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REFERENCE DATA SHEET ON AIR POLLUTION CONTROL DEVICES

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With the passage of the 1971 Clean Air Act, American industry experienced a significantly increased need to reduce air pollution. The application of existing and new technology resulted in the development of many air pollution control devices. They included:

- Cyclones
- Incinerators
- Catalytic reactors
- Baghouses
- Electrostatic Precipitators
- Adsorption
- Absorption equipment & wet scrubbers

In the last two dozen intervening years, much of this equipment has reached the end of its useful life, the original process parameters have changed rendering this equipment less effective, and historical failure modes and equipment limitations have been identified.

The major controlling performance parameters are:

- Particle size, weight, shape
- Particle velocity
- Gas temperature / density
- Solubility and pH
- System pressure drop and mass transfer conditions
- Particle size distribution
- Gas viscosity
- Humidity level
- Chemical stoichiometry
- Residence time

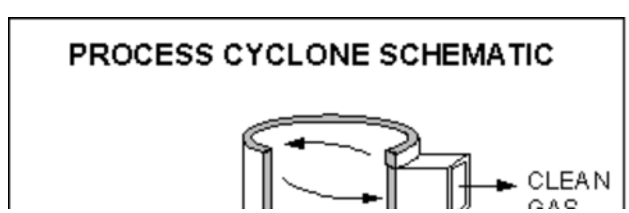
The following is a short primer on these devices, some of the effects of their controlling parameters, and their limitations, advantages, and operating problems.

1. CYCLONES

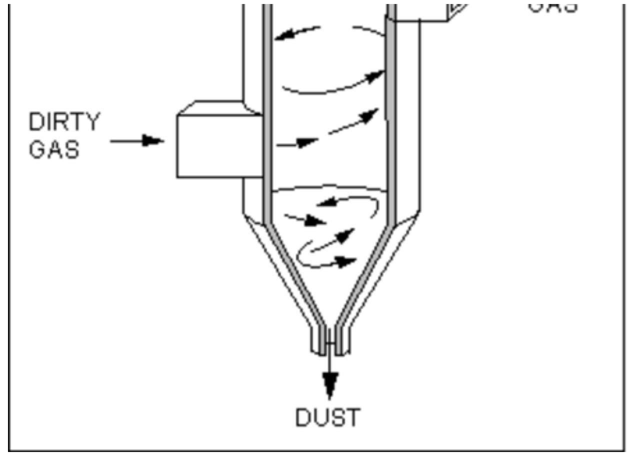
Cyclones operate to collect relatively large size particulate matter from a gaseous stream through the use of centrifugal forces. Dust laden gas is made to rotate in a decreasing diameter pathway forcing solids to the outer edge of the gas stream for deposition into the bottom of the cyclone. Efficiencies of 90% in particle sizes of 10 microns or greater are possible.

Performance & Collection Efficiency

- Linear increases with: particle density, gas stream velocity, and rotational passes
- Linear decrease with fluid viscosity



- Exponential increase with particle diameter



Limitations / Advantages / Problems

- Reduces internal access needs
- Optimal flow rate difficult to adjust
- Prone to internal erosion / corrosion
- Operation at elevated temperatures possible
- Low efficiency for small diameter material
- Hopper recirculation / flow distribution problems
- High energy costs for volumetric flow requirements
- Dew point agglomeration, bridging, and plugging
- Few moving parts, few mechanical / electrical ignition sources

2. INCINERATORS

Incineration involves the high efficiency combustion of certain solid, liquid, or gaseous wastes. The reactions may be self sustaining based on the combustibility of the waste or require the addition of fuels. They may be batch operations or continuous as with flares used to burn off methane from landfills; and, they may incorporate secondary control methods and operate at efficiency levels of 99.99%, as with hazardous waste incinerators. Combustion temperatures, contact time, and mass transfer are the major parameters affecting incineration performance.

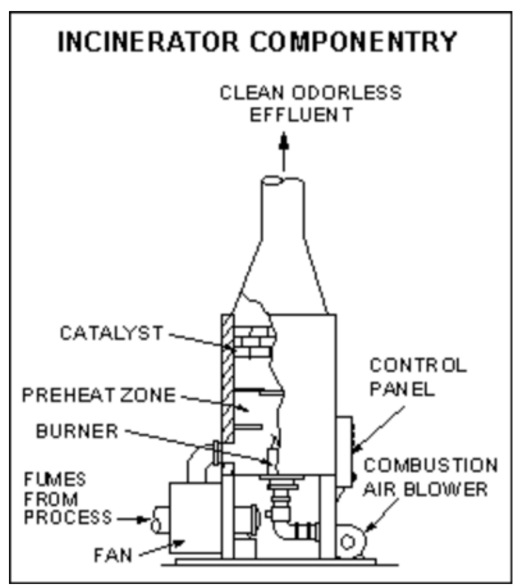
Performance & Efficiency Parameters

$t = V/Q$ where; t = residence time
V = incinerator volume
Q = gas volumetric flow rate at combustion conditions

Increased residence times mean increased performance

$$\text{hydrocarbon incineration rate} = \frac{d\,[HC]}{dt} = -k\,[HC]$$

where; [HC] = concentration of hydrocarbon
-k = reaction rate constant



Increased waste stream concentrations mean increased percentage rates of incineration

Limitations / Advantages / Problems

- High destruction efficiencies possible
- Variations in fuel content of waste
- Transition among wastes require significant control changes
- Good for gases, liquids, and solids
- High cost of supplementary fuel
- High temperatures require good thermal loss control
- Hot surfaces, flashback, and explosive conditions

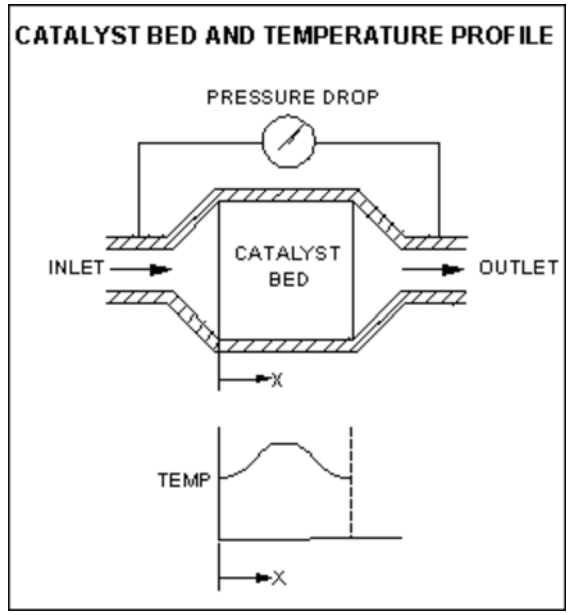
3. CATALYTIC REACTORS

Catalytic reactors can perform similar thermal destruction functions as incinerators, but for selected waste gases only. They incorporate beds of solid catalytic material that the unwanted gases pass through typically for oxidation or reduction purposes, and have the advantages of lowering the thermal energy requirements and allow small, short-term fluctuations in stoichiometry. Efficiencies of 99.99% are possible with reduced energy costs. Increasing pressure drops across the catalyst bed increase energy / operating costs.

Performance & Efficiency Parameters

$$\text{Pressure drop} = \frac{(L)(u_f)(V^2)}{A}$$

where; L = bed thickness
V = velocity
u_f = fluid viscosity
A = cross-sectional area



Limitations / Advantages / Problems

- Supplementary fuel savings
- Short-circuiting of flow through bed
- Excessive oxidation and thermal failure
- Breakthrough of emissions as failure mode
- Abrasion and thermal shock of catalyst
- Poisoning of catalyst and drop in performance
- Thick beds cause high pressure drops and increased energy costs

4. ABSORPTION & WET SCRUBBING EQUIPMENT

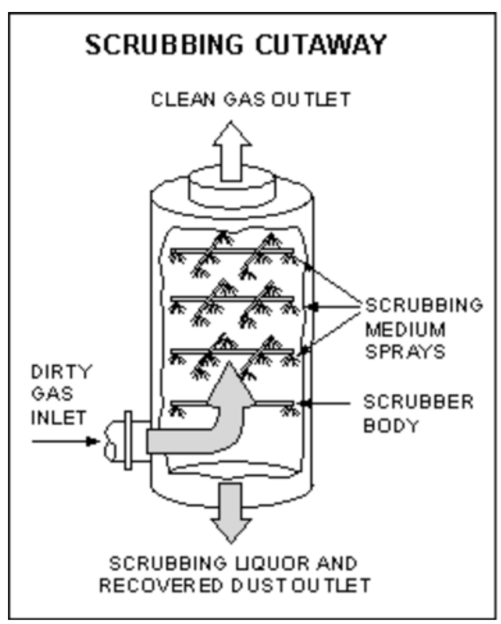
The goal in absorption and wet scrubbing equipment is the removal of gases and particulate matter from an exhaust stream by causing the gaseous contamination to become dissolved into the liquid stream and the solids to be entrained in the liquid. The rate of gas transfer into the liquid is dependent upon the solubility, mass transfer mechanism, and equilibrium concentration of the gas in solution. Gas collection efficiencies in the range of 99% are possible. The rate of particulate matter collection at constant pressure drops is inversely proportional to the aerodynamic mean diameter of the particulate matter and scrubber droplets.

Performance & Efficiency Parameters

For gas collection, the maximum equilibrium concentration in solution is described by Henry's law:

$$[C_{gas}] = (H_k)\,[C_{liquid}]$$

where; (H_k) is Henry's constant
$[C_{gas}]$ is the concentration in the gas stream
$[C_{liquid}]$ is the concentration in the liquid stream



Limitations / Advantages / Problems

- High pressure drops required
- Internal plugging, corrosion, erosion
- Increased need for internal inspection
- Formation / precipitation of solids
- Few internal moving parts
- Reduced opportunity for gas ignition

- Gas and liquid chemistry control important
- Increased relative velocity between scrubbing the fluid and gas stream, increases efficiency for solids

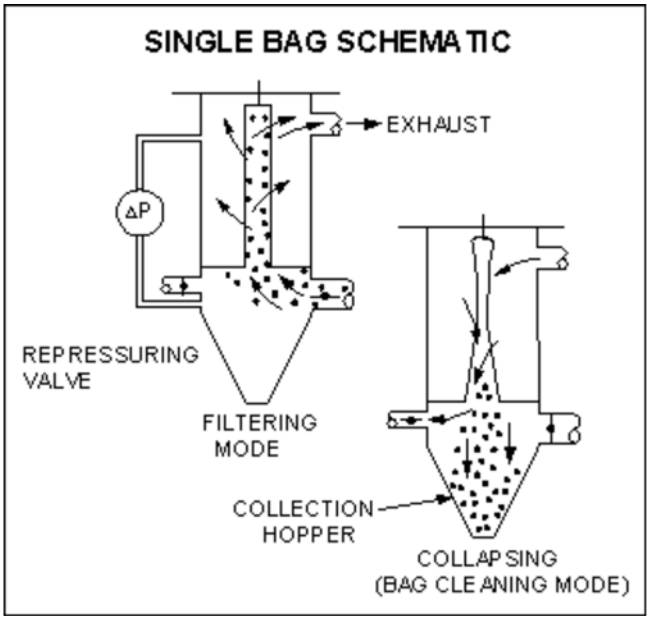
5. Baghouses

Baghouses utilize sieving, impaction, agglomeration, and electrostatic filtration principles to remove solids from a gaseous exhaust stream. Baghouses maximize the filtration area by configuring the fabric filter media into a series of long small-diameter fabric tubes referred to as bags. They are tightly packed into a housing wherein the dust laden air moves across the bag fabric thereby removing it from the gas stream and building up a filter cake which further enhances air cleaning. The filter cake is removed to hoppers by various shaking means. The operating pressure drop across the bags is described by:

Performance & Efficiency Parameters

Pressure drop = $dP = S_eV + KCV^2t$

where; S_e = drag coefficient
V = velocity
K = filter cake coefficient
C = inlet dust concentration
t = Collection running time



Limitations / Advantages / Problems

- High collection efficiencies
- Internal condensation / corrosion
- Over-temperature limitations
- Need for internal inspection / access
- Possible to have variable flow rates
- Plugging / short-circuiting / break-through/ collection media fouling
- Accumulation of flammable gases/ dusts and ignition sources
- Unexpected bag failure due to changes in operating parameters

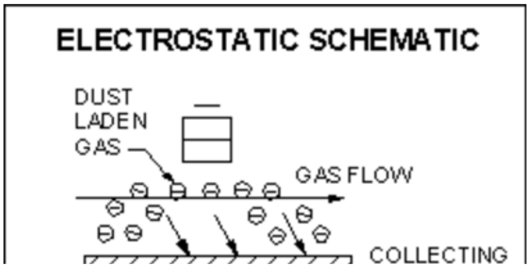
6. ELECTROSTATIC PRECIPITATORS

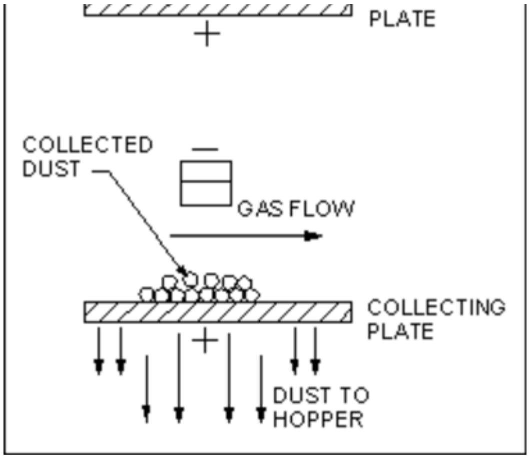
This control device utilizes gaseous ions to charge particles which are then moved through an electric field to be deposited onto charged collection plates. Collected particulate material is then removed by rapping or washing of the plates. To produce the free ions and electric field, high internal voltages are required. Since the collection process does not rely on mechanical processes such as sieving or impaction, but rather electrostatic forces, the internal gas passages within a precipitator are relatively open with small pressure drops and lower energy costs to move the gas stream. High collection efficiencies are possible, but collecting efficiency may drastically change with changes in operating parameters.

Performance & Efficiency Parameters

Collection Eff. % = $1 - e^{-WA/Q}$

where; A = collecting electrode area
Q = volumetric gas flow rate
W = particle drift velocity





and drift vel. = W = $\frac{E_o E_p aC}{(pi)\ n}$

where; E_o = charging field
E_p = collecting field
a = particle radius
C = proportionality constant
n = gas viscosity

Limitations / Advantages / Problems

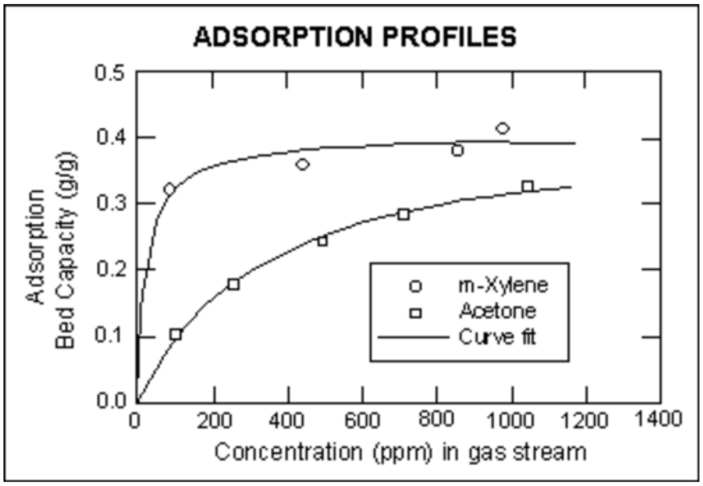
- Large installation space required
- High efficiencies for small particles possible
- Low pressure drops and air moving costs
- High potential for ignition sources
- Re-entrainment, spark-over, back corona problems
- High temperature operation possible
- Susceptible to changes in moisture and resistivity

7. ADSORPTION

The process of adsorption involves the molecular attraction of gas phase materials onto the surface of certain solids. This attraction may be chemical or physical in nature and is predominantly a surface effect. Certain materials like activated carbon charcoal possess the large internal surface area and the presence of physical attraction forces to adsorb large quantities of certain gases within their structure. The rate of adsorption is affected by the temperature, concentration, atmospheric pressure, and molecular structure of the gas.

Performance & Efficiency Parameters

The following figure shows typical trends for adsorption.



Limitations / Advantages / Problems

- Can recover contaminant for reuse
- May require multiple units; one in service, one in recycle mode
- Few internal parts, controls, and alternating cycler required
- Potential for step-function change in efficiency
- Normal operation at ambient temperature
- Flammable hydrocarbons
- Chemical mixture problems

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