

Ozone Transport Commission (OTC)
Stationary & Area Sources Committee

**White Paper on Control Technologies and OTC State Regulations for
Nitrogen Oxides (NO_x) Emissions from Eight Source Categories**

Executive Summary

Purpose

This white paper identifies current emission limits and regulations for nitrogen oxides (NO_x) emissions from eight source categories within the member states of the Ozone Transport Commission (OTC), in partial fulfillment of item 4 of the November 5, 2015 Charge to the OTC's Stationary and Area Sources (SAS) Committee. That Charge reads as follows:

“To provide each state with a common base of information, a workgroup will develop a listing of emissions rates in each state within the Ozone Transport Region (OTR) for source categories responsible for significant NO_x and VOC emissions and identify a range of emissions rates that the respective state has determined to be RACT. Some of the source categories that should be included in the listing include electrical generating units, turbines, boilers, engines and municipal waste combustors.”

The white paper focuses on eight NO_x source categories, which together account for 95% of the annual NO_x emissions from non-(large) electric generating unit (EGU) stationary sources within the OTR, based on the 2014 EPA National Emissions Inventory, version 1.

The range of NO_x emission rates is available in the source category-specific tables provided in this Executive Summary and in the Appendices to the white paper. Because of variation in the expression of NO_x emission rates in the states (e.g., units, averaging times), a simple range is not provided.

A separate OTC workgroup (the CP/AIM workgroup) is currently working on a Technical Support Document for seven current OTC VOC model rules covering the period from about 2010 to 2014. The Technical Support Document could be used in revising and updating this white paper.

Note that this white paper states the emission rates required in the OTC states as of the date of this paper. The OTC states will be required to perform a RACT review for the 2015 ozone national ambient air quality standard (NAAQS), which may result in revisions to the emission rates provided here.

NO_x RACT Background

The Environmental Protection Agency (EPA) defines RACT as “the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility” (44 FR 53762, September 17, 1979).

Sections 182(f) and 184(b)(2) of the Clean Air Act (CAA) require states with ozone non-attainment areas, classified as moderate, serious, severe, and extreme--as well as all areas in the OTR--to implement RACT for existing major stationary sources of NO_x.

NO_x RACT Applicability

Section 302 of the CAA defines a major stationary source as any facility which has the potential to emit of 100 tons per year (tpy) of any air pollutant. Section 182 of the CAA reduces the major stationary source potential to emit threshold for certain ozone nonattainment classifications: 50 tpy for serious areas; 25 tpy for severe areas; and 10 tpy for extreme areas. The anti-backsliding provisions of the CAA require an area to continue to apply the area’s historical most stringent major source threshold. Current and historical area classifications may be found in the EPA Green Book online at <https://www3.epa.gov/airquality/greenbook/index.html>.

NO_x Emission Control Technologies and Strategies

The following NO_x emissions control technologies and strategies are described in this whitepaper:

- Combustion Modification
 - Low Excess Air (LEA) or Reducing O₂ levels
 - Lean Combustion
 - Staged Combustion
 - Low Nitrogen Fuel Oil
 - Flue Gas Recirculation (FGR)
 - Low-NO_x Burner (LNB) and Overfire Air (OFA)
 - Wet controls
- Post-Combustion Modifications
 - Gas Reburn
 - Non-Selective Catalytic Reduction (NSCR)
 - Selective Catalytic Reduction (SCR)
 - Selective Non-Catalytic Reduction (SNCR)
- Other Control Strategies
 - Combustion Tuning and Optimization
 - Use of Preheated Cullet

Current NO_x regulations and emission limits for source categories in the Ozone Transport Region (OTR)

1. Industrial/Commercial/Institutional (ICI) Boilers in OTR

Results of a recent survey of the NO_x emission limits and regulations for ICI Boilers in the OTR found in **Appendix A** of the white paper are summarized below:

NO_x limit based on boiler capacity and fuel type

Capacity (mmBtu/hr)	NO _x Limit (lbs/mmBtu)			
			Oil	
	Coal	Nat. Gas	Distillate	Residual
50 – 100	0.28 – 0.50	0.05 – 0.43	0.08 – 0.43	0.20 -0.50
100 – 250	0.08 – 1.00	0.06 – 0.43	0.10 – 0.43	0.20 -0.50
>250	0.08 – 1.40	0.08 – 0.70	0.10 – 0.43	0.15 -0.50

2. Stationary Gas (Combustion) Turbine Engines in OTR

Results of a recent survey of the NO_x emission limits and regulations for Combustion Turbines (>25 MW capacity) in the OTR found in **Appendix B** of the white paper are summarized below:

TURBINE ENGINES (>25 MW)	Simple Cycle		Combined Cycle	
	Gas-fired	Oil-fired	Gas-fired	Oil-fired
State	NO _x Limit (ppmvd @15% O ₂)			
CT - Statewide	258 (42 - 0.9 lb/MMBtu) ^a 42 – 55 ^b ; 40 ^c	240 (40 - 0.9 lb/mmBtu) ^a 40 – 75 ^b ; 40 – 50 ^c	258 (42 - 0.9 lb/MMBtu) ^a 42 ^b ; 25 ^c	240 (40 - 0.9 lb/mmBtu) ^a 40 – 65 ^b ; 40 – 42 ^c
DC (If ≥100 mmBTU/hr)	NA	75	NA	NA
DE - Statewide	42	88	42	88
MA - Statewide	65	100	42	65
MD - Select Counties	42	65	42	65
ME - Statewide	NA	NA	3.5 – 9.0	42
NH - Statewide	25 (55 for pre-1999)	75	42	65
NJ – Statewide (≥15 MW)	25 (1.00 lb/MWh)	42 (1.60 lb/MWh)	25 (0.75 lb/MWh)	42 (1.20 lb/MWh)
NY - Statewide	50	100	42	65
PA - Statewide	>1,000 bhp & <6,000 bhp (150); >6000 BHP (42)	>1,000 bhp and <6,000 bhp (150); >6000 BHP (96)	1,000 bhp and <180 MW (42); >180 MW (4)	1,000 bhp and <180 MW (96); >180 MW (8) F42
RI - Statewide	No RACT Sources (new only)	No RACT Sources (new only)	No RACT Sources (new only)	No RACT Sources (new only)
VA - OTR jurisdiction	42	65 - 77	42	65 - 77
VT - Statewide	NA			

Notes:

- CT: ^aExisting RCSA Sec. 22a-174-22 (to be repealed as of June 1, 2018); ^bRCSA Sec. 22a-174-22e starting June 1, 2018; ^cRCSA Sec. 22a-174-22e starting June 1, 2023.
- NJ: lb/mmBtu limit converted to ppmvd @15% O₂ based on Part 75 Eq-F5 and F-factors of 8710 for natural gas and 9190 for oil; lb/MWh limit converted to ppmvd@15% O₂ based on New Jersey technical support document; 25 ppm ≈ 1.0 lb/MWh for simple cycle gas; 42 ppm ≈ 1.60 lbs/hr for simple cycle oil. (NJ Proposal Number: PRN 2008-260).
- NA = Not Applicable

3. Stationary Reciprocating Internal Combustion (IC) Engines in OTR

Results of a recent survey of the emission limits and regulations for IC Engines (>500 hp) in the OTR presented in **Appendix C** of the white paper are summarized below:

IC ENGINES >500 hp	NOx Limit (g/hp-hr)			
	Gas-fired, Lean Burn	Gas-fired, Rich Burn	Diesel	Dual Fuel
CT - Statewide	2.5*; 1.5 - 2.0**	2.5*; 1.5 - 2.0**	8.0*; 1.5 - 2.3**	Multi-fuel provisions*,**
DC	NA	NA	NA	NA
DE - Statewide	Technology Stds.	Technology Stds.	Technology Stds.	Technology Stds.
MA - Statewide	3.0	1.5	9.0	9.0
MD - Select Counties	150 ppmvd @ 15% O ₂ (Approx. 1.7 g/hp-hr)*	110 ppmvd @ 15% O ₂ (Approx. 1.6 g/hp-hr)*	175 ppmvd @ 15% O ₂	125 ppmvd @ 15% O ₂
ME - Statewide	NA	NA	3.7 (Source-specific RACT)	NA
NH - Statewide	2.5	1.5	8.0	8.0
NJ - Statewide	1.5	1.5	2.3	2.3
NY - Statewide	1.5	1.5	2.3	2.3
PA - Statewide	3.0	2.0	8.0	8.0
RI - Statewide	2.5	1.5	9.0	No specified in Regulation, no sources.
VA - OTR Jurisdiction	Source-specific RACT	Source-specific RACT	Source-specific RACT	Source-specific RACT
VT - Statewide	4.8	4.8	4.8	4.8

Notes:

- CT - * existing RCSA section 22a-174-22 (to be repealed as of June 1, 2018) and RCSA section 22a-174-22e starting June 1, 2018); **RCSA section 22a-174-22e starting June 1, 2023.
- MD - * Conversion factors from ppmv @ 15% O₂ to g/hp-hr from EPA ACT, July 1993 EPA453-R-93-032
- NJ: For an engine ≥37 kW and that has been modified on or after March 7, 2007, 0.90 grams/bhp-hr or an emission rate which is equivalent to a 90% NOx reduction from the uncontrolled NOx emission level
- NA = Not Applicable

4. Municipal Waste Combustors (MWCs) in OTR

Results of a recent survey of the emission limits and regulations for MWCs in the OTR presented in **Appendix D** of the white paper are summarized below:

- There are no MWCs in DC, DE, RI, and VT.
- The unit level capacity of MWCs ranges from 50 - 2,700 tpd of MSW.
- The types of combustors include: mass burn units (waterwall, refractory, stationary grate, reciprocating grate, single chamber), two types of rotary incinerators, and refuse-derived fuel incinerators.
- The types on NO_x controls employed include FGR and SNCR with the majority of the units controlled with SNCR.
- The NO_x emission limits vary within the OTR by state and by combustor technology.
 - 372 ppmvd NO_x @ 7% O₂, 1-hour average (control technology not specified)
 - 185 - 200 ppmvd NO_x @ 7% O₂, 3-hour average (with SNCR)
 - 120 - 250 ppmvd NO_x @ 7% O₂, 24-hour average (control technology not specified)
 - 150 ppmvd NO_x @ 7% O₂, calendar-day average (with SNCR)
 - 0.35 - 0.53 lb NO_x/MMBtu, calendar-day average (with SNCR)
 - 135 ppmvd NO_x @ 7% O₂, annual average (with no controls)

5. Cement kilns in OTR

Results of a recent survey of the emission limits and regulations for cement kilns in the OTR are presented below:

- There are no cement kilns in CT, DC, DE, MA, NH, NJ, RI, and VT.
- Depending on the type of kilns (wet or dry, with or without pre-calciner), the NO_x emission limits range from 2.33 - 6.0 lbs/ton clinker in the existing state rules.

State	NO _x Limit (lbs/ton clinker)				Regulations
	Long Dry	Long Wet	Pre-heater	Pre-calciner	
MD	5.1 3.4*	6.0 NA*	2.8 2.4*	2.8 2.4*	COMAR 26.11.30: http://www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=26.11.30 .
ME	2.33	-	-	-	EPA Consent Agreement (Docket 01-2013-0053, Sept 2013)
PA	3.44	3.88	2.36	2.36	Final RACT 2 Rule (46 Pa.B. 2036, April 23, 2016): http://www.pabulletin.com/secure/data/vol46/46-17/694.html
NY	2.88 (using SNCR) (SCC: 3-05-006-06)	5.2(SCC: 3-05-007-06)			Subpart 220-1 - Effective: 7/11/2010 Submitted: 8/19/2010; Final: 77 FR 13974, 78 Fr 41846: https://www3.epa.gov/region02/air/sip/ny_reg.htm
VA - OTR jurisdiction	No Limits				

Notes:

- MD: *After 04/01/2017

6. Hot Mix Asphalt Production Plants in OTR

Results of a recent survey of state regulations for Asphalt Production Plants in the OTR found in **Appendix E** of the white paper are summarized below.

State	Hot Mix Asphalt Production Plants – Regulations	State Contacts
CT	RCSA section 22a-174-22 will be replaced with RCSA section 22a-174-22e (RCSA section 22a-174-22 will be repealed as of June 1, 2018). Note: Neither section includes a limit that specifically applies to "asphalt production plants" but the fuel-burning equipment is regulated. http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424 3416, Merrily.Gere@ct.gov ;
DC	150 ppmvd @ 7% O ₂ is the NOx RACT standard for major sources (25 TPY) of NOx only (two of the three HMA facilities in DC). No NOx RACT standard is specified for minor sources of NOx. The third HMA facility, a 225 TPH continuous drum-mix asphalt plant, has NOx limits of 12.4 lb/hr and 22.0 tons per 12-month rolling period to emit keeping NOx below the major source threshold. 20 DCMR § 805.6, RACT for Major Stationary Sources of Oxides of Nitrogen: http://www.dcregs.dc.gov/Gateway/RuleHome.aspx?RuleNumber=20-805 ;	Alexandra Catena, 202 535-2989, alexandra.catena@dc.gov
DE	Specific emissions limitations in lb/HMA are determined on a facility by facility basis. http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml	Mark Prettyman 302-739-9402 mark.prettyman@state.de.us
MA	No specific NOx RACT emission limits for this source category in state NOx RACT regulations; BACT determination for Benevento Asphalt: 0.044 lb/MMBtu (Nat Gas), 0.113 lb/MMBtu (#2 Oil and other fuel types)	Marc Cohen 617.292.5873 Marc.Cohen@MassMail.State.MA.US
MD	Search Title 26, Chapter 11; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	NOx Limit: 0.12 lb/ton asphalt for all fuel types; http://www.maine.gov/dep/air/rules/ ;	Jeff Crawford, 207 287 7647, jeff.s.crawford@maine.gov
NH	NOx Limit: 0.12 lbs/ton asphalt for all fuel types; NH Administrative Rule Env-A 1300 NOx RACT (Part Env-A 1308 Asphalt Plant Rotary Dryers) http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf	Gary Milbury 603 271-2630, gary.milbury@des.nh.gov
NJ	NOx Limit (ppmvd @7% O ₂): 75 (Natural Gas), 100 (No. 2 Oil), 125 (No. 4 or heavier fuel oil or on-spec used oil or mixture of these three); N.J.A.C. 7:27-19.9, based on OTC ADDENDUM TO RESOLUTION 06-02 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095 Margaret.Gardner@dep.nj.gov
NY	Hot mix asphalt plants cap out of Title V. www.dec.ny.gov/regs/2492.html	John Barnes, 518 402 8396, john.barnes@dec.ny.gov ; Robert Bielawa, robert.bielawa@dec.ny.gov

PA	Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC; Effective April 23, 2016. Federal Register -TBD Case by Case; http://www.pacode.com/secure/data/025/articleICIII_toc.html	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov
VA - OTR jurisdiction	All of ~15 plants have federally enforceable limits on their PTE of NOx and VOC to make them minor sources (<100 tpy NOx, <50 TPY VOC). None of them trigger the major stationary RACT source definition under 9 VAC 5 Chapter 40 Article 51 at this time.	Doris McLeod doris.mcleod@deq.virginia.gov
VT	No specific regulatory emission limits for Hot Mix Asphalt Production Plants, but most permits contain 0.06 lb/ton asphalt limit based on application submittal; http://dec.vermont.gov/air-quality/laws	Doug Elliott, 802 377 5939, Doug.Elliott@vermont.gov

Notes:

- No RACT Sources in RI;

7. Glass Furnaces in OTR

Results of a recent survey of Glass Furnaces in the OTR found in **Appendix F** of the white paper are presented below.

State	Glass Furnaces – Regulations	State Contacts
MA	Global consent decree for Ardagh Glass Inc. (formerly Saint Gobain Containers), Milford; Emission limit (lbs NOx/ton glass) = 1.3 *, 30 day rolling average, oxyfuel furnaces; https://www.epa.gov/enforcement/consent-decree-saint-gobain-containers-inc	Marc Cohen 617.292.5873 Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.09.08I, Search Title 26, Chapter 11; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier (410) 537-4488 Randy.Mosier@maryland.gov
NJ	Emission limit (lbs NOx/ton glass) = 9.2 (for flat glass); 4.0 (for others), Oxyfiring installed at rebricking; N.J.A.C. 7:27-19.10, based on OTC ADDENDUM TO RESOLUTION 06-02 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095 Margaret.Gardner@dep.nj.gov
NY	Emission limit (lbs NOx/ton glass) = 1.89 - 4.49; Subpart 220-2 - Effective: 7/11/2010 Submitted: 8/19/2010; Final: 77 FR 13974, 78 Fr 41846; www.dec.ny.gov/regs/2492.html	John Barnes (518) 402-8396 john.barnes@dec.ny.gov Robert Bielawa robert.bielawa@dec.ny.gov
PA	Emission limit (lbs NOx/ton glass) = 4.0 (container and fiberglass furnaces); 7.0 (pressed or blown, and flat glass furnaces); 6.0 (all other glass melting furnaces); Control of NOx Emissions From Glass Melting Furnaces. Sections 129.301 - 129.310. The rule limits the emissions of NOx from glass melting furnaces on an annual basis. Effective September 21, 2011. 08/22/2011; 76 Federal Register 52283 http://www.pacode.com/secure/data/025/articleICIII_toc.html	Susan Hoyle shoyle@pa.gov Randy Bordner ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich sewenrich@pa.gov
VA - OTR jurisdiction	No glass plants trigger the major stationary source RACT threshold in 9 VAC 5 Chapter 40 Article 51 at this time that are located in the OTR portions of Virginia	Doris McLeod doris.mcleod@deq.virginia.gov

Notes:

- No Sources in CT, DC, DE, ME, NH, RI, and VT;
- MA: * excludes Abnormally Low Production Rate Days; Furnace Startup, Malfunction of the Furnace, and Maintenance of the Furnace.

8. Natural Gas Pipeline Compressor Prime Movers in OTR

Results of a recent survey of regulations for Natural Gas Pipeline Compressor Primer Movers in the OTR found in **Appendix G** of the white paper are presented below.

State	Natural Gas Pipeline Compressor Prime Movers – Regulations	State Contacts
CT	RCSA section 22a-174-22 (to be repealed as of June 1, 2018). Will be replaced with RCSA section 22a-174-22e. Note: Does not specifically apply to "natural gas pipelines" but fuel-burning equipment such as compressors is regulated; http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424-3416, Merrily.Gere@ct.gov
DE	http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml http://regulations.delaware.gov/AdminCode/title7/1000/1100/1144.shtml *	Mark Prettyman 302-739-9402 mark.prettyman@state.de.us
MA	310 CMR 7.19(7) NOx RACT simple cycle turbine existing emission limit of 65 ppm @ 15% O ₂ , proposed for more stringent standard of 40 ppm in 2017. A BACT determination in 2006 for a replacement of a 53.8 MMBtu/hr; Allison turbine at Tennessee Gas Pipeline Charlton station with two 50-6200LS Solar Centaur split shaft gas turbine compressor sets equipped with Solar's pre-combustion SoLoNOx technology each rated at 6,037 hp with a maximum heat input = 53.52 MMBtu/hr at ISO conditions): 15 ppm @ 15% O ₂ (or alternatively 3.22 lbs/hr)	Marc Cohen, 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.29; Search Title 26, Chapter 11; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	Source specific BACT	Jane Gilbert, (207) 287-2455, jane.gilbert@maine.gov
NH	Regulated under Part Env-A 1306 <i>Combustion Turbines</i> (no separate rule for compressor stations): http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf	Gary Milbury, 603 271 2630, Gary.milbury@des.nh.gov
NJ	N.J.A.C. 7:27-19.5 and 19.8, amendments in progress (applicable to turbines and engines at natural gas compressor stations) based on draft OTC white paper. http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095 Margaret.Gardner@dep.nj.gov
NY	Covered under NOx RACT Rule (Subpart 227-2) Effective: 7/8/2010, Submitted: 8/19/2010, Final: 77 FR 13974, 78 FR 41846; www.dec.ny.gov/regs/2492.html	John Barnes, 518 402 8396, john.barnes@dec.ny.gov Robert Bielawa, robert.bielawa@dec.ny.gov
PA	Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC. Effective April 23, 2016. Federal Register - TBD (No Distinction) http://www.pacode.com/secure/data/025/articleCIII_toc.html	Susan Hoyle, shoyle@pa.gov Randy Bordner ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov

RI	One source; Source specific RACT for engines at compressor station	Laurie Grandchamp, 401 222 2808, laurie.grandchamp@dem.ri.gov
VA - OTR jurisdiction	9 VAC 5 Chapter 40 Article 51, case by case RACT	Doris McLeod doris.mcleod@deq.virginia.gov

Notes:

- *DE: Reg. 1144 only applies to stationary generators, and not all engines.

The OTC identified natural gas pipeline compressor prime movers as a potential category for emission control strategies at its November, 2010 meeting and tasked the SAS Committee to explore the issue. In 2011 a SAS workgroup prepared a white paper to describe the issue and recommend potential Commission action, e.g., adopt a model rule drafted by the SAS to achieve NO_x emissions reductions from this emission source and assist the OTC states in achieving the National Ambient Air Quality Standards (NAAQS) for ozone.

Within the OTR, natural gas pipeline compressor prime movers fueled by natural gas are used in several phases of natural gas supply: 1) gathering the natural gas from the well field and transporting it to the main transportation pipeline system; 2) moving natural gas through the main pipeline system to distribution points and end users; and 3) injecting and extracting natural gas from gas storage facilities. These natural gas pipeline compressor prime movers, mostly driven by internal combustion (IC) reciprocating engines and combustion turbines, are a significant source of nitrogen oxide (NO_x) emissions year-round. Data sources indicate that nine OTR states have large natural gas compressor facilities (CT, MA, MD, ME, NJ, NY, PA, RI, VA); three OTR states contain a number of natural gas well field compressors (MD, NY, PA); and two OTR states have natural gas underground storage facilities (PA, NY).

The SAS Committee examined other areas of natural gas production (beyond the natural gas pipeline compressor prime movers addressed by the white paper) and concluded that potentially significant NO_x reductions may be possible from the “upstream” activities of well drilling, well completion, and well head and field gathering natural gas compressor prime movers. Preliminary information indicates that NO_x emissions from these sources may greatly exceed those of the pipeline and underground storage compression sources. This is more evident in the expansion of natural gas production due to shale gas activities.

Only limited data were available regarding the population of natural gas pipeline compressor prime movers fueled by natural gas in the OTR at the time that this white paper was written. The most comprehensive data that were available at that time was the 2007 emissions inventory (including a MARAMA point source emissions inventory for that year); therefore, 2007 was the base year used for analysis.¹ The 2007 data indicate that there are a multitude of natural gas compressor facilities in the OTR (including 150 classified as “major emissions sources”) including 2-stroke lean-burn internal

¹ OTC Nat Gas Compressor Prime Mover Inventory Rev 092711 from BC 092513.xlsx.

combustion (IC) reciprocating engines, 4-stroke lean-burn IC reciprocating engines, 4-stroke rich-burn IC reciprocating engines, and combustion turbines. The 2007 data showed:

- At least 409 reciprocating engine prime movers with ratings of 200 - 4300 hp, which includes a large number of makes and models
- At least 125 combustion turbine prime movers with ratings of 1000 - 20,000 hp, which includes a moderate number of makes and models.

Many of these prime movers may be >40 years old. The MARAMA point source emissions inventory data indicates that in 2007 this population of natural gas prime movers emitted ~11,000 tons of NO_x in the OTR annually (~30 tpd on average).

OZONE TRANSPORT COMMISSION

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OTC State Regulations for Nitrogen Oxides
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STATIONARY and AREA SOURCES COMMITTEE

2/10/2017

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ABBREVIATIONS

Alternative Control Techniques (ACT)	35
British Thermal Units Per Hour (MMBtu/hr)	21
Combined Heat And Power (CHP)	29
Compression Ignited (CI).....	29
Excess Air (EA).....	32
Flue Gas Recirculation (FGR).....	9
Fuel Reburning (FR).....	9
Heavy Duty (HD).....	30
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Industrial/Commercial/Institutional (ICI)	21
Internal Combustion Engine (ICE)	27
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Reciprocating Internal Combustion Engines (RICE)	27
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I. Introduction

A. Purpose

This white paper identifies current emission limits and regulations for nitrogen oxides (NOx) emissions from eight source categories within the member states of the Ozone Transport Commission (OTC), in partial fulfillment of item 4 of the November 5, 2015 Charge to OTC's Stationary and Area Sources (SAS) Committee which reads as follows:

“To provide each state with a common base of information, a workgroup will develop a listing of emissions rates in each state within the Ozone Transport Region (OTR) for source categories responsible for significant NOx and VOC emissions and identify a range of emissions rates that the respective state has determined to be RACT. Some of the source categories that should be included in the listing include electrical generating units, turbines, boilers, engines and municipal waste combustors.”

B. NOx RACT Background

The Environmental Protection Agency (EPA) defines RACT as “the lowest emission limitation that a particular source is capable of meeting by the application of control technology that is reasonably available considering technological and economic feasibility” (44 FR 53762, September 17, 1979).

Sections 182(f) and 184(b)(2) of the Clean Air Act (CAA) require states with ozone non-attainment areas, classified as moderate, serious, severe, and extreme--as well as all areas in the Ozone Transport Region (OTR)--to implement RACT for existing major stationary sources of NOx.

C. NOx RACT Applicability

Section 302 of the CAA defines a major stationary source as any facility which has the potential to emit of 100 tons per year (tpy) of any air pollutant (Table 1). Section 182 of the CAA reduces the major stationary source potential to emit threshold for certain ozone nonattainment classifications: 50 tpy for serious areas; 25 tpy for severe areas; and 10 tpy for extreme areas.

The anti-backsliding provisions of the CAA require an area to continue to apply their historical most stringent major source threshold. Current and historical area classifications may be found in the EPA Green Book online at <https://www3.epa.gov/airquality/greenbook/index.html>.

**Table 1 RACT Major Stationary Source Thresholds
(lowest historical value generally applies)**

Area	NOx Emissions (potential to emit; tpy)
Ozone Transport Region	100
Moderate ozone nonattainment	
Serious ozone nonattainment	50
Severe ozone nonattainment	25
Extreme ozone nonattainment	10

II. NOx Emission Control Technologies and Strategies

The formation of nitrogen oxides (nitrous oxide, nitric oxide, dinitrogen dioxide, dinitrogen trioxide, nitrogen dioxide, dinitrogen tetroxide, dinitrogen pentoxide) collectively known as NOx¹ is strongly dependent on temperature of combustion and occurs by three fundamentally different mechanisms:

Thermal NOx: is the result of oxidation of nitrogen (N₂) to NOx through reactions that involve oxygen (O₂), hydrogen and hydroxyl radicals² at temperatures at or above 1,300°C (2,370°F)³ It also arises directly from the thermal dissociation and subsequent reaction of molar amounts of N₂ and O₂ in the combustion air and is the principal mechanism of NOx emission in turbines firing natural gas or distillate oil fuel. Most thermal NOx is formed at a slightly fuel-lean mixture (because of excess oxygen available for reaction) in high temperature stoichiometric flame pockets downstream of the fuel injectors where combustion air has mixed sufficiently with the fuel to produce the peak temperature fuel/air interface.⁴ “Avoiding local high flame temperatures, high residence times, recirculation patterns and excess air can reduce the formation of thermal NOx.”⁵ (Table 2)

Prompt NOx: forms within the flame from early reactions of N₂ molecules in the combustion air and hydrocarbon radicals (such as the Intermediate Hydrogen Cyanide or HCN) in the fuel. Prompt NOx formation is favored by excess hydrocarbons, and “is less temperature dependent than thermal NOx and the reactions are relatively faster”.⁶ The amount of prompt NOx is usually negligible compared to thermal NOx.⁷ “Avoiding local excess of unburned hydrocarbons and keeping the flame lean of fuel can reduce the formation of prompt NOx.”⁸

Fuel NOx: stems from the evolution and reaction of fuel-bound nitrogen compounds (such as in coal) with O₂. Chemically-bound nitrogen is negligible in natural gas fuel (although some N₂ is present) and is found in low levels in distillate oils. Fuel NOx from distillate oil-fired turbines may become significant in turbines equipped with a high degree of thermal NOx controls.

Combustion and post-combustion control technologies are commonly used to reduce emissions of thermal NOx and fuel NOx⁹ (Table 3).

¹ EPA-456/F-99-006R: Nitrogen Oxides (NOx), Why and How They Are Controlled. 11/1999.

<https://www3.epa.gov/ttnca1/dir1/fnoxdoc.pdf>

² S. Barendregt, L. Risseuw, and F. Waterreus. Applying ultra-low-NOx burners. 2006. Petrochemicals & Gas Processing. Technip Benelux PTQ Q2. <https://www.johnzink.com/wp-content/uploads/ultra-low-nox-burners.pdf>

³ <https://www3.epa.gov/ttnca1/dir1/fnoxdoc.pdf>

⁴ EPA-453/R-94-037. Alternative Control Techniques Document – NOx Emissions from Glass Manufacturing. 06/1994. <https://www3.epa.gov/ttnca1/dir1/glassact.pdf>

⁵ <https://www.johnzink.com/wp-content/uploads/ultra-low-nox-burners.pdf>

⁶ <https://www.johnzink.com/wp-content/uploads/ultra-low-nox-burners.pdf>

⁷ <https://www3.epa.gov/ttnca1/dir1/glassact.pdf>

⁸ <https://www.johnzink.com/wp-content/uploads/ultra-low-nox-burners.pdf>

⁹ <https://www3.epa.gov/ttnca1/dir1/glassact.pdf>

Table 2 NOx Control Methods¹⁰

Abatement or Emission Control Principle or Method	Successful Technologies	Pollution Prevention Method (P2) or Add-on Technology (A)
1. Reducing peak temperature	Flue Gas Recirculation (FGR)	P2
	Natural Gas Reburning	P2
	Low NOx Burners (LNB)	P2
	Combustion Optimization	P2
	Burners Out Of Service (BOOS)	P2
	Less Excess Air (LEA)	P2
	Inject Water or Steam	P2
	Over Fire Air (OFA)	P2
	Air Staging	P2
	Reduced Air Preheat	P2
	Catalytic Combustion	P2
2. Reducing residence time at peak temperature	Inject Air	P2
	Inject Fuel	P2
	Inject Steam	P2
3. Chemical reduction of NOx	Fuel Reburning (FR)	P2
	Low NOx Burners (LNB)	P2
	Selective Catalytic Reduction (SCR)	A
	Selective Non-Catalytic Reduction (SNCR)	A
4. Oxidation of NOx with subsequent absorption	Non-Thermal Plasma Reactor	A
	Inject Oxidant	A
5. Removal of nitrogen	Oxygen Instead Of Air Ultra-Low Nitrogen Fuel	P2
		P2
6. Using a sorbent	Sorbent In Combustion	A
	Chambers Sorbent In Ducts	A
7. Combinations of these Methods	All Commercial Products	P2 and A

A. Combustion Modifications

“Maximum reduction of thermal NOx can be achieved by controlling both the combustion temperature (i.e. reducing the temperature below the adiabatic flame temperature, for a given stoichiometry) and the stoichiometry of air to fuel (O₂:N₂).”¹¹

Combustion control technologies control the temperature or O₂ to reduce NOx formation (Table 4). Combustion controls could be dry controls which use advanced combustion design to suppress NOx formation and/or promote CO burnout, or wet controls which use water to lower combustion temperature. “Since thermal NOx is a function of both temperature (exponentially) and time (linearly), dry controls either lower the combustion temperature

¹⁰ <https://www3.epa.gov/ttnecatc1/dir1/fnoxdoc.pdf>

¹¹ AP-42, Vol. I, 3.1: Stationary Gas Turbines. <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

using lean mixtures of air and/or fuel staging, or decrease their residence time in the combustor.”¹² A combination of the dry control methods described below may be used to reduce NOx emissions:

1. Low Excess Air (LEA) or Reducing O₂ levels

In LEA systems, NOx formation is reduced by decreasing the amount of O₂ that is available to react with N₂ in the combustion air. This is achieved through the use of oxygen trim controls (e.g. a combustion analyzer) which “measure the stack O₂ concentration and automatically adjust the inlet air at the burner” for optimal fuel and air mixture resulting in a ~ 1% thermal efficiency¹³. “This method can reduce the level of NOx produced by up to 10%, but may increase the emissions of CO very significantly.” This method is widely used in many processes that employ rich burn engines.¹⁴

2. Lean combustion

Lean combustion (two stage lean/lean combustion) involves “increasing the air-to-fuel (A/F) ratio of the mixture so that the peak and average temperatures within the combustor will be less than that of the stoichiometric mixture, thus suppressing thermal NOx formation. Introducing excess air not only creates a leaner mixture but it also can reduce residence time at peak temperatures.”¹⁵ While a rich-burn engine is characterized by excess fuel which results in an exhaust O₂ content of about 0.5%, a lean-burn engine is characterized by excess air with an exhaust O₂ content typically >8%.¹⁶

“In lean premixed combustion the fuel is typically premixed with >50% theoretical air resulting in lower flame temperatures thus suppressing thermal NOx formation. Operation at excess air levels and at high pressures increases the influence of inlet humidity, temperature, and pressure leading to variations in emissions of ≥30%. For a given fuel firing rate, lower ambient temperatures lower the peak temperature in the flame, lowering thermal NOx significantly. Similarly, turbine operating loads affect NOx emissions with higher emissions expected for higher loads due to higher peak temperature in the flame zone.”¹⁷

3. Staged Combustion

In staged combustion, the amount of underfire air (air supplied below the combustion grate) is reduced, which generates a starved-air region reducing thermal NOx formation. In this method, “only a portion of the fuel is burned in the main chamber” greatly

¹² <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

¹³ <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

¹⁴ Combustion Training: NOx Reduction Methods. <http://www.e-inst.com/combustion/nox-reduction>

¹⁵ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

¹⁶ Manufacturers of Emission Controls Association (MECA), 05/2015. Emission Control Technology for Stationary Internal Combustion Engines.

http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

¹⁷ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

reducing the temperature in the main chamber thereby reducing the amount of thermal NOx. "All of the fuel is eventually burned, producing the same amount of energy."¹⁸

"Two-stage lean/lean combustors are essentially fuel-staged, premixed combustors which allow the turbine to operate with an extremely lean mixture burned at each stage while ensuring a stable flame. A small stoichiometric pilot flame which ignites the premixed gas and provides flame stability has insignificant NOx emissions. Low NOx emission levels are achieved by this combustor design through cooler flame temperatures associated with lean combustion and avoidance of localized "hot spots" by premixing the fuel and air."¹⁹

"Two stage rich/lean combustors are essentially air-staged, premixed combustors in which the primary zone is operated fuel rich and the secondary zone is operated fuel lean. The rich mixture produces lower temperatures (compared to stoichiometric), higher concentrations of CO and H₂ because of incomplete combustion, and also decreases the amount of oxygen available for NOx generation. Before entering the secondary zone, the exhaust of the primary zone is quenched (to extinguish the flame) by large amounts of air and a lean mixture is created. The lean mixture is pre-ignited and the combustion completed in the secondary zone where the lower temperature environment minimizes NOx formation."²⁰

4. Low Nitrogen Fuel Oil

"The use of low nitrogen oils, which can contain up to 15 - 20 times less fuel-bound nitrogen than standard No. 2 oil, can greatly reduce NOx emissions as fuel-bound nitrogen can contribute 20-50% of total NOx levels."²¹

5. Flue Gas Recirculation (FGR)

FGR lowers the temperature of the flame thereby reducing thermal NOx. "In FGR, cooled flue gas and ambient air are mixed to become the combustion air. This mixing reduces the O₂ content of the combustion air supply and lowers combustion temperatures."²² "A portion of the exhaust gas is re-circulated into the combustion process, cooling the area. This process may be either external or induced, depending on the method used to move the exhaust gas. FGR may also minimize CO levels while reducing NOx levels."²³

6. Low-NOx Burner (LNB) and Overfire Air (OFA)

LNB and OFA (air supplied above the combustion grate) (Fig. 1) can be used separately or as a system, and can reduce NOx emissions by 40 - 60%.²⁴ LNBs are applicable to

¹⁸ <http://www.e-inst.com/combustion/nox-reduction>

¹⁹ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

²⁰ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

²¹ <http://www.e-inst.com/combustion/nox-reduction>

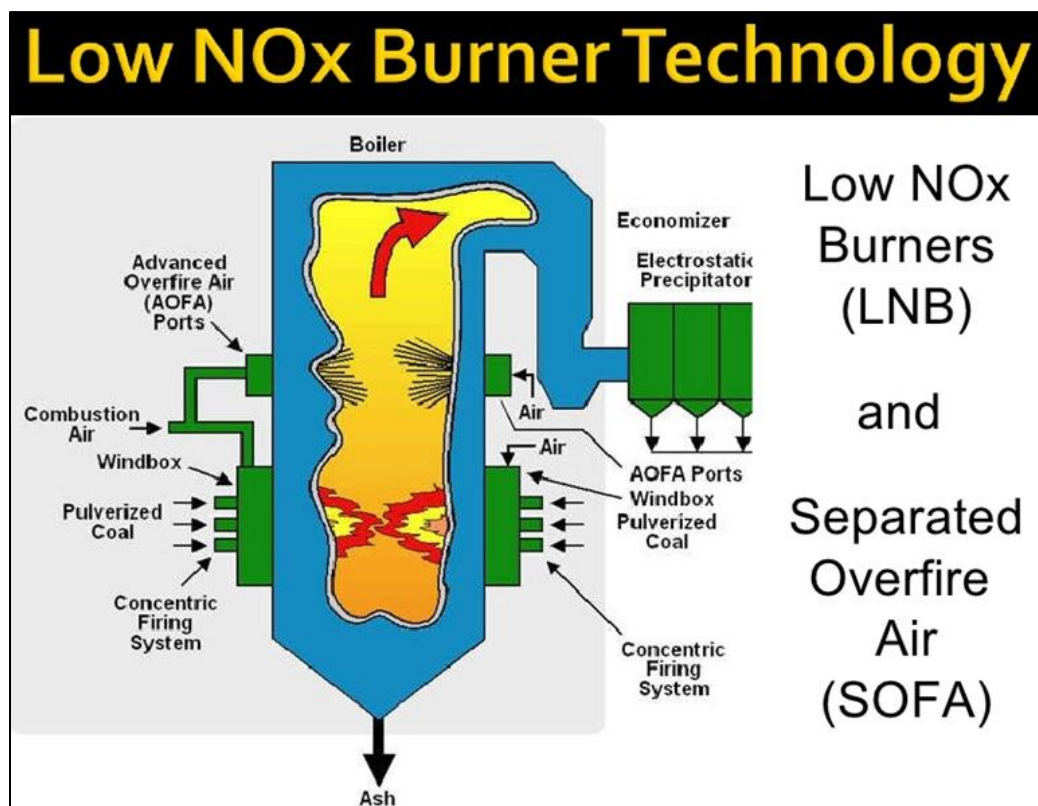
²² AP-42, Vol. I, CH 2.1: Refuse Combustion: <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

²³ <http://www.e-inst.com/combustion/nox-reduction>

²⁴ Northeast States for Coordinated Air Use Management (NESCAUM) Report, 01/2009. [Applicability and Feasibility of NOx, SO₂, and PM Emissions Control Technologies for Industrial, Commercial, and Institutional \(ICI\) Boilers.](#)

most ICI boiler types, and are being increasingly used at ICI boilers <10 MMBtu/hr. These technologies require site-specific suitability analyses since several parameters can have substantial impact on their performance or even retrofit feasibility.²⁵ LNBs use gas, distillate or residual oil, and coal, and can be coupled with FGR or Selective Non-Catalytic Reduction (SNCR) for additional reductions.²⁶

Figure 1 Schematic of Low NO_x Burner Technology²⁷



Ultra Low NO_x Burner (ULNB) can achieve NO_x emission levels in the order of single digits in ppm.²⁸

7. Wet controls

Wet controls use steam or water injection to reduce combustion temperatures and thermal NO_x formation. The injected water-steam “increases the thermal mass by dilution” and also acts as a heat sink absorbing the latent heat of vaporization from the flame zone thereby reducing combustion peak temperatures in the flame zone and decreasing thermal NO_x.²⁹ Water or steam is typically injected into turbine inlet air at a water-to-fuel weight ratio of <1.0 and depending on the initial NO_x levels, such

²⁵ NESCAUM Report

²⁶ A. M. Bodnarik

²⁷ NGS Emissions and Air Quality Compliance <http://www.slideshare.net/en3pro/ngs-emissions-and-air-quality-compliance>

²⁸ NESCAUM Report

²⁹ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

injections may reduce NOx by $\geq 60\%$. “Water or steam injection is usually accompanied by an efficiency penalty (typically 2-3%) and “excess amounts of condensation may form.” An increase in power output (typically 5-6%) results from “the increased mass flow required to maintain turbine inlet temperature at manufacturer's specifications. Both CO and VOC emissions are increased by water injection depending on the amount of water injection”.³⁰

B. Post-Combustion Modifications

Post-combustion controls or add-on controls include natural gas re-burning or catalytic controls (e.g. catalytic converters) which selectively reduce NOx and/or oxidize CO exhaust emissions through a series of chemical reactions without itself being changed or consumed³¹ (Table 5). Catalytic control devices are used to lower the emissions of combustion processes in varied sources including stationary engines, boilers, heaters and internal combustion engines. Catalytic converters break down nitrogen oxides into separate nitrogen and oxygen particles. Some catalytic converters are also used to reduce the high CO levels produced when reducing NOx, as low CO levels are important to ensuring complete combustion.

“An emission control catalyst system consists of a steel housing (its size being dependent on the size of the engine for which it is being used) that contains a metal or ceramic structure which acts as a catalyst support or substrate. There are no moving parts, just acres of interior surfaces on the substrate coated with either base or precious catalytic metals, such as platinum (Pt), rhodium (Rh), palladium (Pd), or vanadium (V), depending on targeted pollutants. Catalysts transform pollutants into harmless gases through chemical reactions in the exhaust stream depending on the technology being used, and also depending on whether the engine is operating rich or lean.”³²

1. Gas Reburn

“Natural gas reburning involves limiting combustion air to produce an LEA zone. Recirculated flue gas and natural gas are then added to this LEA zone to produce a fuel-rich zone that inhibits NOx formation and promotes reduction of NOx to N₂.”³³

Gas reburn has been used only in large EGU applications, but is an option for larger watertube-type boilers including stokers. Reburn may yield 35 - 60% reductions in NOx emissions but requires appropriate technical and economic analyses to determine suitability.³⁴ “Economic benefit of reburning depends on available steam demand,

³⁰ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

³¹ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

³² http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

³³ <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

³⁴ NESCAUM Report

natural gas and electricity costs, and the ability to operate the system at higher than designed heat input.”³⁵

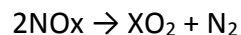
2. Non-Selective Catalytic Reduction (NSCR)

“NSCR is an effective NOx-reduction technology for rich-burn, spark-ignited stationary gas engines. NSCR is currently the most economical and accepted emission control method for rich-burn engines. This same catalyst technology is referred to as a three-way catalyst when the engine is operated at the stoichiometric point where not only is NOx reduced but so are CO and non-methane hydrocarbons (NMHC). Conversely, lean NOx catalyst systems and oxidation catalysts provide little, if any, emission control in a rich-burn environment. However, in a lean-burn environment, oxidation catalysts provide significant reductions in both CO and NMHC, and lean NOx catalyst systems provide reductions in NOx, CO, and NMHC.”³⁶

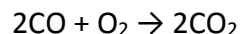
“NSCR systems are similar in design to three-way catalytic converters used on most modern cars and light-duty trucks. Exhaust from the engine is passed through a metallic or ceramic honeycomb covered with a platinum group metal catalyst. The catalyst promotes the low temperature (approximately 850°F) reduction of NOx into N₂, the oxidation of CO into CO₂, and the oxidation of HCs into water vapor.”³⁷

An NSCR system has three simultaneous reactions³⁸:

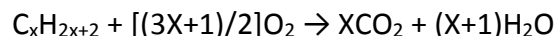
1. Reduction of nitrogen oxides to nitrogen and oxygen:



2. Oxidation of carbon monoxide to carbon dioxide:



3. Oxidation of unburnt hydrocarbons to carbon dioxide and water:



“NSCR catalyst efficiency is directly related to the air/fuel mixture and temperature of the exhaust. Efficient operation of the catalyst typically requires the engine exhaust gases contain no more than 0.5% oxygen. In order to obtain the proper exhaust gas O₂ across the operating range, an A/F ratio controller is installed that measures the oxygen concentration in the exhaust and adjusts the inlet A/F ratio to meet the proper 0.5% O₂ exhaust requirement for varying engine load conditions, engine speed conditions, and ambient conditions.”³⁹

“Lean NOx Catalyst (LNC) technology ‘has demonstrated NOx emission reductions from stationary diesel and lean-burn gas engines. LNCs control NOx emissions by injecting a small amount of diesel fuel or other hydrocarbon reductant into the exhaust upstream

³⁵ C. A. Penterson, H. Abbasi, M. J. Khinkis, Y. Wakamura, and D. G. Linz. Natural gas reburning technology for NOx reduction from MSW combustion systems. <http://www.seas.columbia.edu/earth/wtert/sofos/nawtec/1990-National-Waste-Processing-Conference/1990-National-Waste-Processing-Conference-20.pdf>

³⁶ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

³⁷ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

³⁸ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

³⁹ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

of a catalyst. The fuel or other hydrocarbon reductant serves as a reducing agent for the catalytic conversion of NOx to N₂. Because the mechanism is analogous to SCR but uses a different reductant, LNC technology is sometimes referred to as hydrocarbon selective catalytic reduction, or HC-SCR. Other systems operate passively without any added reductant at reduced NOx conversion rates.

The typical LNC is constructed of a porous material made of zeolite (a micro-porous material with a highly ordered channel structure), along with either a precious metal or base metal catalyst. The zeolites provide microscopic sites that attract hydrocarbons and facilitate NOx reduction reactions. Without the added fuel and catalyst, reduction reactions that convert NOx to N₂ would not take place because of excess oxygen present in the exhaust. For diesel engines over transient cycles, peak NOx conversion efficiencies are typically 25 - 40% (at reasonable levels of diesel fuel consumption), although higher NOx conversion efficiencies have been observed on specially designed HC-SCR catalysts that employ an ethanol-based reductant.

For stationary lean-burn gas engines, two types of lean NOx catalyst formulations have emerged: a low temperature catalyst based on platinum and a high temperature catalyst utilizing base metals (usually copper). Each catalyst is capable of controlling NOx over a narrow temperature range. A copper-exchange zeolite-based catalyst is active at temperatures between 350 - 450°C, resulting in 60% NOx conversion, while a platinum catalyst is active at lower temperatures of approximately 200 - 300°C, with 50% NOx conversion capability.”⁴⁰

3. Selective Catalytic Reduction (SCR)

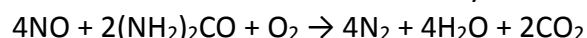
“SCR systems selectively reduce NOx emissions using a three-way catalyst in a low-oxygen environment by injecting a reducing agent into lean-burn exhaust gas stream upstream of a catalyst which reacts with NOx, and O₂ to form N₂ and H₂O.

Pure anhydrous ammonia (NH₃), aqueous ammonia (NH₄OH), or urea (CO(NH₂)₂) can be used as the reductant, is stored on site or injected into the exhaust stream upstream of the catalyst, but, in stationary gas engine applications, urea is most common because of its ease of use. As it hydrolyzes, each mole of urea decomposes into two moles of NH₃. The NH₃ then reacts with the NOx to convert it into N₂ and H₂O.”⁴¹

The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

1. $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$
2. $2\text{NO}_2 + 4\text{NH}_3 + \text{O}_2 \rightarrow 3\text{N}_2 + 6\text{H}_2\text{O}$
3. $\text{NO} + \text{NO}_2 + 2\text{NH}_3 \rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}$

The reaction for urea instead of either anhydrous or aqueous ammonia is:



⁴⁰ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

⁴¹ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

“An oxidation catalyst must be added to the SCR design if hydrocarbons and CO need to be controlled in addition to NOx on a lean-burn engine. The oxidation catalyst first oxidizes the exhaust stream to convert CO to CO₂ and hydrocarbons to CO₂ and water. The CO₂, water, and NOx then enter the SCR catalyst where the NOx reacts with the NH₃. The exhaust gas must contain a minimum amount of O₂ and be within a particular temperature range (typically 450 - 850°F) for the SCR system to operate properly. Exhaust gas temperatures greater than the upper limit (850°F) cause NOx and NH₃ to pass through the catalyst unreacted. The temperature range is dictated by the catalyst material which is typically made from noble metal oxides such as vanadium and titanium, or zeolite-based material.

Catalyst selection is somewhat based on the expected temperature range of the engine exhaust and is sized to achieve the desired amount of NOx reduction. Both precious metal and base metal catalysts have been used in SCR systems. Base metal catalysts, typically vanadium and titanium, are used for exhaust gas temperatures between 450 - 800°F. For higher temperatures (675 - 1100°F), zeolite catalysts may be used. Precious metal SCR catalysts are also useful for low temperatures (350 - 550°F). The catalyst can be supported on either ceramic or metallic substrate materials (e.g., cordierite or metal foil) constructed in a honeycomb configuration. In some designs, the catalyst material is extruded directly into the shape of a honeycomb structure. Most catalysts are configured in a parallel-plate, "honeycomb" design to maximize the surface area-to-volume ratio of the catalyst. The reagent injection system is comprised of a storage tank, reagent injector(s), reagent pump, pressure regulator, and electronic controls to accurately meter the quantity of reagent injected as a function of engine load, speed, temperature, and NOx emissions to be achieved.

Ammonia emissions, called “ammonia slip”, may be a consideration when specifying an SCR system.⁴² “SCR systems can attain NOx conversion efficiencies of 95% or greater, but ammonia/urea requirements tend to increase with higher NOx conversion efficiencies, creating the potential to slip more ammonia. Ammonia cleanup catalysts can be installed behind the SCR catalyst to collect any excess ammonia that slips through (converting it into nitrogen and water). The ideal ratio of ammonia to NOx is 1:1 based on having ammonia available for reaction of all of the exhaust NOx without ammonia slip. However, SCR efficiency can be less than ideal at low temperatures (potential low SCR activity) and at higher temperatures with high exhaust flow rates (high space velocities). Optimizing the ammonia to NOx ratio is shown to lead to potential improvements in overall NOx conversion efficiency with little additional ammonia slip.”⁴³

“Although an SCR system can operate alone, it is typically used in conjunction with water-steam injection systems or lean-premix system to reduce NOx emissions to their lowest levels (<10 ppm at 15% O₂ for SCR and wet injection systems). The SCR system for landfill or digester gas-fired turbines requires a substantial fuel gas pretreatment to

⁴² <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁴³ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

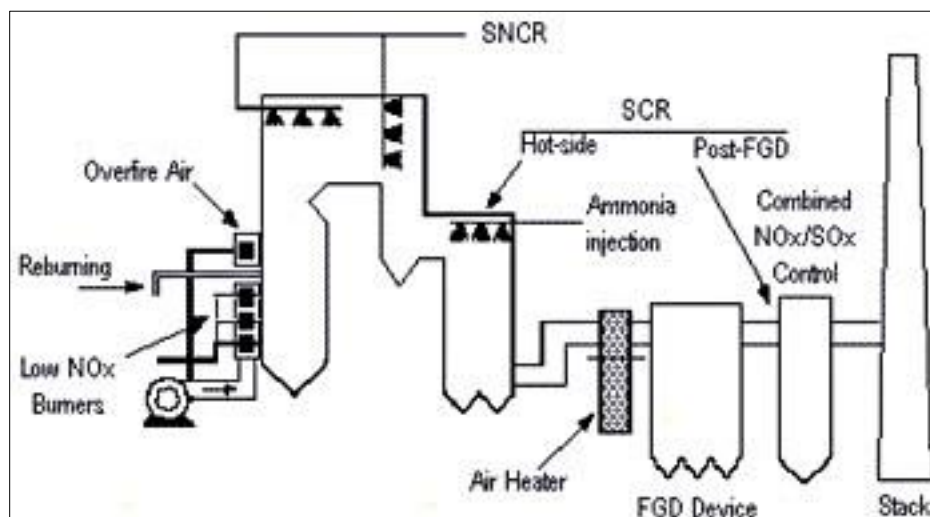
remove trace contaminants that can poison the catalyst. Therefore, SCR and other catalytic treatments may be inappropriate control technologies for landfill or digester gas-fired turbines. The catalyst and catalyst housing used in SCR systems tend to be very large and dense (in terms of surface area to volume ratio) because of the high exhaust flow rates and long residence times required for NO_x, O₂, and NH₃ to react on the catalyst. Some SCR installations incorporate CO catalytic oxidation modules along with the NO_x reduction catalyst for simultaneous CO/NO_x control.”⁴⁴

4. Selective Non-Catalytic Reduction (SNCR)

“SNCR is a process that involves a reductant, usually urea, being added to the top of the furnace and going through a very long reaction at approximately 1400 - 1600°F. This method is more difficult to apply to boilers due to the specific temperature needs, but it can reduce NO_x emissions by 70%.”⁴⁵ “With SNCR, NH₃ or urea is injected into the furnace along with chemical additives to reduce NO_x to N₂ without the use of catalysts. Based on analyses of data from U. S. MWCs equipped with SNCR, NO_x reductions of 45% are achievable (Fig. 2)”⁴⁵

SNCR systems are “commercially installed on a wide range of boiler configurations including dry bottom wall fired and tangentially fired units, wet bottom units, stokers and fluidized bed units. These units fire a variety of fuels such as coal, oil, gas, biomass, and waste. Other applications include thermal incinerators, municipal and hazardous solid waste combustion units, cement kilns, process heaters, and glass furnaces.”⁴⁶

Figure 2 Schematic of Selective Catalytic and Non-Catalytic Reduction⁴⁷



⁴⁴ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

⁴⁵ <http://www.e-inst.com/combustion/nox-reduction>

⁴⁶ EPA-452/F-03-031: Air Pollution Control Technology (Selective Non-Catalytic Reduction (SNCR) Fact Sheet. <https://www3.epa.gov/ttnecat1/dir1/fsnscr.pdf>

⁴⁷ <http://www.e-inst.com/combustion/nox-reduction>

C. Other Control Strategies

1. Combustion Tuning and Optimization

Combustion Tuning may be required to minimize NOx emissions especially since “the combustion system may drift over time from its optimum setting or certain controls (e.g., dampers) may not be operational due to wear.”⁴⁸ Tuning of the combustion system may involve a simple visual check by an experienced boiler or stationary engineer, or parametric testing involving “changes in the key control variables of the combustion system and observation of key parameters” such as flue gas outlet (stack) temperature, and NOx emissions.⁴⁹

Combustion optimization can be accomplished “based on parametric testing, analysis of the results, and estimating optimum operating parameters” based on specific objectives such as combustion efficiency (measure of completeness of fuel oxidation), NOx emissions, boiler efficiency (“net energy output/energy input” ratio), plant efficiency, or a combination of these goals.

Based on their size, periodic testing and manual tuning are adequate for most ICI boilers. Economic considerations and/or specific requirements (such as maximizing boiler efficiency or minimizing NOx emissions) may warrant the installation of digital optimization systems or instrumentation (temperature sensors, oxygen monitors to help avoid incomplete combustion and maintain a stable flame, etc.) for larger boilers particularly those with frequently changing operating conditions such as load.⁵⁰ However, there are “no fixed requirements for instrumentation” since “very little instrumentation is essential to operate the boiler safely”.⁵¹

“One process control measure that has been used for ICI boilers is the use of oxygen trim controls” which “measure the stack O₂ concentration and automatically adjust the inlet air at the burner for optimum efficiency” (a gain of ~1%).⁵² While tuning, optimization, and instrumentation and controls (I&C) are applicable to all boilers, optimization and I&C may be economical and justified for only the larger coal or biomass fired boilers “because their operating parameters (e.g., fuel quality) may be variable and difficult to control”. “Implementing these measures may be technically straightforward and would require raising the awareness of facility staff and management regarding the potential cost savings and importance of tuning/optimization.”⁵³

Combustion Tuning and Optimization efforts can yield NOx reductions of 5-15% or more.⁵⁴

⁴⁸ <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

⁴⁹ <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

⁵⁰ <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

⁵¹ <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

⁵² <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

⁵³ <https://www.epa.gov/sites/production/files/2015-12/documents/iciboilers.pdf>

⁵⁴ NESCAUM Report

2. Use of Preheated Cullet

The use of cullet (recycled, broken, or waste glass) in container glass manufacturing reduces NOx emissions besides saving costs on raw material, fuel, and energy. Cullet melts at a lower temperature than raw materials resulting in lowered thermal NOx emissions from the furnace and avoiding NOx emissions associated with raw materials besides reducing energy demands, lowering production costs, reducing the wear and tear of the furnace, and ultimately lowering maintenance costs and prolonging furnace life.⁵⁵

Preheating cullet through a direct heat transfer from furnace exhaust to a cullet layer or passing the cullet through a vertical funnel surrounded by hollow chambers that is heated externally by the furnace exhaust helps achieve additional energy savings. Once preheated, the cullet is released from the base of the funnel for transport to the batch charger. Direct preheating reduces furnace energy by up to 12% for cullet contents of 50% or greater while indirect heat transfer systems can reduce furnace energy by up to 20%.

After leaving the hollow chambers, the furnace exhaust passes through a conventional filter system and is released to the atmosphere.⁵⁶

“Every 10% increase in the amount of cullet used reduces melting energy by ~2.5%” depending on the preheat temperature and the amount of cullet (thickness) used. Studies show that to achieve notable savings, the cullet must be preheated to at least 650 °F but if temperature exceeds ~1025°F, it will begin to soften and become difficult to transport.⁵⁷

Given that a container glass manufacturing furnace is capable of producing from 100 - 400 tons of glass per day, the reduction in NOx emissions can be substantial. Technical issues such as the design and implementation of the preheating unit, and monitoring of the preheating temperature should be evaluated with the over-all system configuration and carefully reviewed prior to the implementation.⁵⁸

⁵⁵ CWC BP-GL3-01-04: Best Practices in Glass Recycling 06/1996. http://www.cwc.org/gl_bp/3-01-04.pdf

⁵⁶ http://www.cwc.org/gl_bp/3-01-04.pdf

⁵⁷ http://www.cwc.org/gl_bp/3-01-04.pdf

⁵⁸ http://www.cwc.org/gl_bp/3-01-04.pdf

III. Current NO_x RACT rules and emission limits for source categories in the Ozone Transport Region (OTR)

A. INDUSTRIAL/COMMERCIAL/INSTITUTIONAL (ICI) BOILERS

1. ICI Boilers in OTR

Results of a recent survey of the NO_x emission limits and RACT regulations for ICI Boilers in the OTR are found in **Appendix A** and are summarized below in Table 3:

Table 3 NO_x limits based on ICI boiler capacity and fuel type in OTR

Capacity (mmBtu/hr)	NO _x Limit (lbs/mmBtu)			
	Coal	Nat. Gas	Oil	
			Distillate	Residual
50 – 100	0.28 – 0.45	0.05 – 0.43	0.08 – 0.43	0.20 -0.43
100 – 250	0.08 – 1.00	0.06 – 0.43	0.10 – 0.43	0.20 -0.43
>250	0.08 – 1.00	0.08 – 0.70	0.10 – 0.43	0.15 -0.43

2. Background

Industrial boilers “are used by heavy industry (e.g. paper products, chemical, food, and petroleum industries) to produce heat or electricity to run processes or machinery. Most of these boilers have a capacity of 10 - 250 million British thermal units per hour (MMBtu/hr)”.⁵⁹

Commercial boilers “are used by wholesale and retail trade establishments, office buildings, hotels, restaurants, and airports to supply steam and hot water for space heating.” These boilers are generally smaller than the industrial units with heat input capacities generally of <10 MMBtu/hr.⁶⁰

Institutional boilers are used in educational facilities such as medical centers, universities and schools, and also in government buildings, and military installations to provide steam and hot water used for space heating and/or electricity. These boilers have heat input capacities generally <10 MMBtu/hr.⁶¹

“The complete boiler system includes the furnace and combustion system, the heat exchange medium where combustion heat is transferred to the water, and the exhaust system.”⁶² There are four major boiler configurations based on their heat transfer configuration: watertube, firetube, cast iron, and tubeless.⁶³

⁵⁹ Combustion Portal - ICI Boilers <http://www.combustionportal.org/boilerregulations.cfm>

⁶⁰ <http://www.combustionportal.org/boilerregulations.cfm>

⁶¹ <http://www.combustionportal.org/boilerregulations.cfm>

⁶² EPA-453/R-94-022: Alternative Control Techniques Document—NO_x Emissions from Industrial/Commercial/Institutional (ICI) Boilers. <https://www3.epa.gov/ttnecat1/dir1/icboiler.pdf>

⁶³ <https://www3.epa.gov/ttnecat1/dir1/icboiler.pdf>

The ICI Boilers burn a variety of fuels including coal (crushed and pulverized forms of bituminous, sub-bituminous, anthracite and lignite), distillate and residual fuel oils, natural gas, biomass (wood residue and bagasse), liquefied petroleum gas, refinery gas, and a variety of process gases and waste materials to produce steam for generating electricity, providing heat, and for other uses.^{64,65} Boilers fired with coal, wood, or process byproducts are larger, i.e. >100 MMBtu/hr in capacity, while natural gas- and oil-fired boilers tend to be <20 MMBtu/hr on average.⁶⁶ For smaller industrial and commercial units <50 MMBtu/hr capacity, coal is not preferred “because of the high capital cost of coal handling equipment relative to the costs of the boilers.”⁶⁷

3. Emissions Control

Based on the type of boiler, firing, fuel combusted, combustion modification, fuel treatment, and/or post-combustion processes⁶⁸, combinations of the following methods and technologies are frequently used to control ICI boiler NOx emissions: boiler tuning or optimization, LNB (applicable to most ICI boiler types, and increasingly used at ICI boilers <10 MMBtu/hr) and OFA, ULNB, gas reburn (used only in large EGU applications, but is an option for larger watertube-type boilers including stokers), SCR, and SNCR.⁶⁹

B.COMBUSTION TURBINES

1. Combustion Turbine Engines in OTR

Results of a recent survey of the NOx emission limits and RACT regulations for Combustion Turbines (>25 MW capacity) in the OTR are found in **Appendix B**.

2. Background⁷⁰

Gas turbines, also referred to as “combustion turbines” are used in multiple applications including electric power generation, cogeneration, natural gas transmission, and various processes. They operate differently from traditional coal-fired electricity generating units in that they use the expansion of air when heated, instead of steam, to drive turbines (Fig. 3). Combustion turbines are available with power outputs ranging from 300 horsepower (hp) to >268,000 hp using natural gas and distillate (No. 2 low sulfur) fuel oil as primary fuels.⁷¹

⁶⁴ Final reconsideration of the air toxics standards for industrial, commercial, and institutional boilers and process heaters at major source facilities. 11/05/2015. <https://www3.epa.gov/airquality/combustion/docs/20151105fs.pdf>

⁶⁵ Fact Sheet: https://www3.epa.gov/airquality/combustion/docs/20121221_sum_overview_boiler_ciswi_fs.pdf

⁶⁶ Applicability and Feasibility of NOx, SO₂, and PM Emissions Control Technologies for Industrial, Commercial, and Institutional (ICI) Boilers.

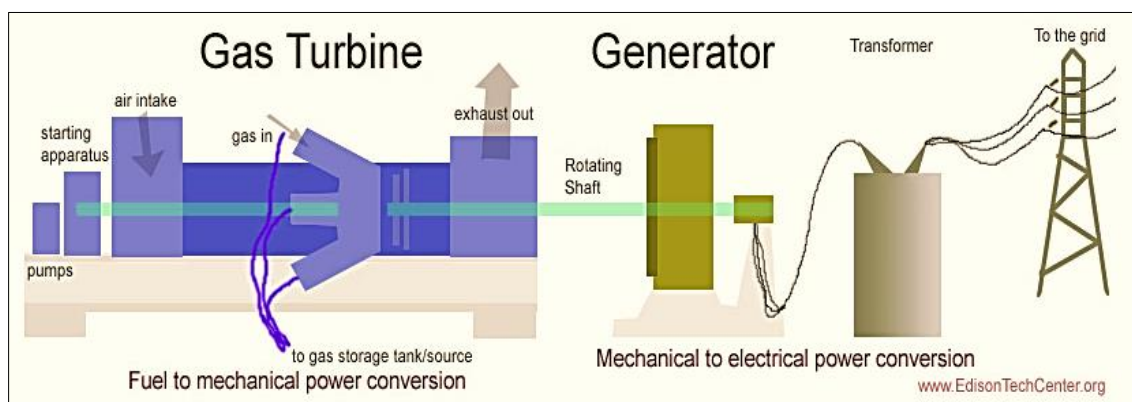
⁶⁷ <https://www3.epa.gov/ttnca1c1/dir1/icboiler.pdf>

⁶⁸ A. M. Bodnarik, 09/03/2009. ICI Boiler NOx & SO₂ - Control Cost Estimates Control Cost Estimates; <http://otcair.org/upload/Documents/Meeting%20Materials/ICI%20Boiler%20Control%20Cost%20presentation%20090309%20long%20version.pdf>

⁶⁹ NESCAUM Report

⁷⁰ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁷¹ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

Figure 3 Schematic of Power Generation using Gas Turbines⁷²

In electric power generation, combustion turbine units referred to as peaking units are used infrequently for short periods to supplement power supply during peak demand periods when electricity use is highest although they are also capable of operating for extended periods.⁷³ Combustion turbine units can operate together or independently. Peaking units have much lower capacity factors than baseload units (which are nearly always operating when available) or intermediate load units (which typically run very little at night but have higher capacity factors during the day).

Natural gas is the marginal fuel for power generation in both Texas and the northeastern United States and marginal units are those that set the price for electricity. Natural gas combustion turbines are usually dispatched in response to price signals, i.e. real-time wholesale hourly electricity prices.⁷⁴ Although these turbines are more expensive to operate than other types of power plants, since they can respond quickly when needed (like hydroelectric stations), they tend to be used to meet short-term increases in electricity demand related to ramping or when loads (and therefore prices) are higher.⁷⁵

Combustion (gas) turbines are complex machines but essentially involve three main components⁷⁶:

Compressor: draws in ambient air, compresses it ~30 times ambient pressure, and feeds it to the combustion chamber at speeds of hundreds of miles per hour.^{77,78}

Combustion system: where fuel is introduced, ignited, and burned, is typically a ring of fuel injectors that inject a steady stream of burning fuel (low sulfur fuel oil or natural gas) into combustion chambers where it mixes with the compressed air and is ignited at

⁷² Edison Tech Center. Gas Turbines: Learn about the history and development of the gas turbine.

<http://www.edisontechcenter.org/gasturbines.html>

⁷³ <https://www.duke-energy.com/about-energy/generating-electricity/oil-gas-fired-intro.asp>

⁷⁴ October 1, 2013, Natural gas-fired combustion turbines are generally used to meet peak electricity load.

<http://www.eia.gov/todayinenergy/detail.cfm?id=13191>

⁷⁵ <http://www.eia.gov/todayinenergy/detail.cfm?id=13191>

⁷⁶ HOW GAS TURBINE POWER PLANTS WORK. <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁷⁷ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁷⁸ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

temperatures >2000°F. The resulting combustion develops a 300,000 hp gas stream that enters and expands through the turbine section.⁷⁹

The combustion process can be classified as:

- Diffusion flame combustion: In this process, the fuel/air mixing and combustion take place simultaneously in the primary combustion zone generating regions of near-stoichiometric fuel/air mixtures where the temperatures are very high.⁸⁰
- Lean premix staged combustion: Here, the fuel and air are thoroughly mixed in an initial stage resulting in a uniform, lean, unburned fuel/air mixture which is delivered to a secondary stage where the combustion reaction takes place. The majority of gas turbines currently manufactured are lean-premix staged combustion turbines also referred to as Dry Low NOx combustors. Manufacturers use different types of fuel/air staging, including fuel staging, air staging, or both applying the same staged, lean-premix principle.⁸¹

There are three types of Combustors:

- annular combustor: “is a doughnut-shaped, single, continuous chamber that encircles the turbine in a plane perpendicular to the air flow”.⁸²
- can-annular combustor: is similar to the annular but incorporates “several can-shaped combustion chambers rather than a single continuous chamber”. “Annular and can-annular combustors are based on aircraft turbine technology and are typically used for smaller scale applications”.⁸³
- silo (frame-type) combustor: “has one or more combustion chambers mounted external to the gas turbine body. These are typically larger than annular or can-annular combustors used for larger scale applications”.⁸⁴

Turbine: “A gas turbine is an internal combustion engine that operates with rotary rather than reciprocating motion.”⁸⁵ It is an “intricate array of alternate stationary and rotating aerofoil-section blades” similar to propeller blades. As hot combustion gas expands through the turbine, it spins the rotating blades which perform dual functions: “they drive the compressor to draw more pressurized air into the combustion section”, and “they spin a generator to produce electricity” much like steam does in a steam-electric station. Two-thirds of the energy generated rotates the air-compressor turbine while the remaining horsepower spins the electric generator.^{86,87}

Land based gas turbines are of two types:

- Heavy Frame engines: are characterized by lower (typically <20) pressure ratios (compressor discharge pressure/inlet air pressure) and tend to be physically large.

⁷⁹ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁸⁰ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁸¹ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁸² <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁸³ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁸⁴ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁸⁵ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁸⁶ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁸⁷ <https://www.duke-energy.com/about-energy/generating-electricity/oil-gas-fired-how.asp>

They have higher power outputs and consequently produce larger amounts of polluting emissions like NOx.⁸⁸

- **Aeroderivative engines:** are derived from jet engines and operate at very high (typically >30) compression ratios. These engines tend to be very compact and used for smaller power outputs.⁸⁹

The temperature at which a turbine operates is key to its fuel-to-power efficiency with higher temperatures corresponding to higher efficiencies, which can translate to more economical operation. While the gas flowing through a typical power plant turbine reach 2300°F, some of the critical metals in the turbine can withstand only 1500 - 1700°F. So the air from the compressor might be used for cooling key turbine components thereby reducing ultimate thermal efficiency. The advanced turbines are able to boost turbine inlet temperatures up to 2600°F thereby achieving efficiencies of ~60%.⁹⁰

“Energy from the hot exhaust gases, which expand in the power turbine section, are recovered in the form of shaft horsepower.”⁹¹ More than 50% of the shaft horsepower is needed to drive the internal compressor and the remainder is available to drive an external load. “Gas turbines may have one, two, or three shafts to transmit power between the inlet air compression turbine, the power turbine, and the exhaust turbine.” The gas turbine is used to provide shaft horsepower for oil and gas production and transmission.

The heat content of the exhaust gases exiting the turbine is either discarded or recovered for further use in the following process cycles:

Simple Cycle: is the most basic operating cycle of gas turbines in which there is no exhaust heat recovery. Simple cycle gas turbines are typically used for shaft horsepower applications e.g. by utilities for backup power generation during emergencies or peak electric demand periods (<5,000 hp) and by the petroleum industry (300-20,000 hp units). Simple cycle turbines operate with a thermal efficiency (ratio of useful shaft energy to fuel energy input) of 15-42%.⁹²

Regenerative Cycle: uses heat exchangers to recover the heat of turbine exhaust gases to preheat the air entering the combustor thereby reducing the amount of fuel required to reach combustor temperatures. Thermal efficiency of this cycle is ~35%.⁹³

Cogeneration: uses the hot exhaust gases in a heat recovery steam generator (HRSG) to raise process steam, with or without supplementary firing. The steam generated by the HRSG can be delivered at a variety of pressures and temperatures to other thermal processes on site. A supplementary burner or duct burner can be placed in

⁸⁸ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁸⁹ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁹⁰ <http://energy.gov/fe/how-gas-turbine-power-plants-work>

⁹¹ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁹² <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁹³ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

the exhaust duct stream of the HRSG for additional steam generation. A cogeneration cycle operates at ~84% thermal efficiency.⁹⁴

Combined Cycle or Repowering: recovers exhaust heat to raise steam for a steam turbine Rankine cycle, with or without supplementary firing. In a combined cycle, the gas turbine drives an electric generator, and the steam from the HRSG drives a steam turbine which also drives an electric generator. A supplementary-fired boiler can be used to increase the steam production. This cycle is used in various applications in gas and oil industry, emergency power generation facilities, independent electric power producers, electric utilities, etc. The thermal efficiency of this cycle is 38-60%.⁹⁵

3. Emissions Control

“Gas turbines operate with high overall excess air because they use combustion air dilution as the means to maintain turbine inlet temperature below design limits. In older gas turbine models, where combustion is in the form of a diffusion flame, most of the dilution takes place downstream of the primary flame, which does not minimize peak temperature in the flame and suppress thermal NOx formation. Diffusion flames are characterized by regions of near-stoichiometric fuel/air mixtures where temperatures are very high leading to significant thermal NOx formation.”⁹⁶

“Newer model gas turbines use lean premixed combustion where the fuel is typically premixed with more than 50% theoretical air resulting in lower flame temperatures thus suppressing thermal NOx formation.” Operation at excess air levels and at high pressures increases the influence of inlet humidity, temperature, and pressure leading to variations in emissions of ≥30%. For a given fuel firing rate, lower ambient temperatures lower the peak temperature in the flame, lowering thermal NOx significantly. “Similarly, turbine operating loads affect NOx emissions with higher emissions expected for higher loads due to higher peak temperature in the flame zone.”⁹⁷

Emission controls for gas turbines include wet controls that use water (to lower combustion temperature thereby reducing thermal NOx formation), and a combination of dry combustion control methods e.g. lean combustion, staged combustion, etc. and post-combustion catalytic controls such as SCR.

C. INTERNAL COMBUSTION ENGINES (ICES)

1. IC Engines in OTR

Results of a recent survey of the emission limits and RACT regulations for IC Engines (>500 hp) in the OTR are found in **Appendix C**.

⁹⁴ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁹⁵ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁹⁶ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

⁹⁷ <https://www3.epa.gov/ttnchie1/ap42/ch03/final/c03s01.pdf>

2. Background

A stationary engine is a large reciprocating engine with an immobile framework and could be a steam engine or an internal combustion engine (ICE).⁹⁸

An ICE consists of a fixed cylinder and a moving piston and the ignition and combustion of the fuel occur within the engine itself.⁹⁹ The expanding combustion gases push the piston which alternatively moves back and forth to convert pressure into rotating motion. Based on the number of piston strokes needed to complete a cycle, ICE can be classified as two stroke or four stroke engines. The cycle includes four distinct processes: intake, compression, combustion and power stroke, and exhaust¹⁰⁰ (Fig. 4). An ICE can use a wide range of fuels including gasoline, diesel, natural gas, propane, biodiesel, or ethanol, and could be ""rich burn" (burning with a higher amount of fuel as compared to air) or "lean burn" (less fuel compared to air) engines."¹⁰¹ ICE are "commonly used at power and manufacturing plants to generate electricity and to power pumps and compressors. They are also used in emergencies to produce electricity and pump water for flood and fire control."¹⁰²

"Reciprocating internal combustion engines (RICE) are used in a variety of stationary applications, including gas compression, pumping, power generation, cogeneration, irrigation, and inert gas production."¹⁰³

⁹⁸ Stationary Internal Combustion Engines <https://www3.epa.gov/airtoxics/icengines/>

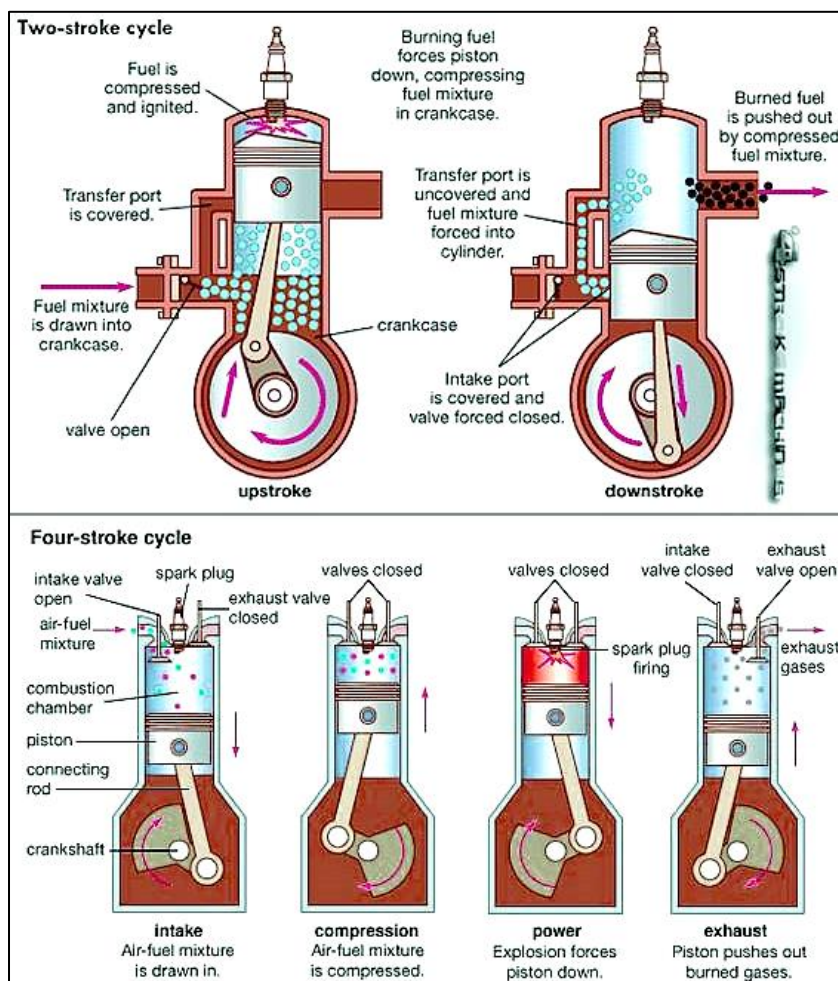
⁹⁹ Internal Combustion Engine Basics. 11/22/2013. <http://www.energy.gov/eere/energybasics/articles/internal-combustion-engine-basics>

¹⁰⁰ <http://www.energy.gov/eere/energybasics/articles/internal-combustion-engine-basics>

¹⁰¹ Reciprocating Internal Combustion Engines (RICE) <https://www3.epa.gov/region1/rice/>

¹⁰² Reciprocating Internal Combustion Engines (RICE) <https://www3.epa.gov/region1/rice/>

¹⁰³ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

Figure 4 Schematic of the workings of Two-Stroke and Four-Stroke Engines¹⁰⁴

“Based on combustion chemistry and air pollution, stationary internal combustion engines are classified into 1. reciprocating piston engines in which combustion is performed periodically in a chamber of changing volume; 2. Steady flow engines in which combustion takes place continuously in a chamber of constant volume.”¹⁰⁵ The stationary RICE can be further classified into spark ignition gasoline engines, or compression ignition diesel engine¹⁰⁶ based on “how they supply and ignite the fuel”¹⁰⁷. Spark Ignition (SI) engines: “In SI engines, the fuel is evaporated and mixed with the oxidizing agent before the ignition takes place.”¹⁰⁸ Here, “the fuel (natural gas, propane or liquefied petroleum gas (LPG), or gasoline) is mixed with air and then inducted into the cylinder during the intake process. After the piston compresses the fuel-air mixture,

¹⁰⁴ <http://www.crazyengineers.com/threads/difference-2-stroke-engine-4-stroke-engine.69275/>

¹⁰⁵ G. St. Cholakov. Control of exhaust emissions from internal combustion engine vehicles. Pollution control technologies v. III. Encyclopedia of Life Support Systems. <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

¹⁰⁶ <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

¹⁰⁷ <http://www.energy.gov/eere/energybasics/articles/internal-combustion-engine-basics>

¹⁰⁸ <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

the spark ignites it, causing combustion. The expansion of the combustion gases pushes the piston during the power stroke.”¹⁰⁹

“Modern SI engines used in passenger and freight vehicles are four stroke” while two-stroke engines are used in small motorcycles, as outboard motors and other small power equipment because of their lower weight, and cost per unit of power input”.

“Two-stroke engines emit 20-50% fuel unburned in the exhaust and also considerable oil”. Two stroke engines with “advanced fuel injection, lubrication and combustion systems achieve lower higher fuel efficiency and lower emissions”. The main pollutants from four-stroke gasoline engines are hydrocarbons, CO and NOx found in their exhaust emissions.¹¹⁰

“Stationary gas engines, typically fueled by natural gas or propane, are widely used for prime power and for gas compression. In gas compression, the types of engines are either rich burn or lean-burn i.e. use different air-to-fuel (A/F) ratios in the combustion chamber during combustion.” “For gas production or gas gathering, the engines can be either rich or lean whereas for gas transmission, the engines are typically all lean-burning. Gas engines are used for prime power applications, especially where it is convenient to connect a natural gas line to the engine. Both rich-burn and lean-burn engines are used for decentralized power or distributed generation, cogeneration, and combined heat and power (CHP) applications. Depending on the application, stationary IC engines range in size from relatively small (~50 hp) for agricultural irrigation purposes to (>1000 hp) used in parallel to meet the load requirements.”¹¹¹

Compression Ignited (CI) engines use diesel as fuel. “In a diesel engine, only air is inducted into the engine and then compressed. These engines then spray the fuel into the hot compressed air at a suitable, measured rate, causing it to ignite.”¹¹²

CI engines could be classified as:

Direct CI engines: Here, the fuel is sprayed directly into compressed heated air whereupon it evaporates and ignites. These engines provide higher power output and better efficiency than engines with indirect ignition but are noisier. Examples of Direct CI engines: jet engines which may use a gas turbine, liquid fuel, air as oxidizing agent and a turbo compressor (aircraft jet engines); rocket jet engines which have chemical agents as fuels and oxidizers.¹¹³

Indirect CI engines: Here combustion takes place in a pre-chamber often by a glow-spark and the combustion then spreads to the main chamber. Examples of Indirect CI engines include passenger cars.¹¹⁴

“Compared to the typical SI engines, both light duty (LD) and heavy duty (HD) diesel CI engines have considerably higher compression ratios and better fuel efficiency leading

¹⁰⁹ <http://www.energy.gov/eere/energybasics/articles/internal-combustion-engine-basics>

¹¹⁰ <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

¹¹¹ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

¹¹² <http://www.energy.gov/eere/energybasics/articles/internal-combustion-engine-basics>

¹¹³ <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

¹¹⁴ <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

to lower hydrocarbon and CO emissions; LD vehicles emit less NOx than comparable gasoline engines but those from HD are higher.”¹¹⁵

“Diesel engines inherently operate lean mode of operation, i.e. use excess air-to-fuel ratios in the combustion chamber during combustion. Stationary diesel engines are widely used in emergency backup generators and for water pumping, especially when the electrical grid is down. In places where an electrical grid is not accessible or available, diesel engines can be used to generate prime power as a distributed generating source.”¹¹⁶

3. Emissions Control

Different emission control technologies such as SCR and NSCR are used to control emissions from stationary IC engines. The choice of control depends on the engine’s A/F ratio, since the exhaust gas composition differs depending on whether the engine is operated in a rich, lean, or stoichiometric burn condition, and on the engine operating mode (speed and load) as it affects the exhaust gas temperature.¹¹⁷

NSCR is currently the most economical and accepted NOx emission control method for rich-burn, spark-ignited stationary gas engines, while SCR is used to reduce NOx emissions from diesel and lean-burn gas engines. For stationary lean-burn gas engines, two types of lean NOx catalyst formulations each of which controls NOx over a narrow temperature range (a low temperature catalyst based on Pt, and a high temperature catalyst utilizing base metals (usually Cu)) are used.

D.MUNICIPAL SOLID WASTE COMBUSTORS (MWCs)

1. MWCs in OTR

Results of a recent survey of the emission limits and RACT regulations for MWCs in the OTR are found in **Appendix D** and are summarized below:

- There are no MWCs located in DE, DC, RI and VT.
- The unit level capacity of MWCs ranges from 50 - 2,700 tpd of MSW.
- The types of combustors include: mass burn units (waterwall, refractory, stationary grate, reciprocating grate, single chamber), two types of rotary incinerators, and refuse-derived fuel incinerators.
- The types on NOx controls employed include FGR and SNCR with the majority of the units controlled with SNCR
- The NOx emission limits vary within the OTR:
 - 372 ppmvd NOx @ 7% O₂, 1-hour average
 - 185 - 200 ppmvd NOx @ 7% O₂, 3-hour average
 - 120 - 250 ppmvd NOx @ 7% O₂, 24-hour average
 - 150 ppmvd NOx @ 7% O₂, calendar-day average
 - 0.35 - 0.53 lb NOx/MMBtu, calendar-day average

¹¹⁵ <http://www.eolss.net/sample-chapters/c09/e4-14-05-01.pdf>

¹¹⁶ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

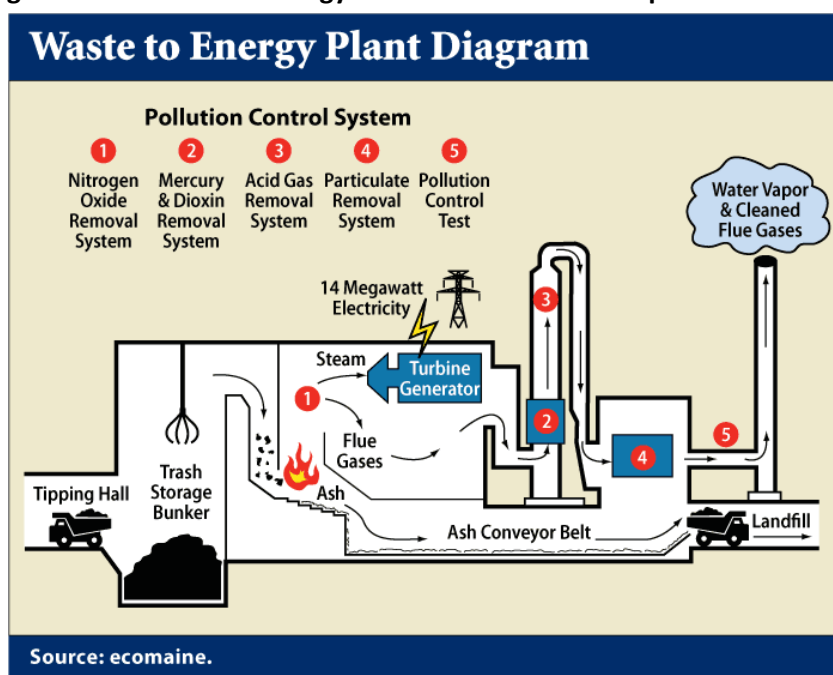
¹¹⁷ http://www.meca.org/resources/MECA_stationary_IC_engine_report_0515_final.pdf

- 135 ppmvd NOx @ 7% O₂, annual average

2. Background

Refuse combustion involves the burning of garbage and other nonhazardous solids, collectively referred to as municipal solid waste (MSW), to generate electric power (Fig. 5). Types of municipal solid waste combustion devices commonly used include single chamber units, multiple chamber units, and trench incinerators.¹¹⁸

Figure 5 Schematic of Energy Generation from Municipal Waste¹¹⁹



There are 3 main classes of technologies used in MWCs:

- **Mass Burn (MB):** These units combust do not require any preprocessing of MSW other than the removal of items too large to go through the feed system. The MSW is placed on a grate that moves through the MB combustor where combustion air in excess of stoichiometric amounts is supplied both as underfire and overfire air. MB combustors are usually erected at the site (as opposed to being prefabricated and transported from another location), and have an MSW throughput of 46-900 megagrams/day (Mg/day) (50-1,000 tpd) per unit.¹²⁰

The MB combustor category has 3 designs¹²¹:

- 1) waterwall (WW) – these designs have water-filled tubes in the furnace walls that are used to recover heat for production of steam and/or electricity;

¹¹⁸ <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

¹¹⁹ Waste To Energy – Incineration Vs. Gasification. 08/31/2014.
<https://ecoandsustainable.com/2014/08/31/waste-to-energy/>

¹²⁰ <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

¹²¹ <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

- 2) rotary combustion waterwall (RC) – this design uses a rotary combustion chamber constructed of water-filled tubes followed by a waterwall furnace;
- 3) refractory wall - these designs are older and typically do not include any heat recovery.
- Refuse-Derived Fuel (RDF): These combustors burn MSW that has been processed such as removing non-combustibles and shredding which generally raises the heating value and provides a finely divided and more uniform fuel suitable for co-firing with pulverized coal. The type of RDF used depends on the boiler design. Most boilers designed to burn RDF use spreader stokers and fire fluff RDF in a semi-suspension model. A subset of the RDF technology is fluidized bed combustors (FBC). RDFs have an MSW throughput capacity of 290-1,300 Mg/day (320-1,400 tpd).¹²²
- Modular Combustors (MOD): These are similar to MB combustors in that they burn waste that has not been pre-processed, but they are typically shop fabricated with an MSW throughput capacity of 4-130 Mg/day (5-140 tpd). One of the most common types of MOD is the starved air (SA) or controlled air type combustor which incorporates two combustion chambers. Air is supplied to the primary chamber at sub-stoichiometric levels and the resultant incomplete combustion products (CO and organic compounds) pass into the secondary combustion chamber where combustion is completed with the additional air. Another MOD design is the excess air (EA) combustor which like the SA also consists of 2 chambers, but is functionally similar to MB units in its use of excess air in the primary chamber.¹²³

3. Emissions Control

Nitrogen oxides in the MWCs are formed primarily during combustion through the oxidation of nitrogen-containing compounds in the waste at relatively low temperatures (<1,090°C or 2,000°F), and negligibly through the fixation of atmospheric nitrogen which occurs at much higher temperatures. Because of the kind of fuel MWCs use and the relatively low temperatures at which they operate, 70–80% of NOx formed in MSW incineration is associated with nitrogen in the MSW.¹²⁴

A variety of technologies are used to control NOx emissions from MWC including combustion controls such as staged combustion, LEA, and FGR, and post-combustion add-on controls like SCR, SNCR, and natural gas re-burning.

E. CEMENT KILNS

1. Cement kilns in OTR

Results of a recent survey of the emission limits and RACT regulations for cement kilns in the OTR are presented below in Table 4:

- There are no cement kilns in CT, DE, MA, NJ, VT, DC, NH, RI

¹²² <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

¹²³ <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

¹²⁴ <https://www3.epa.gov/ttnchie1/ap42/ch02/final/c02s01.pdf>

- Depending on the type of kilns (wet or dry, with or without pre-calciner), the NOx emission limits range from 2.33 - 6.0 lbs/ton clinker in the existing state rules.

Table 4 Cement Kiln Emissions Ranges and Regulations in OTC States

State	NOx Limit (lbs/ton clinker)				RACT Regulations
	Long Dry	Long Wet	Pre-heater	Pre-calciner	
MD	5.1 3.4*	6.0 NA*	2.8 2.4*	2.8 2.4*	COMAR 26.11.30: http://www.dsd.state.md.us/comar/SubtitleSe arch.aspx?search=26.11.30 .
ME	2.33	-	-	-	EPA Consent Agreement (Docket 01-2013-0053, Sept 2013)
PA	3.44	3.88	2.36	2.36	Final RACT 2 Rule (46 Pa.B. 2036, April 23, 2016): http://www.pabulletin.com/secure/data/vol46/46-17/694.html
NY	2.88 (using SNCR) (SCC: 3- 05-006- 06)	5.2 (SCC: 3- 05-007- 06)			Subpart 220-1 - Effective: 7/11/2010 Submitted: 8/19/2010; Final: 77 FR 13974, 78 Fr 41846: https://www3.epa.gov/region02/air/sip/ny_reg.htm
VA (OTR jurisdiction)	No Limits				

*After 04/01/2017

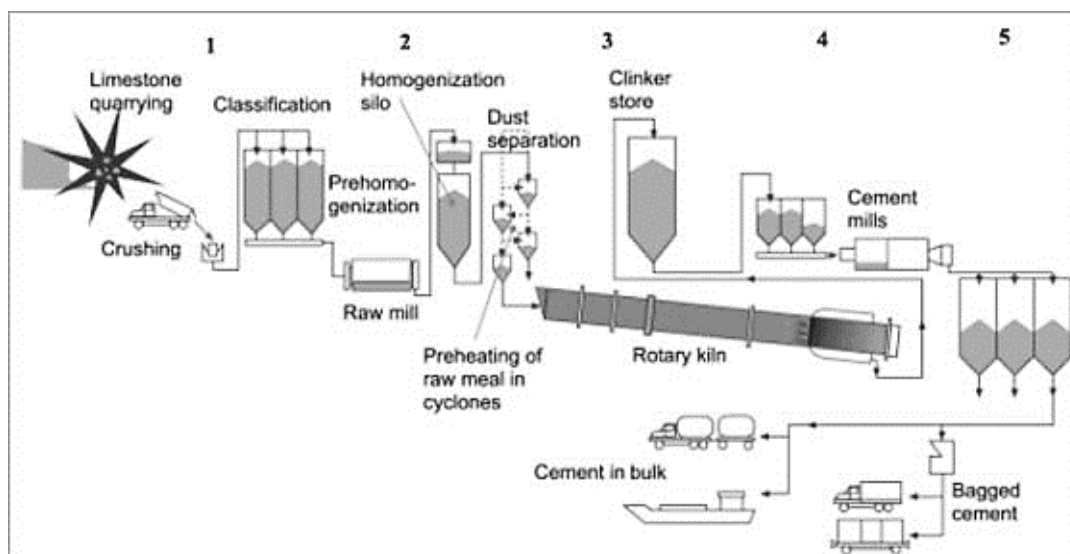
2. Background

Portland cement manufacturing is an “energy-intensive process that grinds and heats a mixture of raw materials such as limestone, clay, sand and iron ore in a rotary kiln” into a product called clinker which “is cooled, ground and then mixed with a small amount of gypsum to produce cement”¹²⁵ (Fig. 6).

“The main source of air toxics emissions from a Portland cement plant is the kiln.” Emissions of a variety of pollutants originate in the kiln from “the burning of fuels and heating of raw feed materials”, and “from the grinding, cooling, and materials handling steps in the manufacturing process”.¹²⁶

¹²⁵ https://www3.epa.gov/ttn/caaa/t3/fact_sheets/cement_amend_fs_120806.html

¹²⁶ Ibid 13 https://www3.epa.gov/ttn/caaa/t3/fact_sheets/cement_amend_fs_120806.html

Figure 6 Schematic of a Cement Kiln Operation¹²⁷

There are essentially two types of cement kilns:

Wet process kilns: The original rotary cement kilns were called 'wet process' kilns since the raw meal used was in the form of a slurry with ~40% water at ambient temperature. Evaporating this water to dry out the slurry is an energy-intensive process and “various developments of the wet process (such as the 'filter press') were aimed at reducing the water content of the raw meal”.¹²⁸ The wet process still continues today because many raw materials are suited to blending as a slurry.¹²⁹

Dry process kilns: The basic dry process system consists of the kiln and a suspension preheater. Raw materials such as limestone and shale are ground finely and blended to produce the raw meal which is fed in at the top of the “suspension preheater” tower. This tower has a series of cyclones through which fast-moving hot gases from the kiln and, often, hot air from the clinker cooler are blown to keep the meal powder suspended in air until it reaches the same temperature as the gas. So the raw meal is heated before it enters the kiln.¹³⁰

“The dry process is much more thermally efficient than the wet process” because the meal is a dry powder with little or no water to be evaporated, and the heat transfer from the hot gases to the raw meal is efficient because of the very high surface area-to-size ratio of meal particles and the large temperature differential between the hot gas and the cooler meal. Typically, 30-40% of the meal is decarbonated before entering the kiln.¹³¹

¹²⁷ Introduction to cement production line: <http://m.great-wall.co/solutions/turnkey-plant/cement-production-line.html>

¹²⁸ Manufacturing - the cement kiln <http://www.understanding-cement.com/kiln.html>

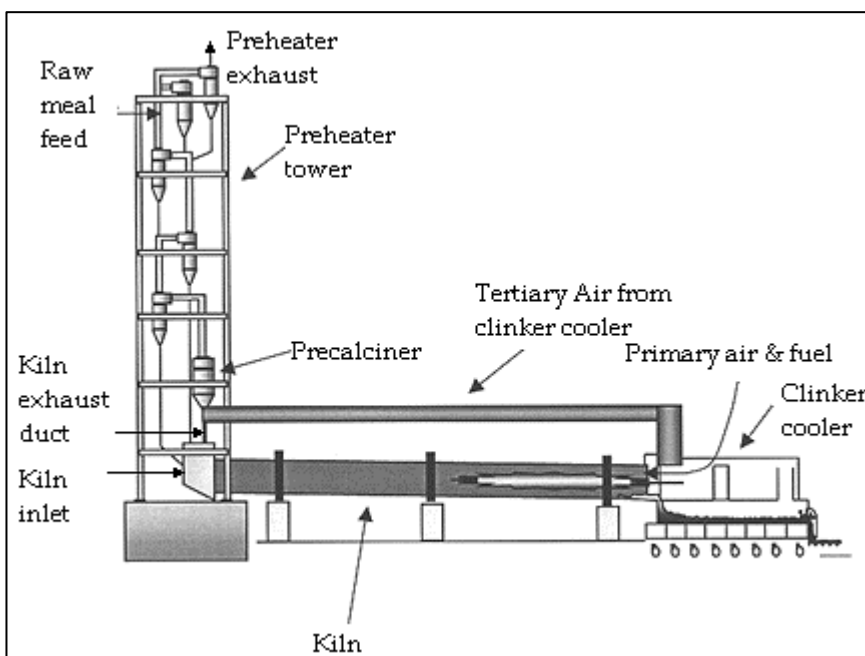
¹²⁹ <http://www.understanding-cement.com/kiln.html>

¹³⁰ <http://www.understanding-cement.com/kiln.html>

¹³¹ <http://www.understanding-cement.com/kiln.html>

Most new cement plants are of the 'dry process' type and use 'precalciner' kilns which operate on a similar principle to that of preheater system but with the major addition of another burner called precalciner (Fig. 7). With this additional heat, about 85-95% of the meal is decarbonated before it enters the kiln. "Whenever economically feasible a wet process kiln can be converted to a state-of-the art dry process production facility" that includes a multi-stage preheater with or without a pre-calciner.¹³²

Figure 7 Components of a Dry Process Precalciner Cement Kiln¹³³



3. Emissions Control

Thermal NOx is the primary form of NOx emissions in cement manufacturing because of the high temperatures and oxidizing conditions required for fuel combustion and clinker formation.¹³⁴ The NOx controls employed in cement plants include LNBS, mid-kiln system firing, staged combustion in the calciner (SCC), SNCR, SCR¹³⁵ or approved Alternative Control Techniques (ACT - EPA-453/R-07-006) during the ozone season.

¹³² <http://ietd.iipnetwork.org/content/dry-kilns-multistage-pre-heaters-and-pre-calcination>

¹³³ M. P.M. Chinyama, August 9, 2011. Chapter 11. Alternative Fuels in Cement Manufacturing. <http://www.intechopen.com/books/alternative-fuel/alternative-fuels-in-cement-manufacturing>

¹³⁴ https://www3.epa.gov/ttnecat1/dir1/cement_updt_1107.pdf

¹³⁵ https://www3.epa.gov/ttnecat1/dir1/cement_updt_1107.pdf

¹³⁵ S. Barna. 02/28/2007. Identification and Evaluation of Candidate Control Measures Final Technical Support Document. <http://www.nj.gov/dep/baqp/2008%20Regional%20Haze/Appendix%20F-3.pdf>

F. HOT MIX ASPHALT PRODUCTION PLANTS

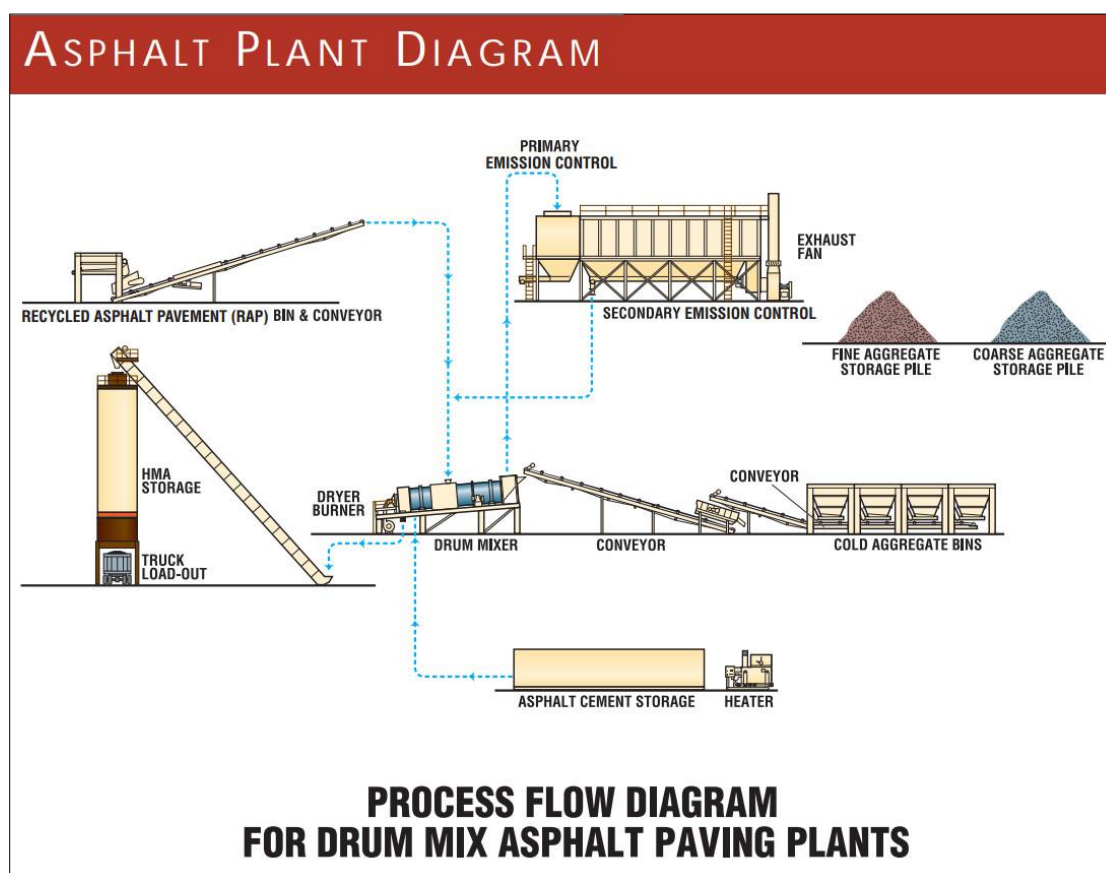
1. Hot Mix Asphalt Production Plants in OTR

Results of a recent survey of the RACT regulations for Asphalt Production Plants in the OTR are found in **Appendix E**.

2. Background

An asphalt production plant, typically a batch type asphalt plant or drum mix asphalt plant, is operated to manufacture asphalt pavement (Fig. 8). Hot mix asphalt (HMA) paving material is produced by mixing measured quantities of size-graded, high quality aggregate including any reclaimed asphalt pavement (RAP) and heated liquid asphalt cement.¹³⁶ HMA characteristics are determined by the amount and grade of asphalt cement, and the relative amounts and types of aggregate and RAP used. Aggregate and RAP (if used) constitute over 92% by weight of the total mixture. Specific percentage of fine aggregate (<74 micrometers [μm] in physical diameter) is required for the production of good quality HMA.¹³⁷

Figure 8 Schematic of a Hot Mix Asphalt Production Plant¹³⁸



¹³⁶ AP-42, Vol. I: Section 11.1 Hot Mix Asphalt Plants <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf>

¹³⁷ <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf>

¹³⁸ http://www.carolinaasphalt.org/aws/CAPA/asset_manager/get_file/35278?ver=14654

“In the reclamation process, old asphalt pavement is removed from the road base. This material is then transported to the plant, and is crushed and screened to the appropriate size for further processing. The paving material is then heated and mixed with new aggregate (if applicable), and the proper amount of new asphalt cement is added to produce HMA that meets the required quality specifications.”¹³⁹

“Hot mix asphalt paving materials can be manufactured by: (1) batch mix plants, (2) continuous mix (mix outside dryer drum) plants, (3) parallel flow drum mix plants, and (4) counterflow drum mix plants. This order of listing generally reflects the chronological order of development and use within the HMA industry.”¹⁴⁰ Nearly all plants being manufactured today are able to use gaseous fuels (natural gas) or fuel oil to dry and heat the aggregate, and also have RAP processing capability. “An HMA plant can be constructed as a permanent plant, a skid-mounted (easily relocated) plant, or a portable plant.”¹⁴¹

3. Emissions Control

“The primary emission sources associated with HMA production are the dryers, hot bins, and mixers, which emit PM and a variety of gaseous pollutants.” Among other emission sources found at HMA plants are hot oil heaters used to heat the asphalt storage tanks. Fugitive emissions include gaseous pollutants and PM resulting from process and open sources.¹⁴²

“As with most facilities in the mineral products industry, batch mix HMA plants have two major categories of emissions: ducted sources, and fugitive sources. The most significant ducted source of emissions of most pollutants from batch mix, parallel flow drum mix and counterflow drum mix plants HMA plants is the rotary drum dryer.” “As with any combustion process, the design, operation, and maintenance of the burner provides opportunities to minimize emissions of NOx, CO, and organic compounds.”¹⁴³

Of these pollutants, stack test results show that NOx emissions, whether generated from drum-type or batch-type dryers, depend on fuel type and size, larger dryers being higher NOx emitters. NOx emissions reductions of at least 35% can be achieved by installing low NOx burners, fluid gas recirculation, water injection, and by implementing best management practices and/or other NOx reduction measures^{144,145}.

Wet aggregate requires longer processing time in a dryer and results in higher NOx emissions. Reducing aggregate moisture can be achieved by following best management practices such as covering the aggregate stockpile to prevent high water content due to rain; or designing and operating stockpiles for better water drainage; and removing sand

¹³⁹ <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf>

¹⁴⁰ <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf>

¹⁴¹ <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf>

¹⁴² <https://www3.epa.gov/ttnchie1/ap42/ch11/related/ea-report.pdf>

¹⁴³ AP-42, Vol. I: Section 11.1 Hot Mix Asphalt Plants <https://www3.epa.gov/ttnchie1/ap42/ch11/final/c11s01.pdf>

¹⁴⁴ <http://www.nj.gov/dep/rules/proposals/080408a.pdf>

¹⁴⁵ http://www.otcair.org/upload/Documents/Meeting%20Materials/RES%2006-02_Concerning%20Coordination%20and%20Implementation%20of%20Control%20Strategies_061115.pdf

and aggregate from piles at a sufficient height above the base to avoid charging wet mix to the dryer.¹⁴⁶

G. GLASS FURNACES

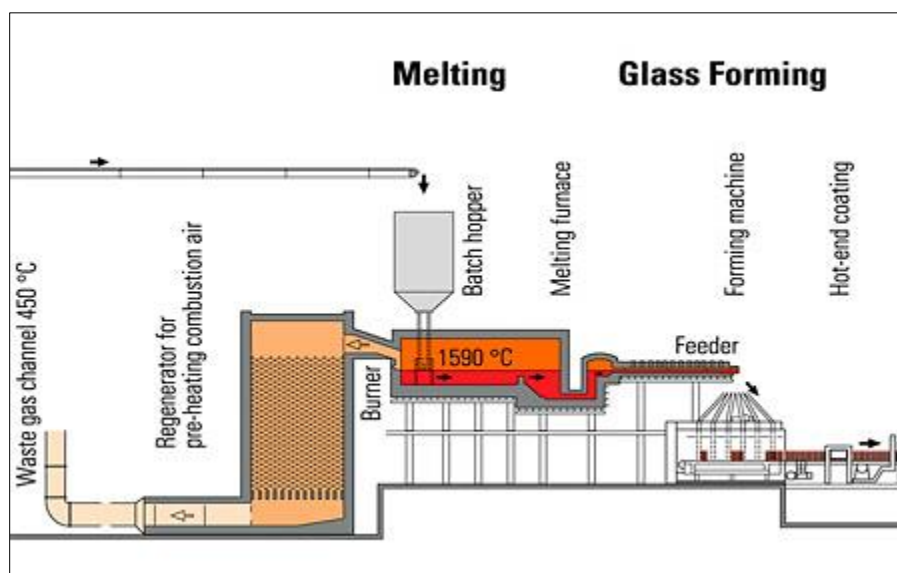
1. Glass Furnaces in OTR

Results of a recent survey of Glass Furnaces in the OTR are found in **Appendix F**.

2. Background

Glass manufacturing involves the mixing of raw materials and then melting the mixture in a furnace, a process in which dry ingredients are first mixed in a batch (Fig. 9). The batch is fed in a semi-continuous way to one end of the melting furnace where chemical reactions take place between the batch ingredients and glass is formed by cooling in such a way that the components do not crystallize but are viscous at high temperatures. Silica compounds are the most common materials used in glass production because of their ability to cool without crystallizing. Melting and fabrication of glass occurs in furnaces which vary in furnace geometry, firing pattern, heat recovery techniques, and specific temperatures depending on the type of glass produced. In principle, the production processes in the manufacture of various types of glass are essentially identical through the melting step. Each of these operations uses vastly different machinery and processes, though each shares the need for controlled heating/forming/cooling steps. All glass furnaces operate at temperatures where NO_x formation takes place.¹⁴⁷

Figure 9 Schematic of Glass Production¹⁴⁸



¹⁴⁶ <http://www.state.nj.us/dep/aqm/Sub19.pdf>

¹⁴⁷ <https://www3.epa.gov/ttnecatc1/dir1/glassact.pdf>

¹⁴⁸ Forming Glass: <http://de.verallia.com/en/about-glass/glass-production>

There are 3 categories of commercial glass produced in the US:

Container glass: In a typical system downstream of the melter consists of so-called individual section (I-S) machines in which molten glass "gobs" are fed into molds and containers are then formed by blowing the molten glass into the mold. The containers are then carefully cooled in the annealing section to relieve stresses introduced in the molding process to form the final products which are then inspected in machines to ensure proper dimension, and packed.¹⁴⁹

Flat glass: Here, the molten glass from the fining section is poured onto a bath of molten tin and as it flows over this bath, it is gradually cooled. Then it enters an annealing section after which it is cut, packed, and either sold or further processed, generally at a separate facility.¹⁵⁰

Pressed/blown glass: This production uses an extremely wide range of operations downstream of the furnace to produce items such as tableware, light bulbs, glass tubing, and other products. Unlike the other two types of glass, production of pressed/blown glass does not generally use regenerators to recover heat from the flue gas leading to its higher energy use.¹⁵¹

The heat for these reactions is usually supplied by natural gas burners that are fired over the glass melt. Heat is transferred primarily by radiation from the flame to the surface of the melt in a furnace which is designed in essentially two configurations:

End-port furnaces: These are smaller than the side-port furnaces, generally used in the container and pressed/blown industries, and limited to <175 tpd. In these furnaces, the flames travel in a U-shape over the melt from one side and flue gases exit the other.¹⁵²

Side-port furnaces: In these furnaces which tend to provide more even heating essential for the high quality necessary for flat glass and some containers, the flames travel from one side of the furnace to the other. These furnaces are also larger with some >800 tpd.¹⁵³

"The cycle of air flow from one checker to the other is reversed about every 15 - 30 minutes in both the end-port and side-port furnaces. In both cases, refractory-lined flues are used to recover the energy of the hot flue gas exiting the furnace to heat the refractory material called a checker. After the checker has reached a certain temperature, the gas flow is reversed and the firing begins on the other side (or end) of the furnace. The combustion air is then preheated in the hot checker and mixed with the gas to produce the flame. The combustion air preheat temperatures in flat glass furnaces can reach 1260°C (2300°F) and substantial NOx can be formed in the checkers.

¹⁴⁹ <https://www3.epa.gov/ttnecatc1/dir1/glassact.pdf>

¹⁵⁰ <https://www3.epa.gov/ttnecatc1/dir1/glassact.pdf>

¹⁵¹ <https://www3.epa.gov/ttnecatc1/dir1/glassact.pdf>

¹⁵² <https://www3.epa.gov/ttnecatc1/dir1/glassact.pdf>

¹⁵³ <https://www3.epa.gov/ttnecatc1/dir1/glassact.pdf>

Lower preheat temperatures are used in container glass, and NOx contributions there are apparently negligible.”¹⁵⁴

Cullet is extensively used in both container and flat glass industries where the batch components and cullet react in the melting chamber to form glass. Cullet may consist of internally recycled glass from waste in downstream operations such as cutting and forming, or it may be externally recycled from glass returned in recycle operations. Because the chemical reactions necessary to form glass have already taken place in the cullet, about half the energy is needed to melt the cullet compared to virgin batch ingredients. Because of the high quality requirements, external or "foreign" cullet is not used in flat glass production but is used in container glass production.¹⁵⁵

3. Emissions Control

Potential sources of NOx formation in glass melting furnaces in glass plants include thermal NOx and the evolution of NOx from the heating of glass raw materials containing nitrate compounds ("niter") used in certain glass formulations.¹⁵⁶

“Uncontrolled NOx emissions depend primarily on various process parameters including fuel firing rate, furnace geometry, fuels used, and raw materials, and can vary significantly from site to site and from furnace to furnace. Uncontrolled thermal NOx emissions range from 8 - 10 lb NOx/ton glass produced from regenerative container glass furnaces, and will vary considerably depending on furnace age, electric boost (which substitutes electrical energy for thermal energy in container glass furnaces), batch/cullet ratio, and from site to site even for nominally similar furnaces. Assuming a heat requirement of 6MM Btu/ton glass, these emissions would correspond to 1.3 - 1.7 lb NOx/MM Btu. As a general rule, NOx emissions from large flat glass furnaces are lower and from smaller pressed/blown furnaces would be higher. NO from nitrates is of the order of 0.36 lb NO per lb niter (as NaNO₃) in the batch formulation.”¹⁵⁷

H. NATURAL GAS PIPELINES

1. Natural Gas Pipeline Compressor Prime Movers in OTR

Results of a recent survey of RACT regulations for Natural Gas Pipeline Compressor Prime Movers in the OTR are found in **Appendix 8**.

Previous Analysis by OTC SAS Committee

The OTC identified natural gas pipeline compressor prime movers as a potential category for emission control strategies at its November, 2010 meeting and tasked the SAS Committee to explore the issue. In 2011 a SAS workgroup prepared a white paper to describe the issue and recommend potential Commission action, e.g., adopt a model rule drafted by the SAS to achieve NOx emissions reductions from this emission source

¹⁵⁴ <https://www3.epa.gov/ttnca1c1/dir1/glassact.pdf>

¹⁵⁵ <https://www3.epa.gov/ttnca1c1/dir1/glassact.pdf>

¹⁵⁶ <https://www3.epa.gov/ttnca1c1/dir1/glassact.pdf>

¹⁵⁷ <https://www3.epa.gov/ttnca1c1/dir1/glassact.pdf>

and assist the OTC states in achieving the National Ambient Air Quality Standards (NAAQS) for ozone.

Within the OTR, natural gas pipeline compressor prime movers fueled by natural gas are used in several phases of natural gas supply: 1) gathering the natural gas from the well field and transporting it to the main transportation pipeline system; 2) moving natural gas through the main pipeline system to distribution points and end users; and 3) injecting and extracting natural gas from gas storage facilities. These natural gas pipeline compressor prime movers, mostly driven by internal combustion (IC) reciprocating engines and combustion turbines, are a significant source of nitrogen oxide (NOx) emissions year-round. Data sources indicate that nine OTR states have large natural gas compressor facilities (CT, MA, MD, ME, NJ, NY, PA, RI, VA); three OTR states contain a number of natural gas well field compressors (MD, NY, PA); and two OTR states have natural gas underground storage facilities (PA, NY).

The SAS Committee examined other areas of natural gas production (beyond the natural gas pipeline compressor prime movers addressed by the white paper) and concluded that potentially significant NOx reductions may be possible from the “upstream” activities of well drilling, well completion, and well head and field gathering natural gas compressor prime movers. Preliminary information indicates that NOx emissions from these sources may greatly exceed those of the pipeline and underground storage compression sources. This is more evident in the expansion of natural gas production due to shale gas activities.

Only limited data were available regarding the population of natural gas pipeline compressor prime movers fueled by natural gas in the OTR at the time that this white paper was written. The most comprehensive data that were available at that time was the 2007 emissions inventory (including a MARAMA point source emissions inventory for that year); therefore, 2007 was the base year used for analysis.¹⁵⁸ The 2007 data indicate that there are a multitude of natural gas compressor facilities in the OTR (including 150 classified as “major emissions sources”) including 2-stroke lean-burn internal combustion (IC) reciprocating engines, 4-stroke lean-burn IC reciprocating engines, 4-stroke rich-burn IC reciprocating engines, and combustion turbines. The 2007 data showed:

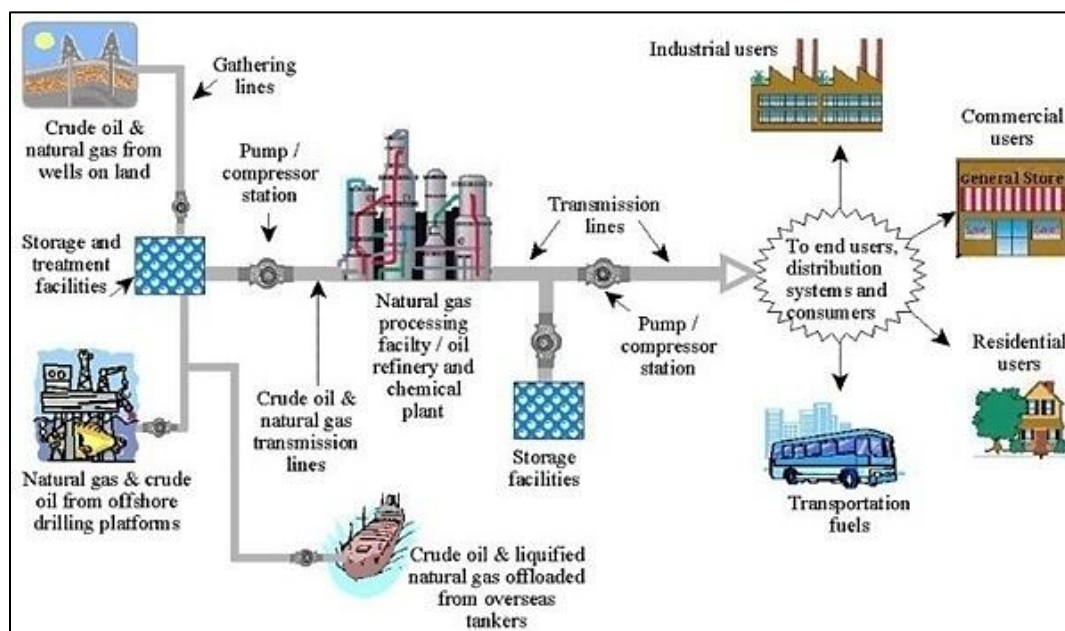
- At least 409 reciprocating engine prime movers with ratings of 200 - 4300 hp, which includes a large number of makes and models
- At least 125 combustion turbine prime movers with ratings of 1000 - 20,000 hp, which includes a moderate number of makes and models.

Many of these prime movers may be >40 years old. The MARAMA point source emissions inventory data indicates that in 2007 this population of natural gas prime movers emitted ~11,000 tons of NOx in the OTR annually (~30 tpd on average).

¹⁵⁸ OTC Nat Gas Compressor Prime Mover Inventory Rev 092711 from BC 092513.xlsx.

2. Background

Figure 3 Oil and Gas Pipeline System Overview^{159,160}



Pumps and compressors are important components of fuel (such as unrefined petroleum, petroleum products, and liquefied natural gas) transport systems working on the same operating principle with the former being used for liquids and the latter for gas.¹⁶¹ Pumps and compressor stations are used to convey these products through pipelines over long distances to their final destination for distribution to refineries and for end-use by consumers or rerouting into storage areas during periods of low demand (Fig. 10). Gases and liquids are moved through impellers in the compressor, or pump. This increases the pressure at the outlet of the component. To keep the Natural gas flowing through the pipelines, it is compressed into a liquid state by applying pressure through compressors and at lowered temperature and avoid “friction losses” in the pipe.¹⁶²

The number of compressor station facilities located along a natural gas pipeline vary (one every 40-100 miles)¹⁶³, and the amount of pressure they generate (200-1,500 pounds per square inch (psi))¹⁶⁴, vary depending on the topography of the area across the pipelines traverse (those on hilly terrain require more frequent pressure increases

¹⁵⁹ Department of Transportation, Fact Sheet: Pump and Compressor Stations;
<https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁶⁰ <https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁶¹ <https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁶² <https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁶³ <https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁶⁴ Compressor Stations: What They Do, How They Work, and Why They Are Important. 01/21/2014.
<http://setxind.com/midstream/compressor-stations-what-how-why/>

than on flat terrain), the pipeline length and diameter, the product being moved, design characteristics of the compressor or pump.

“Supply and demand can also be a factor at times in the level of compression required for the flow of the natural gas.”¹⁶⁵ Pumps are positioned approximately every 20-100 miles.¹⁶⁶

Compressor stations include several key component parts:

Compressor Unit –is the primary equipment “which actually compresses the gas”.

“Some compressor stations may have multiple compressor units depending on the needs of the pipeline.”¹⁶⁷ The compressor unit is a large engine which could be one of the three following types¹⁶⁸:

- Turbines with Centrifugal Compressors – These units use turbines for compression fueled by natural gas from the pipeline itself.
- Electric Motors with Centrifugal Compressors – These are also centrifugal compressors but are powered by high voltage electric motors.
- Reciprocating Engine with Reciprocating Compressor – These compressors use large engines “to crank reciprocating pistons located within cylindrical cases on the side of the unit” to compress the gas, and are fueled by natural gas.¹⁶⁹

Filters, Scrubbers, Strainers: remove liquids (e.g. water, hydrocarbons), dirt, particles, and other impurities from the natural gas, which though considered “dry” as it passes through the pipeline, water and other hydrocarbons may condense out of the gas as it travels.¹⁷⁰

Gas Cooling Systems – offset the heat generated when natural gas is compressed and return it to temperatures that will not damage the pipeline.¹⁷¹

Mufflers – installed to reduce the noise level at compressor stations which is especially important near residential or other inhabited areas.¹⁷²

Pigs¹⁷³ - cylindrical or spherical bullet shaped devices inserted into pipelines to perform multiple functions: for physical separation of different batches of a product or different types of product; for cleaning and maintenance of the pipeline by scraping away buildup/debris thus improving the efficiency and flow of the pipeline and also help prevent corrosive damage; for inspection (by Smart PIGs) of pipeline problems like welding defects, cracks, pitting, etc. using magnetic flux leakage (MFL), ultrasonics or other technologies; for positioning and monitoring (by Smart Pigs) by gathering data about the location and position of specific defects or

¹⁶⁵ <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁶⁶ <https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁶⁷ <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁶⁸ <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁶⁹ <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁷⁰ <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁷¹ <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁷² <http://setxind.com/midstream/compressor-stations-what-how-why/>

¹⁷³ What are PIG's, PIG Launchers, and PIG Receivers and Why Are They Important?
<http://setxind.com/midstream/what-are-pig-launchers-and-receivers/>

problems in the pipeline thus helping avoid unnecessary digging up of the non-damaged parts of the pipeline or replacing while allowing regular close monitoring of problem sections to track damage progression. Caliper PIGs are used to provide estimates of the internal geometry of the pipeline.¹⁷⁴

Many modern compressor stations can be completely monitored and operated remotely.

Pumps and compressors in transmission lines are regulated by the Office of Pipeline Safety and state regulators under 49 CFR Parts 192 and 195.¹⁷⁵

3. Emissions Control

Reduction of NOx emissions from natural gas pipeline compressor stations and transmission facilities involve the use of combustion-based technologies including low emissions combustion (LEC) strategies like enhanced A/F mixing, use of operational controls such as ignition timing, A/F ratios, and other (non-LEC) technologies like exhaust gas recirculation and SCR for lean burn reciprocating engines, and NSCR for rich burn reciprocating engines.¹⁷⁶

IV. Appendices

A. Industrial/Commercial/Institutional (ICI) Boilers in OTR

B. Combustion Turbines in OTR

C. Internal Combustion Engines (ICEs in OTR

D. Municipal Waste Combustors (MWCs in OTR

E. Asphalt Production Plants in OTR

F. Glass Furnaces in OTR

G. Natural Gas Pipelines in OTR

¹⁷⁴ <http://setxind.com/midstream/what-are-pig-launchers-and-receivers/>

¹⁷⁵ <https://primis.phmsa.dot.gov/comm/FactSheets/FSPumpStations.htm>

¹⁷⁶ Availability and Limitations of NOx Emission Control Resources for Natural Gas-Fired Reciprocating Engine Prime Movers Used in the Interstate Natural Gas Transmission Industry. <http://www.ingaa.org/File.aspx?id=22780>

APPENDIX A. INDUSTRIAL/COMMERCIAL/INSTITUTIONAL BOILERS IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

1. COAL-FIRED BOILERS	Boiler capacity (mmBtu/hr)		
	50 - 100	100 - 250	>250
State	NOx Limit (lbs/mmBtu)		
CT - Statewide	0.29 - 0.43 ^a ; 0.28 ^b 0.12 ^c	0.15 - 0.43 ^a ; 0.15 - 0.28 ^b 0.12 ^c	0.15 - 0.43 ^a ; 0.15 - 0.28 ^b 0.12 ^c
DC - District-wide	>20 mmBTU/hr, adjust combustion process	0.43	0.43
DE - Statewide	LEA, Low NOx, FGR	0.38 - 0.43	0.38 - 0.43
MA - Statewide	0.43	0.33 - 0.45	0.33 - 0.45
MD - Select counties	No limits	0.70	0.65
ME - Statewide	0.38 (firing biomass and coal)	0.38 (firing biomass and coal)	0.38 (firing biomass and coal)
NH - Statewide	0.30 - 0.50	0.30 - 1.00	0.30 - 1.40
NY - Statewide	No limits	0.08 - 0.20	0.08 - 0.20
PA - Statewide	0.45 Refinery gas unit 0.25	0.45 Refinery gas unit 0.25	Coal with SCR temp >600°F (0.12); CFB (0.16); Tangential (0.35); Refinery gas unit (0.25); Other (0.40)
VA - OTR jurisdiction	0.38 - 1.0	0.38 - 1.00	0.38 - 1.00
VT - Statewide	No limits	No limits	0.70

2. NATURAL GAS-FIRED BOILERS	Boiler capacity (mmBtu/hr)		
	50 - 100	100 - 250	>250
State	NOx Limit (lbs/mmBtu)		
CT - Statewide	0.20 - 0.43 ^a ; 0.20 - 0.30 ^b ; 0.05 - 0.10 ^c	0.15 - 0.43 ^a ; 0.10 - 0.30 ^b ; 0.10 ^c	0.15 - 0.43 ^a ; 0.10 - 0.30 ^b ; 0.10 ^c
DC - District-wide	>20 mmBTU/hr, adjust combustion process	0.20	0.20
DE - Statewide	LEA, Low NOx, FGR	0.20	0.20
MA - Statewide	0.10	0.20	0.20
MD - Select counties	Tune-up	0.20	0.70
ME - Statewide	Tune-up (20-50 MMBtu/hr)	No limits	No limits
NH - Statewide	0.10 - 0.20	0.10 - 0.25	0.10 - 0.25
NJ - Statewide	0.05	0.10	0.10
NY - Statewide	0.05	0.06	0.08
PA - Statewide	0.10	0.10	0.10
RI - Statewide	0.10	0.10	0.20
VA - OTR jurisdiction	0.20	0.20	0.20
VT - Statewide	No limits	No limits	0.20

3. OIL-FIRED BOILERS	Boiler capacity (mmBtu/hr)					
	50 – 100		100 – 250		>250	
	NOx Limit (lbs/mmBtu)					
State	Distillate	Residual	Distillate	Residual	Distillate	Residual
CT - Statewide	0.20 - 0.43 ^a	0.25 - 0.43 ^a	0.15 - 0.43 ^a	0.15 - 0.43 ^a	0.15 - 0.43 ^a	0.15 - 0.43 ^a
	0.20 - 0.43 ^b	0.25 - 0.43 ^b	0.10 - 0.43 ^b	0.15 - 0.43 ^b	0.10 - 0.43 ^b	0.15 - 0.43 ^b
	0.10 ^c	0.20 ^c	0.10 - 0.15 ^c	0.15 - 0.20 ^c	0.10 - 0.15 ^c	0.15 - 0.20 ^c
DC - District-wide	0.30	Banned	0.25	Banned	0.25	Banned
DE - Statewide	LEA, LNB, FGR		0.38 - 0.43		0.38 - 0.43	
MA - Statewide	Tune-up		0.30	0.40	0.25 - 0.28	
MD - Select Counties	No limits		0.25		0.70	
ME - Statewide	0.30	0.30	0.30	0.30	0.30	0.30
NH - Statewide	0.12	0.30 - 0.50	0.12	0.30 - 0.50	0.12	0.30 - 0.50
NJ - Statewide	0.08	0.20	0.10	0.20	0.10	0.20
NY - Statewide	0.08 - 0.20		0.15		0.15 - 0.20	
PA - Statewide	0.12	0.20	0.12	0.20	0.12	0.20
RI - Statewide	0.12	LNB & FGR	0.12	LNB & FGR	0.25	LNB & FGR
VA - OTR jurisdiction	0.25 - 0.43		0.25 - 0.43		0.25 - 0.43	
VT - Statewide	No limits		No limits		0.30	

Notes:

- No Coal-Fired Boilers in NJ and RI; no coal-only fired boilers in ME
- In Tables 1-3: CT: ^aExisting RCSA Sec. 22a-174-22 (to be repealed as of June 1, 2018); ^bRCSA Sec. 22a-174-22e starting June 1, 2018; ^cRCSA Sec. 22a-174-22e starting June 1, 2023;
- In Tables 2-3: NJ: NOx limits apply to ICI boilers rated 25 - 100 MMBtu/hr
- LEA = Low Excess Air; FGR = Flue Gas Recirculation; LNB = Low Nox Burner;

State	4. ICI Boilers - Regulations	State Contacts
CT	Revising RCSA section 22a-174-22. Will be replaced with RCSA section 22a-174-22e (anticipate finalizing by 2017). http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424 3416, Merrily.Gere@ct.gov
DC	20 DCMR § 805.5, RACT for Major Stationary Sources of Oxides of Nitrogen: http://www.dcregs.dc.gov/Gateway/RuleHome.aspx?RuleNumber=20-805 ; 20 DCMR § 801, includes a ban on No. 5 fuel oil and heavier as of July 1, 2016: http://www.dcregs.dc.gov/Gateway/RuleHome.aspx?RuleNumber=20-801	Alexandra Catena, 202 535-2989, alexandra.catena@dc.gov
DE	7 DE Admin Code 1112, Control of Nitrogen Oxides Emissions: http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml 7 DE Admin Code 1142, Specific Emission Control Requirements: http://regulations.delaware.gov/AdminCode/title7/1000/1100/1142.shtml#TopOfPage http://www.dnrec.delaware.gov/dwhs/Info/Regs/Documents/Reg1142_S1_Recoded_v1.pdf	Mark Prettyman 302-739-9402 mark.prettyman@state.de.us
MA	MassDEP proposed amendments to NOx RACT affecting emission limits for Large Boilers, turbines, and engines and solicited public comment till September 26, 2016. MassDEP is currently preparing the final regulations and Response to Comments.	Marc Cohen, 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.09.08 B, E, F & J - Evaluating potential need for changes; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	<i>Reasonably Available Control Technology For Facilities that Emit Nitrogen Oxides (NOx-RACT)</i> , 06-096 C.M.R. ch. 138: http://www.maine.gov/dep/air/rules/index.html	Jeff Crawford, (207) 287-7647, jeff.s.crawford@maine.gov
NH	NH Administrative Rule Env-A 1300 NOx RACT http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf Parts Env-A 1303 through Env-A 1305	Gary Milbury, 603 271-2630 Gary.Milbury@des.nh.gov
NJ	N.J.A.C. 7:27 19.7, based on OTC ADDENDUM TO RESOLUTION 06-02 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095, Margaret.Gardner@dep.nj.gov
NY	Subpart 227-2, Effective: 7/8/2010, Submitted: 8/19/2010, Final: 77 FR 13974, 78 Fr 41846; https://www.federalregister.gov/articles/2013/07/12/2013-16493/approval-and-promulgation-of-implementation-plans-new-york-state-ozone-implementation-plan-revision	John Barnes, 518 402 8396, john.barnes@dec.ny.gov ; Robert Bielawa, robert.bielawa@dec.ny.gov
PA	Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC. Effective April 23, 2016. Federal Register –TBD; Final RACT 2 Rule (46 Pa.B. 2036, April 23, 2016). http://www.pabulletin.com/secure/data/vol46/46-17/694.html	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov
RI	Air Pollution Control Regulation Number 27, Control of Nitrogen Oxide Emissions	Laurie Grandchamp, 401 222 2808, laurie.grandchamp@dem.ri.gov
VA	9 VAC 5 Chapter 40 Article 51; http://www.deq.virginia.gov/Portals/0/DEQ/Air/Regulations/451.pdf	Doris McLeod, 804-698-4197, doris.mcleod@deq.virginia.gov
VT	No action to date; http://dec.vermont.gov/air-quality/laws	Doug Elliott, 802 377 5939, Doug.Elliott@vermont.gov

APPENDIX B. COMBUSTION GAS TURBINE ENGINES IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

1. TURBINE ENGINES (>25 MW)	Simple Cycle		Combined Cycle	
	Gas-fired	Oil-fired	Gas-fired	Oil-fired
State	NOx Limit (ppmvd @15% O ₂)			
CT - Statewide	258 (42 - 0.9 lb/MMBtu) ^a 42 – 55 ^b ; 40 ^c	240 (40 - 0.9 lb/mmBtu) ^a 40 – 75 ^b ; 40 – 50 ^c	258 (42 - 0.9 lb/MMBtu) ^a 42 ^b ; 25 ^c	240 (40 - 0.9 lb/mmBtu) ^a 40 – 65 ^b ; 40 – 42 ^c
DC - District-wide (If ≥100 mmBTU/hr)	NA	75	NA	NA
DE - Statewide	42	88	42	88
MA - Statewide	65	100	42	65
MD - Select Counties	42	65	42	65
ME - Statewide	NA	NA	3.5 – 9.0	42
NH - Statewide	25 (55 for pre-1999)	75	42	65
NJ - Statewide (≥15 MW)	25 (1.00 lb/MWh)	42 (1.60 lb/MWh)	25 (0.75 lb/MWh)	42 (1.20 lb/MWh)
NY - Statewide	50	100	42	65
PA - Statewide	>1,000 bhp & <6,000 bhp (150); >6000 BHP (42)	>1,000 bhp and <6,000 bhp (150); >6000 BHP (96)	1,000 bhp and <180 MW (42); >180 MW (4)	1,000 bhp and <180 MW (96); >180 MW (8) F42
RI - Statewide	No RACT Sources (new only)	No RACT Sources (new only)	No RACT Sources (new only)	No RACT Sources (new only)
VA - OTR jurisdiction	42	65 - 77	42	65 - 77
VT - Statewide	NA			

Notes:

- CT: ^aExisting RCSA Sec. 22a-174-22 (to be repealed as of June 1, 2018); ^bRCSA Sec. 22a-174-22e starting June 1, 2018; ^cRCSA Sec. 22a-174-22e starting June 1, 2023.
- NJ: lb/mmBtu limit converted to ppmvd @15% O₂ based on Part 75 Eq-F5 and F-factors of 8710 for natural gas and 9190 for oil; lb/MWh limit converted to ppmvd@15% O₂ based on New Jersey technical support document; 25 ppm ≈ 1.0 lb/MWh for simple cycle gas; 42 ppm ≈ 1.60 lbs/hr for simple cycle oil. (NJ Proposal Number: PRN 2008-260).
- NA = Not Applicable

State	2. Combustion Gas Turbine Engines – Regulations	State Contacts
CT	RCSA section 22a-174-22 will be repealed as of June 1, 2018 and will be replaced with RCSA section 22a-174-22e (finalized December 22, 2016). http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424 3416, Merrily.Gere@ct.gov
DC	20 DCMR § 805.4, RACT for Major Stationary Sources of Oxides of Nitrogen: http://www.dcregs.dc.gov/Gateway/RuleHome.aspx?RuleNumber=20-805;	Alexandra Catena, 202 535-2989, alexandra.catena@dc.gov
DE	7 DE Admin Code 1112, Control of Nitrogen Oxides Emissions: http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml 7 DE Admin Code 1148, Control of Stationary Combustion Turbine Electric Generating Unit Emissions: http://regulations.delaware.gov/AdminCode/title7/1000/1100/1148.shtml	Mark Prettyman, 302-739-9402, mark.prettyman@state.de.us Bob Clausen, 302-739-9402, robert.clausen@state.de.us
MA	MassDEP proposed amendments to NOx RACT affecting emission limits for Large Boilers, turbines, and engines and solicited public comment till September 26, 2016. MassDEP is currently preparing the final regulations and Response to Comments.	Marc Cohen, 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.09.08 G Greater than 15% capacity and less than 15% capacity; https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwia9K6f2ZbOAhUI2T4KHVLHDmAQFggiMAE&url=http%3A%2F%2Fwww.mde.state.md.us%2Fprograms%2FAir%2FAirQualityPlanning%2FDocuments%2FOzone_ISIP_2012.pdf&usg=AFQjCNHMy94YhR5yKcchTc-CzzC7-pPeXA	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	No action to date; http://www.maine.gov/dep/air/rules/index.html	Jeff Crawford, (207) 287-7647, jeff.s.crawford@maine.gov
NH	NH Administrative Rule Env-A 1300 <i>NOx RACT</i> (Part Env-A 1306 <i>Combustion Turbines</i>) http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf	Gary Milbury 603 271-2630, gary.milbury@des.nh.gov
NJ	N.J.A.C. 7:27-19.5 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095, Margaret.Gardner@dep.nj.gov
NY	Under Development; https://www.federalregister.gov/articles/2013/07/12/2013-16493/approval-and-promulgation-of-implementation-plans-new-york-state-ozone-implementation-plan-revision	John Barnes, 518 402 8396, john.barnes@dec.ny.gov ; Robert Bielawa robert.bielawa@dec.ny.gov
PA	PA's RACT Rule covers Combustion Turbines. Additional RACT Requirements for Major Sources of NOx and VOCs: Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC. Effective April 23, 2016. Federal Register –TBD; https://www.portal.state.pa.us/portal/server.pt/document/1613671/1_ract_2_final_exec_summary_pdf	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov
RI	Evaluating potential need for changes	Laurie Grandchamp, 401 222 2808, laurie.grandchamp@dem.ri.gov
VA	9 VAC 5 Chapter 40 Article 51: http://www.deq.virginia.gov/Portals/0/DEQ/Air/Regulations/451.pdf	Doris McLeod, doris.mcleod@deq.virginia.gov

VT

No action to date; <http://dec.vermont.gov/air-quality/laws>

Doug Elliott, 802 377 5939,
Doug.Elliott@vermont.gov

APPENDIX C. INTERNAL COMBUSTION ENGINES (STATIONARY GENERATORS) IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

1. IC ENGINES >500 hp	NOx Limit (g/hp-hr)			
State	Gas-fired, Lean Burn	Gas-fired, Rich Burn	Diesel	Dual Fuel
CT - Statewide	2.5*; 1.5 - 2.0**	2.5*; 1.5 - 2.0**	8.0*; 1.5 - 2.3**	Multi-fuel provisions*,**
DC - Districtwide	NA			
DE - Statewide	Technology Std.	Technology Std.	Technology Std.	Technology Std.
MA - Statewide	3.0	1.5	9.0	9.0
MD - Select Counties	150 ppmvd @ 15% O ₂ (Approx. 1.7 g/hp-hr)*	110 ppmvd @ 15% O ₂ (Approx. 1.6 g/hp-hr)*	175 ppmvd @ 15% O ₂	125 ppmvd @ 15% O ₂
ME - Statewide	NA	NA	3.7 (Source-specific RACT)	NA
NH - Statewide	2.5	1.5	8.0	8.0
NJ - Statewide	1.5	1.5	2.3	2.3
NY - Statewide	1.5	1.5	2.3	2.3
PA - Statewide	3.0	2.0	8.0	8.0
RI - Statewide	2.5	1.5	9.0	Not specified in Regulation, no sources.
VA - OTR Jurisdiction	Source-specific RACT			
VT - Statewide	4.8	4.8	4.8	4.8

Notes:

- CT: * existing RCSA section 22a-174-22 (to be repealed as of June 1, 2018); ** RCSA section 22a-174-22e starting June 1, 2023
- MD: * Conversion factors from ppmv @ 15% O₂ to g/hp-hr from EPA ACT, July 1993 EPA453-R-93-032
- NJ: For an engine ≥37 kW and that has been modified on or after March 7, 2007, 0.90 grams/bhp-hr or an emission rate which is equivalent to a 90% NOx reduction from the uncontrolled NOx emission level
- NA = Not Applicable

State	2. IC ENGINES >500 hp – Regulations	State Contacts
CT	RCSA section 22a-174-22 will be repealed as of June 1, 2018 and will be replaced with RCSA section 22a-174-22e (finalized December 22, 2016). http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424 3416, Merrily.Gere@ct.gov
DC	NA	Alexandra Catena, 202 535-2989, alexandra.catena@dc.gov
DE	7 DE Admin Code 1112, Control of Nitrogen Oxides Emissions http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml#TopOfPage 7 DE Admin Code 1144, Control of Stationary Generator Emissions http://regulations.delaware.gov/AdminCode/title7/1000/1100/1144.shtml#TopOfPage	Mark Prettyman, 302-739-9402, mark.prettyman@state.de.us
MA	MassDEP proposed amendments to NOx RACT affecting emission limits for Large Boilers, turbines, and engines and solicited public comment till September 26, 2016. MassDEP is currently preparing the final regulations and Response to Comments.	Marc Cohen, 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.36	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	Source-specific RACT per Title V license	Jane Gilbert (207) 287-2455, jane.gilbert@maine.gov
NH	NH Administrative Rule Env-A 1300 <i>NOx RACT</i> (Part Env-A 1307 <i>Stationary Internal Combustion Engines</i>) http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf	Gary Milbury 603 271-2630, gary.milbury@des.nh.gov
NJ	N.J.A.C. 7:27-19.8 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095, Margaret.Gardner@dep.nj.gov
NY	Part 222, In Progress	John Barnes, 518 402 8396, john.barnes@dec.ny.gov ; Robert Bielawa, robert.bielawa@dec.ny.gov
PA	Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC. Effective April 23, 2016. Federal Register -TBD	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov
RI	Air Pollution Control Regulation Number 27, Control of Nitrogen Oxide Emissions	Laurie Grandchamp, 401 222 2808, laurie.grandchamp@dem.ri.gov
VA	9 VAC 5 Chapter 40 Article 51; http://www.deq.virginia.gov/Portals/0/DEQ/Air/Regulations/451.pdf	Doris McLeod, doris.mcleod@deq.virginia.gov
VT	VT Regulation 5-271	Doug Elliott, 802 377 5939, Doug.Elliott@vermont.gov

APPENDIX D. MUNICIPAL WASTE COMBUSTORS IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

State	Municipal Waste Combustor (MWC) Facility	Unit # - Capacity (tons/day)	NOx Standard (ppmvd @7% O ₂)	Ammonia Slip Limit (ppmvd @7% O ₂)	Averaging Time	Control Technology	Type of System	Date of Installation - Startup
CT	Covanta Southeastern CT (Preston)	1, 2 - 344.5 each	150 for all ^a	20 ^a	24 hr daily av.	SNCR	MB - WW	12-4-1991
	Wheelabrator Bridgeport	1, 2, 3 - 750 each	150 for all ^a	20 ^a	24 hr daily av.	SNCR	MB - WW	1-13-1988
	Covanta Bristol	1, 2 - 358 each	150 for all ^a	20 ^a	24 hr daily av.	SNCR	MB - WW	10-23-1987
	Wheelabrator Lisbon	1, 2 - 562.4 each	150 for all ^a	20 ^a	24 hr daily av.	SNCR	MB - WW	10-19-1995
	MIRA (Hartford)	1, 2, 3 - 675 each	146 for all	20 ^a	24 hr daily av.	SNCR	Processed MWC	9-4-1987
MA	SEMASS	1, 2 - 1000 each	250 for all	10 - default	24 hr		RDF Stoker	1-1-1988
	SEMASS	3 - 1000	180		24 hr	SNCR	RDF stoker	
	Wheelabrator N. Andover	1, 2 - 750 each	205 for all		24 hr	SNCR	MB - WW	3-1/4-1-1985
	Wheelabrator Saugus	1, 2 - 750 each	205 for all		24 hr	SNCR	MB - WW	6-30-1975
	Wheelabrator Millbury	1, 2 - 750 each	205 for all		24 hr	SNCR	MB - WW	9-17-1987
	Covanta Haverhill	1, 2 - 825 each	205 for all		24 hr	SNCR	MB - WW	4-1-1989
	Covanta Springfield	1,2,3 - 136 each	167 for all		24 hr	FGR	MB - REF	5-1-1988
	Covanta Pittsfield	1,2,3 - 120 each	192 for all		24 hr	FGR	MB - REF	6-1-1981
MD	Wheelabrator	3 - 750	205	None	24-hr	SNCR	MB - grate	1985
	Mont. Covanta	3 - 600	205	None	24-hr	SNCR	MB - grate	1995
ME	Eco Maine - Portland	1,2 - 275 each	180	10	24-hr daily av.	SNCR	MB-WW	1988
	Mid Maine Waste Action Corp	1,2 - 125 each	315 (summer) 350 (winter)	NA	24-hr daily av.	NA	MB - oscillating 210°	1992
	Penobscot Energy Recovery Co	1,2 - 360.5 each	230	NA	24-hr daily av	NA	RDF Stoker	1988
NH	Wheelabrator – Concord	1,2 - 287.53 each	0.53 lb/MMBtu (RACT) 0.35 (MWC Std)	20	calendar day avg.	SNCR	MB	1988
	Wheelabrator – Claremont	1,2 - 115 each	0.53 lb/MMBtu	20	calendar day avg.	SNCR	MB	1986
NJ	Essex CRRF (PI 07736)	1,2,3 - 2700 each	150 for all	50	calendar day	SNCR	MB	3-1988
	Warren CRRF (PI 85455)	1,2 - 438 each	150 for all	50	calendar day	SNCR	MB	7-31-1986
	Camden CRRF (PI 51614)	1,2,3 - 1236 each	150 for all	20	calendar day	SNCR	MB	12-7-1988
	Union CRRF (PI 41814)	1,2,3 - 1540 each	150 for all	50	calendar day	SNCR	MB	12-30-1991

	Gloucester CRRF (PI 55793)	1,2 – 575 each	150 for all	20	calendar day	SNCR	MB	6-9-1988
State	Municipal Waste Combustor (MWC) Facility	Unit # - Capacity (tons/day)	NOx Standard (ppmvd @7% O ₂)	Ammonia Slip Limit (ppmvd @7% O ₂)	Averaging Time	Control Technology	Type of System	Date of Installation-Startup
NY	Babylon RRF	1, 2 - 375 each	150 for all	None	24 hr	SNCR	MB - SC	1988
	Hempstead RRF	1, 2, 3 - 773 each	185 for all	None	365 days rolling av.	Part 231		1989
	Huntington RRF	1, 2, 3 - 250 each	185 for all	50	3 hr rolling	SNCR	MB - WW	1991
	MacArthur RRF	1, 2 - 242.5 each	170 for all	None	24 hr		MB - RC	1989
	Dutchess Co RRF	1, 2 - 228 each	170 for all	None	24 hr		MB - RC	1989
	Wheelabrator Westchester	1, 2 - 750 each	184 for all	None	24 hr		MB - SC	1984
	Wheelabrator Hudson Falls	1, 2 - 275 each	372 for all	None	1 hr		MB - WW	1991
	Onondaga County RRF	1, 2, 3 - 330 each	200 for all	50	3 hr	SNCR	MB - REF	1994
	Oswego County RRF	1, 2, 3, 4 - 50 each	none	None		none	RDF incinerator	1984
	Covanta Niagara	1, 2 - 1097.5 each	205 for all	50	24 hr	SNCR	MB - SC	1996
PA	Covanta Delaware Valley	1 - 585	180	NA	24 hr	None	MB - RC	3-1-1991
			88.56 lb/hr		Unknown			
			0.42 lb/MMBtu		Unknown			
		2 - 585	180		24 hr	None	MB - RC	3-1-1991
			88.56 lb/hr		Unknown			
			0.42 lb/MMBtu		Unknown			
		3 - 585	180		24 hr	None	MB - RC	3-1-1991
			88.56 lb/hr		Unknown			
			0.42 lb/MMBtu		Unknown			
		4 - 585	180		24 hr	None	MB - RC	4-18-1991
			88.56 lb/hr		Unknown			
			0.42 lb/MMBtu		Unknown			
		5 - 585	180		24 hr	None	MB - RC	4-23-1991
			88.56 lb/hr		Unknown			
			0.42 lb/MMBtu		Unknown			
		6 - 585	180		24 hr	None	MB - RC	6-8-1991
			88.56 lb/hr		Unknown			
			0.42 lb/MMBtu		Unknown			
	Covanta Plymouth	1 - 608	205	10	Unknown	SNCR	RG - WW	1-1-1991
			109 lb/hr		Unknown			

PA		2 - 608	205		Unknown	SNCR	RG - WW	1-1-1991
			109 lb/hr		Unknown			
	Municipal Waste Combustor (MWC) Facility	Unit # - Capacity (tons/day)	NOx Standard (ppmvd @7% O₂)	Ammonia Slip Limit (ppmvd @7% O₂)	Averaging Time	Control Technology	Type of System	Date of Installation-Startup
	Wheelabrator Falls Twp	1 - 800	180	No Limit	24 hr	SNCR	MB - WW	5-1-1994
			102.6 lb/hr		Unknown			
		2 - 800	180		24 hr	SNCR	MB - WW	5-1-1994
			102.6 lb/hr		Unknown			
	Lancaster Co. Resource Recovery	1 - 400	180	No Limit	24 hr	SNCR	RG - WW	12-1-1990
		2 - 400	180		24 hr	SNCR	RG - WW	12-1-1990
		3 - 400	180		24 hr	SNCR	RG - WW	12-1-1990
	York Co. Resource Recovery	1 - 450	165	NA	24 hr	None	RC	10-23-1989
			135		Annual			
		2 - 450	165		24 hr	None	RC	10-23-1989
			135		Annual			
		3 - 450	165		24 hr	None	RC	10-23-1989
			135		Annual			
	Susquehanna Resource Harrisburg	1 - 267	150	12	24 hr	SNCR	MB - WW	12-30-2005
			135		24 hr			
		2 - 267	150		24 hr	SNCR	MB - WW	2-1-2006
			135		24 hr			
		3 - 267	150		24 hr	SNCR	MB - WW	3-1-2006
			135		24 hr			
VA - OTR jurisdiction	Covanta Fairfax, Inc (Reg # 71920)	001 - 750	205 ppm, 206.3 lbs/hr, 716.2 tpy ^{VA1}	NA	24 hr	SNCR	RG-WW	1987
		002 - 750	205 ppm, 206.3 lbs/hr, 716.2 tpy ^{VA1}		24 hr	SNCR	RG-WW	1987
		003 - 750	205 ppm, 206.3 lbs/hr, 716.2 tpy ^{VA1}		24 hr	SNCR	RG-WW	1987
		004 - 750	205 ppm, 206.3 lbs/hr, 716.2 tpy ^{VA1}		24 hr	SNCR	RG-WW	1987
	Covanta Alexandria/Arlington (Reg # 71895)	001-325	205 ppm ^{VA2}	NA	24 hr	SNCR	RG-WW	1988
		002-325	205 ppm ^{VA2}		24 hr	SNCR	RG-WW	1988

		002-325	205 ppm ^{VA2}		24 hr	SNCR	RG-WW	1988
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Notes:

- No MWCs in DE, DC, RI, & VT;
- CT: ^aCurrent Standard as of 08/02/16;
- ME: Maine Energy Recovery Co (RDF Stoker) installed in 1987 closed permanently in 2012
- VA: ^{VA1}Final 2008 O₃ NAAQS RACT standard for Covanta Fairfax units has not yet been determined. Review/analysis is ongoing; ^{VA2}Final 2008 O₃ NAAQS RACT standard for Covanta Alexandria/Arlington units has not yet been determined. Review/analysis is ongoing.
- Abbreviations: mass burn = MB; waterwall = WW; rotary waterwall = RC; refractory wall = REF; refuse-derived fuel = RDF; reciprocating grate waterwall = RG – WW; mass burn - single chamber = MB – SC; NA = Not Applicable.

State	MWC - Regulations	State Inspectors/Contacts
CT	Revised RCSA section 22a-174-38 (finalized 8/2/16) http://eregulations.ct.gov/eRegsPortal/Search/RMRView/PR2015-192	Merrily Gere, 860 424 3416, Merrily.Gere@CT.gov
MA	310 CMR 7.08(2): http://www.mass.gov/courts/docs/lib/300-399cmr/310cmr7.pdf Covanta Springfield and Covanta Pittsfield - permit	SEMASS: Dan Disalvio, 508 946 2878, dan.disalvio@state.ma.us ; Wheelabrator (N. Andover & Saugus) & Covanta Haverhill: Joseph Su, 978 694 3283, joseph.su@state.ma.us ; Wheelabrator Millbury: Paul Dwiggin, 508 767 2760, paul.dwiggin@state.ma.us ; Covanta (Springfield & Pittsfield): Todd Wheeler, 413 755 2297, todd.wheeler@state.ma.us
MD	COMAR 26.11.08.08; COMAR 26.11.08.07 & 26.11.08.08 - Revising NOx RACT for Large MWCs; planned proposal June 2016: http://www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=26.11.08.* http://www.dsd.state.md.us/comar/SubtitleSearch.aspx?search=26.11.09.*	Wheelabrator: Ariane Kouamou-Nouba, 410 537 4233, ariane.kouamou-nouba@maryland.gov Mont. Covanta: Mitchell Greger, 410 537 3235, mitchell.greger@maryland.gov
ME	http://www.maine.gov/dep/air/rules/	Jeff Crawford, 207 287 7647, jeff.s.crawford@maine.gov
NH	Env-A 1309 (RACT) Env-A 3300 (NH MWC Std); Evaluating comments from draft RACT submittal; http://des.nh.gov/organization/commissioner/legal/rulemaking/documents/env-a3300-adpt-pstd.pdf	Gary Milbury, 603 271 2630, gary.milbury@des.nh.gov
NJ	N.J.A.C. 7:27-19.12 - basis for OTC draft MSW white paper	Essex CRRF (PI 07736): Scott Michenfelder, 609 439 2432, Scott.Michenfelder@dep.nj.gov ; Warren CRRF (PI 85455): Douglas Bannon, 973 656 4444, Douglas.Bannon@dep.nj.gov Camden CRRF (PI 51614): Matthew Zehr, 609 439 9406, Matthew.Zehr@dep.nj.gov ; Union CRRF (PI 41814): Robin Jones, 609 439 9418, Robin.Jones@dep.nj.gov ; Gloucester CRRF (PI 55793): Vince Garbarino, 609 439 9396, Vince.Garbarino@dep.nj.gov
NY	Babylon - RRF Subpart 219-2; Hempstead - RRF Part 231; Huntington - RRF 40 CFR 52.21; MacArthur RRF - 40 CFR 60.1705(a)(1); Dutchess Co RRF - 40 CFR 60.1705(a)(1); Wheelabrator Westchester - 40 CFR 52.21(j); Wheelabrator Hudson Falls - 40 CFR 52.21(j)(2); Onondaga County RRF- 40 CFR 52.21(j); Covanta Niagara - 40 CFR 60.33(b); Part 219, Effective 12/31/1988	John Barnes, 518 402 8396, john.barnes@dec.ny.gov
PA	Covanta Delaware Valley - 25 Pa. Code §127.12 (BAT) and 25 Pa. Code §129.91 (RACT); Covanta Plymouth, Wheelabrator Falls Twp - 25 Pa. Code §127.12 (BAT) and 40 CFR Part 60, Subpart Cb; Lancaster Co. Resource Recovery - 25 Pa. Code §127.12 (BAT); York Co. Resource Recovery - 25 Pa. Code §127.12 (BAT), 25 Pa. Code §129.91 (RACT); Susquehanna Resource Harrisburg - 40 CFR Part 60, Subpart Eb, 25 Pa. Code §127.12 (BAT); Voluntary limit for netting purposes; Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC. Effective April 23, 2016. Federal Register –TBD; http://www.pacode.com/secure/data/025/articleICIII_toc.html	Susan Hoyle shoyle@pa.gov Randy Bordner ranbordner@pa.gov Susan Foster sufoster@pa.gov Sean Wenrich sewenrich@pa.gov
VA	9 VAC 5 Chapter 40 Article 51 http://www.deq.virginia.gov/Portals/0/DEQ/Air/Regulations/451.pdf	Doris Mcleod, doris.mcleod@deq.virginia.gov

APPENDIX E. HOT MIX ASPHALT PRODUCTION PLANTS IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

State	NO _x Limit (ppmvd @ 7% O ₂)		
	Natural Gas	No. 2 Oil	Other Fuels
CT	No specific emission limits for Hot Mix Asphalt Production Plants		
DC	150	150	150
DE	No specific emission limits for Hot Mix Asphalt Production Plants		
MA	BACT determination for Benevento Asphalt:		
	0.044 lb/MMBtu	0.113 lb/MMBtu	0.113 lb/MMBtu
MD			
ME	0.12 lb/ton asphalt	0.12 lb/ton asphalt	0.12 lb/ton asphalt
NH	0.12 lb/ton asphalt	0.12 lb/ton asphalt	0.12 lb/ton asphalt
NJ	75	100	125*
NY	No specific emission limits for Hot Mix Asphalt Production Plants		
PA			
VA - OTR jurisdiction	NA		
VT	No specific regulatory emission limits for Hot Mix Asphalt Production Plants, but most permits contain 0.06 lb/ton asphalt limit based on application submittal.		

Notes:

- No Sources in RI;
- NJ: * No. 4 or heavier fuel oil or on-spec used oil or mixture of these three
- VA – OTR jurisdiction: All of ~15 plants have federally enforceable limits on their PTE of NO_x and VOC to make them minor sources (<100 tpy NO_x, <50 TPY VOC)
- DE: Specific emissions limitations in lb/HMA are determined on a facility by facility basis.
- DC: 150 ppmvd @ 7% O₂ is the NO_x RACT standard for major sources (25 TPY) of NO_x only (two of the three HMA facilities in DC). No NO_x RACT standard is specified for minor sources of NO_x. The third HMA facility, a 225 TPH continuous drum-mix asphalt plant, has limits on potential to emit keeping NO_x below the major source threshold. Its NO_x limits are 12.4 lb/hr and 22.0 tons per 12-month rolling period.

State	Hot Mix Asphalt Production Plants – Regulations	State Contacts
CT	RCSA section 22a-174-22 will be repealed as of June 1, 2018 and will be replaced with RCSA section 22a-174-22e (finalized December 22, 2016). Note: Neither section includes a limit that specifically applies to "asphalt production plants" but the fuel-burning equipment is regulated: http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424 3416, Merrily.Gere@ct.gov
DC	20 DCMR § 805.6, RACT for Major Stationary Sources of Oxides of Nitrogen: http://www.dcregs.dc.gov/Gateway/RuleHome.aspx?RuleNumber=20-805	Alexandra Catena, 202 535-2989, alexandra.catena@dc.gov
DE	http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml	Mark Prettyman 302-739-9402, mark.prettyman@state.de.us
MA	No specific NOx RACT emission limits for this source category in state NOx RACT regulations.	Marc Cohen 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	Search Title 26, Chapter 11; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	http://www.maine.gov/dep/air/rules/	Jeff Crawford, 207 287 7647, jeff.s.crawford@maine.gov
NH	NH Administrative Rule Env-A 1300 <i>NOx RACT</i> (Part Env-A 1308 <i>Asphalt Plant Rotary Dryers</i>) http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf	Gary Milbury 603 271-2630, gary.milbury@des.nh.gov
NJ	N.J.A.C. 7:27-19.9, based on OTC ADDENDUM TO RESOLUTION 06-02 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095, Margaret.Gardner@dep.nj.gov
NY	Hot mix asphalt plants cap out of Title V www.dec.ny.gov/regs/2492.html	John Barnes, 518 402 8396, john.barnes@dec.ny.gov ; Robert Bielawa, robert.bielawa@dec.ny.gov
PA	Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC; Effective April 23, 2016. Federal Register -TBD Case by Case; http://www.pacode.com/secure/data/025/articleIcIII_toc.html	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov
VA - OTR jurisdiction	No asphalt plants trigger the major stationary RACT source definition under 9 VAC 5 Chapter 40 Article 51 at this time.	Doris McLeod, doris.mcleod@deq.virginia.gov
VT	No action to date; http://dec.vermont.gov/air-quality/laws	Doug Elliott, 802 377 5939, Doug.Elliott@vermont.gov

APPENDIX F. GLASS FURNACES IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

State	Facility	Emission rate (lb NOx/ ton of glass)	Averaging Time	Technology
MA	Ardagh Glass Inc. (formerly known as Saint Gobain Containers), Milford	1.3*	30 day rolling	Oxy-fuel combustion furnaces
MD				
NJ	Statewide	9.2 (flat glass); 4.0 (except flat glass)		Oxyfiring installed at rebricking
NY	Statewide	1.89 - 4.49		
PA	Statewide	4.0 (container and fiberglass furnaces); 7.0 (pressed or blown, and flat glass furnaces); 6.0 (all other glass melting furnaces)		

Notes:

- No Sources in CT, DC, DE, ME, NH, RI, VA (OTR Jurisdiction), and VT;
- MA: * this excludes Abnormally Low Production Rate Days, Furnace Startup, Malfunction of the Furnace, and Maintenance of the Furnace;
- NJ: Applicability depends on type of glass manufacturing , maximum production rate , PTE NOx >10tpy

State	Glass Furnaces - Regulations	State Contacts
MA	Global consent decree for Ardagh Glass Inc. (formerly Saint Gobain Containers), Milford; https://www.epa.gov/enforcement/consent-decree-saint-gobain-containers-inc	Marc Cohen, 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.09.08I, Search Title 26, Chapter 11; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier, 410 537-4488, Randy.Mosier@maryland.gov
NJ	N.J.A.C. 7:27-19.10, based on OTC ADDENDUM TO RESOLUTION 06-02 http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095, Margaret.Gardner@dep.nj.gov
NY	Subpart 220-2 - Effective: 7/11/2010 Submitted: 8/19/2010; Final: 77 FR 13974, 78 Fr 41846; www.dec.ny.gov/regs/2492.html	John Barnes, 518 402-8396, john.barnes@dec.ny.gov ; Robert Bielawa robert.bielawa@dec.ny.gov
PA	Control of NOx Emissions From Glass Melting Furnaces. Sections 129.301 - 129.310. The rule limits the emissions of NOx from glass melting furnaces on an annual basis. Effective September 21, 2011. 08/22/2011, 76 Federal Register 52283 http://www.pacode.com/secure/data/025/articleIcIII_toc.html	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov

APPENDIX G. NATURAL GAS PIPELINE COMPRESSORS IN OZONE TRANSPORT REGION

(Data as of 01/18/2017)

State	Natural Gas Pipeline Compressors – Regulations	State Contacts
CT	RCSA section 22a-174-22 will be repealed as of June 1, 2018 and will be replaced with RCSA section 22a-174-22e (finalized December 22, 2016). Note: Does not specifically apply to "natural gas pipelines" but fuel-burning equipment such as compressors is regulated; http://www.ct.gov/deep/lib/deep/air/regulations/mainregs/sec22.pdf https://eregulations.ct.gov/eRegsPortal/Search/getDocument?guid=%7bE2C443EB-00E6-46AF-A260-65881DD13319%7d	Merrily Gere, 860 424 3416, Merrily.Gere@ct.gov
DE	http://regulations.delaware.gov/AdminCode/title7/1000/1100/1112.shtml http://regulations.delaware.gov/AdminCode/title7/1000/1100/1144.shtml *	Mark Prettyman, 302-739-9402, mark.prettyman@state.de.us
MA	310 CMR 7.19(7) NOx RACT simple cycle turbine existing emission limit of 65 ppm @ 15% O ₂ , proposed for more stringent standard of 40 ppm in 2017. A BACT determination in 2006 for a replacement of a 53.8 MMBtu/hr Allison turbine at Tennessee Gas Pipeline Charlton station with two 50-6200LS Solar Centaur split shaft gas turbine compressor sets equipped with Solar's pre-combustion SoLoNOx technology each rated at 6,037 hp with a maximum heat input = 53.52 MMBtu/hr at ISO conditions): 15 ppm @ 15% O ₂ (or alternatively 3.22 lbs/hr)	Marc Cohen, 617.292.5873, Marc.Cohen@MassMail.State.MA.US
MD	COMAR 26.11.29; Search Title 26, Chapter 11; http://www.dsd.state.md.us/COMAR/SearchTitle.aspx?scope=26	Randy Mosier, 410 537 4488, Randy.Mosier@maryland.gov
ME	Source specific BACT	Jane Gilbert, (207) 287-2455, jane.gilbert@maine.gov
NH	Regulated under Part Env-A 1306 <i>Combustion Turbines</i> (no separate rule for compressor stations): http://des.nh.gov/organization/commissioner/legal/rules/documents/env-a1300.pdf	Gary Milbury, 603 271 2630, Gary.milbury@des.nh.gov
NJ	N.J.A.C. 7:27-19.5 and 19.8, amendments in progress (applicable to turbines and engines at natural gas compressor stations) based on draft OTC white paper. http://www.state.nj.us/dep/aqm/Sub19.pdf	Peg Gardner, 609 292 7095, Margaret.Gardner@dep.nj.gov
NY	Covered under NOx RACT Rule (Subpart 227-2) Effective: 7/8/2010, Submitted: 8/19/2010, Final: 77 FR 13974, 78 Fr 41846; www.dec.ny.gov/regs/2492.html	John Barnes, 518 402 8396, john.barnes@dec.ny.gov ; Robert Bielawa, robert.bielawa@dec.ny.gov
PA	Additional RACT Requirements for Major Sources of NOx and VOCs. Sections 129.96 - 129.100. Control of NOx from Major Sources of NOx and VOC. Effective April 23, 2016. Federal Register - TBD (No Distinction) http://www.pacode.com/secure/data/025/article1CIII_toc.html	Susan Hoyle, shoyle@pa.gov Randy Bordner, ranbordner@pa.gov Susan Foster, sufoster@pa.gov Sean Wenrich, sewenrich@pa.gov
RI	One source; Source specific RACT for engines at compressor station	Laurie Grandchamp, 401 222 2808,

		laurie.grandchamp@dem.ri.gov
VA - OTR jurisdiction	9 VAC 5 Chapter 40 Article 51, case by case RACT	Doris McLeod, doris.mcleod@deq.virginia.gov

Notes:

- No Sources in DC and VT;
- DE: * Reg. 1144 only applies to stationary generators, and not all engines.