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NOx BARCT Analysis for Proposed Rule 1109.1

South Coast AQMD

Presentation Outline

- NEC is reviewing the Best Available Retrofit Control Technologies (BARCT) for stationary emitters of NOx from refinery sources.
- Table summarizing BARCT for both new and retrofit applications.
- Limited time for presentation, will focus on select technologies for each application. Detailed information provided in report.
- Averaging time for Heaters, Boilers and SMRs

Assessment of NOx Control Technologies for Proposed Rule 1109.1

Technology	New install applying BACT	Retrofit where the conditions are…			Comments
		Most favorable for the installation	Typical for the installation	Unfavorable for the installation	
Fuel switching to NG	% NOx reduction = 100 x {1 – 1 / [1 + 0.625 x (mol/mol H_2 before switch)] }				Approximation Independent of technology
FGR with staged fuel burner (1)	30 ppmv	> 30 ppmv	< 40 ppmv	< 50 ppmv	Typically applied to boilers
ULNB (1)	15 ppmv	< 20 ppmv	< 35 ppmv	< 50 ppmv	Commercially available ULNBs
Next generation ULNB (1)	> 5 ppmv		< 10 ppmv		Commercial demonstration underway with Clearsign
Flameless combustion (1)	5 ppmv	–	–	–	One demonstration unit on a small heater
SNCR with 5 ppmv NH_3 slip	70% NOx reduction maximum	High inlet NOx (>100 ppmv): 40 to 50% NOx reduction			Limited application due to geometrical considerations
		Low inlet NOx (50 to 100 ppmv): 20 to 40% NOx reduction			
SCR	2 ppmv	2 ppmv			Multiple catalyst beds required
Lo-TOx	10 ppmv	10 ppmv	≤ 90% NOx Reduction	< 50% NOx reduction	Wet Gas Scrubber (WGS) required downstream

Source control

Post-combustion control

(1) Fuel assumed to be RFG unless noted otherwise

In some cases a combination of source and post-combustion control required to achieve BARCT level

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Process Heaters & Boilers

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Heaters & Boilers				
Process Heaters				
<20 MMBtu/hr	22	40 / 9*	3	2 hour
20 - 40 MMBtu/hr	45	30 / 9*	3	2 hour
40 - 110 MMBtu/hr	72	5/2**	3	8 hour
>110 MMBtu/hr	46	5/2**	3	8 hour
Boilers				
<40 MMBtu/hr	5	5	3	2 hour
40 - 110 MMBtu/hr	3	2	3	8 hour
>110 MMBtu/hr	20	2	3	8 hour

* Future effective date.

** Heaters >40 MMBtu/hour that have a permit limit of 5 ppm or less *within 6 months of rule adoption*, can maintain the 5 ppm limit until a future effective date, or when the SCR is replaced, whichever is sooner.

- 35 to 40 ppm NOx emission limit is commonly seen when upgrading existing heaters with modern ULNBs.
- 9 ppm is a long reach that allows time for emerging technologies to gain wider industry acceptance (i.e. ClearSign Core, JZ Solex, Great Southern Flameless)
- 2 ppm NOx BARCT limit will require SCR:
  - Operate at low superficial gas velocity (< 10 ft/s)
  - Operate within the optimal temperature window
  - Multiple SCR catalyst beds (2 minimum) with NH_3 destruction bed
  - Multiple NH_3 injection grids between beds, uniform distribution of NH_3

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Steam Methane Reformer (SMR) Heaters

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Heaters & Boilers				
SMR Heaters				
PSA-off Gas/RFG/NG	11	5	3	8 hour

- High H_2 content in the fuel + high combustion zone temperature = Limited application for NOx source control.
- Fuel gas composition to the furnace swings due to H_2 PSA cycle – O_2 control is challenging in the furnace.
- Lowest NOx BARCT limit that could be set is 5 ppm, expect multiple SCR catalyst beds will be required in most cases.
- Similar arguments apply to the one SMR + Gas Turbine in the District.

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Sulfuric Acid Plant Furnaces

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Heaters & Boilers				
Sulfuric Acid Plant				
Furnace	2	30	3	365 day
SU Heaters/boilers	3	Low Use		

- High combustion zone temperature (> 2000°F) + adiabatic chamber (no cold plane surface) = Limited application for NOx source control.
- Post-combustion options not well suited for this application:
  - Sulfur in flue gas, NH_3 + SO_3 has potential for ABS formation in SCR → plugging/fouling due to capillary condensation.
  - LoTOx requires quench step and wet scrubber.
- 30 ppm NOx BARCT limit consistent with custom designed burner from John-Zink, which at best can achieve ~25 ppm.

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Fluid Catalytic Cracking Unit (FCCU)

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Other Categories				
FCCU				
Regenerator & CO Boiler	5	2 5	0	365 day 7 day
SU Heaters(1 heater ULSD)		Low Use		

- FCCU regenerators operate at temperatures where Thermal NOx formation is low.
  - Primary source of NOx originates from N species in the coke on catalyst, akin to Fuel NOx.
- Catalyst additives available to reduce NOx (ie. Grace DENOX, JM NOxGETTER, etc.) but will not achieve BARCT limit alone.
- Heavily hydro-treated feed to FCCU has been shown to increase CO emissions, small amount of N required in regenerator to burn out CO.
- Multi-bed SCR only viable solution for 2 ppm BARCT limit.

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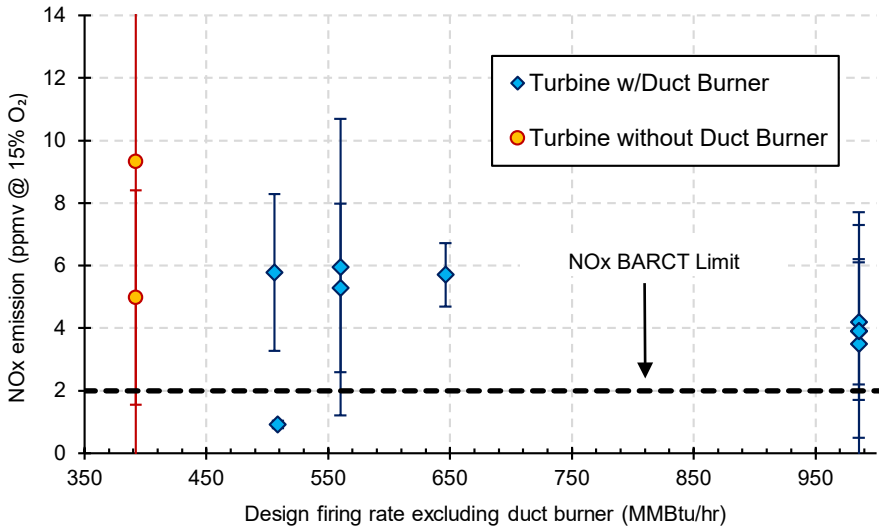
Gas Turbines (Firing on NG or RFG)

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Gas Turbines with Duct Burners				
NG/RFG/Mixed Gas	8	2	15	8 hour
Gas Turbine without Duct Burners				
NG/RFG	2	2	15	8 hour

- NOx control technology a combination of Dry Low NOx (DLN) combustors and SCR.
- Some SCR designs (most likely newer designs) may provide for the addition of ~50% more catalyst to achieve BARCT limit.



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Coke Calciner

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Coke Calciner				
Kiln/Pyroscrubber	2	5	3	365 day
		10		7 day

- High combustion zone temperature (> 2100°F) + adiabatic chamber (no cold plane surface) = Limited application for NOx source control.
- Post combustion NOx control only practical solution (adiabatic chamber too hot for SNCR). ~92% NOx reduction required.
- Several options considered:
  - SCR : Difficult to retrofit within optimal temperature window (650 to 750°F). Stack gas reheat with duct burners may be required.
  - LoTOx : Requires wet scrubber.
  - TriMer UltraCat: Same requirements as SCR, limited field experience, large plot area required.

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SRU Tail Gas (TG) Incinerators, Flares and Thermal Oxidizers

Refinery Equipment Category	No. of Units in Category	Proposed BARCT Limit (ppm)	Corrected O_2%	Proposed Averaging Time
Heaters & Boilers				
SRU/TG Incinerators				
Incinerators	16	30	3	8 hour
Stack Heaters	3			
Flares & Thermal Ox.				
Afterburners, Vapor Incinerators, and Thermal Oxidizers	13	20	3	3 hour
Open Ground Flares	1	Low Use (<20hrs)	3	

SRU TG Incinerators

- Upstream SRU furnace is burning precursors (NH_3 & HCN) at high temperature (> 2000°F), commercially available ULNBs not well suited for this application.
- Downstream SRU TG Incinerator runs at high excess O_2 / low combustion temperature, thermal NOx formation is minimal – NOx emissions from this unit are the result of NOx concentration in the inlet vapor.
- High SO_3 content in flue gas from SRU TG exacerbates ABS plugging/fouling due to capillary condensation, making SCR impractical.
- If a wet scrubber is installed downstream, LoTOx is an option.
- Practical solution is advanced, custom designed burner upgrades to the SRU system like that proposed for Sulfuric Acid Plant heaters.
  - Precursor species conversion to Fuel NOx may limit minimum NOx emission level.

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Thermal Oxidizers

- Key to low NOx operation: Improve the mixing and stage fuel and air to maintain the flame as cool and as uniform as possible while still destroying criteria pollutants.
- Retrofit options for NOx source control are available but difficult to install on existing equipment.

Proposed Averaging Times for Heaters, Boilers & SMRs

- For SCR with 10% design margin, 2 ppmv NOx BARCT limit and:
  - 2 hr average : 3.4 ppmv = 15 min response (2.2 ppmv = 1 hr response).
  - 4 hr average: 5 ppmv = 15 min response (2.6 ppmv = 1 hr response).
  - 8 hr average: 8.2 ppmv = 15 min response (3.4 ppmv = 1 hr response).
  - 24 hr average: 21 ppmv = 15 min response (6.6 ppmv = 1 hr response).
- Based on the detection of a meaningful fluctuation and the time for operations to diagnose and remedy problem(s), 24 hour averaging is recommended.
- 24 hour averaging time recommended for any unit with CEMS.
- SSM provision in Rule 1109.1 will handle deviations related to start-up, shutdown and equipment malfunction - does not need to be addressed with averaging time.