Proposed Amended Rule 1134 Working Group #3

June 13, 2018

Agenda

- Summary of previous working group meeting
- Continue BARCT analysis
  - Technology assessment
  - Establishing BARCT emission limit
  - Cost-effectiveness
- Rule concepts

Previous Working Group Meeting

- Presented initial BARCT analysis
  - Identified emission levels of existing units
  - Assessed other rules and BACT determinations
- Provided initial rule concepts for Applicability, Emission Limits, and Exemptions

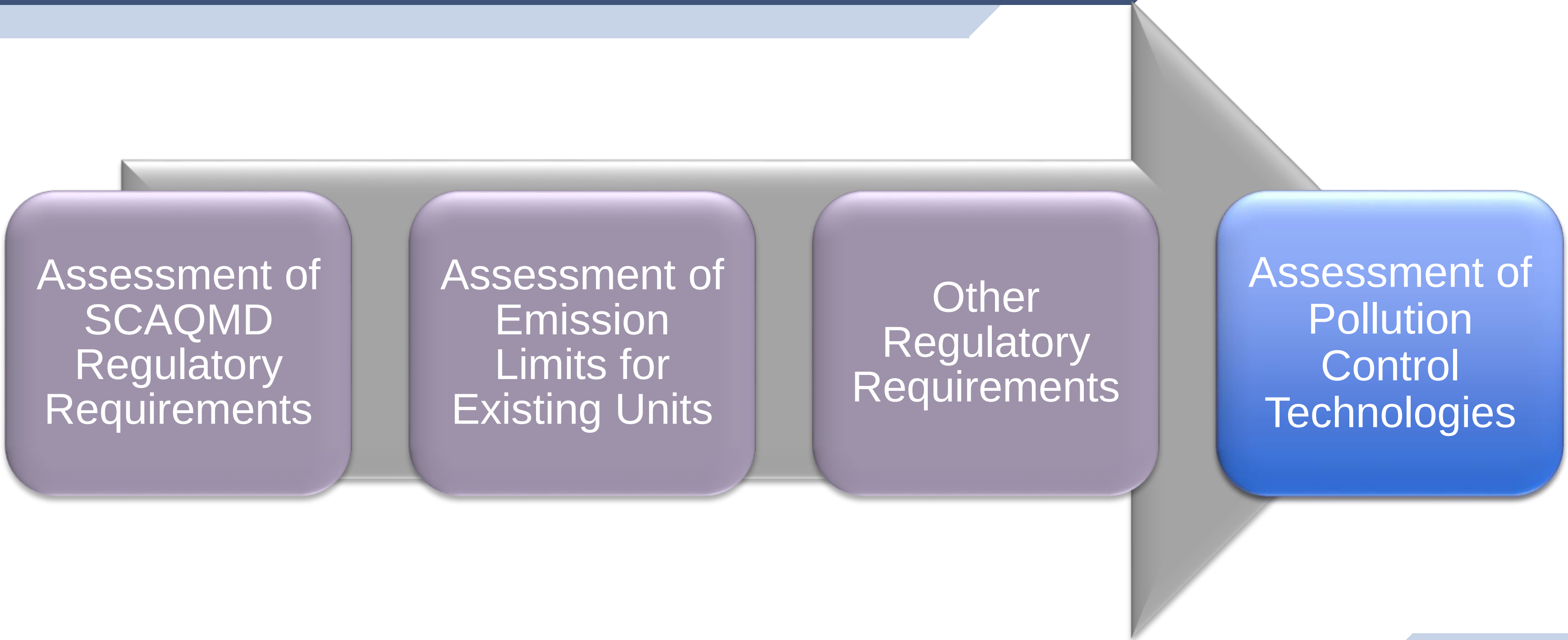
BARCT Analysis

BARCT Analysis Approach for PAR 1134

- *Identify Emission Levels of Existing Units* ✓
- *Assess Rules in Other Air Districts Regulating Same Equipment* ✓
- Technology Assessment
- Establishing the BARCT Emission Limit and Other Considerations
- Cost-Effectiveness

Technology Assessment

Overview of Technology Assessment



Background

- Purpose of technology assessment is to assess current NOx control technologies for turbines
- Various sources researched to determine technological feasibility for NOx controls for turbines
  - Scientific literature
  - Vendor information
  - Strategies utilized in practice to achieve low NOx emissions
- Three major strategies identified to reduce NOx emissions from gas turbines
  - Combustion alteration
    - Steam/water injection
    - Lean premixed combustion
  - Exhaust controls
    - Selective Catalytic Reduction

Steam/Water Injection

- Injection of water or steam into the high temperature flame zone
  - Lowers combustion zone temperature
  - Reduces NOx levels to approximately
    - 25 ppm for natural gas; and
    - 42 ppm for liquid distillate fuels
  - Imprecise application leads to some hot zones so NOx is still created
- Added water or steam increases mass flow through turbine creating a small amount of additional power

Control to 25 ppm

Lean Premixed Combustion

- Gaseous fuel and compressed air are pre-mixed minimizing localized hot spots that create high levels of NOx
  - Single digit (< 9 ppm) NOx emissions have been demonstrated on natural gas and landfill gas turbines with no SCR
  - Not available for liquid fuel turbines
- Requires that the combustor becomes an intrinsic part of the turbine design
  - Not available as a “retrofit” technology; must be designed for each turbine application

Control to 9 ppm

Selective Catalytic Reduction

- Primary post-combustion technology for NOx reduction[1]
  - Used in turbines, boilers, internal combustion engines (including heavy duty trucks), and other NOx generating equipment
  - Ammonia is injected into flue gas and reacts with NOx
  - Metal-based catalyst increases the reaction rate of NOx reduction
  - 80 to 90%+ reduction (reduces NOx levels to 2-5 ppm)
  - Improved reductions where mixture of NOx and ammonia is uniform
  - System susceptible to "poisoning" if flue gas contains contaminants (siloxanes, sulfur compounds, etc.)
- May be used in conjunction with combustion alteration NOx control technologies

Control to
2 - 5 ppm

1. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf

Selective Catalytic Reduction *(continued)*

- Facilities may be space constrained to add more catalyst modules
- Environmental trade-offs
  - Pure anhydrous ammonia is extremely toxic and no new permits issued
  - Aqueous ammonia is somewhat safer but requires vaporization of water
  - Urea is safer to store, but requires conversion to be used
  - All have the potential for ammonia slip where unreacted ammonia is emitted from control device

Other NOx Reduction Technologies

- Catalytic Combustion[1]
  - Lean premixed flameless combustion
  - On-going long-term testing indicates NOx levels below 3 ppm without SCR
    - Turbines with catalytic combustion are entering commercial market
  - Only available for replacement as it must be designed specifically for each turbine type
- Catalytic Absorption Systems[2]
  - Catalytic conversion of NOx with absorption/regenerative process
  - Similar NOx reduction potential as SCR (80-90% reduction; reduces NOx levels to 3-5 ppm)
  - Eliminates need for ammonia
  - High capital costs, complex system, high on-going costs, and regeneration issues remain

1 https://www.energy.gov/eere/amo/catalytic-combustion
2 https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies_section_3._technology_characterization_-_combustion_turbines.pdf

Summary of Primary NOx Control Technologies

Control Technique	NOx Levels (ppm)
Steam/Water Injection	25
Lean Premixed Combustion	9
Selective Catalytic Reduction	2 - 5
Lean Premixed Combustion and Selective Catalytic Reduction	2
Lean Premixed Combustion and Selective Catalytic Reduction	2

BARCT Analysis Approach for PAR 1134

Identify Emission Levels of Existing Units ✓

Assess Rules in Other Air Districts Regulating Same Equipment ✓

Technology Assessment ✓

Establishing the BARCT Emission Limit and Other Considerations

Cost-Effectiveness

Establishing the BARCT Limit

Establishing the BARCT Limit

- Recommended BARCT limits are established using information gathered from:
  - Existing units
  - Other regulatory requirements
  - BACT requirements
  - Technology assessment

Simple Cycle Natural Gas Turbines

	Existing Units	Other Regulatory Requirements	Technology Assessment	BARCT Recommendation
Retrofit		5-25 ppm*	2.5 ppm	2.5 ppm
New Install	2.5 ppm	2.5-25 ppm*	2.5 ppm	2.5 ppm

* Limit dependent on capacity

Combined Cycle Natural Gas Turbines

	Existing Units	Other Regulatory Requirements	Technology Assessment	BARCT Recommendation
Retrofit		5-25 ppm*	2.0 ppm	2.0 ppm
New Install	2.0 ppm	2.0-25 ppm*	2.0 ppm	2.0 ppm

* Limit dependent on capacity

Landfill Gas Turbines

	Existing Units	Other Regulatory Requirements	Technology Assessment	BARCT Recommendation
Retrofit		50 ppm	25 ppm	25 ppm
New Install	12.5 ppm	50 ppm	12.5 ppm	12.5 ppm

Sewage Digester Gas Turbines

	Existing Units	Other Regulatory Requirements	Technology Assessment	BARCT Recommendation
Retrofit	18.8 ppm	50 ppm	18.8 ppm	18.8 ppm
New Install		50 ppm	15 ppm	15 ppm

Process Gas Turbines

	Existing Units	Other Regulatory Requirements	Technology Assessment	BARCT Recommendation
Retrofit		50 ppm		
New Install	5 to 9 ppm	50 ppm	5 ppm	5 to 9 ppm

BARCT Recommendation

- Based on technology assessment, other air district regulations, and BACT requirements, the following limits are technically feasible
  - Limits may be met by retrofit or replacement

Turbine Type	NOx Limit (ppm @ 15% O2)
Natural Gas	
Combined Cycle	2.0
Simple Cycle	2.5
Landfill Gas	12.5
Sewage Digester Gas	18.8
Process Gas	5.0

BARCT Analysis Approach for PAR 1134

- *Identify Emission Levels of Existing Units* ✓
- *Assess Rules in Other Air Districts Regulating Same Equipment* ✓
- Technology Assessment ✓
- Establishing the BARCT Emission Limit and Other Considerations ✓
- Cost-Effectiveness

Cost-Effectiveness

Cost-Effectiveness

- Cost-effectiveness is a cost-benefit analysis comparing relatives costs and outcomes
- It is measured in cost per ton of pollutant reduced
- SCAQMD uses Discounted Cash Flow Method to calculate cost-effectiveness
  - Cost-Effectiveness = Present Value/Emissions Reduced Over Equipment Life
  - Present Value = Capital Costs + (Annual Operating Costs * Present Value Formula)
  - Present Value Formula = $(1 – 1/(1 + r)^n)/ r)$
    - $r = (i – f)/(1 + f)$
    - i = nominal interest rate
    - f = inflation rate

Cost Estimates for Natural Gas Turbines

- Using U.S. EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction[1] to determine retrofit costs
  - Methodology based on U.S. EPA Clean Air Markets Division Integrated Planning Model
  - Size and costs of SCR based on size, fuel burned, NOx removal efficiency, reagent consumption rate, and catalyst costs
  - Capital costs annualized over 25 years at 4% interest rate
  - 2015 annual reported emissions used to estimate annual MW output
  - Values reported in 2015 dollars
- Turbine replacement costs are $1.2 million to $3.3 million per MW[2] (2015 dollars)
- Stakeholders are welcome to provide staff with their own costs and cost-effectiveness calculations

1 - Available at: https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf
2 – Available at: https://www.epa.gov/sites/production/files/2015-07/documents/catalog_of_chp_technologies.pdf

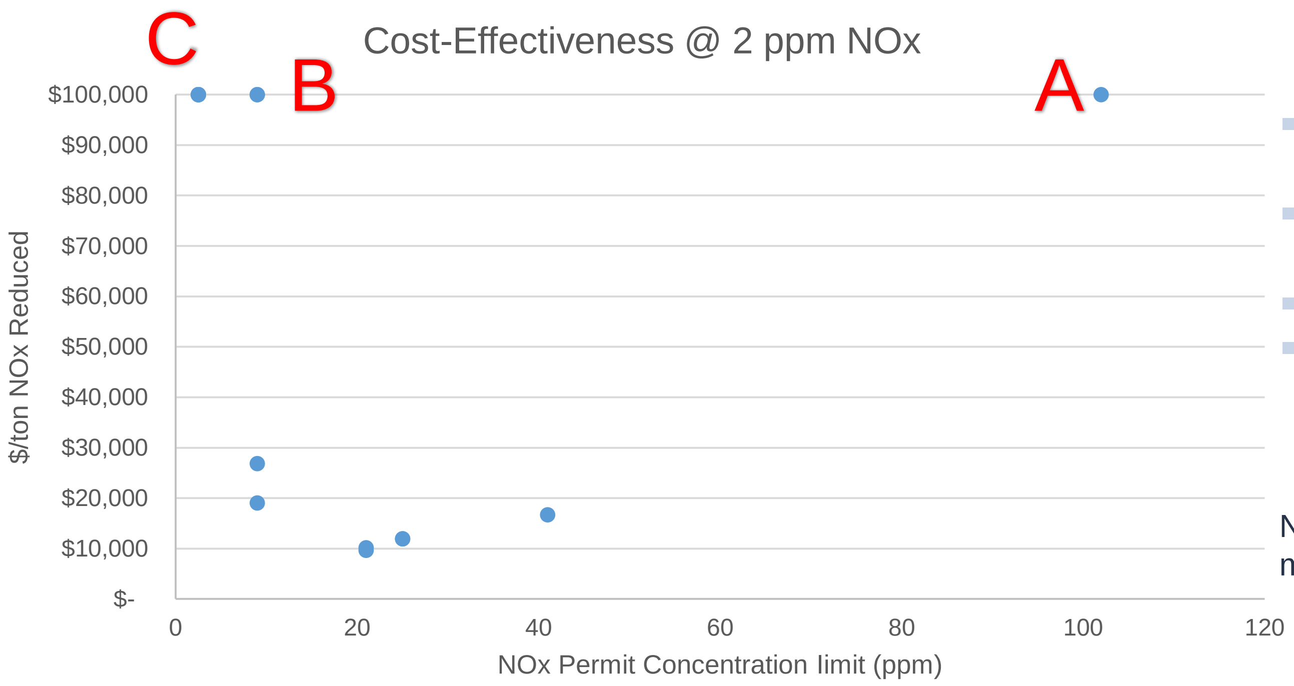
Estimated Emissions Inventory and Reductions

- Baseline Emissions determined by using reported fuel consumption and permitted emission limit
- PAR 1134 Emissions determined by using reported fuel consumption and proposed emission limit
- Emission reductions are the difference between Baseline Emissions and PAR 1134 Emissions

Evaluation of Cost-Effectiveness for Natural Gas Turbines

- Evaluated cost-effectiveness for all PAR 1134 turbines at the following proposed NOx concentration limits:
  - Combined cycle: 2.0 ppm
  - Simple cycle: 2.5 ppm
- Used 2015 emission data and costs
- Cost-effectiveness evaluation based on retrofit costs using U.S. EPA's Air Pollution Control Cost Estimation Spreadsheet for Selective Catalytic Reduction

Combined Cycle Natural Gas Turbines



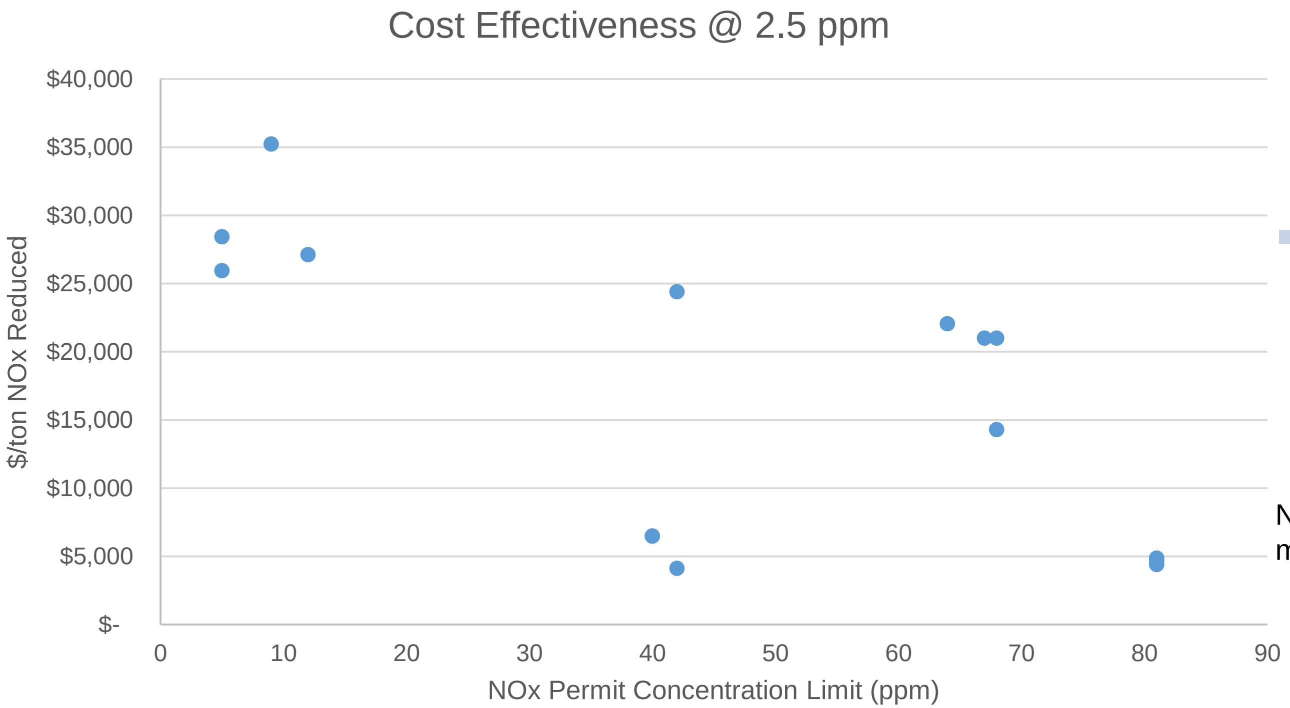
- A – Low-use turbine (< 10% use)
- B – Low-use turbines (< 10% use)
- C – Five 2.5 ppm units
- Other seven turbines have cost effectiveness < $30,000/ton

Note that some dots represent multiple units

BARCT Determination for Combined Cycle Natural Gas Turbines

- Proposed limit of 2.0 ppm cost effective for remaining seven units
  - Average cost effectiveness (excluding low-use and 2.5 ppm units) is approximately $15,200/ton reduced
  - Highest cost effectiveness (excluding low-use and 2.5 ppm units) is approximately $26,900/ton reduced
- Proposed limit of 2.0 ppm not cost effective (> $100,000/ton reduced) for:
  - Low-use units utilized < 10% of capacity
  - Turbines currently permitted at 2.5 ppm NOx

Simple Cycle Natural Gas Turbines



- All 15 turbines have cost effectiveness < $36,000/ton

Note that some dots represent multiple units

BARCT Determination for Simple Cycle Natural Gas Turbines

- Proposed limit of 2.5 ppm cost effective all 15 units
  - Average cost effectiveness is approximately $16,800/ton reduced
  - Highest cost effectiveness is approximately $35,300/ton reduced

Natural Gas Pipeline Turbines

- Four < 1 MW turbines used for natural gas pipelines
  - Challenged by variation in fuel flow
  - Currently emitting < 10 tons combined annually
- BACT and SJVAPCD limits are currently 8 ppm steady and 12 ppm transition
- Analyzing technical feasibility and incremental cost-effectiveness to meet 2.5 ppm limit
  - BACT/SJVAPCD limit would result in approximately one ton of NOx emission reductions foregone annually

Cost-Effectiveness for Landfill Gas Turbines

- Based on recent source testing, 12 of 16 landfill gas turbines can meet 12.5 ppm NOx limit
  - Considerations may be necessary for short periods where low loads or other permit restriction impact NOx emission concentrations
- Remaining four units installed in 2007 already using SCR control technology
  - Recent test results indicate that meeting 25 ppm permit limit is challenging
  - Experiencing high costs due to frequent catalyst replacement
- More recent version of turbine model reportedly has NOx emissions of 15 ppm with no SCR
  - Stranded assets may be somewhat offset by elimination of SCR control costs
  - Estimated cost effectiveness for replacement is $42,000 per ton (45 tons reduced); without stranded assets cost effectiveness is $30,100 per ton
  - If significant changes to filters, piping, etc. are required then cost effectiveness is approximately $82,000 per ton

Sewage Digester Gas Turbines (Retrofit)

- Three turbines currently meet 18.8 ppm NOx using SCR
- Examining cost for other three turbines to meet same limit
- In addition to SCR costs, filtering costs to remove contaminants
  - Filtering capital costs range from $1.0 to $7.1 million[1]
  - Annual filtering operation and maintenance costs range from $0.3 to $1.1 million[1]
  - Estimated 23.2 tons of NOx reduced annually from all four turbines

1 – GTI Technical – Final Report AQMD Contract #: 13432; Conduct a Nationwide Survey of Biogas Cleanup Technologies and Costs

Sewage Digester Gas Turbines (Replacement)

- Recent version of model installed in early 2000’s reportedly has NOx emissions of 15 ppm with no SCR
  - Lean combustion control produces less NOx than steam injection control
  - Some loss of power from steam removal
  - If loss of power doesn’t impact operations, then cost impacts may be insignificant
  - If larger units required to make up for lost power, then significant changes may be necessary for piping, filtering, housing, etc.
  - Estimated 46 tons of NOx reduced from all four turbines

Process Gas Turbine

- Six offshore platform process gas turbines to be replaced
  - Plans are to replace three by electrification and three with new turbines
  - New turbines will be subject to BACT
  - Turbines utilize diesel fuel as back-up to process gas
    - Diesel fuel allowed only when there is no access to natural gas
  - Considering 5 to 9 ppm limit for process gas and 25 ppm limit for liquid fuel

Incremental Cost for Offshore Platform Process Gas Turbines

- Differential cost effectiveness between new turbine purchase and new turbine purchase with SCR control
  - Estimated capital cost of new turbines = $16.5 million ($5.5 million each)
  - Estimated capital cost of SCR = $2.7 million ($0.9 million each)
  - Estimated annual costs for SCR = $0.2 million
  - Estimated emission reduction without SCR (9 ppm) = 18.5 tons
  - Estimated annual emission reductions with SCR @ 5 ppm = 18.8 tons
- Cost effectiveness of new turbines = $36,000 per ton of NOx reduced
- Cost effectiveness of new turbines with SCR = $48,000 per ton of NOx reduced
- Incremental cost effectiveness > $800,000 per ton

BARCT Analysis Summary

Gas Turbine Fuel	Proposed Limit (ppmv @ 15% O_2)	Cost-Effectiveness (cost per ton of NOx reduced)
Natural Gas		
Simple Cycle	2.5	$16,800
Combined Cycle	2.0	$15,200
Landfill Gas	12.5	$42,000 to $82,000
Sewage Digester Gas	18.8	Still assessing costs
Process Gas	5 – 9 (25 for liquid fuel)	$36,000 to $48,000

Rule Concepts

Rule Concepts – *Emission Limits*

Gas Turbine Fuel	Proposed Limit (ppmv @ 15% O_2)
Natural Gas	
Simple Cycle	2.5
Combined Cycle	2.0
Landfill Gas	12.5
Sewage Digester Gas	18.8
Process Gas	5 – 9 (25 for liquid fuel)

- Limits averaged over one hour
  - Explore longer averaging period for sewage digester gas turbines
- Effective date January 1, 2024
- Considering replacement requirement for turbines older than 25 to 35 years

Rule Concepts – *Monitoring*

Monitoring is critical to ensure equipment is operating properly

- Retain continuous emission monitoring system for units ≥ 2.9 MW
- New requirements for monitoring
  - Update Continuous Emission Monitoring Systems (CEMS) Requirements Document for Utility Boilers
  - Relative Accuracy Test Audit (RATA) annually
  - Relative Accuracy Audit (RAA) quarterly
  - Daily calibration
  - Missing data procedures for up to 72 hours in any one calendar month
  - Remove monitoring requirements for volumetric flow, heat input rate, and net MWH produced
  - Add monitoring requirements for ammonia

Rule Concepts – Data Acquisition

- Data acquisition system requirements
  - NOx emission rate (ppm)
  - O_2 concentration (ppm)
  - Ammonia (ppm)

Rule Concepts – *Source Testing*

- Current requirements
  - Annual source testing if unit emits more than 25 tons annually
  - Otherwise within 90 days after 8,400 hours of operation
- Proposed requirements
  - Source testing every three years only if RATA not applicable

Rule Concepts – *Recordkeeping and Reporting*

- Current requirements
  - Records maintained for two years
  - Monthly reporting of emissions
  - RECLAIM requirements
- Proposed Requirements
  - Require records maintained and made available upon request for five years

Schedule

Current Tentative Schedule

Next Working Group Meeting	July 2018
Public Workshop	Summer 2018
Stationary Source Committee	Fall, 2018
Set Hearing	Fall 2018
Public Hearing	Fall 2018

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