Pollution Controls and Available Monitoring Techniques

A quick summary of various control measures and important monitoring characteristics

Peter Westlin, EPA, OAQPS
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
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

\[ V_1 = \text{velocity at hood} \]

\[ P_1 = \text{differential pressure sensor (between enclosure interior and surrounding area/room)} \]
THC/OHAP Control Techniques – Capture Systems

Compliance monitoring (parametric)

- Permanent total enclosures
  - Differential pressure (e.g., < -0.007 in. H₂O)
  - 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 condensible PM)
- High voltages
- Often with multiple sections (fields)
- Efficiencies up to 99+ percent with multiple sections
PM Control Techniques - ESP

[Diagram showing gas flow into paper]

480V Supply
T/R set H-V Secondary

25
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

**SINGLE BAG SCHEMATIC**

1. **EXHAUST**
2. **REPRESSURING VALVE**
3. **FILTERING MODE**
4. **COLLECTION HOPPER**
5. **COLLAPSING (BAG CLEANING MODE)**
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. H₂O
- 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\textsubscript{x} Control Techniques – Selective Catalytic Reduction

General description

- Ammonia or urea is injected into exhaust streams with plenty of oxygen to reduce NO\textsubscript{x} to N\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{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\textsubscript{x} control – Low-NO\textsubscript{x} burners

Performance monitoring

- NO\textsubscript{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$_x$ emissions?
- If not CEMS, which operating parameters are appropriate for monitoring compliance for
  - Water or steam injection?
  - Low NO$_x$ burners
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