IPRO 303

Failure Prediction Modeling for Power Plant Emission Control Systems

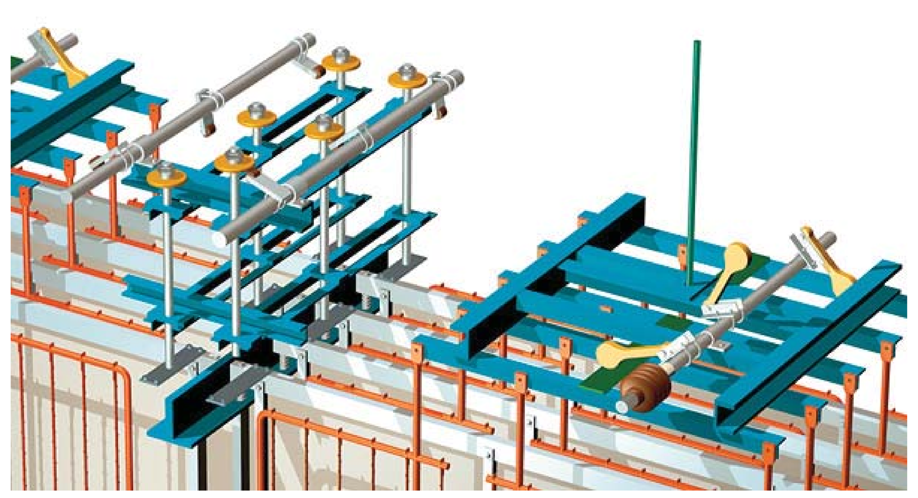
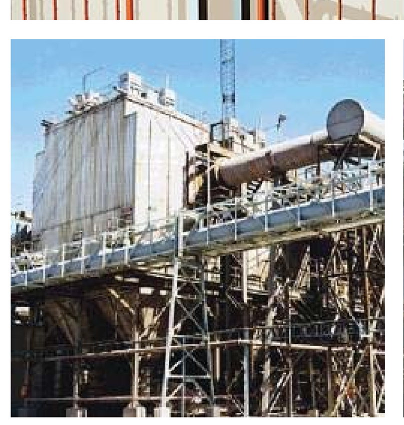
Baghouses




Baghouse are used to remove fly ash from the flue gas stream. Baghouses are primarily used in Europe because the power plants in Europe have a huge pressure differential which is required to pass the gas through the filters. In the states, they are only found at 10% of power plants. Baghouses have a series of filters that filter the air. The three most common types of baghouses are mechanical shaker, reverse air, and reverse jet

photos courtesy: airex-industries, novo-energy.com, usairfiltration.com. sparkdetectioncom

Electrostatic Precipitators


Working of ESP

- Ionization
  This is the initial process of charging the dust particles from any process
- Migration
  Transporting the particles to the collecting surface
- Collection
  Precipitating the particles on to that surface
- Charge Dissipation
  Neutralizing the charged particles to facilitate its collection on the surface
- Particle Dislodging
  Removing the particles from the collecting surface to hopper (hopper is a collecting area for particles).
- Particle Removing
  Putting the particles to its disposal area via a conveyor.

photos courtesy: beth-filter.de, bateman-environmental.com, arb.ca.gov

IPRO Purpose & Objectives

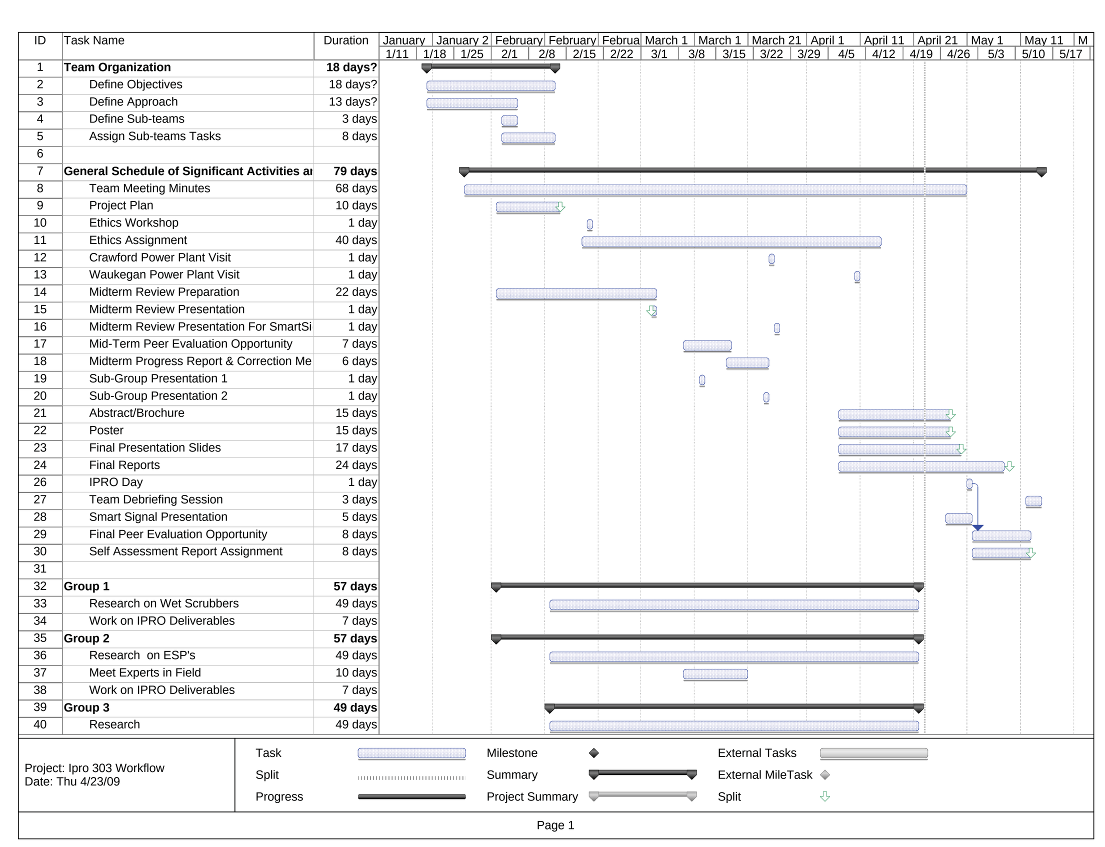
The main goal of IPRO 303 is to investigate how SmartSignal's modeling technology can provide value in detecting problems on environmental systems: The main objectives that SmartSignal would like for the team to investigate are:

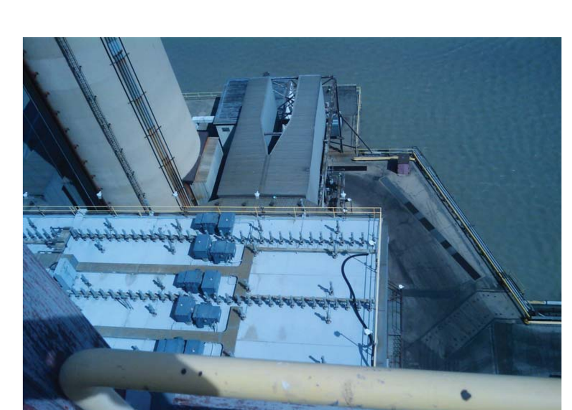
- What are the regulatory drivers?
- What types of systems are being deployed to remove what pollutants?
- How much instrumentation is available on these systems, and what signals are measured (temperature, pressure, chemistry analysis, etc.)?
- What are the failure and performance degradation problems that occur?
- How can the available instrumentation be used to remotely monitor and detect developing problems?

IPRO Approach

- Get a better understanding of how a power plant works as a system
- Visit a power plant to understand how its emission systems function
- Looking at various regulation proposed by the current government
- Study about various pollutants emitted by fossil fuel combustion
- Determine what kinds of sensors are available on air treatment systems
- Look into the reliability of air treatment systems and the various degradation problems associated with them
- Look into sensors and the reliability of water treatment systems.

Gantt Chart



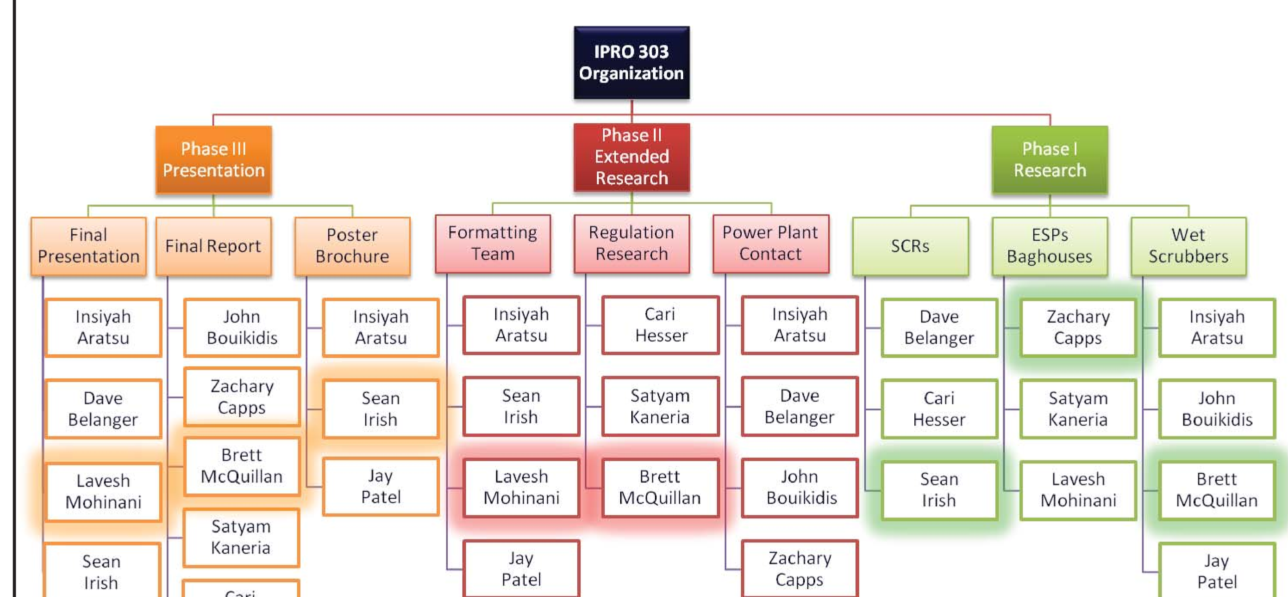



photos from Waukegan power plant visit

Sponsor Information

SmartSignal is a corporation that provides applications to increase equipment performance by means of predictive analysis. SmartSignal's solution analyzes information gathered from equipment in power plants, monitors behavior of the plant as a whole, and identifies the risk of failures. SmartSignal's clients include a number of major power plants nationwide and worldwide. The company is located in Lisle, Illinois.

Team Breakdown



Obstacles and Solutions

- Team Organization
  - Early into the semester we had problems defining a team structure and direction. After some discussion we came to the decision to nominate an overall team leader, then divide the rest of the team into subgroups, as shown above.
- Contacting power plants and equipment manufacturers
  - We did not get in contact with suppliers and power plants because of lack of responses to our attempts. To solve this we tried harder, called more companies and re-wrote e-mail scripts to encourage more re sponses. The effort did yield results, and we eventually did visit two power plants.
- Ethical issues
  - As an IPRO we took the time to look into our ethical issues within the IPRO itself and the more general issues of working in teams.
- Lack of Information
  - Some of the systems that the IPRO was researching were fiarly new technologies, or technologies that had very little documentation. We sloved the problem by contacting manufacturers and getting detailed information from the source.

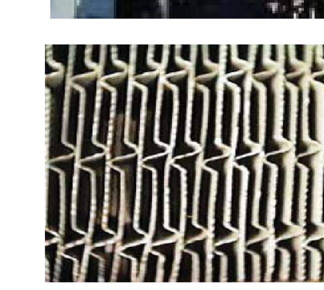
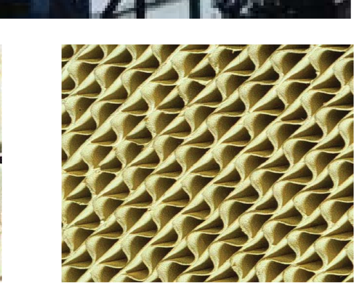
Wet-Scrubbers


Wet scrubbers is a form of pollution control technology that uses scrubbing liquid, water with lime, to remove pollutants from furnace flue gas or from other gas streams. Within the scrubber the polluted gas stream is brought into contact with the scrubbing liquid by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, to remove the pollutants. There are many different types of scrubbers. The type of scrubber selected is based on factors such as the gas temperature, pollutants to be removed, space available, and desired efficiency. Some types of scrubbers are designed to remove particulate pollutants, like the venture scrubbers, and other are designed to mostly remove gaseous pollutants or soluble particulates.

Wet scrubbing is a two step process, the first step being the capture of the gas stream contaminants in the liquid and the second step being the separation of the scrubbing liquid droplets from the gas stream after it leaves the scrubber. This is a very important step in the final collection of the pollutants because poor liquid separation will cause reentrainment of droplets containing the pollutants.

photos courtesy: product-image.tradeindia.com, cbh.net.au

Selective Catalytic Reducers

Selective Catalytic Reduction is a process used to eliminate NOx gases from power plant emissions. The way this happens is Ammonia (or Urea) is injected into the flue gas within a temperature range of about (600 to 750 degrees Fahrenheit), upstream of a catalyst. Subsequently, as the flue gas contacts the SCR catalyst, NOx is chemically reduced to nitrogen and water.

photos courtesy: Babcock Power, apiconst.com

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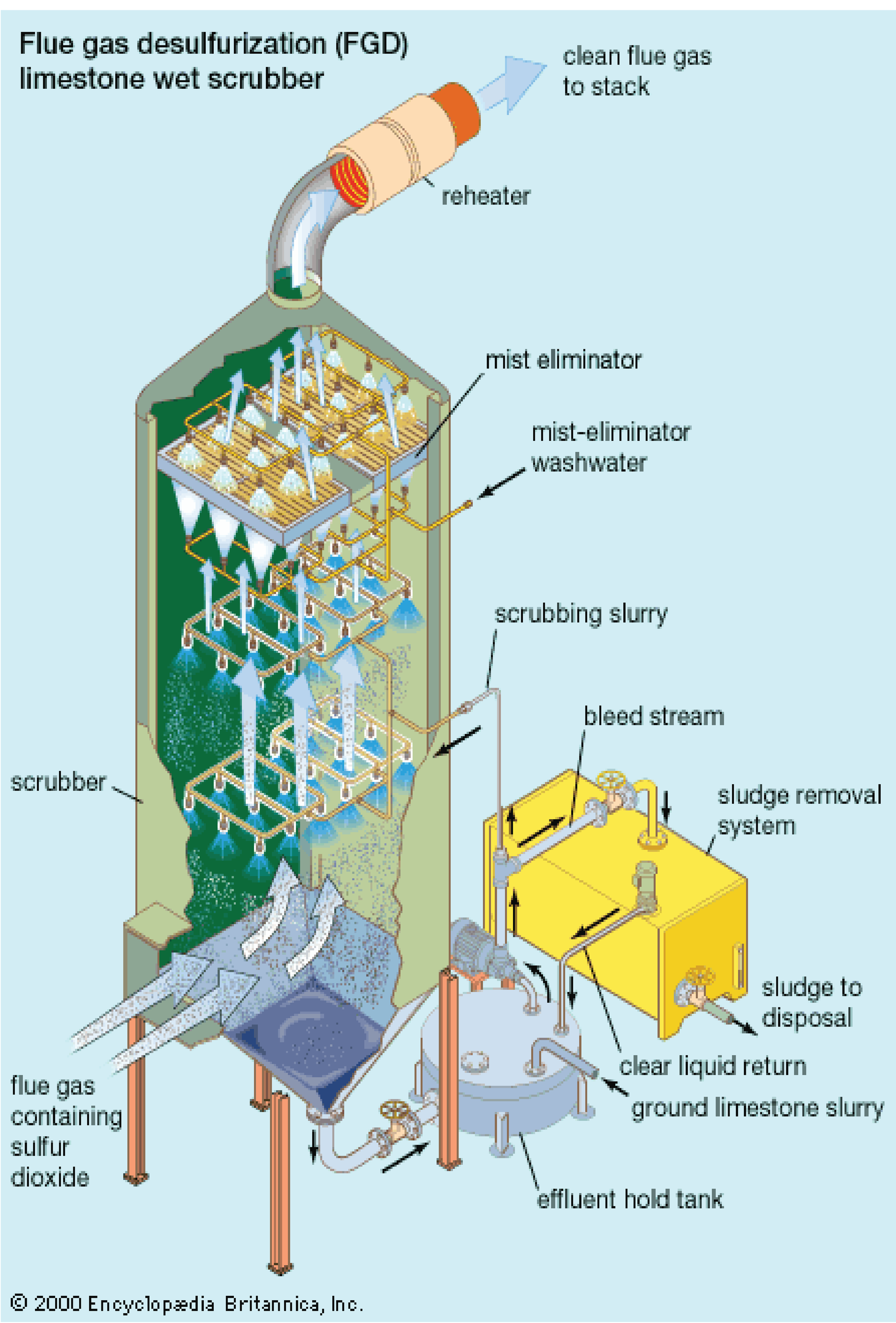
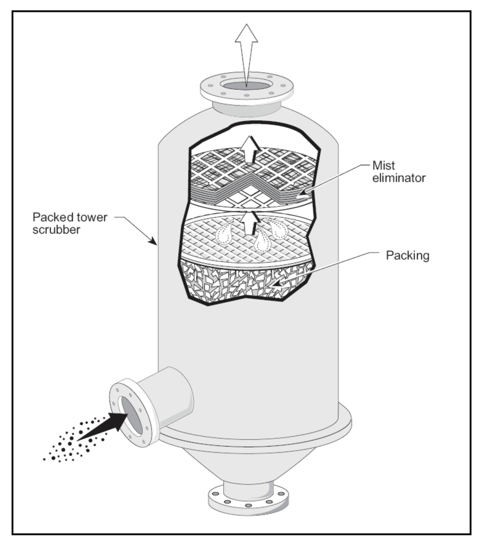
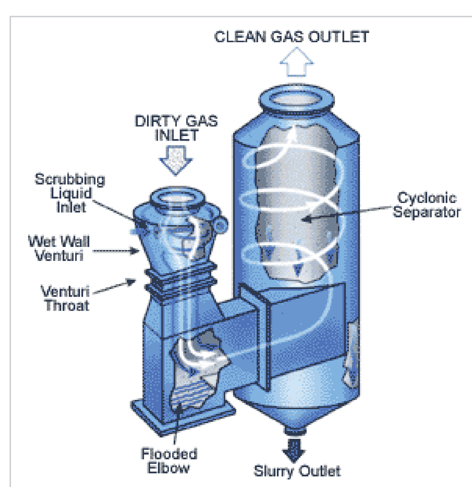
Wet-Scrubbers





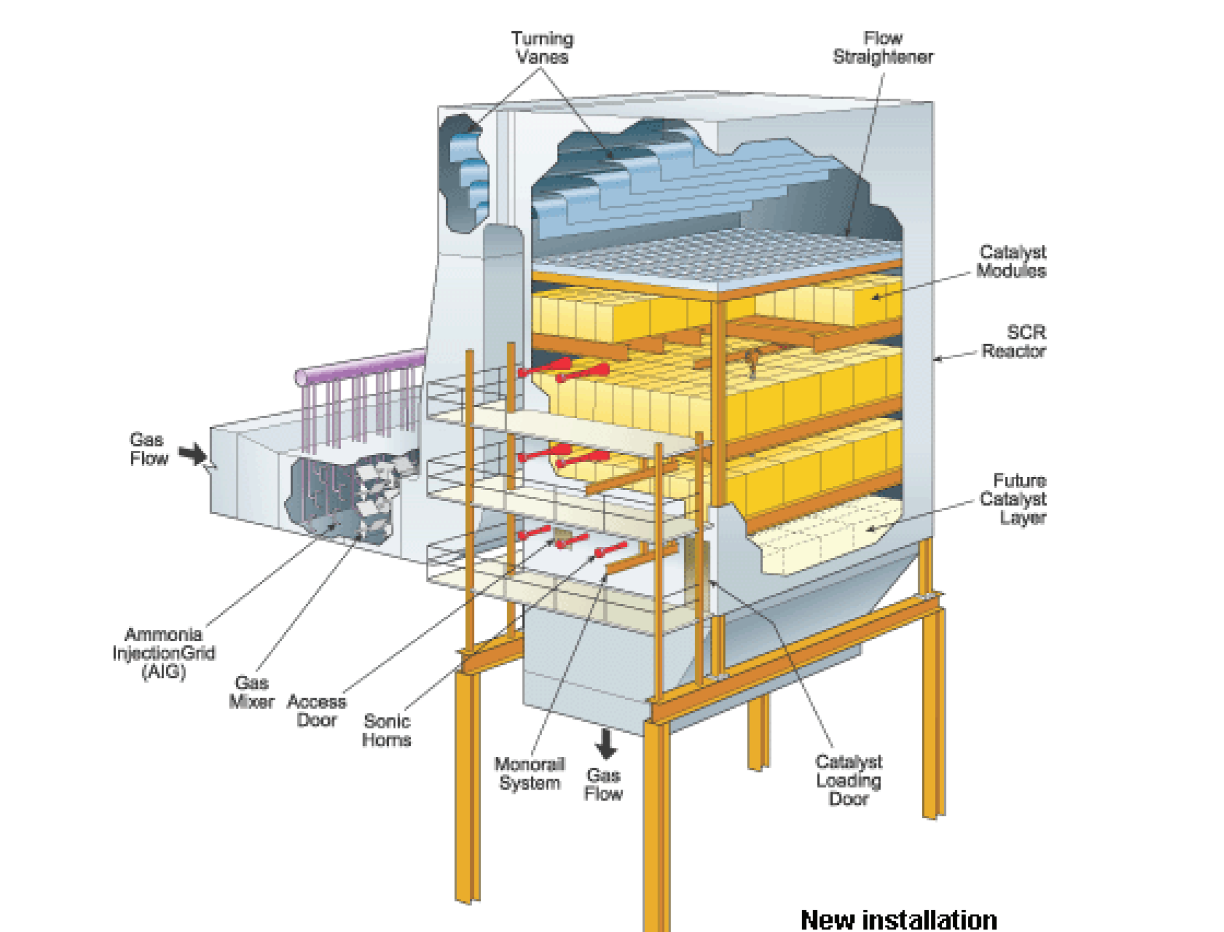
http://en.wikipedia.org/wiki/File:Packedtowerex.gif

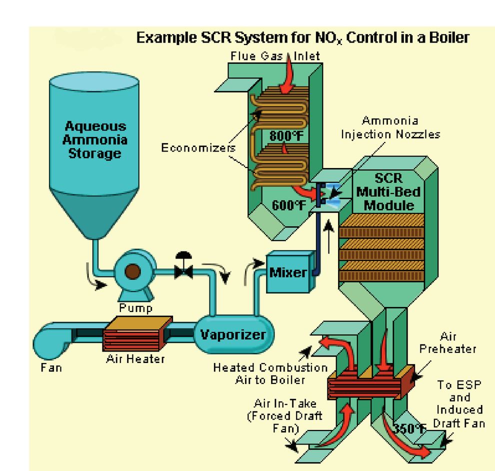


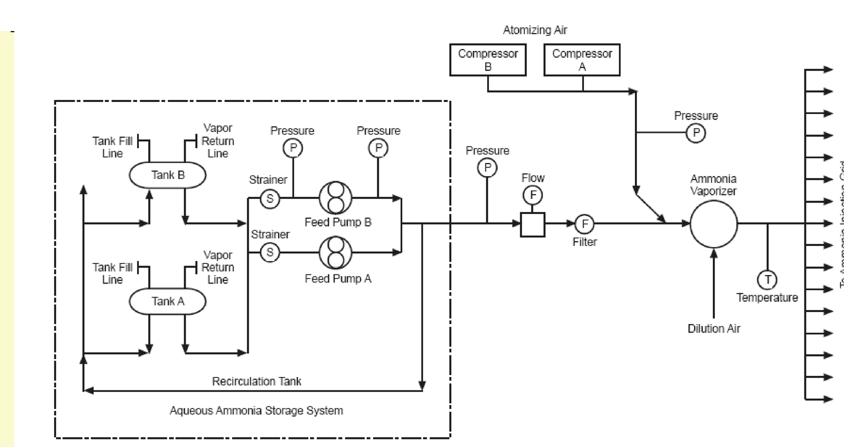
Summary of problems associated with Wet Scrubbers

Instrumentation	Indicator	Possible Failures
1. Pressure Gages (Gas Flow)	High Pressure Difference	Leakage in the system --> Check Sealants --> Check for structural cracks (Stack, ducts, etc.) --> Corrosion Gas Flow Unbalance --> Fan malfunction --> Check Inlet Duct Particle Build Up
	Low Pressure Difference	Gas Flow Unbalance -->Fan malfunction -->Check Inlet Duct Leakage in the system -->Check Sealants -->Check for structural cracks (Stack, ducts, etc.) -->Corrosion
2. Pressure Gages (Nozzle Slurry Line)	High Pressure	Nozzle Plugging Valve Failure
	Low Pressure	Pump Failure Line Leakage Valve Failure
3. Temperature Monitor	High Temperature	Gas Flow Unbalance -->Fan Malfunction -->Check Inlet Duct
	Low Temperature	Leakage in the system -->Check Sealants -->Check for structural cracks (Stack, ducts, etc.) -->Corrosion Check Gas Flow (Fans)
4. pH Probe	Low/High pH	Check Slurry System -->Lime Addition -->Pump Failure -->Valve Failure -->Solids Removal -->Flushing/Drains
5. Humidity Sensors	High Humidity	Gas Flow Unbalance -->Fan malfunction -->Check Inlet Duct Mist Eliminator Failure/Plugging Packed Bed/Plate Failure Nozzle Plugging Check Slurry System
6. Vibration Acoustic Monitors (Ducts, Fans, Pumps, etc)	High/ Low Vibration	Corrosion Pump Failure Valve Failure Fan/Local Equipment Failure Leakage in the system -->Check Sealants -->Check for structural cracks (Stack, ducts, etc.)

Selective Catalytic Reducers







http://www.babcock.com/library/pdf/BR-1646.pdf

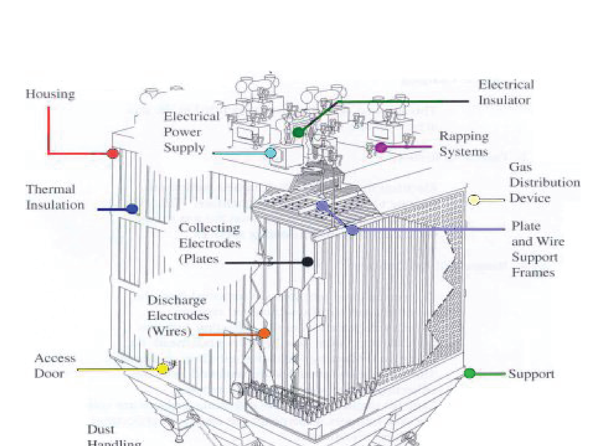
Summary of problems associated with Selective Catalytic Reducers

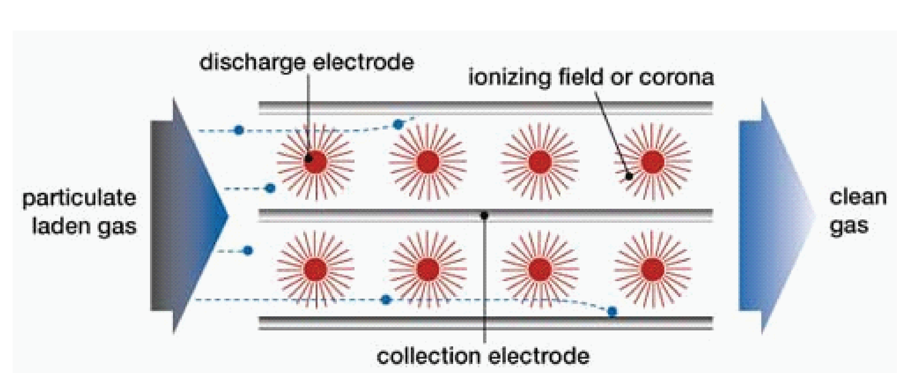
Malfunction	Cause	Effect on System	Corrective Action	Preventative Measures
1.Catalyst Deactivation	1. Catalyst poisoning A. Deactiviation of the Catalyst by chemical attack 2. Catalyst Masking B. Macroscopic Blockage of the catalyst surface by dense second phase coating 3. Catalyst Plugging C. Microscopic blockage of the catalyst system pore system by small flash ash particles	1. Reduces Efficiency of Nox Removal 2. Amonia Slip	1. Replace Catalyst	1. Soot Blowers (to accommodate for Blockage and Plugging) 2. Screens to block out fly ash particulates 3. Sonic Horns
2. Catalyst Deterioration	1. Use across life span causes the catalyst to deteriorate	1. Reduces Efficiency of Nox Removal 2. Ammonia Slip	1. Replace Catalyst	1. This will happen over the course of the life span of the SCR (unavoidable)
3. Ammonia Slip	1. Unreacted ammonia exiting SCR reactor 2. Un-even distribution of Ammonia across catalyst surface 3. Un-even distribution of Flue Gas across catalyst surface	1. No affect on system, affects EPA regulations for Nox Emissions	1. Ensure Mixer is working properly 2. Prevent clogging of the Ammonia Injection Grid	1. This is allowed and expected to happen 2. Correct design of SCR system
4. Broken Pump	1. Broken Housing or Shafts A. Excessive Vibration and unbalance i. Bent, cracked or broken fan ii. Fan not squarely mounted on shaft iii. Cracked or bent pulleys due to improper handling or installation B. Belts too tight i. Excessive Loading ii. Bending force on the shaft causing a deflection from the center of rotation	Improper distribution of flue gas and ammonia	Replace Pump	1. Do not overload pump 2. Inspect pump during installation

Summary of problems associated with Electrostatic Precipitators

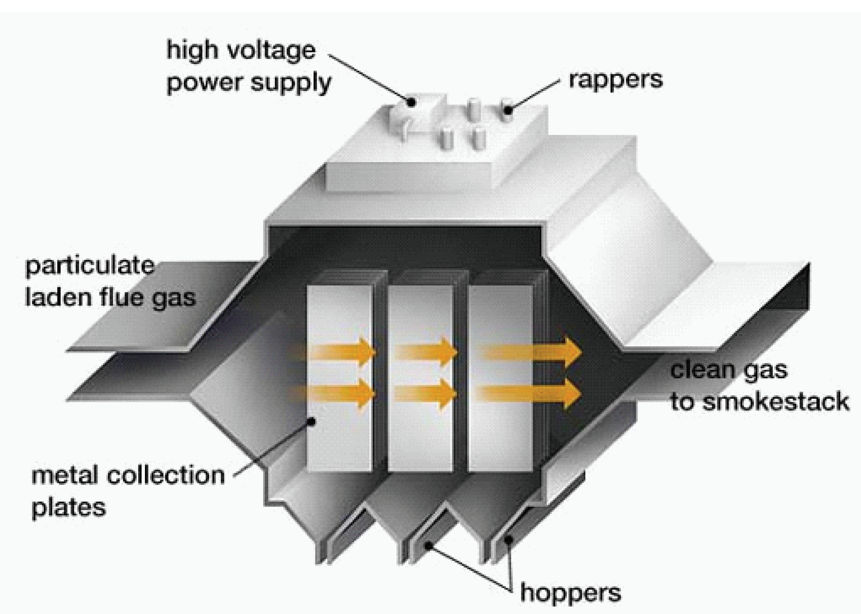
Malfunction	Cause	Effect on system efficiency[1]	Corrective action	Preventive Measures
1. Poor electrode alignment	1. Poor design 2. Ash buildup on frame hoppers 3. Poor gas flow	Can drastically affect performance and lower efficiency	Realign electrodes Correct gas flow	Check hoppers frequently for proper Operation
2. Broken electrodes	1. Wire not rapped clean, causes an arc which embroglios and burns through the wire 2. Clinkered wire.	Reduction in efficiency due to reduced power input, bus section unavailability	Replace electrode	Boiler problems; check space between recording steam and air flow pens, pressure gauges, fouled screen tubes
3. Distorted or skewed electrode plates	1. Ash buildup in hoppers 2. Gas flow irregularities 3. High temperatures	Reduced efficiency	Repair or replace plates Correct gas flow	Check hoppers frequently for proper operation; check electrode plates during outages
4. Vibrating or swinging electrodes	1. Uneven gas flow 2. Broken electrodes	Decrease in efficiency due to reduced power input	Repair electrode	Check electrodes frequently for wear
5. Inadequate level of power input (voltage too low)	1. High dust resistivity 2. Excessive ash on electrodes 3. Unusually fine partical size 4. Inadequate power supply 5 Inadequate sectionalization. 6. Improper rectifier and control operation 7. Misalignment of electrodes	Reduction in efficiency	Clean electrodes; gas conditioning or alterations in temperature to reduce resistivity; increase sectionalization	Check range of voltages frequently to make sure they are correct; check insitu resistivity measurements
6. Back corona	1. Ash accumulated on electrodes causes excessive sparking requiring reduction in voltage charge	Reduction in efficiency	Same as above	Same as above
7. Broken or cracked insulator or flower pot bushing leakage	1. Ash buildup during operation causes leakage to ground 2. Moisture gathered during shutdown or low-load operation	Reduction in efficiency	Clean or replace insulators and bushings	Check frequently; clean and dry as needed; check for adequate pressurization of top housing
8. Air leakage through hoppers	1. From dust conveyor	Lower efficiency; dust reentrained through electrostatic precipitator	Seal Leaks	Identify early by increase in ash concentration at bottom of exit to ESP.
9. Air in Leakage through ESP Shell	1. Flange expansion	Same as above; also causes intense sparking	Seal leaks	Check for large flue gas temperature drop across the ESP
10. Gas bypass around ESP • Dead passage above	1. Poor design; improper isolation of ective portion of ESP	Only few percent drop in efficiency unless sever	Baffling to direct gas into active ESP Section	Identify early by measurement of gas flow in suspected areas

Electrostatic Precipitators





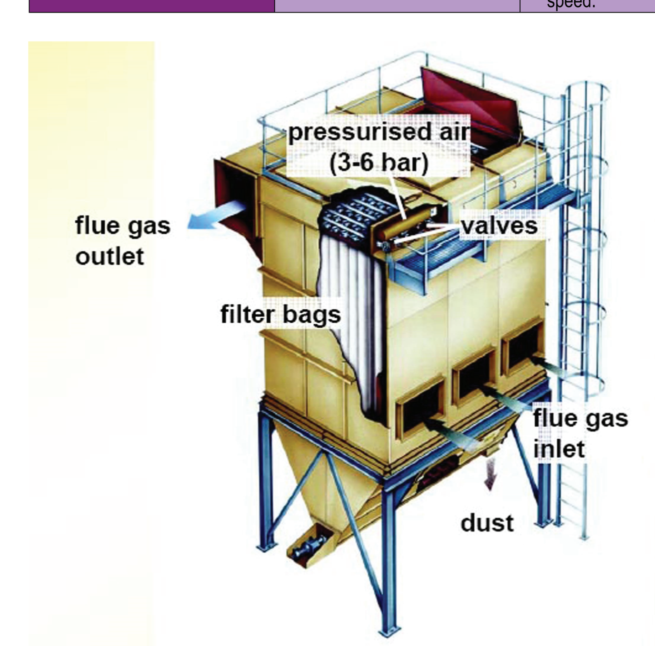
Top View of ESP Schematic Diagram [Source: Powerspan Corp.].



Side view of ESP Schematic Diagram [Source: Powerspan Corp.].

Summary of problems associated with Baghouses

Symptom	Cause	Remedy
1. High Baghouse pressure drop, LOW Cubic feet per minute	• Bag Cleaning Mechanism not adjusting properly • Not Capable of Removing dust from bags • Excessive Reentrainment of dust • Incorrect pressure reading	• Increase cleaning frequency. Clean longer duration • Send sample of dust to manufacturer. Send bag to lab for analysis for blinding. Dry clean or replace bags • Continuously empty hopper. Clean row of bags randomly instead of sequentially • Clean out pressure taps Check hoses for leaks. Check diaphragm in gauge
2. Low Baghouse pressure drop, High cubic feet per minute	• Pressures will be less with high temperature gases or at high altitudes • Filter bag ruptured • Fan speed too high • Ambient air infiltrating system	• Reduce fan speed • Check for visible emission from stock • Check drives • Check all doors and hatches. Check system for leakage.
3. Low Baghouse pressure drop, Low cubic feet per minute	• Induced draft fan failure • Restrictions in duct before or after	• Check fan rotation, drives and speed • Check all dampers. Check fan damper. Check for dust plugging ductwork. Review duct design, (may be more restrictive flow than expected). Increase Fan speed.



Baghouse Failure Table

The Causes	The Problem: Continuous release of Dust-Laden Air	Intermittent release of Dust-Laden Air	Loss of Plant Air Pressure	Blow-Down Ineffective	Insufficient Capacity	Excess Differential Pressure	Fan/Blower Motor Trips	Fan Has High Vibration	Premature Bag Failures	Differential Pressure too low	Chronic Plugging of Bags
Bag Material Incompatible for Application									X		X
Bag Plugged						X	X	X			
Bag Torn or Improperly Installed	X							X	X	X	
Baghouse Undersized					X		X				X
Blow-Down Cycle Interval Too Long						X	X				
Blow-Down Cycle Time Failed or Damaged						X	X				
Blow-Down Nozzles Plugged						X					
Blow-Down Pilot Valve Failed to Open (Solenoid Failure)			X			X					
Dust Load Exceeds Capacity											X
Excessive Demand			X								
Fan/Blower Not Operating Properly					X						
Improper or Inadequate Lubrication								X			
Leaks in Ductwork or Baghouse	X				X						
Misalignment of Fan and Motor								X			
Moisture Content Too High											X
Not Enough Blow-Down Air (Pressure and Volume)			X	X		X					
Not Enough Dust Layer on Filter Bags	X	X						X		X	
Piping/Valve Leaks			X								
Plate-Out (Dust Build-up on Fan's Rotor)								X			
Plenum Cracked or Seal Defective	X		X							X	
Rotor Imbalanced								X			
Ruptured Blow-Down Diaphragms			X	X		X					
Suction Ductwork Blocked or Plugged					X						

Baghouses