Visible Emissions Training and Certification Program

Initial Classroom Session

Program Outline

I. History of Opacity
   a. Background
   b. Principles of Opacity
   c. Theory of Opacity
II. Visible Emissions
   a. Types of Emissions
   b. Size and Common Origins
   c. Particle Size & Wavelength of Light
III. Combustion & Fuels
   a. Needs of the Combustion Process
   b. Types of Fuels
IV. Control Equipment
V. Types of Plumes
VI. Meteorology
VII. Preparing to Read Stationary Sources
   a. Distance
   b. Sun Angle
   c. Multiple Stacks
   d. Military Time (24-hour clock)
VIII. Method 9 and More
IX. Legal Considerations
X. What Makes You An Expert?

I. History of Opacity

1. Maximilian Ringelmann - early 1800's
   - coal-fired boilers - system to gauge efficiency of burn
   - devised grids to be read at 50 feet to compare to color of smoke (grey or black) **but not WHITE smoke**.
2. 1910 - Ringelmann test adopted by municipalities for nuisance smoke levels
3. 1914-1940's - courts began using police power of states to enforce nuisance smoke levels.
4. 1948 - US Surgeon General "smoke and other air pollutants are not only a nuisance, but a health hazard"
5. 1950-60's - LA added "EQUIVALENT OPACITY" (white smoke is equivalent to a Ringelmann number in its ability to obscure the view of the background) by expanding Ringlemann test to white and other colors.

6. Set Up new "Opacity System" that will allow us to perceive a target through a plume that is equivalent to Ringelmann's 0 - 20 - 40 – 60 - 80 - 100% Most are written like this today
   a. Takes out the concept of Color
   b. Read Opacity in terms of Percentages - White, Black, Colored

OPACITY - the degree to which transmitted light is obscured.

"The ability to perceive the Opacity of a Plume depends on the Emissions being of such a condition that we can see THROUGH them to a Target."

Example: "20% Opacity" means that vision is obscured through the plume by 20%.

II. Visible Emissions

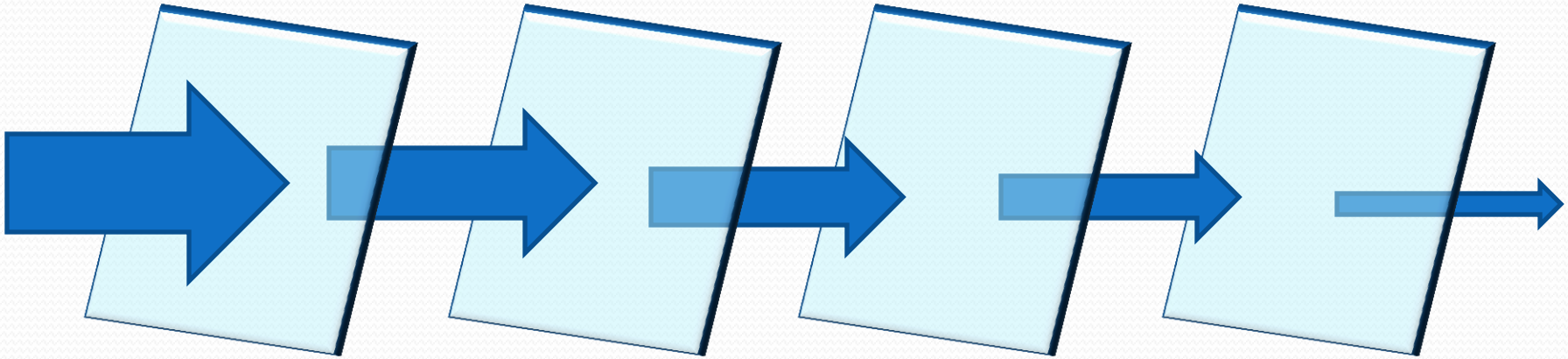
A. Particulate Size & Wave-Length of Light

- We are really looking at Particles

- We are tempted to say “They are blocking the light”
  - but that is not really what is going on - that's only a part of what is happening

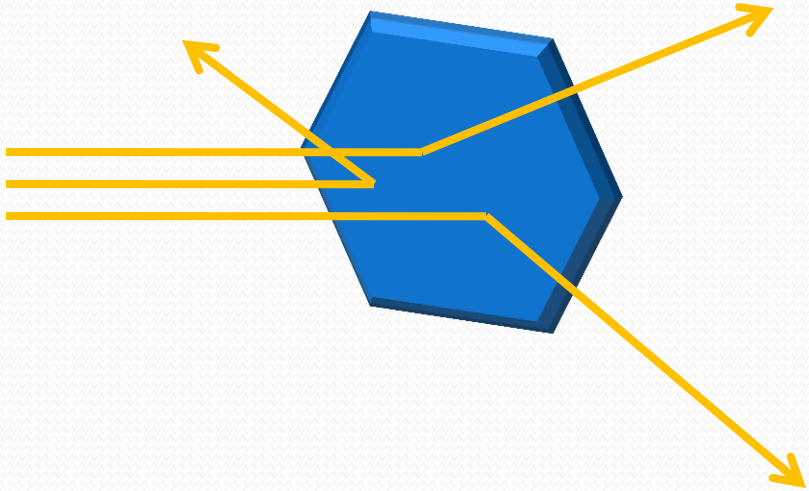
1. Absorption –

Light *PASSES THROUGH* - the thicker the particle, the more light is *Absorbed*.



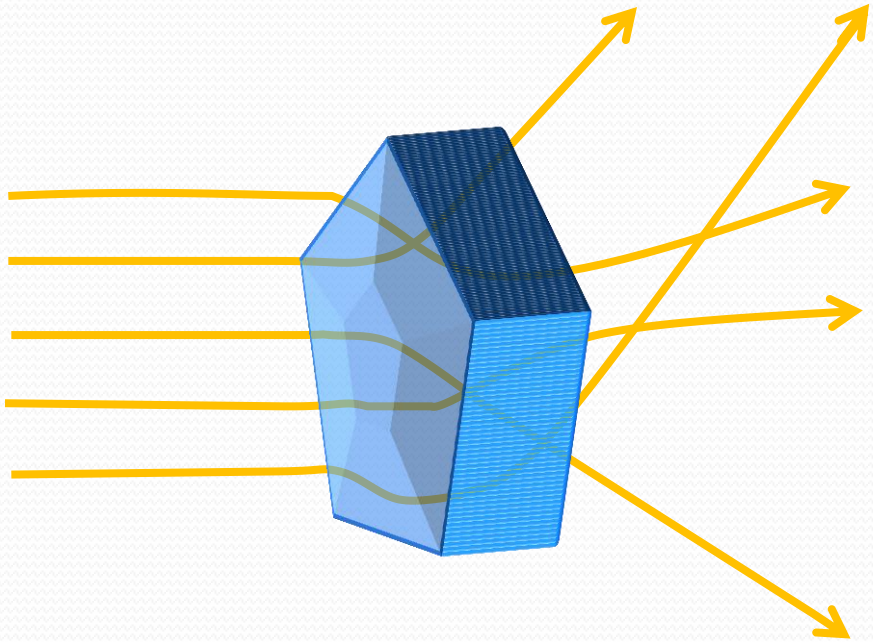
2. Reflection –

The Surface of the Particles tend to *REFLECT* the light - in a lot of different directions.



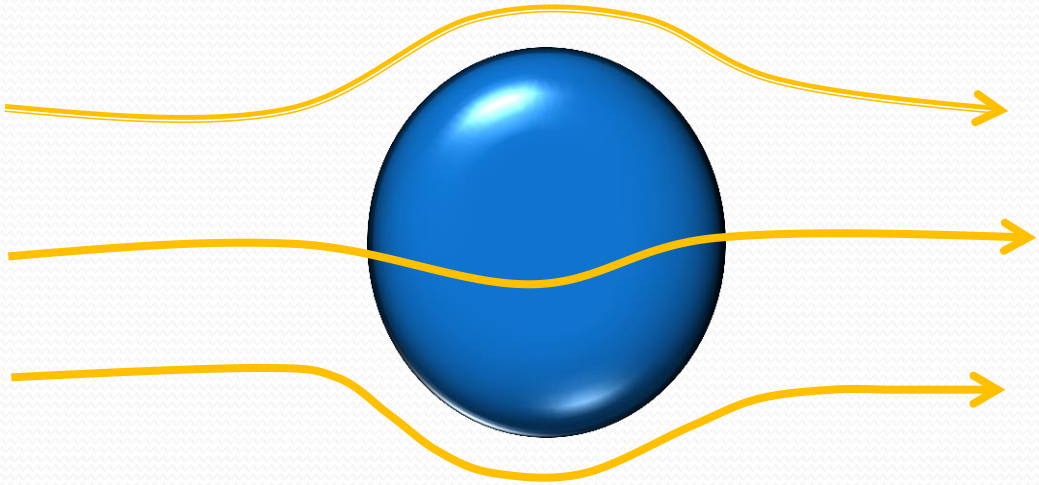
3. Refraction –

As with a *PRISM*, which *BENDS* light. What happens is that the light *SCATTERS*: you don't see it - it *SCATTERS*.



4. Diffraction –

The particle has a *very slight* *ADHESION* - the light "sticks" a little bit.



Absorption …
Reflection …
Refraction …
Diffraction …

So, the process you *thought* was happening is really not what was going on;

The particles *SCATTER* the light in such a way that you cannot view the object (Target) clearly.

➡ **The particles that give you the greatest amount of scatter** are in the range of .1 to 1.0 micron (µm) – just about the same size range as the wave length of visible light:

➡ **The size range of visible light is .3 to .7 µm**

➡ **The maximum amount of obscuring** (**Highest Opacity**): if **the light source is placed *behind the plume***, that is, coming at you.

➡ **The least amount of obscuring** (**Lowest Opacity**): when the **light source is behind *you.***

➡ **Reading Opacity is like taking a photograph** - the light should always be to your back.

REMEMBER: HIGH HUMIDITY can create problems with reading opacity; the fact that you cannot take a reading should not be a surprise - sometimes you just have to take your time and return even several times to get a good reading.

B. Types of Emissions

When readings are being taken, it is very helpful to know:

- ✓ What is going on
- ✓ The types of emissions with which you are dealing
- ✓ That different particles can look very similar

Emissions – The Main Four Types:

Important: IT IS NOT WHAT THE PARTICLES *LOOK LIKE*, BUT HOW THEY ARE FORMED!

And remember – Combustion is *not* the only source of Visible Emissions!

Emissions – The Main Four Types:

1. **Smoke** - generally considered to be a result of **Incomplete Combustion**; if you don't burn *all* the fuel, what you see is Smoke.
2. **Dust** - arises from the **Application of Force** - "Making little ones out of big ones" - Smashing Grinding Crushing.
3. **Mist** - somewhat the same as Fumes: Liquid at normal temperatures is vaporized at some point and condenses back into droplets. Examples: Asphalt, Paint
4. **Fumes** - generally, **Material that condenses**; Solid at normal temperatures, then is vaporized in some way and condenses. Generally these are **metals**.

Visible Emissions – Size and Origins of Particulates

1. **DUST** Particles
   - Small Particles formed by Force
   - Settle fairly close to source, fairly quickly
   - ❖ Size tends to be large - larger than 1.0 µm

2. **FUME** Particles
   - often metals, condensed from vapor back to solid state
   - ❖ very small particle size: 1.0 µm to 0.1 µm

3. **MIST** Particles
   - usually from materials normally in liquid state
   - often residuals from:
     - Scrubbers
     - Acid Baths
     - Asphalt Impregnation
     - Paint Spraying

   - ❖ tend to be larger particles - Liquid

4. **GAS** Particles

a. if in high enough concentrations, may become visible

- Oxides of Nitrogen: Yellow to Brownish
- Iodine: Purple
- Bromine: Reddish to Brown
- Chlorine: Yellow to Green
- Water: White

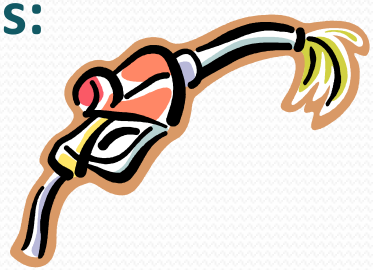
Note : IF they are of high enough concentration that they are VISIBLE, then a problem exists - not opacity, but TOXICITY.

III. Combustion and Fuels

Combustion (Fire) is a Chemical Reaction

A. **Combustion Needs:**

1. Fuel

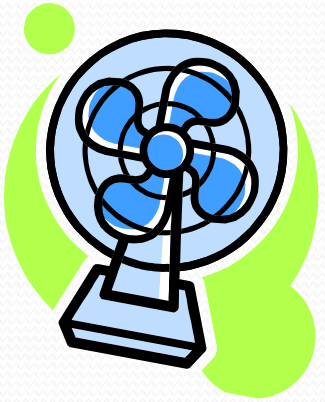


2. Oxygen

3. Ignition (Heat)

The Three "T"s of Combustion in a Combustion Unit:

1. **T**ime - give fuel enough time to burn
2. **T**emperature - give fuel enough heat to burn
3. **T**urbulence - adds more air to the fuel mixture



An efficient Combustion Unit:

- Must be designed for a specific fuel of preference.
- Must be operated within its design parameters.
- Must be properly maintained

- If any one of these Three "T"s are violated, *it will not burn clean and efficiently.*

- Incomplete or Inefficient Combustion results in SMOKE.

B. Types of Fuels

1. **Gasoline**
   - mixes easily
   - pretty clean to burn
   - usually a preferred fuel

2. **Oil**
   - must be vaporized first
   - either atomized or heated)
   - needs more time to prepare fuel
   - a little more difficult than gasoline to burn cleanly

3. Coal

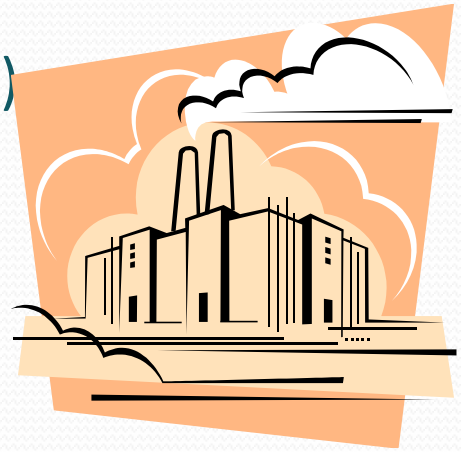
- generally burns on a grate
- air flow is *critical*
- tends to burn less efficiently
- contains a lot of contaminants when it is mined
- has 7-8% non-combustible material (dirt)

4. **Wood**

- is usually WET - must be dried first
- moisture drops temperature, results in SMOKE

5. **Refuse**

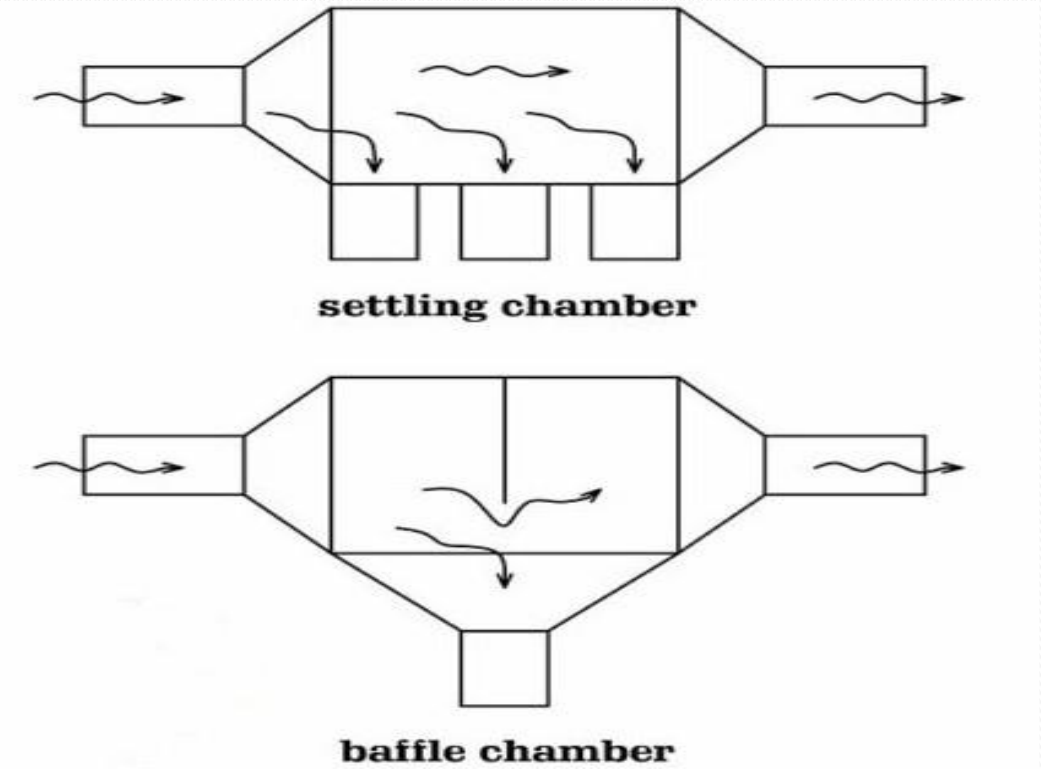
- as in apartment buildings (chute to basement)
- or grocery stores



IV. CONTROL EQUIPMENT

A. DRY COLLECTORS

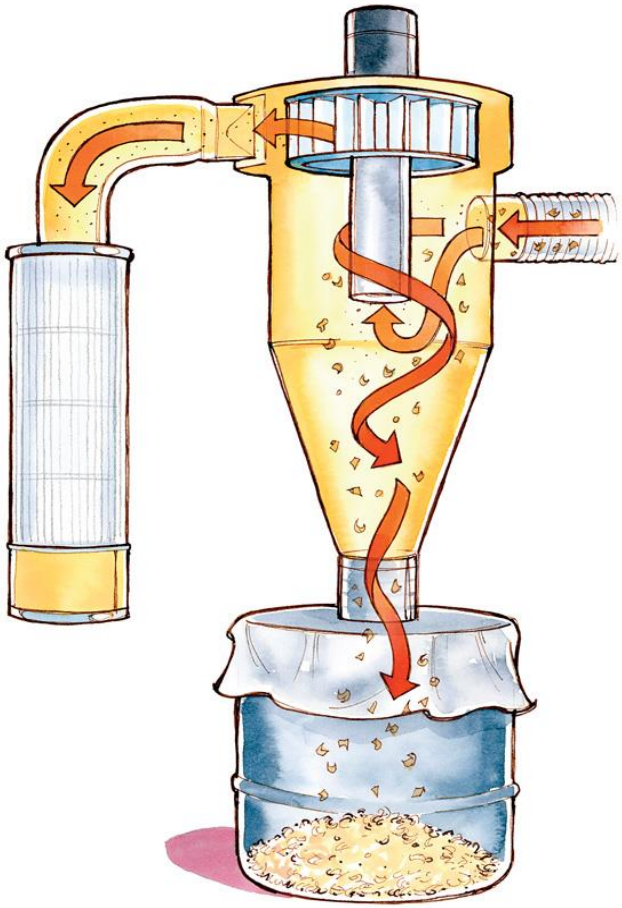
1. SEDIMENTATION CHAMBER



Usually used as a "First Step" in that it collects only very large and/or very dense particles - 100 µm or so in size.

DRY COLLECTORS

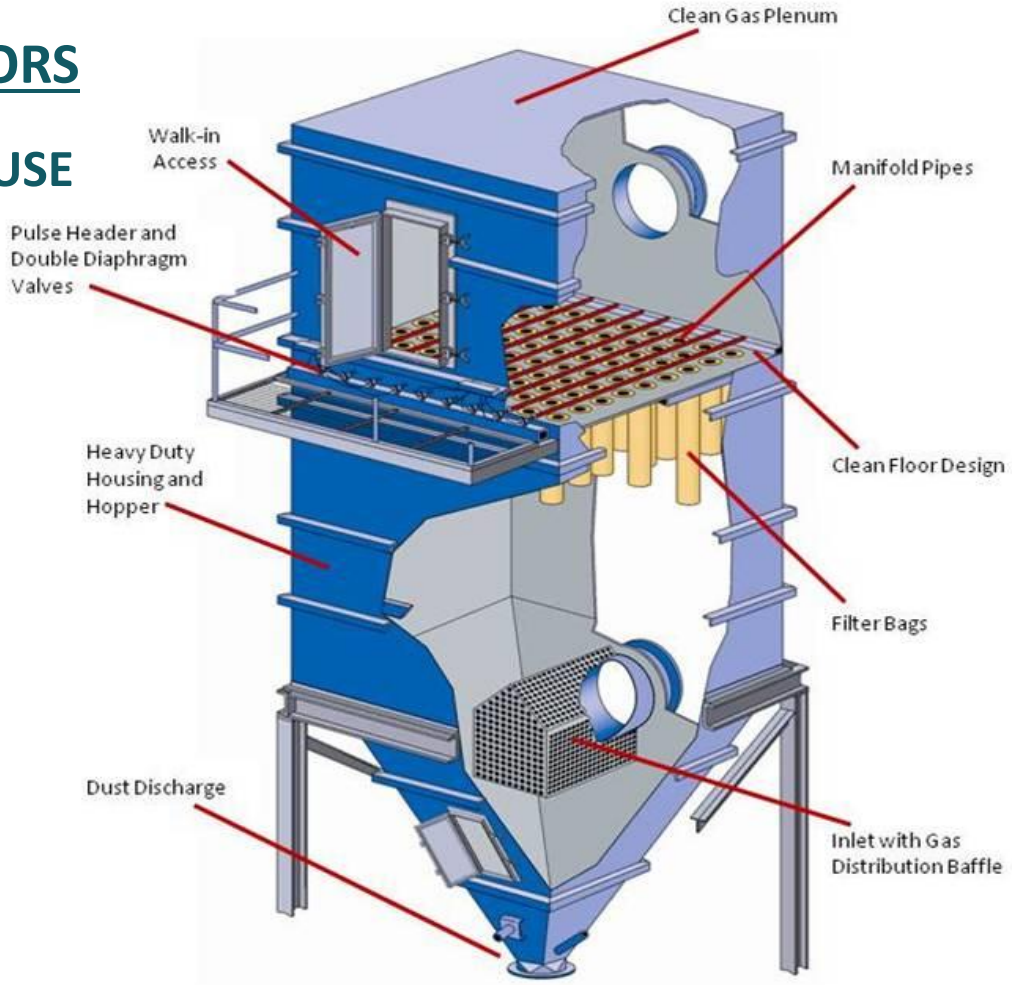
CYCLONE



- Works pretty well down to 20 µm size particles
- No added efficiency if used in series : the 1st unit removes all large particles

DRY COLLECTORS

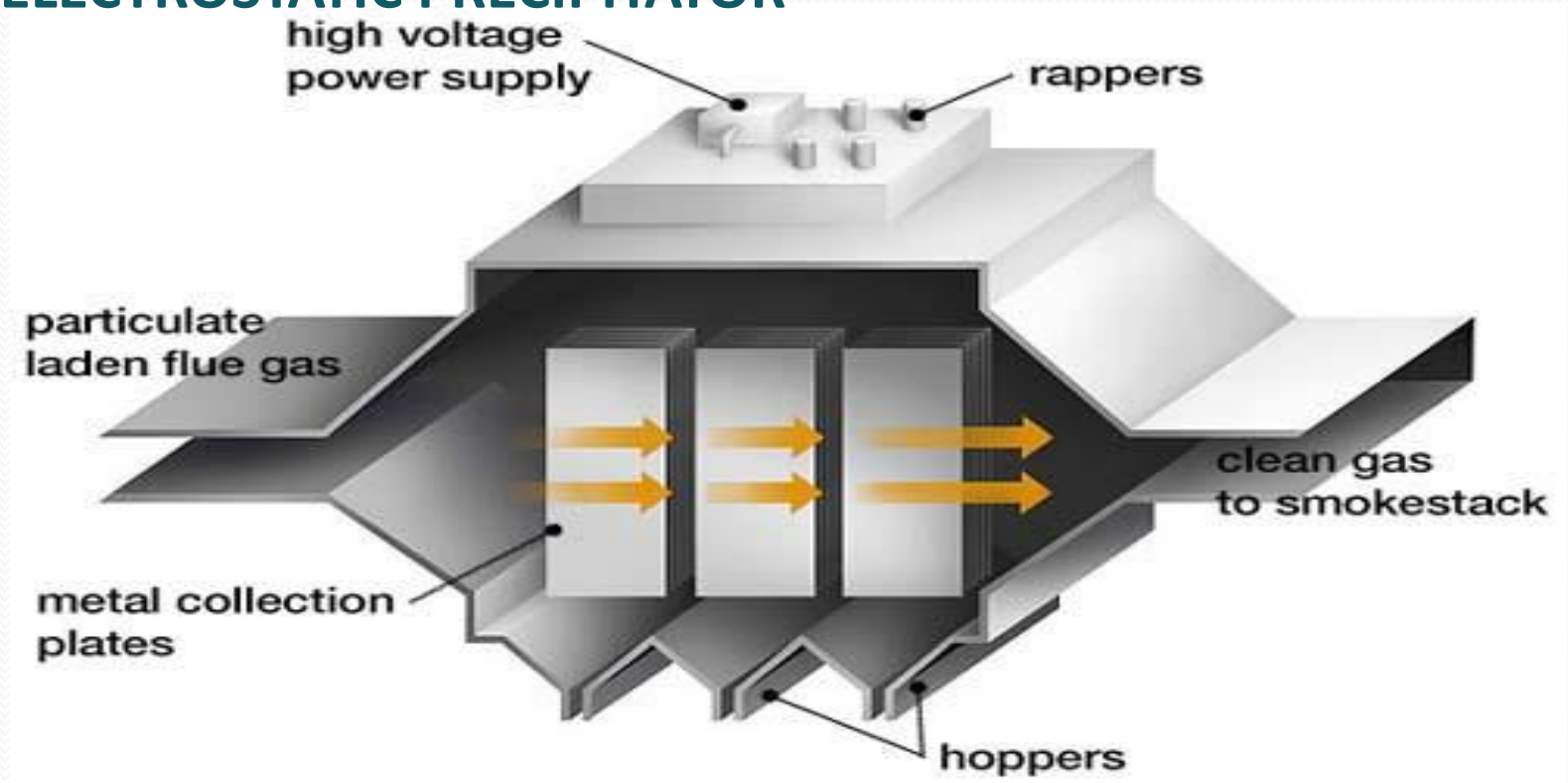
3. BAG HOUSE



- SAWTOOTH EFFICIENCY - becomes more efficient as dust collects, then must be cleaned, loses efficiency, builds back up, etc.
- EFFICIENCY – 99% - Can get down to 1.0µm or 0.1µm filtering size.

DRY COLLECTORS

4. ELECTROSTATIC PRECIPITATOR



- PRODUCES Ionization, which breaks the **GAS** down.
- very LARGE system which periodically needs to be cleaned (plates)
- Very, very efficient - - collects particles down to 0.1 µm

IV. CONTROL EQUIPMENT

B. WET COLLECTORS

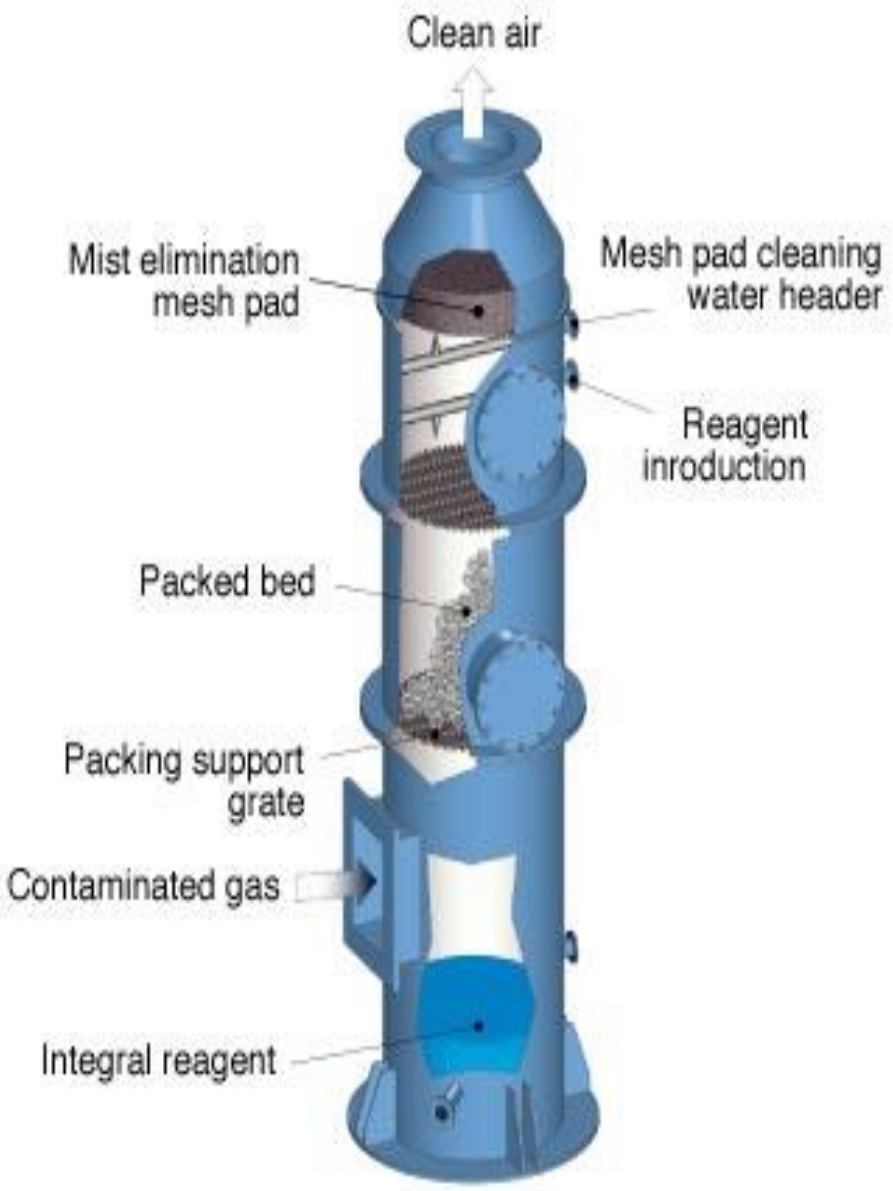
ARE USED primarily to control CONTAMINANT GASSES i.e. Take the air (gas) - hopefully soluble in water - introduce it into water where it is separated from the contaminants, and take it out (clean) from the water.

1. **Packed Towers**
2. **Plate Towers**
3. **Spray Towers**
4. **Venturi** (the only WET process specifically used for Particles)

WET COLLECTORS

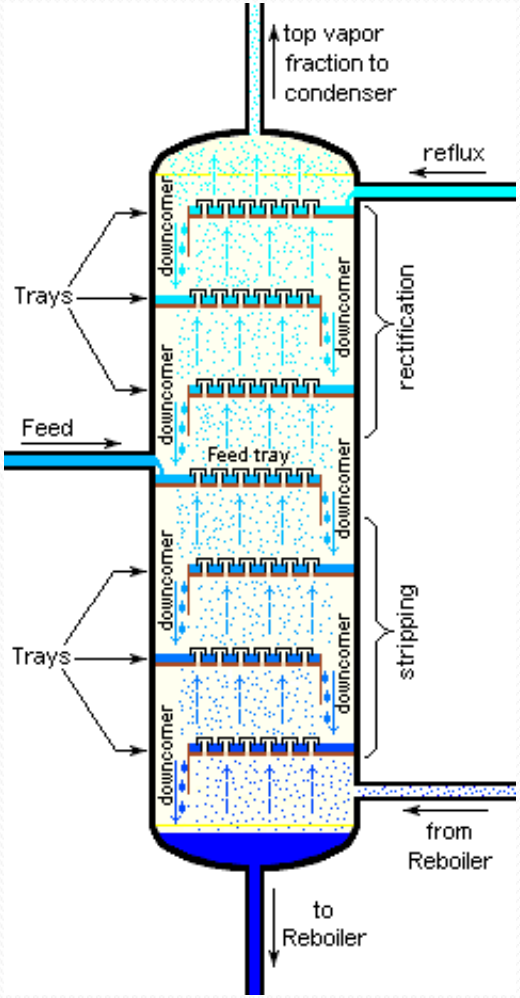
1. PACKED TOWER

- LIQUID (usually waste) flows down through the packing material.
- CONTAMINANT-LADEN GAS passes counter-current to it.
- SLURRY with Contaminants remains in collector at bottom and is removed.
- SOME PARTICULATES may be removed with the water, but these are PRIMARILY NOT PARTICULATE COLLECTORS.
- PRIMARILY A REMOVAL SYSTEM FOR **GASSES**

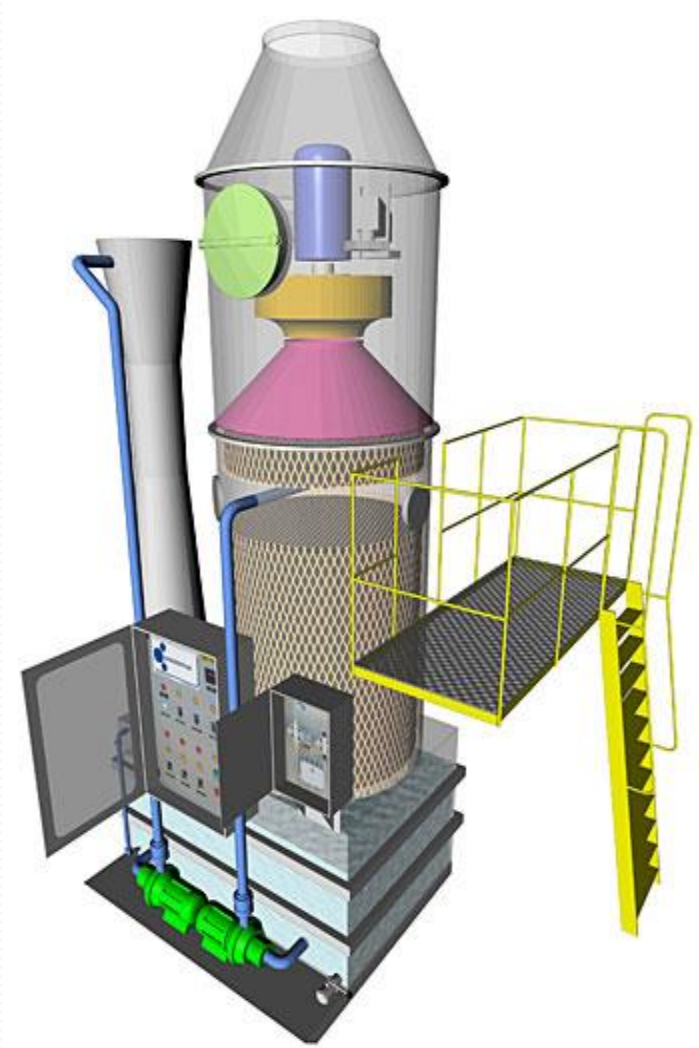


WET COLLECTORS

2. PLATE TOWER



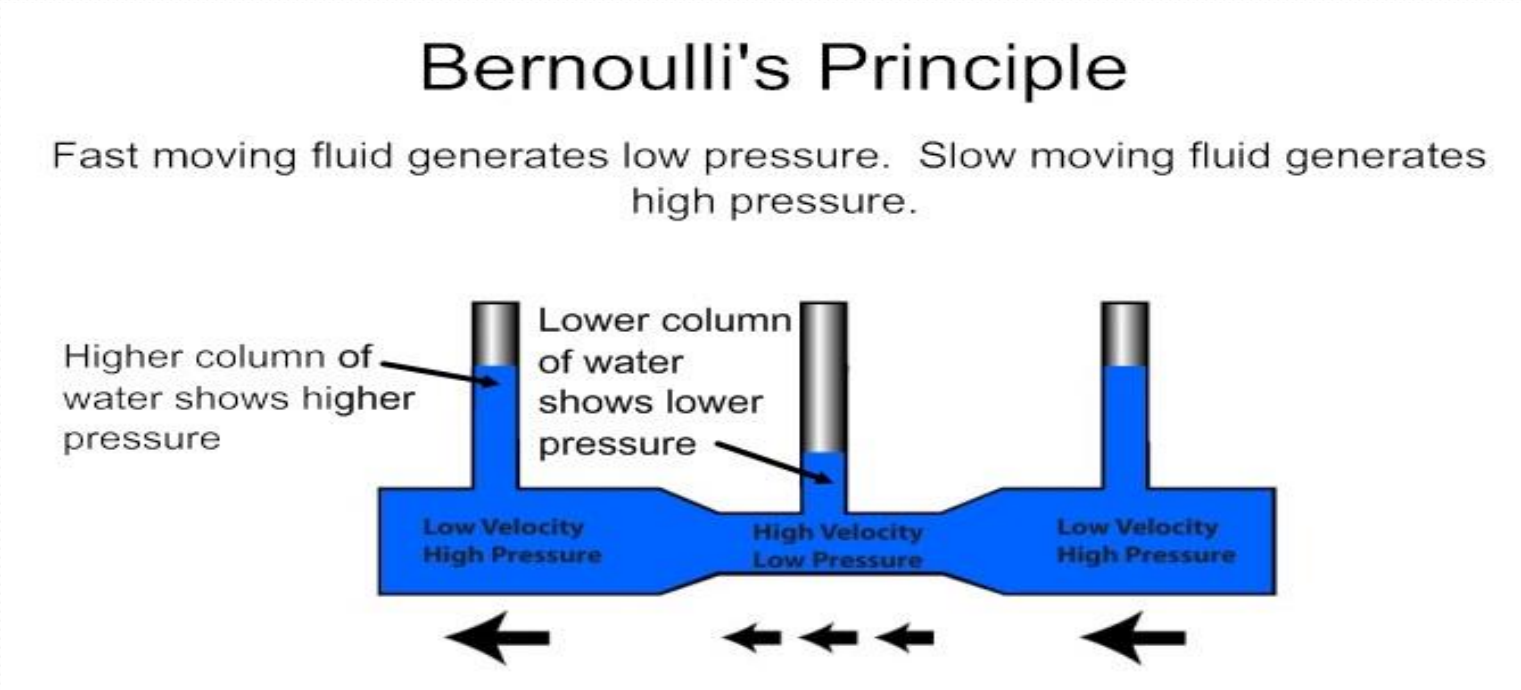
3. SPRAY TOWER



WET COLLECTORS

4. VENTURI

- **Bernoulli's Principle**: As the **speed** of a moving fluid **in**creases, the **pressure** within the fluid **de**creases.



- the only WET process specifically used for **Particles**.
- MOST EXPENSIVE units - requires a lot of PRESSURE (Power).

V. PLUME STRUCTURE

A. TYPES OF EMISSIONS or "CLOUDS":

1. Totally Detached
   - Similar to Wildfire Smoke which persists to the next day
   - We are not so concerned with this type today

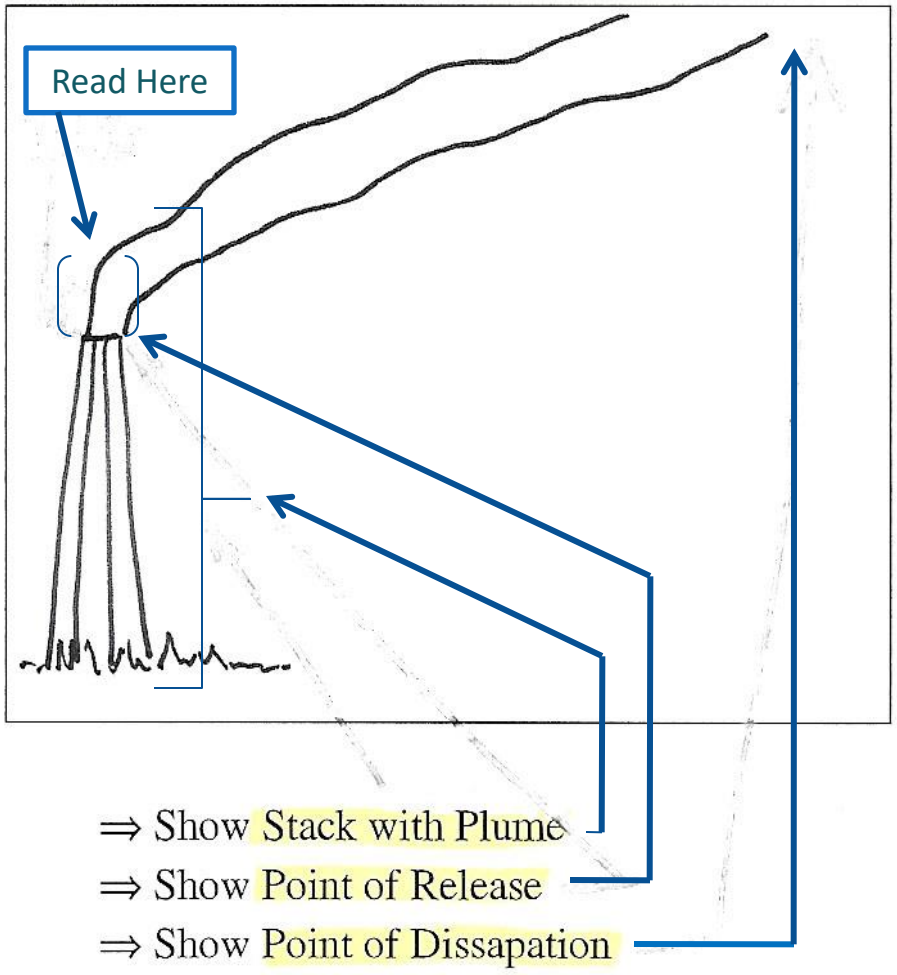
2. Haze and Fog
   - We are not concerned with this type either

3. Plume from a Discreet Point of Release
   - This is our concern today

PLUME STRUCTURE

1. DRY ATTACHED PLUME:

An “Ideal” Plume:

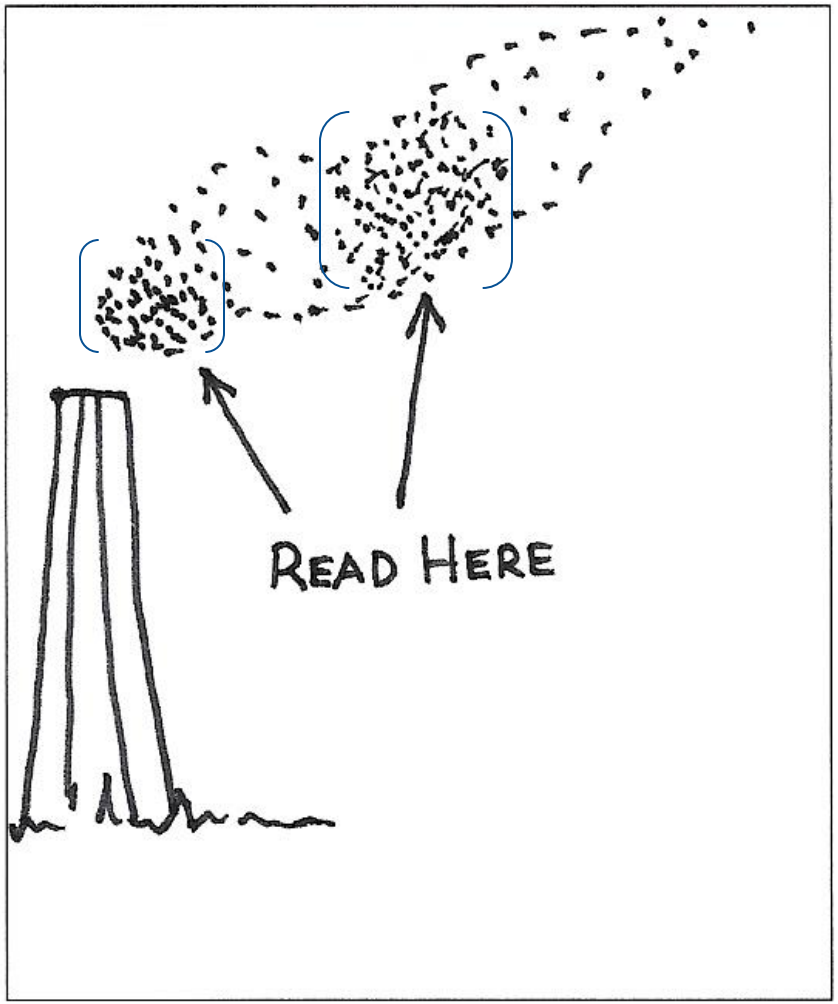


- *NOTE*: A PLUME FORMED OF WATER DROPLETS (often mis-labeled as "Steam") is not currently considered to be an Air Pollutant. We do not read Water Vapor Plumes

- the Point of Release is where you Make a reading
- The Body of the Plume shows Wind Direction

PLUME STRUCTURE

4. DRY DETACHED PLUME:



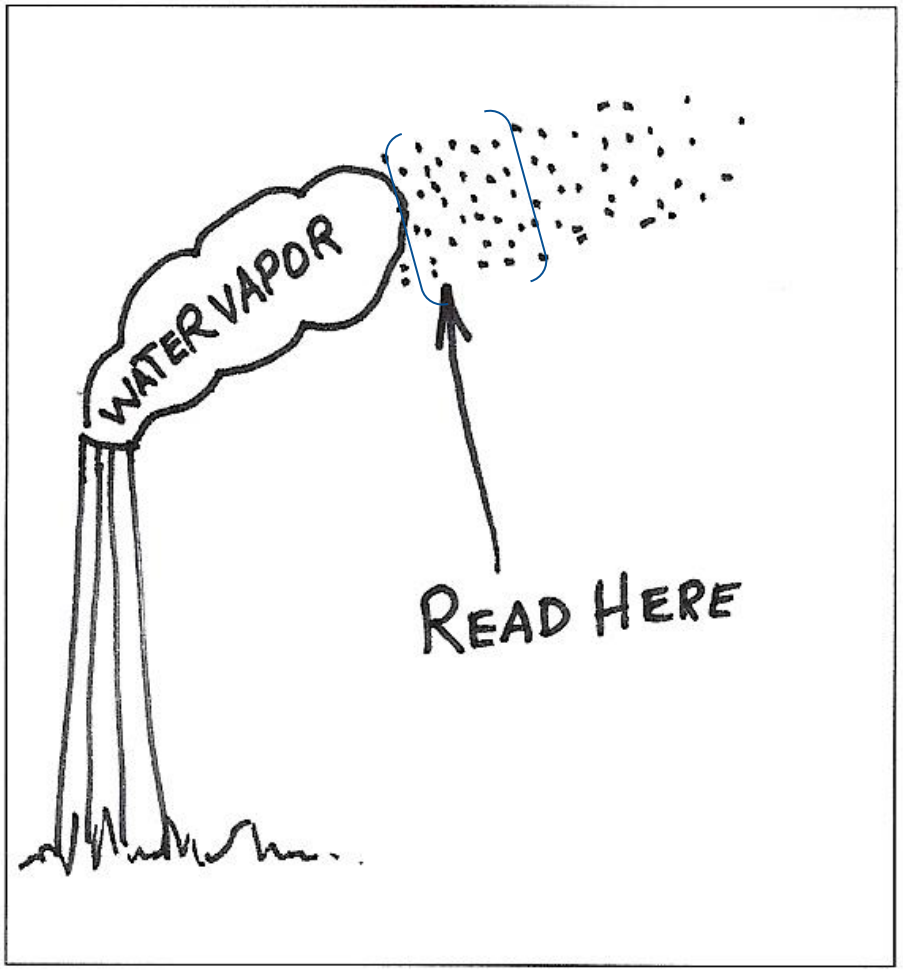
READING TAKEN:

- at Point of Formation, *or*
- at Point of Maximum Opacity (in Plume) *where water is not present*.

(usually Particle Formation is not clearly defined)

PLUME STRUCTURE

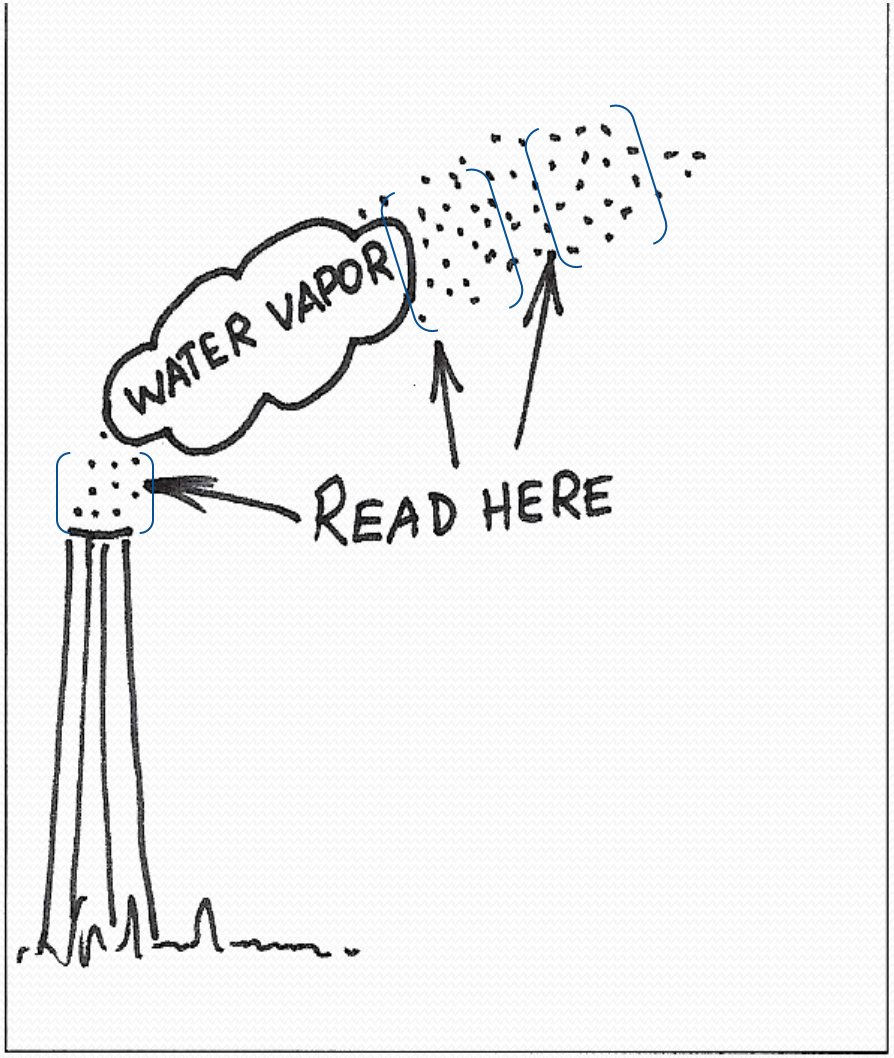
2. WET ATTACHED PLUME:



- WATER (Non-Pollutant) tends to be a Fluffy White color
- WATER tends to dissipate rather quickly, i.e. a few feet.
- RESIDUAL AEROSOLS (Pollutants) tend to be Grey, Grey-Brown and rather dull in color.
- RESIDUAL AEROSOLS can continue a few *miles* downwind.
- **READING is made at Point of Dissipation**

PLUME STRUCTURE

3. WET DETACHED PLUME:



- the part that is detached is the WATER
- Water exits the stack, but condenses and forms *above it*.
- RESIDUAL AEROSOLS are read at Point of Release, immediately above the stack and below the Water Plume.

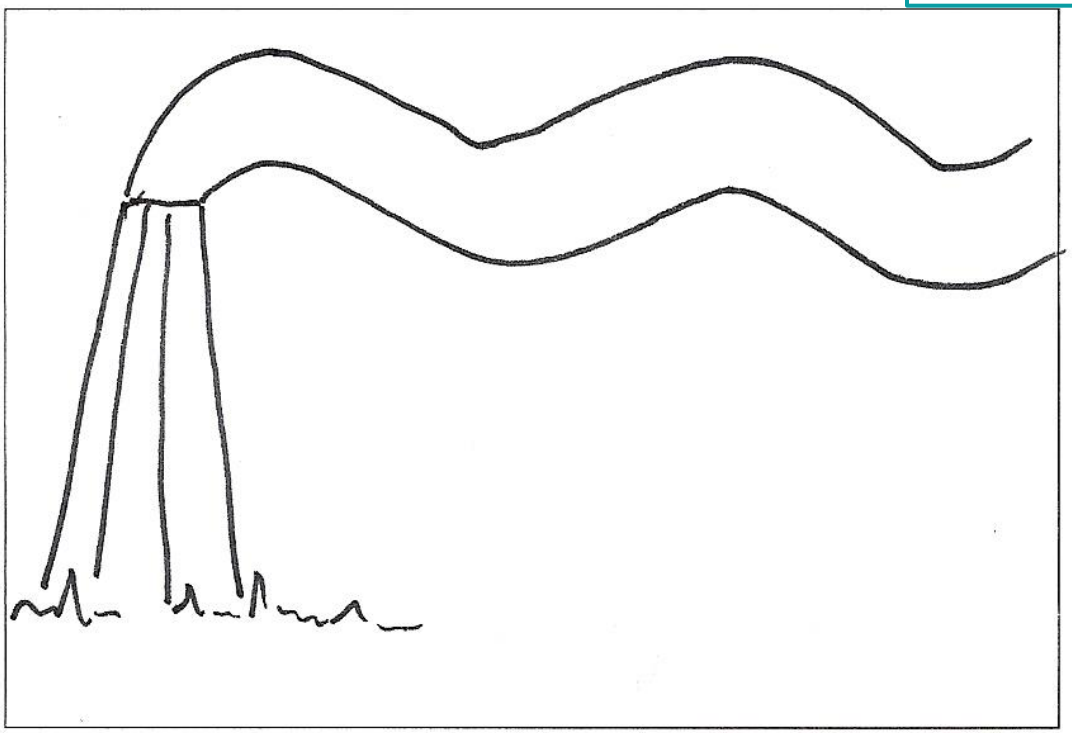
VI. METEOROLOGY

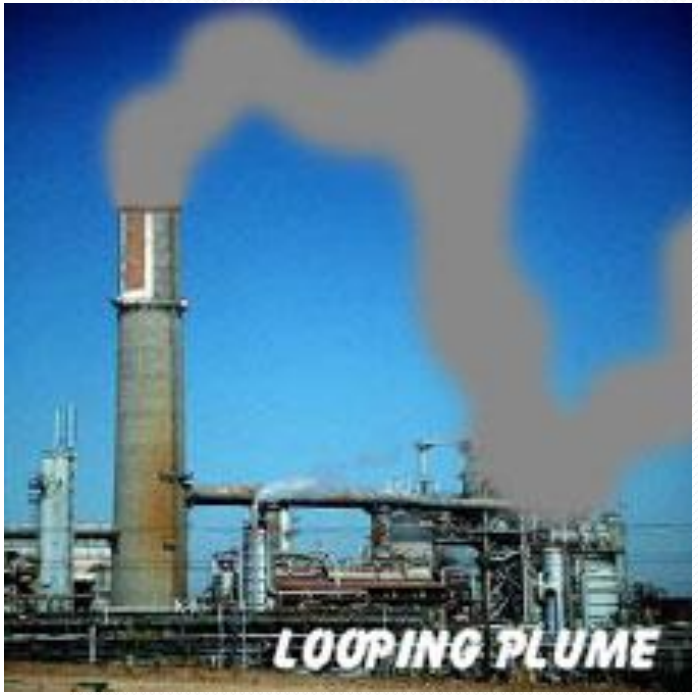
A. PLUME BEHAVIOR:

1. Looping Plume:

NOTE*: Lapse Rate** - The Rate of Change of Temperature and ***it does affect Plume Behavior.

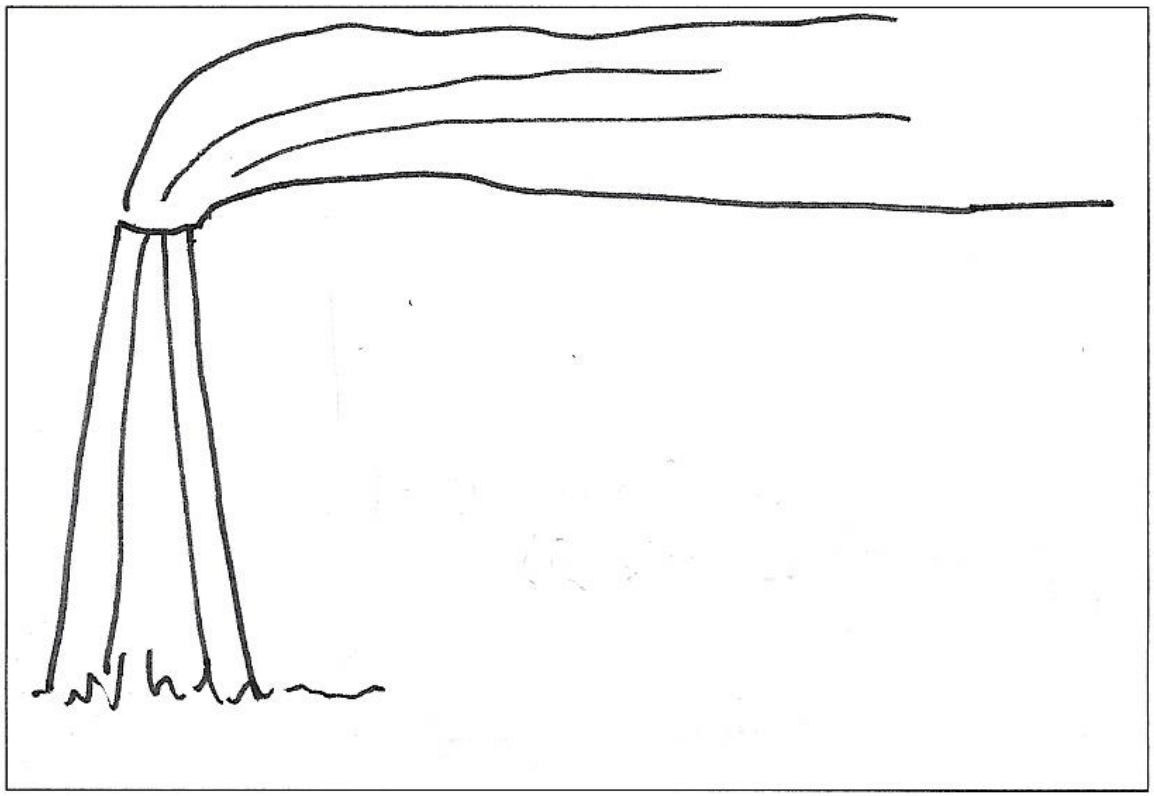
Normal Condition: Ambient Temperatures decrease 5°F with every gain of 1000 feet of Altitude.

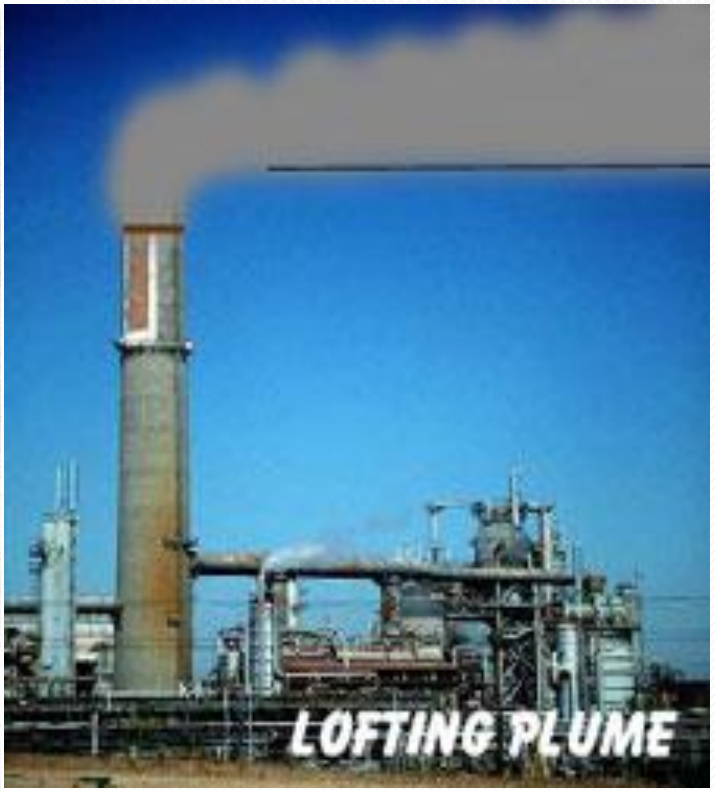




PLUME BEHAVIOR:

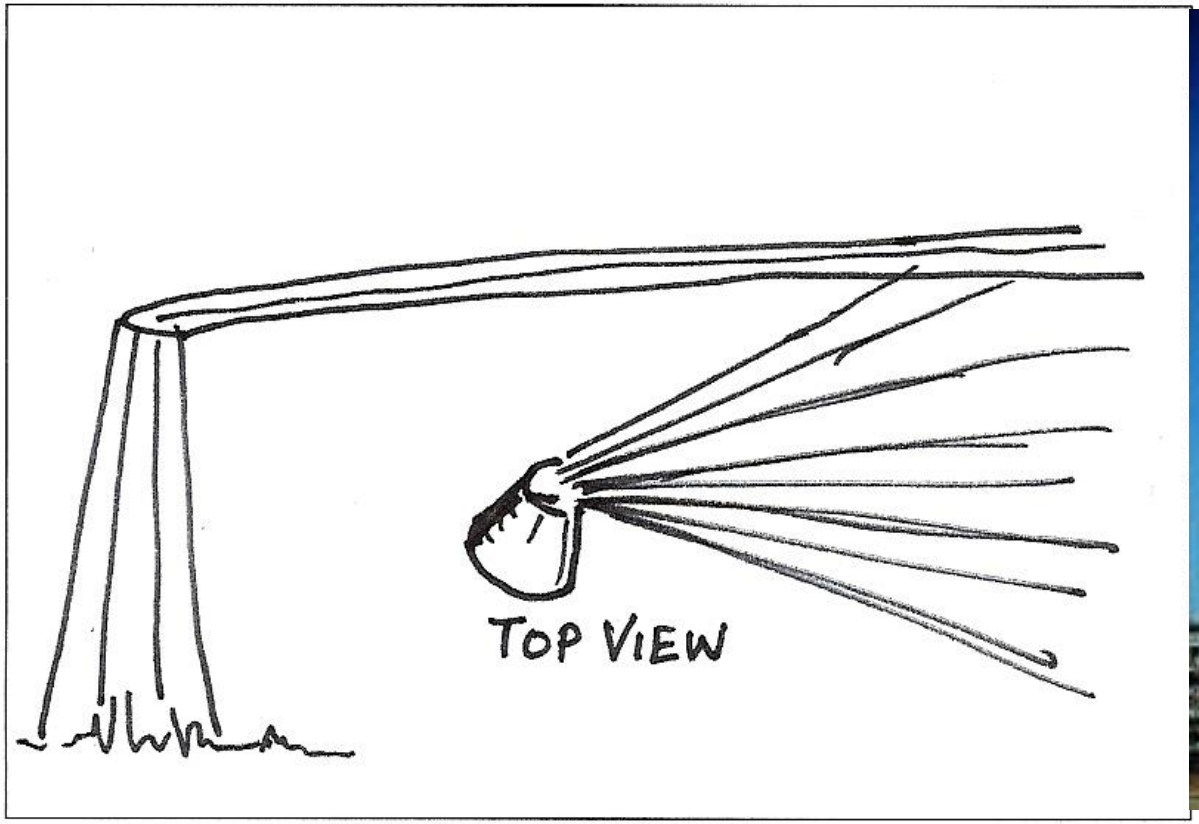
2. Lofting Plume

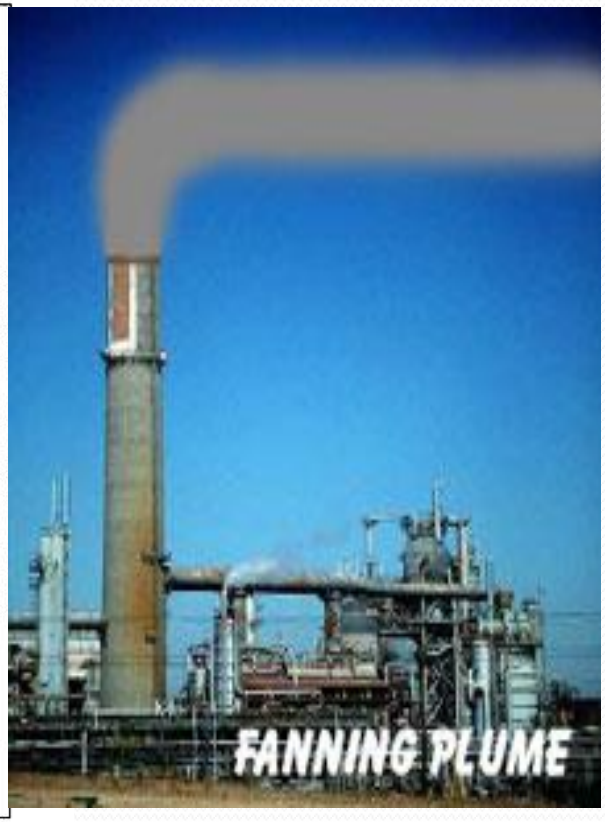




PLUME BEHAVIOR:

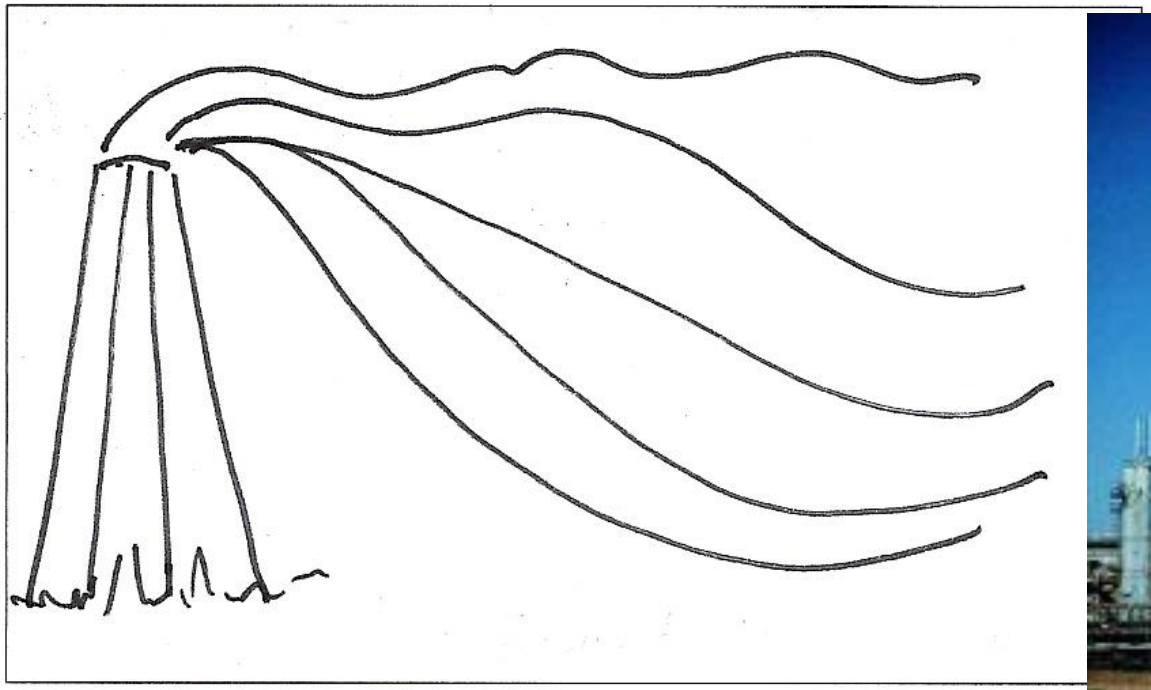
3. Fanning Plume

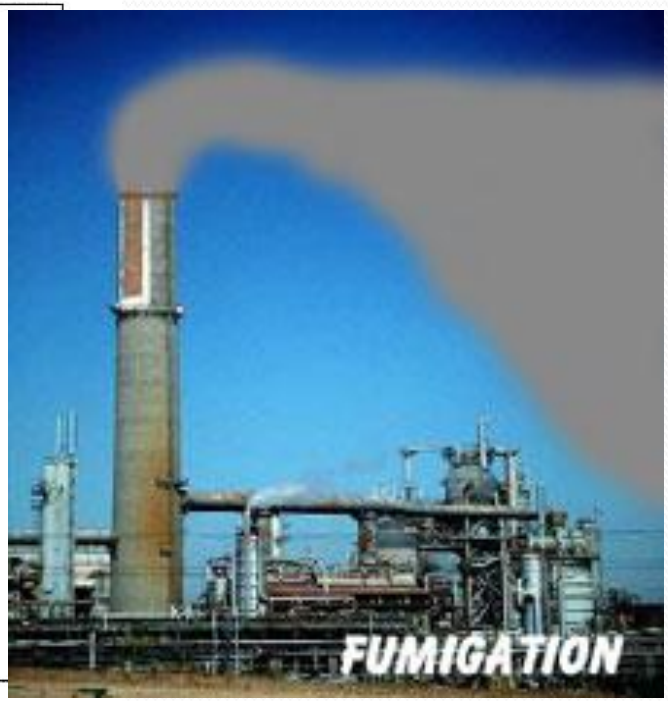




PLUME BEHAVIOR:

4. Fumagation

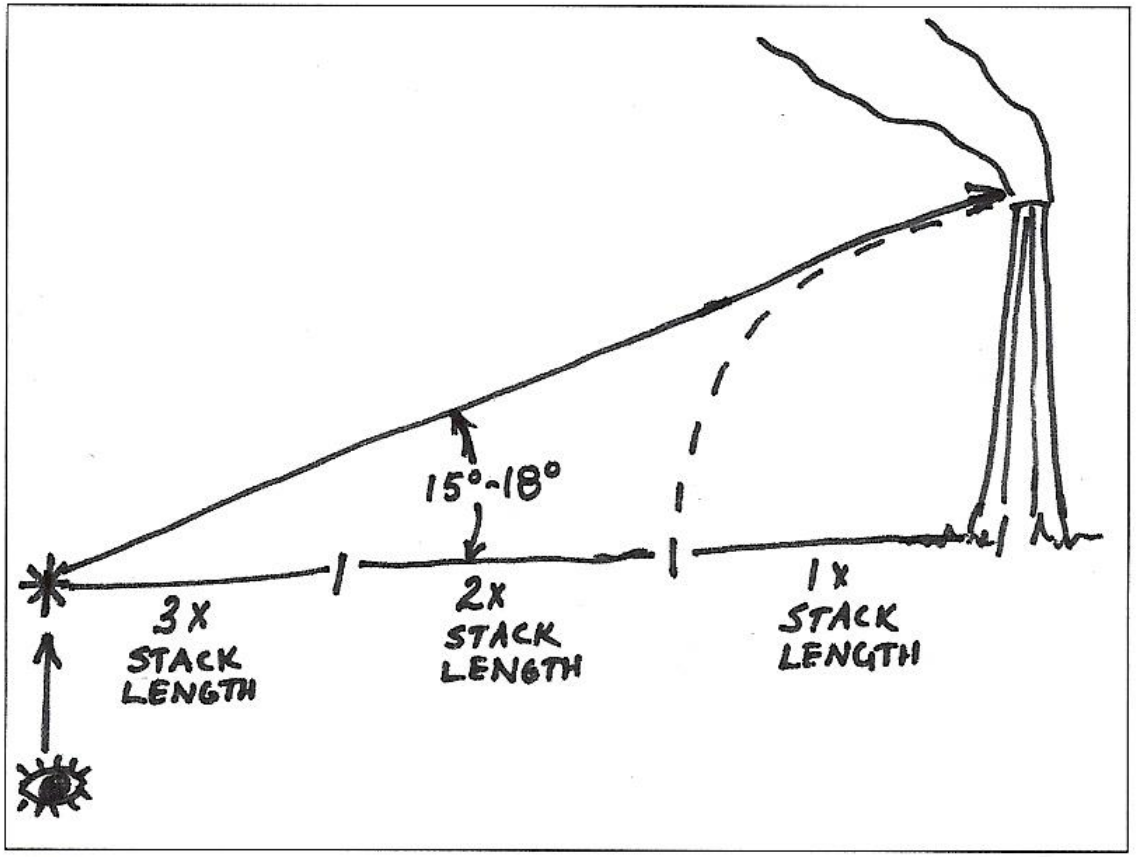




VII. READING OPACITY

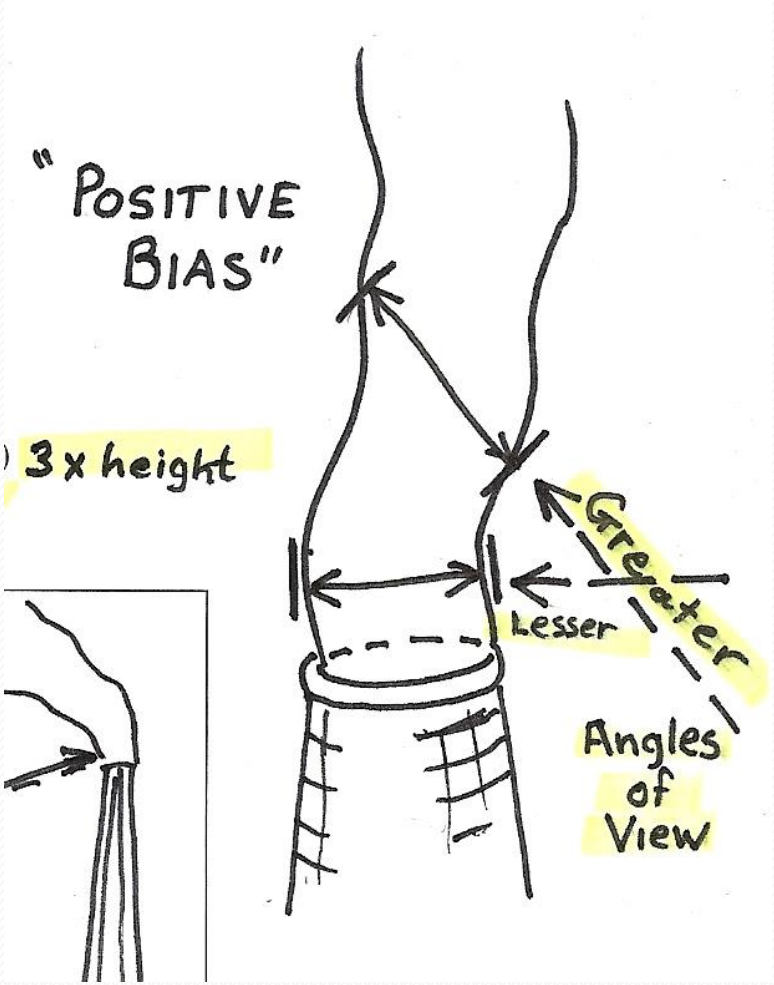
A. Position – Stationary Sources:

1. Distance to Stack:



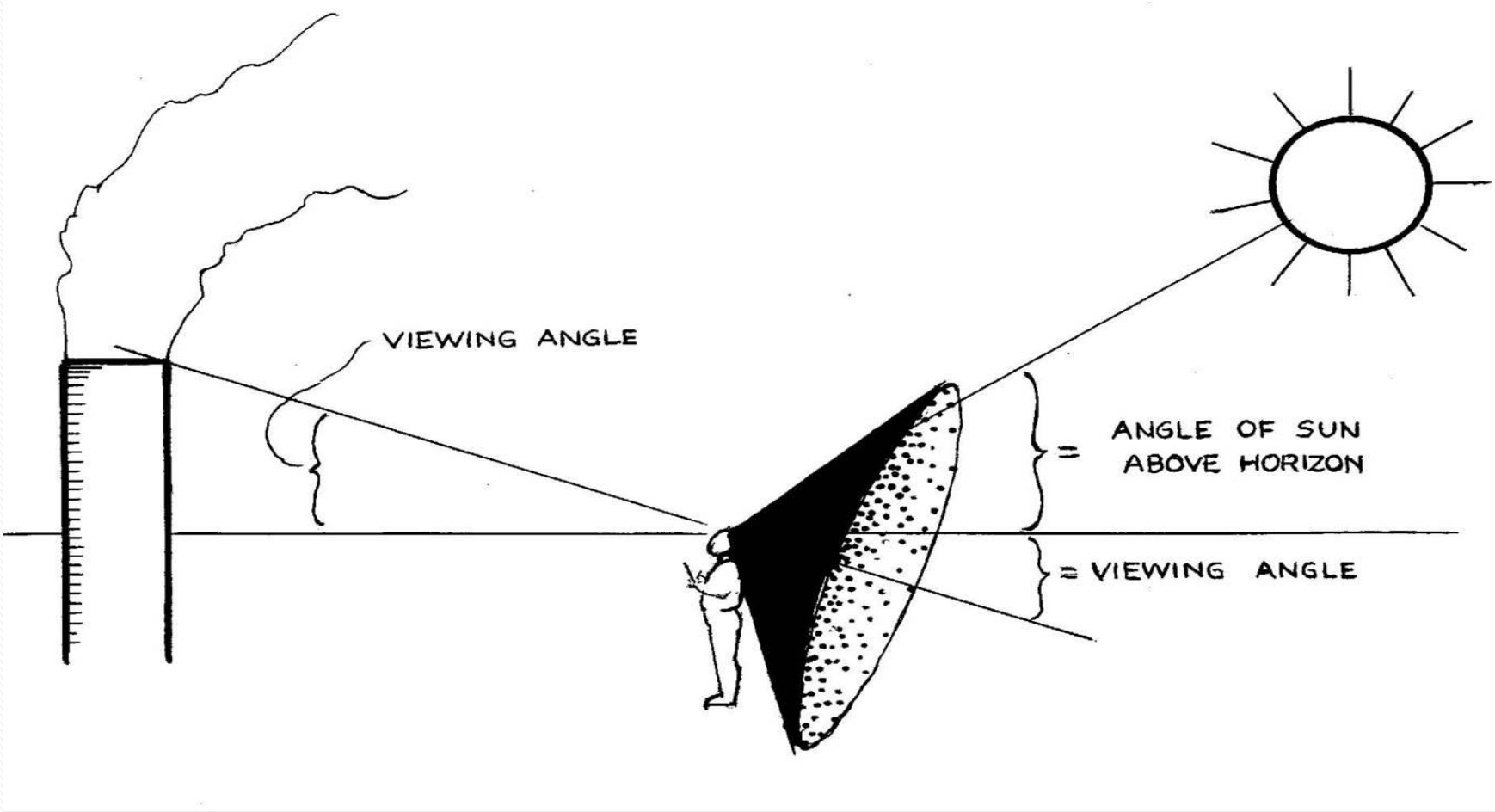
A. Position – Stationary Sources:

2. Positive Bias:

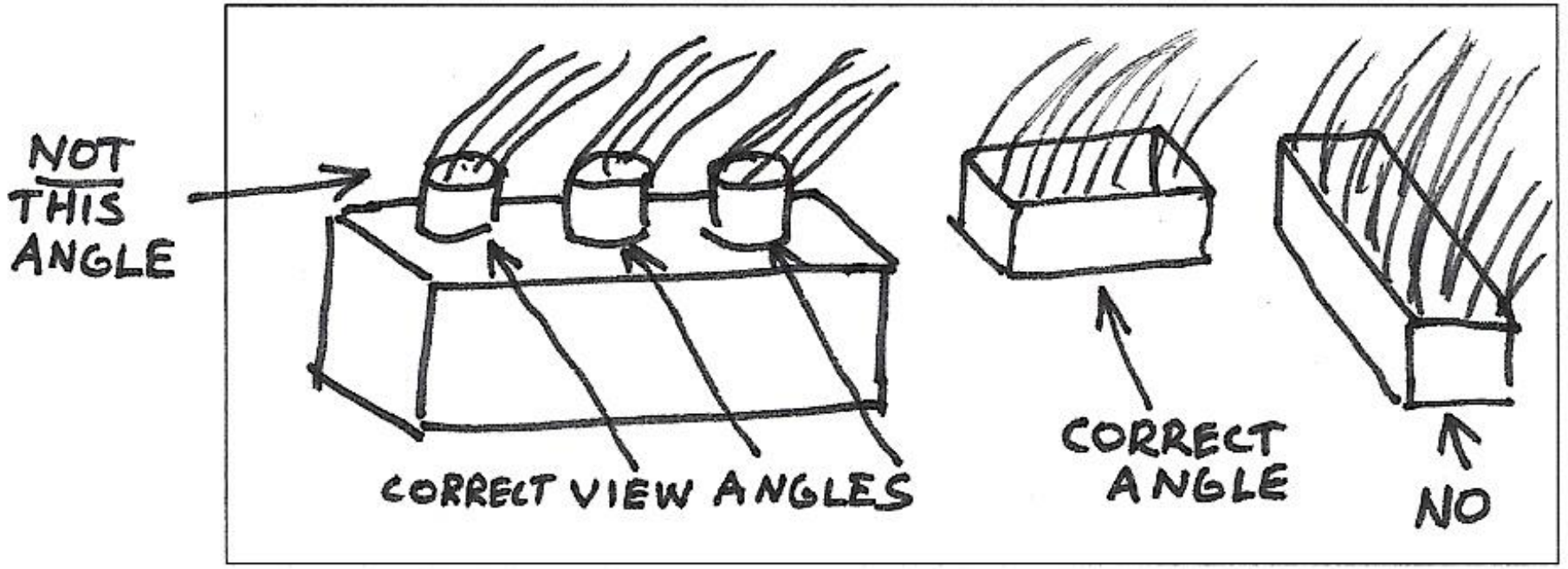


B. Position – Sun Angle

1. SUN ANGLE:



C. Multiple Stacks



Recording Time

Military Time - 24-hour clock

- Is best indication of time of day, AM or PM.
- Eliminates AM or PM controversy
- Still requires PST, PDT, GMT, etc.
- PDT = GMT minus 0700, (Summer)
  Starts 3-14-10 0200 Sunday
- PST = GMT minus 0800, (Winter)
  Starts 11-07-10 2022 Sunday

GMT = Greenwich Mean Time, Greenwich, England

UTC = Co-ordinated Universal Time (= GMT)

Can You Read VE's in the Rain?

… Most of the time … *Yes*!

Rain becomes a problem only when it is so heavy as to obscure your target.

Beaufort Scale of Wind Speed

General Description	Specifications	Miles per Hour 33 ft. Above ground level
Calm	Smoke rises vertically	Under 1
	Direction of wind shown by smoke drift but not by wind vanes	1 to 3
Light	Wind felt on face; leaves rustle; ordinary vane moved by wind	4 to 7
Gentle	Leaves and small twigs in constant motion; wind extends light flag	8 to 12
Moderate	Raises dust and loose paper; small branches are moved	13 to 18
Fresh	Small trees in leaf begin to sway; crested wavelets form on inland waters	19 to 24
	Large branches in motion; whistling heard in telegraph wires; umbrellas used with difficulty	25 to 31
Strong	Whole trees in motion; inconvenience felt in walking against the wind	32 to 38
	Breaks twigs off trees; generally impedes progress	39 to 46
Gale	Slight structural damage occurs (chimney pots and slate removed)	47 to 54
	Trees uprooted; considerable structural damage occurs	55 to 63
Whole Gale	Rarely experienced; accompanied by widespread damage	64 to 75
Hurricane		Above 75