Bay Area Air Quality Management District

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Workshop Report

BAAQMD Regulation 9, Rule 8: Nitrogen Oxides and Carbon Monoxide from Stationary Internal Combustion Engines

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WORKSHOP REPORT
Regulation 9, Rule 8, Nitrogen Oxides and Carbon Monoxide Emissions from Stationary Internal Combustion Engines

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I. INTRODUCTION

Currently, the Bay Area Air Quality Management District (District) does not attain the State air quality standards for particulate matter (PM) and ozone and the California Air Resources Board (ARB) has determined that ozone and ozone precursors are sometimes transported from the Bay Area to neighboring air basins. Regulatory amendments to Regulation 9, Rule 8: Nitrogen Oxides and Carbon Monoxide Emissions from Stationary Internal Combustion Engines (Rule 9-8) are part of the strategy to reduce PM and will also reduce ozone formation from emissions of oxides of nitrogen (NOx).

A. Overview of the Proposal

District staff has developed amendments to Rule 9-8 to reduce NOx emissions from stationary internal combustion (IC) engines to the lowest feasible levels. Reducing NOx emissions would have the additional benefit of reducing secondary PM formation from NOx. This Workshop Report presents the staff's regulatory proposal for amending Rule 9-8 to reduce NOx and secondary PM emissions from stationary IC engines. The proposal would:

1. Expand the scope of the rule to regulate NOx emissions from smaller stationary IC engines of 50 brake horse power (bhp) or larger,
2. Regulate NOx emissions from liquid-fueled engines such as diesel engines, and
3. Reduce the emissions limits for NOx for all affected stationary IC engines.

Table 1 provides a summary of the NOx emissions limits and compliance schedule that the staff is currently proposing for incorporation into Rule 9-8. The NOx emissions limits are based on several federal, State, and district rules and regulations implemented since the 1993 adoption of Rule 9-8.

TABLE 1
Summary of Proposed NOx Emission Limits for Existing IC Engines

Engine Type and Fuel	Existing Engines	
	Emission Limits (g/bhp-hr)	Compliance Dates
Compression-Ignited (All Engines)	0.50 - 2.6	2011 - 2012
Compression-Ignited (Alt. limits for 1996 or later)	0.30 - 0.50	2016
Spark-Ignited Gaseous & Liquid	0.36 (rich[a]) / 1.0 (lean[b])	2011
Spark-Ignited Waste Gas	0.70 (rich[a]) / 1.0 (lean[b])	2011

a. Rich burn engines operate using an air to fuel ratio that is close to the stoichiometric balance (excess fuel); this combustion ratio results in a small fraction of the fuel remaining uncombusted and exiting in the exhaust stream.
b. Lean burn engines operate with excess air and can result in increased formation of NOx.

B. The Current Rule

Rule 9-8 was originally adopted in 1993 and, currently, regulates emissions of NOx and CO from stationary IC engines of 250 bhp or greater powered by gaseous fuels such as natural gas or LPG. The current rule, however, does not include emissions limits for liquid-fueled engines such as diesel engine or engines below 250 bhp. The rule currently affects about 200 of the more than 5000 stationary IC engines within the District. The following table summarizes the current NOx emission limits for gaseous-fueled IC engines of 250 bhp or greater.

TABLE 2
Rule 9-8 Current Emissions Limits for NOx

Fuel Type	NOx Emission Limits (ppm (g/bhp-hr))	
	Rich Burn	**Lean Burn**
Fossil Fuels	56 (0.8)	140 (2.0)
Waste Gas	210 (3.0)	

C. Stationary IC Engines and Their Emissions

Stationary IC engines are typically used as both primary and backup engines to generate electricity and power pumps and compressors. IC engines are fueled by diesel, natural gas and liquid petroleum gas (LPG), refinery fuel gas, digester gas and landfill gas. Over 80 percent of these engines are powered using diesel fuel.

All of these IC engines emit criteria and toxic pollutants such as NOx, carbon monoxide (CO). Diesel-fueled engines emit diesel PM – a subset of total PM that is identified as a toxic air contaminant. Bay Area stationary IC engines emit approximately 20.8 tons per day (tpd) of NOx; diesel-fueled engines are responsible for about 9.6 tpd of those emissions. Secondary PM emissions[i] from stationary IC engines total about 2.1 tpd, with 1.4 tpd attributable to diesel engines. CO emissions total approximately 5.1 tpd.

D. Regulatory Activity Since the Adoption of Rule 9-8

Since the adoption of Rule 9-8 in 1993, several rule and regulations have been implemented that affect stationary IC engines in California.

The EPA Off-Road Tiered Standards: In 1998 and 2004, the United States Environmental Protection Agency (EPA) promulgated the Off-Road Compression-Ignition (Diesel) Engine Tiered Standards (Federal Off-Road Tiered Standards).[1,2] These tiered standards apply to new diesel engines and become progressively more stringent as model years advance.

The ARB BARCT Determinations: In 2001, the ARB published best available retrofit control technology determinations (BARCT) for spark-ignited stationary IC engines.[3] The BARCT Determinations set recommended NOx limits for the retrofit of stationary spark-ignited engines.

The ARB CI Engine ATCM: In addition, in 2004, the ARB adopted the Airborne Toxic Control Measure for Compression-Ignition [Diesel] Engines (CI Engine ATCM) that sets emissions limits for PM and other criteria pollutants for diesel-fueled engines and requires the use of cleaner-burning fuels for all diesel engines.[4] The CI Engine ATCM will significantly affect stationary diesel engines in California; it will result in either the retrofit or the replacement of virtually all existing prime engines and the reduction of hours of operation for emergency standby engines by 2011.

Other California District Stationary IC Engine Regulations: Subsequently, several air districts in the State have also adopted regulations that reflect emission limits for NOx contained in the ARB BARCT determinations and the EPA Off-Road Tiered Standards, including NOx limits for liquid-fueled engines.

[i] Secondary PM in the form of ammonia nitrate is formed from the photochemical reaction of NOx with ammonia.

II. BACKGROUND

Stationary IC engines directly emit NOx and PM (diesel engines are a large source of primary PM emissions). The NOx emitted is also responsible for the secondary formation of PM. These engines also emit hydrocarbons (HC) and carbon monoxide (CO). Ozone, formed from the reaction of NOx and HC, CO, and PM are criteria pollutants, emissions of which are subject to District and State regulation. Oxides of nitrogen contribute to the formation of PM. The term "NOx" is use to collectively refer to nitric oxide (NO) and nitrogen dioxide (NO_2). Most NO, once emitted, reacts rapidly in the atmosphere to form NO_2. NO_2, in turn, reacts in the atmosphere with compounds in the presence of sunlight to form PM – both PM_{10} (ten microns (μm) or less in size) and $PM_{2.5}$ (2.5 μm or less). Therefore, reducing NOx emissions would help to reduce secondary PM formation. The Bay Area is currently in attainment of the federal PM_{10} and $PM_{2.5}$ standards; but, like most of the State, is classified as non-attainment for the more stringent State PM standards. State law requires that the region make progress in reducing ambient ozone and PM levels and protect public health.

A. What Is Prompting this Rulemaking?

PM Formation and Senate Bill 656: In 2003 the California Legislature enacted Senate Bill 656 (SB 656, Sher), codified as Health and Safety Code (H&SC) section 39614, to reduce public exposure to PM_{10} and $PM_{2.5}$. SB 656 requires the ARB, in consultation with local air districts, to develop and adopt, by July 3, 2005, a list of the most readily available, feasible, and cost-effective control measures that could be used by ARB and the air districts to reduce PM_{10} and $PM_{2.5}$. The goal of the legislation is to make progress toward attainment of State and federal PM_{10} and $PM_{2.5}$ standards.

The proposed control measures are to be based on rules, regulations, and programs existing in California as of January 1, 2004, to reduce emissions from new, modified, and existing stationary, area, and mobile sources. The bill requires the ARB and air districts to adopt implementation schedules for appropriate ARB and air district measures. In the District's PM Implementation Schedule adopted pursuant to SB 656, the District identified Regulation 9, Rule 8 (Rule 9-8) as one of several measures to be considered to reduce PM levels in the Bay Area.[5]

Ozone Attainment: NOx also contributes to the formation of ozone, which is the principal component of smog. Ozone is highly reactive, and at high concentrations can be harmful to public health. Ozone forms when NOx chemically reacts with HC in the presence of sunlight. The Bay Area Air Basin periodically experiences high ozone levels and is in non-attainment for the State one-hour air quality standard for ozone. Additionally, the ARB has determined that ozone and its precursors are sometimes transported from the Bay Area Air Basin into neighboring air basins. Accordingly, the Bay Area 2005 Ozone

Strategy describes how the District will fulfill California Clean Air Act (CCAA) planning requirements for the State one-hour ozone standard, as well as transport mitigation requirements, through the proposed control strategy. As part of our commitment to meet the State ozone standard, the District must implement all feasible measures available to control emissions of criteria pollutants to reduce the potential for ozone formation.

Emissions from IC Engines: The District regulates NOx emissions from internal combustion engines under Rule 9-8, which imposes NOx limits on engines powered with gaseous fuels. Rule 9-8 was adopted in 1993 pursuant to ARB pollution transport regulations (California Code of Regulations, section 70600, et seq.). Those regulations required the District to adopt best available retrofit control technology (BARCT) for source categories that collectively amounted to 75 percent of the 1987 NOx emissions inventory. Because the majority of IC engine emissions at the time came from approximately 60 large engines fired with gaseous fuels, Rule 9-8 imposed controls only on gaseous-fueled engines. Rule 9-8 set emissions limits for gaseous-fueled engines that became effective in 1997 and, as a result, reduced NOx emissions from these engines by 8.3 tons per day (tpd)[6]. However, since the adoption of Rule 9-8, many more diesel-powered engines have come online in the Bay Area and now these engines account for the majority of NOx emissions. Collectively, the total current inventory of NOx emissions from stationary engines in the Bay Area is estimated to be 20.9 tpd. The NOx emitted from stationary diesel engines is estimated to be 9.6 tpd, about 46 percent of the 20.9 tpd total. The PM inventory for stationary IC engines is estimated to be 1.8 tpd; 1.4 tpd of which is attributable to stationary diesel engines.

B. What Are Stationary IC Engines?

IC engines generate power through explosive combustion of an air/fuel mixture in an enclosed chamber. IC engines range in size from relatively small engines (less than 50 brake horsepower (bhp)) to extremely large engines (thousands of horsepower[7]) and are used primarily to generate electricity, operate pumps and compressors, and power water pumps for irrigation. There are two primary types of IC engines: compression-ignited (CI) and spark-ignited engines. All IC engines operate under one of three modes: rich burn (excess fuel), stoichiometric (a chemical balance between fuel and oxygen), or lean burn (excess air). Generally, uncontrolled engines that run rich emit higher levels of HC and CO, and lower levels of NOx and PM; while uncontrolled engines that run lean emit less HC and CO, and emit higher NOx and PM.

Compression-Ignited Engines: CI engines run lean (excess air) using diesel fuel or other longer-chained hydrocarbon, including fuel oil, distillate oil, or jet fuel. CI engines operate by compressing air, which increases the temperature of the air; when a gas is compressed, both its pressure and temperature increase. A diesel engine uses this property to ignite the air fuel mixture and power the engine. The larger fraction of stationary IC engines in the District are CI engines, of which, diesel-fueled engines are the vast majority.

Spark-Ignited Engines: Another category of internal combustion engine is the spark-ignited (SI) engine. This term is normally used to refer to internal combustion engines where the fuel-air mixture is ignited with a spark. The term contrasts with CI engines, where the heat from compression alone ignites the mixture. Natural gas fired spark-ignited engines are the second largest category of stationary IC engines in the Bay Area. These engines are operate as either rich-burn (excess fuel) or lean-burn.

C. How Are Stationary IC Engines Categorized?

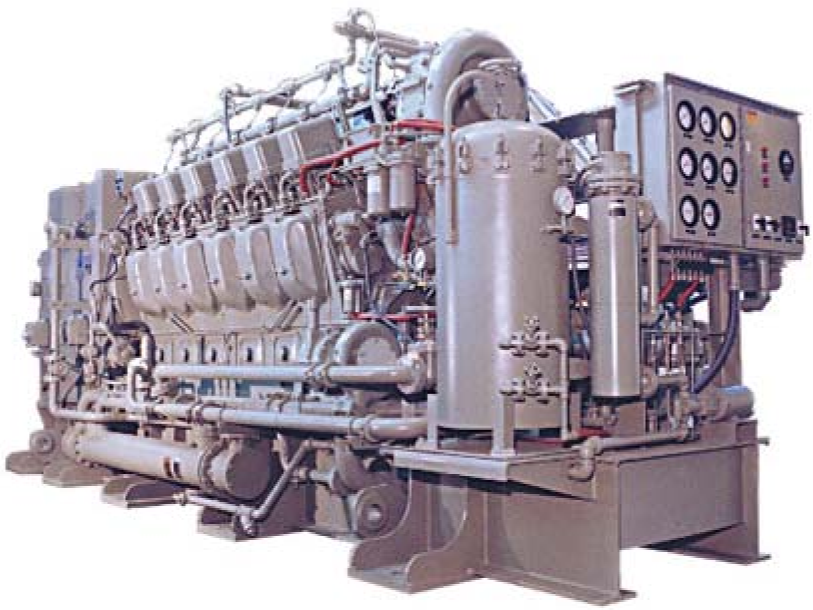
For regulatory purposes, stationary IC engines can be divided into two main categories by usage: emergency/standby and prime engines.

Emergency / Standby Engines: Emergency/standby engines are typically used for emergency back-up electric power generation or the emergency pumping of water. In the District, there are over 4700 emergency/standby engines ranging in size from less than 10 bhp to almost 4000 bhp. Currently, Rule 9-8 exempts these engines from emission standards, provided the annual hours of operation do not exceed 100 hours for reliability testing, maintenance, and source testing. Emergency/standby engines are fueled by both liquid and gaseous fuels.

Prime Engines: Prime engines are stationary engines that are not used in an emergency back-up or standby mode. There are approximately 700 prime engines within the District. These engines are used primarily to generate electricity, or to power compressors, pumps, cranes, generators, and grinders[8]. As with emergency and standby engines, prime engines are fueled by both liquid and gaseous fossil fuels. Prime engines may also be powered by waste, digester and landfill gases, which may require natural gas as a supplemental fuel.

Shown in Figure 1 is one of the largest diesel-fuel station IC engines for electrical generation. This engine can provide up to 2810 kWe (3766 bhp) of power.

FIGURE 1
Large-Size Stationary IC Engines for Electrical Generation



Source: Fairbanks Morse

Figure 2 shows an engine typically used as an emergency standby engine and is approximately 50 bhp in size.

FIGURE 2
Small-Size Emergency Standby Stationary IC Engine

Source: Olympian

III. TECHNICAL REVIEW

This section discusses the populations of all stationary IC engines located in the District by fuel type and use category (emergency standby or prime use). It also includes NOx and PM emission inventories for the populations of stationary IC engines. Also discussed are the various NOx emission reduction technologies available for stationary IC engines.

A. Inventory of Engines

Staff has identified 5450 stationary internal combustion engines located within the District. These engines are powered by a variety of gaseous and liquid fuels including diesel, natural gas, LPG, digester gas, landfill gas, and gasoline. Table 3 provides an inventory of the types of fuel used and the numbers of engines that are power by each fuel type.

TABLE 3
Population of Stationary IC Engines by Use Category and Fuel

Fuel	**Engine Type**		
	Emergency Standby	**Prime**	**Totals**
Diesel (incl. Bio-Diesel)	4364	412	4776
Natural Gas	230	169	399
Liquid Petroleum Gas (LPG)	75	5	80
Digester Gas	3	49	52
Landfill Gas	0	52	52
Gasoline & other liquid fuels	35	25	60
Propane & other gaseous fuels	27	4	31
Totals	**4734**	**716**	**5450**

Table 4 illustrates the variety of uses of the stationary IC engines and the populations of engines associated with each use category. Prime engines greater than 250 bhp are listed separately because these are the engines to which the current emission limits of Rule 9-8 apply.

TABLE 4
Population of Engines by Primary Use and Engine Type

Engine Use	Engine Type			
	Emergency Standby	**Prime** All Sizes	**Prime** ≥ 250 bhp	**Totals**
Electrical Generation	4391	287	137	4678
Co-Generation	2	145	116	147
Pump Driver	52	4	2	56
Fire Pump Driver	48	2	0	50
Process Heater	6	2	0	8
Testing	3	2	2	5
Space Heater	3	1	1	4
Waste Disposal	0	3	2	3
Compressor Driver	0	2	0	2
Tub Grinder	0	1	1	1
Other	229	267	94	496
Totals	**4734**	**716**	**355**	**5450**

B. Emissions Inventory

Staff developed baseline emissions inventories for both NOx and PM for all stationary IC engines by categorizing each engine by ignition and fuel type. The inventory was categorized by compression-ignited or spark-ignited engines. Compression-ignited engines are fueled by diesel or fuel oil; whereas, spark ignited engines are fueled by gaseous fuels, such as natural gas, LPG, digester gas, landfill gas or propane; or liquid fuels, such as gasoline.

1. NOx Emissions

The daily NOx emissions were estimated to be 20.8 tons. To estimate the inventory, the appropriate BACT emission limit for NOx[9] was applied to all IC engines in the inventory identified as being equipped with BACT. The applicable EPA off-road emissions standard for compression ignition engines were applied to all non BACT-equipped diesel fueled engines. [1,2] The NOx emission estimate for natural gas- or other gaseous fuel-powered engines (non-BACT equipped) was based on the applicable current emission limits of Rule 9-8.

Table 5 summarizes the baseline NOx emissions inventory for stationary IC engines located within the District. The first four fuel types account for over 99 percent of NOx emissions, with diesel-powered engines accounting for about 46 percent of the total NOx emissions.

TABLE 5
Inventory of NOx Emissions by Fuel Used and Engine Type

Fuel	**Engine Type**			
	Emergency Standby (tpd)	**Prime**[b] All Sizes (tpd)	**Prime**[c] ≥250 BHP (tpd)	**Total** (tpd)
Diesel (incl. Bio-Diesel)[a]	4.5	5.1	4.9	9.6
Natural Gas	0.05	3.3	2.1	3.4
Landfill Gas	0.0	4.3	4.3	4.3
Digester Gas	0.0	3.5	3.5	3.5
LPG	0.009	0.002	0.001	0.01
Gasoline[a] & Other Liquids	0.004	0.025	0.009	0.03
Propane & Other Gases	0.001	0	0	0.001
Totals	**4.6**	**16.2**	**14.8**	**20.8**

a. Liquid-fueled engines are currently exempt from the emissions standards of Rule 9-8.
b. This category represents those engines not listed as "standby/emergency power source."
c. Non-exempt engines using gaseous fuels (natural gas, LPG, digester gas, and landfill gas) and are 250 bhp or greater are the engines currently subject to the emissions limits of Rule 9-8.

Table 6 presents a summary of the average daily NOx emissions per engine for each type of engine. This summary indicates that prime engines (on an engine-by-engine basis) are the largest contributor to NOx emissions, the greatest of which are prime engines larger than 250 bhp.

TABLE 6
Average NOx Emissions per Engine by Engine Type

	Engine Type			
	Emergency Standby (lbs/day)	**Prime** All Sizes (lbs/day)	**Prime** ≥250 BHP (lbs/day)	**All Engines** (lbs/day)
Average Emissions	1.93	45.3	83.2	7.6
Engine Totals	4734	716	355	5450

Although individually, prime engines on average emit more NOx than emergency standby, Tables 5 and 6 indicate that emergency standby engines contribute significantly to the total NOx inventory. It should be noted that the emissions values attributable to emergency standby engines are likely overestimated. This is because the values were estimated using the maximum allowable hours of operation in their permits, while the annual hours of operation typically are less.

2. PM Emissions

The PM emissions inventory shown in Table 7 reflects a combination of PM directly emitted from stationary IC engines (primary emissions) and the secondary conversion of NOx to ammonium nitrate (NH_4NO_3). The ARB estimated this conversion rate to be 0.1 gram of NH_4NO_3 formed per gram of NOx emitted.[10] District staff, however, has estimated the ratio between NH_4NO_3 formation to NOx emissions to range between 1:6 and 1:10.[11] The primary emissions inventory for PM was estimated using various emissions factors (AP 42 for non-diesel engines) and emissions limits based on current or anticipated regulations (the CI Engine ATCM for diesel engines, Tiers 1 & 2).

TABLE 7
Inventory of PM Emissions by Fuel Used and Engine Type

Fuel	**Engine Type**			
	Emergency Standby (tpd)	**Prime**[b] All Sizes (tpd)	**Prime**[b] ≥250 BHP (tpd)	**Total** (tpd)
Diesel (incl. Bio-Diesel)[a]	0.45	0.51	0.49	0.96
Natural Gas	0.006	0.37	0.24	0.38
Landfill Gas	0	0.45	0.45	0.45
Digester Gas	0.007	0.72	0.72	0.73
LPG	0.002	0.0002	0.0001	0.002
Gasoline[a] & Other Liquids	0.002	0.003	0.001	0.005
Propane & Other Gases	0.0001	0	0	0.0001
Totals	**0.47**	**2.05**	**1.90**	**2.52**

a. Liquid-fueled engines are currently exempt from emissions standards.
b. This category represents those engines not listed as "standby/emergency power source."

Table 8 presents a summary of the average daily PM emissions per engine for each type of engine. This summary indicates that prime engines (on an engine-by-engine basis) are the largest contributor to PM emissions (as is the case for NOx emissions); the greatest contributors are prime engines larger than 250 bhp.

TABLE 8
Average PM Emissions per Engine by Engine Type

	Engine Type			
	Emergency Standby (lbs/day)	**Prime** All Sizes (lbs/day)	**Prime** ≥250 BHP (lbs/day)	**All Engines** (lbs/day)
Average Emissions	0.20	5.73	10.7	0.92
Engine Totals	4734	716	355	5450

3. Emissions from Agricultural Equipment

Stationary engines are sometimes used in agricultural operations, primarily diesel engines used as water pumps in remote locations. These engines do not have District permits and are not included in the above estimates. Based on ARB data, emissions from stationary agricultural engines total 0.076 ton per day of NOx and 0.01 tons per day of PM.

C. Emission Reduction Technologies

There are three primary approaches for emissions reduction control for stationary IC engines:

1. Combustion Modification
2. Fuel Switching
3. Post Combustion (Exhaust) Controls

Combustion modifications affect the way fuel is combusted or "burned." Some of these techniques include changing the air to fuel ratio, reducing the peak combustion temperature, shortening the residence time at high temperatures, or adjusting the ignition or injection timing. Fuel switching involves using another fuel that produces less NOx or PM, such as clean diesel fuel or methanol, or the addition of water to the fuel, which cools combustion temperatures, reducing NOx and some PM emissions. The primary means to treat NOx emissions after they are created (post combustion control) is either by chemically reacting the NOx with ammonia or urea in the presence of a catalyst to convert the NOx back into nitrogen or by the use of a noble metal that reduces NOx, CO and hydrocarbons. The first process is referred to as Selective Catalytic Reduction (SCR) and has been shown to be over 90% effective at reducing NOx. The second process is referred to as Non-Selective Catalytic Reduction (NSCR) and has demonstrated a control effectiveness of greater than 95% for NOx.

These control technologies have varying degrees of effectiveness for NOx control and some, while reducing NOx, may result in the increase of other criteria pollutants. Table 9 presents a summary of these various technologies that includes affected engine type, approximate effectiveness over uncontrolled emissions, cost estimates, and a general description.

TABLE 9
Summary of NOx Emission Control Technologies for Stationary IC Engines

Control Technology	Engine Types	Compounds Affected	Effectiveness[a]	Costs[b]	Description
Non-Selective Catalytic Reduction (NSCR) [3,7,12,13,14, 15]	Rich Burn & Stoich SI Engines	NOx, CO, HC	NOx: >98% CO: >97% HC: >80%	$13-25/bhp	**Exhaust Control:** Post combustion oxidation of HC & CO by O_2 and NOx over a catalyst (usually a noble metal like platinum, rhodium, or palladium). The HC & CO are converted to CO_2 and water, while the NOx is reduced to N_2.
Selective Catalytic Reduction (SCR)[3,7,12,13 ,14,15]	Lean Burn SI Engines	NOx, CO, HC	NOx: >95% CO: >97% HC: >80%	$75-225/bhp	**Exhaust Control:** Ammonia or urea injected in the exhaust before a catalyst. The HC & CO are converted to CO_2 and water, while the NOx is reduced to N_2.
Post Combustion Oxidation & Selective Catalytic Reduction [7,12,13,16]	CI Engines NG Engines (Retrofits)	NOx, PM, CO, HC	NOx: >90% PM: 60% CO: <10 ppm	$12-13/bhp	**Exhaust Control:** NOxTECH Emission Control System ▪ Muffler-sized reactor (similar to afterburner) ▪ Non-Catalytic Oxidation of HC, PM, CO ▪ Exhaust heated to 1,400 to 1,550 ^{o}F through fuel introduction to exhaust ▪ Urea injected to reduce NOx ▪ Ammonia Slip (2 ppm) ▪ South Coast BACT Certified ▪ $ 1000/ton of NOX removed
SCR with Diesel Particulate Filtration [3,7,12,17,18]	CI Engines	NOx, PM, CO, HC	NOx: 95% (1.06 g/bhp-hr) PM: 89%	$64-160/bhp	**Exhaust Control:** SINOx System is SCR combined with a diesel particulate filter. ▪ Aqueous urea injected ▪ Ammonia slip: 4.4 ppm with 30 ppm spikes
Lean + Derating[12]	SI Engine	NOx, HC, CO	NOx: >80%	n/a	**Combustion Control:** Increase the air-to-fuel ratio toward lean and derate, or decrease the cylinder pressures and temperature which reduces the power output of an engine. The lower pressure and temperature reduces NOx, but may increase HC & CO.
Pre-Stratified Charge[12,18]	SI Engines	NOx	NOx: >80%	$1250-1825/bhp	**Combustion Control:** Small amounts of air are introduced to the intake manifold create sequential fuel-rich and fuel-lean zones. This provides both a fuel-rich ignition zone and rapid flame cooling in the fuel-lean zone. This reduces NOx.
Low-Emission Combustion[12]	SI Engines	NOx	NOx: >80%	$285/bhp	**Combustion Control:** Lean Burn combined with: ▪ precombustion chamber, ▪ ignition system improvement, ▪ turbocharging, ▪ air/fuel ratio controller

Control Technology	Engine Types	Compounds Affected	Effectiveness[a]	Costs[b]	Description
"Clean Burn" Retrofit[3,7,12]	SI Engines	NOx, HC, CO	NOx: >80% CO: 60% HC: 60%	$145-320/bhp	**Combustion Control:** ▪ After-market retrofit kit to allow extremely lean burn without fuel consumption penalties. ▪ Smaller Engines: cylinder redesigned for thorough mixing ▪ Larger Engines: 2 combustion chambers: main chamber & precombustion chamber. ▪ Prechamber: spark ignition, Rich fuel mix ▪ Main chamber: Lean fuel mix ▪ Reduced temp because 1) Rich ignition mixture, 2) heat transfer loss as combustion proceeds, 3) dilution effect of lean mix. ▪ Replace engine head with new heads, or work with existing head with prechamber fitting into spark plug hole. ▪ Modified spark plug instead of separate chamber with small, built-in fuel nozzle which injects fuel toward the spark plug electrode.
Lean + "Clean Burn" Retrofit[7,12]	SI Engines	NOx, HC, CO	NOx: 80%	$13-25/bhp	**Combustion Control:** A combination of excess air and Clean Burn Retrofit.
Fuel Switching (Methanol)[3,12]	Natural Gas Engines	NOx	NOx: 30%	$1200/engine	**Fuel Switching:** Replacing or converting natural gas engines with methanol-fueled engines.

a. Effectiveness is based on a comparison of controlled to uncontrolled emissions.
b. Cost estimates were adjusted to May 2006 dollars using U.S. Department of Labor Bureau of Labor Statistics, Consumer Price Indices.

IV. REGULATORY REVIEW

Staff reviewed various rules and regulations applicable to stationary IC engines in California with particular focus on three primary areas:

1. BACT, RACT, and BARCT determinations,
2. Federal and State off-road emissions limits for diesel engines, and
3. Applicable local air district rules adopted or amended since Rule 9-8 was adopted in 1993.

A. BACT, RACT and BARCT Determinations

On November 15, 2001, the ARB approved the Guidance for the Permitting of Electrical Generation Technologies.[18] This document was developed to provide assistance to districts in making permitting decisions for electrical generation technologies. The document provides ARB staff evaluation of recent BACT determinations for electrical generation, including reciprocating engines.

ARB staff also released the Determination of Reasonably Available Control Technology (RACT) and Best Available Retrofit Control Technology (BARCT) for Stationary Spark-Ignited Internal Combustion Engines.[3] Table 10 provides a comparison of the current NOx limits of Rule 9-8 with the limits of the BACT, RACT, and BARCT determinations provided in these documents.

TABLE 10
Comparison of Rule 9-8 NOx Limits with ARB BACT, RACT, and BARCT NOx Limits for Stationary Spark-Ignited IC Engines[3,18]

Engine	Rule 9-8 (ppm)		BACT[18] (ppm)	RACT[3] (ppm)		BARCT[3] (ppm)	
	Lean	**Rich**		**Lean**	**Rich**	**Lean**	**Rich**
Fossil Fuels	140	56	10*	125	50	65	25
Waste Gas		210	42*				50

* These concentration values in parts per million were estimated from emission limits provided as 0.15 and 0.6 g/bhp-hr respectively.

B. Off-Road NOx Emissions Limits for Diesel Engines

The United State Environmental Protection Agency (EPA) promulgated non-methane hydrocarbon (NMHC), NOx, CO and PM emissions limits for off-road compression-ignition (diesel) engines in 1998 and 2004. These standards are collectively known as the EPA Off-Road Tiered Standards or Tiered Standards. Table 11 provides the ranges of NOx emission limits for each of the four tiers and the number of engines in the Bay Area that fall within each Tier group; the tiers and emission limits vary with the engine model year and engine size.

TABLE 11
Summary of the US EPA Off-Road Tiered NOx Emissions Standards and Associated Populations of Diesel Engines

Tier Level	Model Years	Range NOx Emission Limits (g/bhp-hr)	Number of Diesel Engines Identified ≥ 50 bhp
Tier 1	1995-2005	6.7	4217
Tier 2	2001-2010	4.7 – 5.6*	559
Tier 3	2006-2011	3.0 – 4.7*	0
Tier 4 Interim	2008-2015	0.5 – 2.6	0
Tier 4 Final	2013-2016+	0.3 – 0.5	0
		Total	**4776**

* Limits represent a combination of NMHC and NOx emissions.

The primary purpose of the EPA Tiered Standards is to reduce the emissions of various criteria pollutants from diesel engines. The Tier 1 standards primarily set minimum emission limits to ensure that the emissions of criteria pollutants do not increase the established baseline for existing diesel engines. The higher tier standards apply to new and future model diesel engines and increasingly reduce the emissions limits for all criteria pollutants.

All of the diesel-fueled stationary IC engines located in the District can be categorized (by size and model year) as either Tier 1 or Tier 2 engines. Pre-1995 model engines are characterized as Tier 1 engines. Tier 1 engines represent 88 percent of the 4776 diesel engines and Tier 2, the remaining 12 percent. No engine in the District is currently certified to the Tier 3 or Tier 4 emissions standards.

The Tiered Standards are incorporated into the California Off-Road Certification Standards (Title 13 CCR section 2423). The Off-Road Standards form the basis for the emission limits in the ARB CI Engine ATCM, which regulates PM and other criteria pollutant emissions from stationary diesel engines in California.

C. Compression-Ignition ATCM

In 2004, the ARB adopted the CI Engine ATCM. The CI Engine ATCM establishes emissions standards, including standards for diesel PM emissions, that sellers of stationary diesel-fueled (compression-ignition) engines must meet. The ATCM also sets emissions standards and operational requirements for stationary IC engines. The ATCM also requires that specific classes of CI engines meet the off-road engine standards in Title 13, California Code of Regulations. These standards, as mentioned above, are based on the EPA Tiered Standards. The primary purpose of the CI Engine ATCM is to reduce PM emissions from diesel engines 50 bhp or greater. The ATCM affects two main types of CI engines: emergency standby engines and prime use engines. The CI Engine ATCM emissions standards for these engines, which reflect the EPA Tiered PM and NOx standards, are summarized in Table 12.

TABLE 12
CI Engine ATCM PM and NOx Emission Standards for Diesel Engines of 50 bhp or Greater[10]

<table>
<tr><th>Engine Type</th><th>Maximum Hours of Operation</th><th>PM Standard (g/bhp-hr)</th><th>NOx Standard (g/bhp-hr)</th><th>Compliance Date by Model Year</th></tr>
<tr><td rowspan="2">New Emergency Standby</td><td>District Discretion up to 50</td><td>≤ 0.15</td><td rowspan="2">EPA Tier 1</td><td rowspan="2">January 1, 2005</td></tr>
<tr><td>District Discretion up to 100</td><td>≤ 0.01</td></tr>
<tr><td rowspan="4">In-Use Emergency Standby</td><td>20*</td><td>Not limited by ATCM</td><td rowspan="4">No increase above baseline</td><td rowspan="5"><u>Pre-89 thru 89</u>
1/1/2006

<u>90 to 95</u>
1/1/2007

<u>96 thru Post-96</u>
1/1/2008</td></tr>
<tr><td>30*</td><td>≤ 0.40</td></tr>
<tr><td>50*</td><td>≤ 0.15</td></tr>
<tr><td>100*</td><td>≤ 0.01</td></tr>
<tr><td>In-Use Prime (≤ 3 engines)</td><td>Unlimited</td><td>≤ 0.01</td><td>No increase above baseline</td></tr>
<tr><td>In-Use Prime (4 or more engines)</td><td>Unlimited</td><td>≤ 0.01</td><td>No increase above baseline</td><td>1/1/2006 thru 1/1/2009 depending on model year</td></tr>
<tr><td rowspan="2">Uncertified Prime Engines</td><td rowspan="2">Unlimited</td><td>30% reduction</td><td rowspan="2">No increase above baseline</td><td>January 1, 2006</td></tr>
<tr><td>≤ 0.01</td><td>July 1, 2011</td></tr>
</table>

* Maintenance and testing hours, no limits on hours of operation for emergency use.

The CI Engine ATCM will significantly affect all stationary diesel engines in the District of 50 bhp or more. The staff report that accompanied the proposed CI Engine ATCM and ARB staff[19] indicate that most of the existing prime diesel engines will have to be either replaced or retrofitted to meet the PM emission limit of 0.01 g/bhp-hr. This means that of the 4776 stationary diesel engines in the District, over 400 prime engines will have to be replaced to comply with the CI Engine ATCM. The remaining 4364 emergency standby engines will either have to reduce the allowed maximum hours of non-emergency operation to less than 20 hours or comply with one of the PM emissions limits listed in Table 12.

All engines must be in compliance with the ATCM no later than July 2011, with earlier compliance dates for specific engine/use categories as shown in Table 12.

D. Other California District Rules

District Rule 9-8 regulates NOx emissions from gaseous-fueled stationary IC engines that have an output of 250 bhp or more. Under the rule, engines fired with fossil-derived fuels must meet a NOx limit of 56 ppm if rich burn and 140 ppm if lean burn. Engines fired with waste-derived fuel must meet a NOx limit of 140 ppm if lean burn and 210 ppm if rich burn. However, since the rule was adopted in 1993, several air districts – San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD), the South Coast Air Quality Management District (South Coast AQMD), and Ventura County Air Pollution Control District (Ventura County APCD) – have adopted NOx emission standards for stationary IC engines. These standards reflect the most current State and federal standards that address NOx and PM emissions from CI engines.

A few general observations can be made from a review of the various rules and regulations affecting stationary IC engines in California.

1. The emission limits affect engines that are 50 bhp or greater in size. (District Rule 9-8 has emissions limits for engines 250 bhp and greater.)
2. There is a significant distinction made between compression ignition (diesel) engines and spark ignited engines.
   a. NOx emissions limits for diesel engines reflect the federal off-road tiered emission standards; however, the standards are applied to earlier engine models (Tier 1 or 2) and may be implemented sooner than required for comparable engines by the federal standards.
   b. Emissions limits for spark-ignited engines range between 25 ppm and 125 ppm, depending on the engine type (two- or four-stroke), air/fuel ratio (lean or rich burn) and the source of fuel use (fossil or waste) and are based on the NOx emission limits published in the ARB's BARCT Determination for Stationary IC Engines.
3. All emergency standby engines are exempt from emissions limits, providing the annual operating time for testing and maintenance is limited to 50 hours or less.
4. As per State Law (H&SC 41750, et seq.), all portable engines in the state are exempt from district emissions limits provided the engine is registered with the district under the Portable Equipment Registration Program (PERP)[20].

Overall, the most stringent California air district rule addressing NOx emissions from IC engines is South Coast AQMD Rule 1110.2. Rule 1110.2 requires that all diesel engines meet a NOx emission reference limit of 45 ppm for engines less than 500 bhp and 36 ppm for engines of 500 bhp or more. These emissions limits are actually reference limits that may be increased to account for an engine's ability to convert heat into work. As the thermal efficiency of the engine increases above the baseline level of 25 percent, the allowable NOx limits may increase proportionally and should not exceed 160 percent of the above referenced levels.

Furthermore, Rule 1110.2 includes requirements for portable engines that are not registered under the State portable engine registration program.

V. DRAFT REGULATORY AMENDMENTS

Staff has drafted proposed amendments that would change the current rule in three primary ways. First, the emission limits Rule 9-8 would be expanded to apply to IC engines in the range of 50 to 250 bhp. Currently, emission limits of the rule apply only to engines of 250 bhp or more. Second, the amendments propose to include liquid-fueled engines, such as diesel-fired engines. The emission limits of the rule currently only apply to gaseous-fueled engines, which are primarily natural gas- and LPG-fueled engines. Finally, the NOx emissions limits would be reduced to reflect the most stringent limits in the State.

The most stringent NOx standards for diesel engines are the EPA Off-Road Tier 4 final emission standards. The most stringent emission limits for both gaseous- and other liquid-fueled engines are found in the ARB RACT / BARCT determinations for spark-ignited engines that serve as the basis for the emissions limits for spark-ignited engines. [3,12]

The draft amendments reflect emission limits achievable with the most stringent demonstrated retrofit control technology available for spark-ignited engine sizes of 50 bhp or greater. The draft amendments would also incorporate the more stringent future-effective EPA standards for diesel engines. Existing spark-ignited engines would have to be in compliance with the more stringent standards by 2011. Operators of existing prime diesel engines would be provided the option of complying in one of three ways:

1. Limit hours of operation to 20 or less;
2. Compliance with the EPA Tier 3 or Interim Tier 4 Standards for NOx and CO by 2011; or
3. Compliance with the more stringent EPA Final Tier 4 Standards for NOx and CO by 2016 provided the engine model year is 1996 or later.

Emergency standby engines would be exempt from the draft emissions limits as long as non-emergency operation was limited to 20 hours per year. This reflects the exemption criterion for emergency standby engines in the CI Engine ATCM.

Requiring compliance with the EPA Tier 3 or Interim Tier 4 standards for NOx and CO would ensure that operators replacing or retrofitting engines for compliance with the CI Engine ATCM would also meet the federal NOx and CO emissions standards for new engines. The EPA standards only affect new diesel engines and only 50 percent of new engines offered for sale in each model year are required to meet those standards. Further, because compression-ignited engines generally have long operating lives (10 to 20 years[10]), there is the possibility that facilities could operate diesel engines for many years to come that emit higher levels of NOx than is specified in the EPA Tiered Standards.

The proposed amendments would allow the operators of compression-ignited engines no older than model year 1996 until 2016 to comply with the emissions limits of the rule. The final Tiered standards for NOx and CO begin to take effect starting in 2013[ii]. This extra time would provide an opportunity for the operators of more recently purchased engines to recoup most of the useful operating life of their diesel engines. There is debate about whether technology that would be capable of meeting the Tier 4 final standards (0.3 g/bhp-hr or less for engines of 75 bhp or greater) will exist by the time these more stringent limits become effective. According to the Engine Manufacturers Association, currently no engine is manufactured that can meet these standards,[21] however, engine manufactures are working to develop such technology.[iii]

The proposed amendments are discussed below and the proposed emissions limits for stationary IC engines of 50 bhp or greater are summarized in Table 13.

[ii] Tier 4 Final NOx emission standards initially take effect for engines sizes of 50 to 75 bhp beginning with the 2013 model year; however, these limits are equivalent to the Tier 3 and Tier 4 Interim emission limits for larger sized engines (50 to 100 bhp) for which there is technology currently available to meet these limits. The standards are for NMHC and NOx combined.

[iii] It should be noted that this potential issue only affects engines of operators who chose to comply with the above alternative compliance option. If, at the time the provision would take, there is still not technology available to meet the final Tiered standard, the engine would have to comply with the most stringent NOx standards available at that time, which would be best available control technology or BACT.

TABLE 13
Summary of Proposed Emission Limits for Existing Stationary IC Engines[a]

Engine Fuel Type	Emission Limits (g/bhp-hr)	Compliance Dates
Compression-Ignited[b] (All model years)	0.50 - 2.6	2011 - 2012
Compression-Ignited[c,d] (1996 or later compliance option)	0.30 - 0.50	2016
Spark-Ignited Gaseous & Liquid[e]	0.36 (rich) 1.0 (lean)	2011
Spark-Ignited[e] Waste Gas	0.70 (rich) 1.0 (lean)	2011

a. Engines 50 bhp or greater in size.
b. Federal off-road Tier 4 Interim NOx emissions standards for compression ignition engines.
c. Alternative compliance option only for diesel engines of model year 1996 or later.
d. Federal off-road Tier 4 Final NOx emissions standards for compression ignition engines.
e. The California Air Resources Board (ARB) Determination of Reasonably Available Control Technology and Best Available Control Technology for Stationary Spark-Ignited Internal Combustion Engines.

A. General

Section 9-8-110 exempts engines of less than 250 bhp. That would be changed such that engines between 50 and 250 bhp will have to comply with the emissions limits of the rule. This would apply to both liquid- and gaseous-fueled stationary engines.

Section 9-8-111 would reduce the exemption for engines that operate for limited hours from 100 or 200 hours to 50 hours to reflect the exemption for emergency standby engines.

Section 9-8-112 would exempt any portable engine registered under the Regulation to Establish a Statewide Portable Equipment Registration Program (Portable Equipment Registration Program), Article 5, sections 2450 – 2465, Title 13, CCR.[22] Any portable engine that was not registered under this program would be subject to the requirements of Rule 9-8 pursuant to section 2451(e) of the Portable Equipment Registration Program.

B. Definitions

Section 9-8-234 would define the term "new compression-ignited engine" as a compression-ignited engine of model year 2008 or later. This definition is necessary for new engines that would replace existing engines that do not comply with the Tier 3 or Tier 4 interim standards.

Section 9-8-235 would define the term “portable” in a manner similar to the definition used in the Portable Equipment Registration Program.

Section 9-8-236 would define the term “unforeseeable,” which is included in the exemption for emergency use. The addition of this term aligns the definition with the CI Engine ATCM.

C. Standards

Sections 9-8-301 and 302, which currently contain emissions limits for gaseous fossil fuel- and waste fuel-powered spark-ignited engines, would be changed to include both liquid- and gaseous-fueled engines. Further, the emissions limits would be changed according to the limits above in Table 13 and would be expressed in grams per brake-horse power (g/bhp) instead of the current parts per million (ppm) concentrations.

Section 9-8-303 would specify the emissions limits and compliance dates for existing CI engines and compliment the CI Engine ATCM adopted by the ARB.

Section 9-8-304 is included as an alternative to compliance with the emission limits in section 9-8-303 for engines between 75 and 750 bhp and model year 1996 or newer. This section would allow these engines to operate for an additional four to five years beyond the compliance dates specified in Section 9-8-303. However, these engines would ultimately have to comply with more stringent NOx standards by January 2016.

Section 9-8-305 would be added to set emissions limits for new compression-ignited engines. The section would require new engines to be certified to meet the federal Off-Road Tiered Standards for NOx and CO starting January 2008.

D. Administrative Requirements

Section 9-8-401 sets a compliance schedule such that the compliance dates for authorities to construct (District permits) would reflect new compliance dates listed in the sections on emissions limits.

Section 9-8-402 was added to require the operator of a CI engine who opted to comply via section 9-8-304, the delayed compliance option for selected engines, to notify the District of that intention. The notification to the District would also include information about the facility and the engine.

E. Monitoring and Records

Section 9-8-501 would be changed to reflect the need for an initial demonstration of compliance with the new emission limits. The new dates would be no later than three months following the various compliance dates listed in section 9-8-301. This section also includes the dates by which the demonstration of compliance must be submitted to the District.

Section 9-8-502, the section on recordkeeping, would be changed to include requirements to maintain records for both the initial and annual demonstrations of compliance.

Section 9-8-503 has been added to require an annual demonstration of compliance. This requirement is intended to ensure continued compliance with the emission limits.

VI. EMISSIONS REDUCTIONS

The emissions reductions presented in this section are based on the estimated differences in emissions from the application of the current version of Rule 9-8 and the proposed amendments. The amendments fall into three general categories:

1. Reduction of emission limits for gaseous-fired spark-ignited engines;
2. Addition of NOx emissions limits for certain engines such as liquid-fired compression-ignited and spark-ignited engines (which include diesel- and gasoline-powered engines) and all engines between 50 and 250 bhp; and
3. Reduction in the hours of operation for emergency standby and limited use engines.

A. NOx Emission Reductions

Table 14 presents estimates of current and expected NOx emissions from the implementation of the proposal; Table 15 summarizes the NOx emissions reductions and percent reductions that would be expected from the implementation of the proposal.

TABLE 14
NOx Emissions by Fuel Used and Engine Type for the Current and Proposed Amendments to Rule 9-8

	Engine Type					
	Emergency Standby (tpd)		**Prime** > 50 bhp (tpd)		**Total** (tpd)	
Fuel	Current	Proposal	Current	Proposal	Current	Proposal
Diesel (incl. Bio Diesel)	4.5	3.3	5.1	0.5	9.6	3.9
Natural Gas	0.05	0.03	3.3	1.0	3.4	1.1
Landfill Gas	0.0	0	4.3	1.3	4.3	1.3
Digester Gas	0.0	0.0	3.5	1.2	3.5	1.2
LPG	0.01	0.006	0.002	0.001	0.01	0.007
Gasoline & Other Liquids	0.004	0.002	0.025	0.001	0.03	0.003
Propane & Other Gases	0.001	0.0	0.0	0.0	0.001	0.0
Emissions Totals	**4.6**	**3.4**	**16.2**	**4.0**	**20.8**	**7.5**

TABLE 15
NOx Emissions Reduction and Percent Reduction Due to the Proposed Amendments to Rule 9-8

Engine Use Category	**Emission Reductions** (tpd)	**Percent Reduction**
Emergency Standby	1.2	26%
Prime	12.2	75%
Total Reduction	**13.4**	**64%**

B. PM Emission Reductions

PM emission reduction estimates are wholly attributable to the reduction of secondary formation of PM from primary NOx emissions. This is because the proposal does not directly impact primary PM emissions from spark-ignited engines. This means that the primary PM emission for spark-ignited engines under the proposal would be the same as those under the current rule. The implementation of the CI Engine ATCM will significantly reduce PM emissions from CI engines, but this proposal does not include reductions attributable to the ATCM. Table 16 presents estimates of current and expected PM emissions from the implementation of the proposal; Table 17 summarizes the PM emissions reductions and percent reductions that would be expected from the implementation of the proposal.

TABLE 16
PM Emissions by Fuel Used and Engine Type for the Current and Proposed Amendments to Rule 9-8

	Engine Type					
	Emergency Standby (tpd)		Prime > 50 bhp (tpd)		Total (tpd)	
Fuel	Current	Proposal	Current	Proposal	Current	Proposal
Diesel (incl. Bio Diesel)	0.45	0.33	0.5	0.06	0.96	0.39
Natural Gas	0.006	0.004	0.37	0.15	0.38	0.15
Landfill Gas	0.0	0.0	0.45	0.15	0.45	0.15
Digester Gas	0.007	0.0	0.72	0.50	0.73	0.50
LPG	0.002	0.0006	0.0002	0.0001	0.001	0.001
Gasoline & Other Liquids	0.002	0.002	0.003	0.002	0.001	0.0
Propane & Other Gases	0.0001	0.0	0.0	0.0	0.0001	0.0
Emissions Totals	**0.5**	**0.3**	**2.0**	**0.9**	**2.5**	**1.2**

TABLE 17
PM Emission Reduction and Percent Reduction Due to the Proposed Amendments to Rule 9-8

Engine Use Category	**Emission Reductions** (tpd)	**Percent Reduction**
Emergency Standby	0.2	40%
Prime	1.1	55%
Total Reduction	**1.3**	**52%**

C. Methodology Used to Estimate Emission Reductions

The emissions reduction estimates from the application of the proposal were made using the following approach.

1. BACT emissions limits were applied to engines designated as equipped with BACT.
2. Engines listed as emergency standby were limited to 50 hours per year of non-emergency use and the emissions were estimated using baseline emissions factors (Tier 1 or 2 for compression-ignited engines and uncontrolled for sparked-ignited engines).
3. The remaining engines were assumed to be prime engines and not subject to BACT. The applicable emission limits of the current rule and the proposal were applied.

It should be noted that the air-to-fuel ratios of most of the spark-ignited engines were not listed in the database; however, from the fraction of engines with rich or lean burn designations and discussions with staff from other air districts,[23,24,25] a ratio of 80:20 was assumed for the ratio of rich-burn to lean-burn engines. Emission limits for both rich burn and lean burn engines were applied to all spark-ignited engines and the resulting emission totals weighted accordingly (rich burn – 80 percent and lean burn 20 percent). Further, staff assumed an overall engine load factor of 100 percent. Actual loads may be lower (ranging between 50 to 80 percent) and the emissions would decrease proportionately.

VII. COST ESTIMATES

The potential cost estimates presented in this section were based on compliance through the application of either:

1. Selective catalytic reduction (SCR) technology to compression-ignited and lean-burning spark-ignited engines, or
2. Non-selective catalytic reduction (NSCR) technology to rich-burning spark-ignited engines combined with air-fuel ratio controller (AFRC).

Table 18 provides a summary of the estimated costs for both SCR and NSCR + AFRC.

TABLE 18
Approximate Cost Estimates per Brake Horsepower for NSCR + AFRC and SCR [3,15, 25]

Horsepower Range	NSCR + AFRC	SCR
50-150	$200	$510
151-300	$120	$225
301-500	$75	$170
501-1000	$55	$225
1001-1500	$50	$170
1501-2000	$50	$135
2001-3000	$50	$100

In developing the cost estimates, staff assumed a worse case cost scenario in which all affected engines irrespective of their compliance status with the current Rule would have to be retrofitted with SCR or NSCR to meet the emissions limits.[iv] Emergency standby engines were assumed to comply by a reduction of operating hours, which should result in a cost savings. (However, the cost

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[iv] Many IC engines in the Bay Area may already be equipped with control technology that may be capable of meeting the emission limits of the proposal and, therefore, would not have to incur the cost of installing additional retrofit control technology.

estimates do not account for any potential savings.) Engines equipped with BACT were assumed to be able to meet the emission limits of the proposal and, therefore, would not incur any cost due to the proposal. The cost of controls was amortized over ten years at seven percent annual interest.

The compliance costs for diesel engines, which are listed in Table 19, reflect only the cost of installation of SCR on prime diesel engines. The costs do not account for the potential cost of compliance with the CI Engine ATCM, which would most likely result in the replacement or retrofit (with diesel particulate filters) of all prime diesel engines. Because the owners of diesel engines would have to comply with the ATCM independently of Rule 9-8 through replacement or retrofit, those costs are not included in the cost analysis for this proposal.

TABLE 19
Total Annualized Capital Cost Estimates for Compliance with the Proposal

Fuel Type	Totals
Diesel (incl. Bio Diesel)*	$2,800,000
Natural Gas	$1,300,000
Landfill Gas	$970,000
Digester Gas	$440,000
LPG	$141,000
Gasoline & Other Liquids	$12,000
Propane & Other Gases	$4,300
Total	**$5,670,000**

* These costs do not include the cost of compliance with the CI Engine ATCM.

VIII. CLIMATE CHANGE AND GREEN HOUSE GAS EMISSIONS

The District Climate Protection program encourages reductions in greenhouse gas emissions such as carbon dioxide (CO_2). To this end, the draft emissions limits shown in Table 13 are listed in grams per brake horse power-hour (g/bhp-hr). Listing the limits using g/bhp-hr incorporates an incentive to run an IC engine in an energy efficient manner. This is because as the efficiency of the engine decreases, it becomes increasingly difficult to achieve the proposed emissions standard, which is based on mass emissions per energy output. The opposite is true for emissions limits based in parts per million (ppm) as in the current version of Rule 9-8. The mass emissions rates of both NOx and CO_2 may increase as the energy efficiency of an engine decreases, even though the engine can continue to achieve the concentration-based ppm emissions limit. To encourage affected engines continue to operate in an energy efficient manner and, thereby reduce, or at least not increase, CO_2 emissions, staff proposes emissions limits in terms of grams per brake horsepower-hour.

IV. RULE DEVELOPMENT / PUBLIC CONSULTATION PROCESS

This report and associated Public Workshop comprise the latest step in the District's rule development process for Rule 9-8. District staff has met with industry representatives including California Council for Environmental and Economic Balance, consulted with engine manufacturers, other air district personnel and ARB staff members to gather information compiled in this report.

District staff also collected information on each of the 5450 IC engines in the Bay Area that enabled estimates of emissions, emission reductions and costs.

The purpose of the Public Workshop is to solicit comments from the public on the proposed amendments to Rule 9-8. During the workshop, staff will also respond to questions about information presented in the Workshop Report. Based on the input received at the workshop and during the associated public comment period, staff will assess whether changes to the proposal are necessary prior to preparing final proposed amendments for consideration at a public hearing before the District's Board of Directors.

VII. REFERENCES

[1] Final Rule; Control of Emissions of Air Pollution from Nonroad Diesel Engines; 40 CFR Parts 9, 86, and 89.

[2] Final Rule; Control of Emissions of Air Pollution from Nonroad Diesel Engines; 40 CFR Parts 9, 69, et seq.

[3] Determination of Reasonably Available Control Technology and Best Available Control Technology for Stationary Spark-Ignited Internal Combustion Engines, ARB, November 2001.

[4] Airborne Toxic Control Measure for Stationary Compression Ignition Engines, section 93115, title 17, California Code of Regulations.

[5] SB 656 Particulate Matter Implementation Schedule, BAAQMD, November 2005.

[6] Rule Development Staff Report, Regulation 9, Inorganic Gaseous Compounds, Rule 8, Nitrogen Oxides and Carbon Monoxide from Stationary Internal Combustion Engines, BAAQMD, November 1992,

[7] "Emission Control Technology for Stationary Internal Combustion Engines" MECA, July 1997.

[8] "Risk Reduction Plan to Reduce Particulate Matter Emissions from Diesel-Fueled Engines and Vehicles," ARB, October 2000.

[9] "Guidance for the Permitting Generation of Electrical Generation Technologies," ARB, July 2002.

[10] Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Airborne Toxic Control Measure for Stationary Compression-Ignition Engines, Stationary Source Division, ARB, September 2003.

[11] Internal District Memorandum, A First Look at NOx/ammonium nitrate tradeoffs, David Fairley, September 8, 1997.

[12] DRAFT CAPCOA/ARB Proposed Determination of Reasonably Available Control Technology and Best Available Control Technology for Stationary Internal Combustion Engines, December 1997.

[13] Diesel Progress North American Edition, June 2000.

[14] Diesel Retrofit Technology for Clean Air, MECA, 2005. http://www.meca.org/page.ww?name=Home&section=Diesel+Retrofit+Subsite

[15] Letter from Timothy A. French of the Engine Manufactures Association to Mr. John D. Barnes, P.E., New York State Department of Environmental Conservation, March 4, 2003.

[16] Appendix II, Stationary and Portable Diesel-Fueled Engines: Appendix to the Diesel Risk Reduction Plan. October 2000.

[17] Diesel Progress North American Edition, September 2003.

[18] Guidance for the Permitting of Electrical Generation Technologies.

[19] Conversation with ARB staff member, Ron Hand, June 21, 2006.

[20] Portable Equipment Registration Program (PERP), Article 5, title 13, sections 2450 through 2465, California Code of Regulations.

[21] Joe Suchecki, Engine Manufacturers Association, Email to Victor Douglas, August 25, 2006.

[22] Regulation to Establish a Statewide Portable Equipment Registration Program, Article 5, sections 2450-2465, Title 13, California Code of Regulations.

[23] Marty Kay, South Coast Air Quality Management District, Phone conversation with Victor Douglas, August 30, 2006.

[24] Keith Duval, Ventura County Air Pollution Control District, Phone conversation with Victor Douglas, August 30, 2006.

[25] Saul Gomez, San Joaquin Valley Unified Air Pollution Control District, Phone conversation with Victor Douglas, August 30, 2006.