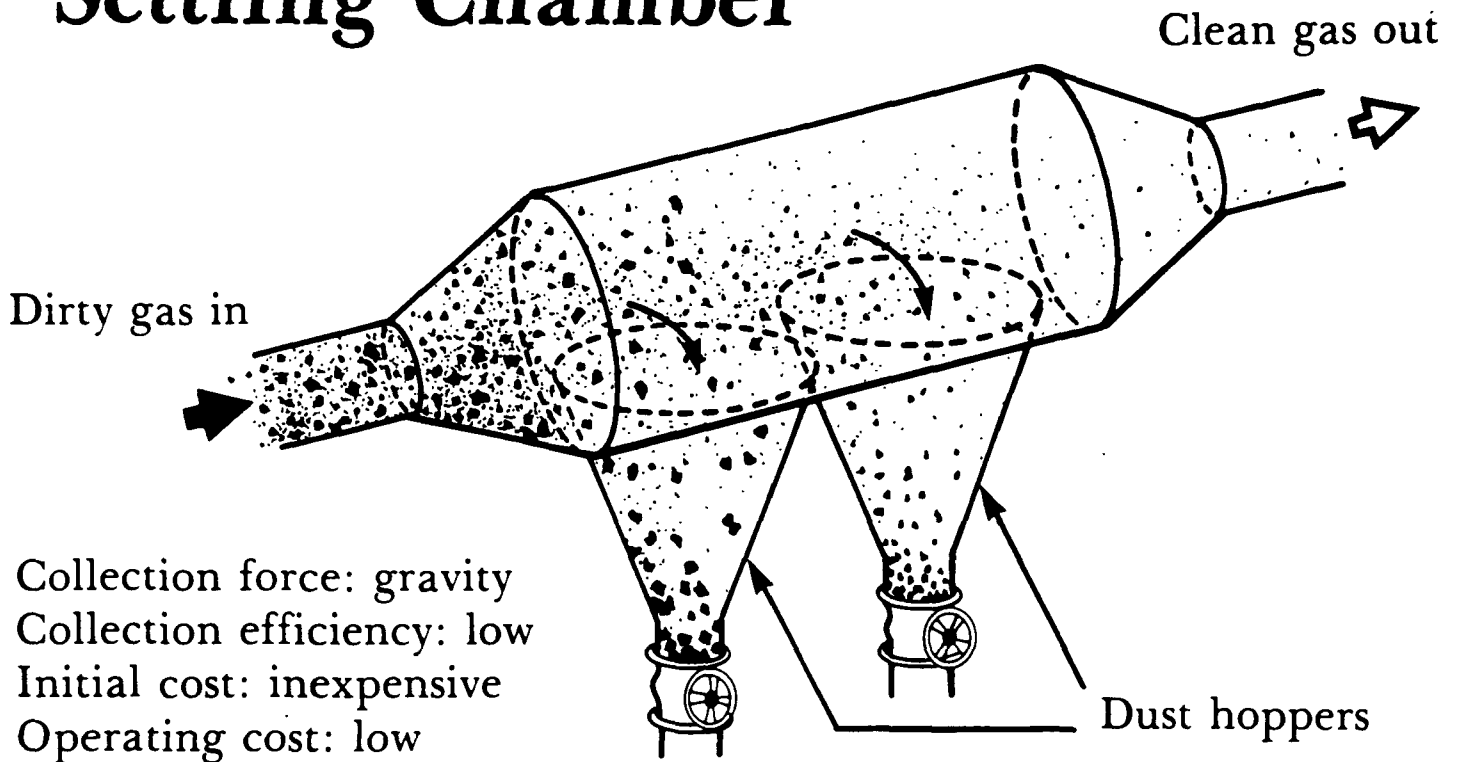


## Particulate Control Devices

- Settling chamber
- Cyclone
- Wet collector (scrubber)
- Electrostatic precipitator
- Fabric filter (baghouse)

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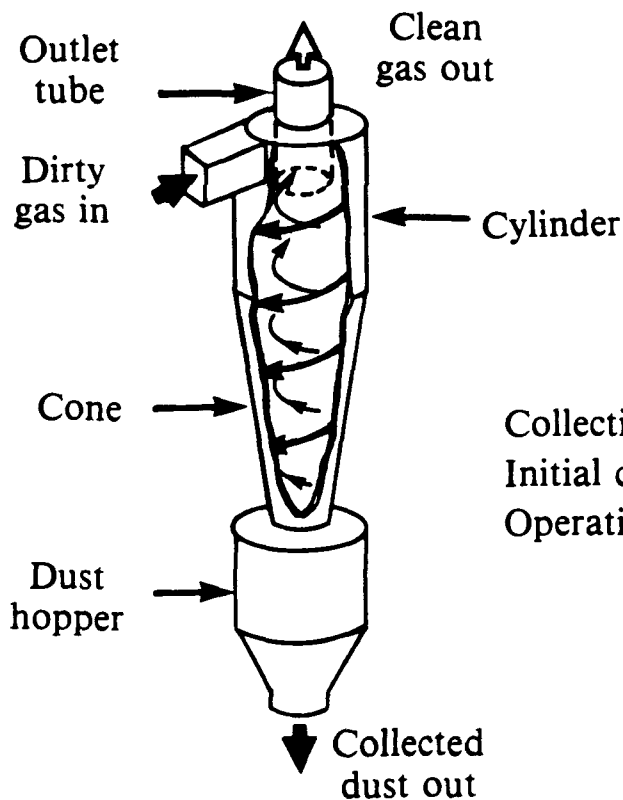
# Settling Chamber



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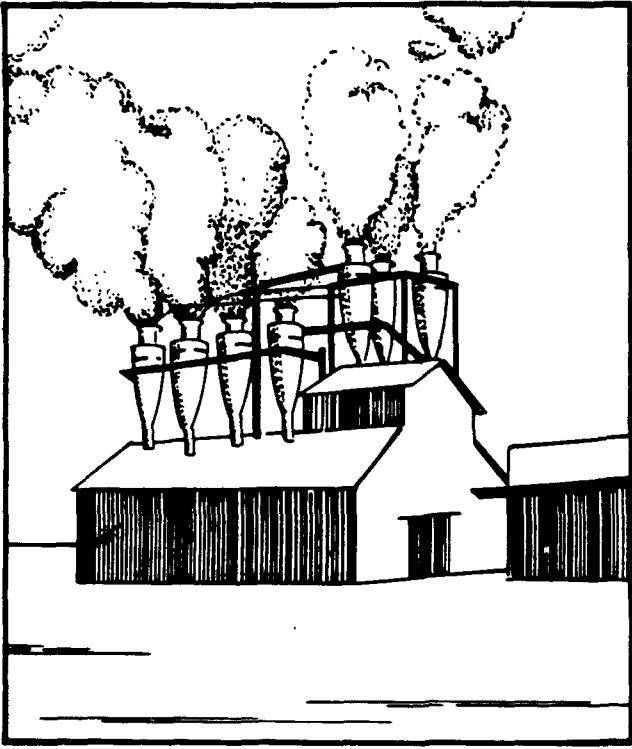


# Cyclone

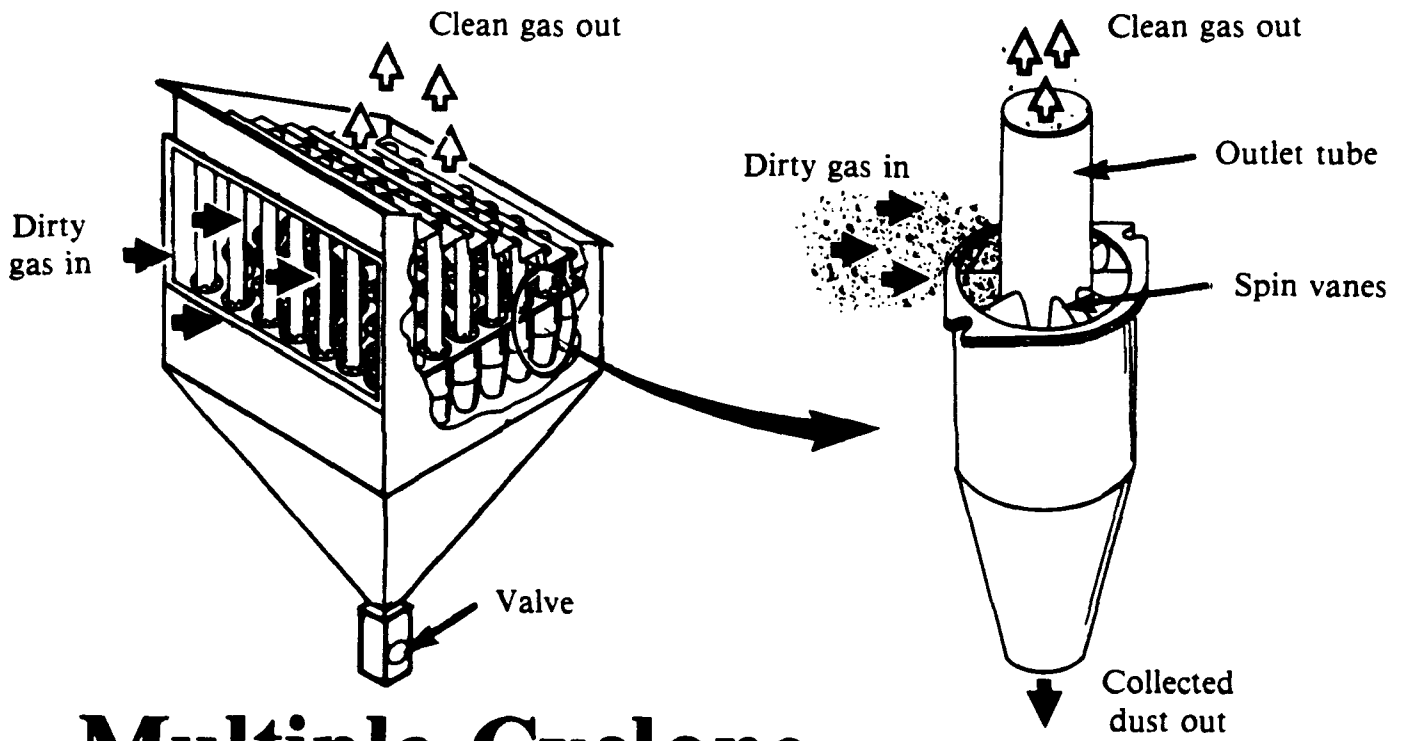


Collection efficiency: low to medium  
 Initial cost: inexpensive  
 Operating cost: low

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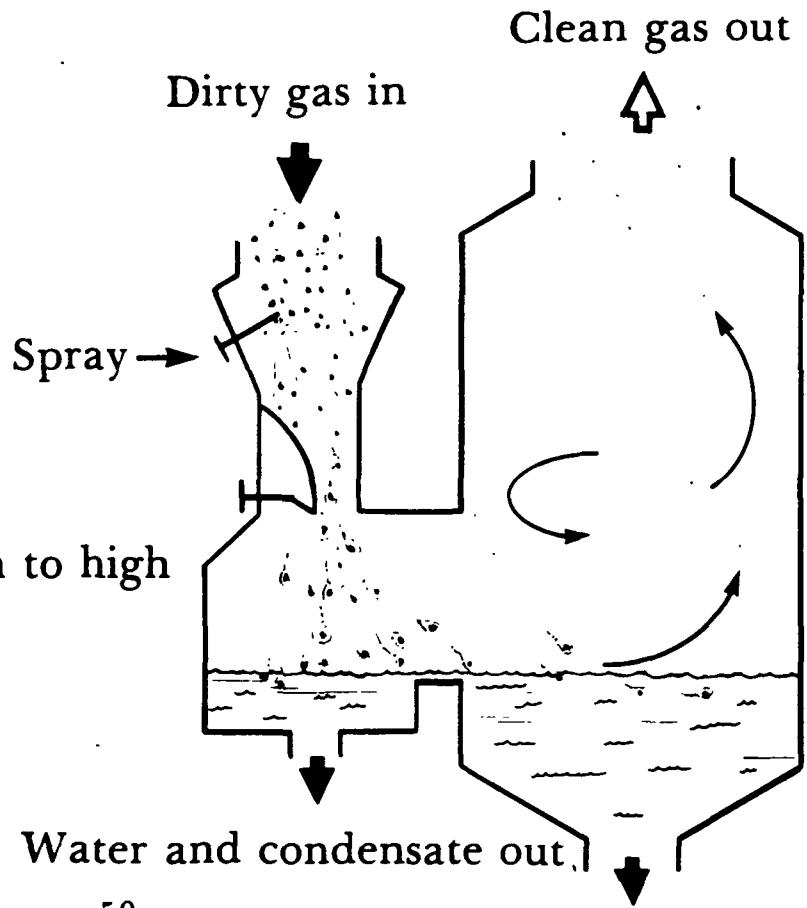
Several small cyclones are used together to increase collection efficiency.



# Multiple Cyclone

# Wet Collector (Scrubber)

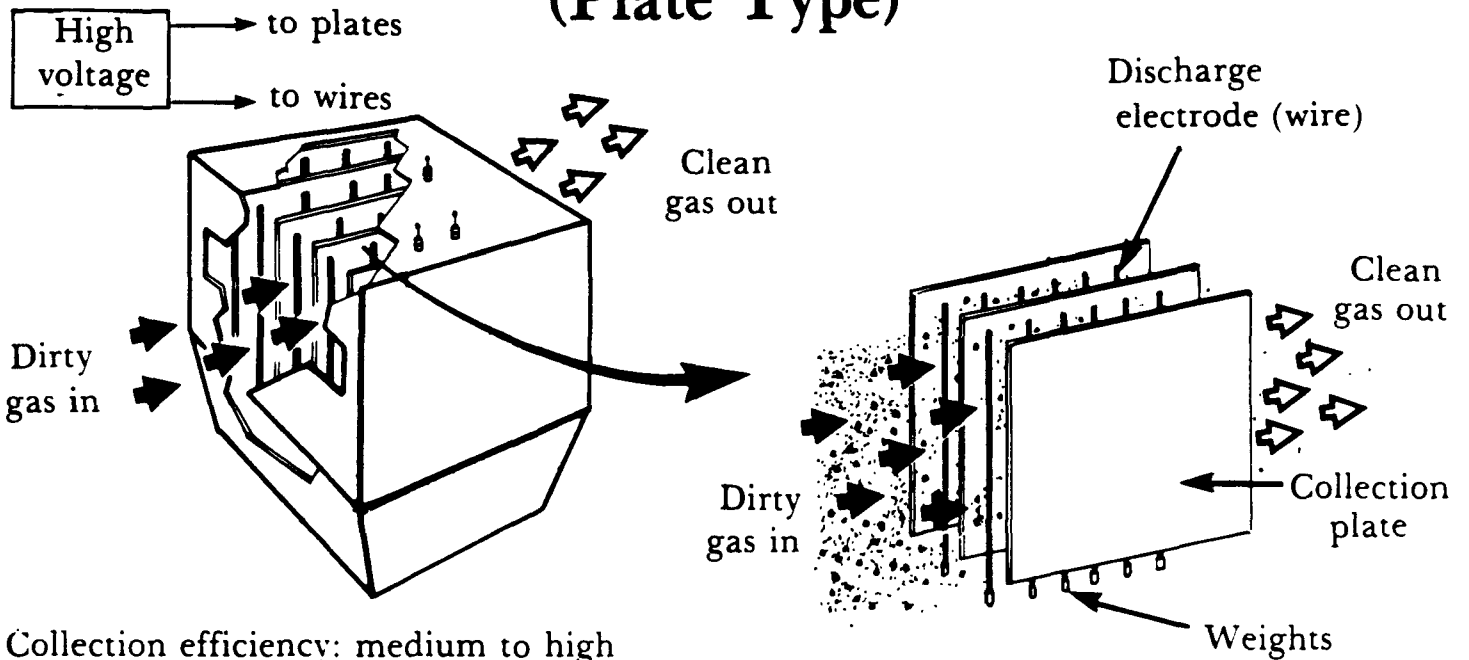
Collection efficiency: medium to high  
 Initial cost: moderate  
 Operating cost: high



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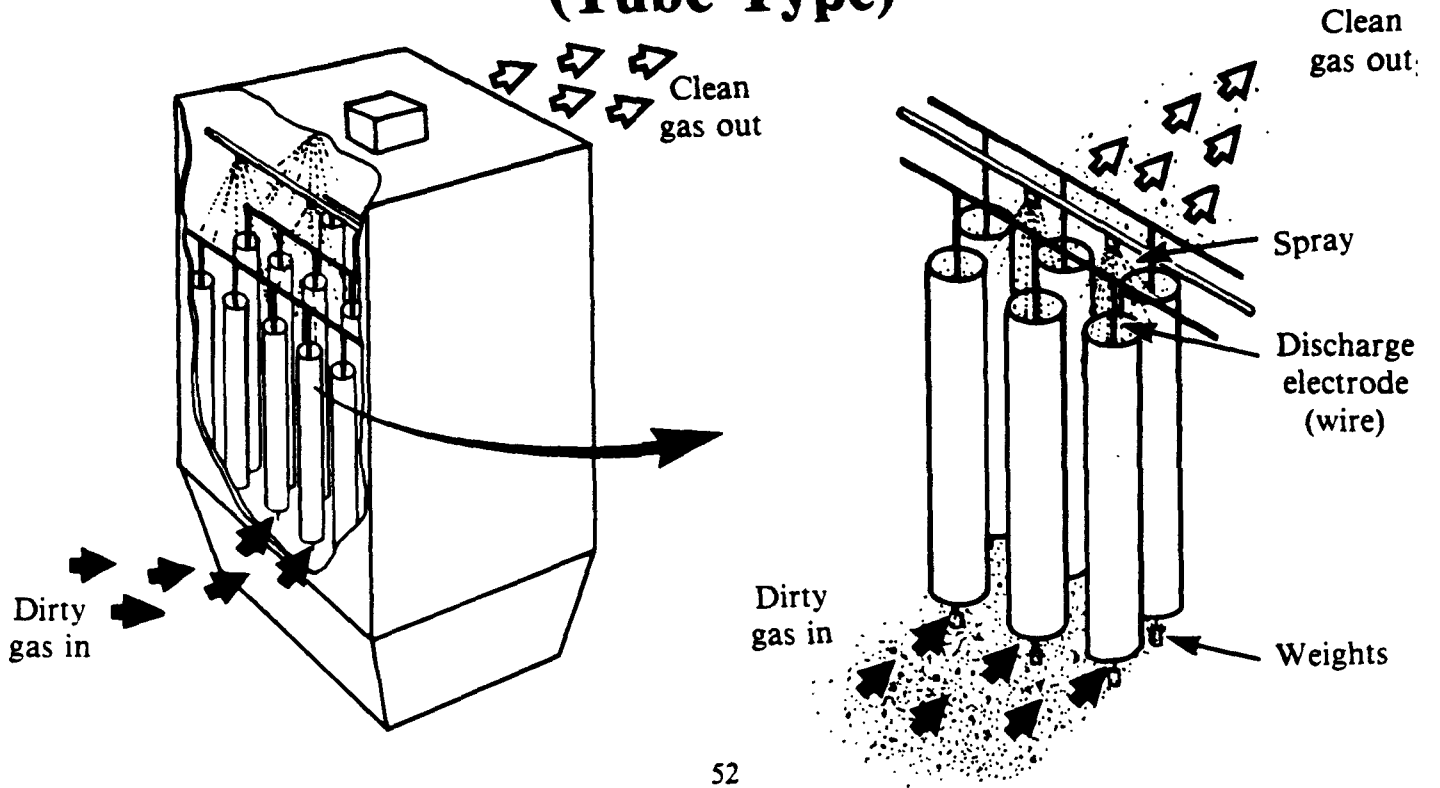
# Electrostatic Precipitator (Plate Type)



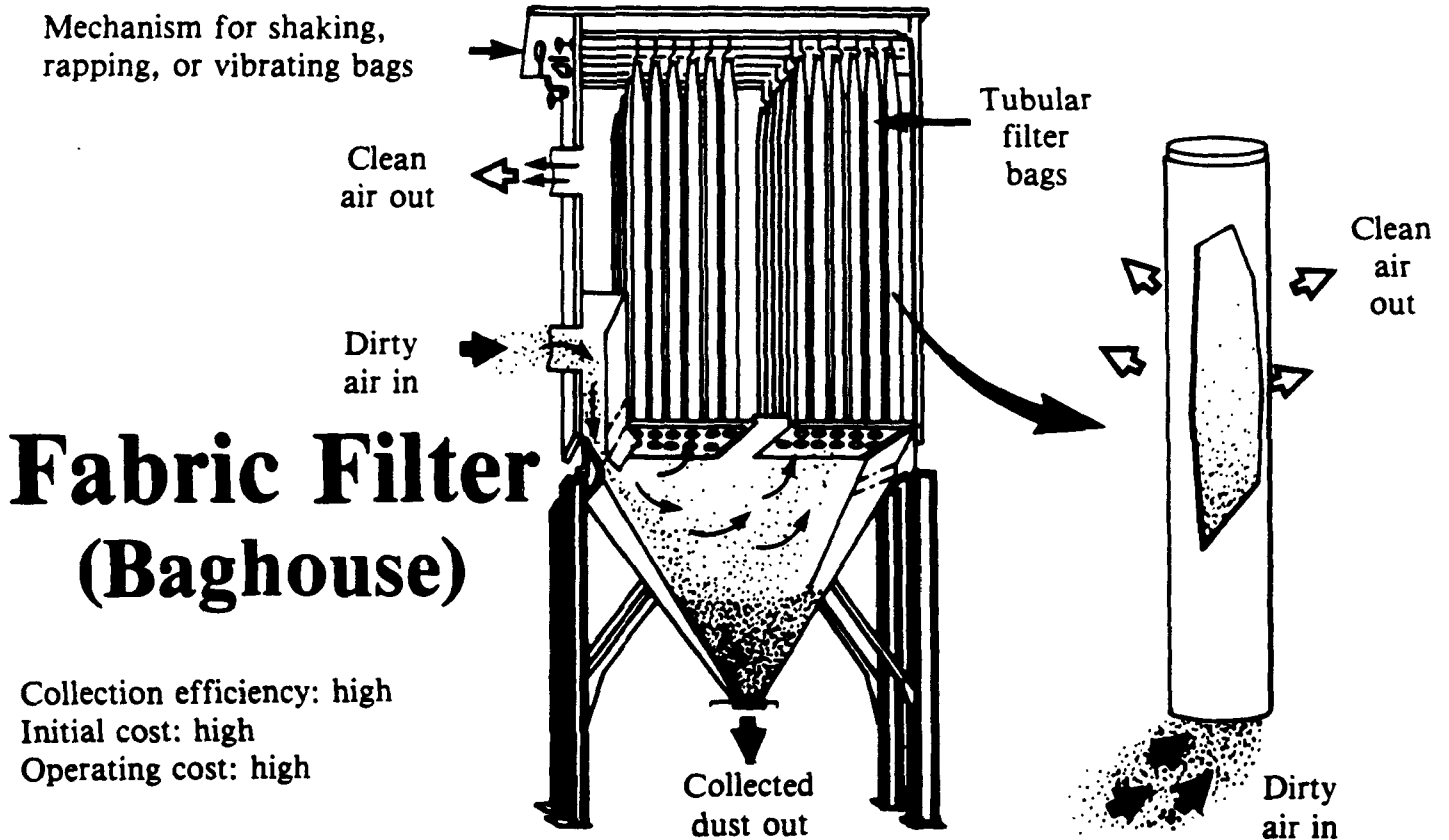
Collection efficiency: medium to high  
 Initial cost: high  
 Operating cost: moderate to high

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# Electrostatic Precipitator (Tube Type)



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# Fabric Filter (Baghouse)

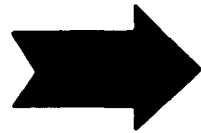
Collection efficiency: high  
Initial cost: high  
Operating cost: high

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Particulate control systems often require two or more control devices to obtain the highest possible efficiency.

For example,

Cyclone  
to collect large  
particles



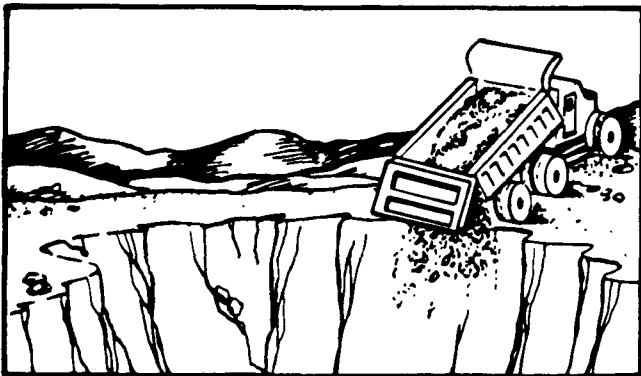
Electrostatic  
Precipitator  
to collect  
remaining  
small particles

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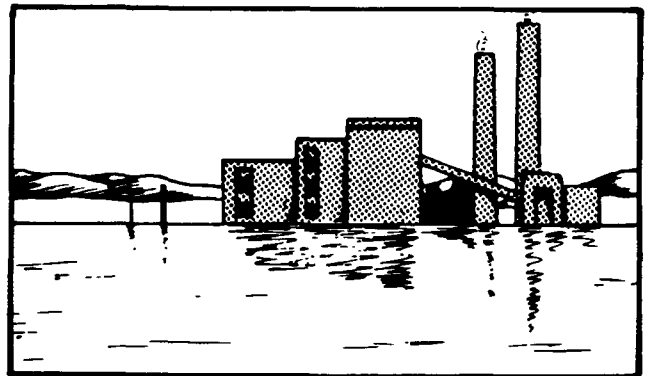


## Disposal of Collected Material

Most dry particulate material will be disposed of in land-fills or dumps.



Water slurries go to basins or sewers or treatment plants.



The ideal solution is to recycle the collected material.

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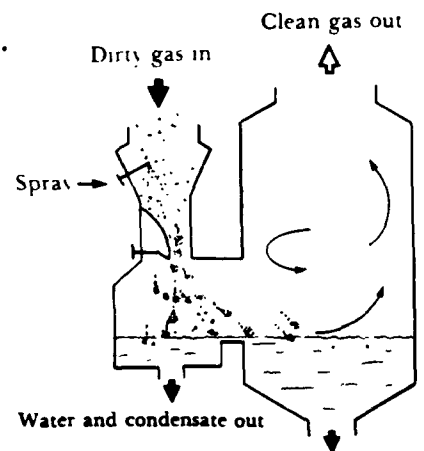
## Lesson III Questions

1. Name at least four common kinds of particulate matter.
2. Which of the following is (are) liquid particle(s)?
  - a. dust
  - b. mist
  - c. fumes
  - d. smoke
3. Which of the following should be considered before choosing a particulate control device?
  - a. moisture content of stack gas
  - b. gas flow rate
  - c. characteristics of particles
  - d. type & concentration of particles
  - e. temperature
  - f. all of the above

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4. Name the five main types of particulate control devices.
5. The control device depicted at the right is a(n):
  - a. settling chamber.
  - b. cyclone.
  - c. wet collector.
  - d. electrostatic precipitator.
  - e. fabric filter.
  - f. none of the above.
6. Describe briefly the ideal solution to the problem of collected particulate matter disposal.



*Answers on next page.*

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## Lesson III

### Answers

1. dust, smoke, fumes, mist
2. b. mist
3. f. all of the above
4. settling chamber  
cyclone  
wet collector (or scrubber)  
electrostatic precipitator  
fabric filter (or baghouse)
5. c. wet collector (or scrubber)
6. The recycling of the collected material

*After checking your responses, review any material that you are not sure of, and then take the Unit Test which begins on the next page.*

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### Unit Test

1. The two physical forms of air pollutants are:
  - a. liquid and particulate.
  - b. liquid and gaseous.
  - c. gaseous and particulate.
  - d. gaseous and vaporous.
  - e. none of the above.
2. Which of the following is not a method for reducing pollutant emissions?
  - a. tall chimneys
  - b. plant shutdown
  - c. change in fuel
  - d. process change
  - e. good operating practices

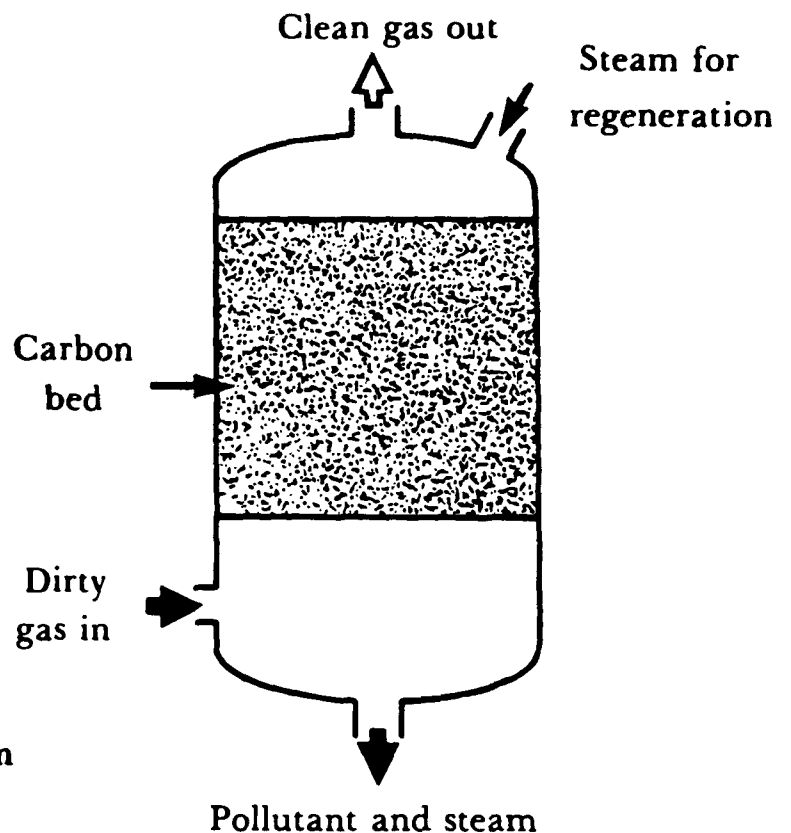


3. Which of the following is *not* a technique used in devices that control *gaseous* emissions?
- a. adsorption
  - b. condensation
  - c. absorption
  - d. combustion
  - e. electrostatic precipitation
4. The phrase “the dissolving of a gaseous pollutant in a liquid solvent” defines which of the following terms?
- a. adsorption
  - b. absorption
  - c. condensation
  - d. combustion
  - e. none of the above

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5. The diagram at the right depicts which of the following types of control device?
- a. adsorption
  - b. absorption
  - c. combustion
  - d. condensation
  - e. electrostatic precipitation



**Regenerative System**

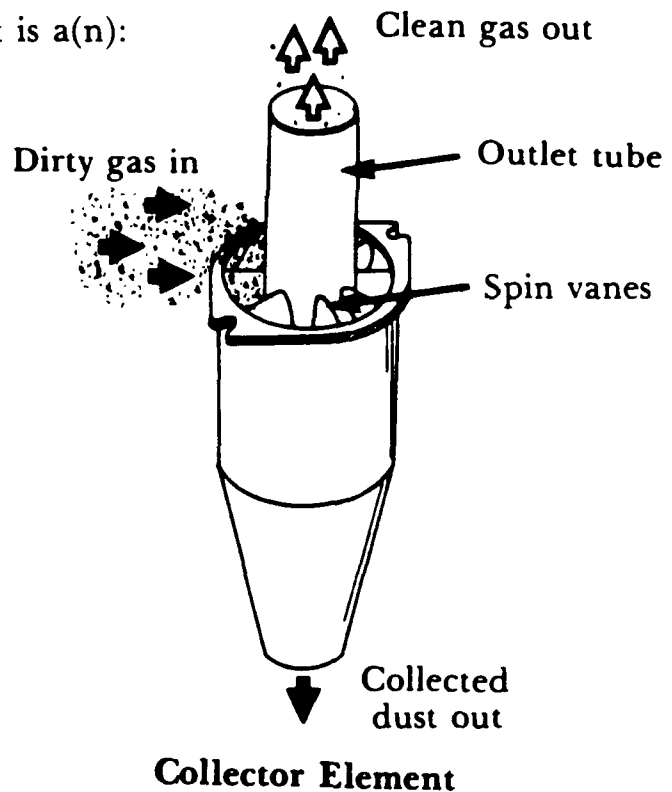
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6. Which of the following must be considered when choosing a device for the control of gaseous emissions?
- a. equipment costs
  - b. whether or not the pollutant will burn
  - c. age of the plant
  - d. whether or not the pollutant can be reused
  - e. solubility of the pollutant
7. Which of the following is *not* a common kind of particulate matter?
- a. mist
  - b. dust
  - c. smoke
  - d. vapor
  - e. fumes
8. Which of the following should be considered before choosing a device to control particulate pollutants?
- a. moisture content of stack gas
  - b. gas flow rate
  - c. characteristics of particles
  - d. type and concentration of particles
  - e. temperature
  - f. all of the above

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9. The control device depicted at the right is a(n):
- a. settling chamber.
  - b. cyclone.
  - c. wet collector.
  - d. electrostatic precipitator.
  - e. fabric filter.



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10. Describe briefly the ideal solution to the problem of collected particulate matter disposal.

*Answers on next page.*

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## Answers

1. c. gaseous and particulate
2. a. tall chimneys
3. e. electrostatic precipitation
4. b. absorption
5. a. adsorption
6. a-e. equipment costs, whether or not the pollutant will burn, age of the plant, whether or not the pollutant can be reused, and solubility of the pollutant.
7. d. vapor
8. f. all of the above
9. b. cyclone
10. The recycling of the collected material.

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