# Rule 1109.1 – NOx Emission Reduction for Refinery Equipment

**Working Group Meeting #5**

**November 28, 2018**

# Agenda



- Progress of Rule Development
- Technology/BARCT Analysis
- Survey Data Overview
- Survey Data Analysis for Source Category
- Next Steps

# Progress of Rule Development



## Summary of Working Group #4 (9/12/18)

- Discussed fourth step of the BARCT technology assessment
- Focused on commercially available and emerging technologies
- Presented source specific rules for boilers/heaters, thermal oxidizers, and Incinerators

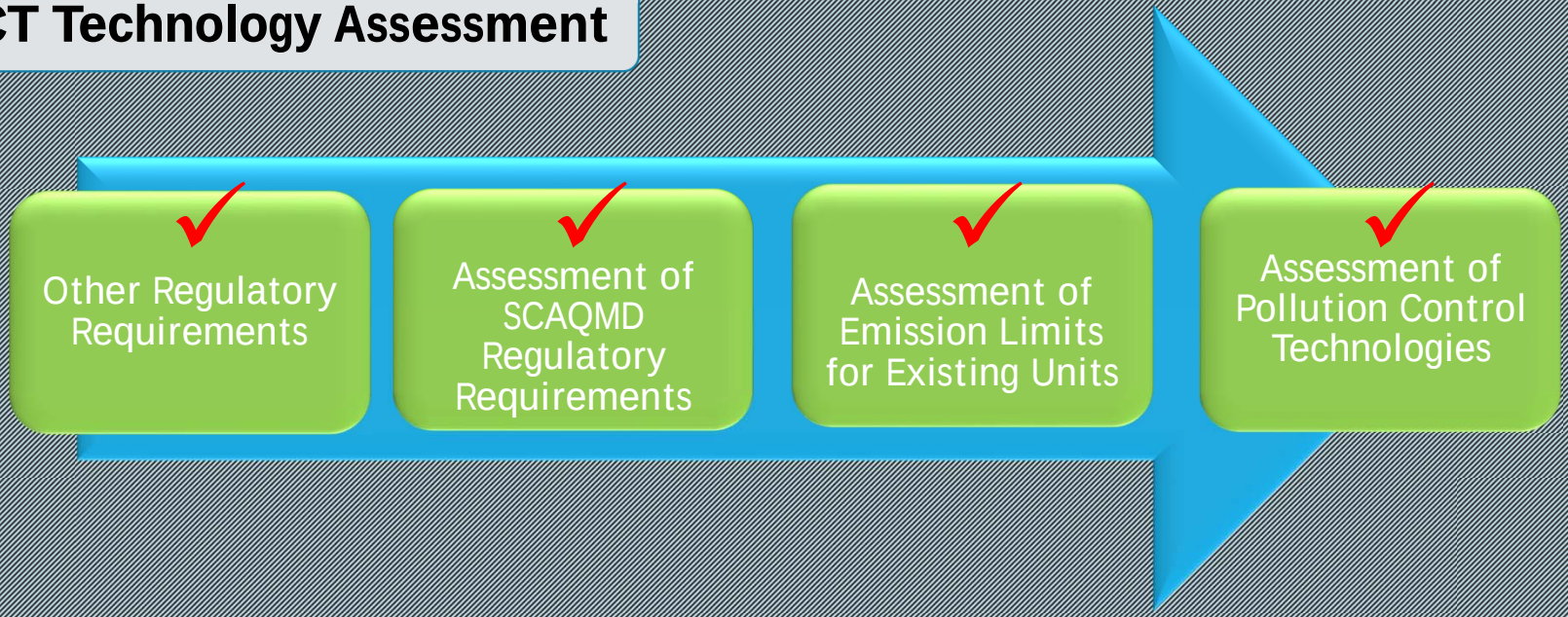
## Since last Working Group Meeting

- Analyzed submitted survey data
- Coke calciner stakeholder meeting
- Meetings with control technology suppliers
- Request for Proposal (RFP) Board approval scheduled for release 12/7/18 (Contractor selection 2/8/19 and final report due 5/24/19)
- Continuing site visits and meetings with stakeholders and non-stakeholders to assess control technology transferability

# Technology Assessment Review

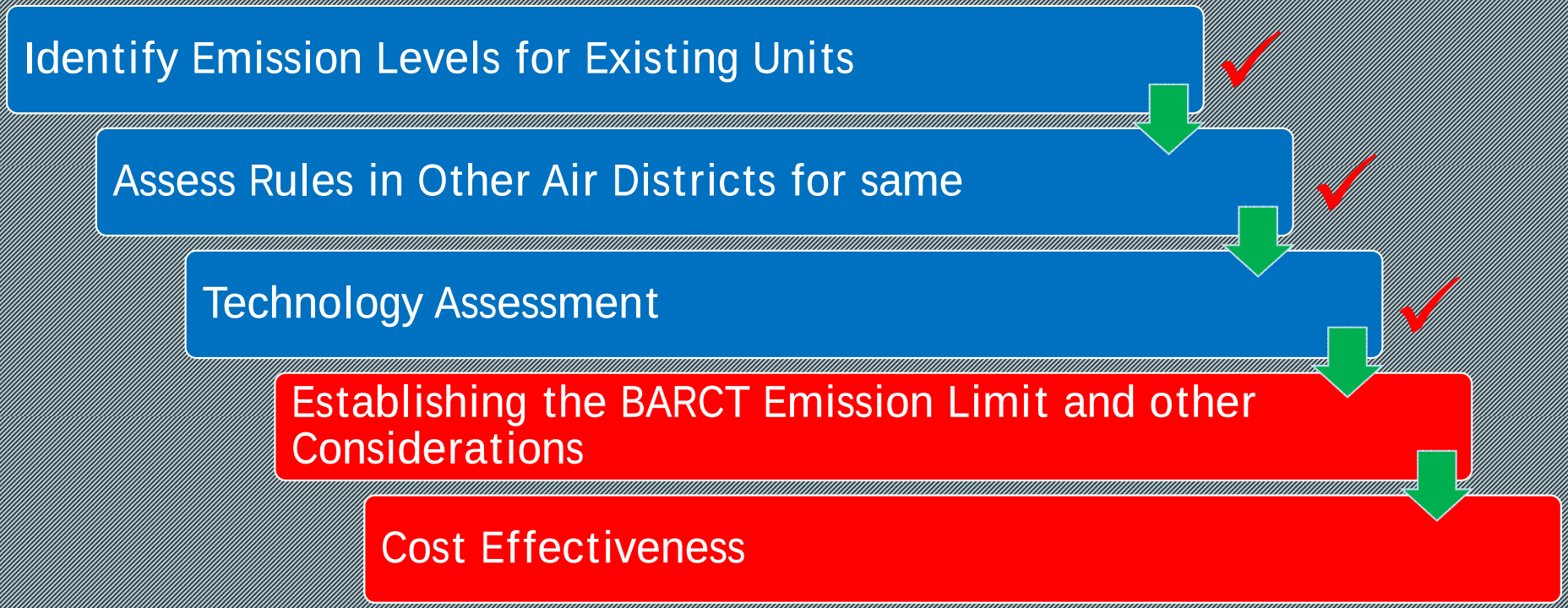


## BARCT Technology Assessment



# BARCT Analysis Approach Review





# Survey Data Overview

# Survey Data Overview



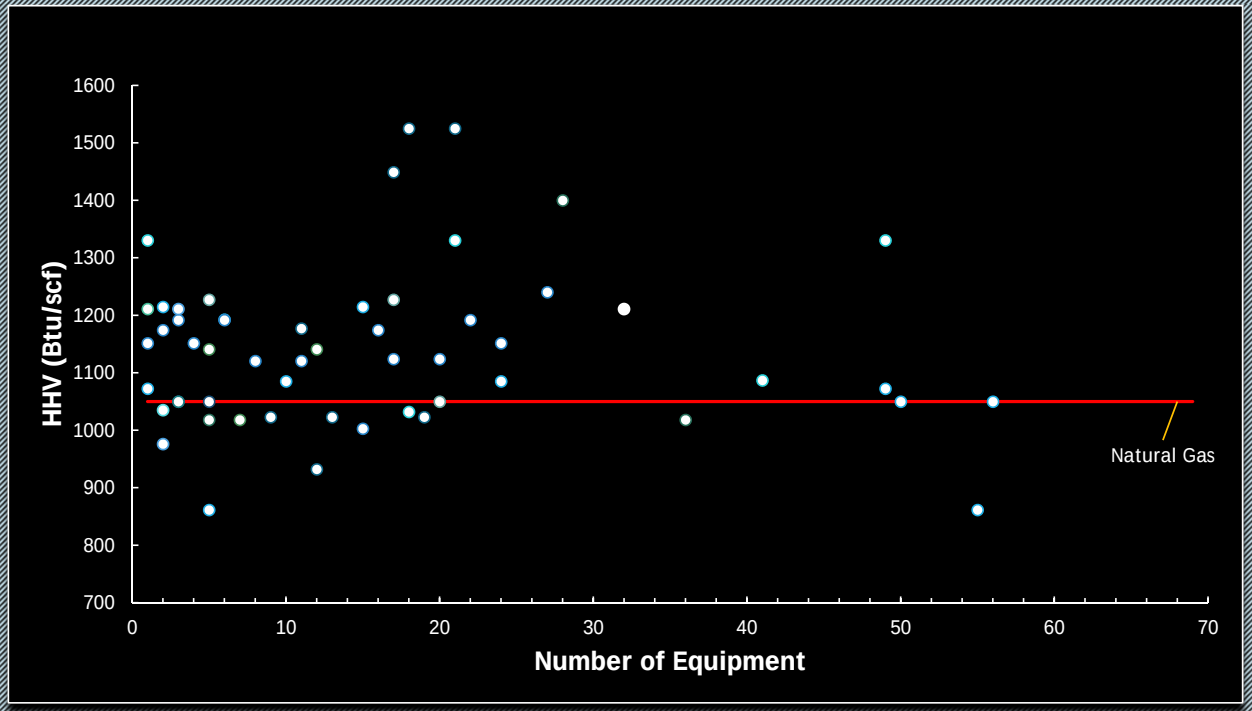
- Information gathered from survey used to determine:
  - Proposed BARCT limits
  - Cost-effectiveness analysis
- Provides staff with most up-to-date information for current equipment
  - Number of permitted equipment
    - Some equipment are not in operation, removed, or never built
  - Age of equipment and retrofit controls
  - Average heating value of fuel
  - Fuel usage
  - Utility of heater operated (% capacity utilized)
  - Currently installed control technology (if equipped)
  - Outlet NOx Emissions – what is currently being achieved
    - Compared to CEMS (RATA) and Source test data
  - Planned or scheduled installation of control technology

# Refinery Fuel Gas (RFG)



**Refinery/Process Fuel Gas**

- Predominant fuel used is RFG and/or mixed gas (RFG and natural gas)
- RFG has different properties than pipeline-quality natural gas fuel
- RFG composition varies amongst refineries and over time
- Combustion characteristics of RFG
  - Higher heating value (HHV) also varies
  - Significantly higher heating value than natural gas (as high as 1400 Btu/scf) due to olefins
  - Thus burns hotter, more NOx
  - RFG mixed with NG at fuel gas mix-drum to maintain consistent HV




*Snapshot of fuel HHV at a given time. Data sampling from 53 pieces of equipment from each source category located at each facility*

# Survey Data Equipment



The survey provided data and information for the following category of equipment

- Process heaters and boilers
- Gas turbines
- FCCU
- SRU/TG Incinerators
- Thermal oxidizers and incinerators
- Coke calciner
- Auxiliary ICE (formerly primary ICE)

# Survey Data Analysis
# Process Heaters & Boilers

# Process Heaters & Boilers



- Represents the largest source category of NOx emissions
  - 69% of total equipment (235 total)
- Located in a majority of processing units
- Heat generated from a fueled-fired process heater or boiler is provided by combustion
- Boilers and steam generators are devices that heat or boil water
- Process heaters heat process streams other than water to unit processing temperatures
- Refinery fuel gas and natural gas are predominant fuel
- Hydrogen reformer heaters use Pressure Swing Adsorber (PSA) off gas as primary fuel with RFG and NG as trim fuel (~90/10 ratio)

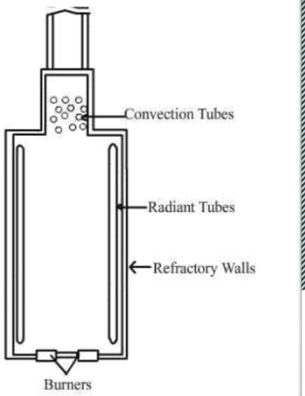


Fig:3.1 Vertical Cylinder Process Heater

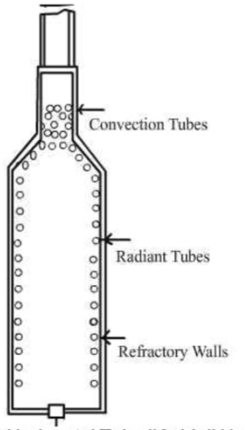


Fig:3.2 Horizontal Tube "Cabin" Heater

# Process Heaters & Boilers



- Largest Source category for Rule 1109.1 NOx emissions at 2,974 tons/year (69%), but highest number of equipment
- After further refinement of heater/boiler data, the following categories will be used:
  - Heaters (primary heaters & start-up/shutdown)
    - Crude processing (crude & coker units)
    - Hydroprocessing (hydrocracking, isomerization, and reformer units)
  - Boilers (excludes heat recovery boilers & CO boilers)
    - Utilities (steam generation)
  - Hydrogen reformer heaters
  - Sulfuric acid plant heaters (furnace & start-up/shutdown heaters)
- Each heater/boiler category will further be sub-divided into heater size category
- Classification of NOx control:

| Control | Current Technology | Survey |
|---|---|---|
| LNB | 15 – 25 ppm | 14 – 81 ppm |
| ULNB | 9- 15 ppm | 19 – 60 ppm |

- Definition of ULNB and LNB may have been different at time of installation
  - Based on survey, burners were retrofitted on average 27 years ago

# Process Heaters & Boilers Categories



## Heaters

- **Primary heaters –** includes all heaters used in a majority of refinery processing units
- **Start-up/shutdown heaters –** heaters used only for start-up/shutdown (excludes FCCU Start-up heaters)

## Boilers (steam generation)

- Fuel-fired boilers that produce plant steam from boiling water
- Does not include heat recovery steam boilers and CO boilers (heat input is from heat recovery)

## Hydrogen reformer heaters

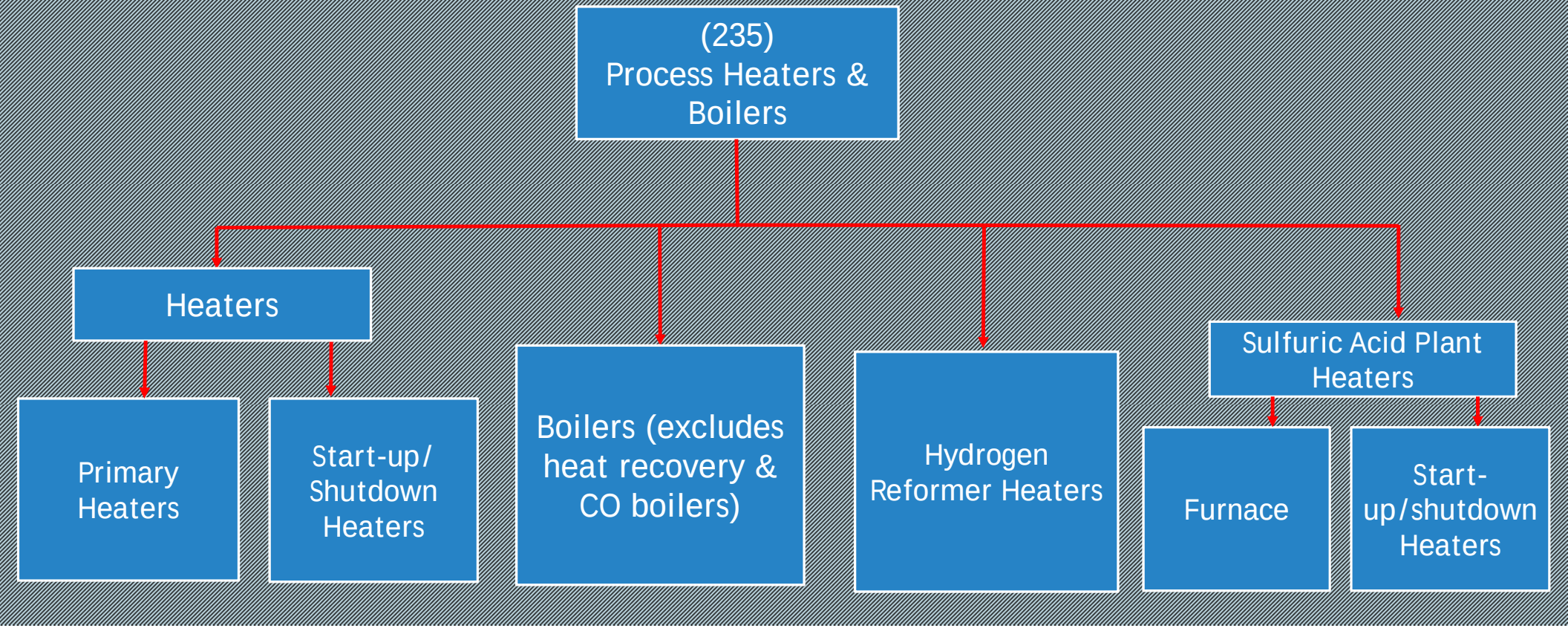
- Large heaters
- Primary fuel is PSA-off gas (composition consist of CO, methanol, and some $H_2$)
- Trim fuel can either be refinery gas or natural gas

## Sulfuric acid plant heaters

- **Furnaces –** spent sulfuric acid is sprayed into furnace with fuel and air in the combustion process
- **Start-up/shutdown heaters** – exhaust from heaters are aggregated with furnace, used as preheat or used during maintenance activities

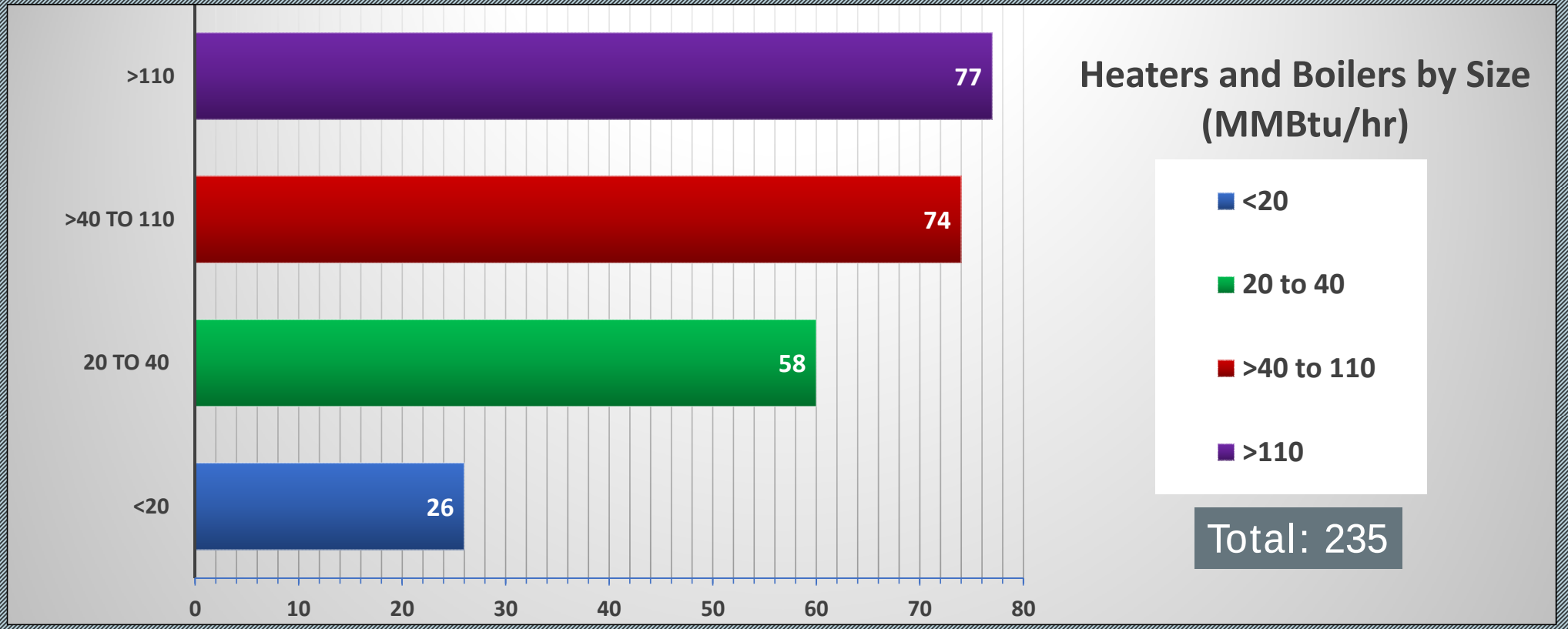
# Heaters & Boilers by Category





# Process Heaters & Boilers by Size





# Heaters & Boilers breakdown by Size & Category



| Size/Capacity (MMBtu/Hr) | Heaters | | Boilers | Hydrogen Reformer Heaters | Sulfuric Acid Plant Heaters | | Total |
|---|---|---|---|---|---|---|---|
| | Primary Heaters | Start-up & Shutdown Heaters | | | Furnace | Start-up & Shutdown Heaters | |
| <20 | 23 | | 2 | | | 1 | 26 |
| 20 to 40 | 54 | | 3 | | 1 | | 58 |
| >40 to 110 | 68 | | 3 | | 2 | 1 | 74 |
| >110 | 44 | | 19 | 13 | 1 | | 77 |
| Total | 189 | | 27 | 13 | 4 | 2 | 235 |

# Primary Heaters



| Size/Capacity Range (MMBtu/hr) | Primary Heaters | LNB | Equipped with SCR | No Control | Average Age (years)*1 | Avg. Num. of Burners | Avg. Flow Rate (dscf/min) | Average % Capacity | NOx Emissions Low (ppm)*2 | NOx Emissions High (ppm)*2 | 2016 Emissions (tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <20 | 23 | 21 | 1 | 2 | 47 | 3 | 2,961 | 61% | 4.4 | 68 | 25 |
| 20 to 40 | 54 | 53 | 8 | 1 | 39 | 10 | 6,410 | 59% | 3.8 | 97 | 154 |
| >40 to 110 | 68 | 55 | 15 | 12 | 34 | 22 | 13,776 | 54% | 2.8 | 113 | 669 |
| >110 | 44 | 42 | 16 | 2 | 44 | 35 | 46,067 | 72% | 2.6 | 122 | 957 |
| Total | 189 | 171 | 40 | 18 | | | | | | | 1,805 |

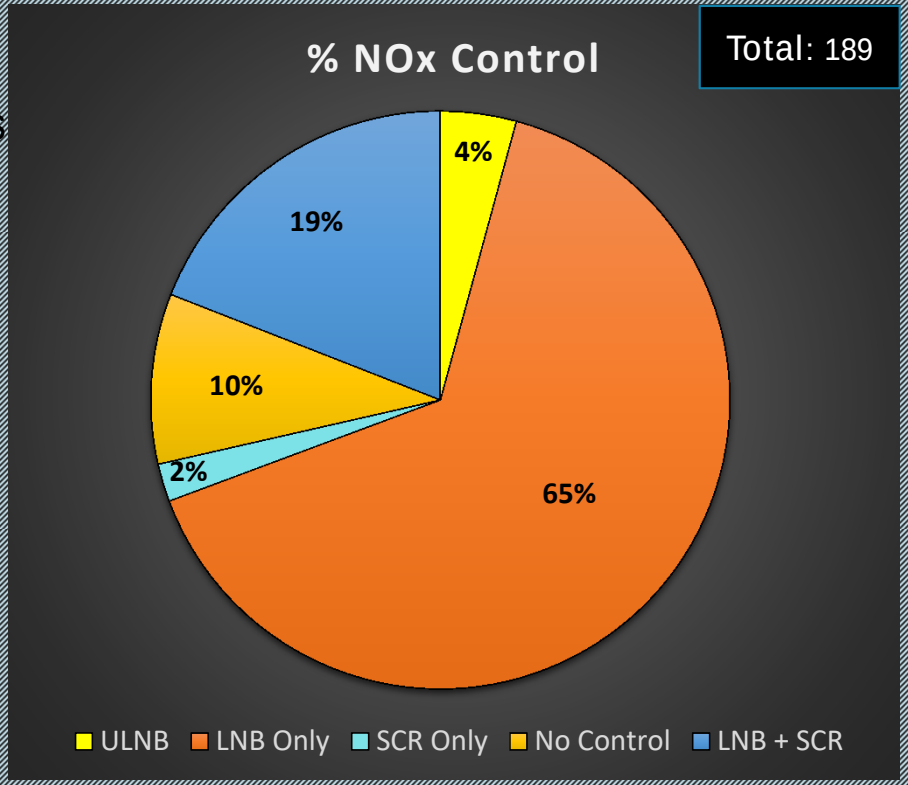
*1-Age averaged over reported installation year. Some equipment age not reported.

*2-NOx emissions corrected to 3% $O_2$

# Primary Heaters Summary



- Represents 61.3% of total heater annual NOx emissions
- Majority located in hydroprocessing units, followed by crude and coker units
- 7 heaters located in FCCU (non-startup heaters)
- Average age of equipment from 34 to 47 years
- Lowest NOx emissions (@3% O2)
  - <20 MMBTU/hr : 4.4 ppm (RFG, SCR)
  - 20 to 40 MMBtu/hr: 3.8 ppm (NG, LNB, and SCR)
  - >40 to <110 MMBtu/hr: 2.8 ppm (RFG, ULNB, SCR)
    - Low ppm achieved with ULNB and SCR
  - >110 MMBtu/hr: 2.6 ppm (RFG, LNB, SCR)



# Boilers



| Size/Capacity Range (MMBtu/hr) | Boilers | LNB | Equipped with SCR | No Control | Average Age (years)*1 | Avg. Num. of Burners | Avg. Flow Rate (dscf/min) | Average % Capacity | NOx Emissions Low (ppm)*2 | NOx Emissions High (ppm)*2 | 2016 Emissions (tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <20 | 2 | 2 | 0 | | | 1 | 846 | 54% | 33 | 36 | 3.3 |
| 20 to 40 | 3 | 1 | 0 | 2 | 17 | 1 | 4,240 | 34% | 7.3 | 9 | 0.4 |
| >40 to 110 | 3 | 0 | 0 | 3 | | | 5,417 | 28% | 71 | 105 | 14 |
| >110 | 19 | 10 | 5 | 6 | 37 | 3 | 33,913 | 51% | 4.4 | 141 | 721 |
| Total | 27 | 13 | 5 | 11 | | | | | | | 738.7 |

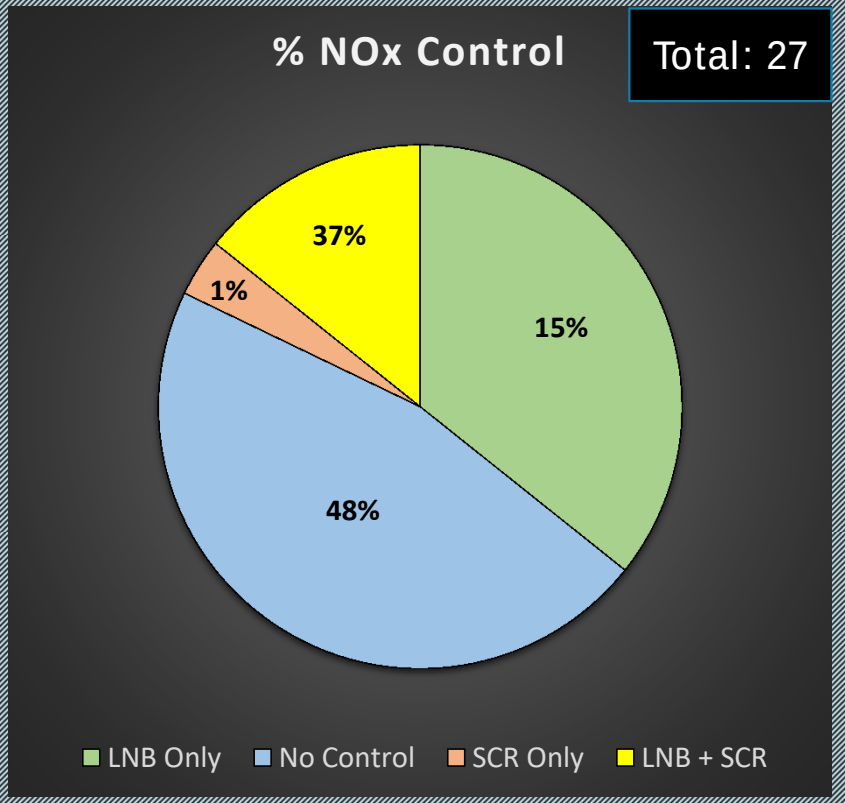
*1-Age averaged over reported installation year. Some equipment age not reported.

*2-NOx emissions corrected to 3% $O_2$

# Boilers Summary



- Represents 25% of total annual heaters & boilers emissions
- Does not include heat recovery steam boilers, only fuel-fired utilities boiler
- Majority of boilers are >110 MMBTU/hr
- Most boilers are used on average 28% to 54% of capacity
- 2 boilers are located in sulfur plant
- Lowest NOx Outlet (@3% O2)
  - < 20 MMBTU/hr: 30 ppm (NG, LNB)
  - 20 to 40 MMBTU/hr : 7.3 ppm (NG, LNB)
  - >40 to 110 MMBtu/hr : 71 ppm (RFG, no control)
  - >110 MMBtu/hr : 4.4 ppm (RFG, SCR)



# Hydrogen Reformer Heaters



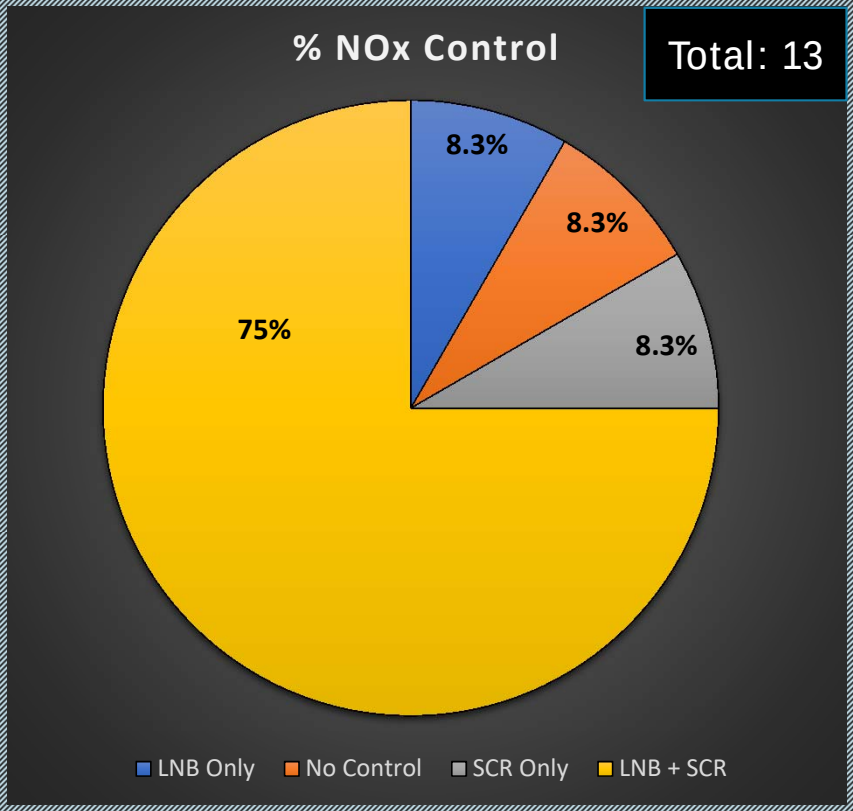
| Size/Capacity Range (MMBtu/hr) | Hydrogen Reformer Heaters | LNB | Equipped with SCR | No Control | Average Age (years)*1 | Avg. Num. of Burners | Average % Capacity | Avg. Flow Rate (dscf/min) | NOx Emissions Low (ppm)*2 | NOx Emissions High (ppm)*2 | 2016 Emissions (tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ≤110 | | | | | | | | | | | |
| >110 | 13 | 11 | 10 | 1 | 29 | 162 | 59% | 106,845 | 4 | 70 | 366 |
| Total | 13 | 11 | 10 | 1 | | | | | | | 366 |

*1-Age averaged over reported installation year. Some equipment age not reported.
*2-NOx emissions corrected to 3% $O_2$

# Hydrogen Reformer Heaters Summary



- Largest heaters in category, all >110 MMBtu/hr
- 12.4 % of total annual heater and boiler emissions
- 12 hydrogen reformer heaters
  - One hydrogen reformer heater has gas turbine attached upstream, but share common stack
  - 13 total pieces of equipment
- Hydrogen reformer heaters are used on average 59% of capacity
- Primary Fuel is PSA off gas with either NG or RFG as trim fuel
- Largest volumetric flow rate of all heaters: ~106,845 dscf/min (average)
- Most are equipped with some form of NOx control or combination of controls
- One with no control is result of control system not operating as designed
- Lowest NOx emissions (@3% O2)
  - 780 MMBtu/hr : 4 ppm
- Equipment equipped with LNB and SCR achieve on average 5.7 ppm NOx



# Sulfuric Acid Plant Heaters



| Size/Capacity Range (MMBtu/hr) | Sulfuric Acid Plant Heaters | LNB | Equipped with SCR | No Control | Average Age (years)* | Avg. Num. of Burners | Avg. Flow Rate (dscf/min) | Average % Capacity | NOx Emissions Low (ppm)* | NOx Emissions High (ppm)* | 2016 Emissions (tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <20 | | | | | | | | | | | |
| 20 to 40 | 1 | 1 | 0 | | 49 | | 2,701 | 56% | 34.0 | | 3.2 |
| >40 to 110 | 2 | 1 | 0 | 1 | 28 | 1 | 22,149 | 66% | 11 | 94 | 10.8 |
| >110 | 1 | 0 | 0 | 1 | 30 | 2 | 66,000 | 49% | 20 | | 23.0 |
| Total | 4 | 2 | | 2 | | 3 | | | | | 37.0 |

| Size/Capacity Range (MMBtu/hr) | Start Up Heaters | LNB | Equipped with SCR | No Control | Average Age (years)* | Avg. Num. of Burners | Avg. Flow Rate (dscf/min) | Average % Capacity | NOx Emissions Low (ppm)* | NOx Emissions High (ppm)* | 2016 Emissions (tons/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| <20 | 1 | 1 | 0 | | 25 | 1 | | | | | 0.1 |
| 20 to 40 | | | | | | | | | | | |
| >40 to 110 | 1 | 0 | 0 | 1 | 28 | 1 | 5,600 | 27% | 29.6 | | 0.2 |
| >110 | | | | | | | | | | | |
| Total | 2 | 1 | | 1 | | 2 | | | | | 0.3 |

*1-Age averaged over reported installation year. Some equipment age not reported.

*2-NOx emissions corrected to 3% $O_2$

# Sulfuric Acid Heaters Summary



- 1.3% of total heater and boiler annual NOx emissions
- Two primary heaters (furnaces) are used approximately 49% to 66% of capacity
  - Spent sulfuric acid is sprayed with fuel during combustion process
- Two heaters are used as preheat or steam superheater (29 and 50 MMBtu/hr)
- Two start-up heaters used only during start-up or maintaining temperature during shutdown
- NOx Outlet (@3% O2)
  - 10 to < 20 MMBtu/hr – Permit limit of 190 ppm (start-up only)
  - 20 to 40 MMBtu/hr – 34 ppm (RFG, LNB)
  - >40 to 110 MMBtu/hr – 11 ppm (RFG, LNB)
  - >110 MMBtu/hr – 20 ppm (NG, no NOx control)
- No post-combustion NOx controls (survey)
- Some challenges of NOx control due to SOx emissions and exhaust temperature
- Continuing to evaluate controls options with system manufacturers

# Heaters & Boilers Category Summary



- Largest source category of Rule 1109.1 NOx emissions at 2,974 tons/year (69%)
- Heaters/boilers are located in all major processing units including FCCU and Sulfur plants
- Primary factors impacting NOx emissions are:
  - Emission rates, time operated, percentage of full firing rate, and currently implemented control technologies
- Lowest achievable limits from combination of controls
  - Boilers and heaters that are equipped with both LNB and SCR achieve the lowest NOx emissions
- Oldest equipment tend to have no control, high ppm emissions
  - Oldest boiler 75 years old (no control, 96 ppm @ 3% O2)
  - Oldest heater 65 years old (no control, 47 ppm @ 3% O2)

# Survey Data Analysis
# Gas Turbines

# Gas Turbines – Combined Cycle



| Size (MMBTU/Hr) | Fuel Type | Control & Year | NOx Permit Limit (ppm) | NH3 Permit Limit (ppm) | Survey NOx ppm | CEMS(RATA) NOx ppm @15% O2 | Source Test NOx ppm @ 15% O2 | Avg. Flow Rate (dscf/min) | % Capacity | 2016 NOx Emissions (tons/year) |
|---|---|---|---|---|---|---|---|---|---|---|
| 508.6 | Natural Gas | DLNB, SCR | 2 | 5 | 1.1* | 1.0 | 1.2 | 238,134 | 91.6 | 9.6 |
| 506 | Natural Gas | SCR, WI, 96 | 9 | 20 | 6.4* | 5.2 | 5.1 | 248,724 | 89.9 | 48.6 |
| 560 | Natural Gas | SCR, WI, 95 | 9 | 20 | 8.2* | 6.0 | 6.1 | 217,943 | 74.6 | 52.1 |
| 560 | Natural Gas | SCR, WI, 95 | 9 | 20 | 4.4* | 2.8 | 7.7 | 237,330 | 84.3 | 44.4 |
| 985.5 | Refinery Gas | SCR, WI, 88 | 8 | 20 | 2.5 | 2.9 | 5 | 528,074 | 80.9 | 71.6 |
| 985.5 | Refinery Gas | DLE, SCR, WI, 88 | 8 | 20 | 2.5 | 3.2 | 3.2 | 548,088 | 79.4 | 78.1 |
| 985.5 | Refinery Gas | SCR, WI 98 | 8 | 20 | 2.5 | 3.0 | 6.0 | 555,389 | 78.7 | 80.7 |
| 985.5 | Refinery Gas | SCR, WI 88 | 8 | 20 | 2.4 | 2.8 | 6.0 | 569,678 | 78.6 | 86.6 |
| 646.3 | Refinery Gas | SCR, 86 | 9 | 20 | 5.7 | 5.9 | 6.5 | 311,586 | 67 | 50.3 |
| **Total** | | | | | | | | | | 522 |

NOx: 1-hour average @15 % oxygen, dry basis
CEMS and Source Test- 9 runs at 30 min each

*uncorrected

DLNB: Dry Low NOx Burner; DLE: Dry Low Emitter;
WI: water/steam Injection; SCR: Selective Catalytic Reduction

# Gas Turbines – Simple Cycle



| Size (MMBTU/ Hr) | Source | Fuel Type | Control & Year | NOx Permit Limit (ppm) | NH3 Limit (ppm) | Survey NOx ppm@ 15% O2 | CEMS (RATA) NOx ppm @15% O2 | Source Test NOx ppm @15% O2 | Avg. Flow Rate (dscf/min) | % Capacity | 2016 NOx Emissions (tons/ year) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 392 | Major | Refinery Gas | SCR, WI | 96 | 5 | 9.9 | 11.2 | 11.1 | 218,518 | 82.3 | 50.6 |
| 392 | Major | Refinery Gas | SCR, WI | 96 | 5 | 7.8 | 5.7 | 8.6 | 236,518 | 80.9 | 41.5 |
| Total | | | | | | | | | | | 92.1 |

NOx: 1-hour average @15 % oxygen, dry basis
CEMS and Source Test- 9 runs at 30 min each

WI: water/steam Injection; SCR: Selective Catalytic Reduction

# Gas Turbines Category Summary



- Second largest source category of total annual NOx emissions at 14.4%
- Largest stack flow rate of all equipment
- Gas turbines are used 67% to 91% of capacity
- Compared NOx emissions from survey data, CEMS (RATA), and source test data
- 10 Combined cycle turbines (one not in operation since 2012, not included in table)
  - 5 fueled by natural gas
    - Lowest survey NOx emission at stack is 1.1 ppm (<2 ppm permit limit)
  - 5 fueled by refinery fuel gas
    - Lowest survey NOx emission is 2.4 ppm (<8 ppm permit limit)
- 3 Simple cycle
  - 2 gas turbines are equipped with heat recovery boilers
    - Approximately used 80% capacity
    - NOx emission is at 7.8 ppm
  - One cogen gas turbine combined with reformer heater, emissions are aggregated with heater (not in table, but included with hydrogen reformer heaters)
    - NOx emission at 4.5 ppm @ 3% O2

# Survey Data Analysis
# FCCU

# FCCU



| Device ID | Size (MMBTU/Hr) | Fuel Type | Control | Device/Class | NOx Permit Limit(ppm) | NH3 Permit Limit (ppm) | Survey NOx ppm @3 % O2* | CEMS (RATA) NOx ppm @3% O2 | Source Test NOx ppm @3% O2 | Avg. Flow Rate (dscf/min) | 2016 NOx Emissions (tons/year) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | N/A | -- | SCR | Regenerator | 40 | 10 | 6 | 14.0 | | 148,974 | 70.0 |
| 2 | N/A | -- | SCR | Regenerator | 60 | 10 | 1.2 | 5.0 | 9.5 | 186,153 | 7.2 |
| 3 | N/A | -- | SCR | Regenerator | 40 | 10 | 11.3 | 14.2 | 7.2 | 215,920 | 76.0 |
| 4 | 464 | Refinery Gas | LNB | CO Boiler | 20 | | | | | | |
| 5 | 300 | Refinery Gas | LNB | CO Boiler | N/A | 10 | 18 | 18.7 | 11.6 | 90,259 | 32 |
| 6 | N/A | -- | no SCR | Regenerator | 89 | | | | | | |
| 7 | N/A | -- | no SCR | Regenerator | 40 | 10 | 12.8 | 14.1 | 20.5 | 85,859 | 58 |
| 8 | N/A | -- | no SCR | Regenerator | 82 | 10 | 32.7 | 26.1 | 27.7 | 85,918 | 112.3 |
| Total | | | | | | | | | | | 355 |

*7 day average @ 3% O2, dry basis

CEMS (RATA) and Source Test- 9 runs at 30 min each

# FCCU Category Summary



- Third largest source category of total annual NOx emissions at 8.4%
- 5 total FCCU regenerator units
- 1 FCCU no longer in operation
- 3 equipped with SCR
- 2 equipped with CO boiler (not fired, used as heat recovery only)
- Lowest survey NOx emissions from FCCU is 1.2 ppm @ 3% O2
- 7 regenerator start-up/air heaters are included with FCCU
  - Start up heater emissions are aggregated under the FCC regenerator
  - Fueled by refinery fuel gas and/or natural gas
  - Start-up heater sizes range from 108 to 300 MMBtu/hr
  - 1.3% of heater capacity used per year

# Survey Data Analysis
# SRU/TG Incinerators

# SRU/TG Incinerators



| Size (MMBTU/Hr) | Fuel Type | NOx Permit Limit(ppm) | Survey NOx ppm @ 3% O2 | CEMS(RATA) NOx ppm @3% O2 | Source Test NOx ppm @ 3% O2 | Control | 2016 NOx Emissions (tpy) |
|---|---|---|---|---|---|---|---|
| 45 | Natural Gas | 110 | 97 | | | | 2.3 |
| 52 | Natural Gas | | 67 | 92 | | Low NOx Burners | 6.8 |
| 35.8 | Natural Gas | 250 | 45 | 107 | 81 | Low NOx Burners | 3.7 |
| 44.5 | Refinery Gas | | 46 | 43.2 | 28 | Low NOx Burners | 20.3 |
| 50 | Natural Gas | 41 | 4.2 | 3.7 | 3.8 | Ultra Low NOx Burner | 8.3 |
| 19.5 | Refinery Gas | | 18.4 | | 19.2 | Low NOx Burner | 4.5 |
| 19.5 | Refinery Gas | | 14.7 | | 14.8 | Low NOx Burner | 0.31 |
| 15 | Refinery Gas | | 10.8 | | 9.9 | | 0.0002 |
| 27.5 | Refinery Gas | | 27 | | | | 15.2 |
| 39.5 | Refinery Gas | 50 | 25 | | 20.8 | Low NOx Burner | 11.5 |
| 100 | Refinery Gas | | 20 | | 17.9 | Low NOx Burner | 6.2 |
| 30 | Refinery Gas | | 43 | 32.7 | 48 | | 11 |
| 30 | Refinery Gas | | 53 | 41 | 52.8 | | 11.3 |
| 58 | Refinery Gas | | 58.3 | 53 | 60.2 | | 18 |
| 10 | Natural Gas | | 137 | 146 | | | 5.0 |
| 60 | Refinery Gas | | 45 | | 69 | | 18 |
| Total | | | | | | | 142 |

# SRU/TG Incinerators Category Summary



- 3.3% of total annual NOx emissions
- NOx emissions vary widely
  - Range from 4.2 ppm to 137 ppm
- 19 pieces of equipment in category
  - 16 Incinerators
  - 3 equipped with in-line stack heaters (combined with SRU incinerators)
  - 50% equipped with LNB
- No post combustion control (survey)
- Challenges due to SOx emissions
- Will consider control options feasibility and cost effectiveness of controls

# Survey Data Analysis
# Thermal Oxidizers and Incinerators

# Thermal Oxidizers and Incinerators



| Size (MMBTU/Hr) | Process Type | Fuel Type | Device/Class | NOx Permit Limit(ppm) | Survey NOx ppm @ 3% O2 | Control | 2016 NOx Emissions (tons/year) |
|---|---|---|---|---|---|---|---|
| 1 | Soil Vapor | Propane | Incinerator | 8.46 | 97 | | 0.01 |
| 1.4 | Air Pollution Control | Natural Gas | Incinerator | 107 | 67 | Low NOx Burners | 0.60 |
| 2 | Soil Vapor | Natural Gas | Thermal Oxidizer | 102 | 45 | Low NOx Burners | 0 |
| 2 | Soil Vapor | Natural Gas | Thermal Oxidizer | 102 | 46 | Low NOx Burners | 0.09 |
| 3 | Thermal Oxidizer | Natural Gas | Incinerator | 100 | 4.2 | Ultra Low NOx Burner | 3.47 |
| 3.4 | RTO | Refinery Gas/Refinery Mixed Gas | Incinerator | 150 | 18.4 | Low NOx Burner | 3.45 |
| 4 | API | Natural Gas | Incinerator | | 14.7 | Low NOx Burner | 2.42 |
| 4 | API | Natural Gas | Thermal Incinerator | | 10.8 | | 1.20 |
| 4 | Groundwater remediation | Natural Gas | Thermal Oxidizer | 130 LBS/MMSCF | 27 | | 0.18 |
| 6 | Groundwater remediation | Natural Gas | Thermal Oxidizer | 130 LBS/MMSCF | 25 | Low NOx Burner | 0.10 |
| 8 | Duct burner | Natural Gas | Thermal Oxidizer | 30 | 20 | Low NOx Burner | 0.00 |
| 10 | Fumes Incinerator | Renewable Fuel Gas | Oxidizer | | 43 | | 4.98 |
| 14 | Air Pollution Control | Natural Gas / Refinery Gas | Oxidizer | 45 | 53 | | 3.88 |
| 30 | Fumes Incinerator | Renewable Fuel Gas | Oxidizer | 6.6 | 58.3 | | 5.57 |
| Total | | | | | | | 25.95 |

# Thermal Oxidizers and Incinerators Category Summary



- 14 pieces of equipment
- Accounts for 0.6% of total annual NOx emissions
- Size range from 1 to 30 MMBtu/hr
- 57% are equipped with LNB (survey)
- Usage and hours of operation vary widely
- NOx emissions varies from 4.2 ppm to 9.7 ppm
- Capacity varies and is dependent upon location and unit

# Coke Calciner

# Coke Calciner



- Will continue to hold separate meeting with stakeholder to discuss BARCT limits, cost effectiveness, and control technologies
- Next proposed meeting: 12/14/18 during upcoming site visit
- Will discuss with stakeholder

# Auxiliary Internal Combustion Engines

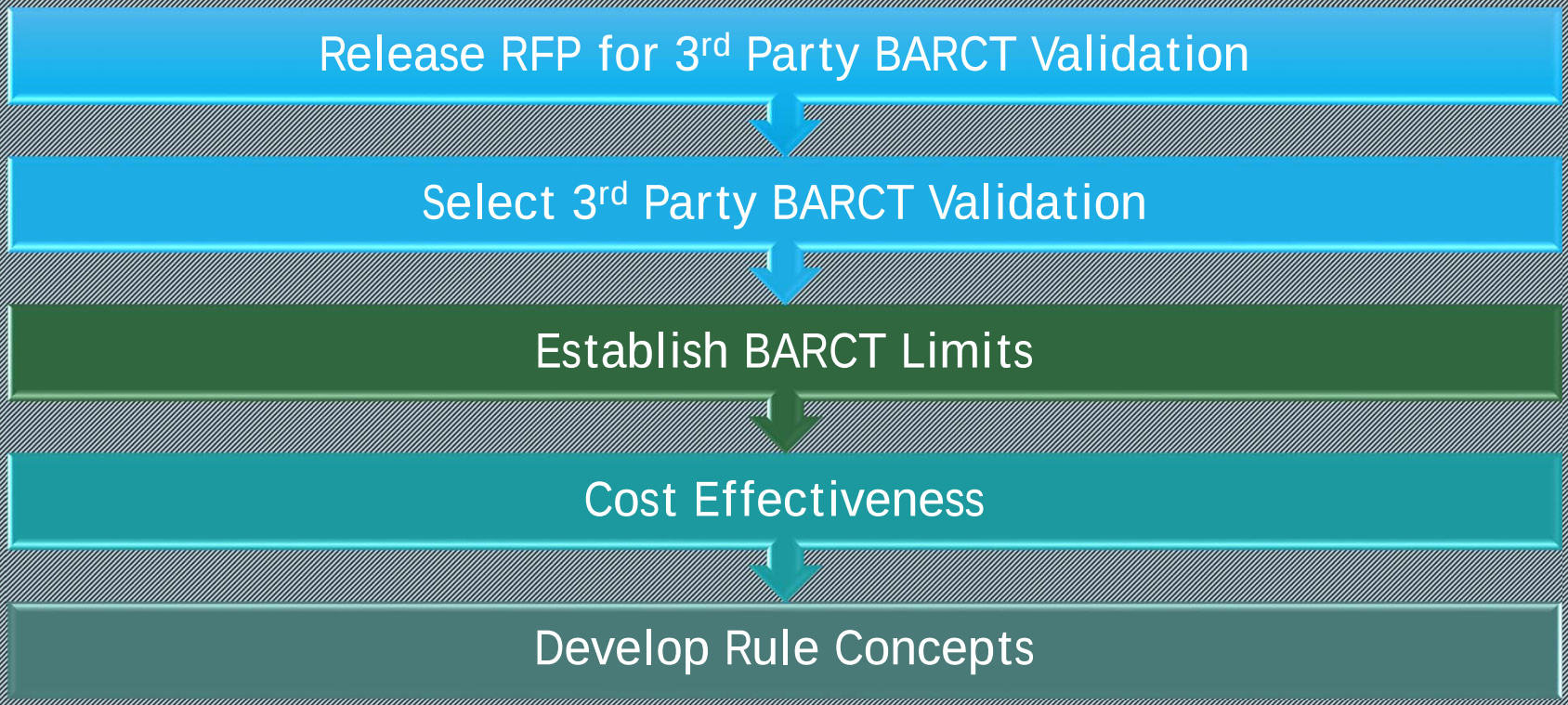
# Auxiliary Internal Combustion Engines



- Three auxiliary internal combustion engines (ICE)
- Initially classified as primary ICE
- Survey data indicates that engines are used to power cogeneration systems during start-ups only
- Low use (approximately 10 hours a year)
- 2016 NOx emissions less than 0.45 tons a year
- Will consider cost-effectiveness of installing NOx controls

# Next Steps




Release RFP for 3rd Party BARCT Validation
Select 3rd Party BARCT Validation
Establish BARCT Limits
Cost Effectiveness
Develop Rule Concepts

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