Rule 1109.1 – NOx Emission Reduction for Refinery Equipment

Working Group Meeting #13

August 12, 2020

Join Zoom Meeting
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Agenda

- Progress of Rule Development
- BARCT Assessment Follow-Up: SMR Heaters
- BARCT Assessment: Sulfuric Acid Plants
- BARCT Assessment Follow-Up: Heaters and Boilers with SCR
- Fuel Sulfur Clean Up Impacts
- Implementation Concepts
- Next Steps

Progress of Rule Development

Summary of Working Group # 12 (7/17/20)

- Response to WSPA/RFG comment letter
- Revised staff recommendation for internal combustion engine category
- Proposed BARCT limits for coke calciner and thermal oxidizers/flares category

Since Last Working Group Meeting

- Stakeholder meetings and follow-ups
- Discussions with control technology manufacturers
- Continued BARCT analysis for remaining categories
- Reviewed and analyzed fuel gas sulfur survey data and evaluated costs provided

BARCT Follow-Up

SMR Heaters

Comments Received From Working Group Meeting #11

Slide 12 from Working Group Meeting #11

SMR Heaters: Permit Limit versus Performance

12

- All SMR heaters perform below their NOx permit limits
- Five of six SMR heaters performing at ~5 ppm or less on annual basis
- One performing greater than 5 ppm on an annual basis

Heater	NOx Permit Limit @3% O_2	Permitted Avg Time (hrs)	Annual CEMS NOx Conc. (ppmv)	NH_3 Permit Limit (ppmv)	NH_3 Conc.* (ppmv)
1	12	Not specified	7.2	20	12.2
2	12	Not specified	5.1	20	1.8
3	7	Not specified	3.8	20	6.0
4	5	3 hour	3.6	20	5.4
5	5	3 hour	3.7	5	3.9
6	9	24 hour	4.9	20	6.6

*Source test

- Staff proposed a 5 ppm BARCT limit for SMR heaters fueled with PSA-off gas with an 8-hour rolling average
  - Based on the *annual* average NOx concentration in the flue gas, 5 of the 6 units met the proposed 5 ppm NOx limit (with existing SCRs)
- Stakeholders commented:
  - Units that can meet a 5 ppm NOx limit based on an *annual* average may not meet the limit based on an 8-hour rolling averaging time
  - All SMR heaters should be included in the same category
    - Units fueled by refinery fuel gas operate and are configured similar to SMR heaters fueled by PSA gas

SMR Heaters: CEMS Evaluation

Staff further evaluated the CEMS data for the six SMR heaters using PSA off-gas based on an 8-hour averaging time and confirmed **three** of six units would need to take action to meet the proposed 5 ppm NOx limit

- Three units met the proposed 5 ppm limit more than 97% of the time
- Two units met the proposed 5 ppm limit between 65% to 68% of time
- One unit met the proposed 5 ppm limit 28% of time (previously determined to be cost-effective with an SCR upgrade)

CEMS Analysis on an 8-hour Average (PSA off-gas)

Heater	NOx Permit Limit @3% O_2	Annual CEMS NOx Conc. (ppmv)	Percent Time in a Year Meeting 5 ppm over an 8-hour avg
1*	12	7.2	28
2*	12	5.1	68.3
3	7	3.8	97.7
4	5	3.6	99.6
5	5	3.7	100
6*	9	4.9	64.8

* Units would require SCR upgrade to meet the proposed 5 ppm limit on an 8-hour rolling average

SMR Heaters Fueled by Refinery Gas

Heater	Current NOx Control	NOx Control Required to meet 5 ppm	Primary Fuel
1	LNB/SCR	SCR Upgrade	PSA
2	LNB/SCR	SCR Upgrade	PSA
3	LNB/SCR	No Action	PSA
4	LNB/SCR	No Action	PSA
5	LNB/SCR	No Action	PSA
6	LNB/SCR	SCR Upgrade	PSA
7	SCR	SCR Upgrade	RFG
8	SCR	SCR Upgrade	RFG
9	No SCR	New SCR Install	RFG
10	No SCR	New SCR Install	RFG
11	LNB/SCR	No Action	RFG

- Staff considered stakeholders' comments to include *all* SMR heaters in one category regardless of their fuel type based on the following:
  - Similar design, arrangement, and challenges amongst SMR heater as compared to process heaters
  - Large number of burners (>48 burners per heater) needed to maintain heat flux across heater
  - Process tube metallurgy the same and have similar impacts on SCR catalyst
  - Higher operating temperature than traditional process heaters
    - High temperature needed to drive hydrogen reaction in process tubes

Revised Cost-Effectiveness for SMR Heaters using PSA Gas

Cost-Effectiveness for all SMR heaters (PSA off-gas and RFG)	
Heater Category	5 ppm
SMR Heaters	$15,041

- Staff is proposing to include all SMR heaters into one category regardless of fuel type
- Conducted a new cost-effectiveness evaluation of the (RFG and PSA-off gas) SMR heater category meeting a 5 ppm NOx limit
- Evaluated 11 total SMR heaters in the category based on a CEMS 8-hour average:
  - Six SMR heaters using PSA off-gas:
    - Three heaters meet 5 ppm and require no action (excluded from cost-effectiveness)
    - Three heaters require SCR upgrades (included)
  - Five SMR heaters using RFG:
    - One heater meets 5 ppm and require no action (excluded from cost-effectiveness)
    - Two heaters require SCR upgrades (included)
    - Two heaters require brand new SCR installs (included)

Staff Recommendation for SMR Heaters

SCR Upgrades or New SCRs

(5 ppm)

Cost-Effectiveness:
$ 15,041

Recommendation:
5 ppm

Staff Recommendation:

- BARCT limit of 5 ppm at 3% O_2 with an 8-hour rolling average for all SMR heaters
- Consider provisions in rule to address some allowance for operational issues

BARCT Assessment

Sulfuric Acid Plants

corrected

Heaters & Boilers by Category

- Heaters & Boilers
  - ✓ Process Heaters
  - ✓ Boilers (excludes heat recovery & CO boilers)
  - ✓ Steam Methane Reformer Heaters
  - Sulfuric Acid Plants
    - Furnace
    - Start-up Heaters

Sulfuric Acid Plant Assessment

Sulfuric Acid Plant Category

Sulfuric Acid Plants

Furnaces
(2)

Start-up
Heaters and
Boiler
(2 heaters and 1
boiler)

Sulfuric Acid Plant Background

- Two sulfuric acid production plants in PR 1109.1 universe that regenerate sulfuric acid used in refinery alkylation units
  - Both facilities have a main furnace and a start-up heater; one has a start-up boiler
  - Feedstock consist of spent acid and/or elemental sulfur
  - Fuel source is natural gas, hydrogen sulfide(H_2S), and refinery fuel gas
- Sulfuric acid production is a ***process*** accomplished through a series of steps:
  - Burning feedstock in furnace
  - Conversion to SO_3
  - Absorption
- Feedstock composition influences fuel gas demand (ratio of sulfur compounds/spent acid)
  - Higher spent acid rates require higher fuel gas demand which impacts NOx emissions
  - Sulfur and sulfur gases have higher heating value which reduces fuel gas demand
- Feedstock composition can vary throughout the year
- Longer averaging times required to accommodate variation

NOx Control Lo-NOx Burners

- NOx combustion control
  - Each furnace equipped with two burners
  - One furnace currently equipped with LNB
- LNBs are specialized for high sulfur and high temperature applications
  - Furnace operates at high temperatures (~2,200°F)
  - LNB engineered for the specific application
    - Feed stream and fuel type considered in burner design
  - Robust design to withstand environment of furnace
- Burner upgrades may require a engineering evaluation of furnace
- NOx reductions from LNB are between 25% to 50% from original burners

SCR Control Evaluation

Two potential SCR locations

Upstream of catalytic converter

- Ammonia may adversely impact process and foul catalyst in converter
- Major re-engineering and process modification required
  - Increases costs
- Not preferred

Downstream of scrubber

- Low temperature
- Flue gas reheating to 600°F, supplemental firing may be required
- Potential impacts on SOx emission control needs to be considered

SCR Control Technical Feasibility

- SCR requires a minimum temperature of 600°F for optimal operation and NOx reductions
- Flue gas temperatures are below SCR requirements at both potential locations
  - Upstream of catalytic converter (~500°F)
    - Potential plugging or contamination of catalyst
    - Impact process and production yields
    - Catalytic converter requires balance of temperature and conversion reaction
  - Downstream of scrubber (~85°F)
    - Less impacts to the process
    - Reheating from either a fired source or heat recovery system will be necessary to achieve optimal operating temperature
      - ~43 MMBtu/hr will be required to raise temperature 600°F

LoTOx Control Evaluation

LoTOx, Replacement of existing scrubber

- Ozone injection used in conjunction with a wet scrubber system to remove NOx in flue gas
- Ozone generation equipment required on-site and modulated on demand
- System can also be used to control SOx concurrently (multi-pollutant)
- Requires waste effluent treatment system
- High operating cost

LoTOx Control Technical Feasibility

- Potential location after absorber tower involves replacement of existing scrubber for SOx
- LoTOx does not require high operating temperatures, optimal temperature range from 200 to 300˚F
  - Less than 200°F will affect kinetics and NOx removal efficiency
  - Greater than 300°F will impact half-life decay of ozone
- Requires waste effluent treatment or modifications to existing treatment system
- High operating cost due to oxygen requirement and onsite ozone generation
- Currently, no existing LoTOx installation on a sulfuric acid plant, but there is a project in development

Sulfuric Acid Plant Assessment

	RECLAIM 2005/2015 BARCT	Existing Units	Other Regulatory	Technology Assessment	Initial BARCT NOx Limit	Cost-Effectiveness
Start-up Heaters and Boilers	N/A	30 to 190 ppm[1]	N/A	2 and 20 ppm	2 and 20 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit
Furnace: 74 and 150 MMBtu/hr	N/A	23 to 60 ppm[2]	N/A	2 and 20 ppm	2 and 20 ppm	Need to conduct cost-effectiveness on initial BARCT NOx limit

[1] Source test and permit limit

[2] CEMS data, 365 day average

Cost-Effectiveness for Start-Up Heaters and Boiler

2 ppm

LNB and SCR for Start-Up Heaters & Boilers

(95% Reduction)

Potential NOx BARCT Emission Limit

20 ppm

Low NOx Burners

(32 to 80% Reduction)

Potential NOx BARCT Emission Limit

Total NOx emission for category is 0.0011 tpd

Cost-Effectiveness for Sulfuric Acid Plant Start–Up Heaters and Boilers

Cost-Effectiveness		
Heater Category	2 ppm (LNB + SCR)	20 ppm (LNB)
Start-Up Heaters	$2.2 MM	$334,630
Start-Up Boiler	$3.3 MM	$ 4.8 MM

- Two start-up heaters and one start-up boiler in category
  - All units are:
    - Less than 50 MMBtu/hour
    - Used less than 200 hours a year
  - Heaters permitted for use during start-up of acid plant only (heating of converter)
  - Boiler used for steam during acid plant start-up
  - Permit limit on firing rates between 23,000 to 90,000 MMBtu per year
  - Current NOx controls:
    - Start-up heaters are uncontrolled
    - Start-up boiler has LNB

Recommendations for Start-Up Heaters and Boiler

Low NOx Burners

(20 ppm)

Cost-Effectiveness:
$ 334,6300 and $4.8 MM

Not Cost-Effective

Low NOx Burners and SCR

(2 ppm)

Cost-Effectiveness:
$2.2 MM to $3.3 MM

Not Cost-Effective

Staff Recommendation:

- Not cost-effective for 2 or 20 ppm NOx BARCT limit, low-use exemption for start-up heater and boilers
- Maintain current permit limit on firing rate limit per year

Initial BARCT NOx Limits for Cost-Effectiveness for Sulfuric Acid Plant Furnaces

2 ppm

SCR or LoTOx

(95% reduction)

Potential NOx BARCT Emission Limit

20 ppm

Low NOx Burners

Currently Performing

Total NOx emission for category is 0.097 tpd corrected

Cost-Effectiveness for Sulfuric Acid Plant Furnaces

Cost-Effectiveness			
Equipment	2 ppm		20 ppm
Sulfuric Acid Plant Furnaces	SCR	LoTOx	LNB
	$67,755	$91,702	$49,892

- Emission reductions based on annual average NOx ppm for representative year as provided by facility
- SCR cost-effectiveness calculation based on U.S EPA cost spreadsheet assumed a downstream installation and includes:
  - Addition of ~43 MMBtu/hr duct burner
    - Cost of duct burner and larger SCR required to reduce additional NOx from burner ~$4MM
    - Natural gas to fuel heater ~$1.79/MMBtu
    - NOx emissions increase ~0.25 tpy
    - Larger SCR to accommodate NOx reductions for heater/duct burner
- LoTOx cost based on manufacturer feedback
  - ~$15MM total install
  - ~$1MM O&M
- LNB costs
  - Only includes costs for one facility, other facility achieving 20 ppm
  - Total installed cost (TIC) estimated using LNB cost curve generated for process heaters & boilers
    - ~$3.2MM TIC
    - ~$2,000 O&M

Recommendation for Sulfuric Acid Plant Furnace

Low NOx Burners

(20 ppm)

Cost-Effectiveness:
$ 49,892

Recommendation:
20 ppm

Staff Recommendation:

- 20 ppm at 3% O_2 BARCT limit
- 365-day rolling average due to feed and process variations throughout year

BARCT Assessment

Heaters and Boilers with SCRs

Heaters & Boilers with Existing SCRs

- Previous BARCT assessment of the heater and boiler categories only included units that currently have no post-combustion controls
- For heaters >40 MMBtu/hr, BARCT limit can be achieved through combination of LNB and SCR
  - BARCT for units >40 MMBtu/hr: 2 ppm NOx at 3% O_2 8-hour avg time
- Staff further assessed heaters and boilers with existing post controls (e.g., SCR)
- Addresses stranded asset issue for facilities who recently retrofitted equipment to meet the 2015 RECLAIM NOx shave but do not meet proposed BARCT limit of 2 ppm

Heaters & Boilers with Existing SCRs

Units with Existing SCRs in 1109.1		
	Heaters	Boilers
Total Number of Units	50	7
Total Number Equipped with LNB	48	7
Total Number of SCRs	27*	7
Newest SCR Installation	2008	1994
Oldest SCR Installation	1988	1988
Total Number of Units with Permit Limits	15*	7

*Some heaters share a common SCR/stack

Heaters and Boilers with Existing SCRs (*cont.*)

- For units with permit limits close to the proposed 2 ppm BARCT limit, staff evaluated the cost-effectiveness to upgrade the SCR to achieve the 2 ppm limit
  - Upgrade costs assumed to be 25% of a new SCR and 10% increase for O&M
  - Emissions reductions were calculated from the permit limit to proposed 2 ppm BARCT limit

Lowest and Highest Permit Limits (Heaters and Boilers with Existing SCRs)

Units with Permit Limits (Existing SCRs)		
	Heaters	**Boilers**
Lowest Permit Limit	5 ppm	9 ppm
Number of Units	14*	3
Number of SCRs	6**	3
Next Lowest Permit Limit	12 ppm	12 ppm
Number of Units	1	3
Number of SCRs	1	3

* Three units not in use, but share a common SCR with a heater that is in use, summed the heat inputs for all heaters to estimate SCR cost and O&M (included in cost-effectiveness)

** Some heaters share a common SCR/Stack

Cost-Effectiveness for Heaters & Boilers with Existing SCRs

Heaters	5 ppm to 2 ppm	~$200,000/ton reduced
	12 ppm to 2 ppm	~$44,000/ton reduced
Boilers	9 ppm to 2 ppm	~$45,000/ton reduced
	12 ppm to 2 ppm	~$29,000/ton reduced

Recommendations for Heaters and Boilers with Existing SCRs

Heaters

>40 MMBtu/hour

BARCT:
2 ppm at 3% O_2

Units with permit limits of 5 ppm or less upon rule adoption:
Retain 5 ppm limit*

Boilers
>40MMBtu/hour

BARCT:
2 ppm at 3% O_2

BARCT limits required for all boilers

* Heaters shall comply with 2 ppm BARCT limit **upon equipment replacement**

Co-Pollutants and Fuel Sulfur Clean Up Impacts

Co-Pollutant and PM Emissions from SCR

- South Coast AQMD received comments letters regarding Regulation XIII
  - April 21, 2020 from Regulatory Flexibility Group (RFG)
  - April 27, 2020 from Western States Petroleum Association (WSPA)
- Both letters have similar comments regarding interpreting and implementing Regulation XIII
- WSPA comment letter included additional issues specific to 1109.1
- Response to the comment letters were provided at the RECLAIM working group on June 11, 2020
  - Staff is continuing to look at the impacts of sulfur in the fuel
  - Staff views this as an NSR issue and is continuing to work with EPA

Ammonia Emissions from SCR

- SCR uses a catalyst and ammonia to reduce NOx to N_2 and H_2O
  - NOx emissions up to 95% can be achieved
- Unreacted ammonia is directly emitted (ammonia slip)
- Operators need to balance NOx and ammonia emissions
- Lower NOx limits can affect ammonia emissions
- Various techniques can be used to minimize ammonia slip
- Best Available Control Technology (BACT) is triggered when there is a net increase in ammonia (Rule 1303(a)(1))
  - Current BACT for ammonia is 5 ppm for SCR

PM Emissions from Refinery Fuel Gas

Refinery fuel gas contains sulfur species which convert to SOx (mostly SO_2)

SO_2 is converted to SO_3 on SCR catalyst

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Unreacted ammonia reacts with SO_3 to form PM

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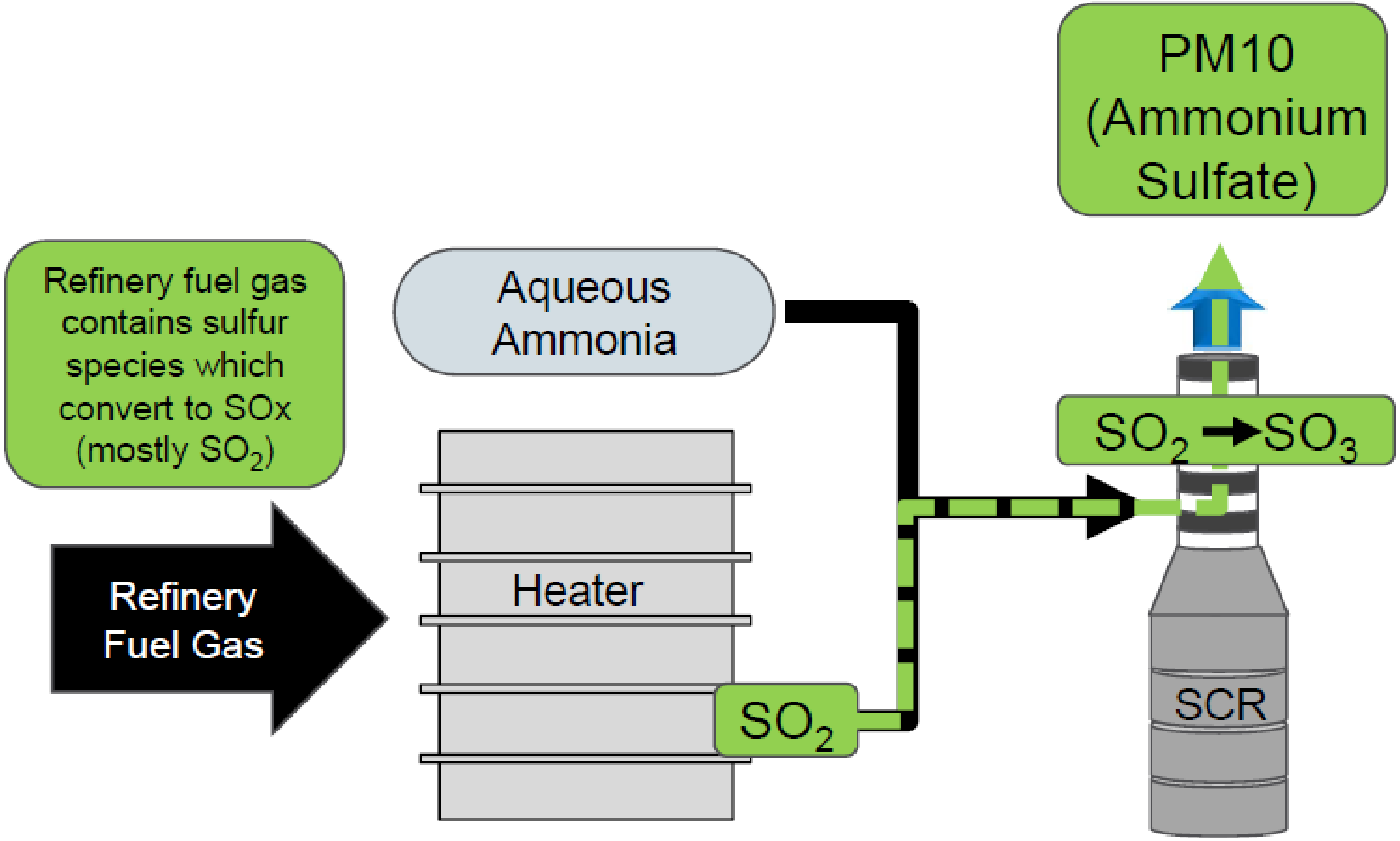
Larger heaters or boilers create higher PM emissions

Directly Emitted PM10 Emissions



- Sulfur in fuel increases SO_2 emissions from boilers and heaters
- SO_2 is converted to SO_3 on SCR catalyst
- Unreacted ammonia reacts with SO_3 to form PM

Rule 431.1-Sulfur Content in Gaseous Fuels

- Rule 431.1 requires sulfur content for gaseous fuels not to exceed 40 ppm
  - RECLAIM facilities are currently exempt from Rule 431.1
- Current sulfur levels in refinery gas vary between refineries
- Lowest sulfur content in refinery fuel is 30 ppm
- Because 30 ppm has been achieved in practice, it represents Best Available Control Technology (BACT) for sulfur content in refinery fuels

New Source Review (NSR) Requirements for PM from Refinery Fuel

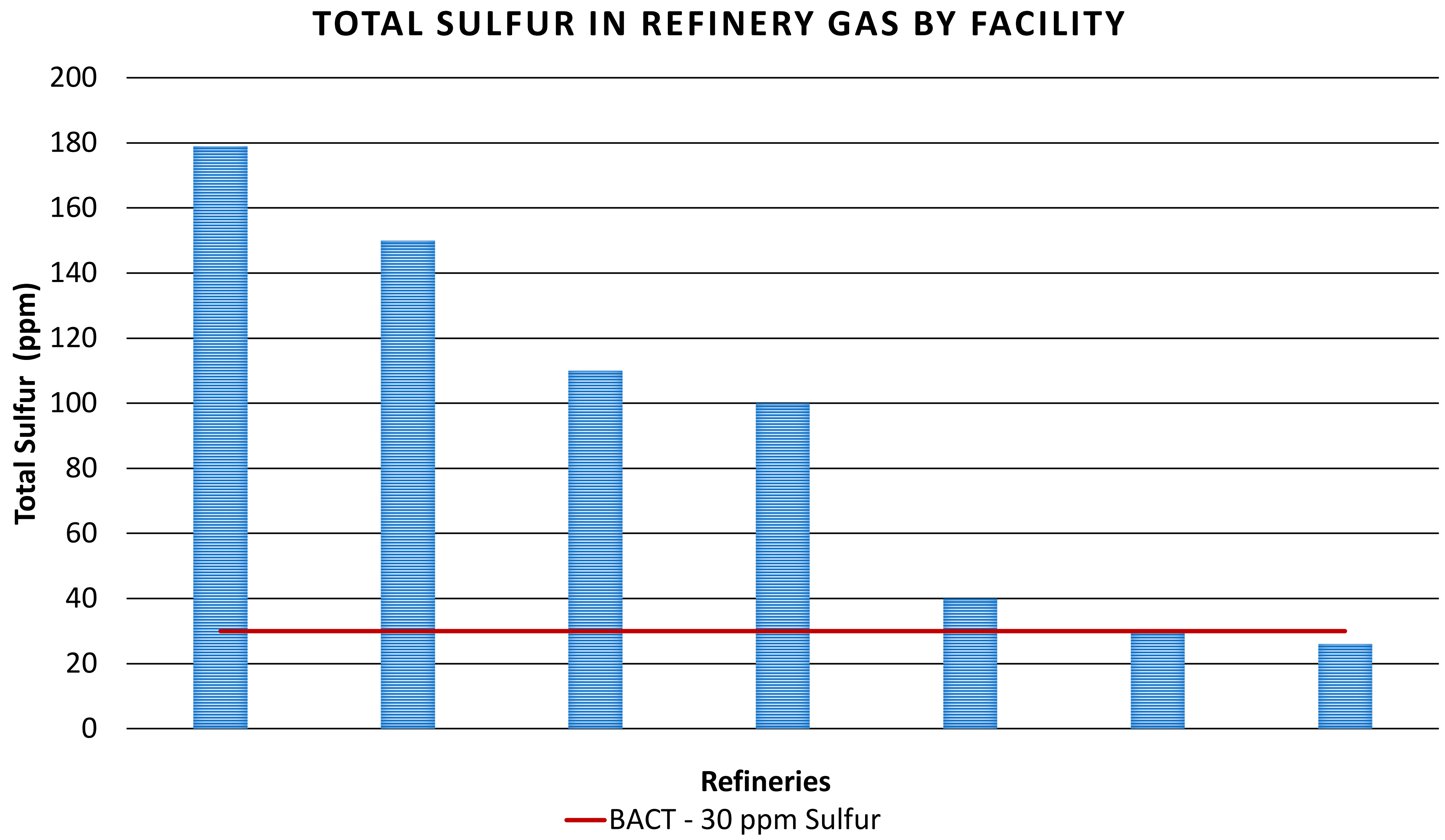
- Under Regulation XIII, the significant emissions threshold is one pound per day for PM10
- Some installations of SCR can trigger BACT requirements if the PM10 emissions are greater than one pound per day
- If BACT is triggered due to PM10 emissions increase from sulfur in refinery fuel
  - Refinery fuel required to meet 30 ppm sulfur limit
  - Sulfur removal in refinery gas can cost up to $350 million (facility estimate)
  - No action is required under Regulation XIII NSR:
    - If emission increase is less than 1 lb/day; or
    - Unit currently meets BACT sulfur limit of 30 ppm

Refinery Fuel Gas Sulfur Background

- Refinery fuel gas is a by-product of crude oil processing and is used in a majority of refinery combustion equipment (process heaters and boilers)
- Refinery fuel gas contains sulfur species, mainly H_2S and mercaptans
  - Sulfur species present will determine treatment or removal process
    - Mercaptans typically treated with MEROX process
    - H_2S typically treated with DEA system process
- Sulfur species concentrations vary by facility
  - Two refineries currently have sulfur treatment systems achieving 30 ppm or less
  - Remain refineries will need sulfur treatment to meet 30 ppm BACT limit

Refinery Fuel Gas Sulfur Survey

- To assess the scope of the co-pollutant issue, staff distributed a fuel gas sulfur survey to each facility that generates refinery fuel gas
- Most facilities have submitted survey, most relevant information:
  - Sulfur concentration
    - 27 to 180 ppm
  - Estimated cost of sulfur clean-up, if any
    - $100 to 340 million total install
    - $2 to 8.5 million O&M


TOTAL SULFUR IN REFINERY GAS BY FACILITY
200
180
160
140
120
100
80
60
40
20
0
Total Sulfur (ppm)
Refineries
BACT - 30 ppm Sulfur

Cost-Effectiveness Analysis

- Staff will be revising the cost-effectiveness for the proposed NOx BARCT emission limits for SCR including the sulfur clean up
- Analysis will be based on NOx reductions and incorporate the additional cost for sulfur clean up
  - Cost-effective calculation will **NOT** include other co-pollutant reductions that will be achieved with sulfur cleanup
- This will be presented at the September Working Group meeting

Implementation Concepts

Background

- Most command-and-control rules are source-specific, meaning they regulate a specific equipment source category such as engines, boilers, or turbines
- PR 1109.1 is an industry-specific rule that applies to refineries and refinery related operations
  - ~300 pieces of equipment
- Using a traditional implementation approach that establishes a specific date for equipment categories may not be the most effective approach to ensure emission limits can be achieved
- Staff is exploring different implementation approaches for PR 1109.1 to ensure proposed NOx emission limits can be achieved

Magnitude of PR 1109.1

- PR 1109.1 will be the most significant command-and-control rulemaking to address NOx emissions
- NOx emission reductions are needed to achieve federal and state ozone standards
- Proposed NOx emission limits were developed through the rigorous BARCT analysis that includes cost-effectiveness based on a bottom up approach
- Implementation of these NOx emission limits will take time – emission reduction potential is very substantial
  - Initial NOx estimates are between 7 to 9 tons per day
- If the implementation schedule is too rigid, it is possible that critical NOx reductions will be sacrificed because BARCT controls cannot be installed

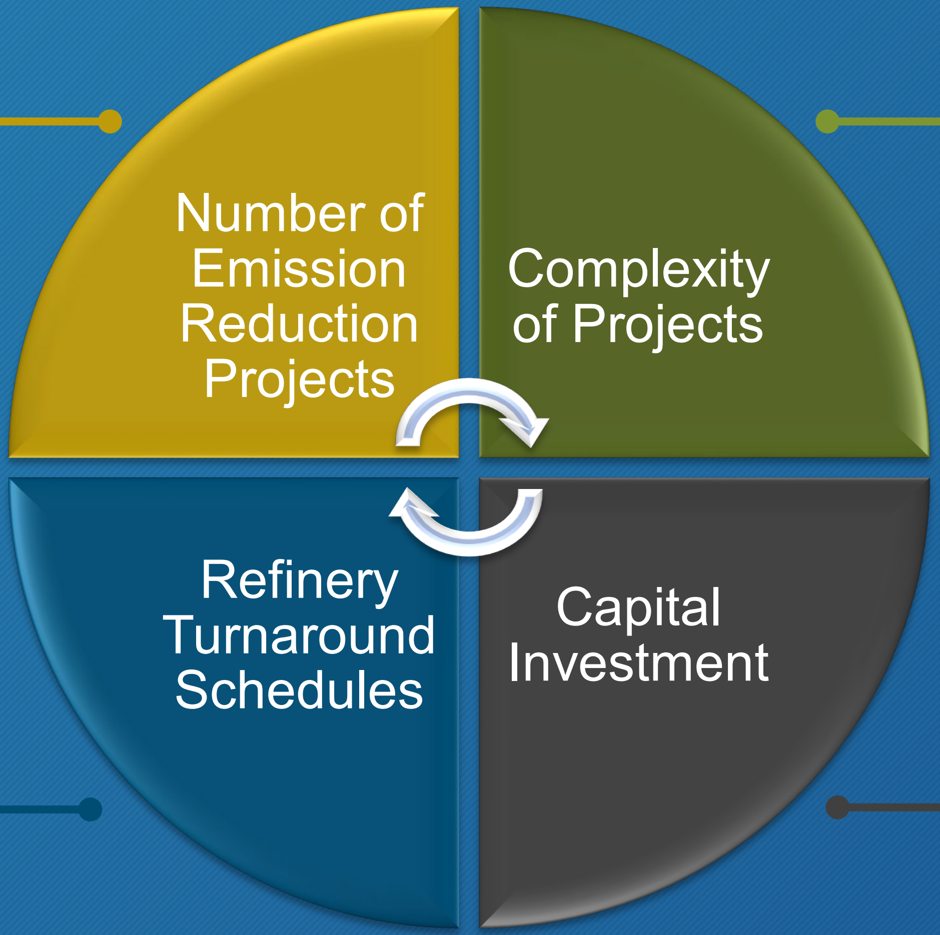
Key Objectives

- Ensure proposed NOx BARCT emission limits are achieved
- Highest priority for implementation will be for those sources that “have not modified emissions-related permit conditions the greatest period of time,” consistent with AB 617
  - These sources will be further prioritized based on those with the greatest emission reduction potential
- Allow some flexibility in the implementation schedule without compromising the ability for each source to meet the specified emission limits, thus ensuring the overall air quality benefit is achieved
- Important that any implementation approach is as quick as feasible, accounting for considerations that are unique to PR 1109.1

Key PR 1109.1 Considerations

- ~ 250 pieces of equipment are not meeting proposed NOx emission limits

- Projects are complex requiring significant engineering, design, installation, and commissioning
- ~110 SCR/SCR upgrade projects for the boiler/heater category
- ~115 burner replacement projects that can involve 10's to 100's of burner replacements per unit



- Accounting for refinery turnarounds schedules will minimize disruptions
- Staggered schedules will reduce the demand for construction resources

- Most emission reduction projects will be more than $10 million
- Each of the petroleum refineries have many projects

Initial Thoughts

- Implementation schedule for facilities with five or less units can be directly addressed in PR 1109.1
- Implementation schedule for facilities with more than five units will be addressed through a Refinery Specific Compliance Plan
- PR 1109.1 would establish provisions for Refinery Specific Compliance Plan
- Staff is seeking input on initial concepts and elements

Possible Elements for the Refinery Specific Compliance Plan

Prioritization of Units

- Longest time period unit was last modified?
- Emission reduction potential?
- Other criteria to consider?

Flexibility

- Can units move between priority groups?
- How will facilities under common ownership be addressed?
- What other flexibilities should be considered?

Interim Milestones and Final Compliance Date

- What are the interim milestones?
- What is the basis of Interim Milestones – number projects, emissions, etc.?
- What is the final compliance date?

Next Steps

Further Define Implementation Plan

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Continued Meeting with Stakeholders

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Final Assessment Report from Consultants

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Draft Rule Language

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Draft Staff Report

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Public Workshop/Public Hearing

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