# SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

**Preliminary Draft Staff Report**

**Proposed Amended Rule 1110.2 – Emissions from Gaseous- and Liquid-Fueled Engines**

**Proposed Amended Rule 1100 – Implementation Schedule for NOx Facilities**

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**Deputy Executive Officer**
Planning, Rule Development, and Area Sources
Philip M. Fine, Ph.D.

**Assistant Deputy Executive Officer**
Planning, Rule Development, and Area Sources
Susan Nakamura

**Planning and Rules Manager**
Planning, Rule Development, and Area Sources
Michael Morris

Author: Rodolfo Chacon – Air Quality Specialist

Contributors:
Al Baez – Program Supervisor
Shawn Bennage – Supervising Air Quality Inspector
Rizaldy Calungcagin – Senior Air Quality Engineer
Bhaskar Chandan – Supervising Air Quality Engineer
Mike Garibay – Senior Air Quality Engineer
Kate Kim – Air Quality Engineer I
Peter Ko – Air Quality Engineer II
Tom Lee – Senior Air Quality Engineer
Danny Luong – Senior Air Quality Engineering Manager
Roy Olivares – Air Quality Engineer II
Chris Perri – Air Quality Engineer II
Barbara Radlein – Program Supervisor
Angela Shibata – Senior Air Quality Engineer
Dipankar Sarkar – Program Supervisor
Tracy Tang – Air Quality Specialist
Jason Taylor – Senior Air Quality Engineer
Victor Yip – Senior Enforcement Manager

Reviewed By:
Kevin Orellana – Program Supervisor
Gary Quinn, P.E. – Program Supervisor
William Wong – Principal Deputy District Counsel

**SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT**
**GOVERNING BOARD**

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## EXECUTIVE SUMMARY

The Regional Clean Air Incentives Market (RECLAIM) program was adopted in October 1993 under Regulation XX. RECLAIM is a market-based emissions trading program designed to reduce NOx and SOx emissions and includes facilities with NOx or SOx emissions greater than 4 tons per year. The 2016 Final Air Quality Management Plan (2016 AQMP) included Control Measure CMB-05: Further NOx Reductions from RECLAIM Assessment (CMB-05) to ensure the NOx RECLAIM program was achieving equivalency with command-and-control rules that are implementing Best Available Retrofit Control Technology (BARCT) and to generate further NOx emission reductions at RECLAIM facilities. The adoption resolution for the 2016 AQMP directed staff to achieve five tons per day of NOx emission reductions as soon as feasible but no later than 2025, and to transition the Regional Clean Air Incentives Market (RECLAIM) program to a command-and-control regulatory structure requiring BARCT as soon as practicable. On July 26, 2017 the Governor approved California State Assembly Bill 617, which required air districts to develop, by January 1, 2019, an expedited schedule for the implementation of BARCT no later than December 31, 2023 for facilities that are in the State greenhouse gas cap-and-trade program with priority given to older higher polluting sources that need to install BARCT.

As facilities transition out of NOx RECLAIM, a command-and-control rule that includes NOx emission standards that reflect BARCT will be needed for all equipment categories. Proposed Amended Rule 1110.2 – Emissions from Gaseous- and Liquid-Fueled Engines (PAR 1110.2) is a command-and-control "landing" rule for RECLAIM facilities with internal combustion engines. Proposed Amended Rule 1110.2 will remove exemptions previously allowed under the NOx RECLAIM program pertaining to internal combustion engines with a rating greater than 50 brake horsepower. As a result, engines at existing RECLAIM facilities will be required to comply with the NOx emission standards under Proposed Amended Rule 1110.2, and with existing monitoring, reporting, and recordkeeping requirements. PAR 1110.2 will also establish ammonia limits, will add clarification to its applicability to engines operated at remote radio transmission towers, and will also include other clarifications for existing provisions. PAR 1100 is also being amended to include the compliance schedule for equipment at RECLAIM facilities that will be subject to PAR 1110.2.

Of the facilities in RECLAIM, twenty-one will be affected by PAR 1110.2 and seventy-six engines will become subject to the NOx requirements in the rule. Currently, 21 engines meet an emission limit of 11 ppmv[1] required by PAR 1110.2. Because engines in RECLAIM are already required to comply with the VOC and CO requirements in Rule 1110.2, no further requirements are proposed for these pollutants. Eight engines are portable engines and will be subject to the state's Air Toxic Control Measure (ATCM). For the remaining 47 engines that will be required to meet the NOx emission limits under PAR 1110.2, the overall rule cost-effectiveness is approximately $33,800 per ton of NOx reduced. As a result of PAR 1110.2, NOx emissions are expected to decrease by approximately 0.29 tons per day.

[1] Parts per million by volume, corrected to 15% oxygen on a dry basis and averaged over 15 minutes.

# CHAPTER 1: BACKGROUND

**REGULATORY HISTORY**

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**BACKGROUND**

In October 1993, Regulation XX- RECLAIM was adopted. The purpose of the RECLAIM program was to provide industry with a flexible, market-based approach to reduce NOx and SOx emissions. Participants were initially allocated RECLAIM Trading Credits (RTCs) based on emissions from their highest production level from 1989 to 1992. With the adoption of RECLAIM, engines that had been regulated under Rule 1110.2 were exempt from NOx emission standards.

Over time, the allocation of RTCs was gradually reduced requiring businesses to either install new emissions controls, replace older equipment, or purchase unused RTCs from other sources. In response to concerns regarding actual emission reductions and implementation of BARCT under RECLAIM, Control Measure CMB-05 of the 2016 AQMP committed to an assessment of the RECLAIM program in order to achieve further NOx emission reductions of five tons per day, including actions to transition the program and ensure future equivalency to command-and-control regulations. During the adoption of the 2016 AQMP, the resolution directed staff to modify Control Measure CMB-05 to achieve the five tons per day NOx emission reduction as soon as feasible but no later than 2025, and to transition the RECLAIM program to a command-and-control regulatory structure requiring BARCT-level controls as soon as practicable.

In addition, on July 26, 2017, Governor Brown signed AB 617 which addressed non-vehicular air pollution. AB 617 was companion legislation to AB 398 which extended California's cap-and-trade program for reducing greenhouse gas emissions from stationary sources. RECLAIM facilities that are part of the cap-and-trade program are now also subject to the requirements of AB 617. AB 617 requires an expedited schedule for implementing BARCT for cap-and-trade facilities. Under AB 617, the State's air districts were to develop a schedule by January 1, 2019 for the implementation of BARCT no later than December 31, 2023. The highest priority would be given to older, higher polluting units that would need to install retrofit controls.

As facilities transition out of NOx RECLAIM, a command-and-control rule that includes NOx emission standards that reflect BARCT will be needed for all equipment categories. Proposed Amended Rule 1110.2 – Emissions from Gaseous- and Liquid-Fueled Engines (PAR 1110.2) is a command-and-control "landing" rule for RECLAIM facilities with internal combustion engines. Proposed Amended Rule 1110.2 will remove exemptions previously allowed for the NOx RECLAIM facilities pertaining to internal combustion engines with a rating greater than 50 brake horsepower. Engines at existing RECLAIM facilities will be required to comply with the NOx emission standards under Proposed Amended Rule 1110.2, and with existing monitoring, reporting, and recordkeeping requirements. PAR 1110.2 will also establish ammonia limits and will add clarification to its applicability to engines operated at remote radio transmission towers.

With the transition of the RECLAIM program to a command-and-control regulatory structure, internal combustion engines that were once exempt would now be subject to Rule 1110.2. As part of the transition from RECLAIM to a command-and-control structure, staff conducted an analysis to determine if Rule 1110.2 reflects current BARCT and to provide an implementation timeframe for achieving BARCT compliance limits for certain RECLAIM internal combustion engines.

**REGULATORY HISTORY**

The following provides a regulatory history of Rule 1110.2 and associated actions affecting internal combustion engines.

- In October 1984, Rule 1110.1 was adopted, which regulated emissions from internal combustion engines. Rule 1110.1 required reductions of NOx and carbon monoxide (CO) emissions from gaseous-fueled internal combustion engines rated greater than 50 bhp. This rule was the precursor to Rule 1110.2.

- In August 1990, the Board adopted Rule 1110.2, which required additional reductions for NOx and also volatile organic compounds (VOC) from stationary, non-emergency gaseous- and liquid-fueled internal combustion engines.

- In October 1993, Regulation XX was adopted, which established the RECLAIM program. Engines at RECLAIM facilities were exempted from Rule 1110.2 for NOx.

- In June 2005, Rule 1110.2 was amended to comply with California Senate Bill (SB) 700, which eliminated a statewide agricultural operations exemption. It required that BARCT be applied to previously-exempted agricultural engines.

- In February 2008, Rule 1110.2 was amended, lowering NOx, VOC, and CO emission limits for stationary, non-emergency engines. It also established lower emission standards for new, non-emergency electrical generation engines. The amendment also increased monitoring requirements to include more frequent emissions testing and the development of Inspection and Monitoring (I&M) plans. The amendment affected 859 engines at 405 facilities.

- In July 2010, Rule 1110.2 was amended to provide an exemption from the emissions requirements for engines operated by the County of Riverside for the purpose of public safety communication at one remote location.

- In September 2012, Rule 1110.2 was amended to establish biogas engine emissions limits to meet those for natural gas engines. The amendment included an accompanying technology assessment for biogas engine control technology.

- In May 2013, Rules 219 and 222 were amended to exempt engines powering remote radio transmission towers from permitting requirements. The exemption applied to any compression-ignited reciprocating internal combustion engine used exclusively for electrical generation at remote two-way radio transmission towers where no utility, electricity, or natural gas is available within ½ mile radius, has a manufacturer's rating of 100 bhp or less, and is fired exclusively on diesel #2 fuel, compressed natural gas, or liquefied petroleum gas.

- In December 2015, Rule 1110.2 was amended to extend the compliance deadline for biogas engines by one year. The amendment also addressed concerns raised by the United States Environmental Protection Agency related to State Implementation Plan (SIP) approval issues contained in the rule language regarding excess emissions from startup, shutdown, and malfunction (SSM).

- In June 2016, Rule 1110.2 was amended to extend the compliance deadline for one landfill gas facility due to economic concerns related to its power purchase agreement. The facility is required to retire its engines subject to the rule by October 1, 2022.

## AFFECTED FACILITIES AND EQUIPMENT

*RECLAIM Facilities and Associated Engines*

Out of the 254 facilities currently in the NOx RECLAIM program, approximately 21 facilities were identified as facilities with engines subject to PAR 1110.2. Appendix B contains a list of RECLAIM facilities that operate engines affected by PAR 1110.2.

As part of the RECLAIM transition, several source-specific rules are also being adopted and amended. In addition, several new industry-specific rules are being developed. In such cases, facilities that are affected by these industry-specific rules may have non-emergency, internal combustion engines that are excluded from Rule 1110.2 (e.g., engines operated at electricity generating facilities and in refineries).

*Rule 222-RT Engines*

In May 2013, Rules 219 and 222 were amended to allow engines that provide power to remote radio transmission towers and that meet specific criteria to be exempt from permitting. To harmonize Rules 219, 222, and 1110.2, staff recommends that Rule 1110.2 be updated to explicitly exempt engines registered under Rule 222-RT from emission requirements. The facilities impacted are not RECLAIM sources.

*Biogas Engines*

The clarifications that are proposed apply specifically to biogas engines, and pertain to existing monitoring requirements. Currently, there are 8 facilities that are biogas facilities (e.g., operate engines fueled by digester gas or landfill gas) with 23 biogas engines that operate with continuous emissions monitoring systems (CEMS).

## PUBLIC PROCESS

The development of PAR 1110.2 was conducted through a public process. Five Working Group meetings were held on: June 28, 2018, September 27, 2018, February 6, 2019, April 24, 2019 and May 30, 2019. Working Group meetings included staff and representatives from affected businesses, environmental groups, public agencies, consultants, and other interested parties. The purpose of the Working Group meetings is to discuss details of proposed amendments and to listen to concerns and issues with the objective to build consensus and resolve key issues.

# CHAPTER 2: BARCT ASSESSMENT

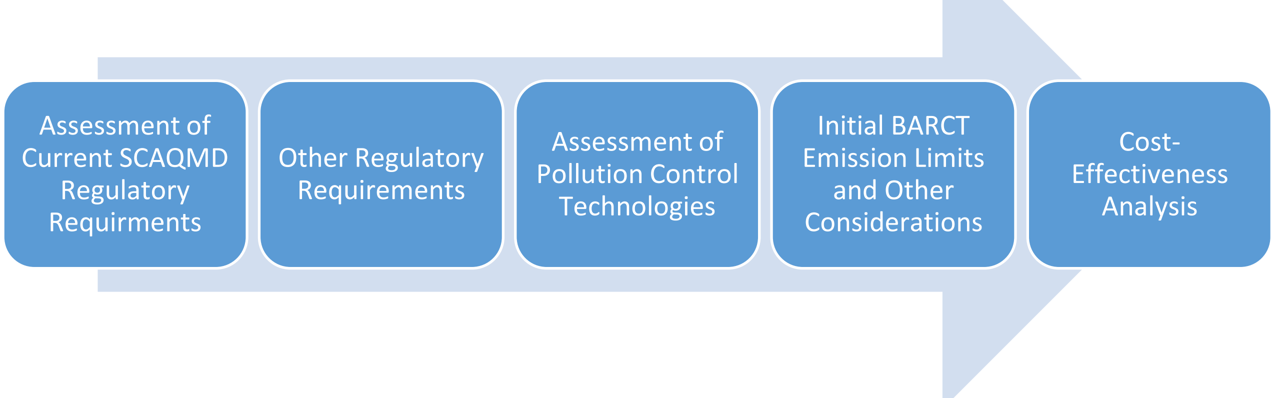
## INTRODUCTION

Staff conducted an assessment of the NOx emission limit under Rule 1110.2 to ensure it is still representative of BARCT for engines. BARCT analyses are periodically performed for equipment categories to assess technological changes that may reflect a lower emission limit. The 2008 amendments to Rule 1110.2 represent the most recent BARCT analysis for engines. Under California Health and Safety Code § 40406, BARCT is defined 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 BARCT assessment for this rule development consisted of a multi-step analysis. The first three steps represent the technology assessment where staff first conducts a review of current South Coast AQMD regulatory requirements, staff then surveys other air districts and agencies outside of the South Coast AQMD's jurisdiction to identify emission limits that exist for similar equipment, and in the third step, staff identifies and assesses pollution control technologies to determine what degree of reduction could be achievable for the affected sources. Based on the collected information, initial BARCT emission limits were then established. Once the initial BARCT emission limits are determined, a cost-effectiveness analysis is conducted.

Figure 2-1: BARCT Analysis Approach




## BARCT ANALYSIS APPROACH

*Assessment of Current South Coast AQMD Regulatory Requirements*

In the first step of the BARCT analysis, staff reviewed South Coast AQMD rules that affect engines operating within its jurisdiction: Rule 1470 and Rule 1110.2. Each rule was evaluated based on their respective regulatory effect on emission of NOx, VOC, and CO.

South Coast AQMD Rule 1470

Rule 1470 is a toxics rule designed to reduce diesel particulate emissions, which is a carcinogen. Rule 1470 applies to stationary, diesel-fueled engines owned or operated with a rated brake horsepower greater than 50 bhp with limited exceptions and regulates particular matter (PM) emissions from diesel engines. Within Rule 1470, any reference to NOx, VOC, and CO for prime engines is referred to Rule 1110.2.

- Rule 1470 states that all new stationary prime diesel-fueled compression-ignition engines (> 50 bhp) shall meet the applicable emission standards specified in Rule 1110.2.

- Rule 1470 states that owners or operators that choose to meet the diesel PM limits with emission control strategies that are not verified through the Verification Procedure shall meet the applicable HC, NOx, NMHC+NOx, and CO emission standards specified in South Coast AQMD Rule 1110.2 – Emissions From Gaseous and Liquid-Fueled Engines.

Although engines in the RECLAIM program were exempt from the requirements of Rule 1110.2, compliance to Rule 1470 is still mandatory for PM emissions to address diesel PM. For specific NOx limits, Rule 1470 defers to Rule 1110.2. It should be noted that Rule 1470 primarily applies to emergency engines that operate under the Rule 1110.2 exemption of 200 hours per year. Emergency engines operated at RECLAIM facilities that are subject to Rule 1470 are not proposed to be subject to PAR 1110.2.

South Coast AQMD Rule 1110.2

Rule 1110.2 applies to engines with a rated brake horsepower greater than 50 bhp. The rule separates engines into two sub-categories: stationary or portable.

For existing stationary prime engines, the NOx, VOC, and CO emission limits are listed in Table 2-1. The rule does not distinguish by engine type (e.g., whether the engine is two-cycle, four-cycle, lean-burn, or rich-burn). The limits have been in effect for gaseous- and liquid-fueled engines since July 1, 2011 and for biogas engines since January 1, 2017.

**Table 2-1: Rule 1110.2 Emissions**

| Emission Limits for Stationary Prime Engines (ppmv) | |
|---|---|
| NOx[1] | 11 |
| VOC[2] | 30 |
| CO[1] | 250 |

[1] Corrected to 15% $O_2$ on a dry basis, averaged over 15 minutes
[2] Measured as carbon, corrected to 15% $O_2$ on a dry basis, averaged over 15 minutes

For new non-emergency engines driving electrical generators, the emission limits differ from those for existing stationary prime engines. The emission limits were established during the 2008 rule amendment and modeled in part from CARB's approach for distributed generation (DG) equipment that do not require local district permits. The CARB standards were based on the emissions from large new central generating stations (e.g., electricity generating facilities or utility power plants) equipped with best available control technology (BACT). Table 2-2 lists the emission limits for all new, non-emergency engines driving electrical-generators. Rule 1110.2 differs slightly from the CARB standards for VOC and CO (which are set at .02 lb/MW-hr and 0.10 lb/MW-hr, respectively) in that Rule 1110.2 contains slightly higher emission limits. It should be noted that these limits are for brand new installations and do not apply for retrofits.

**Table 2-2: Comparison of Emission Limits**

| Limits for New Electrical Generation Devices (lbs/MW-hr) | | |
|---|---|---|
| | South Coast AQMD | CARB |
| NOx[1] | 0.07 | 0.07 |
| VOC[2] | 0.10 | 0.02 |
| CO[1] | 0.20 | 0.10 |

[1] Corrected to 15% $O_2$ on a dry basis, averaged over 15 minutes
[2] Calculated using a ratio of 16.04 lbs of VOC per lb-mole of carbon

For portable prime engines, Rule 1110.2 refers to state regulations for emissions limitations (State Air Toxics Control Measure).

*Other Regulatory Requirements*

Staff compared emission limits for similar equipment in other air districts (contained in Table 2-3). Equipment categories varied, but the most stringent emission limit relevant to stationary prime engines was selected for comparison. Based on staff's review, the South Coast AQMD has the lowest NOx limits for stationary internal combustion engines of 11 ppmv (corrected to 15% O2 on a dry basis), relative to other air districts. In addition, the South Coast AQMD has the lowest emission standards for CO and VOC relative to other air districts.

Within California, staff reviewed regulations in the following air districts (listed alphabetically):

- Antelope Valley
- Bay Area
- Mojave Desert
- Santa Barbara
- San Diego
- San Joaquin Valley
- San Luis Obispo
- Ventura County

Outside California, staff reviewed regulations in the following air districts (listed alphabetically):

- New Jersey
- New York
- Pennsylvania
- Texas

**Table 2-3: Lowest NOx Emission Limits in Other Jurisdictions**

| Jurisdiction | Type of Engine | Limit (ppmv[1]) |
|---|---|---|
| Antelope Valley AQMD | General, spark-ignited | 36 |
| Bay Area AQMD | Fossil-derived fuel, rich-burn | 25 |
| Mojave Desert APCD | Non-agriculture, rich-burn, spark-ignited engines | 50 |
| Santa Barbara APCD | Rich-burn, noncyclically-loaded spark ignition engines | 50 |
| San Diego APCD | Gaseous fuel or gasoline, rich-burn | 25 |
| San Joaquin Valley APCD | Non-exempted ICEs | 11 |
| San Luis Obispo APCD | Spark-ignited, rich-burn | 50 |
| Ventura County APCD | General, rich-burn | 25 |
| New Jersey | Non-exempted ICEs | 70 |
| New York | Natural gas, >200 hp | 116 |
| Pennsylvania | Rich-burn, natural gas | 155 |
| Texas (Dallas-Fort Worth Area) | Non-exempted ICEs | 39 |

[1] ppmv corrected to 15% oxygen, dry basis

*Assessment of Pollution Control Technologies*

Current air pollution control technology for internal combustion engines can be divided into two commercially available systems: Non-Selective Catalytic Reduction (NSCR) and Selective Catalytic Reduction (SCR).

<u>NSCR</u>

NSCR is a commercially available air pollution control system used to reduce emissions from rich-burn, stationary engines. The system has been commercially available for many years from different sources and is considered cost effective to install. It uses a precious metal catalyst base to reduce NOx to nitrogen, to oxidize CO to carbon dioxide ($CO_2$), and to convert VOCs to $CO_2$ and water. Catalyst efficiency relies on good air-to-fuel ratio (A/F) control. Most systems control the A/F ratio using exhaust oxygen measurement, along with air/fuel ratio controllers. Removal efficiencies for a 3-way catalyst are greater than 90 percent for NOx, greater than 80 percent for CO, and greater than 50 percent for VOC. Greater efficiencies, below 10 parts per million NOx, are possible through use of an improved catalyst containing a greater concentration of active catalyst materials, use of a larger catalyst to increase residence time, or through use of a more precise air/fuel ratio controller.

As part of this evaluative process, staff solicited and received information from catalyst vendors related to the installation and/or retrofitting of NSCR systems for various engine sizes. This data was used to calculate cost-effectiveness in achieving proposed emission limits for these type of engines.

SCR

SCR is another commercially available air pollution control system used to reduce NOx emissions from diesel or other lean-burn, stationary engines. SCR technology injects ammonia into an engine's exhaust. The exhaust is then passed through a fixed catalyst bed where NOx reacts with the ammonia and is converted into nitrogen. If CO and VOCs are also to be controlled, then an oxidation catalyst is added to the exhaust stream typically upstream of the SCR. Catalyst efficiency relies on good dispersion and mixing. Typical conversion efficiencies for SCR systems range between 90 – 95% for NOx.

As part of this evaluative process, staff solicited and received information related to the installation and/or retrofitting of SCR systems. In addition, data from previous rulemaking efforts was reviewed and considered. This data was used to calculate cost-effectiveness in achieving proposed emission limits for these type of engines.

Other Technology Options

Staff reviewed two alternative technologies to NSCR and SCR. The first alternative that was considered was developed by a company called Tecogen. Tecogen has a patented, 3-step emissions control system that can be retrofitted onto an existing engine. The technology is currently applied only on select rich-burn natural gas fueled engines. Compared to a standard NSCR system, the Tecogen product is designed to provide an operator with a wider air-to-fuel ratio control window by utilizing its dual catalyst system.

Within the South Coast AQMD's jurisdiction, several engines equipped with the Tecogen system have been recently permitted. The initial testing results indicate that these engines meet Rule 1110.2 NOx and CO limits. At this time, however, the technology has been installed on mostly smaller engines under 1,000 brake horsepower and it has not been demonstrated whether this technology can be applied to a wider range of engines, especially larger engines. This technology is capable of achieving the lower emission standard for non-emergency electrical generators. In addition, operators have expressed that when employed for compliance with the 11 ppm NOx limit, it offers a larger and safer compliance margin than in utilizing only a single catalyst. Staff will continue to monitor and evaluate future installations.

The second alternative was developed by a company called EtaGen. EtaGen has designed and constructed what is called a linear generator. The generator produces electricity unlike a traditional combustion engine. In this design, magnets are driven through copper coils to produce electricity.

This type of engine is expected to produce lower emissions approaching DG levels. At this time, no engine equipped with the EtaGen system has been permitted within the South Coast AQMD jurisdiction.

*BARCT Emission Limits and Other Considerations*

The 2008 Rule 1110.2 amendment established a NOx emission limit of 11 ppmv @ 15% $O_2$ for non-RECLAIM engines effective July 1, 2011 except for engines fueled by landfill or digester gas (biogas). Subsequently, engines fueled by landfill or digester gas (biogas) were required to meet this limit by July 1, 2017.

Currently, the NSCR and SCR are commercially available and cost-effective to establish a NOx emission limit of 11 ppmv @ 15% $O_2$. NSCR systems can be used for rich-burn engines and SCR systems can be used for lean-burn engines. As part of its analysis of non-RECLAIM engines operating within the South Coast AQMD's jurisdiction, staff reviewed available source test data for stationary, non-emergency engines and found that existing engines are complying with a NOx emission limit of 11 ppmv @ 15% $O_2$.

*Engine Categories*

Seventy-six engines that are currently in the RECLAIM program would be subject to Rule 1110.2. As part of the BARCT analysis, engines were subdivided into four categories based on the unique characteristics of each type of engine and the associated emissions controls available to each category:

- Lean-Burn, 2 stroke
- Lean-Burn, 4 stroke
- Rich-Burn
- Engines, subject to the ATCM

Figure 2-2 lists the number of RECLAIM engines by type and by the number of engines that meet the current emission limit of 11 ppmv[1] NOx. Engines subject to the State ATCM will not be affected due to PAR 1110.2. These engines have been identified as portable diesel engines subject to Rule 1110.2 (d)(2)(B). Currently, Rule 1110.2 (d)(2)(B) defers emission limits to the State ATCM for any portable diesel engines. In general, these engines either will be phased out or will be operated as low-use engines under 200 hours or less in a calendar year, per the provisions of the ATCM.

[1] Parts per million by volume, corrected to 15% oxygen on a dry basis and averaged over 15 minutes

Figure 2-2: RECLAIM Engines by Type

| Lean Burn (2-stroke) | Lean Burn (4-stroke) | Rich Burn | Engines subject to ATCM |
|---|---|---|---|
| Count<br>11 | Count<br>34 | Count<br>23 | Count<br>8 |
| Engines meeting 11 ppmv[1] NOx<br>0 | Engines meeting 11 ppmv[1] NOx<br>8 | Engines meeting 11 ppmv[1] NOx<br>13 | Engines meeting 11 ppmv[1] NOx<br>0 |

# CHAPTER 3: PROPOSED AMENDMENTS TO RULE 1110.2

## INTRODUCTION

The primary purpose of the proposed amendments is to transition equipment from the RECLAIM program to a command-and-control regulatory structure. As such, rule references made to RECLAIM are to be modified to reflect the transition.

The rule also will be harmonized with Rules 219 and 222 to provide a specific exemption to engines that are used in 2-way radio transmission communication that are remote and that serve a public safety function.

## PROPOSED AMENDMENTS TO RULE 1110.2

*Definitions – Subdivision (c)*

The definitions were revised to reflect the transition of equipment from the RECLAIM program to a command-and-control regulatory structure. Staff included definitions to differentiate between a FORMER RECLAIM FACILITY, NON-RECLAIM FACILITY, and RECLAIM FACILITY. In addition, staff included a definition for SOUTH COAST AQMD to clarify its use within the rule.

- FORMER RECLAIM FACILITY – means a facility, or any of its successors, that was in the Regional Clean Air Incentives Market as of January 5, 2018, as established in Regulation XX, that has received a final determination notification, and is no longer in the RECLAIM program.

- NON-RECLAIM FACILITY – means a facility, or any of its successors, that was not in the Regional Clean Air Incentives Market as of January 5, 2018, as established in Regulation XX.

- RECLAIM FACILITY – means a facility, or any of its successors, that was in the Regional Clean Air Incentives Market as of January 5, 2018, as established in Regulation XX.

- SOUTH COAST AQMD – means the South Coast Air Quality Management District.

*Modification of RECLAIM Language*

The language in the clauses and subclauses listed below were changed from “subject to Regulation XX (RECLAIM)” to “at RECLAIM or former RECLAIM facilities”. The purpose of the change was to reflect the transition from RECLAIM to a command-and-control regulatory structure:

- (d)(1)(L)(iv)
- (f)(1)(D)(ii)(II)
- (f)(1)(D)(ii)(III)

*Clarification of Rule Language in Subparagraph (d)(1)(B)*

In the current version of Rule 1110.2, there are three clauses that are not delineated with a separate designation of their own. After clause (d)(1)(B)(ii), clauses (d)(1)(B)(iii) – (v) have been added to provide more definitive clarity for reference.

- (d)(1)(B)(iii): The concentration limits effective on and after July 1, 2010 shall not apply to engines that operate less than 500 hours per year or use less than $1 \times 10^9$ British Thermal Units (Btus) per year (higher heating value) of fuel.

- (d)(1)(B)(iv): If the operator of a two-stroke engine equipped with an oxidation catalyst and insulated exhaust ducts and catalyst housing demonstrates that the CO and VOC limits effective on and after July 1, 2010 are not achievable, then the Executive Officer may, with United States Environmental Protection Agency (EPA) approval, establish technologically achievable, case-by-case CO and VOC limits in place of the concentration limits effective on and after July 1, 2010. The case-by-case limits shall not exceed 250 ppmvd VOC and 2000 ppmvd CO.

- (d)(1)(B)(v): If the operator of an engine that uses non-pipeline quality natural gas demonstrates that due to the varying heating value of the gas a longer averaging time is necessary, the Executive Officer may establish for the engine a longer averaging time, not to exceed twenty-four hours, for any of the concentration limits of Table II. Non-pipeline quality natural gas is a gas that does not meet the gas specifications of the local gas utility and is not supplied to the local gas utility.

There is one affected RECLAIM facility that would be subject to clause (d)(1)(B)(v) after the transition. This facility operates a produced gas-fired engine that was permitted to meet 6 ppm NOx averaged over a 24-hour period as well as a 24 ppm NOx limit averaged over a one hour period. The fuel of this engine does not meet pipeline quality natural gas specifications. The proposed language would extend the 6 hour averaging time maximum to 24 hours, to harmonize with the current permitted level of this engine that is achieving NOx emissions well below 11 ppm.

There are several two-stroke engines affected by the RECLAIM transition that are fired with natural gas, and are utilized for natural gas compression and pipeline transportation. Two-stroke engines have unique characteristics that can present some challenges for post-combustion NOx controls, such as more transient contaminants in the exhaust stream. Nonetheless, staff has determined that meeting 11 ppm for NOx is achievable, with a longer averaging time. New clause (d)(1)(B)(vi) would state:

- For owners and operators of two-stroke engines equipped with selective catalytic reduction pollution control equipment, an averaging time of 60 minutes shall be used for demonstrating compliance with the NOx requirements of Table II.

*Ammonia Emission Limits for New Engine Installation with SCRs*

PAR 1110.2 would also require operators that install post-combustion emission controls, such as SCR, to comply with ammonia slip limitations, moving forward. Although source testing of rich burn engines utilizing three-way catalysts (NSCR) has shown ammonia emissions, more investigation is needed to determine the underlying causes and possible solutions. For SCR applications, ammonia slip is excess ammonia that does not react with NOx in the flue gas and exits out of the stack. As part of the RECLAIM transition, Rules 1146, 1134, and 1135 were amended to also include ammonia slip limits because those types of equipment typically use SCR in order to achieve lower NOx emission levels. The proposed provisions would apply to brand new engine installations for lean-burn engines with SCR as well as for retrofit applications, such as RECLAIM engines that will require SCR. The ammonia requirements for PAR 1110.2 would be contained in new clause (d)(1)(B)(vii), which would state:

- Upon startup after (*date of amendment*), any new engine installation with selective catalytic reduction pollution control equipment or retrofit for an existing engine with selective catalytic reduction pollution control equipment that results in ammonia emissions in the exhaust shall not discharge into the atmosphere ammonia emissions in excess of 5 ppm (referenced at 15 percent volume stack gas oxygen on a dry basis, averaged over a period of 60 consecutive minutes).

*Averaging Time Provisions for Biogas Engines*

The 2012 amendments to Rule 1110.2 established emission limits for biogas engines that would correspond to those for natural gas engines. Due to the unique nature of this type of biogas fuel (e.g., lower heating value and contaminant loading), provisions that would allow a longer averaging time were included. The current language contained in subparagraph (d)(1)(I) states that provided the operator of a retrofitted biogas engine can demonstrate that its NOx emissions through CEMS are achieving levels of at least 10% below the 11 ppm NOx concentration limit (e.g., at or below 9.9 ppm for NOx) over a 4 month time period, then longer averaging is allowed. This provision would also apply for CO (e.g., at or below 225 ppm for CO) if it is also selected for averaging, although CO CEMS is not required for lean burn engines. Once the ability to use a longer averaging time is established, an operator could use a monthly fixed averaging time for the first four months of operation and up to a 24-hour fixed averaging time thereafter.

During implementation of these requirements, a need arose for additional clarity, specifically regarding if the longer averaging is allowed immediately upon startup (e.g., before the first four months have elapsed), and how the ongoing requirement is demonstrated and enforced. The proposed rule language would allow the monthly fixed interval averaging time upon startup for the first four months of operation for compliance with 11 ppm NOx and as long as the engine is achieving at or below 9.9 ppm NOx over that four month period (using the 15 minute averaging time) and every four month period thereafter, then the 24 hour averaging would be allowed for demonstrating compliance with 11 ppm NOx (and 250 ppmv CO, if selected for averaging). If CO is also selected for averaging and the engine is achieving at or below 225 ppm, the same provisions would apply. Subparagraph (d)(1)(I) would now read:

- Upon startup of a new engine installation with catalytic controls or a retrofit of catalytic controls for an existing engine, for determining compliance with the NOx and/or CO limits of Table III-B, an operator of a biogas engine with CEMS may utilize a monthly fixed interval averaging time for the first four months after startup. After the initial four month startup period, an operator of a biogas engine may determine compliance by utilizing a 24 hour averaging time, provided the operator demonstrates through CEMS data that the engine is achieving a concentration at or below 9.9 ppmv for NOx and/or 225 ppmv for CO (if CO is selected for averaging), each corrected to 15% O2, over a four month rolling time period. If during any four month period, the engine is not achieving the emissions criteria contained in this subparagraph, the engine shall revert to 15-minute averaging, but can resume 24 hour averaging if the engine can demonstrate the aforementioned emissions criteria over a four month period. Procedures for demonstrating the emissions criteria contained in this subparagraph, for demonstrating compliance with 24 hour averaging, and for reverting to 15-minute averaging shall be contained in the facility's Inspection and Monitoring plan, as specified in subparagraph (f)(1)(D). Exceedances of the emissions criteria contained in this subparagraph shall be reported, pursuant to the requirements in clause (f)(1)(H)(iii).

The existing conditions for determining compliance using either a monthly or 24 hour averaging time through CEMS, previously contained in clauses (d)(1)(I)(i) through (iv) have been moved to subclauses (d)(1)(I)(i)(I) through (IV).

In order to track these ongoing requirements, new provisions in the facility's Inspection and Monitoring Plan (I&M Plan) would require for facilities with biogas engines to maintain records that demonstrate that the CEMS data is showing compliance with the averaging time requirements. Currently, facilities that operate pollutant-specific CEMS (e.g., NOx and/or CO) are not required to maintain an I&M plan. For example, if an operator with an engine has a NOx CEMS and no CO CEMS, then the facility's I&M plan would contain the reporting requirements that pertain to CO only, such as portable analyzer testing requirements. In this case, if the operator would like to opt for the longer averaging time provisions, the operator would need to submit a revision to its I&M plan to include NOx CEMS compliance with the averaging time provisions. If an operator has both NOx and CO CEMS, then a new I&M Plan would need to be submitted, per the new requirements in the proposed amendments. Subclause (f)(1)(D)(i)(I) would state that the operator shall:

- Submit to the Executive Officer for written approval an I&M plan. One plan application is required for each facility that does not have a NOx and CO CEMS for each engine. Facilities with biogas engines using longer averaging times for compliance using CEMS are required to submit an I&M plan. The I&M plan shall include all items listed in Attachment 1.

Attachment 1 contains all the required elements to include in an I&M plan. In the case for biogas engines utilizing CEMS for demonstration of compliance using a longer averaging time, the new requirements would be contained in section F:

- For biogas engines using NOx and/or CO CEMS to demonstrate compliance by using a longer averaging time:
  - 1. Procedures for demonstrating that the NOx and/or CO emissions are at or below 9.9 ppmv for NOx and 225 ppmv for CO (if CO is selected for averaging) over a four month period.

- 2. Procedures for demonstrating a monthly fixed interval averaging time for the first four months after startup following a new engine installation with catalytic emission controls or a retrofit of catalytic emission controls for an existing engine.
- 3. Procedures for demonstrating ongoing compliance with a 24 hour fixed interval averaging time, if the requirements in paragraph F.1. are met.
- 4. Procedures for reverting back to a 15 minute averaging time in the event that the NOx and/or CO emissions are not at or below 9.9 ppmv for NOx and 225 ppmv for CO (if CO is selected for averaging).

In the event that the NOx emissions over the four-month period go above 9.9 ppm, then the facility would revert to using a 15-minute averaging time. However, if the facility can once again demonstrate that it is at or below 9.9 ppm NOx over a four-month period, usage of the 24-hour averaging time could be resumed. These events would now also be required to be included as part of the quarterly report that is currently required under (f)(1)(H)(iii) – Reporting Requirements:

- Within 15 days of the end of each calendar quarter, the operator shall submit to the Executive Officer a report that lists each occurrence of a breakdown, fault, malfunction, alarm, engine or control system operating parameter out of the acceptable range established by an I&M plan or permit condition (including CEMS averaging provisions), or a diagnostic emission check that finds excess emissions.

*Monitoring Requirement Changes*

Under the RECLAIM program, engines categorized as large NOx sources are not required to be equipped with a continuous emission monitoring system (CEMS). Per Rule 2012 - Requirements for Monitoring, Reporting, and Recordkeeping for NOx Emissions, large NOx sources include any internal combustion engine with rated brake horsepower greater than or equal to 1,000 bhp and operating 2,190 hours per year or less, or greater than or equal to 200 bhp but less than 1,000 bhp and operating more than 2,190 hours per year.

Under Rule 1110.2, however, there is no separate designation of a RECLAIM large source. Under Rule 1110.2, CEMS is required for engines of 1,000 bhp and greater and operating more than two million bhp-hr per calendar year. A NOx and CO CEMS is required to be installed, operated and maintained in calibration to demonstrate compliance with the emission limits of the rule. In addition, for facilities with multiple engines that are individually greater than 500 bhp but less than 1000 bhp and have a combined rating of 1500 bhp or greater at the same location, and having a combined fuel usage of more than $16 \times 10^9$ Btus per year (higher heating value), CEMS shall be installed, operated and maintained in calibration to demonstrate compliance of those engines with the applicable $NO_x$ and CO emission limits of the rule.

However, the following engines are not counted toward the combined rating or required to have a CEMS under the current rule:

- engines rated at less than 500 bhp;
- standby engines that are limited by permit conditions to only operate when other primary engines are not operable;

- engines that are limited by permit conditions to operate less than 1,000 hours per year or a fuel usage of less than 8 x $10^9$ Btus per year (higher heating value of all fuels used);
- engines that are used primarily to fuel public natural gas transit vehicles and that are required by a permit condition to be irreversibly removed from service by December 31, 2014;
- engines required to have a CEMS by another provision in the rule
- if permit conditions limit the simultaneous use of the engines at the same location in a manner to limit the combined rating of all engines in simultaneous operation to less than 1500 bhp.

For those engines that will be exiting RECLAIM and transitioning to a command-and-control structure, new subparagraph (e)(3)(C) has been added to provide a compliance schedule for CEMS installation once a facility exits from RECLAIM and becomes a former RECLAIM facility. This subdivision is necessary since there are several engines that are in RECLAIM that were not required to have a CEMS installed, but per the existing provisions of Rule 1110.2, would now require it. For example, an engine that is classified as a large RECLAIM source without CEMS and is rated greater than 1,000 bhp would require CEMS outside of RECLAIM. In addition, engines that are greater than 500 bhp but less than 1,000 bhp and operate in close proximity to each other with an aggregate rating greater than 1,500 bhp would also require a CEMS outside of RECLAIM. Subparagraph (e)(3)(C) would state:

- The operator of any stationary engine that is located at a RECLAIM or former RECLAIM facility that is required to modify an existing CEMS or install a CEMS on an existing engine that is subject to paragraph (f)(1) shall comply with the compliance schedule in Table VII such that the operator shall submit to the Executive Officer applications for a new or modified CEMS within 90 days of becoming a former RECLAIM facility.

The intent of subparagraph (e)(3)(C) is to provide an operator of a former RECLAIM facility with a timeline to install CEMS for its equipment that would require it. Staff considers 90 days of becoming a former RECLAIM facility to submit to the Executive Officer an application for a new or modified CEMS a reasonable amount of time.

Once the application is initially approved, then the following actions would be required, per the existing requirements listed in Table VII of the rule:

| Action Required | Applicable Compliance Date for |
|---|---|
| • Complete installation and commence CEMS operation, calibration, and reporting requirements | • Within 180 days of initial approval |
| • Complete certification tests | • Within 90 days of installation |
| • Submit certification reports to Executive Officer | • Within 45 days after tests are completed |
| • Obtain final approval of CEMS | • Within 1 year of initial approval |

For purposes of clarification, a day is considered on a calendar day basis.

A clarification regarding the interval between source tests is proposed to be included under the source testing provisions of subparagraph (f)(1)(C). Currently, the rule requires source tests once every two years (or once every three years if the engine is below a low use hourly threshold). The interpretation of once every two years can vary.

Example 1: A source test is conducted on January 1, 2019. If the two-years are treated as blocks, then the engine is covered for all of 2019 and 2020. The next two-year block can then be 2021 and 2022. A facility can possibly conduct the next source up to the very end of 2022. This would result in an interval close to four years between source tests.

Example 2: If this can be interpreted as more stringent than the first example for the same source test conducted on January 1, 2019. The next source test can be conducted on December 31, 2021 and still be interpreted as being done once every two year period. Nonetheless, this would result in a source testing interval of almost three years.

To resolve and clarify this issue, the proposed rule language would now specify that the source tests would be conducted:

- …once every two years (within the same calendar month of the previous source test)…

This ensures that the interval between source tests does not become excessive, while allowing for flexibility during the calendar month for scheduling and re-scheduling.

In line with the addition of clause (d)(1)(B)(vii), which adds ammonia emission limits for new engine installations and retrofit engines with SCR, a requirement for compliance determination with CEMS is also inserted. Compliance shall be determined by a new clause (f)(1)(A)(iii), which would state:

- The owner or operator of each stationary engine with selective catalytic reduction pollution control equipment shall conduct source testing pursuant to clause (f)(1)(C)(iii) or utilize an ammonia CEMS certified under an approved South Coast AQMD protocol to demonstrate compliance with the ammonia emission limit.

In line with the addition of clause (f)(1)(A)(iii), clarification for source testing is also inserted if not using CEMS for the compliance determination. Source testing shall be determined by new clause (f)(1)(C)(iii), which would state:

- The owner or operator of each stationary engine with selective catalytic reduction pollution control equipment not utilizing a certified ammonia CEMS shall conduct source tests quarterly to demonstrate compliance during the first twelve months of operation of the pollution control equipment and every calendar year thereafter (within the same calendar month of the previous source test) after four consecutive sources tests demonstrate compliance with the ammonia emission limit. If the engine has not been operated within three months of the date a source test is required, the operator may utilize the provisions for extension of the source testing deadlines contained in clause (f)(1)(C)(i).

The requirements for ammonia source testing would mirror those that exist and that are proposed for NOx, VOC, and CO (e.g., source testing deadline extension and the source testing interval between tests).

Table IX in subdivision (g) contains a list of testing methods to verify compliance with the applicable emissions requirements in the rule. Since ammonia testing has been proposed to be included, this table would also include South Coast AQMD Method 207.1 for ammonia.

*Recordkeeping Modifications*

Under RECLAIM Rule 2012, stationary and portable engines that are designated as a process unit on the facility permit are allowed to maintain a quarterly operating log. An engine is designated as a process unit if it is rated greater than or equal to 200 bhp but less than 1,000 bhp and operating 2,190 hours per year or less; or greater than 50 bhp but less than 200 bhp. Once the facility exits the RECLAIM program, however, the facility shall comply with subparagraph (f)(1)(E) or paragraph (f)(2) which requires a monthly engine operating log for stationary and portable engines, respectively, instead of a quarterly log. Each of these provisions have been modified to reflect this change:

- Facilities subject to Regulation XX may maintain a quarterly log for engines that are designated as a process unit on the facility permit until such time that the facility becomes a former RECLAIM facility. The facility shall maintain a monthly engine log starting in the month that it has become a former RECLAIM facility.

*Harmonize with Rule 219 and Rule 222*

In May 2013, Rules 219 and 222 were amended such that engines powering remote radio transmission towers meeting specific criteria were exempt from permitting. The criteria included any engine used exclusively for electrical generation at remote two-way radio transmission towers where no utility, electricity, or natural gas is available within a ½ mile radius, has a manufacturer's rating of 100 bhp or less, and is fired exclusively on diesel #2, compressed natural gas, or liquefied petroleum gas.

In the staff report for these amendments, staff determined that not only were these engines to be exempted from permitting, but these engines were to be exempted from Rule 1110.2 emission requirements as well. Subparagraph (i)(1)(H) has been modified to remove reference to the engines operated at Santa Rosa Peak and subparagraph (i)(1)(M) has been added to harmonize Rules 1110.2, 219, and 222. Subparagraph (i)(1)(M) states that the emission requirement provisions of subdivision (d) shall not apply to:

- An engine used exclusively for electrical generation at remote two-way radio transmission towers where no utility, electricity, or natural gas is available within a ½ mile radius, has a manufacturer's rating of 100 bhp or less, and is fired exclusively on diesel #2, compressed natural gas, or liquefied petroleum gas.

*Other Exemptions*

Under the exemptions of Rule 1110.2, subparagraph (i)(1)(N) has been inserted as an exemption to the emissions requirements of the rule for any engine that is subject to an industry-specific rule. As part of the RECLAIM transition, several new industry-specific rules are being developed. In such cases, facilities that are affected by these industry-specific rules may have non-emergency, internal combustion engines that are excluded from certain Rule 1110.2 requirements (e.g., engines operated at electricity generating facilities and in refineries). Subparagraph (i)(1)(N) will state that the emission requirements in Rule 1110.2 shall not apply to:

- Any engine at a RECLAM or former RECLAIM facility that is subject to a NOx emission limit in a different rule for an industry-specific category defined in Rule 1100 – Implementation Schedule for NOx facilities.

## PROPOSED AMENDMENTS TO RULE 1100

For RECLAIM or former RECLAIM facilities, paragraph (e)(10) of Rule 1110.2 provides the reference to the implementation schedule proposed per Rule 1100 – Implementation Schedule for NOx Facilities. Specifically, for RECLAIM or former RECLAIM facilities:

- The owner or operator of a RECLAIM or former RECLAIM facility with any unit(s) subject to subdivision (d) shall meet the applicable NOx emission limit in Table II in accordance with the schedule specified in Rule 1100 – Implementation Schedule for NOx Facilities.

Rule 1100 will now include Rule 1110.2 in its applicability for owners or operators of RECLAIM or former RECLAIM facilities. New definitions will also be included that pertain to equipment covered under Rule 1110.2 (COMPRESSOR GAS ENGINE, ENGINE, LOCATION, PORTABLE ENGINE, and STATIONARY ENGINE). In addition, staff included a definition for the use of SOUTH COAST AQMD to clarify its use in the rule.

- COMPRESSOR GAS ENGINE is a stationary gaseous-fueled engine used to compress natural gas or pipeline quality natural gas for delivery through a pipeline or into storage. This includes two-stroke and four-stroke lean-burn engines and four-stroke rich-burn engines.

- ENGINE is any spark- or compression-ignited internal combustion engine, including engines used for control of VOCs, but not including engines used for self-propulsion.

- LOCATION means any single site at a building, structure, facility, or installation. For the purposes of this definition, a site is a space occupied or to be occupied by an engine. For engines which are brought to a facility to perform maintenance on equipment at its permanent or ordinary location, each maintenance site shall be a separate location.

- PORTABLE ENGINE is an engine that, by itself or in or on a piece of equipment, is designed to be and capable of being carried or moved from one location to another. Indications of portability include, but are not limited to, wheels, skids, carrying handles, dolly, trailer, platform or mounting. The operator must demonstrate the necessity of the engine being periodically moved from one location to another because of the nature of the operation.

An engine is not portable if:(A) the engine or its replacement remains or will reside at the same location for more than 12 consecutive months. Any engine, such as a back-up or stand-by engine, that replaces an engine at a location and is intended to perform the same function as the engine being replaced, will be included in calculating the consecutive time period. In that case, the cumulative time of both engines, including the time between the removal of the original engine and installation of the replacement engine, will be counted towards the consecutive time period; or
(B) the engine remains or will reside at a location for less than 12 consecutive months where such a period represents the full length of normal annual source operations such as a seasonal source; or
(C) the engine is removed from one location for a period and then it or its equivalent is returned to the same location thereby circumventing the portable engine residence time requirements.
The period during which the engine is maintained at a designated storage facility shall be excluded from the residency time determination.

- SOUTH COAST AQMD means the South Coast Air Quality Management District.

- STATIONARY ENGINE is an engine which is either attached to a foundation or if no so attached, does not meet the definition of a portable or non-road engine and is not a motor vehicle as defined in Section 415 of the California Vehicle Code.

Subdivision (d) of PAR 1100 will contain the implementation schedule for engines at RECLAIM and former RECLAIM facilities. The final compliance date for stationary engines at RECLAIM and former RECLAIM facilities will be December 31, 2023, consistent with the implementation deadline of AB 617. Stationary engines will be required to meet the emission limits listed in Rule 1110.2 paragraph (d)(1). For compressor gas two-stroke or four-stroke lean-burn engines, compliance with the emission limits listed in Rule 1110.2 (d)(1) would be 24 months after a permit to construct is issued or 36 months after a permit to construct is issued if the application is submitted by July 21, 2021. Subparagraph (d)(1) states:,

- An owner or operator of a RECLAIM or former RECLAIM facility with any stationary engine(s) subject to and not exempt by Rule 1110.2 shall meet the emission limits listed in Rule 1110.2 paragraph (d)(1) on or before December 31, 2023; however compressor gas two-stroke and four-stroke lean-burn engines shall meet the emission limits listed in Rule 1110.2 paragraph (d)(1) 24 months after an applicable permit to construct is issued by the Executive Officer, or 36 months after an applicable permit to construct is issued by the Executive Officer if the application is submitted by July 1, 2021.

Portable engines will be required to meet the emission limits in Rule 1110.2 (d)(2), which defer to the emission limits and compliance schedule in the State ATCM. Subparagraph (d)(2) states:

- An owner or operator of a RECLAIM or former RECLAIM facility with any portable engine(s) subject to Rule 1110.2 shall meet the conditions listed in Rule 1110.2 paragraph (d)(2).

It should be noted that the existing requirements in Rule 1100 that pertain to Title V and non-Title V facilities will apply for sources covered under Rule 1110.2. During the RECLAIM transition, RECLAIM facility operators will continue to comply with the monitoring, reporting, and recordkeeping requirements specified in Rule 2012. For non-Title V facilities, a RECLAIM facility will be required to comply with monitoring, reporting, and recordkeeping requirements of Rule 1110.2 (e.g., Inspection and Monitoring plan provisions pertaining to NOx, NOx portable analyzer diagnostic checks) upon the date that the facility becomes a former RECLAIM facility.

# CHAPTER 4: IMPACT ASSESSMENTS

## INTRODUCTION

The initial analysis of RECLAIM engines identified 98 engines. Subsequent analysis reduced the number of engines to 76 engines. The reduction in the number of engines came as a result of contact with facilities. Eighteen engines were identified as no longer in operation and removed from service, 3 engines were identified as engines permitted with the jurisdiction of the South Coast AQMD, but having been shipped out-of-state, and 1 based on its integration with a connected heater was determined to be regulated by Rule 1146. Of the 76 engines, 14 engines are permitted to meet a NOx emission limit of 11 ppmv[1]. Staff noted that permits for 7 engines listed a NOx limit of 12.3 ppmv[1]. However, staff determined that the permitted value should have been 11 ppmv[1], based on State certification levels. The remaining 55 engines are either permitted or operate at an emission level greater than 11 ppmv[1]. Of the 55 engines that have emissions greater than 11 ppmv[1], 8 are portable engines that would not require changes and will subject to the State ATCM requirements and 47 are engines that will need changes per the proposed requirements of the rule.

In addition to the working group meetings, staff conducted multiple site visits with stakeholders affected by PAR 1110.2. The purpose of the visits is to evaluate site-specific concerns associated with PAR 1110.2. Staff has also met individually with affected stakeholders.

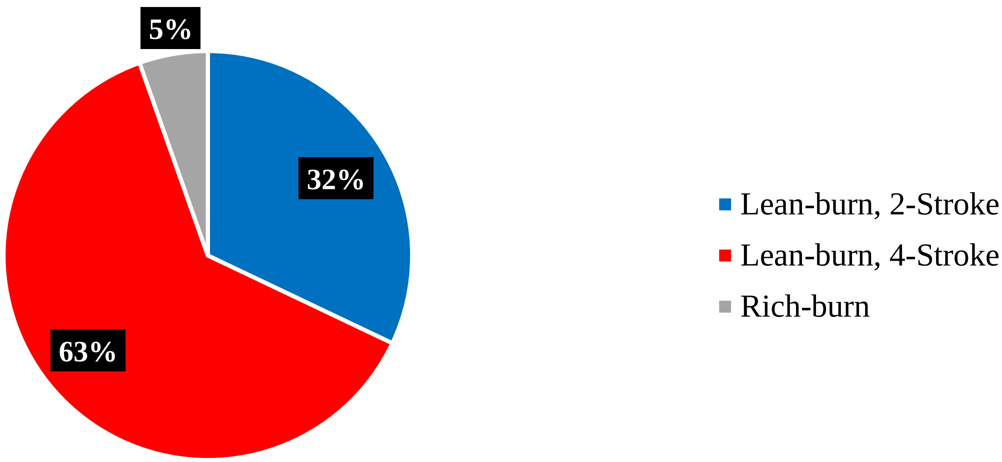
As part of the rule development process, staff sent surveys to both RECLAIM and non-RECLAIM facilities affected by Rule 1110.2. Surveys were sent to 25 RECLAIM facilities that would potentially be covered under Rule 1110.2 and surveys were also sent to 430 non-RECLAIM facilities identified as owning and/or operating prime engines, both portable and stationary. Staff received surveys from 88% of the RECLAIM facilities and 30% of non-RECLAIM facilities. The data collected from the surveys was used to the verify engine inventory at RECLAIM sites and to ascertain operational characteristics at non-RECLAIM sites, such as the annual hours of operation.

## EMISSION REDUCTIONS

RECLAIM emissions from the 2017 compliance year audits were collected for each device. An exception was given for one facility that was not operational during compliance year 2017. For equipment operated at this facility, staff used data from the 2014 Compliance Year audit as a basis, which was the most recent year of normal operation for the facility. The RECLAIM emissions for the 2017 compliance year were selected as the basis for the emission reduction calculations as representative of actual throughput (emissions) and actual reductions achieved by the transition of engines in the RECLAIM program to a command-and-control regulatory structure. In addition, data from the Annual Emissions Reporting (AER) program for the 2017 Compliance Year was reviewed and the information matched the RECLAIM data. The total NOx inventory for the RECLAIM units affected by PAR 1110.2 is estimated to be 0.37 tons per day.

[1] @ 15% $O_2$ averaged over 15 minutes

**Figure 4-1 - Emissions Inventory (0.37 tons per day)**




As presented in Figure 4-1, approximately 63% of the 2017 baseline RECLAIM emissions were emitted from lean-burn, 4-stroke engines. Another 32% of the 2017 baseline RECLAIM emissions were emitted from lean-burn, 4-stroke engines, and rich-burn engines accounted for approximately 5% of the emissions. In general, RECLAIM rich-burn engines equipped with NSCR meet the NOx emission limits of Rule 1110.2, are smaller in size, and subsequently have lower total emissions relative to lean-burn engines.

To estimate the emission reductions for Proposed Amended Rule 1110.2, a baseline emission concentration level for each engine was calculated. The estimate used existing emissions limits listed on the engine permits. Where no expressed limit was given (e.g., engines designated as major sources in the RECLAIM program), staff reviewed the engine's permit application file and utilized the engineering basis that was used to process the permit. For some older engines, the engineering basis relied on limits established per Rule 1110.1. For other engines, the engineering basis relied on actual source test results at the time of permitting.

To calculate the NOx emission reductions, the final emission limit was set to 11 ppmv. Emission reductions were calculated using Equation 4-1. The initial emission factor or concentration level (permitted concentration emission limit) is subtracted by the final emission factor or concentration level (set at 11 ppmv for NOx). The difference is then multiplied by the throughput (RECLAIM NOx emissions) reported for the 2017 compliance year for each device.

Equation 4-1:

$$\text{Emission Reductions} = (E_{initial} - E_{final}) \times \text{Throughput}$$

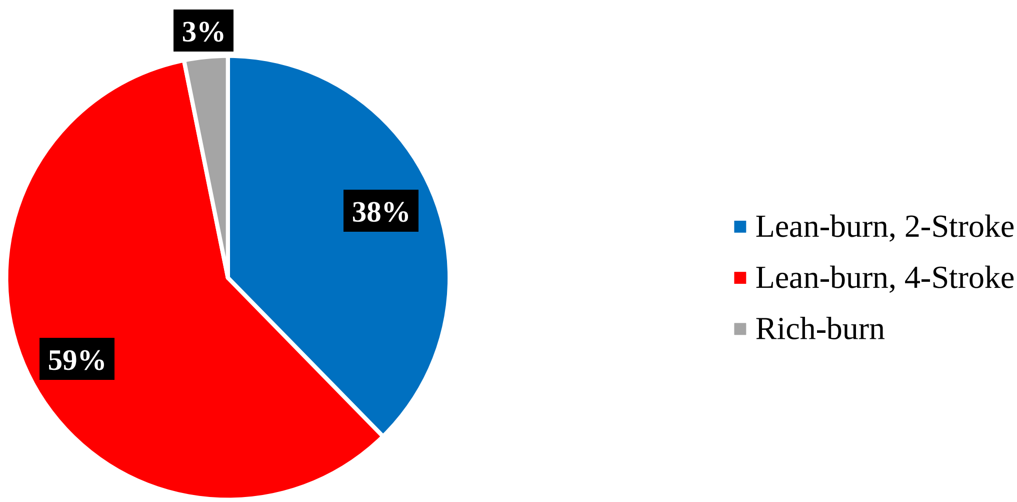
Where,

$E_{initial}$ = permitted concentration limit

$E_{final}$ = proposed concentration limit of 11 ppmv
Throughput = RECLAIM NOx emissions based on 2017 Compliance Year

As presented in Figure 4-2, approximately 59% of the estimated emission reduction is realized from lean-burn, 4 stroke engines. Another 38% of the estimated emission reduction comes from lean-burn, 2-stroke engines. Rich-burn engines account for only approximately 3% of the reductions. As a result of engines transitioning from the RECLAIM program to a command-and-control regulatory structure, NOx emissions are expected to decrease by approximately 0.29 tons per day. For each engine, emission reductions were grouped by engine category. Table 4-1 show the NOx emissions reductions by engine category.

**Figure 4-2 - Estimated Emissions Reductions (0.29 tons per day)**




| Table 4-1 – NOx Emissions Reductions by Engine Category | |
|---|---|
| Category | ton/day |
| (a) Lean-burn, 2-Stroke | 0.109 |
| (b) Lean-burn, 4-Stroke | 0.172 |
| (c) Rich-Burn | 0.009 |
| Total | 0.29 |

## COST-EFFECTIVENESS

Staff conducted a cost-effectiveness analysis for retrofit costs for existing engines operators. The target pollutant of the analysis is NOx. The RECLAIM program had exempted engines from compliance to the NOx emission limits established under Rule 1110.2. However, limits on other pollutants remain in effect (e.g. VOC and CO) and the proposed amendments will not require VOC or CO reductions.

For this analysis, present worth value (PWV) was calculated for the engines requiring retrofits. Included in the PWV calculation, the total installed cost (TIC) of any proposed modification and the anticipated annual cost (AC) were considered. The TIC included the cost for emissions control equipment and associated catalyst. Equipment and catalyst cost data was collected from vendors and actual installations. The data included costs for several engine sizes and the costs for the remaining engines within this range were fit into a curve to interpolate costs for these. In general, a multiplicative factor of 1.5 times the sum of equipment and catalyst costs was used to estimate the installation costs. However, in one unique case, staff used a factor of 2.5 to estimate installed cost due to the site-specific concerns that may contribute to potential increased costs for installation.

In considering AC, staff included an operations and maintenance factor for an incremental cost associated with additional emissions control equipment of 0.5%. The operations and maintenance cost factor was taken from the EPA's 2016 SCR Cost Manual[1]. In addition, for units that require urea injection, the amount of urea used whether for new or existing SCRs was calculated from vendor data.

For units that require CEMS due to their transition from the RECLAIM program to Rule 1110.2, equipment and installation costs were based on information supplied by a vendor specializing on CEMS equipment and installation. For engines that have a horsepower rating greater than or equal to 500 hp but less than 1,000 hp, are operating at a facility with an aggregate horsepower rating of 1,500 hp, and will be required under Rule 1110.2 to install a CEMS, sharing of the CEMS was not considered as part of this evaluation. Staff evaluated worst-case estimates for individual CEMS installations, but there can be a cost savings by employing time-shared CEMS for groups of engines. Despite this, facilities based on their operational characteristics, can apply for permit conditions to limit certain engines that limit usage and operation (e.g., backup engines or engines that are used sparingly or in rotation). For these engines, CEMS would not be required, per existing requirements in Rule 1110.2 subclause (f)(1)(A)(ii)(III).

In the calculation, staff assumed a uniformed series present worth factor (PWF) at a 4% interest rate and a 25-year equipment life expectancy.

$$PWV = TIC + (PWF \times AC)$$

PWV = present worth value ($)
TIC = total installed cost ($)
AC = annual cost ($)
PWF = uniform series present worth factor (15.622)

[1] Reference EPA's 2016 SCR Cost Manual at the following website – https://www3.epa.gov/ttn/ecas/docs/SCRCostManualchapter7thEdition_2016.pdf

Engines were separated into four categories: (1) lean-burn, two-stroke stationary engines, (2) lean-burn, four-stroke stationary engines, (3) rich-burn stationary engines, and (4) portable engines. Categories were selected based on past experience where technology and unique issues were identified and attributed to each. Although identified as a separate category, for purposes of this analysis, portable engines were not included. Portable engines are already required to comply with the State portable ATCM regulation, so cost effectiveness was not calculated for these engines.

Table 4-2 summarizes the result of the analysis. In general, the overall cost-effectiveness was calculated to be $35,300 per ton of NOx reduced. The cost-effectiveness for the lean-burn sub-categories was calculated to be less than $50,000 per ton of NOx reduced. However, the cost-effectiveness for the rich-burn engine category is calculated to be greater than $50,000 per ton of NOx reduced. $50,000 per ton of NOx is a threshold that is used as a general guide when evaluating cost-effectiveness by the Board. This has been done for many BARCT rules in recent years.

For the rich-burn engine sub-category, it should be noted that the incremental amount of NOx reduced for this engine category is minimal at 3% compared to the other two categories. For rich-burn engines, it is anticipated that these engines will meet the NOx emission limit of 11 ppmv with either minimal catalyst modifications or tuning of the air-to-fuel ratio controller. In many instances, the cost increase is due to the requirement to install CEMS for engines that have a horsepower rating greater than or equal to 500 hp but less than 1,000 hp, are operating at a facility with an aggregate horsepower rating of 1,500 hp, and will be required under Rule 1110.2 to install a CEMS on each engine. The cost of installing CEMS on each engine is much greater compared to the cost of additional catalyst or tuning of the controller. These added monitoring costs are reflected in the resultant cost-effectiveness of $71,400 for this sub-category.

**Table 4-2 – Cost Effectiveness Analysis**

| Category | $/ton NOx |
|---|---|
| (a) 2-Stroke, Lean-Burn | 28,100 |
| (b) 4-Stroke, Lean Burn | 35,500 |
| (c) Rich-Burn | 71,400 |
| Total | 33,800 |

Although the cost-effectiveness analysis is based on the average cost-effectiveness for all affected equipment staff does assess outlier data to better understand why the cost-effectiveness is substantially higher for certain engines compared to the majority of the equipment category. A review of operational data for these outlier engines indicated that the engines did not operate more than 200 hours in the year. Due to the low engine use and the resulting small amount of emissions, the cost of additional controls leads to these higher cost-effectiveness values.

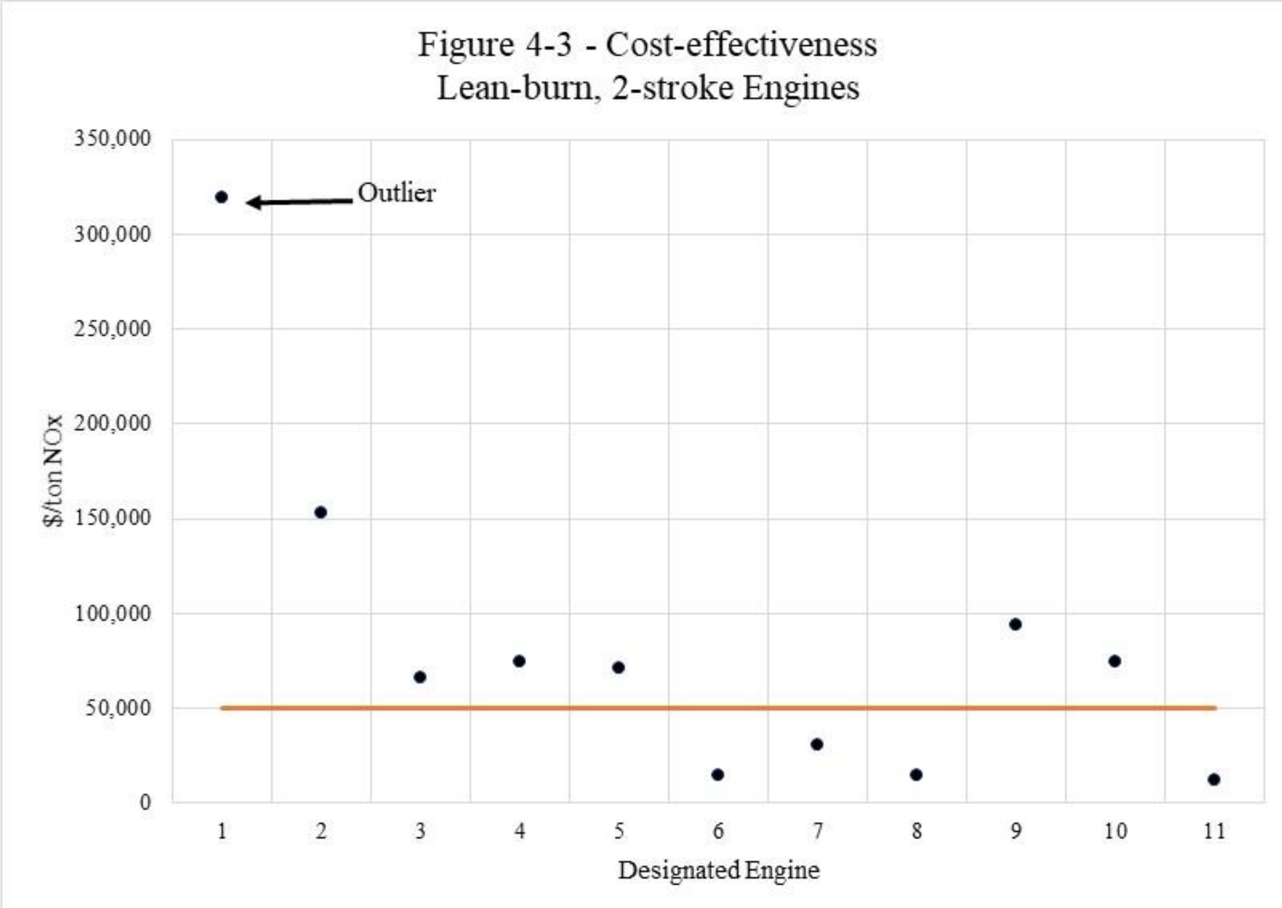



Figure 4-3 presents the distribution of cost-effectiveness for the eleven lean-burn, 2-stroke engines that were evaluated. In this category, an outlier was determined to be a value greater than $213,050 per ton of NOx reduced. Engine No. 1 was identified as an outlier with a calculated value of $362,000 per ton of NOx reduced. Although not considered an outlier, Engine No. 2 also had a high cost-effectiveness. Both are diesel engines, rated at 450 hp and categorized as process units under RECLAIM. Each has a fixed emission factor of 469 lbs/1000 gallon. In 2016 and 2017, both engines operated less than 200 hours each year (one of those engines reported zero operating hours the last two compliance years). For these two engines, a low-use exemption contained in Rule 1110.2 (d)(1)(B)(iii) would be applicable, should the facility decide to use it. If these engines exceed 500 hours of operation or use more than 1 x $10^9$ British Thermal Units (Btus) per year (higher heating value) of fuel, then the emissions limits listed in Table II would apply.

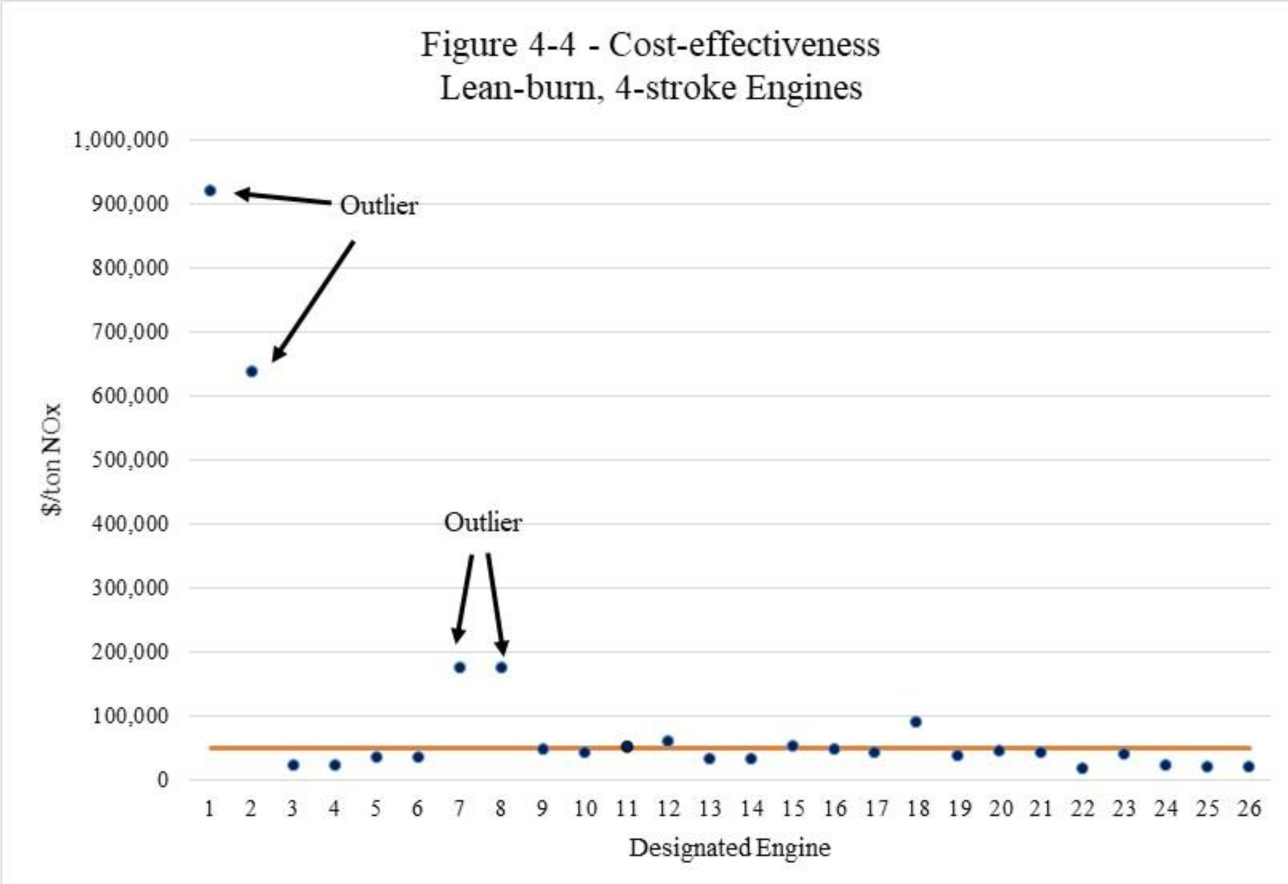



Figure 4-4 presents the distribution of cost-effectiveness for lean-burn, 4-stroke engines. Twenty-six engines were evaluated. In this sub-category, an outlier was determined to be a value greater than $95,288 per ton of NOx reduced. Engine Nos. 1, 2, 7, and 8 were identified as outliers. All four engines are diesel engines rated at 131 hp, 450 hp, 853 hp, and 853 hp, respectively. Engine No.1 was categorized as a process unit under RECLAIM and Engines Nos. 2, 7, and 8 were categorized as RECLAIM large sources. Based on their past reported hours of operation, a low-use exemption contained in Rule 1110.2 (d)(1)(B)(iii) would also be applicable, should the facility decide to use. If these engines exceed 500 hours of operation or use more than 1 x $10^9$ British Thermal Units (Btus) per year (higher heating value) of fuel, then the emissions limits listed in Table II would apply.

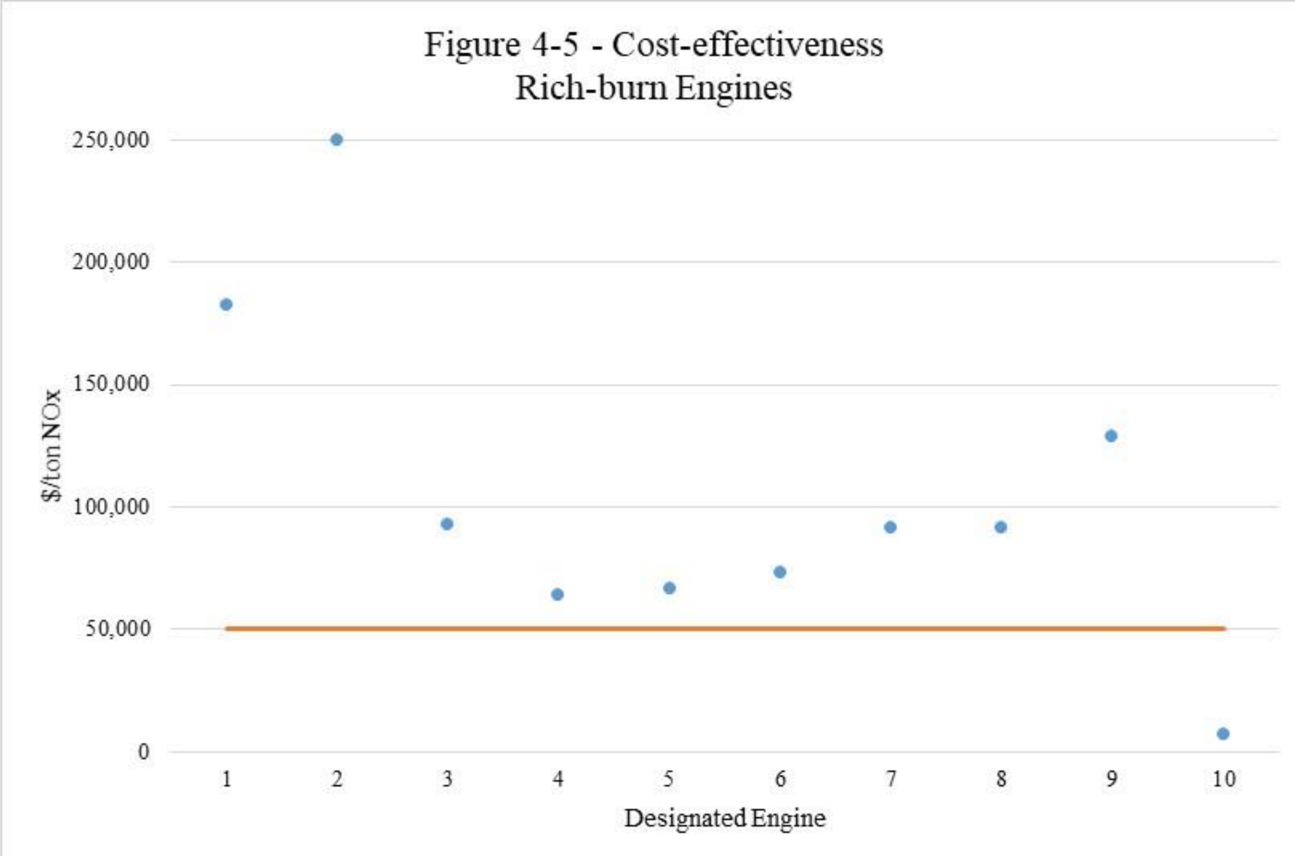



Figure 4-5 presents the distribution of cost-effectiveness for rich-burn engines. Ten engines were evaluated. In this category, an outlier was determined to be a value greater than $256,900 per ton of NOx reduced. Although no engine was identified as an outlier, as a category, the engines had a high cost-effectiveness value relative to a $50,000 per ton of NOx reduced threshold. This was due in large part to CEMS costs that would be required per Rule 1110.2, specifically for those that would fall under the aggregate facility requirement for CEMS. It should be noted that these engines would be able to comply with the proposed emission limit easily with tuning and/or minor catalyst changes. The increased monitoring costs are the main driver for the increased cost effectiveness for this engine subcategory.

Although the cost-effectiveness for rich-burn engines had a high cost-effectiveness value relative to the $50,000 per ton of NOx reduced threshold, the overall cost-effectiveness for all engines affected by the transition from the RECLAIM program to a command-and-control regulatory structure is calculated to be $33,800 per ton of NOx reduced.

**SOCIOECONOMIC ASSESSMENT**

A Draft Socioeconomic Impact Assessment will be prepared and released at least 30 days prior to the South Coast AQMD Governing Board Hearing on PAR 1110.2 and PAR 1100, which are anticipated to be heard on October 4, 2019.

## CALIFORNIA ENVIRONMENTAL QUALITY ACT ANALYSIS

Pursuant to the California Environmental Quality Act (CEQA) and South Coast AQMD's Certified Regulatory Program (Rule 110), the South Coast AQMD, as lead agency for the proposed project, has determined that PARs 1110.2 and 1100 are considered a "project" as defined by CEQA. South Coast AQMD staff has determined that the proposed project contains new information of substantial importance which was not known and could not have been known at the time the March 2017 Final Program Environmental Impact Report (EIR) was certified for the 2016 AQMP (referred to herein as March 2017 Final Program EIR). Because the proposed project may create new, potentially significant effects that were not analyzed in the March 2017 Final Program EIR, the South Coast AQMD will prepare a Subsequent Environmental Assessment (SEA) with significant impacts, which will tier off of the March 2017 Final Program EIR as allowed by CEQA Guidelines Sections 15168 and 15385. The March 2017 Final Program EIR, upon which the Draft SEA will rely, is available from the South Coast AQMD's website at: http://www.aqmd.gov/home/research/documents-reports/lead-agency-South Coast AQMD-projects/South Coast AQMD-projects---year-2017. The SEA will allow public agencies and the public the opportunity to obtain, review, and comment on the environmental analysis.

In addition, since the proposed project could have statewide, regional or area wide significance, a CEQA scoping meeting is required to be held pursuant to Public Resources Code Section 21083.9(a)(2). The CEQA scoping meeting is scheduled to be held in conjunction with the public workshop. Upon completion, a Draft SEA will be released for a 45-day public review and comment period. Comments made at the public workshop/CEQA scoping meeting and responses to the comments will be included in the Final SEA.

## DRAFT FINDINGS UNDER CALIFORNIA HEALTH AND SAFETY CODE SECTION 40727

*Requirements to Make Findings*

California Health and Safety Code Section (H&SC) 40727 requires that prior to adopting, amending or repealing a rule or regulation, the South Coast AQMD Governing Board shall make findings of necessity, authority, clarity, consistency, non-duplication, and reference based on relevant information presented at the public hearing and in the staff report.

*Necessity*

PARs 1110.2 and 1100 are needed for engines under the RECLAIM program that will be transitioning to a command-and-control regulatory structure to establish NOx emission limits for engines that are representative of BARCT, their time of transition, as well as monitoring, reporting, and recordkeeping requirements.

*Authority*

The South Coast AQMD obtains its authority to adopt, amend, or repeal rules and regulations pursuant to H&SC Sections 39002, 39616, 40000, 40001, 40440, 40702, 40725 through 40728, 40920.6, and 41508.

*Clarity*

PARs 1110.2 and 1100 are written or displayed so that their meaning can be easily understood by the persons directly affected by them.

*Consistency*

PARs 1110.2 and 1100 are in harmony with and not in conflict with or contradictory to, existing statutes, court decisions or state or federal regulations.

*Non-Duplication*

PARs 1110.2 and 1100 will not impose the same requirements as any existing state or federal regulations. The proposed amended rules are necessary and proper to execute the powers and duties granted to, and imposed upon, the South Coast AQMD.

*Reference*

In amending these rules, the following statutes which the South Coast AQMD hereby implements, interprets or makes specific are referenced: H&SC Sections 39002, 40001, 40702, 40440(a), and 40725 through 40728.5.

## COMPARATIVE ANALYSIS

Under H&SC Section 40727.2, the South Coast AQMD is required to perform a comparative written analysis when adopting, amending, or repealing a rule or regulation. The comparative analysis is relative to existing federal requirements, existing or proposed South Coast AQMD rules and air pollution control requirements and guidelines which are applicable to internal combustion engines. See Table 4-3 below.

**Table 4-3: Comparative Analysis**

| Rule Element | PAR 1110.2 | PR 1100 | RECLAIM | Equivalent Federal Regulation Title 40, Part 60, Subpart JJJJ | Equivalent Federal Regulation Title 40, Part 60, Subpart IIII |
|---|---|---|---|---|---|
| **Applicability** | All stationary and portable engines over 50 rated brake horsepower (bhp) are subject to this rule | RECLAIM or post-RECLAIM facilities | Facilities regulated under the NOx RECLAIM program (SCAQMD Reg. XX) | Stationary spark ignition (SI) internal combustion engines | Stationary compression ignition internal combustion engines |
| **Requirements*** <br><br> *All parts per million (ppm) emission limits are referenced at 15 percent gas oxygen on a dry basis averaged over a period of 15 consecutive minutes. | Non-emergency engines <br> hp ≥ 50: **11 ppmv** | •Schedule for meeting BARCT emission limits and MRR requirements | • Major Source <br> **None** <br> • Large Source <br> **36 ppmv** <br> • Process Unit <br> Natural gas <br> **3400 lb/mmscf** <br> LPG, propane, butane <br> **139/mgal** <br> Diesel <br> **469 lb/mgal** | • Non-emergency, natural gas and LPG <br> hp ≥ 100: **82 ppmv** <br> • Landfill/digester gas: **150 ppmv** | For engines installed prior to January 1, 2012 <br> • 12.7 g/hp-hr when max engine speed < than 130 rpm <br> • 34 · $n^{-0.2}$ g/hp-hr) when 130 ≤ max engine speed < 2,000 rpm, where n is max engine speed; and <br> • 7.3 g/hp-hr when max engine speed > 2,000 rpm <br> For engines installed on or after January 1, 2012 and before January 1, 2016 <br> • 10.7 g/hp-hr when max engine speed < 130 rpm; <br> • 33 · $n^{-0.23}$ g/hp-hr) when 130 ≤ max engine speed < 2,000 rpm, where n is max engine speed; and <br> • 5.7 g/hp-hr) when max engine speed > 2,000 rpm. <br> For engines installed on or after January 1, 2016, <br> • 2.5 g/hp-hr when max engine speed < 130 rpm; <br> • 6.7 · $n^{-0.20}$ g/hp-hr) when 130 ≤ max engine speed < 2,000 rpm, where n is max engine speed; and <br> • 1.5 g/hp-hr when max engine speed > 2,000 rpm. |
| **Reporting** | Report breakdowns subject to breakdown provisions | As specified in Rule 1110.2 | • Daily electronic reporting for major sources <br> • Monthly to quarterly reporting for large sources and process units | Annual report | Initial report |

| | | | | | |
|---|---|---|---|---|---|
| | | | • Quarterly Certification of Emissions Report and Annual Permit Emissions Program for all units | | |
| **Monitoring** | • A continuous in-stack NOx monitor for units greater than or equal to 1000 bhp and operating 2 million bhp-hr per calendar year or for facilities with engines subject to paragraph (d)(1), having a combined rating of 1500 bhp or greater at the same location, and having a combined fuel usage of more than 16 x 109 Btus per year (higher heating value)<br>• Non-resettable totalizing time meter | As specified in Rule 1110.2 | • A continuous in-stack NOx monitor for major sources<br>• Source testing once every 3 years for large sources<br>• Source testing once every 5 years for process units | Install a non-resettable hour meter | Install a non-resettable hour meter |
| **Recordkeeping** | • Monthly log<br>• All data, logs, test reports and other information required by this rule shall be maintained for at least five years and made available for inspection by the Executive Officer | As specified in Rule 1110.2 | • Quarterly log for process units<br>• < 15-min. data = min. 48 hours; ≥ 15-min. data = 3 years (5 years if Title V)<br>• Maintenance & emission records, source test reports, RATA reports, audit reports and fuel meter calibration records for Annual Permit Emissions Program = 3 years (5 years if Title V) | • Maintain an operating log | • Maintain an operating log |

# APPENDIX A – LIST OF FACILITIES AFFECTED BY PAR 1110.2

| Table A-1: RECLAIM Facilities Affected by PAR 1110.2 | |
|---|---|
| **Facility ID** | **Facility Name** |
| 4242 | San Diego Gas & Electric |
| 5973 | So Cal Gas Co/Honor Rancho Facility |
| 8547 | Quemetco Inc. |
| 8582 | So Cal Gas Co/Playa del Rey Facility |
| 9755 | United Airlines |
| 18931 | Tamco |
| 43201 | Snow Summit Inc. |
| 61962 | LA City, Harbor Dept |
| 62548 | The Newark Group, Inc. |
| 68118 | Tidelands Oil Production Company Etal |
| 124723 | Greka Oil & Gas |
| 143740 | DCOR LLC |
| 143741 | DCOR LLC |
| 150201 | Breitburn Operating LP |
| 155877 | Millercoors, LLC |
| 166073 | Beta Offshore |
| 169754 | So Cal Holding, LLC |
| 173904 | Lapeyre Industrial Sands, Inc. |
| 174544 | Breitburn Operating LP |
| 800128 | So Cal Gas Co/Aliso Canyon Facility |
| 800189 | Disneyland Resort |

**Table A-2: Equipment at RECLAIM Facilities Affected by PAR 1110.2**

| Engine | bhp | Fuel type | Current Controls | Current NOx Limit (ppm[1]) | Proposed Limit (ppm[1]) | Capital Cost ($) | Annual Cost ($) | Present Worth Value ($) | Estimated NOx Reduction (tpd) | CE ($/ton) |
|---|---|---|---|---|---|---|---|---|---|---|
| Lean-burn, 2-stroke engines | | | | | | | | | | |
| 1 | 450 | Diesel | Oxi-cat | 675 | 11 | 603,368 | 711,619 | 1,492,711 | .000 | 318,900 |
| 2 | 450 | Diesel | Oxi-cat | 675 | 11 | 603,368 | 711,619 | 1,492,711 | .001 | 152,900 |
| 3 | 995 | Nat gas | Oxi-cat | 150 | 11 | 947,181 | 1,221,826 | 2,169,007 | .004 | 66,000 |
| 4 | 995 | Nat gas | Oxi-cat | 150 | 11 | 947,181 | 1,221,826 | 2,169,007 | .003 | 74,300 |
| 5 | 995 | Nat gas | Oxi-cat | 150 | 11 | 947,181 | 1,221,826 | 2,169,007 | .003 | 71,500 |
| 6 | 2000 | Nat gas | Oxi-cat | 225 | 11 | 1,683,747 | 1,607,860 | 3,291,607 | .024 | 14,800 |
| 7 | 2000 | Nat gas | Oxi-cat | 225 | 11 | 1,683,747 | 1,607,860 | 3,291,607 | .012 | 30,500 |
| 8 | 2000 | Nat gas | Oxi-cat | 225 | 11 | 1,683,747 | 1,607,860 | 3,291,607 | .025 | 14,400 |
| 9 | 3000 | Nat gas | Oxi-cat | 116 | 11 | 1,380,480 | 1,605,864 | 2,986,344 | .003 | 94,100 |
| 10 | 3000 | Nat gas | Oxi-cat | 116 | 11 | 1,380,480 | 1,605,864 | 2,986,344 | .004 | 74,900 |
| 11 | 3200 | Nat gas | Oxi-cat | 116 | 11 | 1,441,430 | 1,659,134 | 3,100,564 | .029 | 11,800 |
| Lean-burn, 4-stroke engines | | | | | | | | | | |
| 12 | 131 | Diesel | N/A | 208 | 11 | 506,152 | 534,986 | 1,218,863 | 0.000 | 920,400 |
| 13 | 190 | Compliant | | | | | | | | |
| 14 | 190 | | | | | | | | | |
| 15 | 190 | | | | | | | | | |
| 16 | 190 | | | | | | | | | |

| Engine | bhp | Fuel type | Current Controls | Current NOx Limit (ppm[1]) | Proposed Limit (ppm[1]) | Capital Cost ($) | Annual Cost ($) | Present Worth Value ($) | Estimated NOx Reduction (tpd) | CE ($/ton) |
|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 190 | | | | | | | | | |
| 18 | 190 | | | | | | | | | |
| 19 | 190 | | | | | | | | | |
| 20 | 450 | Diesel | N/A | 344 | 11 | 603,368 | 647,641 | 1,251,008 | 0.000 | 637,800 |
| 21 | 853 | Diesel | Oxi-cat | 450 | 11 | 903,907 | 1,161,297 | 2,065,204 | 0.010 | 23,500 |
| 22 | 853 | Diesel | Oxi-cat | 450 | 11 | 903,907 | 1,161,297 | 2,065,204 | 0.010 | 23,500 |
| 23 | 853 | Diesel | Oxi-cat | 450 | 11 | 903,907 | 1,161,297 | 2,065,204 | 0.006 | 35,300 |
| 24 | 853 | Diesel | Oxi-cat | 450 | 11 | 903,907 | 1,161,297 | 2,065,204 | 0.006 | 35,300 |
| 25 | 853 | Diesel | Oxi-cat | 450 | 11 | 903,907 | 1,161,297 | 2,065,204 | 0.001 | 176,400 |
| 26 | 853 | Diesel | Oxi-cat | 450 | 11 | 903,907 | 1,161,297 | 2,065,204 | 0.001 | 176,400 |
| 27 | 881 | Digester | Oxi-cat | 36 | 11 | 912,440 | 1,173,350 | 2,085,790 | 0.005 | 49,800 |
| 28 | 881 | Digester | Oxi-cat | 36 | 11 | 912,440 | 1,173,350 | 2,085,790 | 0.005 | 43,900 |
| 29 | 1468 | Compliant | | | | | | | | |
| 30 | 2000 | Nat gas | Oxi-cat | 23 | 11 | 1,075,730 | 1,295,420 | 2,371,150 | 0.005 | 54,600 |
| 31 | 2000 | Nat gas | Oxi-cat | 43 | 11 | 1,075,730 | 1,295,420 | 2,371,150 | 0.004 | 61,800 |
| 32 | 2000 | Nat gas | Oxi-cat | 30 | 11 | 1,075,730 | 1,295,420 | 2,371,150 | 0.008 | 33,300 |
| 33 | 2000 | Nat gas | Oxi-cat | 46 | 11 | 1,075,730 | 1,295,420 | 2,371,150 | 0.008 | 32,800 |
| 34 | 2000 | Nat gas | Oxi-cat | 24 | 11 | 1,075,730 | 1,295,420 | 2,371,150 | 0.005 | 54,600 |
| 35 | 3043 | Diesel | SCR | 50 | 11 | 214,408 | 423,617 | 638,024 | 0.001 | 49,300 |

| Engine | bhp | Fuel type | Current Controls | Current NOx Limit (ppm[1]) | Proposed Limit (ppm[1]) | Capital Cost ($) | Annual Cost ($) | Present Worth Value ($) | Estimated NOx Reduction (tpd) | CE ($/ton) |
|---|---|---|---|---|---|---|---|---|---|---|
| 36 | 3043 | Diesel | SCR | 50 | 11 | 214,408 | 423,617 | 638,024 | 0.002 | 42,500 |
| 37 | 3043 | Diesel | SCR | 50 | 11 | 214,408 | 423,617 | 638,024 | 0.001 | 90,200 |
| 38 | 3043 | Diesel | SCR | 50 | 11 | 214,408 | 423,617 | 638,024 | 0.002 | 37,400 |
| 39 | 3043 | Diesel | SCR | 50 | 11 | 214,408 | 423,617 | 638,024 | 0.001 | 46,800 |
| 40 | 3043 | Diesel | SCR | 50 | 11 | 214,408 | 423,617 | 638,024 | 0.002 | 42,600 |
| 41 | 5500 | Nat gas | Oxi-cat | 41 | 11 | 2,142,355 | 2,060,472 | 4,202,827 | 0.024 | 19,300 |
| 42 | 5500 | Nat gas | Oxi-cat | 54 | 11 | 2,142,355 | 2,060,472 | 4,202,827 | 0.011 | 41,600 |
| 43 | 5500 | Nat gas | Oxi-cat | 40 | 11 | 2,142,355 | 2,060,472 | 4,202,827 | 0.020 | 22,500 |
| 44 | 5500 | Nat gas | Oxi-cat | 54 | 11 | 2,142,355 | 2,060,472 | 4,202,827 | 0.022 | 20,600 |
| 45 | 5500 | Nat gas | Oxi-cat | 82 | 11 | 2,142,355 | 2,060,472 | 4,202,827 | 0.022 | 21,400 |
| Rich-burn engines | | | | | | | | | | |
| 46 | 147 | Compliant | | | | | | | | |
| 47 | 147 | | | | | | | | | |
| 48 | 189 | | | | | | | | | |
| 49 | 189 | | | | | | | | | |
| 50 | 268 | | | | | | | | | |
| 51 | 268 | | | | | | | | | |
| 52 | 268 | | | | | | | | | |
| 53 | 385 | | | | | | | | | |

| Engine | bhp | Fuel type | Current Controls | Current NOx Limit (ppm[1]) | Proposed Limit (ppm[1]) | Capital Cost ($) | Annual Cost ($) | Present Worth Value ($) | Estimated NOx Reduction (tpd) | CE ($/ton) |
|---|---|---|---|---|---|---|---|---|---|---|
| 54 | 738 | Nat Gas | NSCR | 20 | 11 | 177,725 | 462,713 | 640,438 | 0.000 | 182,200 |
| 55 | 738 | Nat Gas | NSCR | 20 | 11 | 177,725 | 462,713 | 640,438 | 0.000 | 250,000 |
| 56 | 790 | Compliant | | | | | | | | |
| 57 | 790 | | | | | | | | | |
| 58 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 92,900 |
| 59 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 64,000 |
| 60 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 66,700 |
| 61 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 73,200 |
| 62 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 91,600 |
| 63 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 91,700 |
| 64 | 818 | Nat Gas | NSCR | 20 | 11 | 177,725 | 473,973 | 651,698 | 0.001 | 129,100 |
| 65 | 830 | Compliant | | | | | | | | |
| 66 | 845 | Nat Gas | NSCR | 28 | 11 | 0 | 165,334 | 165,334 | 0.003 | 7,215 |
| 67 | 1150 | Compliant | | | | | | | | |
| 68 | 2000 | | | | | | | | | |

Notes:

- Engines 9-11: The emission factor was based on the calculation used in the engineering evaluation at the time of permitting.
- Engines 14-19: Identical engines in the process of installation at a single facility. The engines were permitted at 12.3 ppmv NOx; however, staff reviewed the respective permit file and determined that the engines are actually certified to emit less than 0.15 g/bhp-hr NOx. Staff also reviewed initial source test information and noted that the engines emit less than 11 ppm NOx. Although the individual permits list 12.3 ppmv NOx emission limit, no additional requirement is needed at this time.
- Engines 21-26: Identical engines installed at a single facility. Reviewing operational information for 2016 and 2017, staff noted that hours of operation varied for each engine; however, each engine can be used interchangeably. In its cost-effectiveness evaluation, staff therefore used 1,500 hours of operation for engines 21 and 22, 1,000 hours of operation for engines 23 and 24, and 200 hours of operation for engines 25 and 26 as a basis for its calculation. In addition, due to the aggregate facility horsepower greater than 1,500 hp, staff assumed that each engine would require a CEMS installation; no potential sharing of CEMS was considered at this time.
- Engines 30-34: Identical engines installed at a single facility. The emission factor for each engine was based on source test data found in the engineering evaluation file.
- Engines 41-45: Identical engines installed at a single facility. The emission factor for each engine was based on source test data found in the engineering evaluation file.
- Engines 56-57: Identical engines installed at a single facility. Although the aggregate horsepower at the facility is greater than 1,500 bhp, these engines operate well below 1,000 hours. It is assumed that these engines would not require a CEMS installation.
- Engines 58-64: Identical engines installed at a single facility. Since these engines are greater than 500 hp but less than 1,000 hp and the facility aggregate horsepower is greater than 1,500 hp, CEMS would be required on these engines.
- In general, for the rich-burn engine category, it is anticipated that lowering the emissions to 11 ppmv will be accomplished through minimal catalyst modifications and/or retuning of the respective AFRC. However, engines, greater than or equal to 500 bhp but less than 1,000 bhp and where the aggregate horsepower for the facility is greater than 1,500 bhp, may be required to install a CEMS unit. Staff did not assume any potential sharing of CEMS equipment in its cost-effectiveness evaluation.

## APPENDIX B – ANALYSIS OF NOX EMISSION LIMITS FOR OTHER AIR DISTRICTS

As part of the BARCT analysis, staff reviewed similar regulations related to internal combustion engines in other jurisdictions both within California and outside. In jurisdictions where limits were expressed in g/bhp-hr, conversion to ppmv equivalent was based on a 33% thermal efficiency.

Antelope Valley

Staff reviewed Antelope Valley AQMD Rule 1110.2 – Emissions from Stationary, Non-road and Portable Internal Combustion Engines. The rule applies to all ICEs with a rated brake horsepower greater than 50 bhp. Per Rule 1110.2 (C)(1)(a)(iii), the owner or operator of any stationary ICE subject to this rule shall comply with the general emission limits of 36 ppm NOx, 250 ppm VOC, and 2000 ppm CO (corrected to 15% O2 on a dry basis, averaged over a 15-minute interval). The rule does not differentiate by fuel source whether the source is natural gas, diesel, biogas, or other hydrocarbon. The rule applicability also does not distinguish by engine type whether the engine is two-cycle, four-cycle, lean-burn, or rich-burn.

Bay Area

Staff reviewed Bay Area AQMD Regulation 9 – Inorganic Gaseous Pollutants, Rule 8 – Nitrogen Oxides and Carbon Monoxide from Stationary Internal Combustion Engines. Regulation 9, Rule 8 applies to stationary ICEs with an output rating greater than 50 bhp. The regulation sets different NOx emission limits based on fuel source whether fossil derived or waste derived and engine type whether spark-ignited or compression-ignited or whether lean-burn or rich-burn. The lowest NOx limit is set at 25 ppmv (corrected to 15% O2 on a dry basis) for a spark-ignited, rich-burn engine powered by fossil derived fuels. CO emissions are limited to 2000 ppmv (corrected to 15% O2 on a dry basis).

Mojave Desert

Staff reviewed Mojave Desert AQMD Rule 1160 – Internal Combustion Engines. Rule 1160 applies to any stationary, non-agricultural, ICE with a rated brake horsepower greater than 50 bhp. The regulation sets different NOx emission limits based on engine type whether spark-ignited or compression-ignited or whether lean-burn or rich-burn. The lowest NOx limit is set at 50 ppmv (corrected to 15% O2 on a dry basis averaged over 15 minutes) for a spark-ignited, rich-burn engine. The VOC and CO compliance limits are established as 106 ppmv and 4500 ppmv respectively.

Santa Barbara

Staff reviewed Santa Barbara County APCD Rule 333 – Control of Emissions from Reciprocating Internal Combustion Engines. Rule 333 applies to any engine with a rated brake horsepower greater than 50 bhp. The regulation sets different NOx emission limits based on engine type whether spark-ignited or compression-ignited, whether cyclically or non-cyclically loaded, or whether lean-burn or rich-burn. The lowest NOx limit is set at 50 ppmv (corrected to 15% O2 on a dry basis) for a spark-ignited, non-cyclically-loaded, rich-burn engine. The most stringent VOC and CO compliance limits are established as 250 ppmv and 4500 ppmv respectively.

San Diego

Staff reviewed San Diego County APCD Rule 69.4.1 – Stationary Reciprocating Internal Combustion Engines – Best Available Retrofit Control Technology. Rule 69.4.1 applies to all stationary ICEs with a horsepower rating greater than 50 bhp. The regulation sets different NOx emission limits based on fuel source whether fossil derived gaseous, gasoline, waste derived gaseous, diesel, or kerosene based and engine type whether lean-burn or rich-burn. The lowest NOx limit is set at 25 ppmv (corrected to 15% O2 on a dry basis) for a rich-burn engine powered by either fossil derived fuels or gasoline. The VOC and CO compliance limits are established as 250 ppmv and 4500 ppmv respectively.

San Joaquin Valley

Staff reviewed San Joaquin Valley Unified APCD Rule 4702 – Internal Combustion Engines. Rule 4702 applies to engines rated at greater than 50 bhp. The regulation sets different NOx emission limits based on fuel source whether gaseous, waste derived, or field derived and engine type whether two-stroke or four-stroke, whether lean-burn or rich-burn, or whether spark-ignited or compression-ignited. The regulation also provides consideration for lean-burn engines used for gas compression and engines used in agricultural operations. The lowest NOx limit is set at 11 ppmv (corrected to 15% O2 on a dry basis) for rich-burn or lean-burn engines not specifically exempted. The most stringent VOC and CO compliance limits are set as 250 ppmv and 2000 ppmv respectively.

San Luis Obispo

Staff reviewed San Luis Obispo County APCD Rule 431 – Stationary Internal Combustion. Rule 431 applies to any stationary ICE with a rated brake horsepower greater than 50 bhp. The regulation sets different NOx emission limits based on engine type whether lean-burn or rich-burn, or whether spark-ignited or compression-ignited. The regulation also provides consideration for engines used in agricultural operations. The lowest NOx limit is set at 50 ppmv (corrected to 15% O2 on a dry basis) for a spark-ignited, rich-burn engine. CO emissions are limited to 4500 ppmv (corrected to 15% O2 on a dry basis).

Ventura County

Staff reviewed Ventura County APCD Rule 74.9 – Stationary Internal Combustion Engines. Rule 74.9 applies to any stationary engine with a rated brake horsepower greater than 50 bhp. The regulation sets different NOx emission limits based on fuel source whether gaseous, diesel or waste derived and engine type whether spark-ignited or compression-ignited or whether lean-burn or rich-burn. The lowest NOx limit is set at 25 ppmv (corrected to 15% O2 on a dry basis) for a general rich-burn engine. The most stringent VOC and CO compliance limits are established as 250 ppmv and 4500 ppmv respectively.

Pennsylvania

Staff reviewed the Commonwealth of Pennsylvania Code, Title 25 – Environmental Protection, Chapter 129 –Standards for Sources, subpart 129.97, subsection (g)(3). The code applies to any stationary internal combustion engine with a rated brake horsepower greater than or equal to 500 bhp. The regulation sets different NOx emission limits based on fuel source whether natural gas or liquid-fueled and engine type whether lean-burn or rich-burn. The lowest NOx limit is set at 2.0 g/bhp-hr or 155 ppmv for a rich-burn engine fired on natural gas. VOC emissions are limited to 1.0 g/bhp-hr for engines fired on natural gas. The regulation established no CO compliance limit.

New Jersey

Staff reviewed the New Jersey State Department of Environmental Protection, New Jersey Administrative Code, Title 7, Chapter 27, Subchapter 19 – Control and Prohibition of Air Pollution from Oxides of Nitrogen, Section 7:27-19.8 – Stationary Reciprocating Engines. Section 7:27-19.8 applies to various rated engines beginning at approximately 50 bhp. The regulation sets different NOx emission limits based on engine rating, fuel source whether gaseous or liquid fueled and engine type whether lean-burn or rich-burn. The lowest NOx limit is set at 0.9 g/bhp-hr or 70 ppmv for an engine with a rated brake horsepower greater than 50 bhp that started operation on or after March 7, 2007. The regulation established no VOC or CO compliance limit.

New York

Staff reviewed the New York Codes, Rules and Regulations, 6 CRR-NY 227-2.4, subpart (f) – Control Requirements for Stationary Internal Combustion Engines. The Code varies by engine size whether an engine is in a severe ozone nonattainment zone or not regulating engines greater than or equal to 200 bhp in severe ozone nonattainment zones or engines greater than or equal to 400 bhp in areas outside these zones. The regulation sets different NOx emission limits based on type of fuel used whether natural gas, landfill or digester gas, or diesel. The lowest NOx limit is set at 1.5 g/bhp-hr or 116 ppmv for an internal combustion engine fired solely on natural gas. The regulation established no VOC or CO compliance limit.

Texas

Staff reviewed the Texas Administrative Code, Title 30, Part 1, Chapter 117, Subchapter D, Division 2, Rule 117.2110. The rule applies to stationary reciprocating internal combustion engines. The regulation sets different NOx emission limits based on fuel source whether gaseous, diesel or landfill gas and engine type whether spark-ignited or compression-ignited or whether lean-burn or rich-burn. The lowest NOx limit is set at 0.5 g/bhp-hr or 39 ppmv for an engine fired on natural gas. CO emissions are limited to 400 ppmv. The regulation established no VOC compliance limit.

References

Antelope Valley AQMD Source Specific Rules, Rule 1110.2 – Emissions from Stationary, Non-road and Portable Internal Combustion Engines, Website: https://avaqmd.ca.gov/regulation-xi-source-specific-standards.

Bay Area AQMD, Current Rules, Regulation 9 – Inorganic Gaseous Pollutants, Rule 8 – Nitrogen Oxides and Carbon Monoxide from Stationary Internal Combustion Engines, Website: http://www.baaqmd.gov/rules-and-compliance/current-rules.

Commonwealth of Pennsylvania Code, Title 25 – Environmental Protection, Chapter 129 – Standards for Sources, subpart 129.97, Website: https://www.pacode.com/secure/data/025/chapter129/s129.97.html.

Mojave Desert AQMD, Regulation XI – Source Specific Standards, Rule 1160 – Internal Combustion Engines, Website: http://mdaqmd.ca.gov/rules/rule-book/regulation-xi-source-specific-standards.

New Jersey State Department of Environmental Protection, New Jersey Administrative Code, Title 7, Chapter 27, Subchapter 19 – Control and Prohibition of Air Pollution from Oxides of Nitrogen, Section 7:27-19.8 – Stationary Reciprocating Engines, Website: https://www.nj.gov/dep/aqm/rules27.html

New York Codes, Rules and Regulations, 6 CRR-NY 227-2.4, subpart (f) – Control Requirements for Stationary Internal Combustion Engines, Website: https://govt.westlaw.com/nycrr/Document/I4e978e48cd1711dda432a117e6e0f345?contextData=(sc.Default)&transitionType=Default.

Santa Barbara County APCD, Current Rules and Regulations, Rule 333 – Control of Emissions from Reciprocating Internal Combustion Engines, Website: https://www.ourair.org/current-rules-and-regulations/.

San Diego County APCD, List of Current Rules, Rule 69.4.1 – Stationary Reciprocating Internal Combustion Engines – Best Available Retrofit Control Technology, Website: https://www.arb.ca.gov/drdb/sd/cur.htm.

San Joaquin Valley Unified APCD, Current District Rules and Regulations, Rule 4702 – Internal Combustion Engines, Website: https://www.valleyair.org/rules/1ruleslist.htm#reg4.

San Luis Obispo County APCD, List of Current Rules, Rule 431 – Stationary Internal Combustion Engines, Website: https://www.arb.ca.gov/drdb/slo/cur.htm.

Texas Administrative Code, Title 30, Part 1, Chapter 117, Subchapter D, Division 2, Rule 117.2110, Website: https://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=117&rl=2110.

Ventura County APCD, List of Current Rules, Rule 74.9 – Stationary Internal Combustion Engines, Website: https://www.arb.ca.gov/drdb/ven/cur.htm.

## APPENDIX C – ENGINE SURVEY

Rule 1110.2 Survey – October 2018

Facility ID: ________________ Company Name: __________________________

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) | (11) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Permit No. | Size (bhp) | Primary Fuel Type | 2-stroke engine (Y/N) | Lean/ Rich Burn | Age of Engine (yrs) | Primary Engine Use | Type of Emission Control | Ammonia Slip (ppmv) | Ammonia Type | Type of Monitoring |
| 1 | | | | | | | | | | | |
| 2 | | | | | | | | | | | |
| 3 | | | | | | | | | | | |
| 4 | | | | | | | | | | | |
| 5 | | | | | | | | | | | |
| 6 | | | | | | | | | | | |

| | (12) | (13) | (14) | (15) | (16) | (17) | (18) | (19) | (20) | (21) |
|---|---|---|---|---|---|---|---|---|---|---|
| | Engine Portable (Y/N) | Tier Rating | Engine Efficiency (%) | Typical Load Factor | Any Retrofit (Y/N) | Fuel Usage Units | Annual Fuel Usage | | Annual Operating Hours | |
| | | | | | | | CY 2016 | CY 2017 | CY 2016 | CY 2017 |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |

Additional Comments:

Instructions:

- Please provide data (1) – (21) for each engine.
- Attach most recent emissions data for each engine (e.g. source test report, hand-held portable data, etc.)

Prepared by: ____________________________

Contact Phone: ____________________________

Email: ____________________________

Please return survey to:

South Coast Air Quality Management District
Attn: Kevin Orellana
21865 Copley Drive
Diamond Bar, California 91765-4178
Or via E-mail: korellana@aqmd.gov

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Key

(1) Permit number per engine

(2) Size as rated in bhp

(3) Primary fuel type
1. NG – Natural Gas
2. Diesel
3. Digester
4. Other [Provide type]

(4) 2 Stroke Engine – Y/N

(5) Lean or Rich Burn engine

(6) Age of engine based on initial installation

(7) Primary engine use
1. Prime generator
2. Back-up generator
3. Pump
4. Compressor
5. Other: [Describe]

(8) Type of Emissions Control
1. Three-way catalyst with air/fuel ratio controller
2. Three-way catalyst without air/fuel controller
3. Selective catalyst reduction (SCR)
4. Pre-stratified charge combustion (PSC)
5. Combustion modifications
6. Other: [Provide type]

(9) Ammonia slip ppmv @ 15% $O_2$

(10) Ammonia type (if applicable)
1. Anhydrous
2. Aqueous
3. Urea
4. Other: [Provide type]

(11) Type of monitoring (if applicable)
1. Fuel meter
2. Timer
3. CEMS (list constituent: NOx, CO, $O_2$, stack flow, etc.)
4. Other: [Provide type]

(12) Is engine portable?

(13) Tier rating (if applicable)

(14) Engine efficiency based on higher heating value

(15) Typical load factor

(16) Has the unit been retrofitted? Please describe any retrofits made to engine. (e.g., catalytic controls, DPF, etc.) and indicate the year when retrofitted.

(17) Fuel usage units
1. MMSCFD
2. gal/day
3. Other: [Provide alternate type]

(18) – (19) Annual fuel usage for CY 2016 / CY 2017

(20) – (21) Annual operating hours for CY 2016 / CY 2017

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# APPENDIX D – ASSESSMENT OF AIR POLLUTION CONTROL TECHNOLOGIES

The following assessment of pollution control technologies is derived from the November 2001 California Air Resources Board report, "Determination of Reasonably Available Control Technology and Best Available Retrofit Control Technology for Stationary Spark-Ignited Internal Combustion Engines – Appendix B". Focus is on post-combustion controls.

Post combustion controls generally consist of catalysts or filters that act on the engine exhaust to reduce emissions. Post combustion controls also include the introduction of agents or other substances that act on the exhaust to reduce emissions, with or without the assistance of catalysts or filters.

Oxidation Catalyst

Applicability: This control method is applicable to all engines. For stationary engines, oxidation catalysts have been used primarily on lean-burn engines. Rich-burn engines tend to use 3-way catalysts, which combine nonselective catalytic reduction (NSCR) for NOx control and an oxidation catalyst for control of CO and VOC. The oxidation catalyst has been used on lean-burn engines for nearly 30 years. Oxidation catalysts are used less frequently on stationary engines. In the United States, only about 500 stationary lean-burn engines have been fitted with oxidation catalysts.

Principle: An oxidation catalyst contains materials (generally precious metals such as platinum or palladium) that promote oxidation reactions between oxygen, CO, and VOC to produce carbon dioxide and water vapor. These reactions occur when exhaust at the proper temperature and containing sufficient oxygen passes through the catalyst. Depending on the catalyst formulation, an oxidation catalyst may obtain reductions at temperatures as low as 300 or 400 ºF, although minimum temperatures in the 600 to 700 ºF range are generally required to achieve maximum reductions. The catalyst will maintain adequate performance at temperatures typically as high as 1350 ºF before problems with physical degradation of the catalyst occur. In the case of rich-burn engines, where the exhaust does not contain enough oxygen to fully oxidize the CO and VOC in the exhaust, air can be injected into the exhaust upstream of the catalyst.

Typical Effectiveness: The effectiveness of an oxidation catalyst is a function of the exhaust temperature, oxygen content of the exhaust, amount of active material in the catalyst, exhaust flow rate through the catalyst, and other parameters. Catalysts can be designed to achieve almost any control efficiency desired. Reductions greater than 90 percent for both CO and VOC are typical. Reductions in VOC emissions can vary significantly and are a function of the fuel type and exhaust temperature.

Limitations: A sufficient amount of oxygen must be present in the exhaust for the catalyst to operate effectively. In addition, the effectiveness of an oxidation catalyst may be poor if the exhaust temperature is low, which is the case for an engine at idle. Oxidation catalysts, like other catalyst types, can be degraded by masking, thermal sintering, or chemical poisoning by sulfur or metals. If the engine is not in good condition, a complete engine overhaul may be needed to ensure proper catalyst performance.

Sulfur, which can be found in fuels and lubricating oils, is generally a temporary poison, and can be removed by operating the catalyst at sufficiently high temperatures. However, high temperatures can damage the substrate material. Other ways of dealing with sulfur poisoning include the use of low sulfur fuels or scrubbing of the fuel to remove the sulfur. Besides being a catalyst poison, sulfur can also be converted into sulfates by the catalyst before passing through the exhaust pipe. Catalysts can be specially formulated to minimize this conversion, but these special formulations must operate over a relatively narrow temperature range if they are to effectively reduce VOC and CO and also suppress the formation of sulfates. For engines operated over wide power ranges, where exhaust temperatures vary greatly, special catalyst formulations are not effective.

Metal poisoning is generally more permanent, and can result from the metals present in either the fuel or lubricating oil. Specially formulated oils with low metals content are generally specified to minimize poisoning, along with good engine maintenance practices. Metal poisoning can be reversed in some cases with special procedures. Many catalysts are now formulated to resist poisoning.

Masking refers to the covering and plugging of a catalyst's active material by solid contaminants in the exhaust. Cleaning of the catalyst can remove these contaminants, which usually restores catalytic activity. Masking is generally limited to engines using landfill gas, diesel fuel, or heavy liquid fuels, although sulfate ash from lubricating oil may also cause masking. Masking can be minimized by passing the exhaust through a particulate control device, such as a filter or trap, before this material encounters the catalyst. In the case of landfill gas, the particulate control device can act directly on the fuel before introduction into the engine.

Thermal sintering is caused by excessive heat and is not reversible. However, it can be avoided by incorporating over temperature control in the catalyst system. Many manufacturers recommend the use of over temperature monitoring and control for their catalyst systems. In addition, stabilizers such as CeO2 or La2O3 are often included in the catalyst formulation to minimize sintering. High temperature catalysts have been developed which can withstand temperatures exceeding 1800 ºF for some applications. This temperature is well above the highest IC engine exhaust temperature that would ever be encountered. Depending on the design and operation, peak exhaust temperatures for IC engines range from 550 to 1300 ºF.

Other recommendations to minimize catalyst problems include monitoring the pressure drop across the catalyst, the use of special lubricating oil to prevent poisoning, periodic washing of the catalyst, the monitoring of emissions, and the periodic laboratory analysis of a sample of catalyst material.

Other Effects: A catalyst will increase backpressure in the exhaust, resulting in a slight reduction in engine efficiency and maximum rated power. However, when conditions require an exhaust silencer, the catalyst can often be designed to do an acceptable job of noise suppression so that a separate muffler is not required. Under such circumstances, backpressure from the catalyst may not exceed that of a muffler, and no reduction in engine efficiency or power occur. Often, engine manufacturers rate their engines at a given backpressure, and as long as the catalyst does not exceed this backpressure, no reduction in the engine's maximum power rating will be experienced.

Nonselective Catalytic Reduction (NSCR)

Applicability: This control method is applicable to all rich-burn engines, and is probably the most popular control method for rich-burn engines. The first wide scale application of NSCR technology occurred in the mid- to late-1970s, when 3-way NSCR catalysts were applied to motor vehicles with gasoline engines. Since then, this control method has found widespread use on stationary engines. NSCR catalysts have been commercially available for stationary engines for over 15 years, and over 3,000 stationary engines in the U.S. are now equipped with NSCR controls. Improved NSCR catalysts, called 3-way catalysts because CO, VOC, and NOx are simultaneously controlled, have been commercially available for stationary engines for over 10 years. Over 1,000 stationary engines in the U.S. are now equipped with 3-way NSCR controls.

The dual bed NSCR catalyst is a variation of the 3-way catalyst. The dual bed contains a reducing bed to control NOx, followed by an oxidizing bed to control CO and VOC. Dual bed NSCR catalysts tend to be more effective than 3-way catalysts, but are also more expensive, and have not been applied to as many engines as 3-way catalysts. Improved 3-way catalysts can approach the control efficiencies of dual bed catalysts at a lower cost, and for this reason dual bed catalysts have lost popularity to 3-way catalysts.

Principle: The NSCR catalyst promotes the chemical reduction of NOx in the presence of CO and VOC to produce oxygen and nitrogen. The 3-way NSCR catalyst also contains materials that promote the oxidation of VOC and CO to form carbon dioxide and water vapor. To control NOx, CO, and VOC simultaneously, 3-way catalysts must operate in a narrow air/fuel ratio band (15.9 to 16.1 for natural gas-fired engines) that is close to stoichiometric. An electronic controller, which includes an oxygen sensor and feedback mechanism, is often necessary to maintain the air/fuel ratio in this narrow band. At this air/fuel ratio, the oxygen concentration in the exhaust is low, while concentrations of VOC and CO are not excessive.

For dual bed catalysts, the engine is run slightly richer than for a 3-way catalyst. The first catalyst bed in a dual bed system reduces NOx. The exhaust then passes into a region where air is injected before entering the second (oxidation) catalyst bed. NOx reduction is optimized in comparison to a 3-way catalyst due to the higher CO and VOC concentrations and lower oxygen concentrations present in the first (reduction) catalyst bed. In the second (oxidation) bed, CO and VOC reductions are optimized due to the relatively high oxygen concentration present. Although the air/fuel ratio is still critical in a dual bed catalyst, optimal NOx reductions are achievable without controlling the air/fuel ratio as closely as in a 3-way catalyst.

Typical Effectiveness: Removal efficiencies for a 3-way catalyst are greater than 90 percent for NOx, greater than 80 percent for CO, and greater than 50 percent for VOC. Greater efficiencies, below 10 parts per million NOx, are possible through use of an improved catalyst containing a greater concentration of active catalyst materials, use of a larger catalyst to increase residence time, or through use of a more precise air/fuel ratio controller.

For dual bed catalysts, reductions of 98 percent for both NOx and CO are typical.

The previously mentioned reduction efficiencies for catalysts are achievable as long as the exhaust gases are within the catalyst temperature window, which is typically 700 to 1200 ºF. For many engines, this temperature requirement is met at all times except during startup and idling.

The percentage reductions are essentially independent of other controls that reduce the NOx concentration upstream of the catalyst. Thus, a combination of combustion modifications and catalyst can achieve even greater reductions.

Limitations: As with oxidation catalysts, NSCR catalysts are subject to masking, thermal sintering, and chemical poisoning. In addition, NSCR is not effective in reducing NOx if the CO and VOC concentrations are too low. NSCR is also not effective in reducing NOx if significant concentrations of oxygen are present. In this latter case, the CO and VOC in the exhaust will preferentially react with the oxygen instead of the NOx. For this reason, NSCR is an effective NOx control method only for rich-burn engines.

When applying NSCR to an engine, care must be taken to ensure that the sulfur content of the fuel gas is not excessive. The sulfur content of pipeline-quality natural gas and LPG is very low, but some oil field gases and waste gases can contain high concentrations. Sulfur tends to collect on the catalyst, which causes deactivation. This is generally not a permanent condition, and can be reversed by introducing higher temperature exhaust into the catalyst or simply by heating the catalyst. Even if deactivation is not a problem, the water content of the fuel gas must be limited when significant amounts of sulfur are present to avoid deterioration and degradation of the catalyst from sulfuric acid vapor.

For dual bed catalysts, engine efficiency suffers slightly compared to a 3-way catalyst due to the richer operation of engines using dual bed catalysts.

In cases where an engine operates at idle for extended periods or is cyclically operated, attaining and maintaining the proper temperature may be difficult. In such cases, the catalyst system can be designed to maintain the proper temperature, or the catalyst can use materials that achieve high efficiencies at lower temperatures. For some cyclically operated engines, these design changes may be as simple as thermally insulating the exhaust pipe and catalyst.

Most of these limitations can be eliminated or minimized by proper design and maintenance. For example, if the sulfur content of the fuel is excessive, the fuel can be scrubbed to remove the sulfur, or the catalyst design or engine operation can be modified to minimize the deactivation effects of the sulfur. Poisoning from components in the lube oil can be eliminated by using specially formulated lube oils that do not contain such components. However, NSCR applications on landfill gas and digester gas have generally not been successful due to catalyst poisoning and plugging from impurities in the fuel.

Other Effects: A very low oxygen content in the exhaust must be present for NSCR to perform effectively. To achieve this low oxygen content generally requires richening of the mixture. This richening tends to increase CO and VOC emissions. However, use of a 3-way catalyst can reduce CO and VOC emissions to levels well below those associated with uncontrolled engines.

Another effect of NSCR is increased fuel consumption. This increase is very slight when compared to an uncontrolled rich-burn engine. However, when compared to a lean-burn engine, a rich-burn engine uses 5 to 12 percent more fuel for the same power output. If a rich-burn engine uses a dual bed catalyst, a further slight increase in fuel consumption is generally experienced.

Hybrid System

Applicability: This control method can be applied to all engines. This control method was conceived by Radian Corporation, and has been developed by AlliedSignal and Beaird Industries. There has been one field prototype demonstration in San Diego, and it appears that the system has been offered commercially. However, there are no commercial applications of this technique.

Principle: The hybrid system is a modification of the dual bed NSCR system. The hybrid system adds a burner in the engine exhaust between the engine and the dual bed catalysts. The burner is operated with an excess amount of fuel so that oxygen within the engine exhaust is almost completely consumed, and large amounts of CO are generated. The exhaust then passes through a heat exchanger to reduce temperatures before continuing on to a reducing catalyst. The NOx reduction efficiency of the reducing catalyst is extremely high due to the high CO concentration (the CO acts as a reducing agent to convert NOx into nitrogen gas. The exhaust next passes through another heat exchanger, and air is added before the exhaust passes through an oxidation catalyst. The oxidation catalyst is extremely efficient in reducing CO and VOC emissions due to the excess oxygen in the exhaust.

Typical Effectiveness: NOx concentrations as low as 3 to 4 ppm are achievable with this system. Concentrations of CO and VOC are typical of systems using oxidation catalysts.

Limitations: When the oxygen content of the engine's exhaust is high, such as for lean-burn engines, the burner must use a large amount of fuel to consume nearly all the oxygen and generate sufficient amounts of CO. Therefore, use of this method on lean-burn engines is only practical in cogeneration applications, where heat generated by the burner can be recovered and converted to useful energy.

Other Effects: For rich-burn engines, this method has a fuel penalty of about one to five percent. However, for lean-burn engines, the fuel penalty could be equal to the uncontrolled engine's fuel consumption.

Selective Catalytic Reduction (SCR)

Applicability: This method was patented in the U.S. in the 1950s, and there have been over 700 applications of SCR to combustion devices worldwide. Some of these applications include stationary IC engines. However, most of these applications are external combustion devices such as boilers. SCR systems for IC engines have been commercially available for a number of years, but there have only been a few dozen SCR retrofits of IC engines. SCR is applicable to all lean-burn engines, including diesel engines.

Principle: The exhaust of lean-burn engines contains high levels of oxygen and relatively low levels of VOC and CO, which would make an NSCR type of catalyst ineffective at reducing NOx. However, an SCR catalyst can be highly effective under these conditions. Oxygen is a necessary ingredient in the SCR NOx reduction equation, and SCR performs best when the oxygen level in the exhaust exceeds 2 to 3 percent.

Differing catalyst materials can be used in an SCR catalyst, depending on the exhaust gas temperature. Base metal catalysts are most effective at exhaust temperatures between 500 and 900 ºF. Base metal catalysts generally contain titanium dioxide and vanadium pentoxide, although other metals such as tungsten or molybdenum are sometimes used. Zeolite catalysts are most effective at temperatures between 675 to over 1100 ºF. Precious metal catalysts such as platinum and palladium are most effective at temperatures between 350 and 550 ºF.

In SCR, ammonia (or, in some cases, urea) is injected in the exhaust upstream of the catalyst. The catalyst promotes the reaction of ammonia with NOx and oxygen in the exhaust, converting the reactants to water vapor and nitrogen gas. Ammonia injection can be controlled by the use of a NOx monitor in the exhaust downstream of the catalyst. A feedback loop from the monitor to the ammonia injector controls the amount injected, so that NOx reductions are maximized while emissions of ammonia are minimized. To eliminate the use of a costly NOx monitor, some applications use an alternative system that measures several engine parameters. Values for these parameters are then electronically converted into estimated NOx concentrations.

Typical Effectiveness: The NOx removal efficiency of SCR is typically above 80 percent when within the catalyst temperature window.

Limitations: SCR can only be used on lean burn engines. Relatively high capital costs make this method too expensive for smaller or infrequently operated engines.

Some SCR catalysts are susceptible to poisoning from metals or silicon oxides that may be found in the fuel or lubricating oil. Poisoning problems can be minimized by using specially formulated lubricating oils that do not contain the problem metals, the use of fuels with low metals or silicon oxides content, or the use of zeolite catalysts which are not as susceptible to poisoning.

If platinum or palladium is used as an active catalyst material, the sulfur content of the exhaust must be minimized to avoid poisoning of the catalyst. In addition, for all types of SCR catalysts, high sulfur fuels will result in high sulfur oxides in the exhaust. These sulfur compounds will react with the ammonia in the exhaust to form particulate matter that will either mask the catalyst or be released into the atmosphere. These problems can be minimized by using low sulfur fuel, a metal-based SCR system specially designed to minimize formation of these particulate matter compounds, or a zeolite catalyst.

Ammonia gas has an objectionable odor, is considered an air pollutant at low concentrations, becomes a health hazard at higher concentrations, and is explosive at still higher concentrations. Safety hazards can occur if the ammonia is spilled or there are leaks from ammonia storage vessels. These safety hazards can be minimized by taking proper safety precautions in the design, operation, and maintenance of the SCR system. Safety hazards can be substantially reduced by using aqueous ammonia or urea instead of anhydrous ammonia. If a concentrated aqueous solution of urea is used, the urea tank must be heated to avoid recrystallization of the urea. In addition, if too much ammonia is injected into the exhaust, excessive ammonia emissions may result. These emissions can be reduced to acceptable levels by monitoring and controlling the amount of ammonia injected into the exhaust.

SCR may also result in a slight increase in fuel consumption if the backpressure generated by the catalyst exceeds manufacturer's limits.

Lean NOx Catalyst

Applicability: This control method can be used on any lean-burn engine, although development work has concentrated on diesel engines. This control method is still in the development stage and is not commercially available, but may be available in a few years.

Principle: A number of catalyst materials can be used in the formulation of lean NOx catalysts. The constituents are generally proprietary. NOx reductions are generally minimal unless a reducing agent (typically raw fuel) is injected upstream of the catalyst to increase catalyst performance to acceptable levels. Depending on the catalyst formulation, this method can reduce NOx, CO, and VOC simultaneously.

Typical Effectiveness: Claims for NOx control efficiencies have ranged from 25 to 50 percent. Steady state testing on a diesel-fueled engine yielded NOx reductions of 17 to 44 percent.
Limitations: Use of a reducing agent increases costs, complexity, and fuel consumption. The reducing agent injection system must be carefully designed to minimize excess injection rates. Otherwise, emissions of VOC and particulate matter can increase to unacceptable levels. Tests have shown that lean NOx catalysts produce significant amounts of nitrous oxide (N2O), and that this production increases with increasing NOx reduction efficiencies and reducing agent usage. This method is not commercially available, and is still in the development and demonstration stage.

Other Effects: None known.

Urea Injection

Applicability: This control method is applicable to all lean-burn engines and is also known as selective non-catalytic reduction. It has been used on several boilers to control NOx, but there have been no applications to internal combustion engines.

Principle: Urea injection is very similar to cyanuric acid injection, as both chemicals come in powder form, and both break down at similar temperatures to form compounds which react with nitric oxide. Differences are that a high temperature heating system is not required for urea injection. Instead, the urea is usually dissolved in water, and this solution is injected into the exhaust stream.

Typical Effectiveness: Unknown.

Limitations: The temperature window for urea is higher than the highest exhaust temperature of nearly all engines. Therefore, due to cost-effectiveness considerations, practical applications of urea injection are limited to engines in cogeneration applications. Specifically, these applications are limited to situations where supplemental firing is applied to the engine's exhaust to increase its temperature, and the exhaust heat is recovered and used.

Other Effects: Unknown

<u>Replacement</u>

Another method of reducing NOx is to replace the existing IC engine with an electric motor, or a new engine designed to emit lower NOx emissions. In some instances, the existing engine may be integral with a compressor or other gear, and replacement of the engine will require the replacement or modification of this other equipment as well.

Applicability: This control method is applicable to all engines.

Principle: Rather than applying controls to the existing engine, it is removed and replaced with either a new, low emissions engine or an electric motor.

Typical Effectiveness: New, low emissions engines can reduce NOx by a substantial amount over older, uncontrolled engines. Potential NOx reductions of over 60 percent can be realized by replacing existing SI engines with new certified low emission engines fueled by natural gas or propane.

Another approach is to replace an engine with an electric motor. An electric motor essentially eliminates NOx emissions associated with the removed engine, although there may be minor increases in power plant emissions to supply electricity to the electric motor.

Limitations: In remote locations or where electrical infrastructure is inadequate, the costs of electrical power transportation and conditioning may be excessive. Similarly, the cost of replacing an engine with a natural gas fired unit could be prohibitive if a natural gas pipeline is not in reasonably close proximity to the engine. In cases where the existing engine operates equipment integral to the engines (such as some engine/compressors that share a common crankshaft), both the engine and integral equipment would require replacement.