


Welcome to

Energy Production Systems Engineering



Thomas Blair, P.E.
 USF Polytechnic – Engineering
 tom@thomasblairpe.com

USF UNIVERSITY OF SOUTH FLORIDA POLYTECHNIC

**Session 10:
 Environmental Controls**

Spring 2012

Plant Environmental Control Systems

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 Thomas Blair, P.E.
 (tom@thomasblairpe.com)

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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Plant Environmental Control Systems

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

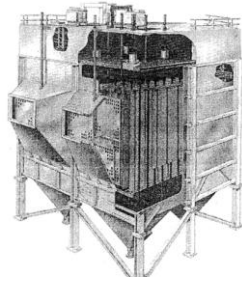
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Plant Environmental Control Systems

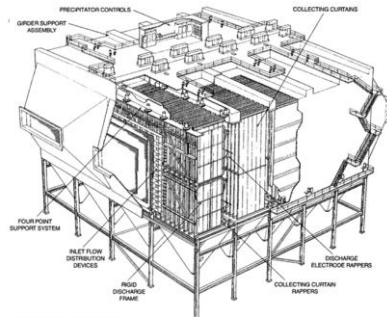
Typical Precipitator



7



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Plant Environmental Control Systems

Fabric Filters
Filter media sewn into cylindrical tubes (bags)
Reverse gas fabric filter
or pulse jet cleaning type.

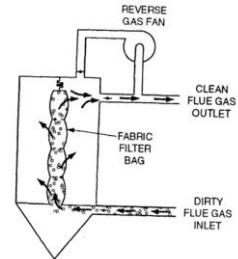
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Plant Environmental Control Systems

Reverse
Gas
Fabric
Filter
Operating
Cycle



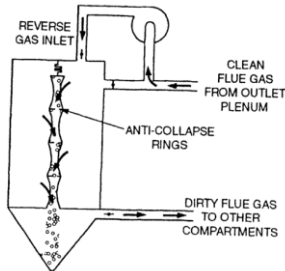
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Plant Environmental Control Systems

Cleaning
Cycle



11



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Plant Environmental Control Systems

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

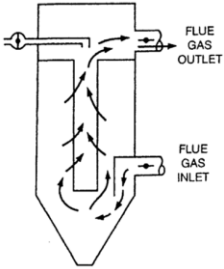
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Plant Environmental Control Systems

Pulse
Jet
Fabric
Filter
Filtering



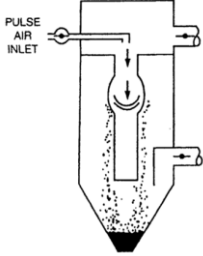
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Plant Environmental Control Systems

Online
Cleaning
Cycle



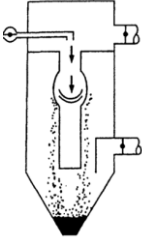
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Plant Environmental Control Systems

Offline
Cleaning
Cycle



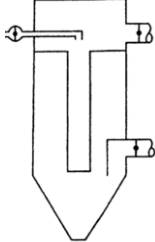
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Plant Environmental Control Systems

Isolated for
Maintenance



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Plant Environmental Control Systems

Pulse
Jet
Fabric
Filter
Filtering

17

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Plant Environmental Control Systems


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.

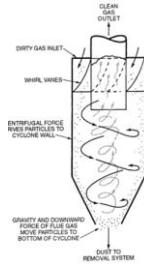
18

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Plant Environmental Control Systems

Cyclone Separator



19



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Plant Environmental Control Systems

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

20



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Plant Environmental Control Systems

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

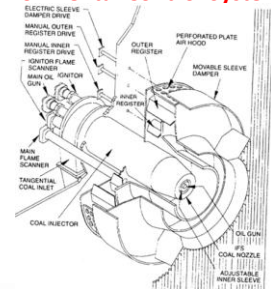
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Plant Environmental Control Systems

Internal Fuel Staged Low NOx Burner



22

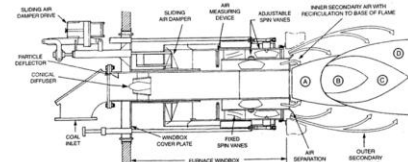


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Plant Environmental Control Systems

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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Plant Environmental Control Systems

Corner Fired System

- LNCFs – Low NOx Concentric Firing System (retrofits)
- PM – pollution minimum system (new)
- LNCFs – auxiliary air directed at 250 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.

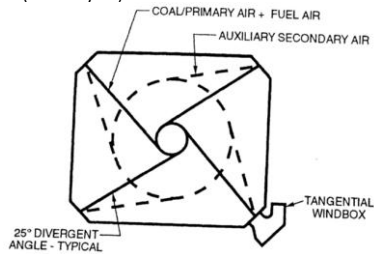
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Plant Environmental Control Systems

LNCFS (Auxiliary air)



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Plant Environmental Control Systems

CT NOx control

Reduction of flame temperature using

Steam

Water

N₂

Premixing of fuel/air upstream of combustion zone

26



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Plant Environmental Control Systems

Post combustion Control – Selective Catalytic Reduction Systems (SCR)

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

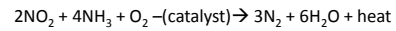
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Plant Environmental Control Systems

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



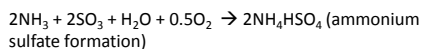
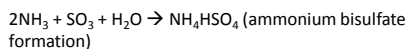
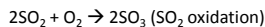
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Plant Environmental Control Systems

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



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Plant Environmental Control Systems

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% NH₃

Aqueous – 25% NH₃, 75% H₂O

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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.

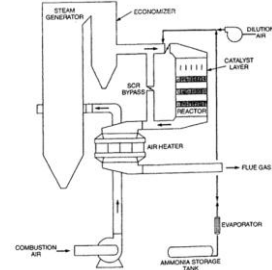


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High Dust – SCR Arrangement

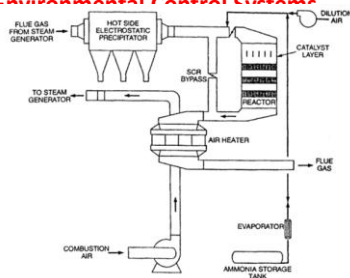


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Low Dust – SCR Arrangement

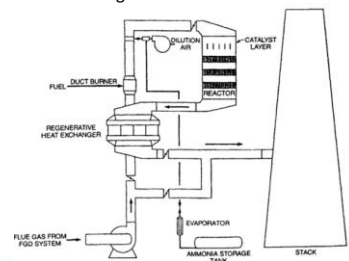


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Tail End – SCR Arrangement



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Catalyst poisoned by alkali metals such as:

- ArsenicLead Beryllium Manganese
- Cadmium Mercury Calcium Nickel
- Chromium Thorium CopperUranium



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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°F to 2200°F

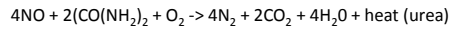
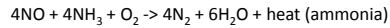


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(tom@thomasblairpe.com)

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Plant Environmental Control Systems

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



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

37

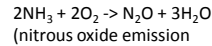
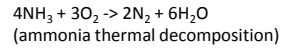
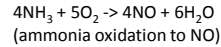


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Plant Environmental Control Systems

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

Same as SCR plus:



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Plant Environmental Control Systems

Sulfur Dioxide Emission Control

Dry Furnace Sorbent Injections (FSI)

Limestone forms Calcium oxide (CaO) (calcination) and reacts with SO₂ and Oxygen to form calcium sulfate CaSO₄ (Sulfation)

Following are equations of reaction depending on if Limestone, dolomite, lime, or hydrated lime are reagents

39

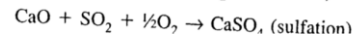
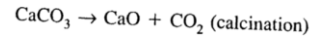


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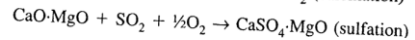
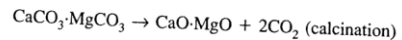
Plant Environmental Control Systems

Desulfurization

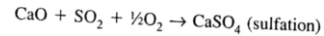
Limestone



Dolomitic limestone



Quick lime



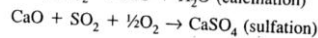
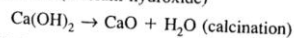
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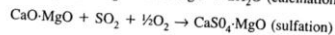
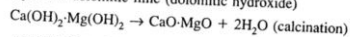
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Hydrated lime (calcium hydroxide)



Hydrated dolomitic lime (dolomitic hydroxide)



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Plant Environmental Control Systems

Post combustion – Wet scrubbing

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

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Plant Environmental Control Systems

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
Range of SO ₂ removed	Medium	High	Low	High
L/D ratio	20-150	20-70	20-130	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	95-99	To 99	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 final plant design.

43



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(tom@thomasblairpe.com)

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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 (CaSO₃) into gypsum (CaSO₄*2H₂O)

Mist eliminators remove slurry droplets from gas on exit of tower

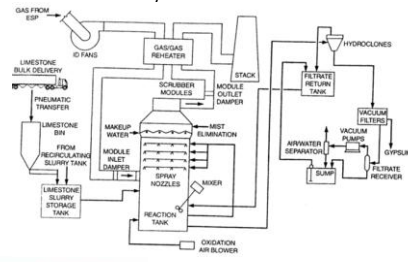
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Plant Environmental Control Systems

Wet limestone FGD system



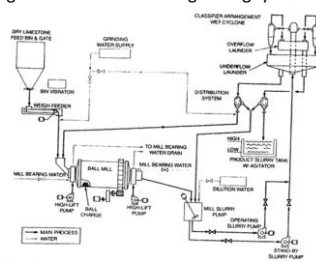
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Plant Environmental Control Systems

Flow diagram for wet limestone grinding system



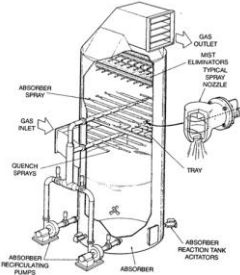
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Plant Environmental Control Systems

Absorber cutaway view



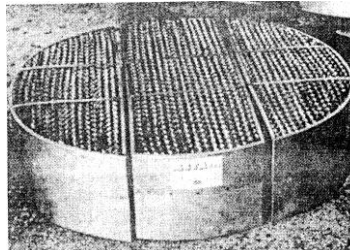
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Counter flow mist eliminator



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Plant Environmental Control Systems

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

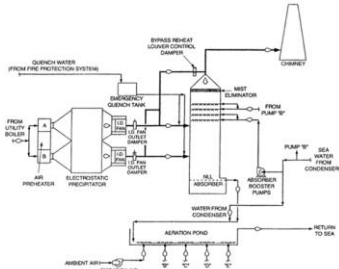
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Seawater scrubber
 PFD



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Plant Environmental Control Systems

Ammonia scrubbing
 Very high efficiency
 Resalable ammonium sulfate fertilizer byproduct

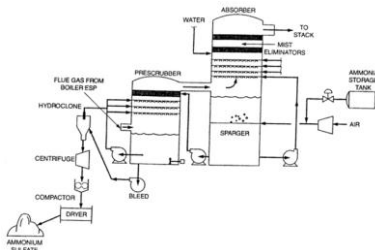
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Ammonium sulfate PFD



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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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 Thomas Blair, P.E.
 (tom@thomasblairpe.com)

End of Environmental Control System



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 Thomas Blair, P.E.
 (tom@thomasblairpe.com)

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Thomas Blair, P.E.
 USF Polytechnic – Engineering
 tom@thomasblairpe.com



End of Session 10:
 Environmental Controls

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