Appendix F:
Concept Paper for Changes to Rule 9-9: Stationary Gas Turbines

Rules to Be Amended or Drafted

Further limits to oxides of nitrogen (NO_X) emissions from stationary gas turbines requires amendments to Air District Regulation 9, Rule 9, *Nitrogen Oxides from Stationary Gas Turbines*.

Goals

The goal of this rulemaking is to achieve technically feasible and cost-effective NO_x emission reductions from certain stationary gas turbines in the Bay Area.

Background

Gas turbines are often used to generate mechanical or electrical power from gaseous fuels such as natural gas, refinery gas, and landfill gas. Gas turbines can be found at oil refineries, landfills, and at a variety of other industrial, commercial, and institutional facilities.

Combustion of gaseous fuels results in emissions of NO_x to the atmosphere. NO_X emissions can be controlled by improved combustion, water or steam injection, selective catalytic reduction, or other catalytic systems.

Currently, Air District Regulation 9, Rule 9 requires stationary turbines to meet the NO_x emission limits provided in the following table. (For simplicity, emission limits for non-gaseous fuel are not shown and limits are expressed in parts per million – volume (ppmv) only.) The Air District is considering the feasibility of reducing the NO_x emission limits for medium sized turbines.

Table F1: Current NO_X Emission Limits for Gas Turbines

Turbine heat input rating (MMBtu/hr)	NO_X Emission Limits (ppmv)	
	Natural Gas	Waste gas, refinery gas, LPG
5-50	42	50
>50 – 150 [(a)]	42	50
>50 – 150 [(b)]	35	50
>50 – 150 [(c)]	25	50
>150 – 250	15	15
>250 – 500	9	9
>500	5	9

(a) No retrofit available
(b) Water injection or steam injection retrofit available
(c) Dry low-NO_x combustion technology is available

Process and Source Description

A gas turbine is a type of internal combustion engine in which expansion of the combustion gases spins a rotor to generate electrical or mechanical energy. The fuel can be natural gas, propane, liquefied petroleum gas (LPG), or any gas with sufficient heating value generated at an oil refinery, landfill, or other industrial facility.

Incomplete combustion can result in emissions of carbon monoxide (CO) and, to a lesser extent, volatile organic compounds (VOC). At high temperatures, nitrogen and oxygen in the combustion air can react to form NO_x. Nitrogen and sulfur, if present in the fuel, can oxidize to form NO_x and sulfur dioxide (SO_2).

Regulatory History and Context

Air District Regulation 9, Rule 9 was adopted on May 5, 1993 and amended on December 6, 2006. Air District Regulation 9, Rule 9 limits NO_x emissions from combustion turbines depending on the size of the turbine (based on heat input rating), the fuel, and, in some cases, whether retrofit control technologies are available. (See Table F1 above for NO_x emission limits for stationary gas turbines).

The U.S. Environmental Protection Agency (EPA) has promulgated two standards of performance that apply to combustion turbines. The first, 40 CFR, part 60, subpart GG, *Standards of Performance for Stationary Gas Turbines*, applies to all stationary gas turbines with a heat input at peak load larger than 10 MMBtu/hr constructed, reconstructed or modified after October 3, 1977. The second, 40 CFR, subpart KKKK, *Standards of Performance for Stationary Combustion Turbines*, applies to all stationary gas turbines with a heat input at peak load larger than 10 MMBtu/hr constructed, reconstructed or modified after February 18, 2005. The emission limits for NO_x in each of these regulations are less stringent than the limits specified in Air District Rule 9-9.

Emissions

Review of the 2013 emission inventory found the following gas turbines in the 50-250 MMBtu/hr heat input size range. The turbines with the best opportunities for emission reductions are highlighted.

Table F2: Gas Turbines in Bay Area in Size Ranges Under Review

Facility	Description	Size MMBtu/hr	Fuel	Permit Limit ppmv	9-9 Limit ppmv	Actual ppmv
Tesoro	**GE Frame 3**	**113**	**Natural Gas**		**42**	**40**
Valero 43	**GE Frame 3**	**143**	**Refinery Gas**		**50**	**38**
Valero 44	**GE Frame 3**	**152**	**Refinery Gas**		**50**	**33**
Valero 46	**GE Frame 3**	**143**	**Refinery Gas**		**50**	**40**
Valero 45	GE Frame 5	173	Refinery Gas	9	9	5
Graphic Packaging	**GE LM2500-33**	**219**	**Natural Gas**		**15**	**14.5**
United Airlines	GE LM2500-33	228	Natural Gas		15	Shutdown?
PE Berkeley	GE LM2500-33	243	Natural Gas		15	17* (.33#/MWhr)
Contra Costa Sanitary District	Solar Centaur	50	Landfill Gas		50	20
ITP – SRI, Menlo Park	Allison 501KB	53.7	Natural Gas		42	22
ITP, San Jose	Cheng Cycle - 501KH	54	Natural Gas		42	40
City of Santa Clara	Allison 501KB	55	Natural Gas		42	40
City of Santa Clara	Allison 501KB	55	Natural Gas		42	40
UCSF - Parnassus	Solar Taurus	76	Natural Gas	5	25	4
UCSF - Parnassus	Solar Taurus	76	Natural Gas	5	25	4

Opportunities for NOx reductions shown in bold, highlighted in yellow

*Currently achieves 9 ppmv equivalent standard of 0.43 lbs NOx/MWhr

Regulatory Concepts and Proposed Regulations

The Air District is not considering any fundamental changes or new(?) regulatory concepts. Air District staff is considering whether lowering the emission limits for NO_x in Air District Regulation 9, Rule 9 for some turbines is technically and economically feasible.

Control Mechanisms

There are several technologies available to control NO_x emissions from stationary gas turbines. Water or steam injection into the turbine combustion zone cools flame temperatures and limits oxidation of nitrogen in the air. Dry Low-NOx technology stages fuel and air injection into the combustion zone and also controls flame temperatures to limit oxidation of nitrogen in the air.

Control of NO_x to the 5 or 9 ppmv levels required by Air District Regulation 9, Rule 9, however, generally requires selective catalytic reduction (SCR), which involves the reaction of ammonia (or urea, which thermally decomposes to liberate ammonia) with NO_x in the presence of a fixed catalyst bed at temperatures of 450-850 °F.

SCR can result in ammonia slip, emission of unreacted ammonia, usually ranging from 3 – 10 ppm in the effluent. Ammonia, like NO_x, is a $PM_{2.5}$ precursor. Additional analysis and modeling studies are needed to determine the fate of incremental ammonia slip and the net costs and benefits from increased use of SCR.

Costs and Emissions Reductions

Cost estimates are based on EPA Air Pollution Control Cost Manual (Sixth Edition), initialized with current SCR equipment cost quotes, plus 30 percent additional costs to accommodate retrofit into an existing facility. Additional input is needed from each facility regarding site specific issues and costs. Emission reductions are based on a final concentration of 9 ppmv NO_x. The Air District requests feedback on the estimated costs and emission reductions from further controlling NO_X from these turbines.

Table F3: Emissions Reductions and Costs

Facility	Description	Size (MMBu/hr)	Fuel	Emission Reduction (tpy)	Annualized Cost ($ M)
Tesoro	GE Frame 3	113	Natural Gas	47	0.42
Valero 43	GE Frame 3	143	Refinery Gas	82	1.36
Valero 44	GE Frame 3	152	Refinery Gas	74	1.36
Valero 46	GE Frame 3	143	Refinery Gas	75	1.36
Graphic Packaging	GE LM2500-33	219	Natural Gas	19	0.67

Additional study is needed to determine if there are cost effective emission reduction opportunities from stationary gas turbines with a heat input rating between 50-100 MMBtu/hr, which have lower overall emissions than the gas turbines addressed in this appendix, or from stationary gas turbines with a heat input greater than 250 MMBtu/hr, which already have to meet the more stringent emissions limits in Air District Regulation 9, Rule 9.