Pollution Controls and Available Monitoring Techniques

A quick summary of various control measures and important monitoring characteristics

Peter Westlin, EPA, OAQPS

March 2012

Topic areas

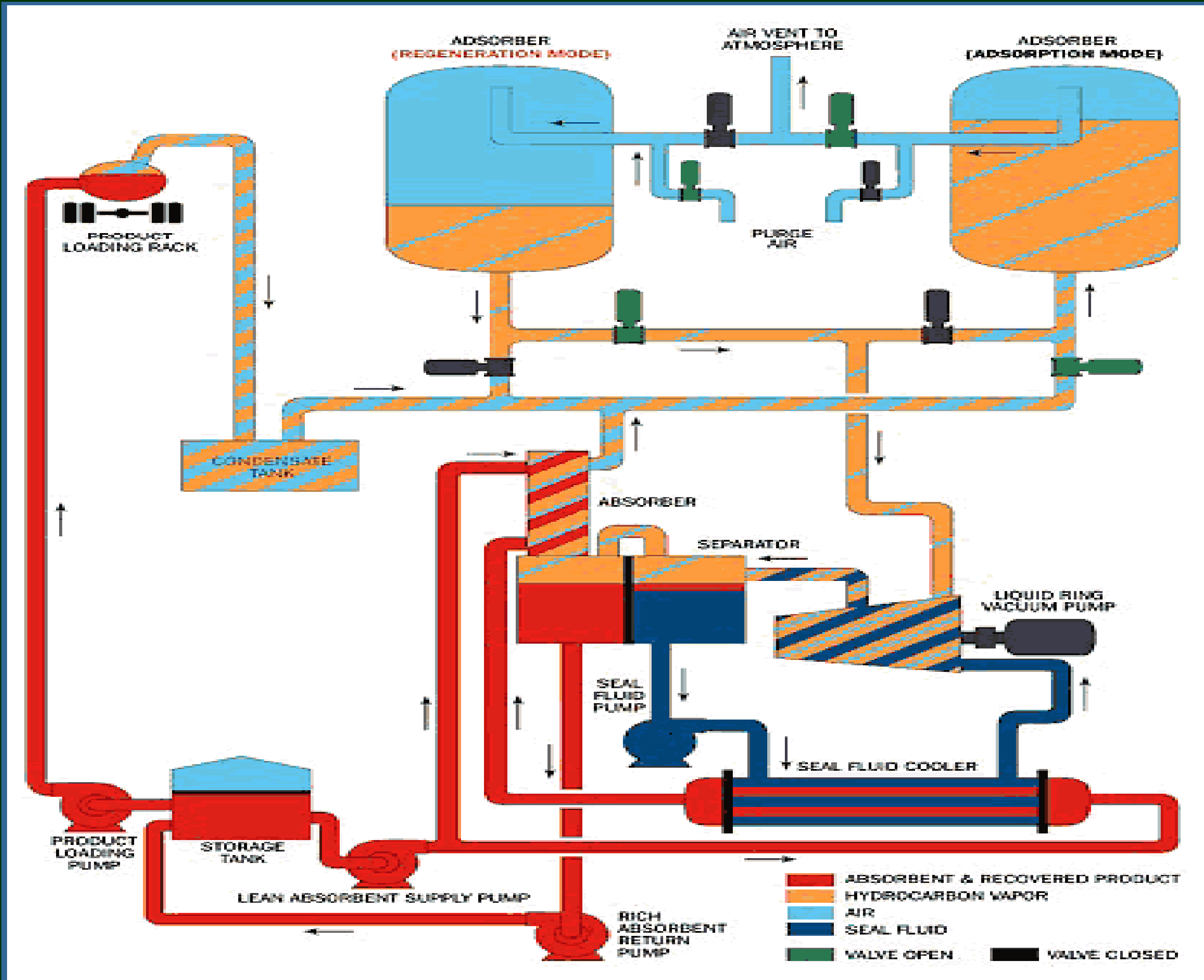
- THC and OHAP
  - Adsorbers
  - Thermal Oxidizers
  - Catalytic Oxidizers
  - Condensers
  - Capture Systems
- PM
  - ESP
  - Fabric Filter
  - Venturi Scrubber
- Acid Gases
  - Wet scrubbers
  - Dry Injection
  - Mercury
- NOx
  - Selective Catalytic Reduction
  - NSCR
  - Water Injection
  - Low Nox Burners
- Other
  - Sulfur in Coal & Oil
  - Coatings and Solvents
  - Design Specs
  - Process Operations

THC/OHAP Control Techniques – Carbon Adsorber

- Some gas molecules will stick to the surface of some solids
- Activated carbon often used for THC/OHAP control
  - Has a strong attraction for organic and non-polar compounds
  - Has a large capacity for adsorption (many pores, lots of surface area)
  - Is cheap
- Silica gel, activated alumina, and zeolites are also used

THC/OHAP Control Techniques – Carbon Adsorber

- Three types – fixed bed (most common), moving bed, and fluidized bed
- Typically appear in pairs – one adsorbing while other desorbs
- Used for material recovery as well as emissions control
- Regenerated via steam, hot gas, or vacuum


ADSORBER
(REGENERATION MODE)
AIR VENT TO ATMOSPHERE
ADSORBER
(ADSORPTION MODE)
PURGE AIR
PRODUCT LOADING RACK
CONDENSATE TANK
ABSORBER
SEPARATOR
LIQUID RING VACUUM PUMP
SEAL FLUID PUMP
SEAL FLUID COOLER
PRODUCT LOADING PUMP
STORAGE TANK
LEAN ABSORBENT SUPPLY PUMP
RICH ABSORBENT RETURN PUMP
ABSORBENT & RECOVERED PRODUCT
HYDROCARBON VAPOR
AIR
SEAL FLUID
VALVE OPEN
VALVE CLOSED

Carbon Adsorber – Fixed Bed Examples

THC/OHAP Control Techniques – Carbon Adsorber

Compliance monitoring

- Outlet THC or compound specific concentration (CEMS)
- Parametric and other monitoring
  - Regeneration cycle timing (e.g., minutes), steam flow, or vacuum profile (e.g., delta P for x minutes)
    - Initial performance tests for confirmation
    - Periodic testing
  - Carbon bed activity (e.g., quarterly)

THC/OHAP Control Techniques – Thermal Oxidizers

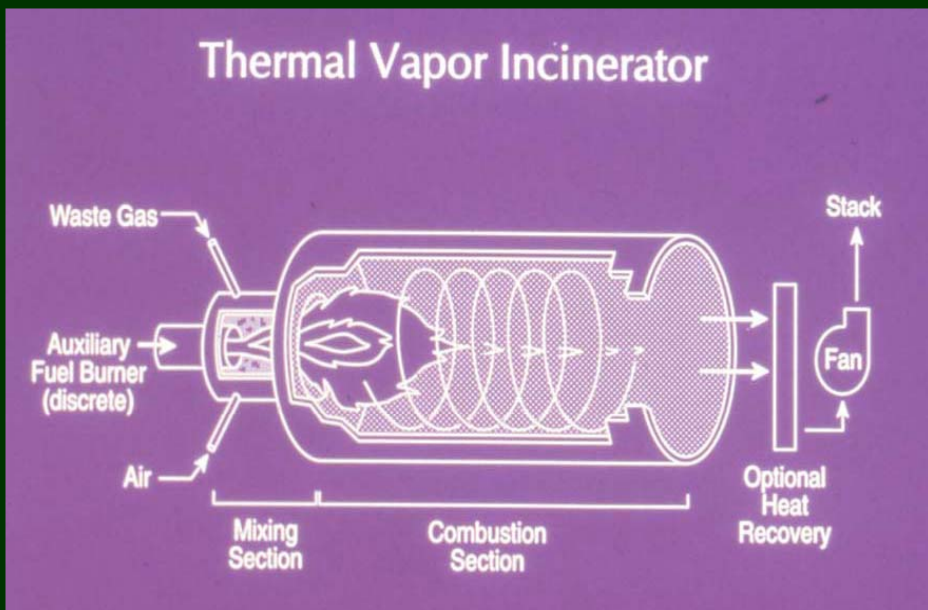
General description

- Waste gas combusted with or without auxiliary fuel to carbon dioxide and water
- Operating temperatures between 800 and 2000°F
- Good combustion requires (remember chemistry class?)
  - Adequate temperature
  - Sufficient oxygen
  - Turbulent mixing
  - Sufficient residence time

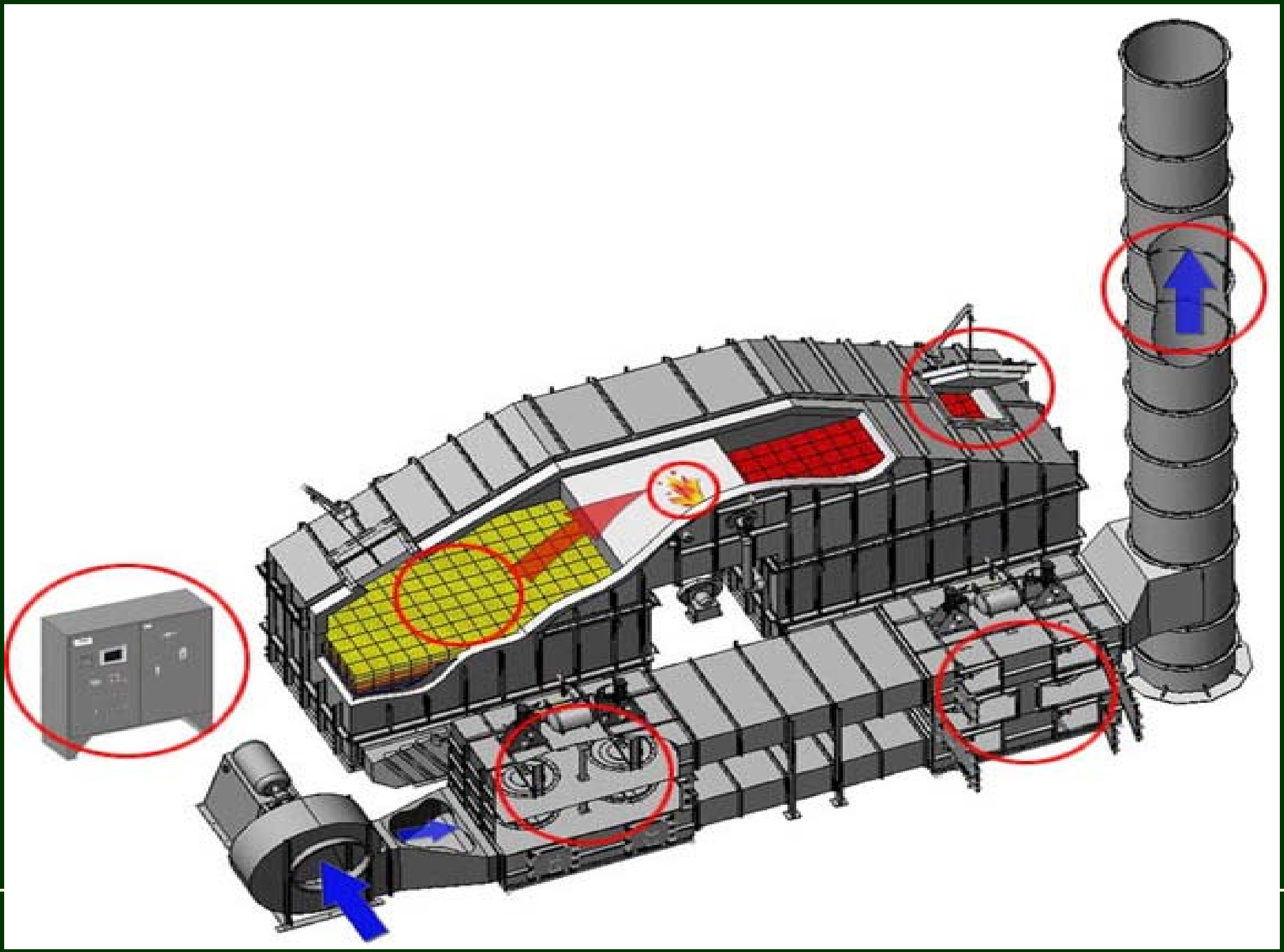
THC/OHAP Control Techniques – Thermal Oxidizers

- Two basic types – thermal oxidizer (TO) and regenerative thermal oxidizer (RTO)
- After construction, process control limited to temperature and oxygen (air to fuel ratio) concentration
- Waste gas has to be heated to autoignition temperature
  - Typically requires auxiliary fuel
  - Can be enhanced with heat recovery exchangers

THC/OHAP Control Techniques TOs and RTOs



THC/OHAP control - RTO



THC/OHAP Control Techniques – Thermal Oxidizers

Compliance monitoring

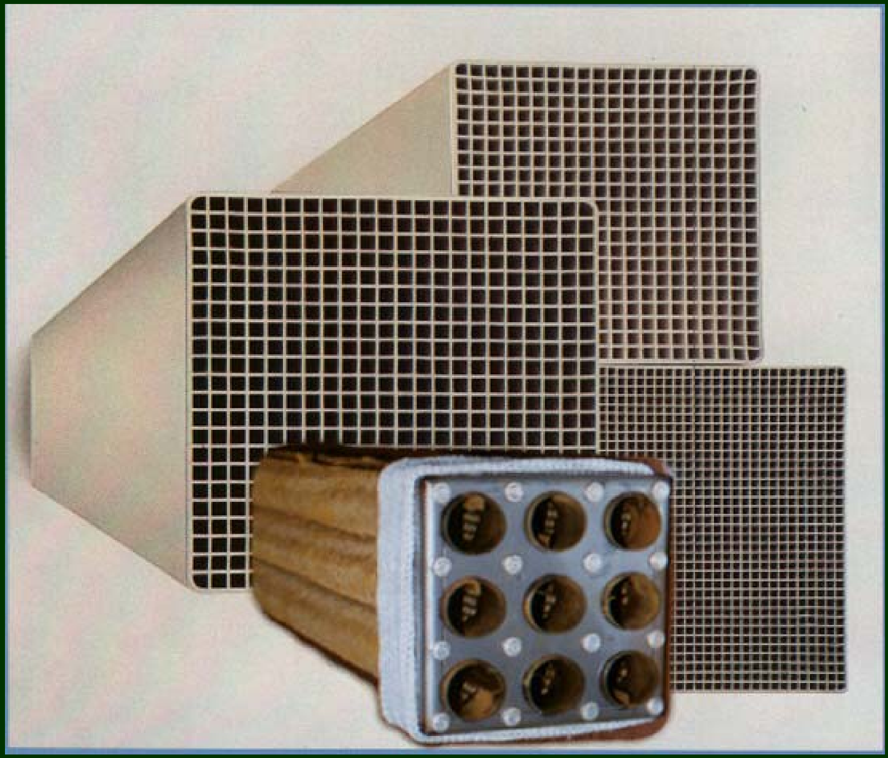
- Outlet THC or compound-specific concentration (CEMS)
- Parametric and other monitoring
  - Outlet CO concentration (CEMS)
    - Correlated with test results
  - Combustion chamber temperature
    - Correlated with test results
  - Periodic testing to confirm

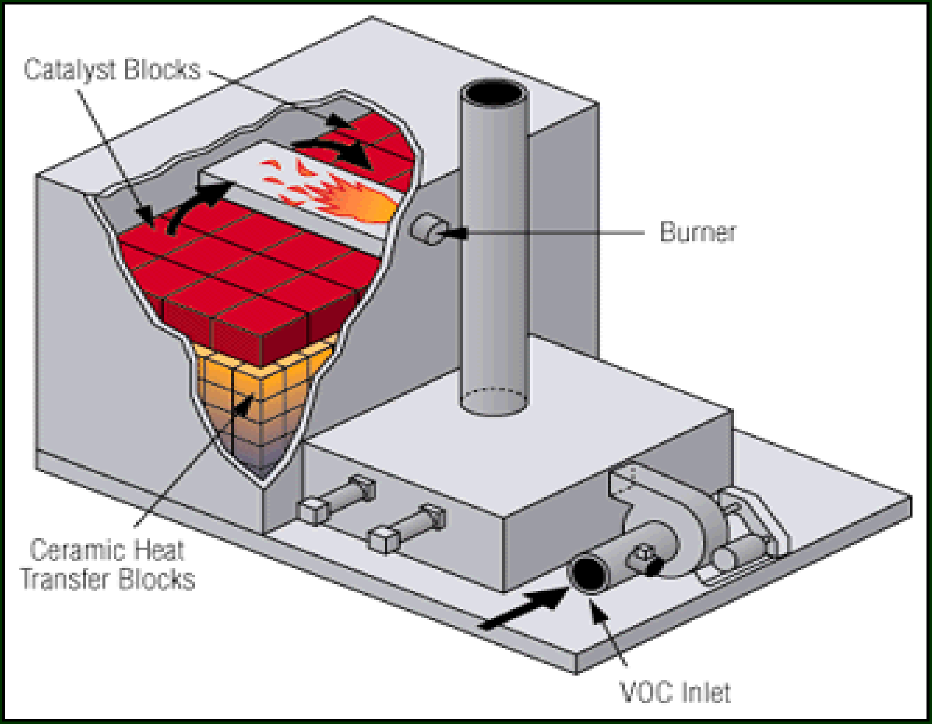
THC/OHAP Control Techniques – Catalytic Oxidizer

General description

- Construction similar to TO or RTO but includes catalyst layer or bricks
- Catalyst causes combustion reactions to occur faster and at lower temperatures (~ 650 to 1000°F)
- Saves auxiliary fuel

Catalytic Oxidizer – Example Bricks





Regenerative catalyst oxidizer

THC/OHAP Control Techniques – Catalytic Oxidizer

Performance monitoring

- Outlet THC or compound-specific concentration (CEMS)
- Parametric and other monitoring
  - Catalyst bed inlet temperature or temperature rise across catalyst bed (if inlet concentration is constant)
    - Correlated with test results
    - Periodic catalyst activity tests (e.g., semi-annually)
  - Periodic testing
- NOT outlet CO concentration (CO preferentially combusted in THC catalysts)

THC/OHAP Control Techniques - Condenser

- General description
  - Gas or vapor liquefied and removed from gas stream via
    - Lowering temperature or
    - Increasing pressure
  - Used to collect and reuse organic materials (e.g., solvents)
  - Used as pretreatment to reduce volumes

THC/OHAP Control Techniques - Condenser

- Two structural types – contact and surface condensers
  - No secondary pollutants from surface type
  - More coolant needed for contact type
- Chilled water, brines, and CFCs used as coolants
- Efficiencies range from 50 to 95 percent

THC/OHAP Control Techniques – Surface Condenser

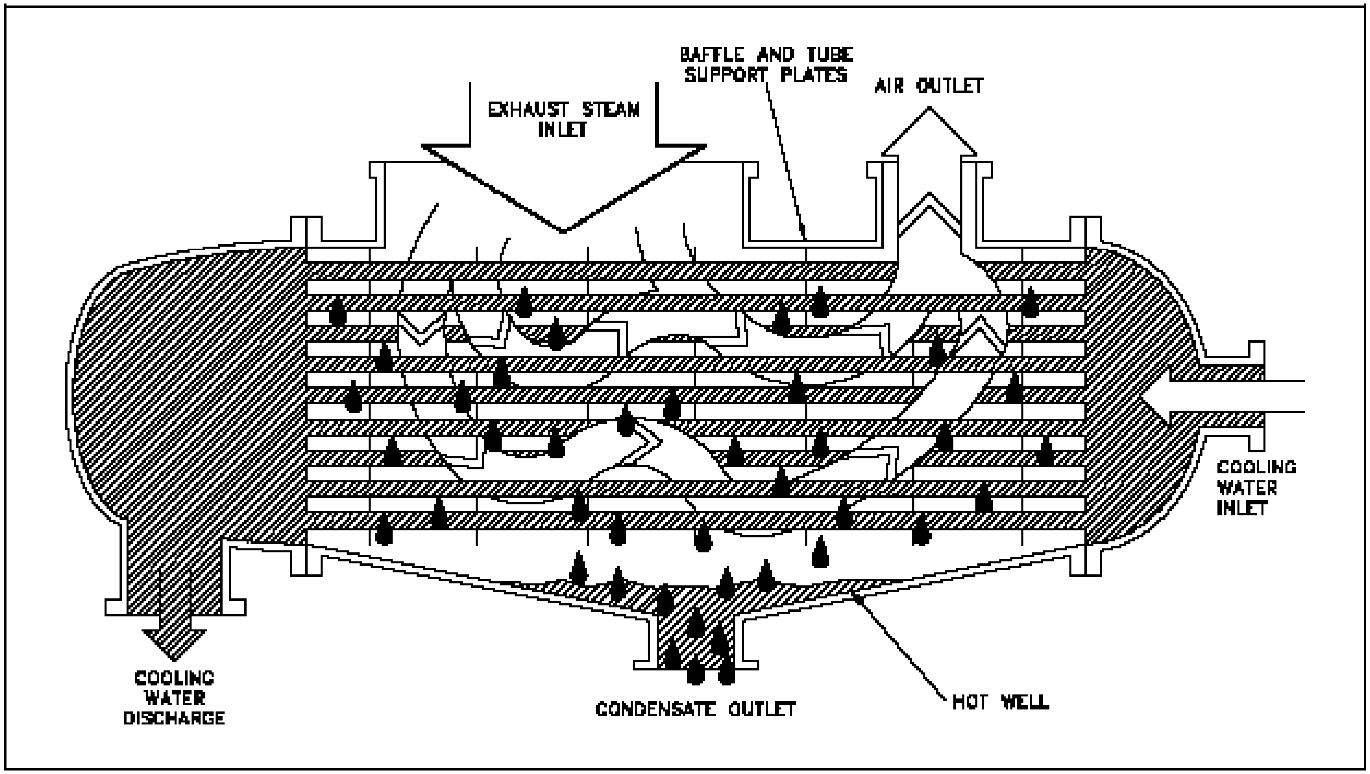


Figure 9 Single-Pass Condenser

THC/OHAP Control Techniques - Condenser

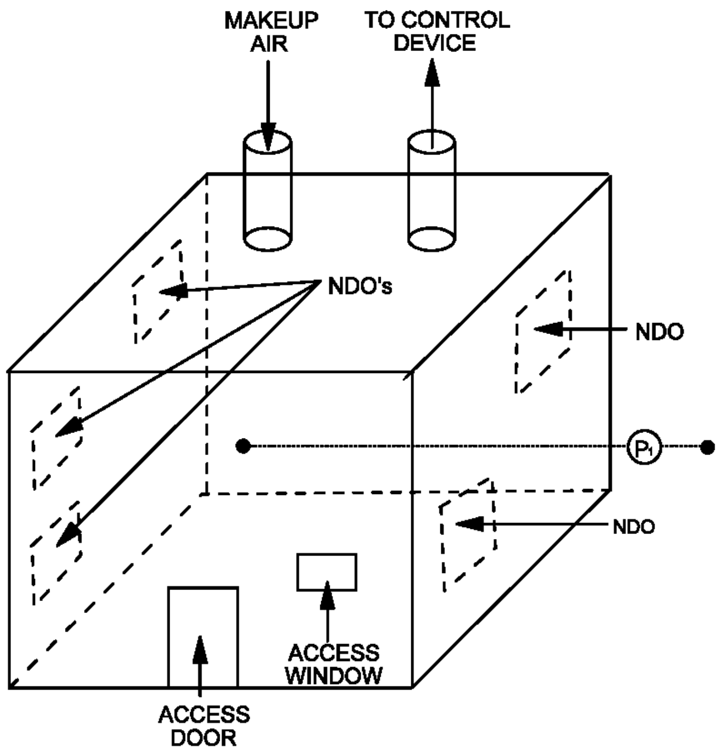
Compliance monitoring

- Outlet THC or compound-specific concentration (CEMS)
- Predict emissions via equilibrium calculations (e.g., organic chemical MACT)
- Parametric and other monitoring
  - Outlet gas temperature (e.g., at or below dew point)
    - Correlated with testing or with equilibrium calculations
  - Coolant inlet/outlet temperature
    - Correlated with testing
  - Periodic testing

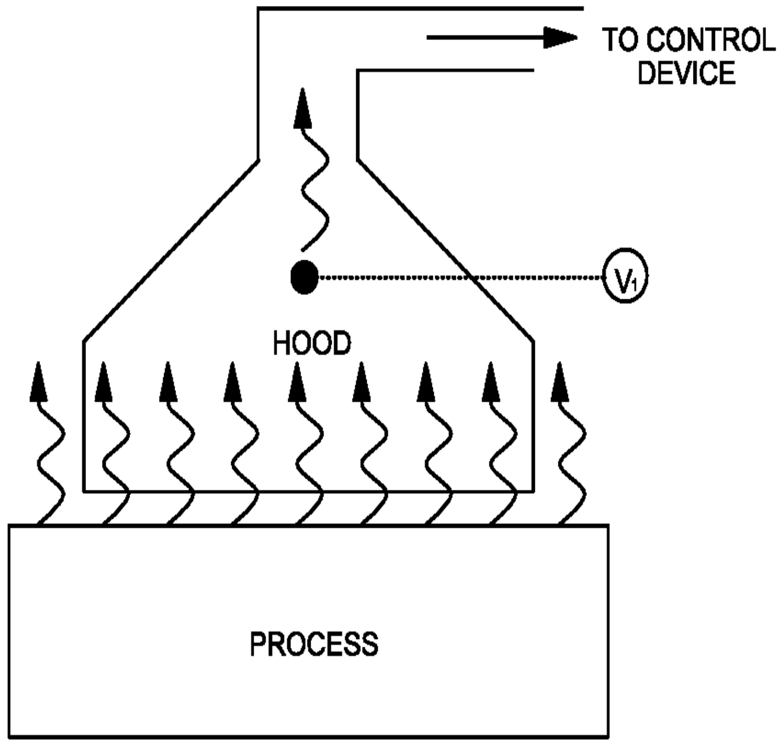
THC/OHAP Control Techniques – Capture Systems

- General description
  - Two types of systems
    - Enclosures and local exhausts (hoods)
  - Two types of enclosures
    - Permanent total (M204 definition) – 100% capture efficiency
    - Nontotal or partial – must measure capture efficiency via Method 204
- Total THC control efficiency is product of capture and control device efficiencies

THC/OHAP Control Techniques – Capture System



P1 = DIFFERENTIAL PRESSURE SENSOR (BETWEEN ENCLOSURE INTERIOR AND SURROUNDING AREA/ROOM)



V1 = VELOCITY AT HOOD

THC/OHAP Control Techniques – Capture Systems

Compliance monitoring (parametric)

- Permanent total enclosures
  - Differential pressure (e.g., < -0.007 in. H_2O)
  - Daily inspections
- Local capture (design and work practice)
  - Conduct visible and portable analyzer leak checks
  - Set spacing above process
  - Monitor exhaust flow rate/differential pressure in duct near hood

Take-aways about THC/OHAP control device monitoring:

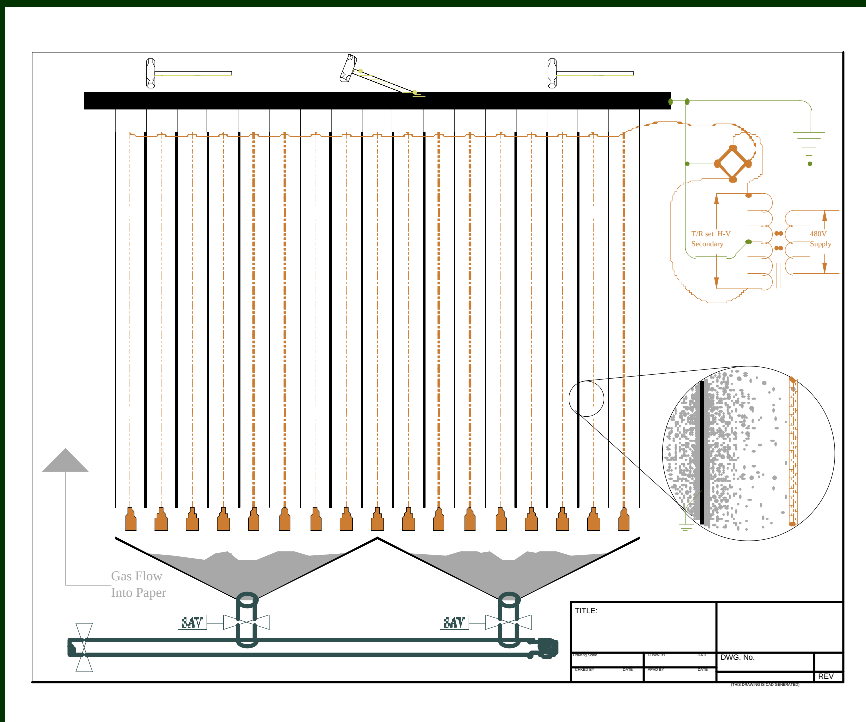
- What can we say about CEMS for monitoring gaseous organic emissions?
- If not CEMS, which operating parameters are appropriate for monitoring compliance for
  - Adsorbers?
  - Thermal oxidizers?
  - Catalytic oxidizers?
  - Capture systems?

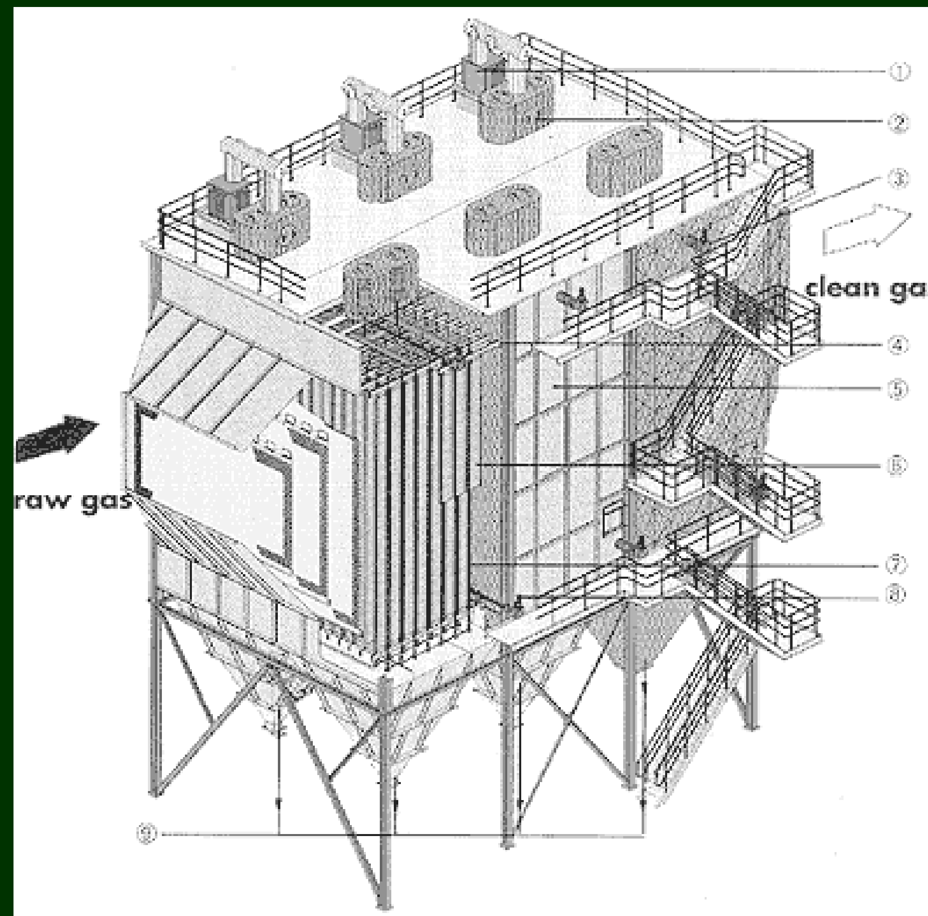
PM Control Techniques – Electrostatic Precipitator (ESP)

General Description

- Charged particles are attracted to grounded plates and removed from exhaust gas
- Two types
  - Dry type use mechanical action to clean plates
  - Wet type use water to prequench and to rinse plates (good for removing condensable PM)
- High voltages
- Often with multiple sections (fields)
- Efficiencies up to 99+ percent with multiple sections

PM Control Techniques - ESP





PM Control Techniques – ESP

Compliance monitoring

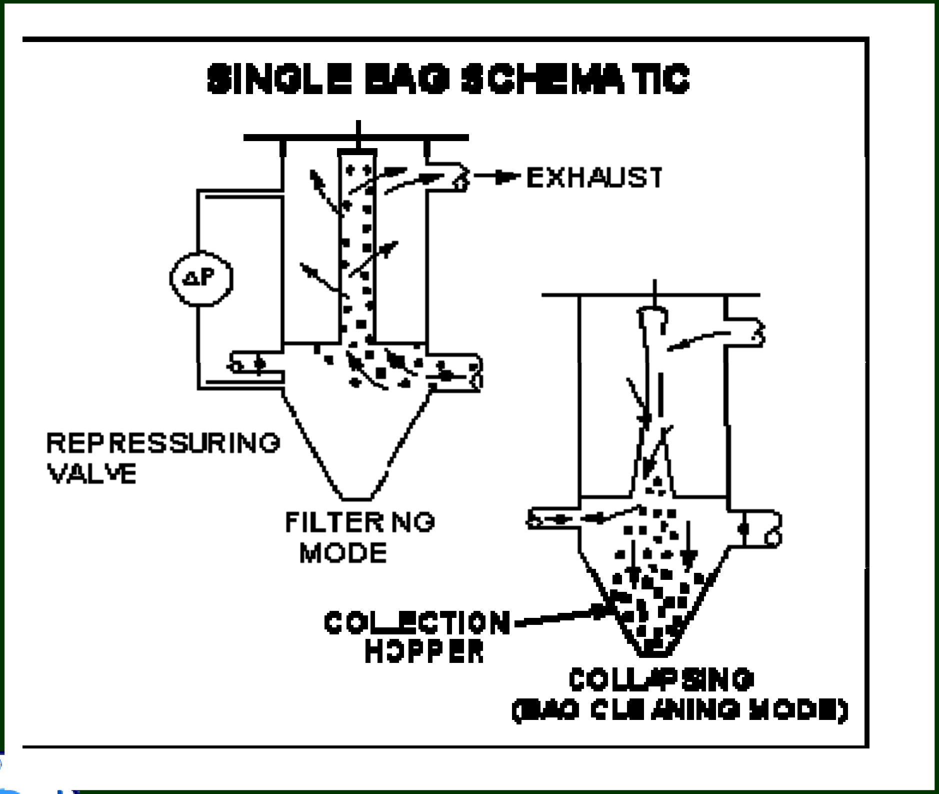
- Outlet PM concentration (PM CEMS)
- Parametric and other monitoring
  - Opacity and secondary power (current and voltage)
    - Correlated with testing
  - Periodic testing
  - EPRI model on TTN/EMC website
    - Comprehensive site-specific correlation
    - Makes use of EPA ESP design model

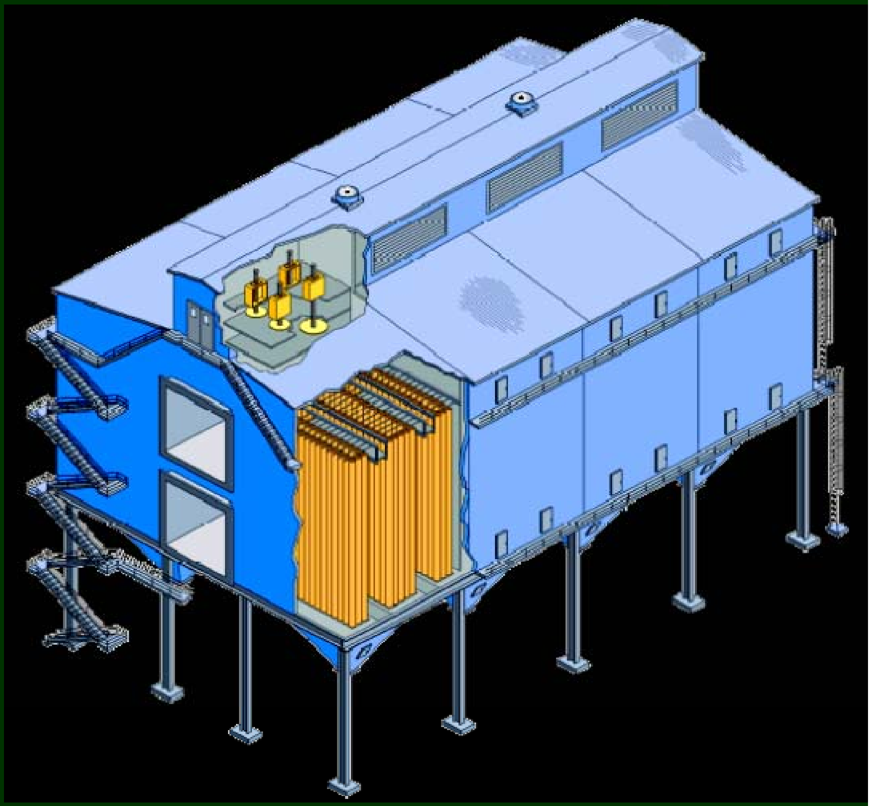
PM Control Techniques – Fabric Filter (bag house)

General description

- Particles trapped on filter media and filter cake
- Either positive or negative pressure (push me, pull you)
- High efficiency for all particle sizes (> 99 percent)
- Frequent bag cleaning
  - Shaker (off-line)
  - Reverse air (low pressure, long time, off line)
  - Pulse jet (60 to 120 psi air, on line)
  - Sonic horn (150 to 550 Hz @ 120 to 140 dB, on line)

PM Control Techniques – Fabric Filter - Schematic

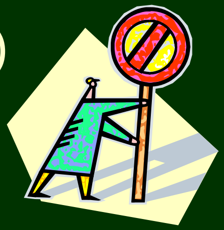




PM Control Techniques – Fabric Filter

Compliance monitoring

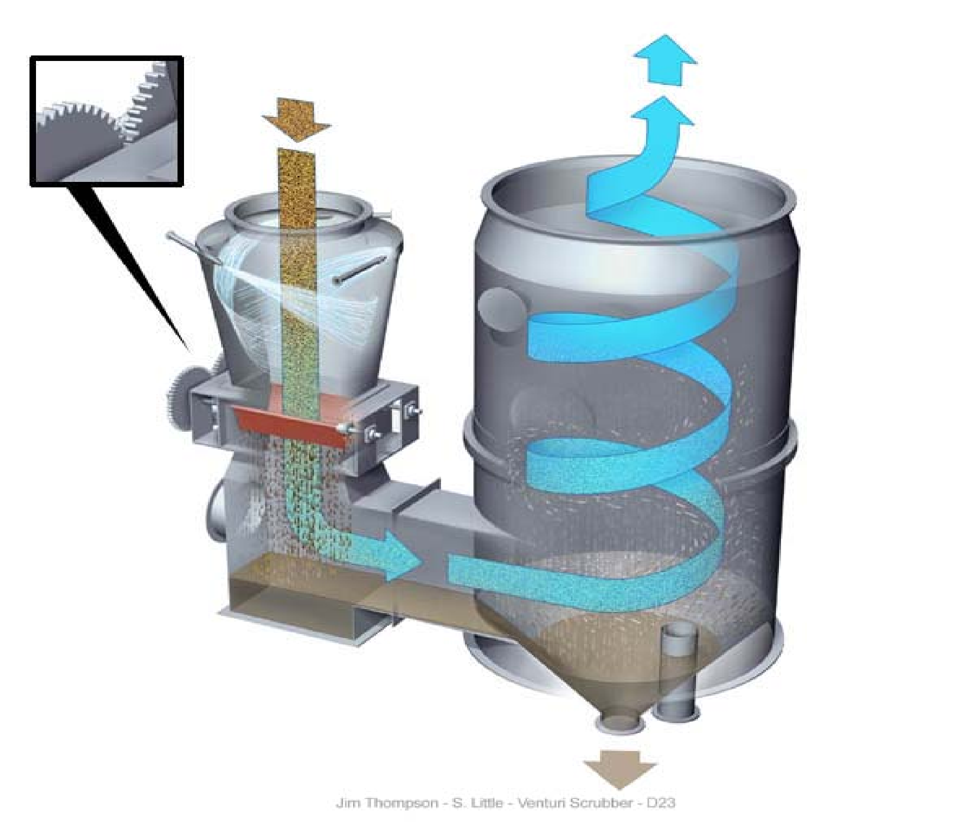
- Outlet PM concentration (PM CEMS)
  - Works for negative pressure FFs
  - Not so good for positive pressure FFs
- Parametric and other monitoring
  - Bag leak detectors (very good choice)
  - Outlet opacity (not so good choice)
  - Pressure differential (bad choice)
  - Periodic inspections
  - Periodic testing



PM Control Techniques – Wet Venturi Scrubber

- Capture of particles in liquids through inertial impaction (less effective at removing gases)
- High energy (velocity through Venturi throat) with pressure drops >20 in. H_2O
- Can be fixed or adjustable throats
- Require exhaust stream mist separators
- Less efficient than FF or ESP (90-98 percent)

PM Control Techniques – Wet Venturi Scrubber



PM Control Techniques – Wet Venturi Scrubber

Compliance monitoring

- Outlet PM concentration (extractive PM CEMS can work)
- Not COMS (water vapor interference)
- Parametric and other monitoring
  - Pressure differential AND liquid flow rate
    - Correlated with performance testing
    - Periodic inspections
  - Periodic testing

Take-aways about PM control device monitoring:

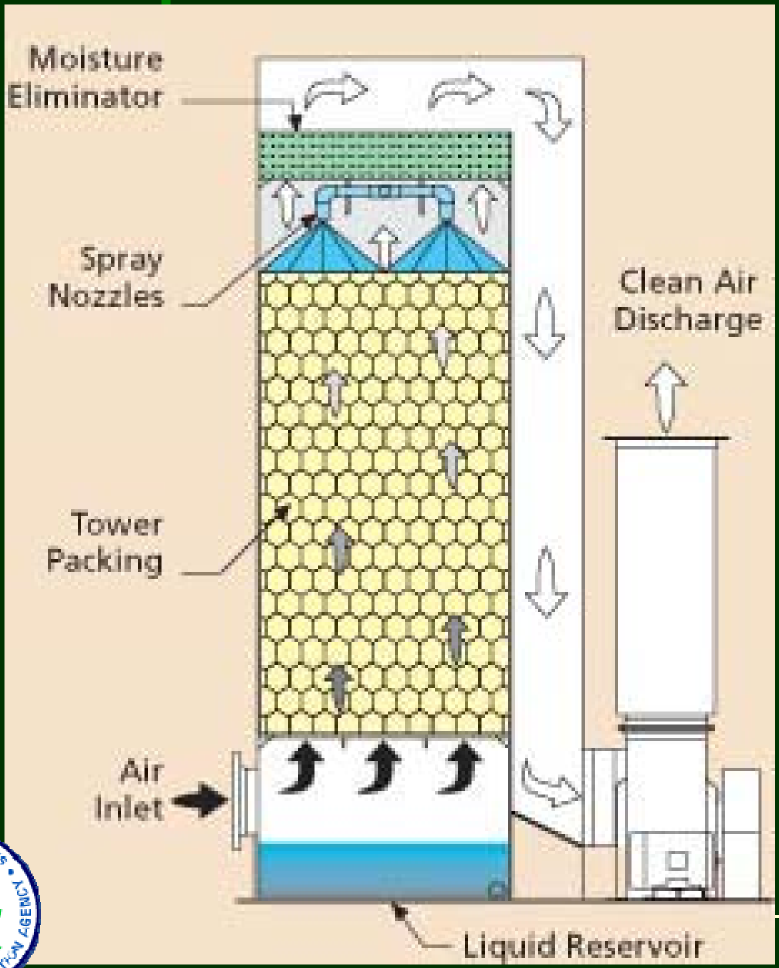
- What can we say about CEMS for monitoring PM emissions?
- What about ESPs and Venturi scrubbers distinguishes them from fabric filters?
- If not CEMS, which operating parameters are appropriate for monitoring compliance for
  - ESPs?
  - Venturi scrubbers?
  - Fabric filters?

Acid gas control – wet flue gas scrubbers

General description

- Acid gases mix with wet alkaline slurries sprayed in packed or plate/tray towers
- Lime, limestone, and sodium bicarbonate often used as sorbents
- Typical efficiencies on the order of >98 percent

Acid gas scrubbers



Acid gas scrubbers

Compliance monitoring

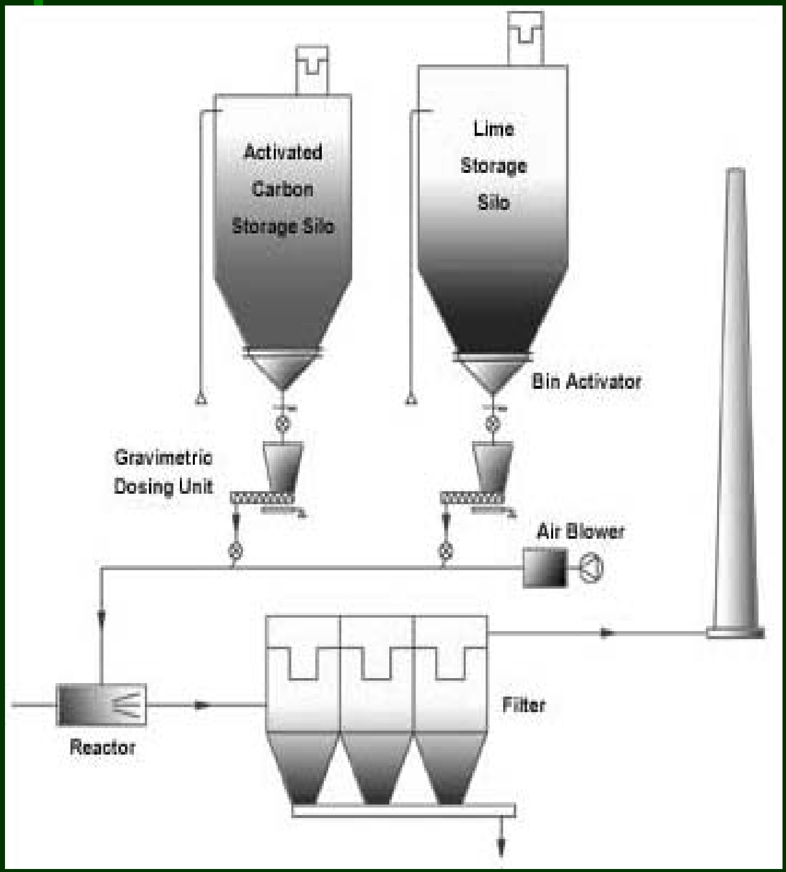
- Acid gas (e.g., SO_2, HCl) concentration (CEMS)
- Parametric and other monitoring
  - Slurry pH AND liquid flow rate
    - Correlated with testing
    - Periodic inspections (check packing)
    - Not pressure drop or flow rate
  - Periodic testing

Acid Gas and Hg Control Techniques – Dry Injection

General description

- Sorbent injected into process
- Sorbent reacts with gas to form salts that are removed in a PM control device (fabric filter)
- Hydrated lime and sodium bicarbonate often used as sorbents for acids
- Activated carbon used for Hg

Acid Gas and Mercury Control Techniques – Dry Injection



Dry injection control systems

- Acid gas (e.g., SO_2, HCl) concentration (CEMS)
- Hg CEMS or sorbent trap
- Parametric and other monitoring
  - Adsorbent injection rate
    - Correlated with testing
  - PM control device monitoring
  - Periodic testing

Take-aways about acid gas and Hg control device monitoring:

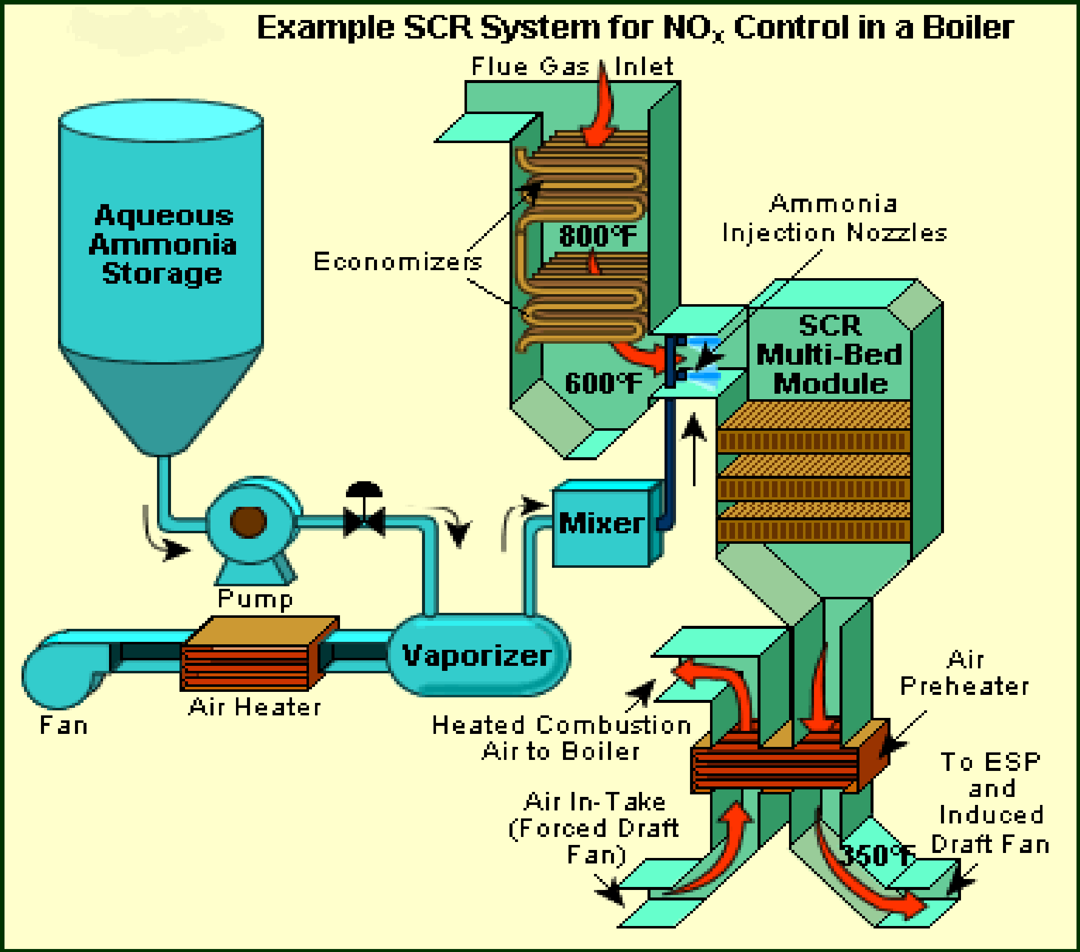
- What can we say about CEMS for monitoring acid gas or Hg emissions?
- What about acid gas scrubbers distinguishes them from and Venturi scrubbers?
- If not CEMS, which operating parameters are appropriate for monitoring compliance for
  - Acid gas scrubbers?
  - Dry injection?

NO_x Control Techniques – Selective Catalytic Reduction

General description

- Ammonia or urea is injected into exhaust streams with plenty of oxygen to reduce NO_x to N_2 and water
- Catalysts made from base and precious metals and zeolites
- Operating temperatures range from 600 to 1100°F
- Efficiency ranges from 70 to 90 percent

NO_x Control Techniques – SCR Schematic



NO_x Control Techniques – Selective Catalytic Reduction

Compliance monitoring

- Outlet nitrogen oxide concentration (CEMS)
- Parametric monitoring
  - Ammonia / urea injection rate
    - Correlated to testing
  - Catalyst activity
  - Initial and periodic testing

NO_x Control Techniques – Non Selective Catalytic Reduction

General description

- Low oxygen exhaust gas transforms via catalytic reaction to form water, CO_2, and N_2 (commonly applied to engines)
- Catalysts made from noble metals
- Operating temperatures range from 700 to 1500°F
- Efficiency ranges from 80 to 90 percent

NO_x Control - NSCR

Oxidation catalyst

NO_x Control Techniques – Non Selective Catalytic Reduction

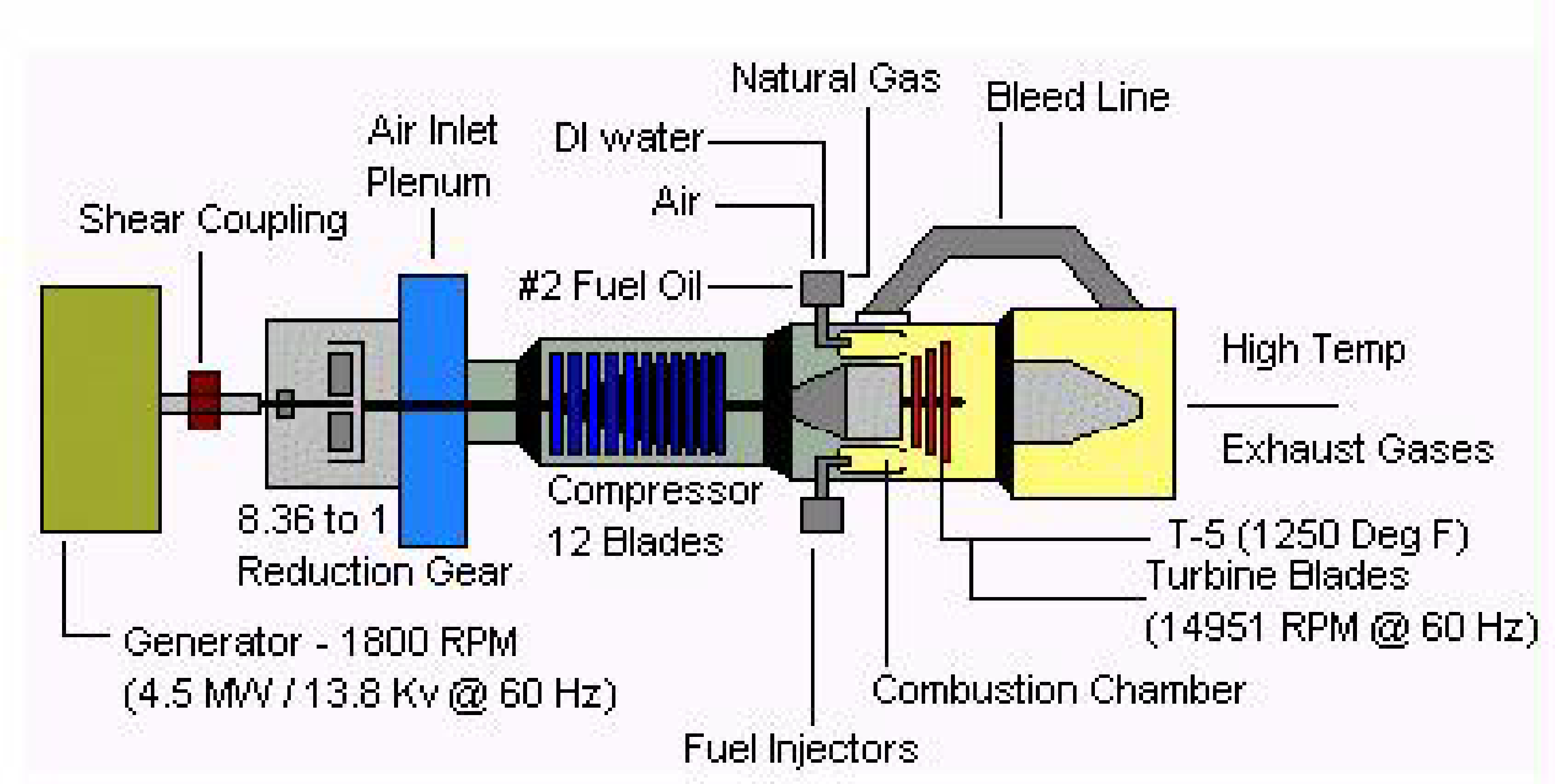
Compliance monitoring

- Outlet nitrogen oxide concentration (CEMS)
- Parametric monitoring
  - Catalyst bed inlet temperature
  - Catalyst activity (replacement)
- Periodic testing, portable analyzers

NO_x Control Techniques – Water or Steam Injection

- General description
  - Water or steam injected in combustion zone reduces temperature and nitrogen oxide formation (applied to gas turbines)
  - Only thermal nitrogen oxides reduced
  - Reductions range from 60 to 80 percent

NO_x Control Techniques – Water or Steam Injection - Schematic



NO_x Control Techniques – Water or Steam Injection

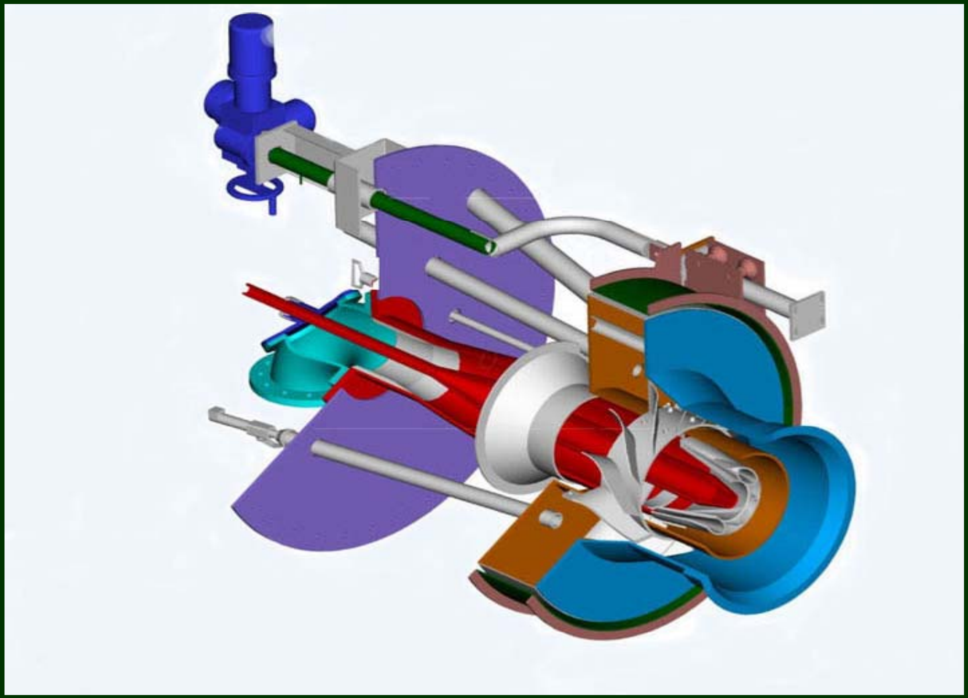
Compliance monitoring

- Outlet nitrogen oxide concentration (CEMS)
- Parametric monitoring
  - Water to fuel ratio
    - Correlated to testing
  - Fuel bound nitrogen concentration (low priority)
- Periodic performance testing

NO_x control – Low-NO_x burners

- Designed to control fuel and air mixing at the burner
  - Staged combustion in a larger flame
  - Reduced O_2 at hottest part of flame
  - Reduced overall flame temperature
  - Complete combustion in third stage
- Often used with flue gas recirculation
- NO_x reductions of ~75 percent possible

Low NO_x burner



NO_x control – Low-NO_x burners

Performance monitoring

- NO_x concentration (CEMS)
- Parametric monitoring
  - Periodic testing and inspections
  - Inspection and maintenance
    - Daily - flame failure detector, A/F recordings
    - Weekly - igniter and burner operation
    - Monthly - fan, fuel safety shutoff, interlocks, fuel pressure
    - Annually – system-wide, instrument calibration

Take-aways about NO_x control device monitoring:

- What can we say about CEMS for monitoring NO emissions?
- What about acid gas scrubbers distinguishes them from and Venturi scrubbers?
- If not CEMS, which operating parameters are appropriate for monitoring compliance for
  - Acid gas scrubbers?
  - Dry injection?

Monitoring raw material or fuel pollutant content limits

- Sulfur in coal or oil
  - ASTM fuel analysis per lot of fuel – S, heat content
  - Monthly records of fuel use – tons, barrels
  - Calculate emissions rate
- THC/OHAP in coatings or solvents
  - Method 24 analysis of each coating or solvent (may be from vendor)
  - Monthly records of use
  - Calculate emissions or verify compliance

Monitoring work practices or design specifications

- Work practice for dust control or liquid spillage
  - Describe practices (e.g., sweep road, water spray, remove spillage, contain waste) and frequencies
  - Define inspection frequencies
  - Record inspections, maintain logs
- Maintain design criteria (e.g., seals on floating roofs)
  - Describe inspections and measurements with frequencies (e.g., annual rim seal checks, weekly visual inspections)
  - Record results and maintain logs

Monitoring process operations (no add-on controls)

- Chemical processes (THC/OHAP emissions)
  - Periodic emissions testing
    - Annual performance test
    - Quarterly portable analyzer checks
  - Process parameter monitoring
    - Temperature on condenser
    - Flow rates
  - Equipment integrity inspections
    - LDAR
    - Capture fans and shrouds
    - Suppression or spraying equipment

Monitoring process operations (no add-on controls)

- Combustion practices for PM control
  - Periodic emissions testing - may tier testing frequency to margin of compliance, for example
    - Annual if ER > 90 % limit
    - Two to three years if 60 < ER > 90 %
    - Five years if ER < 60 %
  - Inspections and parameter monitoring
    - Opacity (e.g., daily VE checks)
    - A/F ratio
    - Fuel or waste charge input rate
    - Equipment (e.g., burners) inspections

Summation

- THC/OHAP Control Techniques
- PM Control Techniques
- Acid Gas Control Techniques
- NO_x Control Techniques
- Passive control measures

What do you want to talk about?

Multiclone
PM collector

Thanks – we appreciate your time and attention!

Contact the Measurement Policy Group, SPPD, OAQPS early and often as you work on your source category rules

westlin.peter@epa.gov - 919-541-1058