California Environmental Protection Agency
AIR RESOURCES BOARD

DETERMINATION OF REASONABLY AVAILABLE CONTROL TECHNOLOGY AND BEST AVAILABLE RETROFIT CONTROL TECHNOLOGY FOR STATIONARY SPARK-IGNITED INTERNAL COMBUSTION ENGINES

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GLOSSARY OF TERMS, ABBREVIATIONS, AND SYMBOLS

AFRC	Air/fuel ratio controller
ARB	Air Resources Board
APCD	Air Pollution Control District
AQMD	Air Quality Management District
BAAQMD	Bay Area Air Quality Management District
BARCT	Best available retrofit control technology
bhp	Brake horsepower
Btu	British thermal unit
BSFC	Brake specific fuel consumption (Btu/bhp-hour)
CAA	Federal Clean Air Act Amendments
CAPCOA	California Air Pollution Control Officers Association
CCAA	California Clean Air Act
CEMS	Continuous Emissions Monitoring System
CI	Compression ignited
CO	Carbon monoxide
EGR	Exhaust gas recirculation
gal	Gallon
gm/bhp-hr	Gram per brake horsepower-hour
HAPs	Hazardous air pollutants
HC	Hydrocarbons
HNCO	Gaseous isocyanic acid
$HNCO_3$	Cyanuric acid
ICCR	Industrial Combustion Coordinated Rulemaking
IC Engines	Internal combustion engines
I & M	Inspection and monitoring
lbm/day	Pounds mass per day
LPG	Liquified petroleum gas
MACT	Maximum achievable control technology
NO	Nitric oxide
N_2	Molecular nitrogen
N_2O	Nitrous oxide
NMHC	Non-methane hydrocarbon compounds
NOx	Nitrogen oxides
NO_2	Nitrogen dioxide
NSCR	Nonselective catalytic reduction
O_2	Oxygen
PAH	Polycyclic aromatic hydrocarbons
PM	Particulate matter
PM2.5	Particulate matter less than 2.5 micrometers
PM10	Particulate matter less than 10 micrometers

ppm	Parts per million
ppmv	Parts per million by volume
PSC	Prestratified charge
RACT	Reasonably available control technology
RECLAIM	Regional Clean Air Incentives Market
ROC	Reactive organic compounds
RRP	Risk Reduction Plan
SCR	Selective catalytic reduction
SI	Spark ignited
SOx	Sulfur oxides
TAC	Toxic air contaminant
VCAPCD	Ventura County Air Pollution Control District
VOC	Volatile organic compounds

RACT/BARCT DETERMINATION FOR STATIONARY SPARK-IGNITED INTERNAL COMBUSTION ENGINES

I. INTRODUCTION

This document presents the determination of reasonably available control technology (RACT) and best available retrofit control technology (BARCT) for controlling nitrogen oxides (NOx), volatile organic compounds (VOCs), and carbon monoxide (CO) from stationary, spark-ignited (SI) reciprocating internal combustion (IC) engines. This report also presents the basis for the determination, an overview of the control technologies for spark-ignited engines, an assessment of the cost and cost-effectiveness, and the expected associated economic and other impacts. The determination was developed by the Air Resources Board (ARB) staff and a workgroup made up of representatives of the air pollution control and air quality management districts (districts).

It is important to note that this determination is a non-regulatory guidance document with the purpose of assisting districts in developing regulations for stationary IC engines. Nothing in our guidance precludes districts from adopting different or more stringent rules or from varying from the determination to consider site specific situations.

A. Background

The California Health and Safety Code section 40000 states that the districts have the primary responsibility for control of air pollution from all sources, other than emissions from motor vehicles. The California Clean Air Act (CCAA) of 1988 requires that the districts develop attainment plans to achieve the state ambient air quality standards by the earliest practicable date. These plans must include measures that require control technologies for reducing emissions from existing sources. RACT/BARCT determinations aid districts in developing regulations to attain and maintain the state ambient air quality standards. The determinations also promote consistency of controls for similar emission sources among districts with the same air quality attainment designations.

While the CCAA does not define RACT, RACT for existing sources is generally considered to be those emission limits that would result from the application of demonstrated technology to reduce emissions. BARCT is defined in the California Health and Safety Code, section 40406, but applicable statewide in this case, as “an emission limitation that is based on the maximum degree of reduction achievable, taking into account environmental, energy, and economic impacts by each class or category of source.”

The California Health and Safety Code, section 40918(a)(2), requires nonattainment areas that are classified as moderate for the State ozone standard to include in their attainment plan the use of RACT for all existing stationary sources, and BARCT for existing stationary sources permitted to emit 5 tons or more per day or 250 tons or more per year of nonattainment pollutants or their precursors. This requirement applies to the extent necessary to achieve standards by the earliest practicable date.

The California Health and Safety Code, section 40919(a)(3), requires nonattainment areas that are classified as serious for the State ozone standard to include in their attainment plan the use of BARCT on all permitted stationary sources to the extent necessary to achieve standards by the earliest practicable date. Districts classified as being severe nonattainment must take all measures required of moderate and serious nonattainment areas. In addition, Title 17, Section 70600 of the California Code of Regulations requires districts to adopt BARCT if the districts are within an area of origin of transported air pollutants, as defined in Section 70500(c).

In developing this determination, the ARB and air districts staff reviewed a number of reports on spark-ignited IC engines, emissions inventory data, vendor literature, source test data, district rules and accompanying staff reports, and other sources of information regarding SI engines.

Stationary spark-ignited IC engines are major contributors of NOx, VOC, and CO emissions to the atmosphere. The 1996 point source emissions inventory for stationary SI engines includes about 21,932 tons of NOx per year, 16,479 tons of CO per year, and 23,606 tons of VOC per year from IC engines. Tables I-1, I-2, and I-3 summarize this inventory by district. As can be seen from these tables, spark-ignited IC engines are responsible for a significant percentage of the NOx, VOC, and CO emissions from stationary point sources in California. This significance, however, varies from district to district. The 1996 point source emissions inventory also indicates that there are approximately 5,900 diesel-fueled and spark-ignited engines located at 1,700 facilities statewide. Forty-four percent of these engines are fueled by diesel fuel; 42 percent are fueled by natural gas; 7 percent are fueled by gasoline; and 4 percent are fueled by propane with the remainder fueled by waste gas and other fuels.

It should be noted that not all districts in California with significant stationary source IC engine emissions are included in Tables I-1, I-2, and I-3. In some districts, all stationary IC engines emissions may not have been reported in the 1996 emissions inventory. In those cases, these tables underestimate the actual emissions.

In other cases, some classes of spark-ignited IC engines with substantial emissions may be exempt from permit, and their emissions may not be reflected in Tables I-1, I-2, and I-3. For example, engines used in agricultural operations in the San Joaquin Valley Unified Air Pollution Control District (APCD) are exempt from permit and their emissions are not included in these tables. Annual NOx emissions for these agricultural engines (spark-ignited and diesel-fueled) have been estimated at 12,000 tons per year. This emissions estimate is greater than the NOx emissions for all stationary engines in the inventory for San Joaquin Valley APCD. Moreover, this annual NOx estimate is approximately 40 percent of the emissions from the stationary IC engines in the State as reported in the 1996 point source inventory. It appears that agricultural engines can be a significant contributor to emissions. Because of the potential adverse air quality impacts from these engines, the control of emissions from IC engines used in agricultural operations will be addressed. It should also be noted that it is believed that the majority of these engines are diesel-fueled.

Table I-1

NO_x Emissions Comparison
Stationary Spark-Ignited IC Engines and All Stationary Sources
in Tons Per Year

District*	Spark-Ignited IC Engines	All Stationary Sources	Percent of Total
Antelope Valley APCD	0.1	365	0.03
Bay Area AQMD	2,077	36,500	5.7
Butte County AQMD	14	730	1.9
Colusa County APCD	680	1,460	47
Feather River AQMD	361	1,100	33
Glenn County APCD	325	1,100	30
Lake County AQMD	0.06	146	0.04
Mojave Desert AQMD	7,499	31,000	24
Monterey Bay Unified APCD	76	7,300	1.0
Northern Sierra AQMD	0.3	730	0.04
Sacramento Metropolitan AQMD	27	1,825	1.5
San Diego County APCD	238	5,840	4.2
San Joaquin Valley Unified APCD	4,882	65,700	7.4
San Luis Obispo County APCD	92	1,460	6.3
Santa Barbara County APCD	985	2,190	45
South Coast AQMD	4,259	47,450	9.0
Ventura County APCD	176	1,825	9.6
Yolo/Solano AQMD	241	1,100	22
Totals	**21,932**	**218,776**	**10**

Source: ARB 1996 Point Source Inventory

* APCD = Air Pollution Control District
AQMD = Air Quality Management District

Table I-2

CO Emissions Comparison
Stationary Spark-Ignited IC Engines and All Stationary Sources
in Tons Per Year

District*	Spark-Ignited IC Engines	All Stationary Sources	Percent of Total
Amador APCD	NR	1,100	-
Antelope Valley APCD	1.3	365	0.4
Bay Area AQMD	1,932	21,170	9.1
Butte County AQMD	1.0	1,460	0.07
Colusa County APCD	88	365	24
Feather River AQMD	128	730	17
Glenn County APCD	75	1,100	6.8
Great Basin Unified APCD	NR	7.3	-
Imperial County APCD	NR	365	-
Kern County APCD	NR	730	-
Lake County AQMD	0.01	3,285	0
Mojave Desert AQMD	1,094	5,840	19
Monterey Bay Unified APCD	79	10,585	0.7
Northern Sierra AQMD	0.06	4,015	0
Placer County APCD	NR	730	-
Sacramento Metro AQMD	56	730	7.7
San Diego County APCD	526	7,665	7.0
San Joaquin Valley Unified APCD	4,818	22,630	21
San Luis Obispo County APCD	57	365	16
Santa Barbara County APCD	928	1,460	64
South Coast AQMD	5,095	22,630	23
Ventura County APCD	1,553	3,285	47
Yolo-Solano AQMD	48	730	6.6
Totals	**16,479**	**111,342**	**15**

Source: ARB 1996 Point Source Inventory

* APCD = Air Pollution Control District
AQMD = Air Quality Management District

Table I-3

VOC Emissions Comparison
Stationary Spark-Ignited IC Engines and All Stationary Sources
in Tons Per Year

District*	Spark-Ignited IC Engines	All Stationary Sources	Percent of Total
Amador County APCD	NR	365	-
Antelope Valley APCD	1.6	1,100	0.15
Bay Area AQMD	822	43,800	1.9
Butte County AQMD	3	1,100	0.3
Colusa County APCD	275	730	38
Feather River AQMD	148	1,460	10
Glenn County APCD	146	730	20
Imperial County APCD	NR	730	-
Kern County APCD	NR	365	-
Lake County AQMD	0.003	730	0
Mojave Desert AQMD	1,209	2,920	41
Monterey Bay Unified APCD	362	5,475	6.6
Northern Sierra AQMD	0.02	730	0
Placer County APCD	NR	2,555	-
Sacramento Metro AQMD	23	6,570	0.4
San Diego County APCD	666	16,425	4.1
San Joaquin Valley Unified APCD	6,,776	43,800	15
San Luis Obispo County APCD	9.6	2,555	0.4
Santa Barbara County APCD	1,684	2,920	58
South Coast AQMD	11,116	109,500	10
Ventura County APCD	352	3,650	9.6
Yolo-Solano AQMD	13	4,015	0.3
Totals	**23,606**	**252,225**	**9.4**

Source: ARB 1996 Point Source Inventory

* APCD = Air Pollution Control District
AQMD = Air Quality Management District

IC engines generate power by combustion of an air/fuel mixture. In the case of spark-ignited engines, a spark plug ignites the air/fuel mixture while a diesel-fueled IC engine relies on heating of the inducted air during the compression stroke to ignite the injected diesel fuel. A more detailed description of spark-ignited IC engine operation is included in Appendix B. Most stationary IC engines are used to power pumps, compressors, or electrical generators. IC engines are used in the following industries: oil and gas pipelines, oil and gas production, water transport, general industrial (including construction), electrical power generation, and agriculture. The combined NOx emissions from the oil and gas industry, manufacturing facilities, power plants, and landfill and waste water treatment facilities contribute almost 85 percent of the annual NOx emissions from stationary IC engines according to the 1996 point source inventory. According to the inventory, approximately 11 percent of the annual NOx emissions from the engines in these categories are emitted by diesel-fueled stationary IC engines with the remaining 89 percent emitted from stationary spark-ignited IC engines.

Engines used for electrical power generation include base load power generation (generally in remote areas), resource recovery facilities in areas where waste fuels are available (such as landfills and sewage treatment facilities), portable units used as temporary sources of electrical power, and emergency generators used during electrical power outages.

There are a wide variety of spark-ignited IC engine designs, such as:

? Two stroke and four stroke
? Rich-burn and lean-burn
? Supercharged, turbocharged, and naturally aspirated

Spark-ignited engines can use one or more fuels, such as natural gas, oil field gas, digester gas, landfill gas, propane, butane, liquefied petroleum gas (LPG), gasoline, methanol, ethanol, residual oil, and crude oil. IC engines can also exhibit a wide variety of operating modes, such as:

? Emergency operation (e.g., used only during testing, maintenance, and emergencies)
? Seasonal operation
? Continuous operation
? Continuous power output
? Cyclical power output

These differences in use, design, and operating modes must be taken into account when setting standards to control emissions from IC engines.

B. Diesel-fueled Engines

Diesel engines not only have significant NOx emissions but also emit particulate matter (PM) which has been identified as a Toxic Air Contaminant (TAC) by the ARB. Once a substance is identified as a TAC, the ARB is required by law to determine if there is a need for further control. Recently, the ARB approved a Diesel Risk Reduction Plan (RRP) in consultation with the Advisory Committee on TACs from Diesel-fueled Engines and Vehicles. The Advisory Committee is made up of industry, environmental groups, other government agencies, and members of the public. Because of the timing of the Diesel RRP and the potential threat to public health from diesel particulate matter, stationary diesel-fueled engines are being addressed separately in a manner which takes into account the potential need to further control diesel PM and NOx simultaneously.

Emissions from diesel-fueled engines have the potential to pose significant cancer risks to the public working or living in close proximity to a diesel engine installation. It is possible that both NOx and PM emissions will need to be controlled from these engines. Unfortunately, many combustion modification techniques and technologies used to reduce NOx emissions can tend to increase PM emissions and vice versa. In addressing diesel-fueled engines, a balanced approach will be taken so that the maximum benefit to public health will be realized in reducing both pollutants. ARB staff is evaluating technologies that reduce PM emissions from diesel-fueled engines and the results from their evaluation will be considered in controlling emissions from stationary diesel-fueled engines. The effect on NOx emissions from these different technologies will also be evaluated in the document addressing diesel-fueled engines.

C. IC Engines used in Agricultural Operations

Also discussed previously, were the potentially significant emissions from the IC engines used in agricultural operations, particularly in the San Joaquin Valley. Although limited information is available, statewide NOx emissions from diesel-fueled engines used in stationary, nonroad, and portable agricultural applications have been estimated to be about 8,400 tons per year, which is about 28 percent of the emissions from stationary spark-ignited and diesel-fueled IC engines in the 1996 point source inventory. It is important to note that the majority of these engines are believed to be diesel-fueled with a smaller portion being natural gas-fueled SI engines. According to Health and Safety Code Section 42310(e), districts are prohibited from requiring permits for agricultural engines which accounts for the incomplete information and data on their engine population, operating hours, and emissions. Presently, these engines are not regulated, and their emissions are uncontrolled. However, the Health and Safety Code prohibition does not preclude districts from controlling the emissions from agricultural engines in some other manner. Appendix F provides a legal opinion on this issue.

In recent years, there has been a growing concern with the NOx and other emissions from these uncontrolled sources and their contribution to ozone. Because of the magnitude of the potential emissions from these engines, we recommend that districts develop alternatives to permitting for regulating these types of IC engines. An example of an alternative would be a voluntary approach such as the Carl Moyer program which provides incentives for owner/operators of internal combustion engines to repower with low emissions engines or to replace an existing engine with an electric motor. This type of program has demonstrated the potential to significantly reduce NOx emissions.

II. SUMMARY OF THE DETERMINATION FOR SPARK-IGNITED IC ENGINES

The provisions of this determination are applicable to all stationary, spark-ignited internal combustion engines with a manufacturer's rating of 50 brake horsepower or greater, or a maximum fuel consumption of 0.52 million Btu per hour or greater. This fuel consumption is equivalent to 50 brake horsepower using a default brake specific fuel consumption (BSFC) rating of 10,400 Btu per brake horsepower-hour. For different BSFC ratings, the maximum fuel consumption ratings should be adjusted accordingly.

The RACT and BARCT limits for NOx, VOC, and CO are summarized in Tables II-1 and II-2. Different limits apply to (1) spark-ignited rich-burn engines, (2) spark-ignited lean-burn engines, (3) rich-burn engines using waste gases, (4) cyclically-loaded rich-burn engines using field gas, and (5) two stroke lean-burn engines rated at less than 100 horsepower. Gasoline-fueled, spark-ignited engines are required to use California Reformulated Gasoline. The exemptions, administrative requirements, and test methods are listed at the end of this chapter.

A. Engines Rated Less Than 50 Horsepower

Most district rules exempt from permit and control requirements engines rated less than 50 horsepower. This document does not make a RACT/BARCT determination for this class of engines. If it is determined that these engines make a significant contribution to district-wide emissions, non-attainment Districts are encouraged to consider making a RACT/BARCT determination for these engines either as an entire subcategory or on a case-by-case basis. In considering this class of engines, ARB staff recommends that the districts evaluate the cost-effectiveness of controlling less than 50 hp engines.

B. Engines Derated to Less Than 50 Horsepower

This document does not make a RACT/BARCT determination for engines derated to less than 50 horsepower. A derated engine is one in which the manufacturer's brake horsepower rating has been reduced through some device that restricts the engine's output. In fact, most district IC engine rules apply to engines with a manufacturer's rating greater than 50 horsepower, regardless of any derating. Districts are encouraged to make a RACT/BARCT determination for these engines either as an entire subcategory or on a case-by-case basis.

ARB staff analysis identified several technically feasible approaches for reducing NOx emissions from engines derated to less than 50 hp. These approaches include electrification, air/fuel adjustments, and use of a catalytic control system. However, the cost effectiveness of implementing these technologies was highly dependent on site-specific considerations, including the proximity of power and the need to cleanup the gaseous fuel prior to making air/fuel adjustments or installing a catalyst.

As a result, ARB staff did not believe it was appropriate to make a statewide RACT/BARCT determination for the entire subcategory of engines derated to less than 50 hp. Instead, ARB staff recommends that the districts evaluate the cost-effectiveness of controlling engines derated to less than 50 horsepower and make a RACT/BARCT determination on either a district-wide or case-by-case basis. Please refer to Chapter IV for a more detailed discussion of this issue.

C. RACT Limits

For spark-ignited rich-burn engines, the RACT limits are expected to be achieved by using catalysts, prestratified charge systems, or by leaning the air/fuel mixture. The RACT limits for spark-ignited lean-burn engines are expected to be achieved by leaning the air/fuel mixture or by retrofitting with low-emission combustion controls to allow further leaning of the air/fuel mixture. Alternative approaches would be the retrofit of existing engines with parts used in newer engines designed for low NOx emissions, replacement of the existing engine with a state-of-the-art low-emissions engine fueled by natural gas or propane, or replacement with an electric motor. Examples of retrofit parts used in low emissions engines would include pistons, heads, electronic engine controllers and ignition systems. It may be necessary to check with the engine manufacturer concerning the compatibility of the components being for retrofit on an existing engine.

D. BARCT Limits

The BARCT limits for spark-ignited rich-burn engines fueled by waste gas are expected to be achieved by using prestratified charge systems. For spark-ignited rich-burn engines, the limits for fuels other than waste gases are expected to be achieved by using catalysts. The spark-ignited lean-burn limits are expected to be achieved by the retrofit of low-emission combustion controls, although some engines may require the use of selective catalytic reduction (SCR).

The BARCT limits reflect a cost-effectiveness threshold of $12 per pound of NOx reduced which is comparable to Sacramento Metropolitan AQMD's threshold of $12 per pound and the South Coast AQMD's threshold of $12.25 per pound. Although the cost-effectiveness for individual engines will generally be lower than $12 per pound, in some individual cases the cost-effectiveness could exceed this figure.

E. Engines with Common RACT and BARCT Limits

In addition, there are two categories of engines which are assigned identical RACT and BARCT limits due to conditions or situations which would make meeting the standard limits onerous. The RACT and BARCT limits for cyclically-loaded, field gas fueled engines used on oil pumps have been set at 300 ppm NOx due to the unique duty cycle of the engine, the character of the fuel which can contain significant amounts of sulfur and moisture, the variable Btu content of the fuel, and the difficulty in controlling emissions from a cyclically-loaded engine. It is expected that the limits for these rich-burn engines will be met by keeping the engines properly maintained and tuned, and by leaning the air/fuel mixture.

There is another category, which includes two-stroke engines fueled by gaseous fuel and rated at less than 100 horsepower. There are a limited number of these engines in use and there are no cost-effective controls available for these engines. The limits for these engines are expected to be achieved by properly maintaining and tuning these engines which would include replacing the oil-bath air filter with a dry unit and cleaning the air/fuel mixer and muffler on a regular basis.

These RACT and BARCT limits should be used as guidance. Districts have the primary responsibility for regulating stationary sources and have the flexibility to adopt IC engine rules that differ from this guidance, as long as these differences do not conflict with other applicable statutes, codes and regulations. The districts may adopt internal combustion engine rules after a case-by-case analysis of engines in the district in order to determine a technically feasible and cost effective way to reduce emissions taking into account site-specific situations or conditions. The districts' decisions on control technologies must not conflict with regulatory requirements and statutory obligations such as attainment plans.

The full text of the determination is provided in Appendix A. The technical basis for the emission limits can be found in Chapter IV.

Table II-1

Summary of RACT Standards for Stationary Spark-Ignited Internal Combustion Engines

Spark-Ignited Engine Type	% Control of NO_X	ppmv at 15% O_2[1]		
		NO_X	VOC	CO
Rich-Burn				
Cyclically-loaded, Field Gas Fueled	--	300	250	4,500
All Other Engines	90	50	250	4,500
Lean-Burn				
Two Stroke, Gaseous Fueled, Less Than 100 Horsepower	--	200	750	4,500
All Other Engines	80	125	750	4,500

1. For NOx, either the percent control or the parts per million by volume (ppmv) limit must be met by each engine where applicable. The percent control option applies only if a percentage is listed, and applies to engines using either combustion modification or exhaust controls. All engines must meet the ppmv VOC and CO limits.

Table II-2

Summary of BARCT Standards for Stationary Spark-Ignited Internal Combustion Engines

Spark-Ignited Engine Type	% Control of NO_X	ppmv at 15% O_2[1]		
		NO_X	VOC	CO
Rich-Burn				
Waste Gas Fueled	90	50	250	4,500
Cyclically-loaded, Field Gas Fueled	--	300	250	4,500
All Other Engines	96	25	250	4,500
Lean-Burn				
Two Stroke, Gaseous Fueled, Less Than 100 Horsepower	--	200	750	4,500
All Other Engines	90	65	750	4,500

1. For NOx, either the percent control or the parts per million by volume (ppmv) limit must be met by each engine where applicable. The percent control option applies only if a percentage is listed, and applies to engines using combustion modification or exhaust controls. All engines must meet the ppmv VOC and CO limits.

ELEMENTS APPLICABLE TO BOTH RACT AND BARCT

Exemptions

- ? Engines operated during emergencies or disasters to preserve or protect property, human life, or public health (e.g., firefighting, flood control)
- ? Portable engines, as defined in Appendix A
- ? Nonroad engines, as defined by the United States Environmental Protection Agency (U.S. EPA), excluding nonroad engines used in stationary applications
- ? Engines not used for the distributed generation of electricity, if operated 200 or fewer hours per year
- ? Emergency standby engines that, excluding period of operation during unscheduled power outages, operate 100 or fewer hours per year

[**Note**: Engines used in agricultural operations are exempt from permitting by the districts according to Health and Safety Code Section 42310(e). However, this prohibition does not preclude districts from controlling agricultural engines in some other manner. Refer to Appendix F.]

Administrative Requirements

- ? Emission control plan
- ? Inspection and monitoring plan
- ? System to monitor NOx and O_2 continuously for engines >1,000 horsepower and permitted to operate >2,000 hours per year
- ? Source test every two years
- ? Monitor NOx and O_2 every three months using a portable NOx analyzer
- ? Conduct source testing and quarterly monitoring at an engine's actual peak load and under the engine's typical duty cycle
- ? Maintain records of inspections and continuous stack monitoring data for two years
- ? Maintain an operating log which shows, on a monthly basis, the hours of operation, fuel type, and fuel consumption for each engine
- ? Installation of nonresettable elapsed operating time meter
- ? Installation of nonresettable fuel meter or an alternative approved by the Air Pollution Control Officer

ELEMENTS APPLICABLE TO BOTH RACT AND BARCT
(continued)

Test Methods

- ? O_2: ARB Method 100 or U.S. EPA Method 3A
- ? NOx: ARB Method 100 or U.S. EPA Method 7E
- ? VOC: ARB Method 100 or U.S. EPA Method 25A or 25B
- ? CO: ARB Method 100 or U.S. EPA Method 10

Alternative test methods which are shown to accurately determine the concentration of NOx, VOC, and CO in the exhaust of IC engines may be used upon the written approval of the Executive Officer of the California Air Resources Board and the Air Pollution Control Officer.

Nonresettable fuel meters installed on stationary spark-ignited internal combustion engines shall be calibrated periodically per the manufacturers' recommendation. The portable NOx analyzer shall be calibrated, maintained, and operated in accordance with manufacturer's specifications and recommendations or with a protocol approved by the Air Pollution Control Officer.

III. SUMMARY OF SPARK-IGNITED IC ENGINE CONTROLS

The combustion of hydrocarbon fuels in IC engines results in emissions of the following criteria pollutants: NOx, CO, VOC, particulate matter, and sulfur oxides (SOx). The pollutant of primary concern from stationary IC engines in this determination is NOx. NOx is a criteria pollutant that reacts in the atmosphere to form ozone which is a significant air pollution problem in California.

There are probably more different types of controls available to reduce NOx from IC engines than for any other type of NOx source. These controls can be grouped into the following general categories: combustion modifications, fuel switching, post-combustion controls, and replacement of the engine with a new, low emissions engine or an electric motor.

Combustion modifications include ignition timing retard, optimization of the internal engine design, turbocharging or supercharging with aftercooling, exhaust gas recirculation, and leaning of the air/fuel ratio. In the case of leaning the air/fuel ratio, this is generally done in combination with other techniques, which allow extremely lean ratios. Fuel switching includes the substitution of methanol for natural gas. Post combustion controls include nonselective catalytic reduction and selective catalytic reduction. Low-emission combustion may use several combustion modifications such as precombustion chambers, turbocharging, and improved ignition systems to reduce emissions, and may also use fuel switching.

Table III-1 summarizes the applicability and effectiveness of the NOx control methods for stationary engines. Although control technologies are shown for NOx control, both CO and VOC emissions must meet their respective requirements. A more detailed description of controls for stationary IC engines can be found in Appendix B.

Table III-1
Summary of Primary NOx Controls For Stationary Spark-Ignited IC Engines

Control Technology	NOx Reduction Effectiveness
Combustion Modifications	
Ignition Timing Retard	15-30%
Prestratified Charge	80+%[1]
Low-emission Combustion	80+%[2]
Turbocharging or Supercharging With Aftercooling	3-35%
Exhaust Gas Recirculation	30%
Fuel Switching	
Methanol	30%[3]
Post-Combustion Controls	
Nonselective Catalytic Reduction	90+%[1]
Selective Catalytic Reduction	80+%[4]
Replacement with Low Emissions Engine Or Electric Motor	60-100%[5]

1. Applies to rich-burn spark-ignited (SI) engines.
2. When the air/fuel mixture is leaned and combined with other NOx reduction techniques (i.e., precombustion chamber, ignition system improvement, turbocharging, air/fuel ratio controller).
3. Applies to natural gas engines.
4. Applies to SI lean-burn engines.
5. For replacement with an electric motor, emissions are reduced 100 percent at the IC engine location, although emissions at power plants may increase.

IV. BASIS FOR DETERMINATION FOR SPARK-IGNITED IC ENGINES

A summary of the determination can be found in Chapter II. The full text of the determination can be found in Appendix A. This chapter will review the basis or reasons for the emissions limits, requirements, and exemptions included in the determination. In developing this determination, the ARB and air districts staff reviewed a number of reports on IC engines, emissions inventory data, vendor literature, source test data, district rules and accompanying staff reports, and other sources of information.

A. Applicability

This determination is applicable to stationary spark-ignited internal combustion engines that have a continuous power rating equal to or greater than 50 brake horsepower. The 50 horsepower cutoff is consistent with the majority of district IC engine rules. Neither a RACT nor BARCT determination was made for engines rated less than 50 horsepower. Districts may consider making a specific determination for this class of engines if their emissions are significant.

In some cases, an engine's power rating may be suspect or unknown. To assure that engines exceeding 50 brake horsepower are not exempt, spark-ignited engines with a maximum hourly fuel consumption rate above 0.52 million Btu per hour are also subject to controls. This fuel consumption level corresponds to engines rated at approximately 50 brake horsepower using a default BSFC rating of 10,400 Btu per brake horsepower-hour. For different BSFC ratings, the maximum fuel consumption ratings should be adjusted accordingly.

1. Engines Derated to Less Than 50 Horsepower

Neither a RACT nor a BARCT determination was made on stationary spark-ignited IC engines derated to less than 50 horsepower due to insufficient, and in some cases, conflicting data. A derated engine is one in which the manufacturer’s brake horsepower rating has been reduced through some device which restricts the engine’s output. One of the largest categories of the derated engines are cyclically-loaded units used to drive reciprocating oil pumps. These engines are generally fueled by oil field gas with variable energy content and composition which may include moisture, hydrogen sulfide and other compounds. The cyclic load on these engines may have a cyclic period of less than 10 seconds. These characteristics would tend to discourage the use of catalysts with air-to-fuel controllers. However, it is interesting to note that a review of source test data in the text of Sections C and D of Chapter IV, Table IV-1 and Appendix D indicates that there have been instances where these engines have been successfully controlled in the past by cleaning up the field gas, and “leaning-out” the engine or installing a catalyst in some cases.

In the case of field gas-fueled engines driving beam-balanced and crank-balanced oil pumps, there are a variety of issues which can affect the approach used to control emissions. The fuel quality and composition of the field gas varies from area to area so that one engine may require treated fuel while another doesn’t. The installation of a gas processing plant may be costly and would affect the cost effectiveness of controlling the emissions from these engines. In addition, consideration should also be given to the number of wells feeding the plant, the proximity of the wells to the plant, and the cost of setting up a gas collection and distribution system for the fuel. An alternative approach is electrification. The majority of the beam-balanced and crank-balanced oil pumps in California are driven by electric motors. This would certainly be an effective approach if electric power is reasonably accessible. However, since some of these engines may be remotely located, the cost of bringing in electrical power could be onerous. Finally, there is a lack of data on certain control technologies which may be effective in reducing emissions from cyclic and non-cyclic engines fueled by field gas with significant amounts of moisture and hydrogen sulfide. Because of the variety of factors that can affect the feasibility and cost-effectiveness of controlling this category, we were unable to make a categorical determination. We recognize that there are technologies (i.e. electrification, cleaning up the field gas and controlling the engine by leaning the air/fuel mixture or adding a catalyst) that can be used to control the emissions from these engines. However, the costs associated with implementing these controls may be cost prohibitive depending on site-specific considerations. We recommend that the districts handle this type of derated engine on a categorical or case-by-case basis due to the uniqueness of the different installations.

Districts may consider controlling the emissions from other categories of derated engines if they determine that it is technically feasible and cost effective. Engines with lower horsepower ratings may be difficult to control due to lack of available emission controls, the relatively high cost of emission controls (especially when compared to the cost of the engine), cost effectiveness, site-specific conditions and other considerations such as operating mode and fuel type. Districts should take these factors into consideration. In addition, repowering with either electric motors or new low-emissions engines should also be considered as alternatives.

Technology development and innovation may also aid in the feasibility of controlling engines derated to less than 50 horsepower. Recently the California Air Resources Board adopted regulations for new small off-road engines and new large off-road spark-ignited engines which included engines rated at less than 50 horsepower. In the rulemaking effort for the large spark-ignited off-road engines, it was concluded that it was feasible and cost effective to control engines rated at 25 horsepower and greater with an air-to-fuel ratio controller and a three-way catalyst also known as non-selective catalytic reduction. Technologies used to control mobile engines certainly have the capability to be used in stationary applications.

B. Alternative Form of Limits

Where applicable, the determination provides a choice of two NOx alternatives: operators must meet either a percent reduction or an emissions concentration limit in parts per million by volume (ppmv). Use of the percentage reduction option may be applied to engines using add-on control devices that treat the exhaust gas stream, engine modifications, or fuel switching. One reason for this NOx control alternative is that exhaust controls typically reduce NOx by a certain percentage, regardless of the initial NOx concentration. Thus, for engines inherently high in NOx, the emission concentration limit may be difficult to achieve when using exhaust controls. Providing an emission limit and percent reduction option allows engine owners or operators a greater degree of flexibility in choosing controls and complying with the emission limits.

In using the percentage reduction option, determining compliance when exhaust controls are used is relatively straightforward, as NOx concentrations can be measured before and after the control device. In contrast, for controls based on engine changes or fuel changes, it is more difficult to determine an accurate percentage reduction. Baseline concentrations must be established by conducting source testing prior to the installation of the engine or fuel modifications. The baseline concentrations will be a function of engine operating parameters such as air/fuel ratio, ignition timing, power output, and the engine duty cycle. When baseline concentrations are being established, it is recommended that the engine operating parameters be thoroughly documented along with the load and the duty cycle under which the engine normally operates. This is done so that the engine can be checked to ensure that it is operating under similar conditions when post-modification source testing is conducted. In this case, compliance is determined by comparing the baseline NOx concentration with the post-modification concentration, estimating a percent NOx reduction and verifying that the control meets the appropriate percent reduction limit.

Except for the optional percentage reduction for NOx, the determination uses limits expressed in parts per million by volume (ppmv). These limits could have been expressed in units of grams per brake horsepower-hour. However, use of limits in terms of grams per brake horsepower-hour would require engines to be simultaneously tested for emissions and horsepower. This would increase costs for compliance verification, and for that reason limits expressed in terms of grams per brake horsepower-hour are not recommended.

C. RACT NOx Limits

It is generally understood that RACT is the application of demonstrated technology to reduce emissions. "Demonstrated" means a particular limit has been achieved and proven feasible in practice. This demonstration need not take place in California. The demonstration also need not be performed on every make and model of IC engine, as long as there is a reasonable likelihood that the technology will be successful on these other makes and models. In addition to the control options discussed below, other options for meeting RACT are discussed in Section F of this chapter. These options include repowering with either a new controlled engine or an electric motor.

1. Rich-Burn Engines

The RACT emission limits for spark-ignited rich-burn engines not cyclically-loaded are based on Ventura County APCD's Rule 74.9 that was in effect between September 1989 and December 1993 (this rule was superseded by a more effective version of Rule 74.9 in December 1993). The 1989-1993 version of this rule required all affected engines to meet applicable limits by 1990. For natural gas-fired rich-burn engines, this NOx limit is 50 parts per million by volume (ppmv), corrected to 15 percent oxygen and dry conditions. Alternatively, rich-burn engines can meet a 90 percent NOx reduction requirement.

The Ventura County rule allowed the emission limits to be increased for engines exhibiting efficiencies greater than 30 percent. However, there are few cases where such efficiency adjustments would increase the allowable emissions significantly. For example, natural gas-fired engines rarely exceed the mid-30s in percentage efficiency, and most of these engines probably are less than 30 percent efficient. In addition, districts that include an efficiency adjustment in their IC engine rules have rarely found a need to use this adjustment to meet rule requirements. This determination does not include an efficiency adjustment. Such an adjustment increases the complexity of the determination, and would complicate enforcement. In many cases, it is difficult to determine the efficiency of an engine. The manufacturer's rated efficiency could be used, but in some cases this information may not be available. Even if this information is available, the efficiency of an engine in the field may differ significantly from the manufacturer's rating due to differences in air density, temperature, humidity, condition of the engine, and power output. The RACT emissions limits can be met without an efficiency adjustment if controls are properly designed, maintained, and operated.

Appendix D summarizes recent source tests from Ventura County for the years 1994 through 1997. Results of source tests for 1986 through 1997 on rich-burn engines are compared to the Ventura IC engine rule applicable at the time (i.e., 50 ppmv NOx or 90 percent reduction). Included in this database were a dozen tests on engines to determine baseline values or emission reduction credits. These engines were not controlled and were not required to meet the rule's emissions limits. Excluding tests conducted to determine baseline values or emission reduction credits leaves over 1000 tests on rich-burn engines. Only about 8 percent of these tests exceeded the applicable NOx limit. In the majority of cases, engines that violated the limit passed other source tests before and after the violation. No particular engine make or model appeared to have a significant problem in attaining the applicable NOx limit. These source tests covered almost sixty different models of engines made by eight different manufacturers.

From the mid-1980s to the mid-1990s, approximately 280 of 360 stationary engines were removed from service in Ventura County. Many of these engines were first retrofitted with controls and were in compliance when they were removed. Though Ventura County's IC engine rule may have contributed to the reduction in the number of stationary IC engines, other areas of the State that did not have a rule controlling NOx emissions from existing stationary engines also experienced significant reductions in stationary engines during the same time period. Most of these engines were used in oil and gas production activities. This reduction in numbers may reflect an overall general reduction in oil and gas production in the State. It may also reflect the impact of new source review. New source review is a collection of emissions and mitigation requirements that must be met before a new or existing stationary source of emissions can be built or modified in the State. New source review may have encouraged the use of electric motors rather than IC engines for new or modified production activities. In addition, new source review may have encouraged the shutdown or replacement of existing IC engines to generate emissions offsets for new or modified production activities.

Based on these data, it appears that the RACT emission levels for rich-burn engines not cyclically-loaded are achievable for a wide variety of gaseous-fueled engines.

It is expected that the most common control method to be used to meet the RACT limits for rich-burn engines not cyclically-loaded will be the retrofit of NSCR controls. For rich-burn engines using waste-derived fuels, where fuel contaminants may poison the catalyst, the most common control method is expected to be the use of prestratified charge controls.

Cyclically-loaded (cyclic) engines including those driving the beam-balanced or crank-balanced oil pumps and fueled by oil field gas have characteristics that may affect the effectiveness of controls. These characteristics include low exhaust gas temperatures (since the engines spend significant periods of time at idle) and rapid fluctuations in power output. The oil field gas may contain significant amounts of moisture and sulfur which may lead to the formation of sulfuric acid which can damage catalysts. The energy content of field gas may vary affecting engine performance. Because of the difficulties and potential costs associated with controlling the emissions from field gas-fueled IC engines driving the beam-balanced and crank-balanced reciprocating oil pumps, the emission limits for these engines are based on San Joaquin Valley Unified APCD's Rule 4701. For beam-balanced or crank-balanced pumping engines, the NOx limit is 300 ppmv corrected to 15 percent oxygen. It is expected that this limit for these rich-burn engines will be met by keeping the engines properly maintained and tuned, and by leaning the air/fuel mixture. We recommend that the districts require the replacement of these engines at the end of their useful life with prime movers having lower NOx emissions.

There have been situations where cyclic rich-burn engines have met the RACT limits of 50 ppmv either by using NSCR or by leaning the air/fuel mixture in conjunction with treating the field gas to reduce the moisture and sulfur content. Both of these control methods have been used successfully on cyclic engines used on "grasshopper" oil well pumps in Santa Barbara County. Source tests of NSCR-equipped cyclic engines in Santa Barbara County have shown that these engines can be effectively controlled with or without air/fuel controllers provided the oil well pumps are air-balanced units. The oil field gas in this particular situation is naturally low in sulfur or "sweet." In the case of beam- and crank-balanced rod pumps, the air/fuel ratio controllers that are part of the control system have slow response times relative to the load fluctuations, making NSCR ineffective due to the low exhaust temperatures. For the beam- and crank-balanced oil well engines, the air/fuel ratio must be leaned along with treating the field gas to meet the NOx limits. Table IV-1 summarizes the results of source tests on cyclically operated engines in Santa Barbara County. These tests were conducted from 1992 through 1995. All engines at Site A used NSCR on engines driving air-balanced oil pumps to control NOx emissions. All engines at other sites used leaning of the air/fuel mixture to control NOx. In addition, it is important to note that the field gas used at the sites referenced in Table IV-1 was either naturally low in sulfur or treated to pipeline-quality natural gas. These engines represent two different manufacturers and six different models. In Ventura County, there are another eight of these rich-burn engines fueled by treated field gas which drive beam-balanced and air-balanced rod pumps. NSCR is installed on all of these engines with five meeting a limit of 50 ppmv NOx and three meeting 25 ppmv.

Table IV-1 Summary of NOx Source Testing of Cyclically Operated Engines Santa Barbara County Emissions in ppmv							
Site	**Engines**	**Tests**	**Engine Size**	**Operating Capacity**	**NO_X**	**CO**	**VOC**
A	18	5	195 hp	50-75%	2-14	79-2445	2-35
B	4	9	131 hp	20-40%	12-35	165-327	29-552[1]
C	16	16	39-46 hp	43-112%	8-28	129-291	25-98
D	18	28	39-49 hp[2]	30-75%	7-33	154-406	31-196

1. One engine exceeded the 250 ppmv VOC limit. After repairs, this engine was retested 6 weeks later and was found to be in compliance.
2. Two engines were derated.

Because of the demonstrated success of meeting the 50 ppmv NOx limit for cyclic rich-burn engines fueled by low-sulfur or treated field gas, we recommend that the districts consider the cost effectiveness of field gas treatment and emission controls in setting limits for these engines on a site-specific basis. In situations where this approach exceeds the cost effectiveness threshold of $12 per pound, we would recommend that districts set a limit of 300 ppm NOx and require the replacement of these engines at the end of their useful life with IC engines having lower NOx emissions or electric motors. In performing the cost effectiveness analysis for treating the field gas and the emission control, the additional costs for field gas treatment should be included along with the incremental materials and labor cost associated with piping the treated gaseous fuel back to the engines from the gas processing unit. Naturally, any costs, benefits, or profits realized from selling the gas should also be included in the analysis.

2. Lean-Burn Engines

The basis for the RACT emission limits for four-stroke spark-ignited lean-burn engines and two-stroke spark-ignited engines rated at 100 horsepower or more is the same as for rich-burn engines: Ventura County APCD’s Rule 74.9 that was in effect between September 1989 and December 1993. For natural gas-fired lean-burn engines, this NOx limit is 125 ppmv, corrected to 15 percent oxygen and dry conditions. Alternatively, these lean-burn engines can meet an 80 percent NOx reduction requirement.

Appendix D summarizes a large number of source tests from Ventura County from the years 1994 through 1997. Results of source tests from 1986 through 1997 on lean-burn engines were compared to the limits of Ventura County's IC engine rule applicable at the time (i.e., 125 ppm NOx or 80 percent reduction). Excluding tests conducted to determine baseline values or emission reduction credits, there were 358 tests on lean-burn engines. Only 21 (approximately 6 percent) of these tests exceeded the applicable NOx limit. In most cases, engines that violated the limit passed several other source tests before and after the violation. No particular engine make or model appeared to have a significant problem in attaining the applicable NOx limit. These source tests covered nineteen different models of engines made by nine different manufacturers.

Based on these data, we conclude that the RACT emission levels for four-stroke lean-burn engines and two-stroke engines rated at 100 horsepower and greater are achievable for a wide variety of gaseous-fueled engines.

We expect the most popular control method used to meet the RACT limits for these lean-burn engines will be the retrofit of low-emission combustion modifications. These modifications will probably include the retrofit of precombustion chambers. In cases where these modifications have not been developed for a particular make and model of engine, SCR may be used as an alternative.

A separate NOx limit of 200 ppmv is set for gaseous-fueled, two-stroke lean-burn engines rated at less than 100 horsepower. This limit is based on recent source test data. There are a relatively small number of these engines which are located in gas fields statewide and are used to drive compressors at gas wells. While precombustion chambers or low-emission combustion retrofits would control emissions from this engine type, there are none available on the market and the cost to develop a retrofit for a limited number of engines would be cost prohibitive. As a result, the only cost-effective way to control emissions from the small two-stroke engines is by properly maintaining and tuning these engines which includes replacing oil-bath air filters with dry units and periodically cleaning the air/fuel mixer and muffler. We recommend that the districts require the replacement of these engines at the end of the two-stroke engine's useful life with prime movers having lower NOx emissions.

D. BARCT NOx Limits

A summary of the BARCT determination can be found in Chapter II. The full text of the BARCT determination can be found in Appendix A.

The Health and Safety Code Section 40406 defines BARCT as "an emission limitation that is based on the maximum degree of reduction achievable, taking into account environmental, energy, and economic impacts by each class or category of source." Control technology must be available by the compliance deadline that has achieved or can achieve the BARCT limits, but these limits do not necessarily need to have been demonstrated on IC engines. A technology can meet the definition of BARCT if it has been demonstrated on the exhaust gases of a similar source, such as a gas turbine, and there is a strong likelihood that the same technology will also work on exhaust gases from IC engines and that systems designed for IC engines are available from control equipment vendors. In addition to the technologies cited below, there are additional candidates described in Appendix B which potentially could be considered to be BARCT. Finally, it is important to note that South Coast AQMD requires owner/operators of stationary engines to comply with Rule 1110.2 by offering them the choice of reducing the engines emissions to specified limits, removing the engine from service, or replacing the engine with an electric motor. Electrification is another approach to consider and is discussed along with other control options in Section F of this chapter.

1. Rich-Burn Engines

The BARCT emission limits for rich-burn engines not cyclically-loaded are based on the current version (adopted December 1993) of Ventura County APCD's Rule 74.9, the Federal Implementation Plan for the Sacramento area, and the Sacramento Metropolitan Air Quality Management District's Rule 412. These NOx limits are 25 ppmv or 96 percent reduction for most rich-burn engines, and 50 ppmv or 90 percent reduction for rich-burn engines using waste gases as fuel. Best available control technology (BACT) determinations of the South Coast AQMD and ARB's BACT Clearinghouse meet or exceed the BARCT limits.

The Ventura County source test data referenced earlier (page IV-2) indicates that about 65 percent of the tests (i.e., 623 out of 962 tests) on rich-burn engines operating on natural gas or oil field gas met the BARCT NOx limit of 25 ppmv or 96 percent NOx reduction. These engines used either NSCR type catalysts or prestratified charge controls. Engines using prestratified charge controls met the limit less often (21 percent, or 32 out of 153 tests) than engines using catalysts (73 percent, or 591 out of 809 tests). The controls for these rich-burn engines were designed to meet a 50 ppmv or 90 percent reduction limit, not the 25 ppmv or 96 percent NOx reduction limit as in the BARCT determination. Better NOx emission reduction performance can be anticipated if controls are designed to meet a 25 (rather than 50) ppmv limit.

There is a separate BARCT NOx limit for rich-burn engines fueled by waste gases (e.g., sewage digester gas, landfill gas). This limit, 50 ppmv or 90 percent reduction, is the same as the RACT limit for rich-burn engines. A review of source tests of rich-burn engines using waste gases indicate a high percentage of the engines complied with a 50 ppmv NOx limit. In addition, identical NOx limits are contained in Ventura County APCD’s Rule 74.9. Comparable limits are included in IC engine rules for South Coast AQMD and Antelope Valley APCD. The waste gas engines that were tested used prestratified charge controls because the application of NSCR to waste gas fueled engines has often been unsuccessful. NSCR catalysts often have problems with plugging and deactivation from impurities in waste gases. In order to use a catalyst, the waste gas should be treated to remove these impurities. This gas treatment process could be a substantial additional cost in controlling the emissions from this class of engines.

It is expected that the most popular control method used to meet the BARCT limits for rich-burn engines not cyclically-loaded using fuels other than waste gases will be NSCR with air/fuel ratio controllers. For engines using waste gases, the use of prestratified charge controls are expected to be the most popular control method.

For cyclic rich burn engines, the discussion and recommendations for RACT NOx limits apply for BARCT NOx limits as well. Due to the difficulties and costs associated with controlling the emissions from these engines, the NOx limit is set at 300 ppmv which is based on San Joaquin Valley Unified APCD’s Rule 4701. We recommend that the districts require the replacement of these engines at the end of their useful life with prime movers having lower NOx emissions. It is expected that this limit will be met by keeping the engines properly maintained and tuned, and by leaning the air/fuel mixture. However, there are situations where it has been feasible to control the emissions from these engines. A review of 34 source tests on 26 cyclic rich burn engines fueled by low-sulfur field gas and driving air-balanced oil well pumps in Santa Barbara County APCD demonstrated that all engines were able to meet the 25 ppm NOx limit by using NSCR. In the case of the "leaned-out"engines fueled by treated field gas and driving beam-balanced and crank-balanced oil wells, the source tests indicate that 81 percent of the source tests met the limit. In setting limits for cyclic rich-burn engines fueled by field gas, we recommend that air districts consider whether the field gas is "sweet" or if it is cost effective to treat the field gas to reduce the moisture and sulfur content and enable the usage of emissions controls. Districts should also consider the cost effectiveness of electrification of these oil pumps to reduce emissions. As mentioned previously, South Coast AQMD in Rule 1110.2 requires owner/operators of stationary engines to reduce the emissions to meet limits, remove the engines from service, or replace the engines with electric motors. Even in remote areas without access to the power grid, South Coast AQMD requires owner/operators of oil pumps to treat the field gas which fuels an IC engine genset with NSCR after-treatment. The genset supplies power to motors driving the beam-balanced and crank-balanced oil pumps contiguous to the genset.

For engines not cyclically-loaded, NSCR can be used to meet the 25 ppmv NOx limit by increasing the size of the catalyst bed along with the amount of active materials in the catalysts, and more precise air/fuel ratio controllers. In addition, closer tolerances, more frequent inspections, an increase in catalyst replacement frequency, and monitoring of a greater number of parameters under the facility's inspection and monitoring plan could be required to maintain the higher performance required to meet the BARCT limits. The inspection and monitoring plan is discussed in Section I, Inspection and Monitoring Program.

2. Lean-Burn Engines

The BARCT emission limits for four-stroke spark-ignited lean-burn engines and two-stroke spark-ignited engines rated at 100 horsepower or greater are based on the current version (adopted December 1993) of Ventura County APCD's Rule 74.9, the Federal Implementation Plan for the Sacramento area, and the Sacramento Metropolitan Air Quality Management District's Rule 412.

We have specified a 65 ppmv or 90 percent reduction level as the BARCT NOx limit. This level is identical to the level in the Federal Implementation Plan for the Sacramento area, and is also identical to the level found in Sacramento Metropolitan AQMD's Rule 412. This level is less effective than the current Ventura County APCD's Rule 74.9 NOx limit of 45 ppmv or 94 percent control. However, the Ventura County APCD's limit includes an efficiency correction that can allow a NOx ppmv limit higher than 45. Our determination does not include an efficiency correction. In addition, only 40 percent of the Ventura County APCD's source tests (143 of 358 tests) showed compliance with a 45 ppmv or 94 percent control NOx limit. On the other hand, the Ventura County APCD's source test data show that approximately 70 percent of the source tests (249 of 358) for lean-burn engines met a NOx limit of 65 ppmv or 90 percent reduction. It is interesting to note that at the time of these source tests these engines were required to meet a less effective limit of 125 ppmv or 80 percent reduction under a previous version of Rule 74.9. The NOx reduction performance for engines using controls designed to meet the BARCT limit is expected to be better than that indicated by the Ventura County source test data.

It is expected that the most common control method used to meet the BARCT emission limit for four-stroke spark-ignited lean burn engines and two-stroke spark-ignited engines rated at 100 horsepower or more will be the retrofit of low-emission combustion controls. Other techniques may also be used to supplement these retrofits, such as ignition system modifications and engine derating. For engines that do not have low-emission combustion modification kits available, SCR may be used as an alternative to achieve the BARCT emission limits.

For two-stroke engines rated less than 100 horsepower, the discussion and recommendations for RACT NOx limits apply for BARCT NOx limits as well. There are relatively few of these small engines located in the state. In addition, emission controls for these engines are not available, and the cost to develop a retrofit for a limited number of engines could be expensive. As a result, the only cost-effective way to control emissions from the small two-stroke engines is by properly maintaining and tuning these engines which includes replacing oil-bath air filters with dry units and cleaning the air/fuel mixer and muffler on a regular basis. Recent source test data indicate that almost 90 percent of the small two-stroke gas field engines tested met the NOx limit of 200 ppmv. We recommend that the districts require the replacement of these engines at the end of their useful life with prime movers having lower NOx emissions.

E. Common Limits

Both the RACT and BARCT determinations include identical limits for CO and VOC. The basis for these common emissions limits is discussed below. Other elements that are identical include alternatives to controlling engines and exemptions which are addressed in Sections F and G.

1. CO Limits

The determination’s limit for CO is 4,500 ppmv. This 4,500 ppmv limit is based on the highest CO limit in any district IC engine rule in California. Most districts have a 2,000 ppmv CO limit. The 4,500 ppmv CO limit in the determination was chosen since the main concern for emissions from IC engines has been on NOx, and some controls for NOx tend to increase CO emissions. The 4,500 ppmv CO limit should allow the determination's NOx limits to be met more easily and economically. In most cases, the determination’s NOx limits will be met either by the use of three-way catalysts or a leaner air/fuel mixture. Either of these techniques should readily achieve a CO level of 4,500 ppmv.

In general, vehicles have been found to be the major source of CO in areas that are nonattainment for CO, and stationary sources do not contribute significantly to the nonattainment status. However, areas that are nonattainment for CO should assess the impact of stationary engines on CO violations, and should consider adopting a lower CO limit than 4,500 ppmv.

2. VOC Limits

VOC limits are included in the determination because VOC emissions, like NOx emissions, are precursors to the formation of ozone and particulate matter. VOCs are hydrocarbon compounds that exist in the ambient air and are termed “volatile” because they vaporize readily at ambient temperature and pressure. In addition, many VOCs are considered to be toxic and are classified as Toxic Air Contaminants (TAC) or Hazardous Air Pollutants (HAP). For stationary engines, the mass and impact of VOC emissions is lower than NOx emissions. However, several NOx controls tend to increase VOC emissions. The determination's VOC limits are designed to assure that VOC increases from NOx controls do not become excessive.

In addition, the determination's VOC limits help assure that engines are properly maintained. If an engine is misfiring or has other operational problems, VOC emissions can be excessive.

The determination’s limit for VOC is 250 ppmv for rich-burn engines and 750 ppmv for lean-burn engines. The 250 ppmv limit for rich-burn engines is readily achievable through the use of three-way catalysts or other NOx control methods involving leaning of the air/fuel mixture. A higher limit is for lean-burn engines, as VOC concentrations tend to increase when such engines are operated at the extremely lean levels needed to achieve the determination's NOx limits. These VOC limits are equal to the highest limits included in any district IC engine rule in California.

In cases where a district requires further VOC reductions to achieve the ambient air quality standards, the adoption of VOC limits more effective than those in the determination should be considered. More effective VOC limits on lean-burn engines can be achieved through the use of oxidation catalysts without impacting NOx reduction performance. Oxidation catalysts reduce VOC and CO emissions from lean-burn engines. See Appendix B for more information on oxidation catalysts.

F. Other Control Options

In addition to combustion modifications, exhaust controls, and use of alternative fuels, other control options can be used to meet the RACT and BARCT limits.

All RACT and BARCT limits can also be met by replacement of the IC engine with an electric motor or a new controlled engine. Although engine replacement does not qualify as “retrofit,” the California Clean Air Act provides that districts can take this approach under “every feasible measure” if districts are having difficulty attaining the State ambient air quality standard. In the case of an engine repower, the new controlled engine would use combustion modifications, exhaust controls, or an alternative fuel similar to an existing retrofitted engine. However, since the engine is new, greater design flexibility is usually available to engineer a more efficient engine and effective control package.

For some engines, another option for meeting the RACT and BARCT limits is to convert a rich-burn engine into a lean-burn engine, or a lean-burn engine into a rich-burn engine. In the case of engines converted to lean-burn, improved engine efficiencies may reduce overall costs compared to controlling the rich-burn engine. In the case of engines converted to rich-burn, the rich-burn controls may be much lower in cost than the lean-burn controls.

It is the intent of this determination to maximize emission reductions. Consequently, owner/operators of rich-burn engines are not allowed to convert these engines to a lean-burn configuration in order to be subject to the less effective NOx emission limits. For rich-burn to lean-burn conversions or vice versa, the more stringent rich-burn NOx limits apply. For instance, in the case of a rich-burn engine converting to a lean-burn unit, the rich-burn limits would apply since emission reductions would be maximized. Likewise, the rich-burn NOx limits would apply for a lean-burn to rich-burn conversion. It should be noted that districts may consider these types of conversions to be modifications, which may fall under New Source Review and trigger best available control technology and offset requirements. We would recommend consultation with the appropriate district prior to undertaking one of these conversions.

In addition, market-based programs allowing the buying and selling of emission reduction credits are another approach that can be used to comply with BARCT requirements. Pursuant to Health and Safety Code, Section 40920.6.(c), a source subject to BARCT may retire marketable emission reduction credits in lieu of a BARCT requirement. Health and Safety Code, Section 40920.6.(d) allows alternative means of producing equivalent emission reductions at an equal or less dollar amount per ton reduced, including the use of emission reduction credits, for any stationary source that has demonstrated compliance costs exceeding an established cost-effectiveness value per unit of pollutant reduced for any adopted rule.

In the South Coast Air Quality Management District (SCAQMD), sources of NOx and SOx that emit greater than 4 tons per year are regulated through a separate market trading program, the Regional Clean Air Incentives Market or RECLAIM. RECLAIM allows these sources to achieve equivalent or greater emission reductions as would have been required otherwise under BARCT. Excess reductions from one RECLAIM facility can be traded to other RECLAIM facilities or permanently retired for an air quality benefit. Stationary internal combustion engines that are regulated under RECLAIM are exempt from the District's NOx/SOx limits. However, these sources must still comply with the limits for other regulated pollutants covered under district rules. Therefore, stationary engines regulated under RECLAIM for NOx and SOx would still need to comply with the CO and VOC limits specified in Rule 1110.2.

G. Exemptions

1. Engines Used During Disasters or Emergencies

Engines are exempt from the determination when used during a disaster or state of emergency, provided that they are being used to preserve or protect property, human life, or public health. Such disasters or states of emergency can be officially declared by local, State, or Federal officials or by an individual if it is determined that property, human life, or public health could be adversely affected without the operation of the applicable engine. Reasons for including this exemption are obvious. If controls fail on an engine used during a disaster, without this exemption the operator is faced with fines for noncompliance if operations continue, or the loss of property, human life, or public health if the engine is shut down. Another situation where this exemption would apply would be the operation of an engine where the emission controls result in a degradation in the power output or performance. It would be considered acceptable to shutdown or disengage the emission controls if that action increases the engine power output and thereby would either prevents or decrease the possibility of the loss of property, human life, or public health which would otherwise occur with the derated engine. Exempting engines under these conditions eliminates the operator dilemma of choosing between the protection of air quality and the more immediate concerns of protecting human life, public health, and property.

2. Portable Engines

A portable engine is defined as one which is designed and capable of being carried or moved from one location to another according to Health and Safety Code, Section 41751. An engine is not considered portable if the engine is attached to a foundation or will reside at the same location for more than 12 consecutive months. This determination exempts portable engines whether they are registered under the Statewide Portable Equipment Registration Program or with a district. The statewide program is authorized under Health and Safety Code Sections 41750 through 41755 which require the ARB to develop a registration program and emissions limits for portable engines (see Chapter VII). Owners or operators of portable engines who decide to take part in this voluntary registration and control program are exempt from meeting the requirements of district rules and regulations.

3. Nonroad or Offroad Engines

To avoid potential conflicts with federal law, the determination exempts nonroad engines. Under the federal Clean Air Act Amendments of 1990, districts are prohibited from adopting emission standards or control technology requirements for all nonroad engines. However, for some categories of nonroad engines, control can be delegated to the ARB. See Chapter VII for further details. It should be noted that nonroad engines used in stationary applications are not exempt from this determination. In addition, engines used in nonroad applications are not considered “nonroad” if the engine remains at a location for more than 12 consecutive months or a shorter period of time for an engine located at a seasonal source.

4. Engines Operated No More Than 200 Hours Per Year

Engines that are not used for distributed generation of electrical power are exempt if they operate 200 hours or fewer per year. Most districts specify 200 hours as the limit for the low-usage exemption in their IC engine rules. Engines in this category are required to have a nonresettable fuel meter and a nonresettable elapsed operating time meter. The owner or operator may use an alternative method or device to measure fuel usage provided that the alternative is approved by the Air Pollution Control Officer.

Distributed generation refers to the practice where an IC engine is operated to produce electrical power, and this power is either fed into the electric utility grid or displaces utility electric power purchased by an industrial or commercial facility. An example of the latter situation is called “peak shaving” where an IC engine genset is operated during periods of high electrical rates, and the electrical power produced by a genset is cheaper than the power from the grid. Distributed generation also refers to the operation of an IC engine that is part of a mechanical drive system (e.g., water pump, conveyor belt) consisting of at least one IC engine and one electric motor, where the system can be powered either by the electric motor(s) or the IC engine(s).

IC engines used for distributed generation are not exempt, regardless of the number of hours of operation per year. The reason for this restriction is to assure that exempt engines will not operate simultaneously on some of the highest ozone days of the year (see the following discussion on the emergency standby engine exemption).

5. Emergency Standby Engines

The exemption for emergency standby engines is limited to engines operating no more than 100 hours per year, excluding emergencies or unscheduled power outages. Emergency standby engines are typically operated for less than an hour each week to verify readiness. Additional operation may be periodically required for maintenance operations. A limit of 100 hours per year allows a reasonable number of hours for readiness testing, maintenance and repairs. Engines in this category are required to have a nonresettable fuel meter and a nonresettable elapsed operating time meter. The owner or operator may use an alternative method or device to measure fuel usage provided that the alternative is approved by the Air Pollution Control Officer.

The definition of emergency standby engine excludes engines that operate for any other purpose than emergencies, unscheduled power outages, periodic maintenance, periodic readiness testing, readiness testing during and after repairs, and scheduled power outages for maintenance and repairs on the primary power system. The purpose of these limitations is to assure that these engines do not operate during nonemergencies to displace or supplement utility grid power for economic reasons such as distributed generation, “peak shaving,” or as part of an interruptible power contract or voluntary load reduction program with an electric power utility.

The current electric utility restructuring that is occurring in California changes the pricing of electricity and the incentives applicable to commercial and industrial facilities. Under restructuring, commercial and industrial customers are able to purchase electricity on the spot market. Spot prices are relatively low during the night, but much higher when the demand for power is at a peak. This peak is typically on hot summer days, when some of the highest ozone concentrations of the year are recorded.

Under restructuring, commercial and industrial facilities have the potential to generate and sell power from their emergency generator engines, and send this power to the electrical grid. Restructuring also allows such facilities to bid a reduction in their electrical demand, and operate emergency generator engines to supplement their grid power purchases. Thus, if the price of electricity is high enough there is an economic incentive for a facility to operate its own emergency generators, and either feed this power into the electrical grid or reduce the facility's demand for power.

Because all facilities within a district simultaneously experience these high electrical prices, the potential is significant for the simultaneous operation of a large number of engine generators, even if such usage is limited to only a few hours per year. If a large number of facilities in a district operate their emergency generators simultaneously, the increase in NOx emissions within the district could be substantial. These increases would occur on the hottest days of the year, which are typically the highest ozone days of the year. Thus, unless the nonemergency operation of emergency generators is restricted, the potential to impact peak ozone concentrations could be significant.

To minimize this impact on air quality, the determination prohibits the nonemergency operation of emergency engines to generate electrical or mechanical power so as to reduce a facility's electrical power consumption from the grid or to realize an economic benefit. Examples of the latter would include operation under an interruptible power contract or voluntary load reduction program, or for purposes of "peak shaving." In addition, emergency engines cannot be used to supply electrical power to the grid or for distributed generation.

6. Other Exemptions

Other exemptions may be justified under certain circumstances, but the inclusion of any additional exemption in a district rule should be fully justified. Before an exemption is added, the district should also investigate whether alternative, less effective controls should be required for a class of engines instead of totally exempting such engines from all control or testing requirements. Factors that should be considered include the need to adopt a RACT or BARCT level of control to meet air quality plan or Health and Safety Code requirements, and cost-effectiveness for a particular engine category.

H. Compliance Dates

For engines subject to RACT or BARCT limits, an application for a permit to construct should be submitted and deemed complete by the district within one year of district rule adoption. Final compliance is required within two years of district rule adoption. This time period should be sufficient to evaluate control options, place purchase orders, install equipment, and perform compliance verification testing.

An additional year for final compliance may be provided for existing engines that will be permanently removed without being replaced by another IC engine. In many cases, such an operation may be nearing the end of its useful life, and it would not be cost-effective to retrofit the engine with controls for only a year of operation. In addition, over the course of several years, the cumulative emissions from the engine to be removed will be less than if this engine were controlled. Although emissions are higher in the first year, lower emissions occur in all subsequent years.

A district adopting a BARCT level of control should consider modifying the compliance schedule for engines that already meet RACT to provide additional time in certain cases to reduce the financial burden on the engine owner or operator. For example, engines complying with a RACT level of control through the use of a catalyst could be subject to an alternative compliance schedule requiring the BARCT level of control when the catalyst is next replaced or 3 years, whichever time period is shorter.

I. Inspection and Monitoring Program

It is the engine owner or operator's responsibility to demonstrate that an engine is operated in continuous compliance with all applicable requirements. Each engine subject to control is required to have an emission control plan describing how the engine will comply. To reduce the paperwork for engine owners or operators, districts can accept an application to construct as meeting the control plan requirements, as long as the application contains the necessary information.

As part of the emission control plan, an inspection and monitoring plan is required. The inspection and monitoring plan describes procedures and actions taken periodically to verify compliance with the rule between required source tests and quarterly NOx monitoring. These procedures and actions should include the monitoring of automatic combustion controls or operational parameters to verify that values are within levels demonstrated by source testing to be associated with compliance.

Examples of parameters that can be monitored in an inspection and monitoring program include exhaust gas concentration, air/fuel ratio (air/fuel ratio control signal voltage for catalyst systems), flow rate of the reducing liquid or gas added to the exhaust, exhaust temperature, inlet manifold temperature, and inlet manifold pressure. For engines that are not required to use continuous monitoring equipment, it is recommended that the inspection and monitoring plan require periodic measurement of exhaust gas concentrations by a portable NOx monitor so that engines can be maintained to produce low emissions on a continuous basis. Where feasible, the portable NOx monitor should be used on a monthly basis. If a portable analyzer is used, it shall be calibrated, maintained and operated in accordance with the manufacturer’s instructions and recommendations or with a protocol approved by the Air Pollution Control Officer. The Air Pollution Control Officer shall specify what data is to be collected and the records to be kept as part of the inspection and monitoring plan. Records of the data shall be retained for two years.

These requirements and recommendations are based on Ventura County APCD’s Rule Effectiveness Study. One of the conclusions of the study was that most non-compliant engines can come into compliance easily and quickly with minor adjustments. It also appears that compliance can be significantly improved if more frequent inspections are performed. During the time period when the study was conducted, the District's rule required quarterly inspections with portable analyzers and an annual source test. To improve rule effectiveness, the rule was revised to change the frequency of inspections with portable analyzers from quarterly to monthly, while the announced source test frequency was decreased from once a year to once every two years.

In addition, this study also found that engine operators often did not adjust engines to optimal settings except for announced source tests and quarterly inspections. We recommend that, during an initial source test, optimal settings are determined for engine operating parameters affecting emissions. The inspection and monitoring program should require that these optimal settings be frequently checked and maintained. In this fashion, emissions reductions should be maximized.

J. Continuous Monitoring

Continuous monitoring of NOx and O_2 are required for each stationary engine with a brake horsepower rating equal to or greater than 1,000 that is permitted to operate more than 2,000 hours per year. This engine size and operating capacity is found in the SCAQMD's IC engine rule, and was determined to be cost-effective. Continuous emissions monitoring systems (CEMS) may be used to fulfill this requirement. Each district's APCO may consider alternatives, if adequate verification of the systems accuracy and performance is provided. One example of an alternative would be a parametric emissions monitoring system (PEMS) which monitors selected engine parameters and uses the values in calculating emissions concentrations of different pollutants. Continuous monitoring data must be recorded and maintained for at least two years.

In the case of engines covered by Title V permits, the continuous monitoring data should be retained for five years. Refer to the appropriate district's Title V rule(s) to determine if there are any additional monitoring requirements under Title V.

K. Source Testing/Quarterly Monitoring

Source testing of each engine subject to controls would be required every 24 months. Alternatives to the specified ARB and U.S. EPA test methods which are shown to accurately determine the concentration of NOx, VOC, and CO may be used upon the written approval of the Executive Officer of the California Air Resources Board and the Air Pollution Control Officer. In addition, a portable NOx analyzer shall be used to take NOx emission readings to determine compliance with the applicable NOx emission limits during any quarter in which a source test is not performed. A NOx emission reading in excess of the limit shall not be considered a violation, so long as the problem is corrected and a follow-up inspection is conducted within 15 days of the initial inspection. The portable analyzer used to provide the emissions data shall be calibrated, maintained and operated in accordance with manufacturers' specifications and recommendations or with a protocol approved by the Air Pollution Control Officer.

Typically, source testing of many other controlled sources is required every year. However, for IC engines, source testing can be a significant expense, and allowing a longer period between tests would assure that the cost of source testing would not be out of proportion to other operating expenses. Extended source test periods normally are associated with operating out of compliance for longer periods of time and increased emissions. However, the determination requires quarterly monitoring with a portable NOx analyzer and the development and implementation of a detailed inspection and monitoring program, which should provide verification that emission controls are operating properly and the IC engine is in compliance between source tests.

According to one rule effectiveness study, "Phase III Rule Effectiveness Study, VCAPCD Rule 74.9, Stationary Internal Combustion Engines," October 1, 1994, the frequency of non-compliance was greater for unannounced source tests than for annual or announced source tests (5 of 22 compared to 1 in 11). One of the main reasons for this difference is that, based on interviews with the engine owners or operators, in most cases portable emission analyzers are used to tune engines for better emissions performance immediately before announced source tests are performed. Based on this observation, we recommend that districts conduct unannounced source tests so that engines will be maintained to produce low emissions on a continuous basis.

L. Records

Records of the hours of operation and type and quantities of fuel consumed each month would also be required for each engine subject to controls or subject to limits on annual hours of operation which includes emergency standby engines and engines operated less than 200 hours annually. Installation of a nonresettable elapsed operating time meter is required on any spark-ignited IC engine subject to the provisions of the determination. Fuel consumption will be monitored by either installing a nonresettable fuel meter or an acceptable alternative approved by the Air Pollution Control Officer. Owner/operators of stationary spark-ignited IC engines can also propose alternative methods or techniques for estimating fuel consumption for the Air Pollution Control Officer’s approval. An example of this latter alternative would be a fuel-use monitoring plan as used in Santa Barbara County. Nonresettable fuel meters installed on stationary spark-ignited internal combustion engines shall be calibrated periodically per the manufacturer’s recommendation. For emergency standby engines, all hours of non-emergency and emergency operation shall be recorded along with the fuel usage. These records would be available for inspection at any time, and would be submitted annually to the district.

As previously noted, data is also collected and recorded as part of source testing, quarterly monitoring, continuous monitoring and the inspection and monitoring programs where required. All data taken as a result of continuous monitoring and inspection and monitoring programs shall be maintained for a period of at least two years and made available for inspection by the Air Pollution Control Officer or the Officer’s designee. Source test reports shall be submitted to the Air Pollution Control Officer for review. Quarterly NOx readings by portable analyzers shall be reported to the Air Pollution Control Officer or the Officer’s designee in a manner specified by the Air Pollution Control Officer.

For engines subject to Title V permits, it is recommended that these records be retained for five years and submitted as part of any Title V reporting requirements as necessary. Refer to the appropriate district’s Title V rule(s).

V. COST AND COST-EFFECTIVENESS

This chapter reviews the costs and cost effectiveness associated with the installation of emission controls on stationary spark-ignited engines. The cost estimates and cost effectiveness numbers provided here are general in nature and apply to generic engines without consideration of the engine application and local or site-specific conditions or situations which could have a significant cost impact. In developing rules, districts are encouraged to perform their own cost analysis and to obtain contemporary cost data from emission control manufacturers, contractors, industry sources and associations, government agencies, and owner/operators of stationary engines which have been retrofitted with emission controls. This approach will ensure that the cost analysis has a greater degree of accuracy.

The cost of NOx controls for reciprocating IC engines can vary widely depending on the individual site, size of engine, fuel type, type of engine, operational characteristics of the engine, and other parameters. For engines requiring the installation or replacement of major pieces of equipment, such as catalysts, engine heads, and turbochargers, the largest expense is the capital cost of controls. The replacement cost for catalysts can also be a major expense.

When an engine is controlled, greater care must be taken to assure that it is properly maintained, and thus maintenance costs may increase.

Fuel consumption may be increased by several percent for some of the controls. However, for some uncontrolled engines, modifications that lean the air/fuel ratio may decrease fuel consumption.

Depending on the existing equipment and requirements, other costs associated with achieving the determination’s requirements may include the purchase and installation of hour and fuel meters; purchase, installation, and operation of emissions monitors; source testing; permit fees; and labor and equipment costs associated with the inspection and monitoring program.

A. Costs for RACT/BARCT

The cost estimates in Table V-1 list the capital (including installation) cost for several of the most commonly used control techniques and technologies. Control techniques such as air/fuel ratio changes or ignition system improvements are not listed in Table V-1. These techniques are usually part of a collection of techniques such as a “low-emission combustion” controls and therefore are included in those cost estimates already shown in Table V-1. However, the benefits and estimated costs of each separate technique is listed in Appendix B. The estimated costs shown in Table V-1 are considered general costs because of the wide variation in engine configuration and application used by the various industries in California as well as the variation in engine specifications within a series of engines produced by a manufacturer.

Table V-1 Cost Estimates for ICE Control Techniques and Technologies							
Horsepower Range	**Ign. Timing Retarding**	**Pre-Stratified Charge**	**NSCR[1] W/O AFRC**	**AFRC[2]**	**SCR[3]**	**Low-Emission Combustion Retrofit**	**Electrification[4]**
50-150	$300	$10,000	$13,500	$4,200	$45,000	$14,000	$28,000
151-300	$450	$23,000	$18,500	$5,000	$45,000	$24,000	$49,000
301-500	$500	$30,000	$20,500	$5,000	$60,000	$42,000	$79,000
501-1,000	$800	$36,000	$30,500	$5,300	$149,000	$63,000	$177,000
1001-1,500	$900	$42,000		$5,300	$185,000	$40,000-256,000	
1501-2,000	$1,000	$47,000		$6,500		$40,000-256,000	
2,001-3,000	$1,400					$40,000-256,000	

1. NSCR is an abbreviation for Nonselective Catalytic Reduction
2. AFRC is an abbreviation for air/fuel ratio controller
3. SCR is an abbreviation for Selective Catalytic Reduction. The costs are based on Urea injection, with parametric emissions monitoring system, and catalyst sized for 96 percent NOx conversion for lean burn engines.
4. The costs for electrification assume the units will be located relatively close to a power grid. If this is not the case, a cost of $5,000 to $10,000 may be incurred to have the local utility company install the appropriate power outlet for the motor to the local utility grid.

The cost estimates shown in Table V-1 are a mixture of quotes and extrapolations of cost from information provided by industry sources, associations, local governments, and the U. S. EPA. It also includes an estimated cost for replacing engines in various horsepower ranges with an electric motor. Electrification may be a consideration as an alternative for internal combustion engines from 50 to 500 horsepower. Beyond that range, modification and installation costs may become so extensive that this approach may not be cost effective. The costs for electrification assume the units will be located relatively close to a power grid. If this is not the case, a cost of $5,000 to $10,000 may be incurred to have the local utility company install the appropriate power outlet for the motor to the local utility grid. In some utility districts, the cost for connecting to the power grid may be waived or refunded if the monthly energy usage matches or approach the cost to connect to the grid.

B. Cost-Effectiveness

Table V-2 lists the estimated cost-effectiveness for the control techniques and technology listed in Table V-1. It should be noted that these costs are estimates and may vary according to site-specific parameters, situations, and conditions. For purposes of this cost analysis, it was assumed that the engines operated at rated load for 2,000 hours per year. The costs for the different control technologies include the capital and installation costs. In the case of ignition timing retard, it was assumed that the ignition timing was retarded during the engine's normal

Table V-2
Cost-Effectiveness Estimates for ICE Control Techniques and Technologies[5]

Control	Horse Power Range	Capital Cost ($)	Installation Cost($)	O & M Cost($/year)	Annualized Cost ($/year)	Cost-Effectiveness ($/ton of NOx Reduced)
Ignition Timing Retard (@ 15% reduction)[3]						
	50 - 150	N/A	N/A	4,700	4,700	7,300
	151 - 300	N/A	N/A	3,400	3,400	2,100
	301 - 500	N/A	N/A	2,900	2,900	1,100
	501 - 1000	N/A	N/A	3,200	3,200	600
	1001 - 1700	N/A	N/A	3,300	3,300	100
Prestratified Charge (@ 80% reduction)[2,3]						
	50 - 150	10,000	N/A	1,000	2,700	800
	151 - 300	23,000	N/A	1,500	5,300	700
	301 - 500	30,000	N/A	2,000	6,900	500
	501 - 1000	36,000	N/A	2,500	8,400	300
	1001 - 1700	47,000	N/A	3,000	10,700	200
Nonselective Catalytic Reduction w/o AFRC (@ 96% reduction)[3]						
	50 - 150	11,000	2,500	6,000	8,200	2,100
	151 - 300	16,000	2,500	6,700	9,000	900
	301 - 500	18,000	2,500	7,700	10,000	600
	501 - 1000	28,000	2,500	10,200	13,000	400
	2500	44,000	3,000	17,800	18,000	300
Selective Catalytic Reduction for Lean Burn(@ 96% reduction)[1,3]						
	50 - 150	32,000	13,000	20,000	27,000	7,300
	151 - 300	32,000	13,000	26,000	33,000	4,400
	301 - 500	43,000	17,000	35,000	36,000	2,900
	501 - 1000	116,000	33,000	78,000	78,000	2,900
	1001 - 1500	132,000	53,000	117,000	148,000	2,400
Low-Emission Combustion Retrofit (@ 80% reduction)[2,3,4]						
	50 - 150	14,000	N/A	N/A	2,300	1,100
	150 - 300	24,000	N/A	N/A	3,900	1,000
	300 – 500	42,000	N/A	N/A	6,900	500
	500 - 1000	63,000	N/A	N/A	10,250	400
	1000 – 1500	40,000-256,000	N/A	N/A	6,500-41,700	100-900
Electrification[3]						
	50 - 150	14,000	13,600	unknown	4,600	1,100
	150 - 300	24,000	25,300	unknown	7,700	900
	300 - 500	40,000	38,800	unknown	12,900	900
	500 - 1000	90,000	87,300	unknown	29,000	1,100

1 The cost for the SCR is based on Urea injection, with parametric emissions monitoring system, and catalyst sized for 96 percent NOx conversion.
2 The cost for fuel is not included in any calculation except for ignition timing retard.
3 The annualized cost do not include local costs such as permit fees, or cost for compliance assurance inspections or source testing.
4 Not Applicable (N/A). The costs for a "low-emission combustion" engine or retrofit kit assume engine replacement or kit installation during the normal rebuild or replacement cycle of the existing engine.
5 The cost effectiveness analysis is performed assuming that the engines are run at rated power (100% load) for 2,000 hours annually. This is equivalent to a capacity factor of approximately 0.23.

tune-up. Consequently, there are no installation costs associated with this technique. This table also includes the expenses associated with additional maintenance and parts for the emission control, and the cost of additional or reduced fuel usage as a result of the control technology. In some applications, stationary engines are used to run compressors or generators. If the compressor or generator and the engine are an integral unit, then any additional costs incurred as a result of this integration should be included in the control equipment cost. Those additional costs are not reflected in the table.

For each control technique or technology, the cost effectiveness is based on an estimated percent of emission reduction of NOx from an uncontrolled engine. Some technologies, such as NSCR, can be used in stages to reduce emissions by having the exhaust gas flow through a series of catalyst modules. In the case of ignition timing retard, fuel usage may increase by as much as 5 percent. The cost for the increased fuel use is included in the annualized cost shown in Table V-2 under that particular option. None of the other technologies are expected to increase fuel consumption drastically enough to contribute significantly to a cost increase. In fact, prestratified charge and low-emission combustion technologies are expected to decrease fuel consumption because they result in a leaner burning engine. Likewise, operational and maintenance costs with the ignition timing retarded engine and the prestratified charged engine is not expected to increase significantly. The maintenance cost for the SCR system is associated with the use of urea and the maintenance of the SCR components, not necessarily with the engine directly.

Some technologies, such as “low-emission combustion”, have nominal emissions limits specified by the manufacturer. The costs for a low-emission combustion engine or retrofit kit assume engine replacement or kit installation during the normal rebuild or replacement cycle of the existing engine. By exchanging the older engine or installing a low-emission combustion kit during an engine’s regularly scheduled rebuild or replacement time allows a majority of the installation cost to be treated as a normal maintenance cost and not a cost directly incurred to achieve emission reduction. Because of the wide range of low-emission combustion configurations for engines above 1,000 horsepower, those costs are listed as a range. Engines larger than 1,000 horsepower should be evaluated on a case-by-case basis.

The cost-effectiveness estimates were derived by first estimating annual costs for each control. The annualized cash flow method was applied to the pre-tax capital and installation costs using a nominal interest rate (including inflation) of 10 percent over a 10 year life. To this annualized cost were added the estimated additional annual fuel (where applicable) cost, plus operation and maintenance cost attributable to the control method. This sum yields the total annual cost which is listed as the “Annualized Cost” in Table V-2. It is assumed that the engines operate 2,000 hours annually at full load. The cost effectiveness for the emissions controls on engines operating fewer hours per year and/or at lower loads will be higher.

Secondly, NOx reductions were estimated. The process used to determine reductions included selecting typical NOx emission rates from uncontrolled engines in each size category listed in Table V-2. Next, we estimated annual NOx emissions, and annual NOx emission reductions for each control method based on the percent NOx reductions listed for each control type in Table V-2. The cost-effectiveness is then calculated by dividing the “Annualized Cost” by the annual emission reductions. It should be pointed out that some of these control methods could result in reductions of other pollutants and/or an increase in fuel economy, which would be additional benefits.

It should be noted that the cost-effectiveness for prestratified charge (PSC) versus NSCR is very competitive in terms of pollutant reduced per dollar spent. In fact, if the cost of an air to fuel ratio controller is included with the cost of the NSCR, it becomes less cost-effective than the PSC. Also, the operation and maintenance cost for NSCR includes catalyst replacement after five years of operation. For lean burn engines, SCR is a very effective NOx reduction technology, but it is also relatively expensive for lean-burn engines when compared to a low-emission combustion retrofit which is more cost effective.

As Table V-2 shows, cost-effectiveness for the selected technologies is equal to or less than $2,500 per ton of NOx reduced, with the exception of Ignition Timing Retard (ITR) for engines with horsepower rating below 150, and SCR on engines with horsepower ratings below 1000. The higher cost-effectiveness for the ITR engines below 150 horsepower is due to the expected increase in fuel use. However, the cost-effectiveness for all of the controls listed are well below the $24,000 per ton bench mark used in this document and by some of the air quality districts. The installed and annualized costs for SCR are the highest in Table V-2. As mentioned previously, each engine site has to be considered on an individual basis along with the characteristics of each control type when considering emission reduction technologies.

Electrification cost-effectiveness is also estimated in Table V-2 for a range of engines up to 3000 horsepower in size. Below 500 horsepower, the installed costs associated with electrification are less than the installed cost for an equivalent internal combustion engine. Between 500 and 1000 horsepower, installed costs for electrification are comparable with that of an internal combustion engine. For engines larger than 1000 horsepower, electrification becomes very expensive with the primary advantage being that NOx emissions are reduced 100 percent although emissions from electrical power generating power plants will increase slightly.

C. Other Costs

The previous tables, for the most part, have covered the capital, operating, and maintenance costs for controls. Other expenses may also be encountered to comply with the determination. In the case of hour meters and fuel meters, many engines already have such measuring devices, so there would be no additional cost. For engines using SCR, often the cost of a continuous NOx monitor is included in the cost of controls.

This determination requires the use of an hour meter on exempt emergency standby engines operating fewer than 100 hours per year. In addition, many districts will likely require the use of fuel and hour meters for recordkeeping and compliance verification purposes. For completeness, the following information on these costs is provided as follows. Hour meters typically cost between $30 and $80 each, while a fuel meter with an accuracy of plus or minus three percent can range in cost from about $340 up to $4,500 depending on the manufacturer, fuel type, and fuel flow rate. A meter for gaseous fuel, such as natural gas, is more expensive than one for liquid fuels because gaseous fuel meters must compensate for pressure and temperature.

The determination also requires the installation of an emissions monitoring system for engines rated 1,000 brake horsepower and greater and permitted to operate more than 2,000 hours per year. Costs of such a system vary depending on whether continuous emissions monitors are used or parametric monitoring is employed. The capital and installation cost of a continuous emission monitor ranges from $25,000 to $100,000, and a parametric system ranges from $25,000 to $40,000. The annual operating and maintenance costs (per engine) are estimated to be $7,500 for a continuous emission monitoring system, and $2,000 for a parametric emissions monitoring system. Costs are also associated with periodic source testing which is required to determine an engine's compliance with the emission limits. The cost of a source test is about $3,000 per engine using a reference method such as ARB Method 100. Costs are less if multiple engines are tested at the same time.

As part of the inspection and maintenance requirements, it is recommended that exhaust emissions be periodically checked with a hand-held portable analyzer. The cost of a hand-held portable analyzer is about $10,000 to $15,000. Many engine operators who perform their own maintenance and maintain several engines already use portable analyzers. Smaller operators generally contract out engine maintenance, and nearly all maintenance contractors already have analyzers. Thus, in most cases, requiring periodic checks with an analyzer is not expected to increase costs significantly.

D. Incremental Costs and Cost-Effectiveness

New requirements for the adoption of rules and regulations were passed by the State Legislature in 1995. These requirements, found in Health and Safety Code Section 40920.6, apply to districts when adopting BARCT rules or feasible measures. Specifically, when adopting such rules, districts must perform an incremental cost-effectiveness analysis among the various control options. Incremental cost-effectiveness data represent the added cost to achieve an incremental emission reduction between two control options. Districts are allowed to consider incremental cost-effectiveness in the rule adoption process.

When performing incremental cost-effectiveness analyses, in some cases an uncontrolled baseline may be appropriate. Table V-3 summarizes an incremental cost-effectiveness comparison for an uncontrolled baseline. For example, the costs for controlling an uncontrolled engine with the application of prestratified charge controls is estimated, along with the costs for replacing the engine with an electric motor. Emission reductions for application of these two

Table V-3 Incremental Cost-Effectiveness Estimates for ICE Control Techniques and Technologies				
Engine Type	**Control Comparison**	**Horsepower**	**Incremental NO_X Reduction (tons/year)**	**Incremental NO_X Cost-Effectiveness ($/ton of NO_X Removed)**
Rich-Burn				
	From Pre-Stratified Charge to NSCR (96%)	50-150	0.7	7,700
		150-300	1.7	2,200
		300-500	2.9	1,100
		500-1000	9.5	500
	From Pre-Stratified Charge to Electrification	50-150	0.9	2,200
		150-300	2.2	1,100
		300-500	3.6	1,700
		500-1000	7.1	2,900
	From NSCR to Electrification	50-150	0.2	(21,200)
		150-300	0.4	(3,000)
		300-500	0.7	4,000
		500-1000	1.6	10,100
Lean Burn				
	From Low-Emission Combustion to SCR (96%)	50-150	0.4	58,900
		150-300	0.8	35,100
		300-500	3.3	8,800
		500-1000	6.6	10,300
	From Low-Emission Combustion to Electrification	50-150	0.9	2,700
		150-300	2.2	1,800
		300-500	3.6	1,700
		500-1000	3.6	2,400

different control methods to an uncontrolled engine are also estimated. The incremental cost-effectiveness is determined by dividing the difference in costs by the difference in emission reductions. The Table V-3 estimates were developed from the cost effectiveness analysis summarized in Tables V-2. For rich-burn engines, it was assumed that the prestratified charge technology would achieve an 80 percent NOx reduction and the NSCR control technology would achieve a NOx reduction performance of 96 percent control. Both of these technologies were compared against electrification as well as each other. The emissions reduction associated with electrification was assumed to be 100 percent. For lean-burn engines, incremental cost-effectiveness analyses compared low-emission combustion to electrification and SCR technologies. The results are included in Table V-3. The numbers in parentheses shown in Table V-3 indicates a cost saving per incremental ton of NOx reduced for the latter technology when compared to the former technology.

Districts that adopt a BARCT level of control for IC engines may have already required a RACT level of control for these engines. Table V-4 summarizes data from Ventura County APCD. Its provides incremental cost-effectiveness estimates for the case where a RACT level of control has already been installed (i.e., baseline is RACT such as prestratified charge or NSCR designed to 90 percent control). In addition the control equipment is either modified or replaced to meet BARCT limits (i.e., NSCR with 96 percent control). It should be noted that Ventura APCD's analysis was performed for lean-burn engines reducing NOx emissions to 45 ppm or achieving reductions of 94 percent as opposed to our BARCT limits of 65 ppm or 90 percent. The base NOx emission limits for this analysis are identical to our RACT NOx limits.

Incremental cost-effectiveness values should be used to determine if the added cost for a more effective control option is reasonable when compared to the additional emission reductions that would be achieved by the more effective control option. Historically, when determining cost-effectiveness, districts have estimated the costs and emission reductions associated with controlling uncontrolled sources. This latter method is sometimes called "absolute" cost-effectiveness. Incremental cost-effectiveness should not be compared directly to a cost-effectiveness threshold that was developed for absolute cost-effectiveness analysis. Incremental cost-effectiveness calculations, by design, yield values that can be significantly greater than the values from absolute cost-effectiveness calculations. Direct comparisons may make the cost-effectiveness of an economic and effective alternative seems exceedingly expensive.

Table V-4
Incremental Cost and Cost-Effectiveness Summary for Application of BARCT to RACT Controlled Engines[1]

Engine/ Control	Size Range (HP)	Number of Engines	Reduction Needed (%)	Emissions Reduction (tons/yr)[2]	Capital Costs ($)	O&M Costs ($/yr)	Cost-Effectiveness ($/ton)[3]	Cost-Effectiveness ($/ton, adjusted to 1999 dollars)
Rich-burn								
From NSCR (90%/50 ppm) to improved NSCR (96%/25 ppm)								
	100-200	6	36	2.93	9,185	1,888	9,300	9,740
	225	1	22	0.37	9,185	1,888	8,200	8,590
	412	2	25	0.79	18,335	1,673	10,000	10,470
	625	1	19	0.79	18,260	2,399	6,000	6,280
	700-800	3	50	6.27	18,260	2,399	2,300	2,410
	1250	3	34	5.85	18,260	2,399	3,300	3,460
From PSC (90%/50 ppm) to NSCR (96%/25 ppm)								
	300	3	50	7.84	10,600	1,673	1,300	1,360
	330	3	53	0.62	10,600	1,673	17,000[4]	17,800
Lean-burn								
From SCR (80%/125 ppm) to improved SCR (94%/45 ppm)								
	660	2	62	14.81	105,000-346,500	15,000	3,800-7,900	3,980-8,270
From Low-Emission Combustion (80%/125 ppm) to added SCR (94%/45 ppm)								
	1108	8	29	39.38	105,000-346,000	15,000	6,300-13,000	6,600-13,610

1. Reference: Ventura County APCD Staff Report for Rule 74.9, December 1993
2. Based on actual emissions rate
3. Capital recovery factor of .125 used (approximately 9 percent interest for 15 years)
4. Operator proposed electrification for these engines

VI. IMPACTS

A. Air Quality

NOx is a precursor to ozone, and State and Federal ozone ambient air quality standards are violated throughout many parts of California. In addition, although most NOx is emitted in the form of nitric oxide (NO), on most days NO will rapidly oxidize to form nitrogen dioxide (NO_2). There are State and federal ambient air quality standards for NO_2. NOx is also a precursor to particulate nitrate, which can contribute to violations of PM10 (particulate matter less than 10 micrometers in aerodynamic diameter) and PM2.5 ambient air quality standards. Violations of PM10 standards are even more widespread than ozone violations in California. Reductions in NOx emissions will reduce ozone, nitrogen dioxide, and PM10 and PM2.5 concentrations, and reduce the number of violations of State and Federal ambient air quality standards for these four pollutants.

Table VI-1 lists emission reduction estimates by district for NOx emissions from stationary IC engines. In order to develop NO_x emissions reductions estimates for this determination, we used the 1996 Air Resources Board's point source emissions inventory. We first identified districts that do not currently have IC engine rules and are designated as nonattainment for the State ozone standard. We also identified which districts are required to adopt RACT rules, and which districts are required to adopt BARCT rules.

The Table VI-1 emission reduction estimates were calculated assuming no reduction would come from engines emitting one ton or less of NOx per year. Engines with emissions of one ton or less are often standby emergency generators, which would be exempt from control requirements. In addition, no reductions were assumed for engines that are already controlled.

In order to determine emissions reduction percentages, we identified control technologies likely to be used for compliance with the guidelines. For spark-ignited engines in districts required to adopt RACT emissions limits, leaning of the air-fuel mixture or retrofitting of low-emission combustion kits are the control technologies expected to be used. These technologies are expected to achieve NO_x reductions of approximately 80 percent. For waste gas fueled engines, the BARCT limits will be met by using prestratified charge systems or clean burn retrofits. These technologies are expected to achieve NO_x reductions of approximately 80 percent. For engines burning fuels other then waste gas, the BARCT emissions limits are expected to be met using NSCR, clean burn retrofit, or SCR. These technologies are expected to achieve NO_x reductions of at least 90 percent. We looked at the number of engines in each district that were spark-ignited, or used waste gas for fuel and applied these NO_x emissions reduction estimates to each engine to determine NO_x emissions reductions. Since in some respects this inventory may underestimate actual emissions (see Chapter I), the actual emission reductions may be greater than the estimates in Table VI-1. However, to the extent that engines have already been controlled but are reported in the inventory as being uncontrolled, the Table VI-1 estimates may be higher than actual emissions reductions. Total statewide NO_x emissions reductions from districts without rules are 601 tons per year, or about 2.5 percent of NO_x emissions from SI engines.

Table VI-1

Estimated NO_x Emissions Reductions for Stationary Source Spark Ignited (SI) Engines from Districts without IC Engine Rules

Emissions in Tons per Year

District	Ozone Classification	1996 Inventory	SI Engine Emissions Reductions
Butte County AQMD	Moderate	14	6
Feather River AQMD	Moderate	361	289
Glenn County APCD	Moderate	325	248
Monterey Bay Unified APCD	Moderate	76	58
Totals		**776**	**601**

Source: Air Resources Board 1996 Point Source Inventory

Potential emissions reductions for some of the larger districts with IC engine rules are estimated in Table VI-2. Engines in districts that already have IC engine rules may already be controlled. Therefore, it may not be cost effective for these districts to require these lower limits. To the extent that requiring lower emissions limits is not cost effective, or if controlled engines are already emitting at levels below those required by district rules, the emissions reductions in Table VI-2 are overestimated.

Table VI-2

Estimated NO_x Emissions Reductions for Stationary Source Spark Ignited (SI) Engines from Larger Districts with IC Engine Rules[1,2]

Emissions in Tons per Year

District	Ozone Classification	1996 Inventory	SI Emissions Reductions
San Diego	Serious	238	155
San Joaquin Valley	Severe	4,882	2,104
Santa Barbara	Moderate	985	433
South Coast[3,4]	Extreme	4,259	1,375
Totals		**10,364**	**4,067**

Source: Air Resources Board 1996 Point Source Inventory

[1] Includes only point sources.
[2] Assumes engines emit at levels required in district rules.
[3] Assumes 87 percent of SI engines are rich-burn per 1990 SCAQMD IC engine staff report.
[4] Assumes 50 percent of rich-burn SI engines are > 500 hp, 50 percent are < 500 hp, as different standards apply for each category.

Totaling tables VI-1 and VI-2 gives potential NO_x reductions of approximately 4,700 tons per year, or approximately 20 percent of statewide NO_x emissions from SI engines.

B. Economic Impacts

The economic impacts from meeting the requirements of this determination will be a function of the type of engine and controls used, and the financial health of the engine owner or operator. The costs and cost effectiveness are discussed in detail in Chapter V.

An NSCR catalyst is the control method expected to be used on most rich-burn engines. The total (annualized capital plus operating and maintenance) cost of an NSCR catalyst will range from approximately $8,200 to $18,000 depending on the size of the engine. This annualized cost is based on a ten-year life for the catalyst. The required source testing would add to this total. These costs are detailed in Table V-2. In addition, source testing of an engine's emissions is required periodically, and this will cost about $3,000 for a single engine, and less on a unit basis if multiple engines are tested during the same period.

The costs of retrofitting a lean-burn engine to meet the determination's NOx limits will generally be greater than for a rich-burn engine. Retrofit costs can vary significantly, with lower costs associated with the use of an economical clean burn retrofit kit, and higher costs if a turbocharger or other expensive equipment must be replaced or added, or if SCR controls are used.

For larger engines operating a substantial number of hours per year, NOx and oxygen concentrations must be monitored continuously. In addition, for other engines using SCR, a continuous NOx monitor is often included as part of the controls package. The cost of continuous monitoring can be significant. The purchase and installation costs of a stand-alone NOx monitor and data acquisition and reporting system can range from $25,000 to $100,000. As an alternative to monitoring NOx directly, districts may find parametric monitoring to be a reasonable alternative. In parametric monitoring, several engine ambient and operational parameters are monitored, and these parameters are used to calculate NOx emissions. The monitoring of engine parameters can be less expensive than monitoring NOx directly. The capital cost for a parametric system ranges from $25,000 to $40,000. The annual operating and maintenance costs (per engine) are estimated to be $7,500 for a continuous emission monitoring system, and $2,000 for a parametric emission monitoring system.

Table VI-3
Cost Estimates for IC Engine Monitoring

Monitoring Device	Capital Costs	O&M Costs (per engine)
Continuous Emissions Monitoring	$25,000-$100,000	$7,500
Parametric Emissions Monitoring	$25,000-$40,000	$2,000

C. Catalysts

Both NSCR and SCR catalysts contain heavy metals and other toxic substances that may create environmental problems if they are not disposed of properly. In the case of NSCR catalysts, it is usually cost-effective to reclaim and recycle the heavy metals from spent catalysts. For all catalysts, the cost of proper disposal is relatively minor, and catalyst vendors generally will agree to dispose of their own used catalysts at no charge.

In the case of SCR, ammonia or urea is injected into the exhaust gas to reduce NOx, and some of the ammonia is released into the atmosphere unreacted. Ammonia is a toxic compound (but not a TAC) at high concentrations and can also be a precursor to the formation of particulate matter. At lower concentrations, ammonia can cause health effects and can be a nuisance due to odor. Therefore, many districts have adopted rules or specified permit conditions, which limit the ammonia concentration in the exhaust vented to the atmosphere. These limits vary from a few ppmv to about 50 ppmv. Two districts have engine rules which set an ammonia emission limit of 20 ppmv from any emissions control device.

There are also safety concerns associated with accidental spills of ammonia. Not only is ammonia a toxic compound, but it is also a fire hazard at extremely high concentrations. Constructing and operating the ammonia system in conformance with existing safety and fire regulations can mitigate these concerns. Another way to minimize the safety concerns with ammonia is to replace it with urea. Urea, which has been used extensively in Europe, is nontoxic, non-odorous, and nonflammable. It dissolves easily in water and has been used as a fertilizer and an additive in animal feed and cosmetics.

D. Methanol

Methanol is a toxic compound that can cause serious health effects if ingested, breathed, or absorbed through the skin. In addition, combustion of methanol in IC engines can result in elevated formaldehyde exhaust emissions. The ARB has identified formaldehyde as a toxic air contaminant. Careful handling of methanol and conformance to existing health and industrial standards should minimize any safety hazards associated with methanol. Formaldehyde emissions can be minimized by assuring that the IC engine does not operate overly rich, and by the use of an oxidation catalyst. Methanol has been used as a fuel for cars and buses for a number of years with little or no adverse health impacts noted.

E. Energy Impacts

Controls used to meet the NOx limits in this determination are not expected to have a significant impact on energy usage. In many instances, controls may increase fuel consumption by a few percent, but there may be a net fuel savings in other instances. For example, if a NOx limit is met by replacing a rich-burn engine with a new, low NOx lean-burn engine, fuel consumption will decrease by about five to eight percent.

F. PM Impacts

Controls used to meet the NOx limits in this determination may also increase PM emissions. Emissions of particulate matter are generally very low for a properly operating spark-ignited engine. Particulate matter emissions from spark-ignited engines can be minimized by assuring that the air/fuel ratio is not overly rich and the fuel is low in sulfur content. Commercial natural gas, commercial LPG, and California cleaner burning gasoline are all extremely low in sulfur. For fuels high in sulfur such as waste gases, scrubbing the sulfur from the fuel before it is introduced into the engine can minimize emissions of particulate matter.

VII. OTHER ISSUES

This chapter addresses miscellaneous issues concerning Federal, State, and local regulation of stationary IC engines, nonroad engines, and portable engines as well as the control of toxic emissions from these engines.

A. Effect of District, ARB, and U.S. EPA Regulations

The districts in California have primary responsibility for control of air pollution from stationary sources. Thus, districts have the authority to adopt rules and regulations controlling emissions from IC engines that are stationary sources. The ARB and U.S. EPA also have authority to control emissions from certain engines, including motor vehicle engines, nonroad (off-road) engines, and other types of engines. The California Health and Safety Code authorizes the ARB to adopt standards and regulations for motor vehicles and for certain off-road or nonvehicle engine categories, including farm equipment and construction equipment. Under the federal Clean Air Act, the U.S. EPA has authority to control emissions from stationary sources and from mobile sources, including nonroad engines. The U.S. EPA may authorize California to enforce requirements for certain motor vehicle engines and nonroad engines if standards are at least as protective as applicable federal standards. U.S. EPA has granted such waivers to California for a number of engine categories.

1. ARB IC Engine Regulations

Two major provisions in State law authorize the ARB to control emissions from nonvehicular IC engines. The first of these, Section 43013 of the Health and Safety Code, grants the ARB authority to adopt standards and regulations for a wide variety of off-road or nonvehicle engines. These include off-highway motorcycles, off-highway vehicles, construction equipment, farm equipment, utility engines, locomotives, and marine vessels. Under Section 43013, the ARB has adopted regulations for several engine categories, including small off-road engines, large off-road spark ignition engines, and portable engines. Some of these engines could be used in applications where the engines are considered to be stationary sources. In such situations, the ARB staff has concluded that the district holds jurisdiction, and the engine must comply with district rules and regulations.

The second major provision in State law regarding ARB authority to control emissions from nonvehicular IC engines can be found in Health and Safety Code sections 41750 through 41755. These sections require the ARB to develop uniform statewide regulations for the registration and control of emissions from portable engines. ARB adopted regulations on March 27, 1997, which became effective September 17, 1997. It should be noted that this RACT/BARCT determination for stationary IC engines exempts all portable engines if they are registered either with a local district or under the statewide registration program described in the following paragraph.

The Statewide Portable Equipment Registration Program establishes a uniform program for portable engines and portable engine-driven equipment units. Once registered, engines and equipment units may operate throughout California without the need to obtain individual permits from local air districts. Districts are pre-empted from permitting, registering, or regulating portable engines and portable equipment units registered with the ARB. However, local districts are responsible for enforcing the Program. The Statewide Portable Equipment Registration Program Regulations can be found in sections 2450 through 2466, title 13, California Code of Regulations.

The California Clean Air Act (CCAA) requires districts that are unable to achieve five percent annual emission reductions to demonstrate to the ARB's satisfaction that it has included every feasible measure in its clean air plan and an expeditious adoption schedule for these measures. ARB interprets the adoption of every feasible measure to mean, at a minimum, that districts consider regulations that have been successfully implemented elsewhere. Districts should also consider going beyond what has already been accomplished by evaluating new technologies and innovative approaches that might offer potential emission reductions. In addition, districts should consider not only technological factors, but social, environmental, and energy factors within the district, as well as cost-effectiveness and the district's ability to realistically adopt, implement, and enforce measures. The use of RACT/BARCT standards on existing stationary sources is one of the feasible measures required by the CCAA. Furthermore, districts may require the repowering or replacement of IC engines with cleaner IC engines or electric motors under every feasible measure. In these situations, it is recommended that districts consider electrification whenever it is feasible in order to maximize emission reductions.

2. U.S. EPA IC Engine Regulations

A district's ability to control emissions from stationary IC engines may be affected by federal regulations for nonroad engines. Effective July 18, 1994, the U.S. EPA promulgated 40 CFR Part 89-- Control of Emissions from New and In-use Nonroad Engines. In 40 CFR 89.2, U.S. EPA adopted a definition of nonroad engine that distinguishes between stationary and nonroad sources for purposes of federal regulation. Under the federal definition, nonroad engines are IC engines that are in or on equipment that is self-propelled or are portable. However, if a portable IC engine remains at one location for more than 12 months (or, for a seasonal source, the duration of the season), it is not a nonroad engine and may be considered a stationary source. On the other hand, if the engine moves within 12 months (or, for a seasonal source, during the season), even if the move is within the boundaries of a single site, the engine may be considered a nonroad engine. Examples of nonroad engine applications are bulldozers, lawnmowers, or agricultural engines that are on trailers. 40 CFR Part 89 should be consulted for a more detailed explanation of the federal definition of nonroad engine.

Under the federal Clean Air Act and U.S. EPA definitions, a district may have adopted definitions that differ from U.S. EPA definitions and therefore, in certain circumstances, may consider a nonroad engine to be a stationary source in certain circumstances.

Under the federal Clean Air Act Amendments of 1990, the U.S. EPA is authorized to regulate newly manufactured nonroad engines. In general, the CAA amendments expressly prohibit states (including districts) from adopting emissions standards or other control technology requirements for nonroad engines [CAA, section 209(e)]. However, Congress provided in the CAA that California, upon receiving authorization from the U.S. EPA, could adopt and enforce standards and regulations for most categories of nonroad engines if the requirements are at least as protective as the applicable federal standards. (However, all states, including California, are preempted from setting emission standards for new nonroad engines that are less than 175 horsepower and are used in farm or construction vehicles or equipment).

In accordance with U.S. EPA preemption provisions, this RACT/BARCT determination exempts from rule requirements engines that meet the U.S. EPA definition for new nonroad engines that are less than 175 horsepower and used in construction or farm equipment or vehicles.

Owners or operators of IC engines may also be subject to Title V of the Federal Clean Air Act. Title V requires California air districts to develop and implement local operating permit programs for major stationary sources. TitleV applicability may vary depending on a source's location and the type and potential amount of air pollutants emitted. In the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD), the major source applicability thresholds are currently 50 tons per year (TPY) for NO_X and VOC (If the district is reclassified from serious to severe nonattainment with respect to national ambient air quality standards, the major source thresholds for NO_X and VOC will change from 50 TPY to 25 TPY). For PM_{10} and SO_X the major source threshold in the SJVAPCD is 70 TPY.

B. Emissions of Hazardous Air Pollutants/Toxic Air Contaminants

1. Hazardous Air Pollutants/Toxic Air Contaminants Emitted

Fuels used in stationary IC engines and exhaust gases from these engines contain toxic substances. These substances are labeled hazardous air pollutants (HAPs) by the U.S. EPA and toxic air contaminants (TACs) by the ARB. A TAC is defined in Health and Safety Code as an air pollutant which may cause or contribute to an increase in mortality or in serious illness, or which may pose a present or potential hazard to human health. In April 1993, the ARB designated all HAPs listed in subsection (b) of Section 112 of the federal CAA as TACs. Toxic substances differ from criteria pollutants such as NOx, CO, SOx, and particulate matter because of the large number of substances that are potentially toxic and identified threshold or safe levels for many toxics. In addition, toxic substances tend to be emitted in much smaller amounts than criteria pollutants, but their toxicity tends to be much greater.

Emissions of toxic substances from the exhaust of natural gas-fired engines are the result of incomplete combustion. These toxic substances include: formaldehyde, polycyclic aromatic hydrocarbons (PAHs), acetaldehyde, acrolein, benzene, ethyl benzene, toluene, and xylenes. Recently, two-stroke and four-stroke, lean-burn engines were tested as part of U.S. EPA's Industrial Combustion Coordinated Rulemaking (ICCR) process. For the four-stroke SI engine, formaldehyde was detected in all of the test runs while acrolein was found in less than half and at levels usually a factor of 1,000 smaller than the formaldehyde. Similarly, formaldehyde was found in all of the test runs on the two-stroke SI engine with significantly smaller amounts of toluene, benzene, and a few PAHs. The rest of the compounds were not measured at detectable levels.

HAP emissions are also regulated by Title V. For sources HAPs in all districts, the major source threshold is 10 TPY of a single HAP or 25 TPY of a combination of HAPs.

2. U.S. EPA Requirements

The source category list published by U.S. EPA under CAA section 112(b) requires the MACT standard for stationary reciprocating IC engines to be promulgated by November 15, 2000. Once U.S. EPA promulgates a MACT standard, it becomes an air toxic control measure (ATCM) under state law, unless an ATCM for the source category has already been adopted. The U.S. EPA developed the ICCR process to develop MACT standards for combustion sources. This process, started in 1996, gathered representatives of industry, environmental groups, and state and local regulatory agencies together to develop MACT standards for industrial and commercial heaters, boilers, and steam generators, gas turbines, and IC engines. U.S. EPA is planning on releasing a MACT standard for reciprocating IC engines soon.

3. State and District Requirements

The State and districts have had, for a number of decades, the authority to control air toxics that pose a health hazard. However, the formal framework for setting emission limits for air toxics was not in place until enactment of the Toxic Air Contaminant Identification and Control Act (AB 1807) in 1983. In 1987, passage of the Air Toxics "Hot Spots" Information and Assessment Act (AB 2588) expanded the role of the ARB and districts by requiring a statewide air toxics inventory and assessment, and notification to local residents of significant risk from nearby sources of air toxics. In 1992, SB 1731 required owners of certain significant risk facilities identified under AB 2588 to reduce the risk below the level of significance.

4. Emission Rates of HAPs/TACs

A number of sources are available for estimating the emission rates for HAPs and TACs from IC engines. Using the formaldehyde emission factors listed in Ventura County APCD's AB 2588 Combustion Emission Factors document, the 10 tons per year major source threshold under the federal CAA may be exceeded if a facility has natural gas-fired engines with a combined rating exceeding about 8,000 horsepower. If this major source threshold is exceeded for an engine that is a stationary source, the engine is subject to federal MACT standards. More recent source testing of engines using natural gas, landfill gas, or field gas indicates the 10 tons per year may be exceed if a facility has engines with a combined rating as low as 4,000 horsepower. This is a worse plausible case, though, as these tests also indicate some facilities may not exceed 10 tons until the combined horsepower rating is as high as 200,000. These data demonstrate that emission rates of HAPs can vary greatly, depending on the type of gaseous fuel, and the design and operating parameters of each individual engine.

5. Control of HAPs/TACs

The toxic substances of most concern emitted from stationary engines burning gaseous fuels are VOCs. These VOCs are the result of incomplete combustion, and can be reduced by methods that either improve combustion inside the engine or destroy VOCs in the exhaust. The VOC emission limits found in this determination will help limit emissions of toxic compounds that are also VOCs.

One of the more popular and effective VOC exhaust control methods for IC engines is the oxidation catalyst. Oxidation catalysts have been shown to reduce VOC emissions by over 90 percent for natural gas-fired engines. Testing conducted on SI engines fueled by liquified petroleum gas and gasoline and with three-way catalysts have indicated substantial reductions in emissions of formaldehyde, acetaldehyde, benzene, 1,3 butadiene, and styrene, all classified as VOCs and HAPs. U.S. EPA's ICCR effort is in the process of testing natural-gas-fired IC engines to determine the effectiveness of oxidation catalysts in controlling HAPs. This testing also will include a rich burn engine with a three-way NSCR catalyst.

Engine modifications that promote complete combustion will reduce emissions of VOCs, thereby also reducing emissions of toxic substances that are VOCs. These engine modifications for natural gas-fired engines include operation of the engine with a lean (but not excessively lean) air/fuel ratio, and the use of improved ignition systems. However, operating an engine slightly lean will tend to maximize NOx emissions.

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