Welcome to

Energy Production Systems Engineering

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UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC

Session 10: Environmental Controls

Spring 2012

Plant Environmental Control Systems

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Plant Environmental Control Systems

Power plant Environmental Controls
All emissions – water, air, solid waste
This presentation on atmospheric emission control
Particulate Emission Control
Nitrogen Oxides Emission Control
Sulfur Dioxide Emission Control
Combination NOX SO2 removal
Hazardous Air Pollutant control
Continuous Emissions Monitoring

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Plant Environmental Control Systems

Particulate Emission Control –
Bottom ash – bottom of boiler
Economizer ash removed after economizer smaller
Fly Ash – removed at electrostatic precipitator or fabric filter

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Electrostatic Precipitator – TR set – HV DC between HV electrode and grounded plate

Particles collect on plates – rappers mechanically vibrate plate and remove particles

Precipitator cross section large to reduce velocity

Increases treatment time.

TR set 25kV to 125kV

Rapping Systems – hammers, vibrators, dropped weights

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Resistivity = measure of how easily the ask acquires electric charge

Varies with Moisture, SO3, chemical composition, temperature.

For low sulfur coal, add SO3 to reduce resistivity.

Weighted wire or pipes as electrodes

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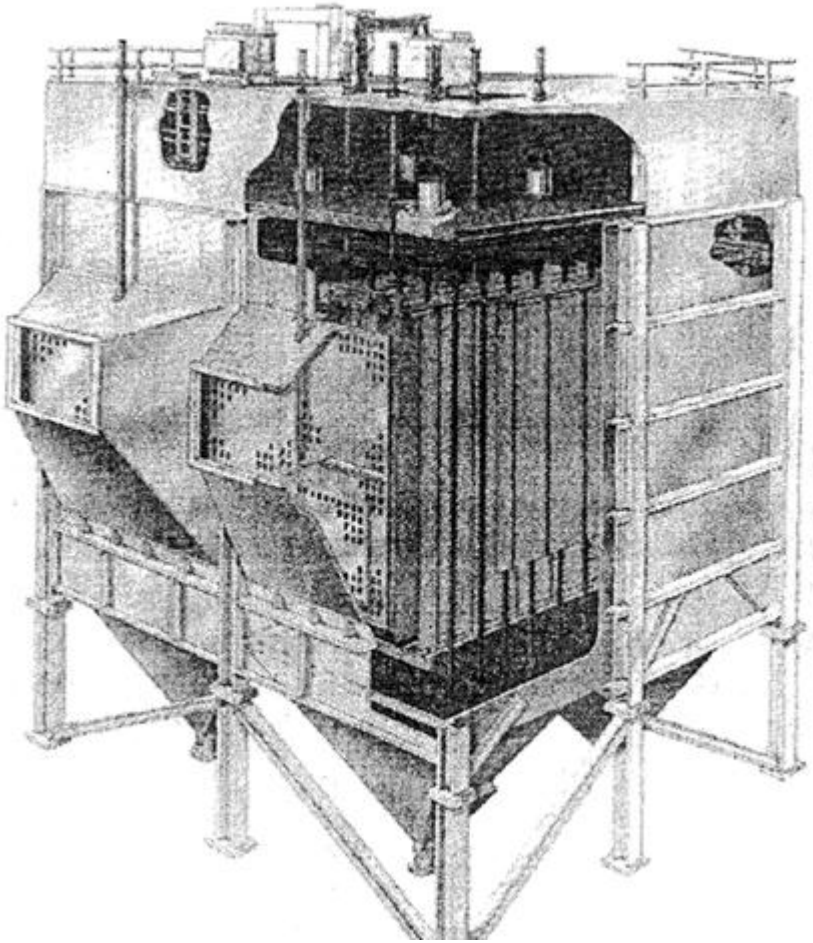
Typical Precipitator



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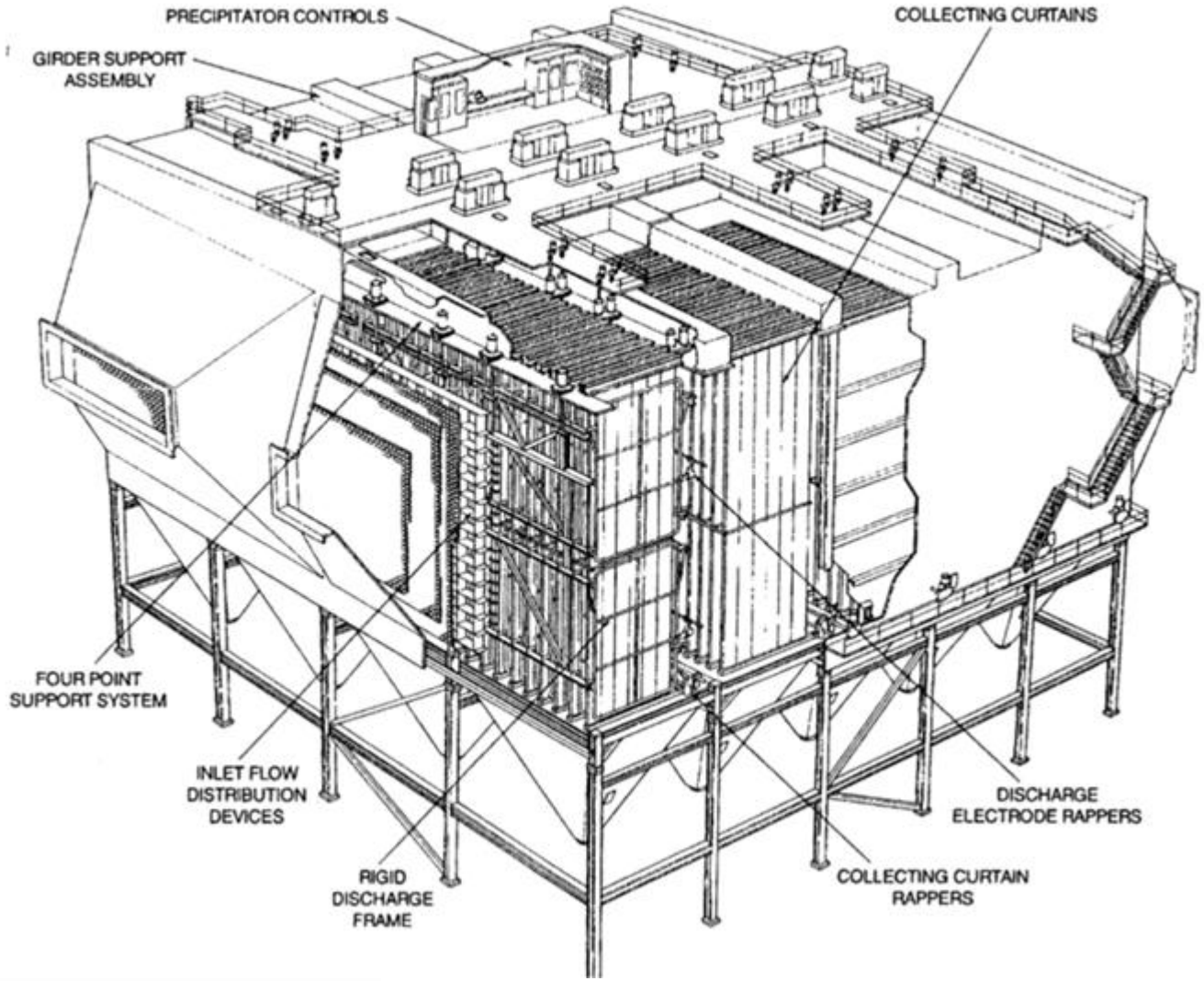

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Fabric Filters

Filter media sewn into cylindrical tubes (bags)

Reverse gas fabric filter

or pulse jet cleaning type.

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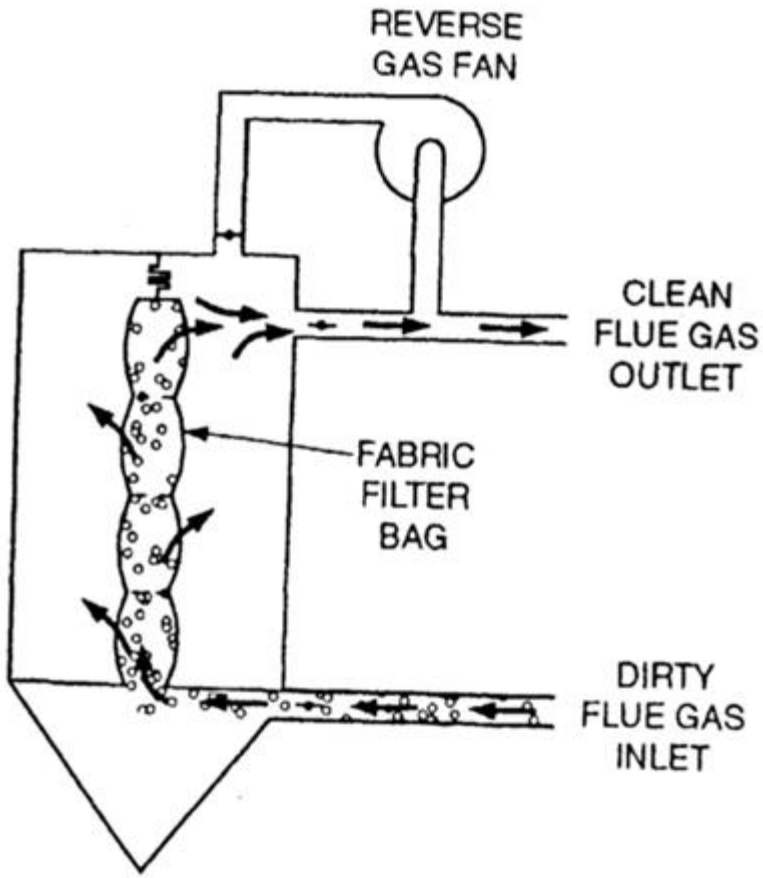
Reverse
Gas
Fabric
Filter
Operating
Cycle



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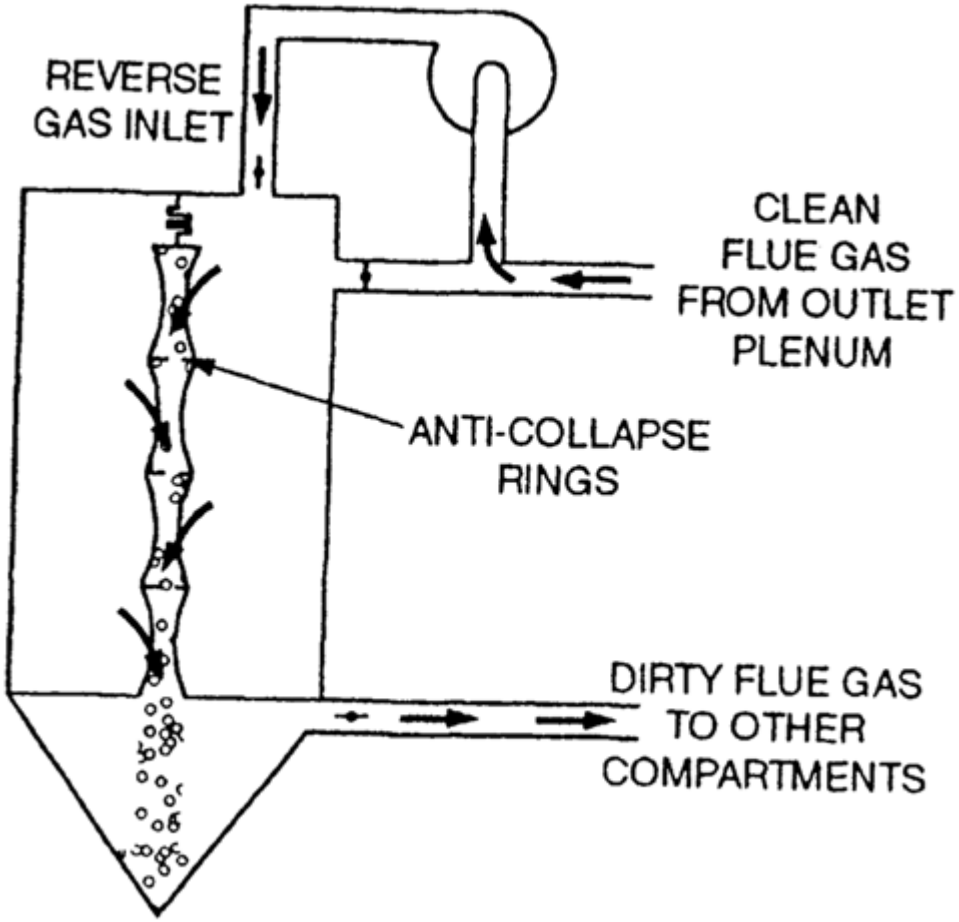
Cleaning Cycle



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Pulse Jet Fabric Filter
Tolerates higher velocity
Cleaned more thoroughly
Smaller footprint for same air flow

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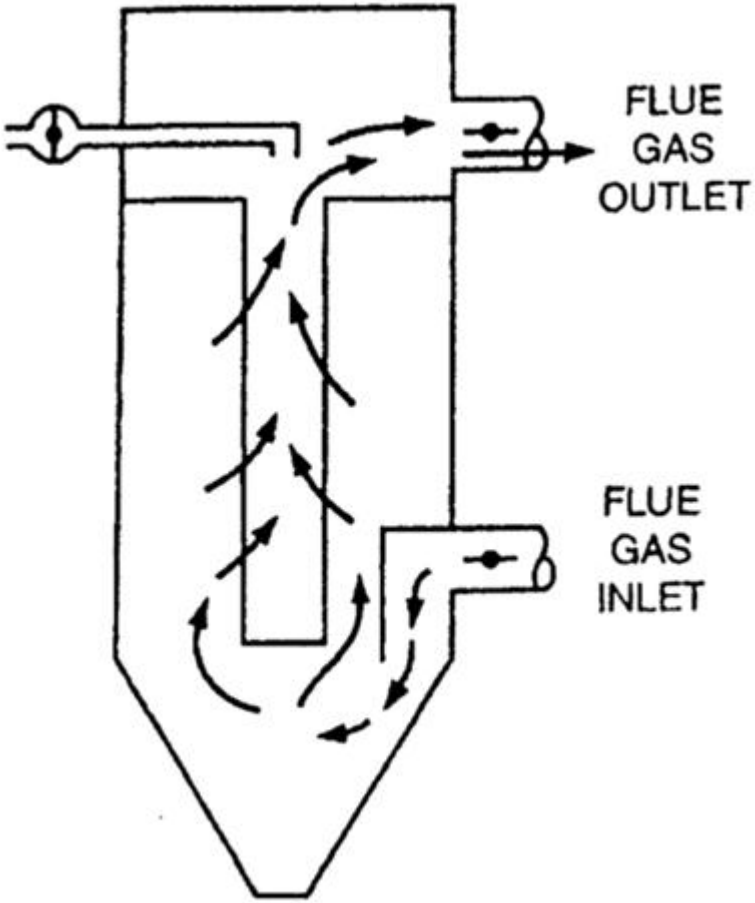
Plant Environmental Control Systems

Pulse
Jet
Fabric
Filter
Filtering



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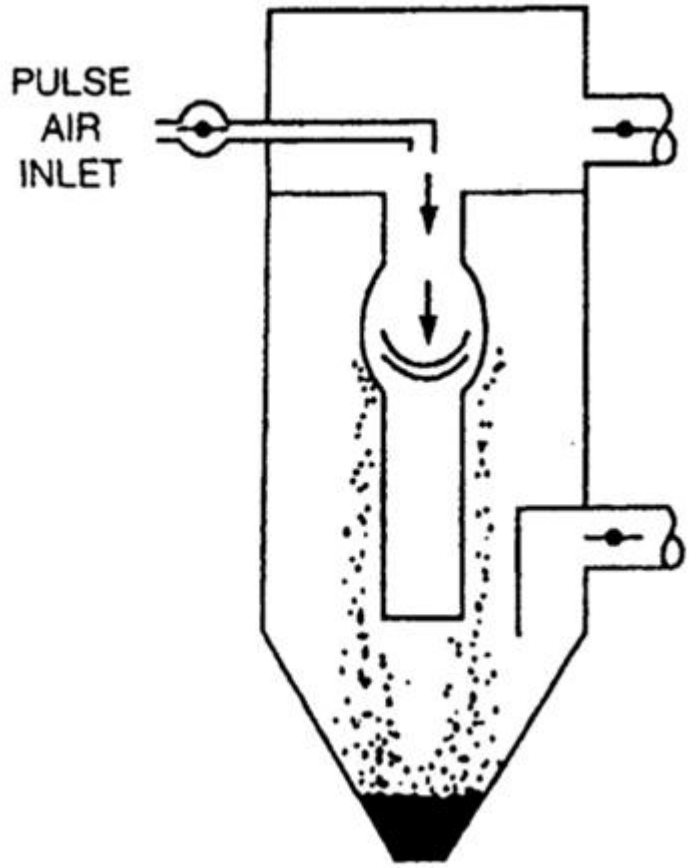
Online
Cleaning
Cycle



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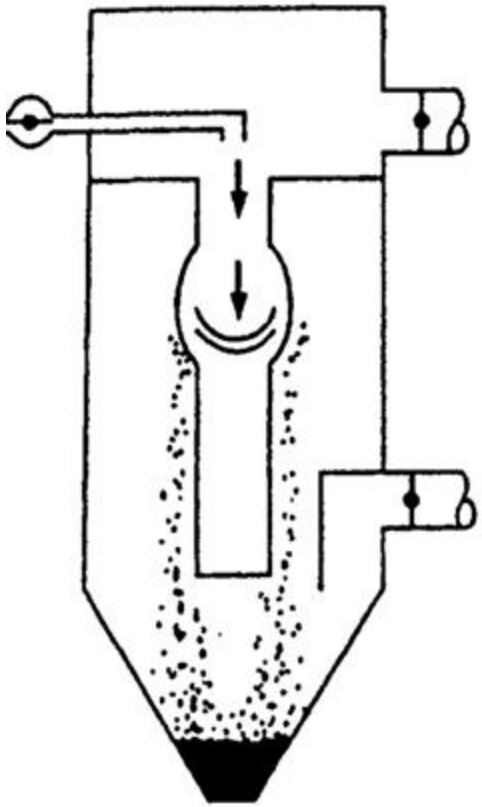
Offline
Cleaning
Cycle



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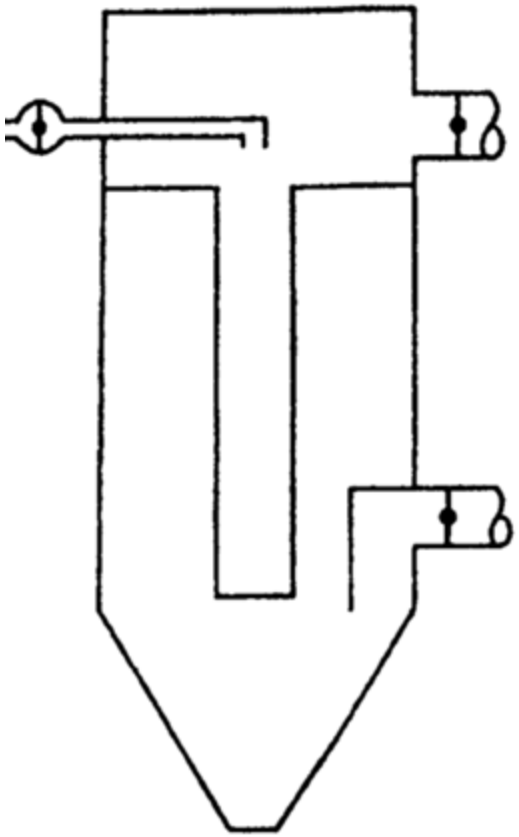
Isolated for Maintenance



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Pulse
Jet
Fabric
Filter
Filtering

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Alternate Particulate Control Technologies

Cyclone Collectors – Uses centrifugal force to separate fly ash

Wet Venturi Scrubber – Use liquid to capture fly ash. Flue gas velocity accelerates in venturi where water droplets are used to collect ash.

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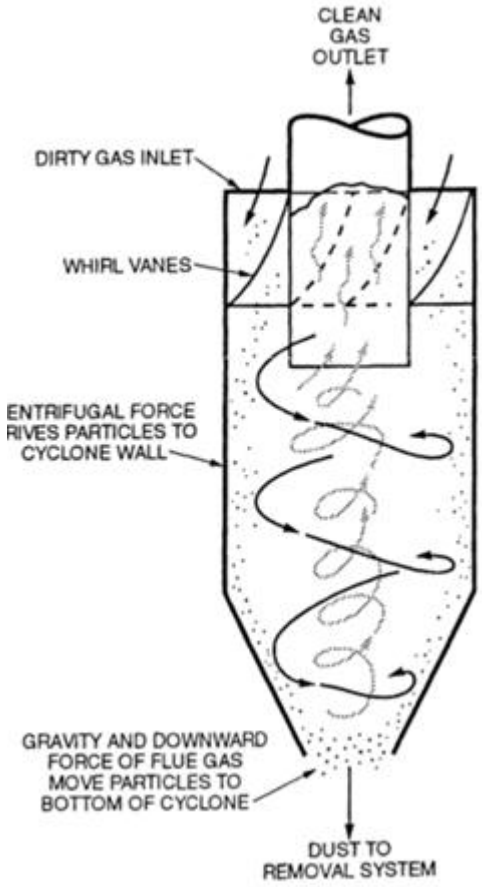
Cyclone Separator



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Nitrogen Oxides Emissions Control

90% NO, 10% NO2

Nitrogen in air (thermal NOx) 25%

Nitrogen in fuel (fuel NOx) 75%

Low temperature (thermal NOx formation)

Control Fuel / Air ratio (fuel NOx formation)

Combustion control and/or post combustion control

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Combustion Control

Reduce temperature
Reduce Oxygen concentration
Reduce reaction time in Oxygen rich, high temp condition
Low NOx burners – 2 separate registers 2 air paths

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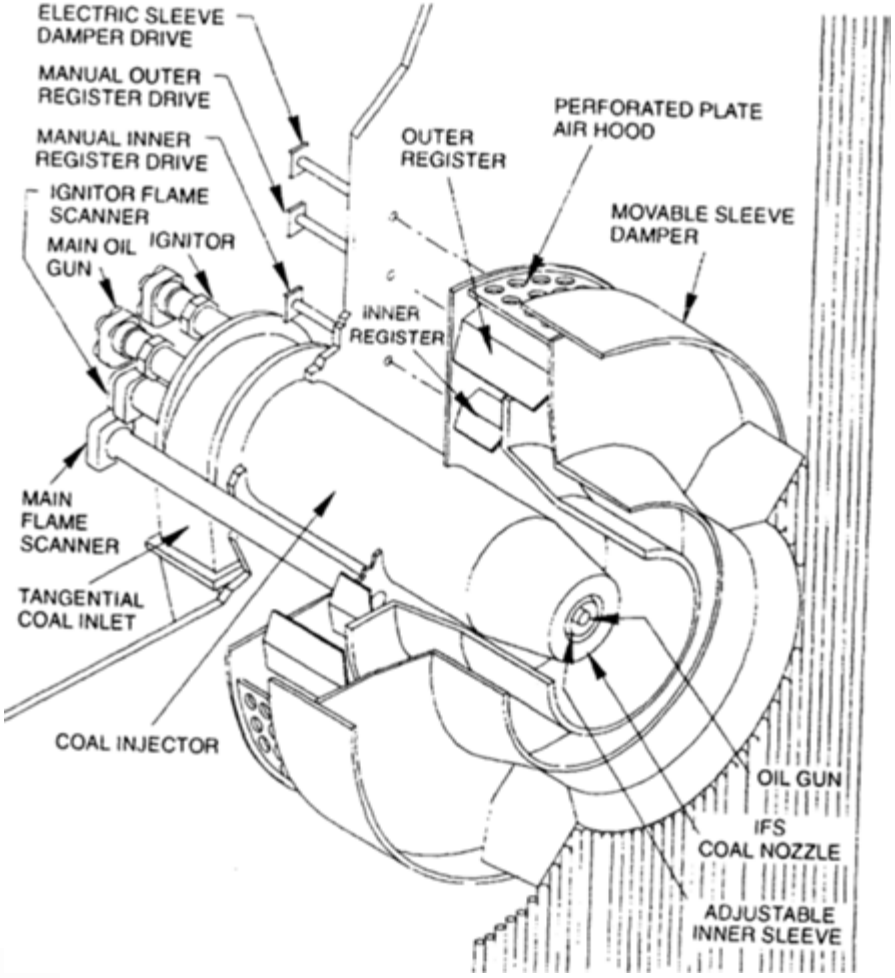
Internal Fuel
Staged
Low NOx
Burner



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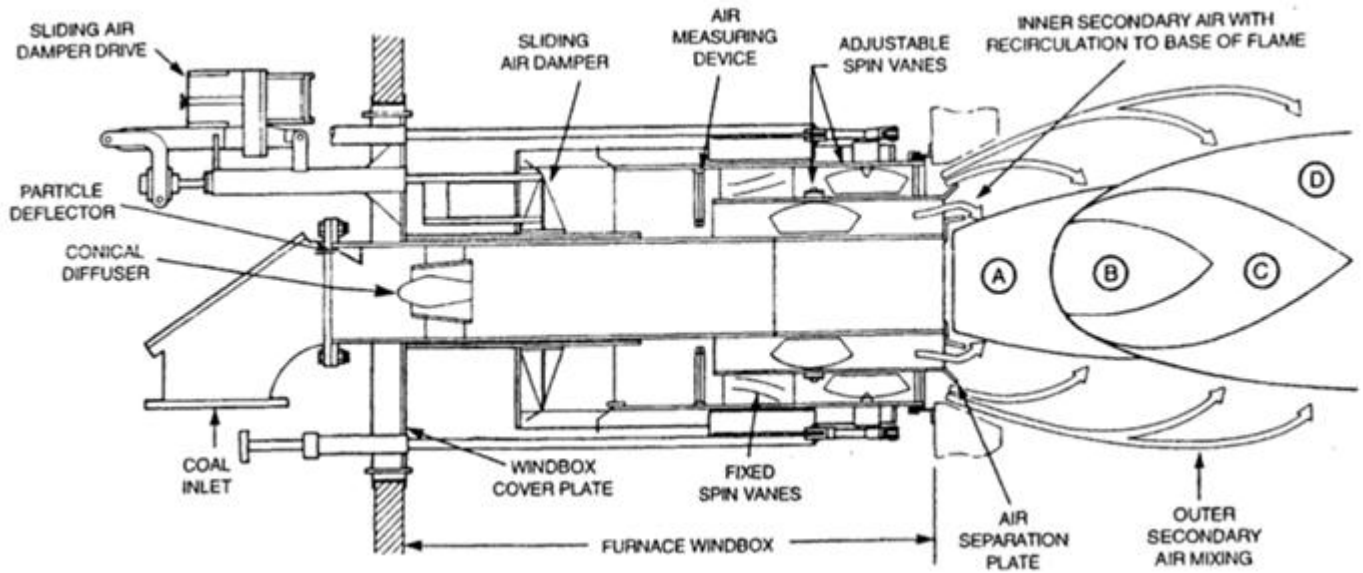
Low NOx burner

A – High Temperature fuel rich zone

B – Production of reducing species zone

C – NOx decomposition zone

D – Char oxidizing zone



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Corner Fired System
LNCFS – Low NOx Concentric Firing System (retrofits)
PM – pollution minimum system (new)
LNCFS – auxiliary air directed at 25O of air/coal stream thereby reducing air in fuel stream
OFA – overfired air provides vertical air staging over furnace height.
PM splits fuel and air stream into two, one fuel rich, one fuel lean.

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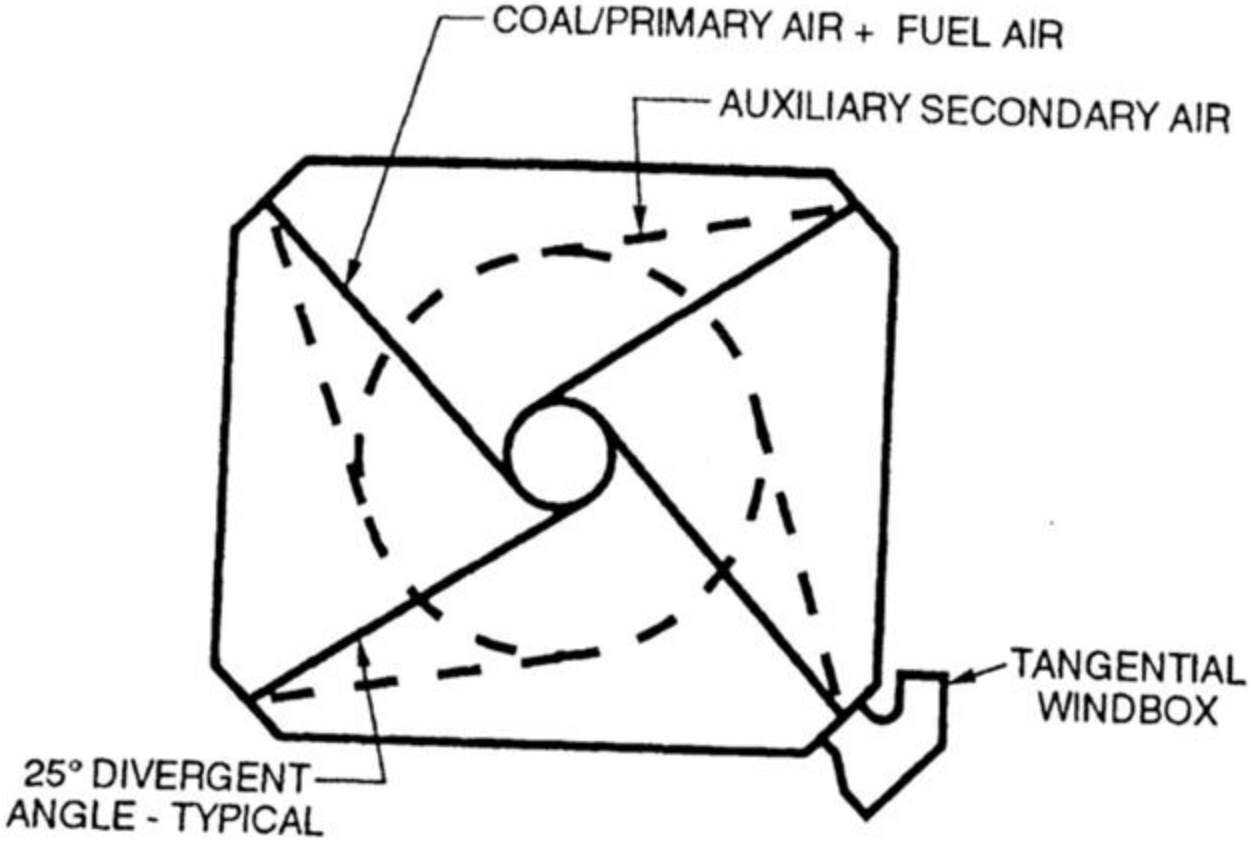
LNCFS (Auxiliary air)



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CT NOx control

Reduction of flame temperature using

Steam

Water

N2

Premixing of fuel/air upstream of combustion zone

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Post combustion Control – Selective Catalytic Reduction Systems (SCR)

Ammonia and NO react in presence of catalyst to form N2 and H2O

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Desired SCR Reactions (exothermic) as Ammonia and NOX flow over catalyst

$4NO + 4NH_3 + O_2 \text{ –(catalyst)} \rightarrow 4N_2 + 6H_2O + \text{heat}$

$2NO_2 + 4NH_3 + O_2 \text{ –(catalyst)} \rightarrow 3N_2 + 6H_2O + \text{heat}$

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Undesirable SCR Reactions (exothermic) as Ammonia and NOX flow over catalyst

$2SO_2 + O_2 \rightarrow 2SO_3$ (SO_2 oxidation)

$2NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$ (ammonium bisulfate formation)

$2NH_3 + 2SO_3 + H_2O + 0.5O_2 \rightarrow 2NH_4HSO_4$ (ammonium sulfate formation)

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SO2 oxidation increased above 700°F, so SCR temps typically held 650°F to 700°F

No less than 570°F to minimize formation of ammonia salts

For non sulfur fuel, max temp 780°F (vanadium/titanium catalyst)

Ammonium sulfate and bisulfate are salts and can deposit on surfaces downstream.

Ammonia slip may effect reuse of fly ash collected.

Anhydrous ammonia – 100% NH_3

Aqueous – 25% NH_3, 75% H_2O

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SCR Arrangement

High Dust – Catalyst located at the outlet of the economizer and upstream of the air heater

Low Dust – Catalyst located at the outlet of the hot side ESP and upstream of the air heater

Tail End – Catalyst located at the outlet of particulate removal and FGD system and upstream of stack.

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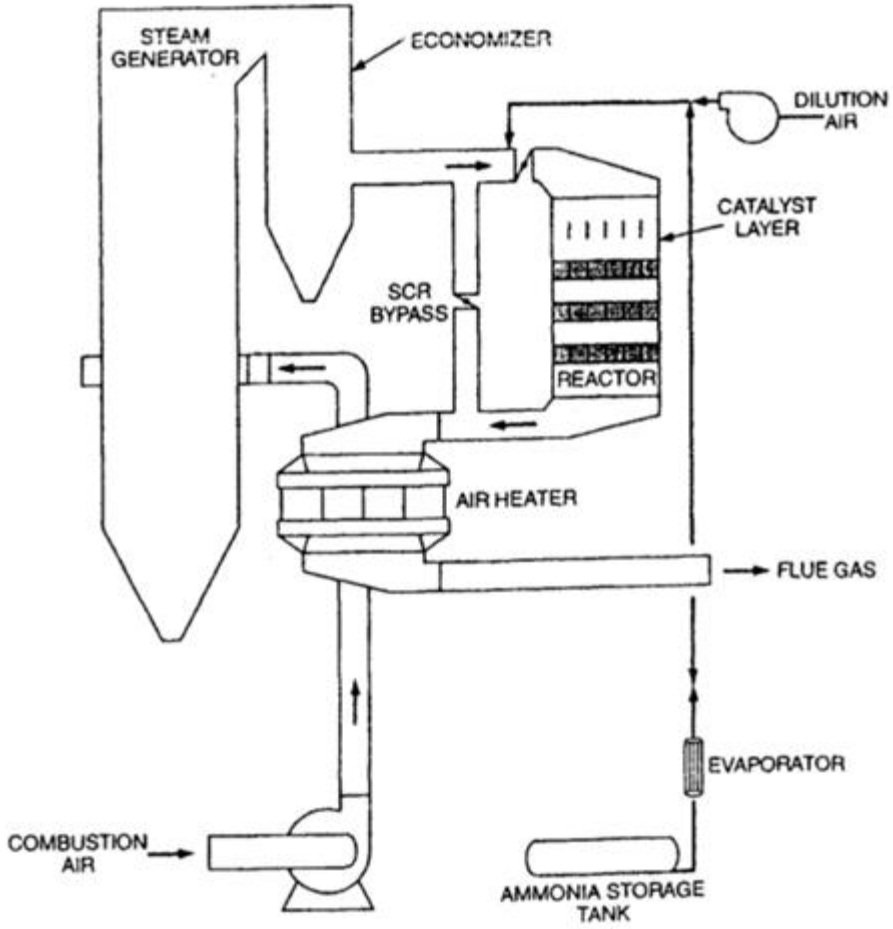
High Dust – SCR Arrangement



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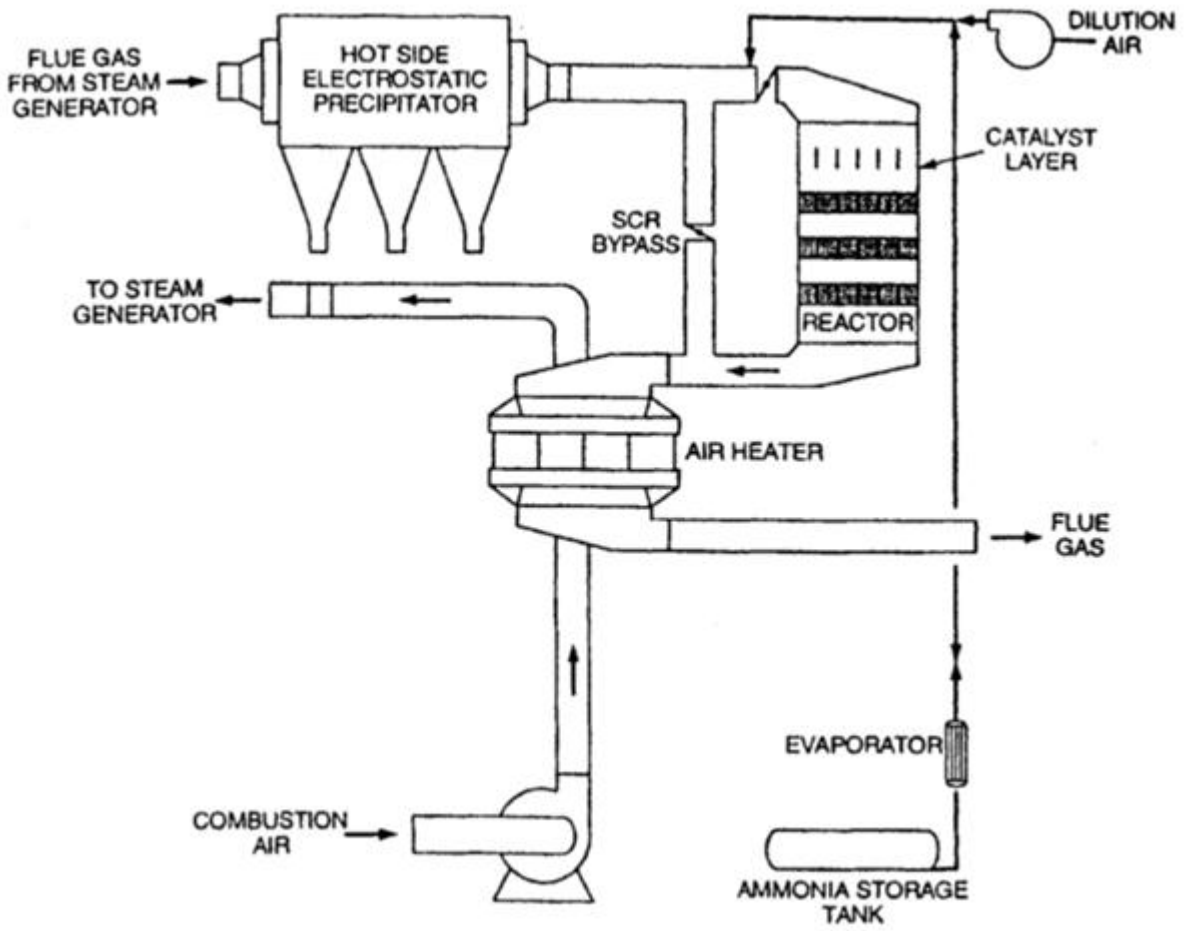
Low Dust – SCR Arrangement



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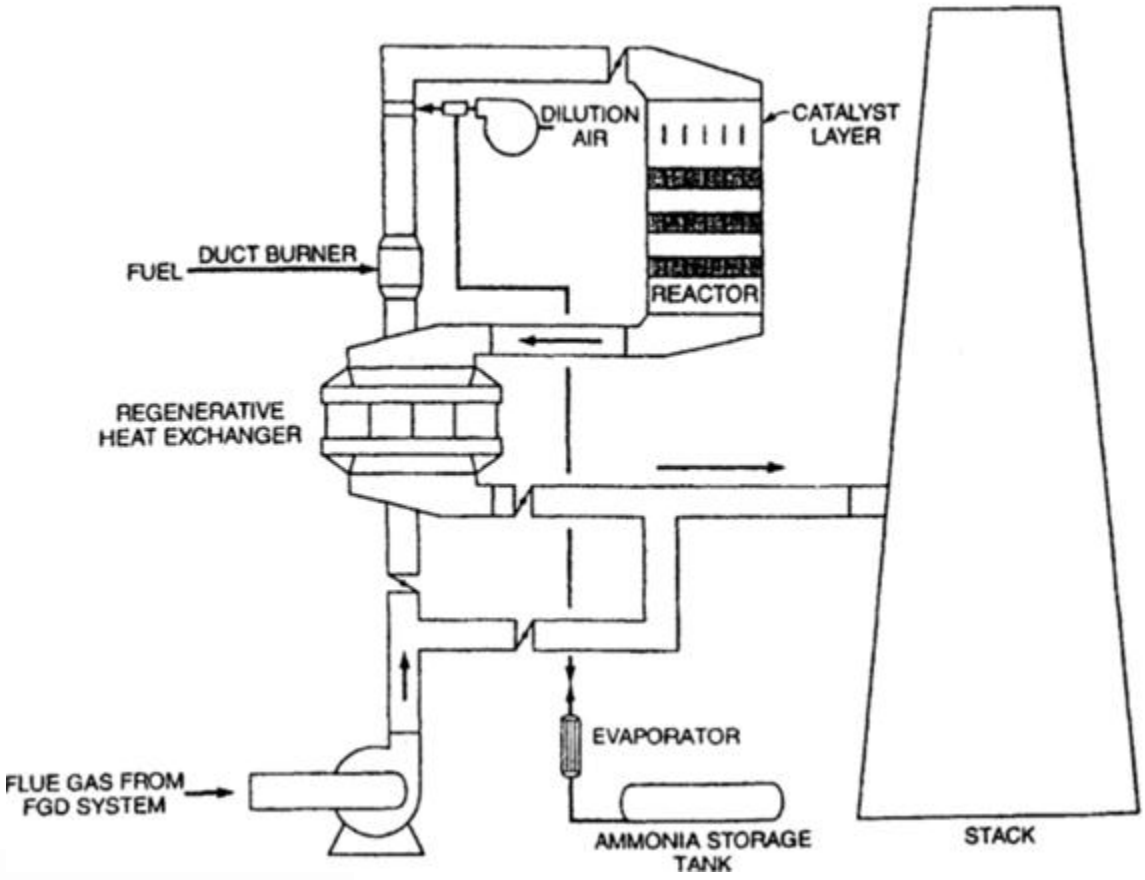
Tail End – SCR Arrangement



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Catalyst poisoned by alkali metals such as:

Arsenic	Lead	Beryllium	Manganese
Cadmium	Mercury	Calcium	Nickel
Chromium	Thorium	Copper	Uranium

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Post combustion Control – Selective Non Catalytic Reduction System (SNCR)

Depend on temperature, gas mixing and reaction time rather than catalyst.

Use ammonia or urea as reagents.

Injection Temperature = 1500^{o}F to 2200^{o}F

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Desired NSCR Reactions (exothermic) as reagent and NOX flow over catalyst

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$ + heat (ammonia)

$4NO + 2(CO(NH_2)_2 + O_2 \rightarrow 4N_2 + 2CO_2 + 4H_20$ + heat (urea)

Note only remove NO not NO2
(does cover about 95% of NOx)

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Undesirable NSCR Reactions (exothermic) as reagent and NOX flow over catalyst

Same as SCR plus:

$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$

(ammonia oxidation to NO)

$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$

(ammonia thermal decomposition)

$2NH_3 + 2O_2 \rightarrow N_2O + 3H_2O$

(nitrous oxide emission

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Sulfur Dioxide Emission Control

Dry Furnace Sorbent Injections (FSI)
Limestone forms Calcium oxide (CaO) (calcination) and reacts with SO_2 and Oxygen to form calcium sulfate $CaSO_4$ (Sulfation)
Following are equations of reaction depending on if Limestone, dolomite, lime, or hydrated lime are reagents

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Desulfurization

Limestone

$$CaCO_3 \rightarrow CaO + CO_2 \text{ (calcination)}$$

$$CaO + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaSO_4 \text{ (sulfation)}$$

Dolomitic limestone

$$CaCO_3 \cdot MgCO_3 \rightarrow CaO \cdot MgO + 2CO_2 \text{ (calcination)}$$

$$CaO \cdot MgO + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaSO_4 \cdot MgO \text{ (sulfation)}$$

Quick lime

$$CaO + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaSO_4 \text{ (sulfation)}$$

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Hydrated lime (calcium hydroxide)

$$Ca(OH)_2 \rightarrow CaO + H_2O \text{ (calcination)}$$

$$CaO + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaSO_4 \text{ (sulfation)}$$

Hydrated dolomitic lime (dolomitic hydroxide)

$$Ca(OH)_2 \cdot Mg(OH)_2 \rightarrow CaO \cdot MgO + 2H_2O \text{ (calcination)}$$

$$CaO \cdot MgO + SO_2 + \tfrac{1}{2}O_2 \rightarrow CaS0_4 \cdot MgO \text{ (sulfation)}$$

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Post combustion – Wet scrubbing

1. Forced Oxidized Wet Limestone
2. Magnesium Enhanced Wet Lime
3. Seawater
4. Ammonium Sulfate

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Wet FGD Systems – Comparison of Attributes

	Forced Oxidized Wet Limestone	Magnesium-Enhanced Wet Lime	Seawater	Ammonium Sulfate
Capital cost	Medium	Low	High	High
Industry experience	High	High	Low	Very low
Reagent cost, $/lb SO_2 removed	Medium	High	Low	High
L/G ratio	50–150	20–70	30–130	Not available
Byproduct dewatering	Low	High	None	Medium
Byproduct management	Disposal to revenue producer	Disposal only	Disposal only	Revenue producer
Maximum removal efficiency achievable, %	95–98	98–99	To 98	To 99
Maintenance requirements	Medium	Medium	Low	To be determined

*Information is general in nature based on vendor and project data. These FGD system attributes should be comparatively evaluated in regard to the specific site and the total plant design.

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Forced Oxidized Wet Limestone

Ball Mill crush limestone and mix with water.

Slurry pumped into absorber tower where slurry mixes with gas.

Forced Oxidation compressors inject air into reaction tank to convert calcium sulfite ($CaSO_3$) into gypsum ($CaSO_4*2H_2O$)

Mist eliminators remove slurry droplets from gas on exit of tower

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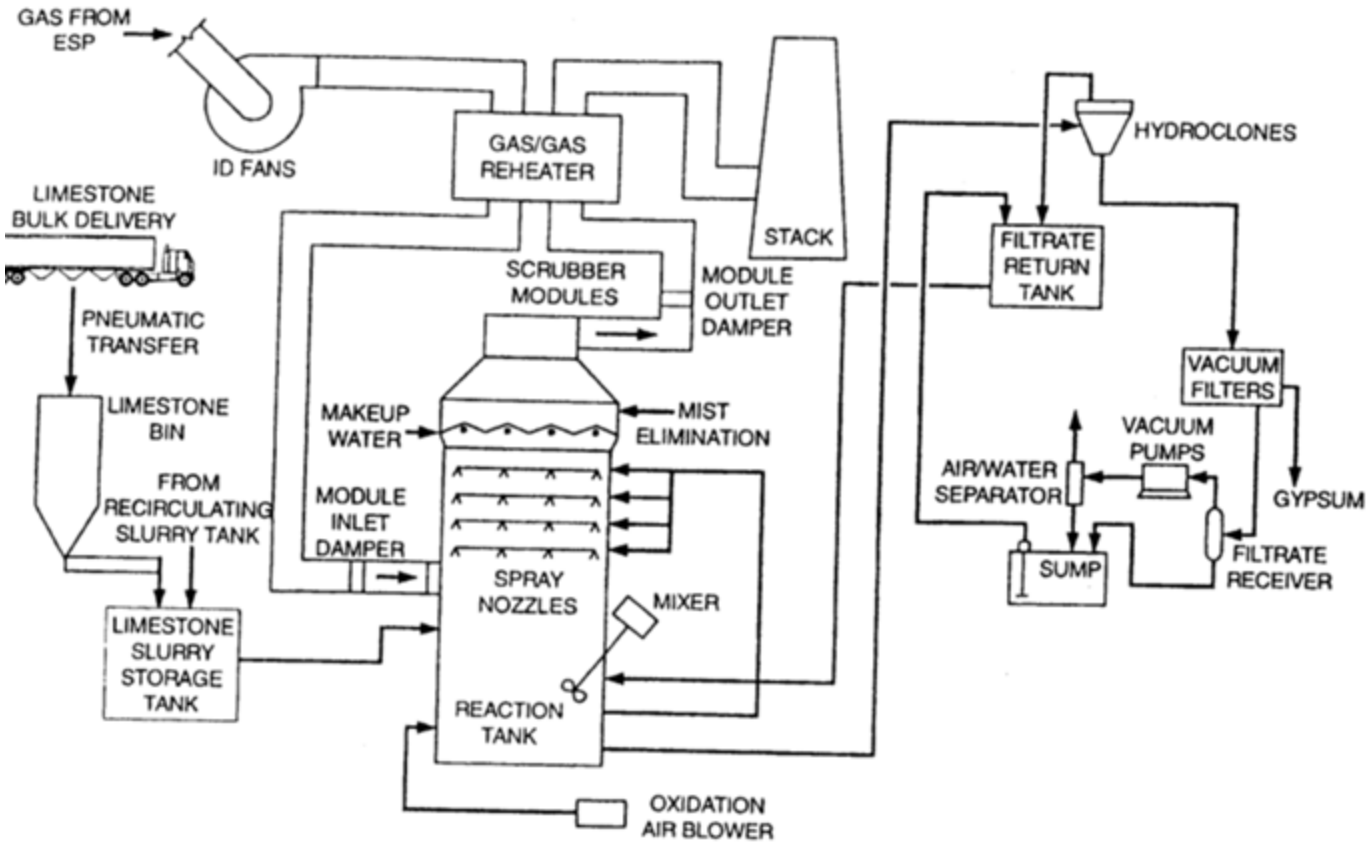
Wet limestone FGD system



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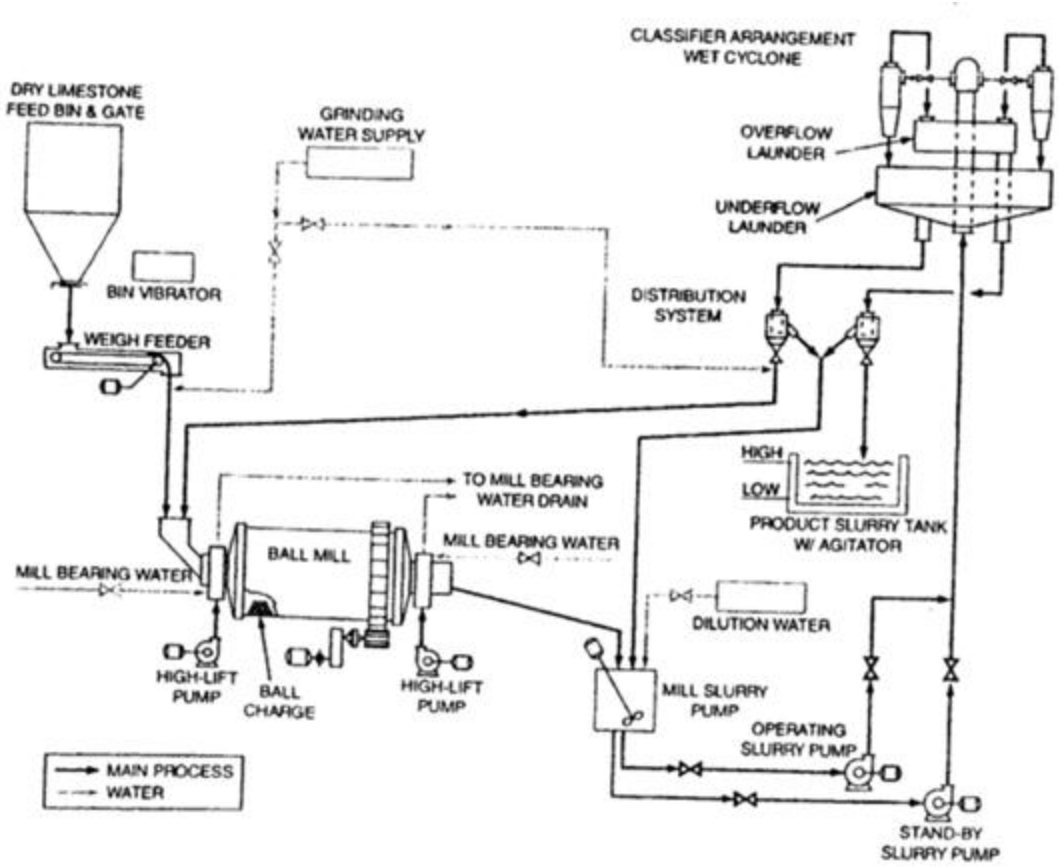
Flow diagram for wet limestone grinding system



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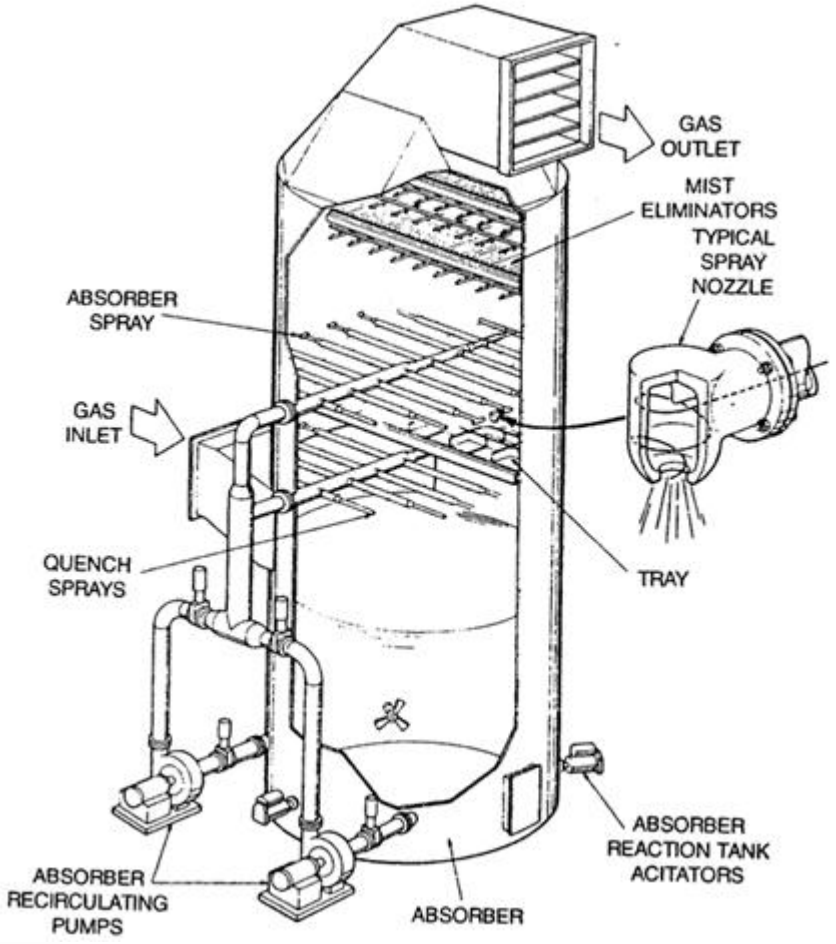
Absorber
cutaway view



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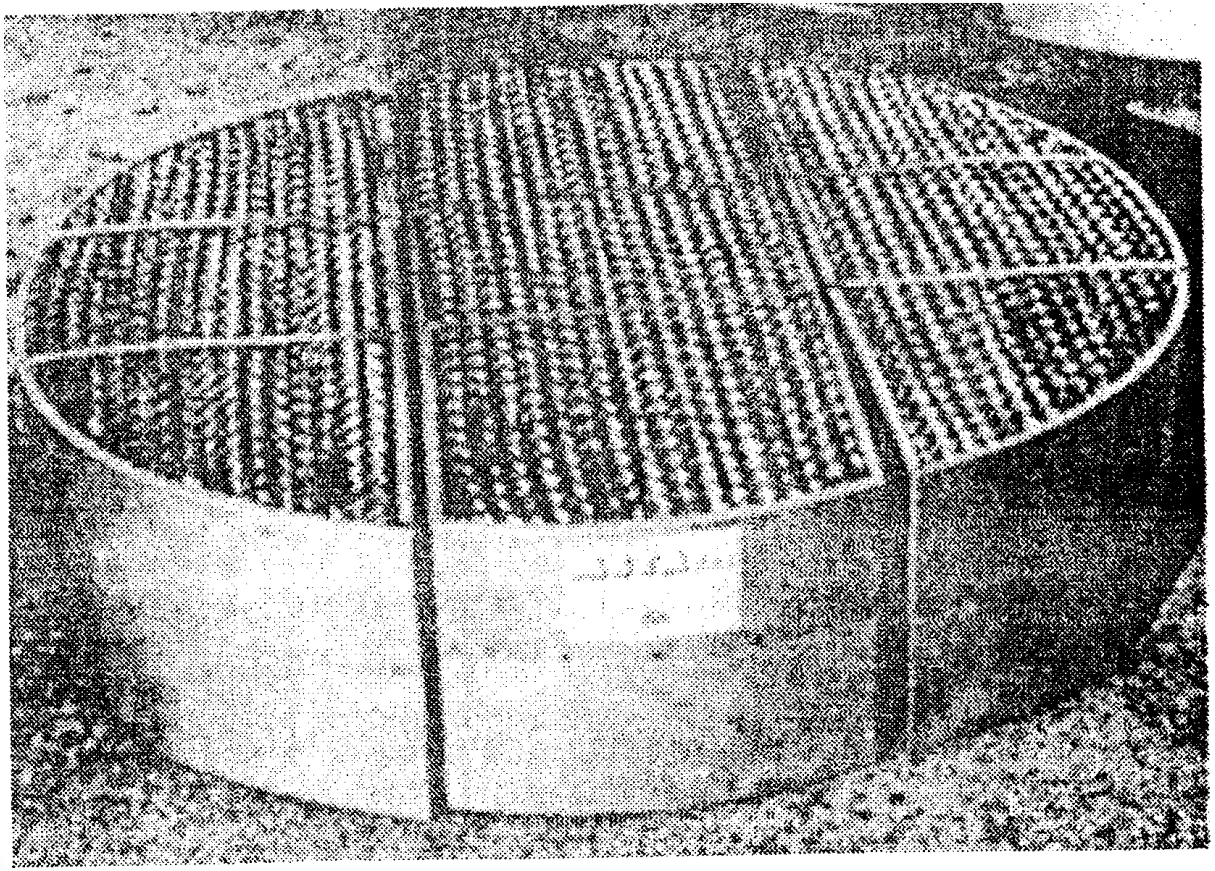
Counter flow mist eliminator



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Magnesium enhanced process
Higher removal efficiency
Absorber tower height less
Pumping head lower
Required Lime to Gas ratio less

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Plant Environmental Control Systems

Seawater and Ammonia are emerging technology

Seawater injection into absorber tower to scrub SO2

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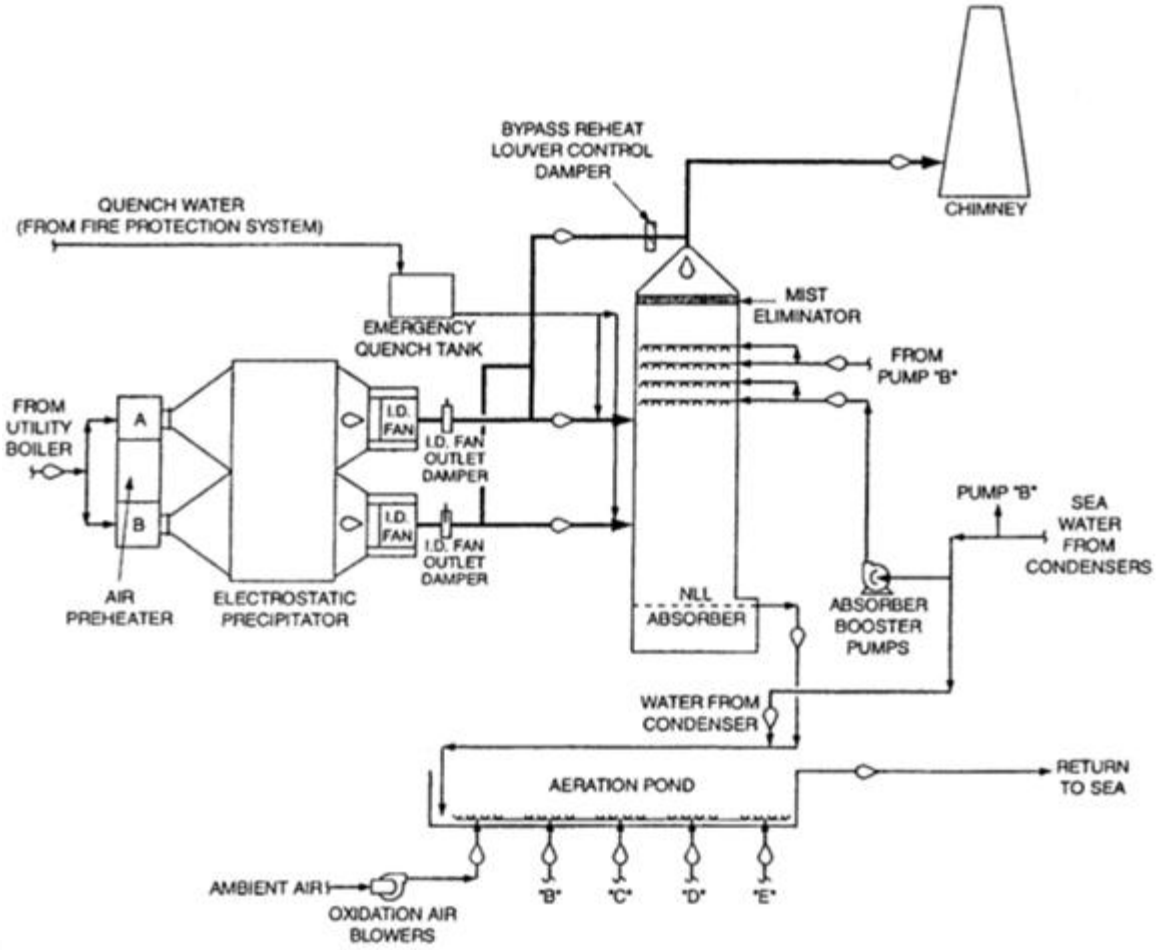
Seawater scrubber PFD



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Ammonia scrubbing

Very high efficiency

Resalable ammonium sulfate fertilizer byproduct

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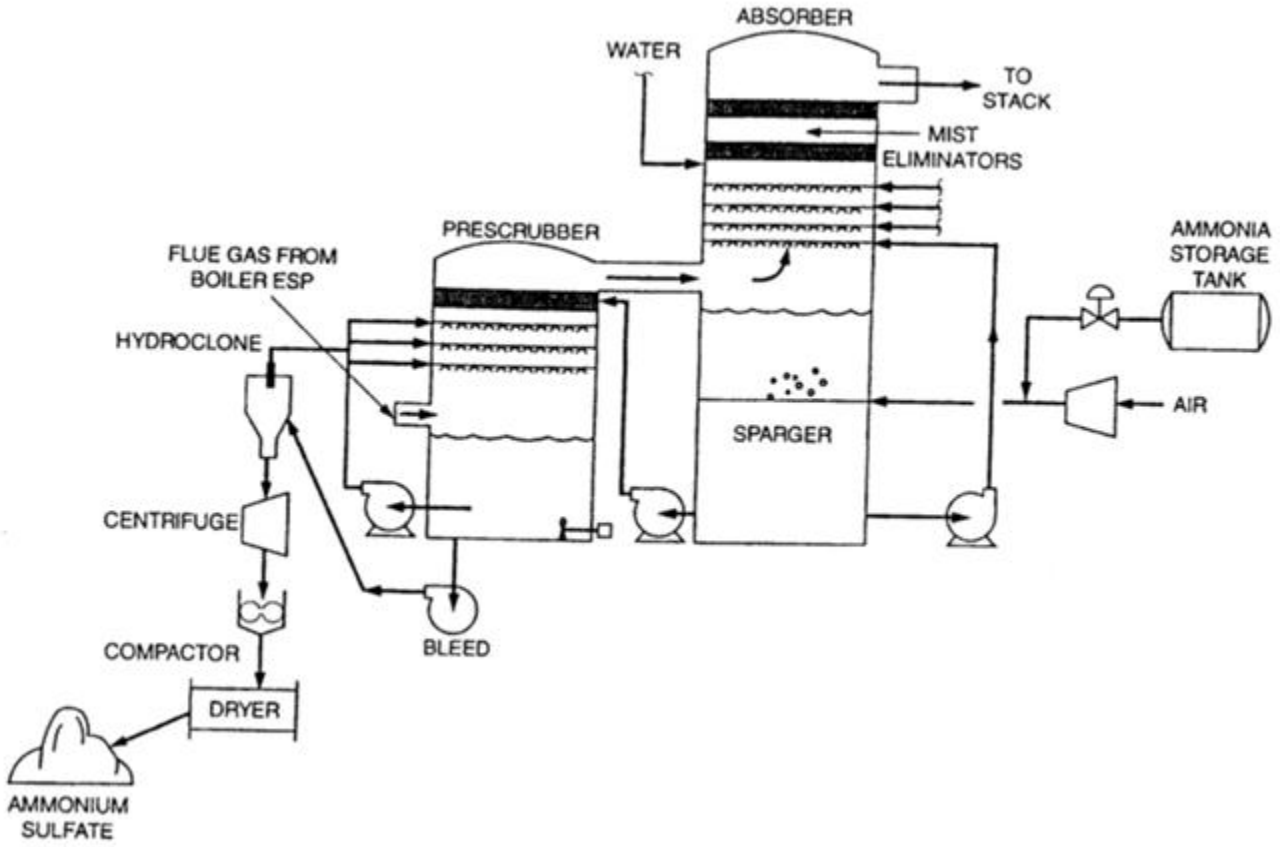
Plant Environmental Control Systems

Ammonium sulfate PFD



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Plant Environmental Control Systems

Semidry Scrubbing

$Ca(OH)_2$ contacts gas as slurry and dried before exit.

Benefits:

Lower energy usage & water consumption

FGD byproducts dry

Reduced slurry requirements

Less complex system

Disadvantage

Greater reagent quantities needed and more solids produced

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Plant Environmental Control Systems

Continuous Emission Monitoring System (CEMS)
In situ systems – monitor the flue gas at the conditions present in the stack at the monitoring location
Extractive systems – draw gas sample to remote location.
Absorption Spectroscopy – scattering of light
Opacity Monitoring – visible light
Gas Monitoring IR Analysis
Luminescence Spectroscopy – light emission of molecules when excited
Electro-analytical – chemical reactions

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End of Environmental Control System

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End of Session 10: Environmental Controls

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