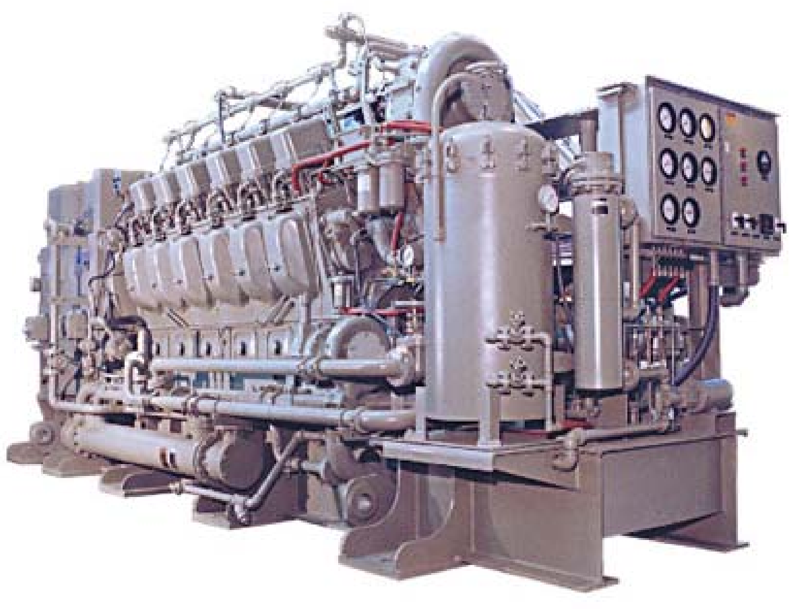
Bay Area Air Quality Management District

939 Ellis Street
San Francisco, California 94109

Staff Report

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



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Prepared By

Victor Douglas
Senior Air Quality Engineer
Planning, Rules and Research Division

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

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I. EXECUTIVE SUMMARY

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 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). Amendments to Rule 9-8 were identified in the District's Senate Bill (SB) 656 Particulate Matter Implementation Schedule. In addition, Further Study Measure 15 from the 2005 Ozone Strategy is a commitment to consider the feasibility of further reducing NOx emissions from stationary internal combustion (IC) engines.

A. Stationary IC Engines and Their Emissions

Stationary IC engines are typically used as either primary or 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 pollutants such as NOx, PM and carbon monoxide (CO) as well as toxic pollutants. 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 14.8 tons per day (tpd) of NOx; diesel-fueled engines are responsible for about 6.8 tpd of those emissions. Total PM emissions from stationary IC engines amount to 2.6 tpd; with primary (directly emitted) PM emissions being 0.8 tpd (the vast majority of primary PM emissions from stationary IC engines being attributable to diesel engines) and secondary PM emissions (due to NOx[i]) totaling about 1.8 tpd. CO emissions total approximately 5.1 tpd.

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 engines 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 (Table 1)

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

summarizes the current NOx emission limits for gaseous-fueled IC engines of 250 bhp or greater.

TABLE 1
Rule 9-8 Current Emissions Limits for NOx

Fuel Type	NOx Emission Limits (ppmv)	
	Rich Burn	**Lean Burn**
Fossil Fuels	56	140
Waste Gas	210	

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

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

The EPA NSPS for Off-Road Compression-Ignited Engines: In 1998 and 2004, the EPA promulgated the Off-Road Compression-Ignition (Diesel) Engine Tiered Standards.[1,2] These tiered standards are combined into what is currently the Standards of Performance for New Stationary Compression-Ignition Internal Combustion Engines (Off-Road CI Engine NSPS)[3]. These standards apply to new diesel engines and become progressively more stringent as model years advance.

The ARB BARCT Determinations: In 2001, ARB published best available retrofit control technology determinations (BARCT) for spark-ignited stationary IC engines.[4] The BARCT determinations set recommended NOx limits for the retrofit of stationary spark-ignited engines.

The ARB CI Engine ATCM: In addition, in 2004, 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.[5] 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: 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 CI Engine NSPS, including NOx limits for liquid-fueled engines.

D. Proposed Amendments

The proposed amendments to Rule 9-8 are a further step towards reducing NOx and PM 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. The proposal would:

1. Expand the scope of the rule to regulate NOx emissions from smaller gaseous-fueled stationary IC engines that are larger than 50 brake horse power (bhp),
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 2 provides a summary of the NOx emissions limits and compliance schedule that District staff is proposing for incorporation into Rule 9-8. The NOx emissions limits are based on several federal, State, and California air district rules and regulations implemented since the 1993 adoption of Rule 9-8.

TABLE 2
Summary of Proposed NOx Emission Limits for
Existing Prime IC Engines

Engine Type and Fuel	Existing Engines	
	Emission Limits (ppmv, dry @ 15% O_2)	Compliance Dates
Compression-Ignited (All Engines 51 to 175 bhp)	180	January 2012
Compression-Ignited (All Engines greater than 175 bhp)	110	January 2012
Compression-Ignited (Alt. limits for 1996 or later)	22 or BACT at time of compliance	January 2016
Spark-Ignited: Gaseous & Liquid	25 (rich[a]) 65 (lean[b])	January 2012
Spark-Ignited Waste Gas	70	January 2012
Spark-Ignited (Alt. limits for 1996 or later or sized less than 250 bhp)	BACT at time of compliance	January 2016

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.

Some of the smaller engines in the 50 to 250 bhp size range utilize the waste heat for water and space heating, thereby improving the overall thermal efficiency of the engine and reducing the need for additional energy usage for heating. Because these engines account for a small fraction of the total emissions and also because the engines are often operated by smaller facilities, the District proposes to allow these operators additional time to recoup the useful life of their engines and to prepare financially to replace these engines with ones that would meet stricter emissions levels at the time of replacement. As Table 2 indicates, these smaller engines (50-250 bhp) would be allowed the option of a January 2016 compliance date, provided the engines meet BACT emissions levels at the time of compliance.

The proposed amendments would reduce NOx emissions from stationary IC engines by 9.6 tpd, which is approximately a 65 percent emission reduction. Secondary PM emissions would be reduced by 1.2 tpd, which is about a 66 percent reduction.

A socioeconomic analysis of the proposed rule amendments concludes that they would not have significant socioeconomic impacts. An initial study of the proposed amendments concludes that there would not be significant adverse environmental impacts, and a California Environmental Quality Act (CEQA) Negative Declaration is proposed for the amendments.

In developing these amendments, staff consulted with various stakeholders, including operators at affected facilities, industry associations representing engine operators, engine manufacturers and distributors, other air districts, the ARB, and the EPA.

II. BACKGROUND

Stationary IC engines directly emit NOx and PM emissions. The NOx emitted contributes to ozone formation and is also responsible for secondary PM formation. These engines also emit hydrocarbons (HC) and CO. Ozone is formed from the reaction of NOx and HC. The formation of particulate matter from NOx through chemical reactions is termed "secondary PM formation."[ii] Reducing NOx emissions would help to reduce secondary PM formation and also would help reduce ozone formation. Ozone, CO and PM are criteria pollutants that are subject to District and State regulation. Ozone can result in reduced lung function, increased respiratory symptoms, increased airway hyperreactivity, and increased airway inflammation. Emissions of VOCs also react in the atmosphere to form PM_{10} and $PM_{2.5}$. Inhalation of PM_{10} and $PM_{2.5}$ deep into the lungs reduces human pulmonary function.

[ii] 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 addition to reacting with HC to form ozone, reacts in the atmosphere to form PM – both PM_{10} (ten microns (μm) or less in size) and $PM_{2.5}$ (2.5 μm or less).

The Bay Area is currently in attainment of the federal PM_{10} standard; but, like most of the State, is designated as non-attainment for the State PM_{10} and $PM_{2.5}$ standards. The Bay Area also is a non-attainment area for the State ozone standards. The Bay Area has not yet been designated for the new federal $PM_{2.5}$ standard. It is important to reduce the public's exposure to these compounds to minimize their adverse health effects. Further reducing NOx and PM emissions from stationary IC engines will help protect public health and comply with State law requiring that the region make progress in reducing ambient ozone and PM levels.

A. What Are Stationary IC Engines?

IC engines generate power through an 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 brake horsepower[6]) 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 hydrocarbons, 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 engine. This term is normally used to refer to internal combustion engines where the air-fuel mixture is ignited with a spark. The term contrasts with CI engines, where the heat from compression alone ignites the mixture. Most spark-ignited engines burn fuels such as natural gas, propane, or waste gas (digester and landfill gases). Natural gas fired spark-ignited engines are the second largest category of stationary IC engines in the Bay Area. These engines operate as either rich-burn (excess fuel) or lean-burn (excess air).

B. How Are Stationary IC Engines Categorized?

Stationary IC engines can be used as emergency standby engines, prime engines that operate more or less continuously, and low usage engines that operate only occasionally in non-emergency situations.

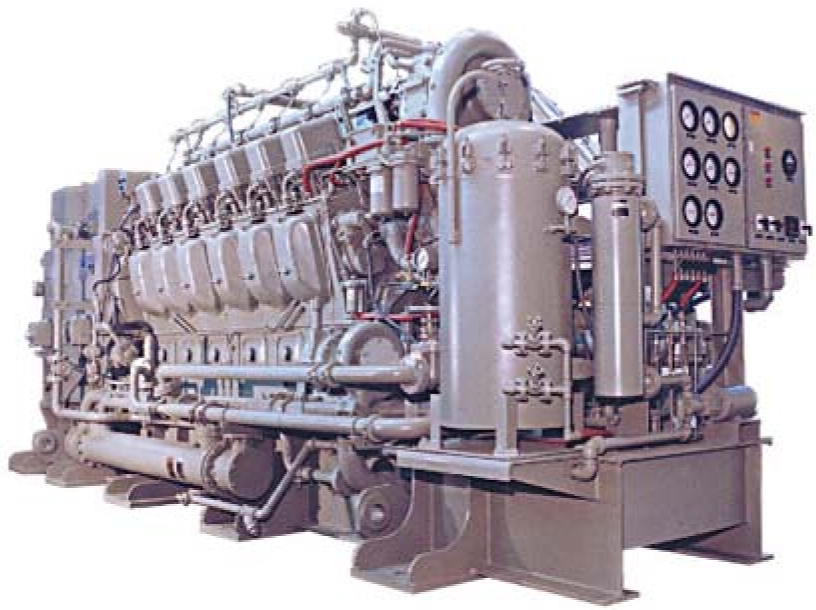
Emergency Standby Engines: Emergency standby engines are typically used for emergency back-up electric power generation or the emergency pumping of water. In the District, there are almost 4700 emergency standby engines ranging in size from less than 10 bhp to almost 4000 bhp. Currently, Rule 9-8 exempts these engines from emission standards, provided the annual hours of operation for reliability testing and maintenance do not exceed 100 hours. 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 400 prime engines within the District. These engines are used primarily to generate electricity, or to power compressors, pumps, cranes, generators, and grinders[7]. 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.

Low Usage Engines: Low usage engines are prime engines that operate less than a hundred hours per year and are often used as non-emergency back up engines or for very limited purposes. There are 279 prime engines that currently operate less than 100 hours per year. This number is expected to increase once the proposal is implemented because one of the means of compliance is by limiting the operation of an engine to less than 100 hours per year.

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

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

C. What Is Prompting this Rulemaking?

PM 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 the 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 listed 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 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 amendments to Regulation 9, Rule 8 (Rule 9-8) as one of several measures to be considered to reduce PM levels in the Bay Area.[8] PM is of concern because it can enter nasal passages and the lungs and cause serious health effects such as aggravated asthma, nose and throat irritation, bronchitis, lung damage, and premature death. People with respiratory illnesses, children and the elderly are more sensitive to the effects of PM, but it can affect everyone.

<u>Ozone Attainment</u>: 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 health effects of ozone are well documented. It causes eye irritation and affects the respiratory system by irritating the mucous membranes in the nose and throat and lung tissue. Normal functioning of lungs is impaired, thus reducing the ability to perform physical exercise. These effects are more severe on people with chronic lung disease such as asthma and emphysema and on the very young, elderly, and athletes. The Bay Area Air Basin periodically experiences high ozone levels and is in non-attainment for the State one-hour and eight-hour air quality standards 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. Under Further Study Measure 15 in the 2005 Ozone Strategy, the District committed to evaluate whether further emission reductions from stationary IC engines were feasible.

<u>Emissions from Stationary IC Engines</u>: The District regulates NOx emissions from stationary IC engines under Rule 9-8, which imposes NOx limits on engines powered with gaseous fuels. Rule 9-8 was adopted in 1993 pursuant to the 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 reduced NOx emissions from these engines by 8.3 tons per day (tpd)[9]. 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 a significant portion of the NOx emissions. Collectively, the total current inventory of NOx emissions from stationary engines in the Bay Area is estimated to be 14.8 tpd. The NOx emitted from stationary diesel engines is estimated to be 6.8 tpd, which is about 46 percent of the 14.8 tpd total. Total PM emissions from stationary IC engines amount to 2.6 tpd; with primary (directly emitted) PM emissions being 0.8 tpd (the vast majority of primary PM emissions from stationary IC engines being attributable to diesel engines). Secondary PM emissions (due to NOx) total about 1.8 tpd. CO emissions total approximately 5.1 tpd.

D. Inventory of Engines

There are almost 5500 stationary internal combustion engines located within the District; of this amount, 5336 engines are larger than 50 bhp and are permitted by 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. These fuels can be separated into three main categories: compression-ignited fuels, spark-ignited fossil fuels, and spark-ignited waste gases. Table 3 provides an inventory of the types of fuel used and the numbers of engines that are powered by each main fuel type.

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

Fuel	Emergency Standby	Low Usage (≤ 100 hrs/yr)	Prime (>100 hrs/yr)	Totals
Compression-Ignited Fuels: Diesel, Bio-Diesel, Fuel Oil, Jet Fuel, Distillate Oil	4312	263	135	4710
Spark-Ignited Fossil Fuels: Natural Gas, CNG, LPG, Gasoline, Propane, Hydrogen	329	16	178	523
Spark-Ignited Waste Gases: Landfill Gas, Digester Gas,	3	0	100	103
Totals	**4644**	**279**	**413**	**5336**

* Engines larger than 50 bhp.

Table 4 illustrates the variety of uses of the stationary IC engines and the populations of engines associated with each use category.

TABLE 4
Population of Engines by Primary Use and Engine Type

Engine Use	**Engine Type**			
	Emergency Standby	**Low Usage** (≤ 100 hrs/yr)	**Prime** (>100 hrs/yr)	**Totals**
Electrical Generation	4305	143	138	4586
Co-Generation	2	0	144	146
Pump Driver	47	2	2	51
Fire Pump Driver	48	0	0	48
Process Heater	6	0	2	8
Testing	3	0	2	5
Space Heater	4	0	1	5
Waste Disposal	0	0	3	3
Compressor Driver	0	1	1	2
Other	229	133	120	482
Totals	**4644**	**279**	**413**	**5336**

III. CONTROL TECHNOLOGY

This section discusses the various emission reduction technologies available for stationary IC engines.

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 methanol or clean diesel fuel, which is mandated by the CI Engine ATCM. One of 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 using a noble metal catalyst that reduces NOx, CO and hydrocarbons. The first process is referred to as Selective Catalytic Reduction (SCR). The second process is referred to as Non-Selective Catalytic Reduction (NSCR). Another NOx reduction technology is called Selective, Non-

Catalytic Reduction (SNCR). It reduces NOx emissions without a catalyst by injecting urea and fuel into a heated muffler-sized reactor to reduce NOx into nitrogen gas.

Table 5 presents a summary of these various technologies that includes affected engine type, approximate effectiveness over uncontrolled emissions, cost estimates, and a general description.

TABLE 5
Summary of NOx Emission Control Technologies for Stationary IC Engines

Control Technology	Engine Types	Compounds Affected	Effectiveness[a]	Capital Costs[b]	Description
Non-Selective Catalytic Reduction (NSCR) [4,6,10,11,12, 13]	Rich Burn & Stoich SI Engines	NOx, CO, HC	NOx: >98% CO: >97% HC: >80%	\$50-200/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)[4,6,10,11 ,12,13]	Lean Burn SI Engines	NOx, CO, HC	NOx: >95% CO: >97% HC: >80%	\$135-510/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 Non-Catalytic Reduction [6,10,11,14]	CI Engines SI Engines (Retrofits)	NOx, PM, CO, HC	NOx: >90% PM: 60% CO: <10 ppm	\$30-155/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 °F through fuel introduction to exhaust ▪ Urea injected to reduce NOx ▪ Ammonia Slip (2 ppm)
SCR with Diesel Particulate Filtration [4,6,10,15,16]	CI Engines	NOx, PM, CO, HC	NOx: 95% (1.06 g/bhp-hr) PM: 89%	\$180-620/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[10]	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[10,16]	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[10]	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]	Capital Costs[b]	Description
"Clean Burn" Retrofit[4,6,10]	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[6,10]	SI Engines	NOx, HC, CO	NOx: 80%	$13-25/bhp	**Combustion Control:** A combination of excess air and Clean Burn Retrofit.
Fuel Switching (Methanol)[4,10]	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 reflect capital costs that were adjusted to May 2007 dollars using U.S. Department of Labor Bureau of Labor Statistics, Consumer Price Indices.

IV. PROPOSED REGULATORY AMENDMENTS

A. Background

On November 15, 2001, ARB approved the Guidance for the Permitting of Electrical Generation Technologies.[16] 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.[4]

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 Compression-Ignition New Source Performance Standards or Off-Road CI Engine NSPS. Table 6 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 6
Summary of the Off-Road CI Engine NSPS 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	**4710**

* Limits represent a combination of NMHC and NOx emissions.

The Off-Road CI Engine NSPS 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.

In 2004, ARB adopted the CI Engine ATCM. The primary purpose of the CI Engine ATCM is to reduce PM emissions from diesel engines greater than 50 bhp. The ATCM affects both emergency standby engines and prime use engines. The ATCM establishes emissions standards for diesel PM emissions, that sellers of new stationary diesel-fueled (compression-ignition) engines must meet. The ATCM also sets emissions standards and operational requirements for existing stationary CI engines. The measure 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 Off-Road CI Engine NSPS.

The CI Engine ATCM will significantly affect all stationary diesel engines in the District greater than 50 bhp. The staff report that accompanied the proposed CI Engine ATCM and ARB staff 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[17,18]. This means that, of the 4710 stationary diesel engines in the District (4312 emergency standby and 398 prime or low usage engines), just under 400 prime engines will have to be replaced or retrofitted to comply with the CI Engine ATCM. The remaining 4312 emergency standby engines will either have to reduce the allowed maximum hours of non-emergency operation to less than 20 hours per year or comply with one of the PM emissions limits listed in the ATCM. All engines must be in compliance with the ATCM no later than July 2011, with earlier compliance dates for specific engine/use categories.

Since the Rule 9-8 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 more stringent standards for IC engines. These standards reflect the EPA off-road tiered standards for CI engines and the ARB BARCT determination for stationary spark-ignited engines.

B. Proposed Amendments

The proposed amendments would change the current rule in three primary ways. First, the emission limits in 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 achievable in the State.

The proposed amendments reflect emission limits achievable with the most stringent demonstrated retrofit control technology available for spark-ignited and compression-ignited engines greater than 50 bhp:

1. Non-selective catalytic reduction (NSCR) and air-to-fuel ratio controller for rich-burn spark-ignited engines,
2. Selective catalytic reduction (SCR) for lean-burn spark-ignited engines and compression-ignited engines, and
3. Selective non-catalytic reduction (SNCR), extra lean burn conversion, or pre-stratified charge (PSC) for waste-fueled engines.

The proposed amendments would also incorporate the more stringent future-effective EPA standards for diesel engines.

The proposal would allow operators of existing prime spark-ignited engines to either:

1. Comply with the reduced emission limits for NOx by 2009; or
2. Comply with the future BACT standards for NOx and CO by 2016, provided the engine model year is 1996 or later.

The CO limits of the rule remain unchanged for spark-ignited engines; however, diesel engines would be subject to the CO levels that are provided below.

Similarly, operators of existing prime diesel engines would either:

1. Comply with NOx emission limits that range between 110 ppmv (2.5 g/bhp-hr) and 180 ppmv (3.7 g/bhp-hr) and CO emission limits that range between 310 ppmv (2.6 g/bhp-hr) and 440 ppmv (3.7 g/bhp-hr); or
2. Comply with either the EPA Final Tier 4 Standards for NOx and CO or the future BACT standard for NOx and CO by 2016 provided the engine model year is 1996 or later.

No limit is proposed on the number of hours an engine can be used in an emergency. Emergency standby engines would be exempt from the proposed emissions limits as long as reliability-related activities were limited to 50 hours per year. Low usage engines that operate no more than 100 hours for non-emergency use in a 12-month period are also exempt from the emission limits of the rule. These engines can also operate under emergency use circumstances; however, the hours of emergency use must be documented.

Because compression-ignited engines generally have long operating lives (10 to 20 years[17]), without this proposal there is the possibility that facilities could operate diesel engines that emit higher levels of NOx for many years to come. This is because the primary focus of the ATCM is PM emission reduction and it allows NOx emissions from diesel engines to remain at current levels. Requiring compliance with the NOx and CO emission levels by 2012 would allow operators replacing or retrofitting compression-ignited engines for compliance with PM standards in the CI Engine ATCM to comply with both regulations on the same schedule.

The proposed amendments would allow the operators of compression-ignited engines of model year 1996 or newer until 2016 to comply with the alternative emissions limits of the rule. The final Tiered standards of the Off-Road NSPS for NOx and CO take effect beginning in 2013[iii]. 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. Engines capable of meeting the Tier 4 final standards (0.3 g/bhp-hr (22 ppm) or less for engines of 75 bhp or greater) are not currently available[19]; however, engine manufactures are working to develop such technology.[iv] If no technology is available at the future effective compliance date, the operators would be required to comply with the best available control technology (BACT) requirements of that time. No later than January 1, 2012, the operators of these engines would need to report to the District their intent to comply with the delayed compliance standards that become effective January 1, 2016.

Operators of newer spark-ignited engines could also elect to be subject to a later compliance date. Operators of prime spark-ignited engines with a size rating between 50 and 250 bhp or engines of model year 1996 or newer would be allowed until 2016 to comply, provided the engines meet the BACT requirements in place for spark-ignited engines at the time of compliance. No later than January 1, 2012, the operators would need to report to the District their intent to comply with the compliance standards that become effective January 1, 2016. Once the initial compliance dates listed in Table 7 have passed, all engines that have not taken steps to comply with those initial emission limits would be required to comply with the BACT limits by January 1, 2016.

Prime spark-ignited engines in the range of 50 to 250 bhp account for about 29 percent of the prime spark-ignited engine population; however, these engines account for only 2.3 percent of the NOx emissions. Many of these smaller engines are often operated by facilities such as schools, retirement and nursing homes, and athletic facilities and are currently exempt from the emissions limits of the rule.

[iii] 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.

[iv] 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 effect, 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.

Some IC engines are combined heat and power (CHP) units. CHP units utilize the waste exhaust heat for water or space heating, in addition to generating electricity. These CHP units, which are typically in the 75 to 125 bhp size range, meet the requirements of the California Distributed Generation Program.[20] Because the heat recovery process is engineered directly into the units, retrofitting them with emissions control would result in a loss of a significant portion, if not all, of the heat recovery capabilities of the CHP units. Consequently, the heating capacity would have to be provided by outside power, producing more emissions elsewhere. In consideration of this, the proposed amendments allow operators of these, and other small engines, the option of additional time to comply to utilize most of the useful life and to recoup the capital cost of these engines. New CHP units are equipped with catalytic controls that will meet the standards in the proposed amendments.

The proposed emissions limits for stationary IC engines of 50 bhp or greater are summarized in Table 7.

TABLE 7
Summary of Proposed NOx Emission Limits for Existing Stationary IC Engines[a]

Engine Fuel Type	**NOx Emission Limits** (ppmv, dry @ 15% O_2)	**Compliance Dates**
Compression-Ignited[b] (All Engines 51 to 175 bhp)	180	January 2012
Compression-Ignited[b] (All Engines greater than 175 bhp)	110	January 2012
Compression-Ignited[c,d] (1996 or later model year compliance option)	22 or BACT at time of compliance	January 2016
Spark-Ignited[e] Fossil Fuels	25 (rich) 65 (lean)	January 2012
Spark-Ignited[e] Waste Gas	70	January 2012
Spark-Ignited (1996 or later model year or engines less than 250 bhp compliance option)	BACT at time of compliance	January 2016

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.

The proposed amendments do not require a reduction in CO emission limits, although new engines frequently have more stringent CO standards included in the permit conditions. The District attains federal and State CO standards.

V. EMISSIONS AND EMISSIONS REDUCTIONS

Staff developed baseline emissions inventories for both NOx and PM for all stationary IC engines by categorizing each engine by ignition and fuel type. 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. The inventory was categorized by: 1) compression-ignited engines; 2) fossil-fueled, spark-ignited engines; and 3) waste gas-fueled, spark-ignited engines.

A. NOx Emissions

Stationary IC engines in the District emit 14.8 tons of NOx per day. District Regulation 2, Rule 1 was amended on May 17, 2000, to require stationary IC engines greater than 50 bhp to be permitted. Staff reviewed the database of permitted IC engines to identify all stationary IC engines affected by Rule 9-8. To develop the emission inventory, staff first applied the appropriate BACT emission limit for NOx[21] to all IC engines identified as being equipped with BACT. Then the applicable EPA off-road emissions standards for compression ignition engines were applied to all non BACT-equipped diesel-fueled engines. The NOx emission estimate for natural gas- or other gaseous fuel-powered engines (non-BACT equipped) was based on the applicable emission limits currently found in Rule 9-8.

Table 8 summarizes the NOx emissions for stationary IC engines located within the District. Diesel-powered engines (which are currently unregulated by Rule 9-8) account for about 46 percent of the total NOx emissions from stationary IC engines. Prime engines account for about 78 percent of the total NOx emissions from stationary IC engines.

TABLE 8
NOx Emissions by Fuel and Engine Type
(tons/day)

Fuel	Emergency Standby*	Low Usage (≤ 100 hrs/yr)	Prime (>100 hrs/yr)	Totals
Diesel, Fuel Oil, Jet Fuel	3.1	0.07	3.6	6.8
Natural Gas & other fossil fuels	0.04	0	2.4	2.4
Waste Gas	0	0	5.6	5.6
Totals	**3.14**	**0.07**	**11.6**	**14.8**

* Based on maximum allowed hours of operation in the District permits.

Table 9 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. Emergency standby and low usage engines, due to their infrequent use, account for relatively small amounts of NOx emissions.

TABLE 9
Average NOx Emissions per Engine by Engine Type

	Engine Type			
	Emergency Standby*	Low Usage (≤ 100 hrs/yr)	Prime (>100 hrs/yr)	All Engines
Engine Counts	4644	279	413	5336
Average Emissions (lbs/day)	1.4	0.5	55.7	5.5

* Based on maximum allowed hours of operation in the District permits.

Although prime engines that operate more than 100 hours per year are the largest contributors, Table 8 and Table 9 indicate that emergency standby engines, collectively, contribute significantly to the total NOx inventory.

B. PM Emissions

Stationary IC engines in the District emit 2.6 tons of particulate matter per day. Of these emissions, 0.8 tons are primary PM emissions, which means they are emitted directly[v]. The primary emissions inventory for PM was estimated using various emissions factors (AP 42 for non-diesel engines) and emissions limits

[v] The primary PM emissions from stationary IC engines are overwhelmingly due to diesel exhaust, with primary PM emissions from spark-ignited engines being less than 0.1 percent of the total PM emissions from these engines.

based on State and federal regulations (the CI Engine ATCM for diesel engines, Tiers 1 & 2 of the EPA Off-Road CI Engine NSPS). Staff estimates that the ATCM will reduce about 94 percent of the primary diesel PM emissions. The remaining 1.8 tons are due to secondary PM formation from NOx emissions. Secondary PM is formed from the conversion of NOx to ammonium nitrate (NH_4NO_3). District staff has estimated the ratio between NH_4NO_3 formation to NOx emissions in the Bay Area to range between 1:6 and 1:10.[22] The PM emissions inventory shown in Table 10 presents an inventory of secondary PM emissions. For this table, staff used a ratio of 1:8 for NH_4NO_3 formation to NOx emissions.

TABLE 10
Secondary PM Emissions by Fuel and Engine Type
(tons/day)

Fuel	**Emergency Standby**	**Low Usage** (≤ 100 hr)	**Prime** (> 100 hr)	**Totals**
Diesel, Fuel Oil, Jet Fuel	0.39	0.01	0.45	0.85
Natural Gas & other fossil fuels	0	0	0.30	0.30
Waste Gas	0	0	0.69	0.69
Totals	**0.4**	**0.01**	**1.44**	**1.84**

Table 11 presents a summary of the average daily secondary 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). Of prime engines the greatest contributors are engines that operate more than 100 hours per year.

TABLE 11
Average Secondary PM Emissions per Engine by Engine Type

	Engine Type			
	Emergency Standby (lbs/day)	**Low Usage** ≤ 100 hrs/yr (lbs/day)	**Prime** > 100 hrs/yr (lbs/day)	**All Engines** (lbs/day)
Engine Counts	4644	279	413	5336
Average Emissions (lbs/day)	0.17	0.07	6.8	0.71

C. NOx Emission Reductions

The proposed amendments would reduce NOx emissions by 9.6 tpd. 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.

It should be noted that the air-to-fuel ratios of most of the spark-ignited engines were not listed in the database. From the fraction of engines with rich or lean burn designations listed in the database and discussions with District permit staff and 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 loading factor of 70 percent; engines loads listed in the database ranged between 50 to 80 percent.

The category of emergency standby engines includes both emergency standby and essential service engines. The proposed amendments would reduce the allowable hours of non-emergency or non-essential use from 200 for essential service engines and 100 for emergency standby engines to 50 for the category of engines. The emission reductions are based on a reduction in service hours.

Table 12 presents estimates of total NOx emission reductions and the percent reductions that would be expected from the implementation of the proposal.

TABLE 12
NOx Emissions by Fuel Used and Engine Type for the Current and Proposed Amendments to Rule 9-8

Fuel Type	Engine Type							
	Emergency Standby* (tpd)		**Low Usage** (tpd)		**Prime** (tpd)		**All Engines** (tpd)	
	Current Emissions	**Emission Reductions**	**Current Emissions**	**Emission Reductions**	**Current Emissions**	**Emission Reductions**	**Current Emissions**	**Emission Reductions**
Diesel, Fuel Oil, Jet Fuel	3.1	1.4	0.07	0	3.6	2.8	6.8	4.2
Spark-Ignited Fossil Fuels	0.04	0.01	0	0	2.4	1.6	2.4	1.6
Spark-Ignited Waste Fuels	0	0	0	0	5.6	3.8	5.6	3.8
Emissions Totals	**3.1**	**1.4**	**0.07**	**0**	**11.6**	**8.2**	**14.8**	**9.6**
Percent Reductions	**45%**		**0%**		**71%**		**65%**	

* Emissions from non-emergency or non-essential use.

D. PM Emission Reductions

This proposal will reduce secondary PM emissions by 1.2 tons per day through the reduction of NOx emissions. The implementation of the CI Engine ATCM will reduce primary PM emissions from CI engines by over 94 percent (0.75 tpd). PM emission reduction estimates due to this proposal are wholly attributable to the reduction of secondary formation of PM from NOx emissions. This is because the proposal does not directly impact primary PM emissions from spark-ignited engines. Table 13 presents estimates of total current and expected PM emissions and the percent reductions that would be expected from the implementation of the proposal.

TABLE 13
PM Emissions by Fuel Used and Engine Type for the Current and Proposed Amendments to Rule 9-8

Fuel Type	Engine Type: Emergency Standby (tpd)		Low Usage (tpd)		Prime (tpd)		All Engines (tpd)	
	Current Emissions	Emission Reductions	Current Emissions	Emission Reductions	Current Emissions	Emission Reductions	Current Emissions	Emission Reductions
Diesel, Fuel Oil, Jet Fuel	0.39	0.11	0.01	0	0.45	0.39	0.85	0.53
Spark-Ignited Fossil Fuels	0	0	0	0	0.30	0.20	0.30	0.20
Spark-Ignited Waste Fuels	0	0	0	0	0.69	0.48	0.69	0.48
Emissions Totals	**0.39**	**0.11**	**0.01**	**0**	**1.44**	**1.07**	**1.84**	**1.21**
Percent Reductions	**27%**		**0%**		**74%**		**66%**	

E. Emissions from Agricultural Equipment

Stationary IC engines are sometimes used in agricultural operations, primarily diesel engines used as water pumps in remote locations. These engines are currently exempt from Rule 9-8, do not have District permits, and their emissions are not included in the above estimates. Based on ARB data, emissions from stationary agricultural engines in the Bay Area total 0.076 ton per day of NOx and 0.01 tons per day of PM. Because the emissions from these engines are low, agricultural engines are not impacted by the proposed amendments.

VI. ECONOMIC IMPACTS

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

1. Non-selective catalytic reduction (NSCR) technology to rich-burning spark-ignited engines combined with air-fuel ratio controller (AFRC); or
2. Selective catalytic reduction (SCR) technology to compression-ignited and lean-burning spark-ignited engines; or
3. Selective Non-Catalytic Reduction (SNCR) for lean-burn waste gas-fired engines.

Table 14 provides a summary of the estimated capital and operating costs for NSCR + AFRC, SCR and SNCR systems.

TABLE 14
Approximate Cost Estimates per Brake Horsepower for Non-Selective Catalytic Reduction and Air-Fuel Ratio Controller, Selective Catalytic Reduction and Selective Non-Catalytic Reduction [4, 13, 24, 26, 27, 28]

Engine Size	NSCR + AFRC		SCR		SNCR	
(bhp)	Capital	Operating	Capital	Operating	Capital	Operating
50-150	$200	$6	$510	$9.10	$155	$11.50
151-300	$120	$7	$225	$11.50	$120	$7.80
301-500	$75	$6	$170	$15.40	$85	$5.80
501-1000	$55	$7	$225	$25.30	$55	$3.80
1001-2000	$50	$5	$170	$29.40	$40	$2.80
> 2000	$50	$3	$135	$55.70	$30	$2.30

To develop the cost estimates, staff assumed a worse case cost scenario in which all affected engines would have to be retrofitted with NSCR, SCR or SNCR to meet the emissions limits.[vi] Emergency standby engines were assumed to comply by a reduction of non-emergency operating hours (reliability testing), which should result in a cost savings. (However, the cost estimates do not account for any potential savings.) Engines currently equipped with BACT were assumed to be able to meet the emission limits of the proposal and, therefore, would not incur any cost. The capital costs were amortized over ten years at seven percent annual interest.

[vi] 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.

A. Cost Effectiveness

The emissions, emission reductions, compliance costs and cost effectiveness for diesel, fossil-fuel and waste gas-fired spark-ignited engines are listed in Tables 15 through 17. The costs contained in Table 15 reflect only the capital cost, cost of installation and cost of operation 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 15
NOx Emissions Reductions and Cost Analyses for Compression-Ignited Engines (Diesel)

Engine Sizes[a] (bhp)	Total / Affected[b] Engines	Current NOx Emissions (tons/day)	Proposal NOx Emissions (tons/day)	NOx Emission Reductions (tons/day)	Annualized Quarterly Monitoring Costs	Annualized Capital Cost	Annualized Operating Cost	Total Annualized Costs	Cost Effective-ness ($/ton)
51-150	36 / 34	0.09	0.04	0.04	$47,396	$272,043	$30,530	$349,969	$26,180
151-300	37 / 32	0.13	0.04	0.10	$44,608	$256,041	$78,633	$379,282	$10,754
301-500	25 / 15	0.22	0.06	0.17	$20,910	$160,027	$108,273	$289,210	$4,543
501-1000	26 / 15	0.62	0.15	0.49	$20,910	$397,403	$292,936	$711,249	$4,007
1001-2000	4 / 3	0.25	0.06	0.20	$4,182	$101,715	$117,979	$223,876	$3,096
< 2001	6 / 6	2.27	0.49	1.78	$8,364	$243,672	$1,007,083	$1,259,119	$1,942
Totals	**134 / 105**	**3.6**	**0.8**	**2.8**	**$146,370**	**$1,430,901**	**$1,635,434**	**$3,212,705**	**$3,180**

a. Prime engines that operate more than 100 hours per year.
b. Engines that were not subject to BACT requirements at the time of installation.

TABLE 16
NOx Emissions Reductions and Cost Analyses for Spark-Ignited, Fossil-Fueled Engines (Natural Gas, LPG, Propane, Gasoline, etc.)

Engine Sizes[a] (bhp)	Total / Affected[b] Engines	Current NOx Emissions (tons/day)	Proposal NOx Emissions (tons/day)	NOx Emission Reductions (tons/day)	Annualized Quarterly Monitoring Costs	Annualized Capital Cost	Annualized Operating Cost	Total Annualized Costs	Cost Effective-ness ($/ton)
51-150	44 / 35	0.5	0.0	0.50	$48,790	$130,551	$52,624	$231,965	$1,279
151-300	43 / 42	0.6	0.1	0.49	$58,548	$195,992	$172,387	$426,927	$2,375
301-500	9 / 8	0.0	0.0	0.02	$11,152	$41,898	$42,539	$95,590	$13,288
501-1000	46 / 25	0.3	0.2	0.14	$34,850	$236,164	$283,722	$554,735	$10,839
1001-2000	24 / 10	0.3	0.2	0.15	$13,940	$148,256	$254,850	$417,046	$7,587
< 2001	18 / 14	0.7	0.3	0.34	$19,516	$326,827	$502,135	$848,478	$6,934
Totals	**184 / 134**	**2.4**	**0.8**	**1.6**	**$186,796**	**$1,079,688**	**$1,308,257**	**$2,574,742**	**$4,314**

a. Prime engines that operate more than 100 hours per year.
b. Engines that were not subject to BACT requirements at the time of installation.

TABLE 17
NOx Emissions Reductions and Cost Analyses for Spark-Ignited, Waste-Fueled Engines (Digester and Landfill Gases)

Engine Sizes[a] (bhp)	**Total / Affected**[b] **Engines**	**Current NOx Emissions** (tons/day)	**Proposal NOx Emissions** (tons/day)	**NOx Emission Reductions** (tons/day)	**Annualized Quarterly Monitoring Costs**	**Annualized Capital Cost**	**Annualized Operating Cost**	**Total Annualized Costs**	**Cost Effective-ness** ($/ton)
51-150	15 / 6	0.12	0.05	0.07	$8,364	$21,556	$29,205	$59,125	$2,469
151-300	0 / 0	0	0	0	$0	$0	$0	$0	$0
301-500	0 / 0	0	0	0	$0	$0	$0	$0	$0
501-1000	33 / 22	1.31	0.39	0.93	$30,668	$151,869	$220,207	$402,744	$1,193
1001-2000	30 / 30	1.82	0.54	1.27	$41,820	$179,701	$304,316	$525,837	$1,131
< 2001	23 / 15	2.30	0.80	1.50	$20,910	$164,436	$342,161	$527,507	$964
Totals	**101 / 73**	**5.6**	**1.8**	**3.8**	**$101,762**	**$517,562**	**$895,890**	**$1,515,213**	**$1,103**

a. Prime engines that operate more than 100 hours per year.
b. Number of engines that were not subject to BACT requirements at the time of installation.

Cost Assumptions:

- Quarterly monitoring with a portable analyzer was estimated to take approximately 2 man-hours per quarter at an hourly rate of $50.
- A portable analyzer costs approximately $7000.

B. Incremental Cost Effectiveness

Section 40920.6 of the California Health and Safety Code requires an air district to perform an incremental cost analysis for any proposed Best Available Retrofit Control Technology rule or feasible measure. The air district must: (1) identify one or more control options achieving the emission reduction objectives for the proposed rule; (2) determine the cost effectiveness for each option; and (3) calculate the incremental cost effectiveness for each option. To determine incremental costs, the air district must "calculate the difference in the dollar costs divided by the difference in the emission reduction potentials between each progressively more stringent potential control option as compared to the next less expensive control option."

In preparing the incremental cost effectiveness, staff compared the cost and emission reductions of the various control options of the proposal to that of the control option of electrification, replacement of the IC engine with an electric motor. Although this control option may eliminate NOx and CO emissions at the source, it ultimately has the potential of increasing NOx and CO emissions at the source of electrical production, when that electricity is produced through the combustion of fossil fuels. The net reduction of pollutants from stationary IC engines would be dependent on the fraction of electricity produced in the Bay Area relative to the total amount consumed (weighted by thermal efficiencies). For the sake of this discussion, it is assumed that electrification results in no increase in NOx or CO emissions to other sources in the District.

The following tables (Table 18 through Table 20) provide the incremental cost effectiveness for the three classes of engines regulated by Rule 9-8.

TABLE 18
Incremental Cost Effectiveness – Electrification
Compression-Ignited Engines (Diesel)

Engine Size Ranges[a]	Annualized Cost[4] of Electrification	NOx Emission Reductions from Electrification (tons/day)	Cost Effectiveness of Electrification	Annualized Cost of Control	Proposal Emissions Reductions (tons/day)	Incremental Cost Effectiveness ($/ton)
51-150	$155,462	0.07	$4,985	$349,969	0.04	-$10,918
151-300	$256,054	0.13	$5,250	$379,282	0.10	-$9,124
301-500	$193,511	0.22	$2,375	$289,210	0.17	-$5,371
501-1000	$433,562	0.62	$1,915	$711,249	0.49	-$5,683
1001-2000	$158,564	0.25	$1,715	$223,876	0.20	-$3,242
< 2001	$605,680	2.27	$731	$1,259,119	1.78	-$3,628
Totals	**$1,802,832**	**3.6**	**$1,378**	**$3,212,705**	**2.8**	**-$4,727**

TABLE 19
Incremental Cost Effectiveness – Electrification
Spark-Ignited, Fossil-Fueled Engines
(Natural Gas, LPG, Propane, Gasoline, etc.)

Engine Size Ranges[a]	**Annualized Cost**[4] **of Electrification**	**NOx Emission Reductions from Electrification** (tons/day)	**Cost Effectiveness of Electrification**	**Annualized Cost of Control**	**Proposal Emissions Reductions** (tons/day)	**Incremental Cost Effectiveness** ($/ton)
51-150	$160,034	0.5	$844	$231,965	0.50	-$8,702
151-300	$336,071	0.6	$1,641	$426,927	0.49	-$3,632
301-500	$103,206	0.0	$7,387	$95,590	0.02	$1,124
501-1000	$722,603	0.3	$6,600	$554,735	0.14	$2,879
1001-2000	$558,486	0.3	$4,787	$417,046	0.15	$2,293
< 2001	$1,287,131	0.7	$5,295	$848,478	0.34	$3,633
Totals	**$3,167,530**	**2.4**	**$3,609**	**$2,574,742**	**1.6**	**$2,111**

TABLE 20
Incremental Cost Effectiveness – Electrification
Spark-Ignited, Waste-Fueled Engines
(Digester and Landfill Gases)

Engine Size Ranges[a]	**Annualized Cost**[4] **of Electrification**	**NOx Emission Reductions from Electrification** (tons/day)	**Cost Effectiveness of Electrification**	**Annualized Cost of Control**	**Proposal Emissions Reductions** (tons/day)	**Incremental Cost Effectiveness** ($/ton)
51-150	$85,243	0.12	$1,980	$59,125	0.07	$1,368
151-300	$0	0	n/a	$0	0	n/a
301-500	$0	0	n/a	$0	0	n/a
501-1000	$812,418	1.31	$1,694	$402,744	0.93	$2,888
1001-2000	$1,351,308	1.82	$2,036	$525,837	1.27	$4,155
< 2001	$1,379,069	2.30	$1,644	$527,507	1.50	$2,921
Totals	**$3,628,036**	**5.6**	**$1,792**	**$1,515,213**	**3.8**	**$3,245**

As the tables indicate, there are some instances in which the cost of control exceeds that of electrification and the resulting incremental cost effectiveness value is negative. This indicates that it would be more cost effective to replace the stationary IC engine with an electric motor. However, as indicated in Table 4, the primary use of stationary IC engines is to generate electricity. Many of the engines have come online subsequent to the State's energy crisis of the late 1990s and early 2000s and are part of the State's Distributed Energy Generator Program which was established to help meet the energy demands of California. Replacing these engines would be counter to the purpose of the Distributed Energy Generator Program and make California more reliant on energy sources that lie beyond the borders of the State. Also, many IC engines provide electricity in areas in which there is not access to the grid. For these reasons, electrification is not a reliable option to mandate even though the emission reductions for both NOx and PM would exceed those expected from the proposed amendments.

C. Socioeconomic Impacts

Section 40728.5 of the California Health and Safety Code requires an air district to assess the socioeconomic impacts of the adoption, amendment or repeal of a rule if the rule is one that "will significantly affect air quality or emissions limitations." Applied Economic Development of Walnut Creek, California has prepared a socioeconomic analysis of the proposed amendments to Rule 9-8. District staff has reviewed and accepted this analysis. The analysis concludes that the affected facilities should be able to absorb the costs of compliance with the proposed rule without significant economic dislocation or loss of jobs.

D. District Impacts

The Proposal will have very little impact on the District resources. All of the affected sources are currently permitted and inspected by district staff. The proposal would not result in an increase in permitting and inspection activities, except as new IC engines and new abatement equipment on existing engines are installed. However, as noted previously, the State CI Engine ATCM will require replacement or retrofit of most prime diesel fuel stationary IC engines. Consequently, as engine operators simultaneously comply with both rules, there would be no increase in permitting or inspection activities. There would be a small increase in staff time devoted to the review of testing and monitoring requirements and also the potential for a small increase in compliance assistance.

VII. ENVIRONMENTAL IMPACTS

Pursuant to the California Environmental Quality Act, the District has had an initial study for the proposed amendments prepared by Environmental Audit, Inc. The initial study concludes that there are no potential significant adverse environmental impacts associated with the proposed amendments. A negative declaration is proposed for approval by the District Board of Directors.

The District Climate Protection program encourages reductions in greenhouse gas (GHG) emissions such as carbon dioxide (CO_2). To this end, staff initially proposed limits expressed in grams per brake horsepower-hour (g/bhp-hr). It was believed that a mass emission per unit energy standard would encourage more efficient use of the engines. However, based on discussions with engine manufacturers and District source test staff, it was concluded that because manufactured engines (like automobiles) can only operate within a narrow range of efficiencies, the expression of the emissions standard would have little effect on an engine's operation. Further, for engines where the gas composition is variable, as is the case with waste gas-fueled engines, determining compliance would be difficult if not impossible because of the gas stream variability. As discussed under the Rule Development / Public Process section below, staff has revised the expression of the emissions limits to parts per million by volume (ppmv) standards. This change does not cause an impact in the generation of greenhouse gas emissions.

The proposal also allows spark-ignited engines in the range between 50 and 250 bhp the option of delayed compliance. This size range includes small CHP units. These engines provide not only electrical power, but the exhaust heat is used to provide space and/or water heating. This use of the exhaust heat substantially increases the effective thermal efficiency of these engines. The proposal allows the operators of these smaller engines, which are not currently subject to any emissions limits in the rule currently, additional time to recoup the useful life out of the units. This allowance was made because it would be difficult to retrofit these engines with control technology and continue to benefit from the recovery of the exhaust heat. Because there exists the potential to lose the benefit of heat recovery, some of the operators would more than likely chose to connect to the grid for electrical power and burn natural gas for space and water heating. This additional power use would result in a increase in GHG emissions, which would be contrary to the aims of our Climate Protection Program. To retain the benefit for the operator and to prevent this increase, the delayed compliance option has been added. New CHP units, which are equipped with catalysts, can meet the proposed standards.

VIII. REGULATORY IMPACTS

Section 40727.2 of the Health and Safety Code requires an air district, in adopting, amending, or repealing an air district regulation, to identify existing federal and district air pollution control requirements for the equipment or source type affected by the proposed change in air district rules. The air district must then note any difference between these existing requirements and the requirements imposed by the proposed change.

<u>The EPA New Source Performance Standards for Off-Road Compression-Ignited Engines</u>: The Off-Road CI Engine New Source Performance Standards (NSPS) applies to new stationary diesel engines. Emission limitations become progressively more stringent as model years advance. While these standards affect new stationary CI engines, they do not retroactively affect existing (in-use) engines. However, operators complying with the proposal may be affected by the Stationary CI Engine NSPS if compliance is achieved by purchasing a new CI engine.

<u>The ARB CI Engine ATCM</u>: In 2004, the ARB adopted the CI Engine ATCM, which 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. This is a State requirement and is not required by HSC Section 40727.2. However, 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. The CI Engine ATCM does not substantially reduce NOx or CO emissions from diesel engines. Many of the engines affected by the CI Engine ATCM will also have to comply with these proposed amendments. The proposed effective dates in Rule 9-8 coincide with the effective dates in the ATCM to allow operators of stationary diesel engines the opportunity to comply with both the ATCM and the proposed amendments to Rule 9-8 on the same schedule.

IX. RULE DEVELOPMENT / PUBLIC CONSULTATION PROCESS

The rule development process to bring these proposed amendments to the Board of Directors has been a comprehensive process involving engine owners and operators, engine manufacturers, consultation with other agencies and District staff, and discussions with trade organizations, including meetings with the California Council for Environmental and Economic Balance. Staff developed the emissions inventory and potential reductions from the review and analysis of over 5000 stationary IC engines listed in the permit database. Staff notified all owners and operators along with other interested parties and conducted a public workshop on March 1, 2007.

The purpose of the Public Workshop was to solicit comments from the public on the proposed amendments to Rule 9-8. During the workshop, which was attended by approximately 30 interested stakeholders, staff responded to questions about information presented in the Workshop Report and the proposed amendments. Based on the comments received at the workshop and during the associated public comment period, staff made several changes to the proposal.

Comments received at the workshop and during the comment period focused mainly on the proposed compliance dates, definitions of “emergency use,” alternative compliance dates for spark-ignited engines, proposed emissions limits for new engines, and compliance determinations and testing.

In response to these comments, staff made the following modifications to the proposal:

- Definition of Emergency Use: The definition of emergency use has been broadened to allow the use of emergency standby engines and low usage engines where necessary for fire, flood, power failure or other emergencies. The rule makes clear that such events must be imminent, not merely speculative. Moreover, an engine operating as a standard component of a system would not be considered an emergency use engine, even if failure of the system might lead to an emergency.

- Effective Dates: The effective date for compliance with the emissions limits for spark-ignited engines was extended to January 1, 2012, to ensure operators have sufficient time to design controls, purchase equipment, secure permits, contract work, and complete construction.
- Alternative Compliance for Spark-Ignited Engines: Operators of spark-ignited engines of model year 1996 or later or engines sized between 50 and 250 bhp have been provided an option to delay compliance until January 2016 to allow for them to recoup most of the useful life of the engine. However, at the time of compliance, the engine must meet the BACT levels that would be applicable at that time.
- Emission Limits for New Engines: The emissions limits for new engines were removed from the proposal. New engines are subject to best available control technology (BACT). Emission limits for new engines would have been redundant of the District's existing new source review process.
- Quarterly Demonstration of Compliance: A provision has been added to require regular monitoring to promote continued compliance. Quarterly monitoring with a hand held device – the approach recommended by the ARB BARCT Determination – is a requirement of this rule. Monitoring protocols have been added to the proposal.
- Grams per Brake Horsepower-Hour Standard: The Workshop Report, released in January 2007, contained emissions limits stated in grams per brake horsepower-hour (g/bhp-hr) instead of parts per million by volume (ppmv). A g/bhp-hour-based standard was intended to promote energy efficiency and reduce greenhouse gas emissions by providing a standard whereby the engine that derives the most useful energy per unit of fuel burned (and unit of pollution produced) would most expeditiously meet the emission standard.

  Staff has returned to the use of the ppmv limits. The ppmv limits can be easily determined using a hand-held monitor and require only one type of measurement. Determining compliance with the g/bhp-hr limits would require measuring of the pollutant in the exhaust (in ppmv) along with measuring the thermal efficiency of the engine and the volume of exhaust gases create from the combustion of the fuel. Thermal efficiency can only be based on a manufacturer's determination and would be very difficult, if not impossible, to verify. Equally, the ability of an operator to adjust an IC engine to increase efficiency is problematic. Also, for waste gas-fueled engines, the energy and exhaust derived varies as the fuel composition varies day-to-day, and even hour-to-hour. Due to these variations it would be difficult to later verify the conditions under which the emission limit determination was made. For these reasons, staff concluded that achievement of the emissions reductions from the proposed amendments of the rule would be better served if the emissions limits are presented in units that are most easily measured, which are ppmv instead of g/bhp-hr.

- Delayed Compliance for Smaller Spark-Ignited Engines: Staff received a comment letter from Tecogen®, a manufacturer of combined heat and power (CHP) engine units that utilize the waste heat from the exhaust to provide water or space heating. Consequently, the engines can achieve overall thermal efficiencies of 80 percent or more. These CHP units, which are typically in the 75 to 125 bhp size range and meet the requirements of the California Distributed Generation Program,[20] are currently exempt from the emissions limits of the rule and are responsible for a small fraction of the NOx emissions. In order to encourage continued use of these CHP units, the proposed amendments allow a delayed compliance option for these spark-ignited natural gas-fueled engines. This allows operators the opportunity to recoup the useful life of these engines and continue utilizing the waste heat for water and space heating and, thereby, reduce greenhouse gas emissions that would otherwise be generated from other sources. New CHP units are equipped with a catalyst that meets the proposed standards.

X. CONCLUSION

Pursuant to the California Health and Safety Code Section 40727, before adopting, amending, or repealing a rule the Board of Directors must make findings of necessity, authority, clarity, consistency, non-duplication and reference. The proposal is:

- Necessary to supplement the District's ability to meet the commitment made as part of the District's PM Implementation Schedule adopted pursuant to Senate Bill 656, and to attain the State one-hour ozone standard, as well as meet transport mitigation requirements;
- Authorized by California Health and Safety Code Section 40702;
- Clear, in that the new regulation specifically delineates the affected industries, compliance options and administrative and monitoring requirements for industry subject to this rule;
- Consistent with other District rules, and not in conflict with state or federal law;
- Non-duplicative of other statutes, rules or regulations; and
- The proposed regulation properly references the applicable District rules and test methods and does not reference other existing law.

A socioeconomic analysis prepared by Applied Development Economics has found that the proposed amendments would not have a significant economic impact or cause regional job loss. District staff have reviewed and accepted this analysis. A California Environmental Quality Act analysis prepared by Environmental Audit, Inc., concludes that the proposed amendments would not result in any adverse environmental impacts. District staff have reviewed and accepted this analysis as well. A Negative Declaration for the proposed amendments has been prepared and will be circulated for comment.

Staff recommends the adoption of the proposed amendments to Regulation 9, Rule 8: Nitrogen Oxide and Carbon Monoxide from Stationary Internal Combustion Engines, and approval of a CEQA Negative Declaration.

XI. 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] Standards of Performance for Stationary Compression Ignition Internal Combustion Engines, 40 CFR 60 Subpart IIII.

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

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

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

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

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

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

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[13] 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.

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

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

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

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

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

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

[26] Mark Szymczak, Cummins West, Inc., Email, January 26, 2007 to Victor Douglas (Proprietary Information).

[27] Mark Szymczak, Cummins West, Inc., Email, March 22, 2007 to Victor Douglas (Proprietary Information).

[28] Steve Cushman, Chief Engineer, Peterson Power Systems, Inc.., Email, April 5, 2007 to Victor Douglas (Proprietary Information).