777 12th Street, Third Floor SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT Sacramento, CA 95814

BEST AVAILABLE CONTROL TECHNOLOGY DETERMINATION

DETERMINATION NO.:	122 & 123
DATE:	July 5, 2016
ENGINEER:	Jeffrey Quok

Category/General Equip Description:	Internal Combustion (I.C.) Engine
Equipment Specific Description:	I.C. Engine Spark – Standby, Gaseous-fueled and Propane/LPG
Equipment Size/Rating:	Engines < 500 BHP (BACT #122) Engines ≥ 500 BHP (BACT #123)
Previous BACT Det. No.:	No. 50

This BACT determination will update the following determinations:

#50 which was made on August 16, 2011 for I.C. Engine Spark - Standby, > 50 BHP

Additionally, this determination is being updated to include T-BACT for volatile hazardous air pollutants (VHAP) associated with gaseous fuel combustion.

BACT/T-BACT ANALYSIS

A. ACHIEVED IN PRACTICE (Rule 202, §205.1a):

The following control technologies are currently employed as BACT/T-BACT for gaseous-fueled and propane/LPG standby engines by the following agencies and air pollution control districts:

Note: Tables 3.2-1, 3.2-2, and 3.2-3 of AP-42 list benzene, formaldehyde, PAHs, naphthalene, acetaldehyde, acrolein, propylene, toluene, xylenes, ethyl benzene, and hexane as the primary drivers for health risks associated with natural gas combustion. These VHAPs/organic compounds are emitted as VOC and the same control technologies that control VOCs also control the listed VHAPs.

District/Agency	Best Available Control Technology (BACT)/Requirements
US EPA	See below

BACT
Source: EPA RACT/BACT/LAER Clearinghouse (See Attachment A)
RBLC ID: MD-0036 (VOC, PM10, & CO) & MI-0390 (NOx)

For standby natural gas (includes propane & LPG) units with a rating of ≥ 500 BHP	
VOC	0.6 g/bhp-hr (MD-0036)[A]
NOx	0.5 g/bhp-hr (MI-0390)[B]
SOx	N/A – No BACT determinations found in the ≥ 500 BHP range
PM10	0.0099 lb/MMBtu (MD-0036)
PM2.5	N/A – No BACT determinations found in the ≥ 500 BHP range
CO	1.5 g/bhp-hr (MD-0036)

(A) MD-0036 was a BACT Determination for a 1,085 BHP engine. This determination did not identify if the engine was lean or rich burn.
(B) MI-0390 was a BACT Determination for a 1,818 BHP engine. This determination did not identify if the engine was lean or rich burn.

For standby natural gas(includes propane & LPG) units with a rating of < 500 BHP	
VOC	N/A – No BACT determinations found in the < 500 BHP range
NOx	N/A – No BACT determinations found in the < 500 BHP range
SOx	N/A – No BACT determinations found in the < 500 BHP range
PM10	N/A – No BACT determinations found in the < 500 BHP range
PM2.5	N/A – No BACT determinations found in the < 500 BHP range
CO	N/A – No BACT determinations found in the < 500 BHP range

RBLC ID: N/A

T-BACT
There are no T-BACT standards published in the clearinghouse for this category.

RULE REQUIREMENTS:
40 CFR Part 60 Subpart JJJJ – Standards of Performance for Stationary Spark Ignition Internal Combustion Engines: This regulation applies to owners/operators of new stationary spark ignition engines that commenced construction after June 12, 2006. [40 CFR §60.4230(a)(4)]

40 CFR §60.4233(d) & §60.4233(e)
Owners and operators of stationary SI ICE with a maximum engine power greater than 19 KW (25 BHP) must comply with the emission standards of Table 1 to this subpart for their emergency stationary SI ICE (applies to both lean and rich burn engines).

40 CFR Subpart JJJJ Table 1: Emission Standards (g/kW-hr)					
Engine Type and Fuel	Maximum Engine Power	Manufacture Date	Emission Standards[A] g/bhp-hr (ppmvd at 15% O_2)		
			NOx	CO	VOC[C]
Emergency[D]	25<BHP<130	1/1/2009	10[B] (N/A)	387 (N/A)	N/A
	BHP≥130		2.0 (160)	4.0 (540)	1.0 (86)

<table>
<tr><th>District/Agency</th><th>Best Available Control Technology (BACT)/Requirements</th></tr>
<tr><td>US EPA</td><td>(A) Owners and operators of stationary non-certified SI engines may choose to comply with the emission standards in units of either g/bhp-hr or ppmvd at 15% O2
(B) The emission standards applicable to emergency engines between 25 BHP and 130 BHP are in terms of NOx + HC.
(C) For purposes of this subpart, when calculating emissions of VOC compounds, emissions of formaldehyde should not be included.
(D) Applies to both lean and rich burn emergency engines.</td></tr>
<tr><td>Air Resources Board (ARB)</td><td><u>BACT</u>
<u>Source: ARB BACT Clearinghouse (SCAQMD)</u> (See Attachment B)

<table>
<tr><th colspan="2">For standby spark ignition natural gas fired units(A)</th></tr>
<tr><td>VOC</td><td>1.5 g/bhp-hr, 3-way catalyst converter with air/fuel ratio controller</td></tr>
<tr><td>NOx</td><td>1.5 g/bhp-hr, 3-way catalyst converter with air/fuel ratio controller</td></tr>
<tr><td>SOx</td><td>N/A – No BACT determinations found</td></tr>
<tr><td>PM10</td><td>N/A – No BACT determinations found</td></tr>
<tr><td>PM2.5</td><td>N/A – No BACT determinations found</td></tr>
<tr><td>CO</td><td>2.0 g/bhp-hr, 3-way catalyst converter with air/fuel ratio controller</td></tr>
</table>
(A) This BACT determination was for a 1334 bhp engine. The determination doesn't specify if the engine is rich or lean burn.

<u>T-BACT</u>
There are no T-BACT standards published in the clearinghouse for this category.

<u>RULE REQUIREMENTS:</u>
None

<u>CARB RACT/BARCT Guidelines for Stationary Spark-Ignited Internal Combustion Engines</u> (11/2001)
This document presents the determination of reasonably available control technology (RACT) and best available retrofit control technology (BARCT) for controlling NOx, VOC, and CO from stationary, spark-ignited reciprocating internal combustion engines. On page IV-14 of the document, emergency standby engines are listed as exempt from the recommended emission limits. Therefore this guideline is not applicable to this BACT determination.</td></tr>
</table>

<table>
<tr><th>District/Agency</th><th>Best Available Control Technology (BACT)/Requirements</th></tr>
<tr><td>SMAQMD</td><td>
<u>BACT</u>
Source: SMAQMD BACT Clearinghouse, BACT Determination Number 50 (8/16/11)

<table>
<tr><th colspan="2">For standby spark ignition units with a rating of > 50 BHP(A)</th></tr>
<tr><td>VOC</td><td>50% Control Efficiency, 3-Way Catalyst with Air-to-Fuel Ratio Controller (0.29 g/bhp-hr for rich burn)(B)</td></tr>
<tr><td>NOx</td><td>85% Control Efficiency, 3-Way Catalyst with Air-to-Fuel Ratio Controller (1.56 g/bhp-hr for rich burn)(B)</td></tr>
<tr><td>SOx</td><td>Natural Gas or Propane Fuel</td></tr>
<tr><td>PM10</td><td>Natural Gas or Propane Fuel</td></tr>
<tr><td>PM2.5</td><td>No Standard</td></tr>
<tr><td>CO</td><td>85% Control Efficiency, 3-Way Catalyst with Air-to-Fuel Ratio Controller (2.56 g/hp-hr for rich burn)(B)</td></tr>
</table>
(A) The determination doesn't specify if the engine is rich or lean burn.
(B) Control efficiency conversion to g/bhp-hr is based on uncontrolled emission factors from AP-42, Table 3.2-3 (7/00), and engine brake-specific fuel consumption (BSFC) from SBCAPCD Piston IC Engine Technical Reference Document, Table 6 (11/1/02).

<u>T-BACT</u>
The current BACT determination does not address T-BACT.

<u>RULE REQUIREMENTS:</u>
Rule 412 – Stationary Internal Combustion Engines Located at Major Stationary Sources of NOx (Adopted 6/1/1995)
This rule applies to any stationary internal combustion engine rated at more than 50 BHP located at a major stationary source of NOx. Section 110 of this rule states that operation of stationary internal combustion engines used for emergency standby are exempt from the standards of this rule. Therefore, this rule is not applicable to this BACT determination.
</td></tr>
</table>

<table>
<tr><th>District/Agency</th><th>Best Available Control Technology (BACT)/Requirements</th></tr>
<tr><td>South Coast AQMD</td><td>
<u>BACT</u>
Source: SCAQMD BACT Guidelines for Non-Major Polluting Facilities, page 71-72 (10/3/08)
<table>
<tr><th colspan="6">BACT Guideline, I.C. Engine Spark Ignition, Stationary, Emergency – g/bhp-hr (A)</th></tr>
<tr><td>Maximum engine power</td><td>VOC</td><td>NOx</td><td>SOx</td><td>CO</td><td>PM</td></tr>
<tr><td>All</td><td>1.5 g/bhp-hr</td><td>1.5 g/bhp-hr</td><td>Use of clean fuels (B)</td><td>2.0 g/bhp-hr</td><td>Use of clean fuels (B)</td></tr>
</table>
(A) This BACT determination applies to all engine BHP size ratings.
(B) Clean fuel is defined as one that produces air emissions equivalent to or lower than natural gas for NOx, SOx, ROG, and fine particulate matter (PM10).

<u>T-BACT</u>
There are no T-BACT standards published in the clearinghouse for this category.

<u>RULE REQUIREMENTS:</u>
Reg IX, Rule 1110.2 – Emissions from Gaseous- and Liquid-Fueled Engines (Amended 12/4/15)

Emergency standby engines are exempt from this Rule.
</td></tr>
<tr><td>San Joaquin Valley Unified APCD</td><td>
<u>BACT</u>
Source: SJVUAPCD BACT
Guideline 3.1.5 – Emergency Gas-Fired IC Engine <132 BHP, Rich Burn (11/27/96)
Guideline 3.1.6 – Emergency Gas-Fired IC Engine ≥132 BHP, Rich Burn (6/20/95)
Guideline 3.1.8 – Emergency Gas-Fired IC Engine ≥250 BHP, Lean Burn (4/4/02)
<table>
<tr><th colspan="2">Emergency Gas-Fired IC engine <132 BHP, Rich Burn</th></tr>
<tr><td>VOC</td><td>1. Positive crankcase ventilation (PCV) (Achieved in Practice)
2. VOC Catalyst (3 way) (Technologically Feasible)</td></tr>
<tr><td>NOx</td><td>NOx Catalyst (3 way) (Technologically Feasible)</td></tr>
<tr><td>SOx</td><td>No Standard</td></tr>
<tr><td>PM10</td><td>Positive crankcase ventilation (PCV) (Achieved in Practice)</td></tr>
<tr><td>PM2.5</td><td>No Standard</td></tr>
<tr><td>CO</td><td>CO Catalyst (3 Way) (Technologically Feasible)</td></tr>
</table>
<table>
<tr><th colspan="2">Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn</th></tr>
<tr><td>VOC</td><td>1. Positive Crankcase Ventilation (PCV) (Achieved in Practice)
2. Natural gas, LPG, or propane as fuel (Achieved in Practice)
3. VOC Catalyst (Technologically Feasible)</td></tr>
<tr><td>NOx</td><td>1. Natural Gas, LPG, or propane as fuel (Achieved in Practice)
2. NOx Catalyst (Technologically Feasible)</td></tr>
<tr><td>SOx</td><td>Natural gas, LPG, or propane as fuel</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><th>District/Agency</th><th>Best Available Control Technology (BACT)/Requirements</th></tr>
<tr><td>San Joaquin Valley Unified APCD</td><td>
<table>
<tr><td>PM10</td><td>1. Positive Crankcase Ventilation (PCV) (Achieved in Practice)
2. Natural gas, LPG, or propane as fuel (Achieved in Practice)</td></tr>
<tr><td>PM2.5</td><td>No Standard</td></tr>
<tr><td>CO</td><td>1. Natural Gas, LPG, or propane as fuel (Achieved in Practice)
2. CO Catalyst (Technologically Feasible)</td></tr>
</table>
<table>
<tr><td colspan="2">Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn</td></tr>
<tr><td>VOC</td><td>1. ≤ 1.0 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) (Achieved in Practice)
2. 90% control efficiency, oxidation catalyst or equivalent control (technologically feasible)</td></tr>
<tr><td>NOx</td><td>≤ 1.0 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) (Achieved in Practice)</td></tr>
<tr><td>SOx</td><td>No Standard</td></tr>
<tr><td>PM10</td><td>Natural gas fuel</td></tr>
<tr><td>PM2.5</td><td>No Standard</td></tr>
<tr><td>CO</td><td>≤ 2.75 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) (Achieved in Practice)</td></tr>
</table>
T-BACT
There are no T-BACT standards published in the clearinghouse for this category.
RULE REQUIREMENTS:
Rule 4702 – INTERNAL COMBUSTION ENGINES (Amended 11/14/13)
Standby Engines are exempt from the emission limitations of this rule.
</td></tr>
<tr><td>San Diego APCD</td><td>
BACT
Source: NSR Requirements for BACT
The engine BACT determinations listed in the SDAPCD Clearinghouse do not apply to standby engines.
T-BACT
There are no T-BACT standards published in the clearinghouse for this category.
RULE REQUIREMENTS:
Regulation 4, Rule 69.4 – Stationary Reciprocating Internal Combustion Engines – Reasonably Available Control Technology (7/30/03)
This rule applies to stationary I.C. Engines ≥ 50 BHP located at a stationary source which emits or has a potential to emit 50 tons per year or more of NOx.
Standby Engines are exempt from the emission limitations of this rule.
Regulation 4, Rule 69.4.1 – Stationary Reciprocating Internal Combustion Engines – Best Available Retrofit Control Technology (11/15/00)
This rule applies to stationary I.C. Engines ≥ 50 BHP.
</td></tr>
</table>

District/Agency	Best Available Control Technology (BACT)/Requirements

San Diego APCD

New or replacement rich-burn engines using fossil derived gaseous fuel

Published Value		Conversion for Naturally Aspirated Engines (g/bhp-hr)[(A)]	Conversion for Turbocharged Engines (g/bhp-hr)[(B)]
VOC	250 ppmvd @ 15% O_2	1.53	1.47
NOx	25 ppmvd @ 15% O_2 OR 96% weight reduction	0.44	0.42
SOx	No standard	-	-
PM10	No standard	-	-
PM2.5	No standard	-	-
CO	4,500 ppmvd @ 15% O_2	48.4	46.4

(A) Based on *Santa Barbara County APCD Piston IC Engine Technical Reference Document* (11/1/02) emission factor conversions, Section II(B)(B7)(e)(vi).
(B) Based on *Santa Barbara County APCD Piston IC Engine Technical Reference Document* (11/1/02) emission factor conversions, Section II(B)(B7)(e)(vii).

New or replacement lean-burn engines using gaseous fuel

Published Value		Conversion for Naturally Aspirated Engines (g/bhp-hr)[(A)]	Conversion for Turbocharged Engines (g/bhp-hr)[(B)]
VOC	250 ppmvd @ 15% O_2	1.53	1.47
NOx	65 ppmvd @ 15% O_2 OR 90% weight reduction	1.14	1.10
SOx	No standard	-	-
PM10	No standard	-	-
PM2.5	No standard	-	-
CO	4,500 ppmvd @ 15% O_2	48.4	46.4

(A) Based on *Santa Barbara County APCD Piston IC Engine Technical Reference Document* (11/1/02) emission factor conversions, Section II(B)(B7)(e)(vi).
(B) Based on *Santa Barbara County APCD Piston IC Engine Technical Reference Document* (11/1/02) emission factor conversions, Section II(B)(B7)(e)(vii).

District/Agency	Best Available Control Technology (BACT)/Requirements

Bay Area AQMD

BACT
Source: BAAQMD BACT
Guideline 96.3.4 (5/7/03)

IC Engine - Spark Ignition, Natural Gas Fired Emergency Engine ≥ 50 BHP	
VOC	1. 1.0 g/bhp-hr (Achieved in Practice) 2. Lean burn technology or equivalent (Achieved in Practice)
NOx	1. 1.0 g/bhp-hr (Achieved in Practice) 2. Lean burn technology or equivalent (Achieved in Practice)
SOx	1. Natural Gas Fuel (Achieved in Practice)
PM10	1. Natural Gas Fuel (Achieved in Practice)
PM2.5	No Standard

<table>
<tr><td>Bay Area AQMD</td><td>
<table><tr><td>CO</td><td>1. 2.75 g/bhp-hr (Achieved in Practice)
2. Lean burn technology or equivalent (Achieved in Practice)</td></tr></table>

<u>T-BACT</u>
There are no T-BACT standards published in the clearinghouse for this category.

<u>RULE REQUIREMENTS:</u>
Reg 9, Rule 8 – Nitrogen Oxides and Carbon Monoxide from Stationary Internal Combustion Engines (7/25/07)

Standby Engines are exempt from the emission limitations of this rule.</td></tr>
</table>

The following control technologies have been identified and are ranked based on stringency:

<table>
<tr><th colspan="2">SUMMARY OF ACHIEVED IN PRACTICE CONTROL TECHNOLOGIES</th></tr>
<tr><td>VOC</td><td><u>For Spark Ignition, Emergency Standby Engines ≥ 50 BHP</u>
1. 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller [SMAQMD]
(0.29 g/bhp-hr for rich burn engines)
2. 1.0 g/bhp-hr [BAAQMD]
3. 1.5 g/bhp-hr [SCAQMD]
4. Lean burn technology or equivalent [BAAQMD]

<u>For Spark Ignition, Emergency Standby Engines ≥ 500 BHP</u>
1. 0.6 g/bhp-hr[(A)] [EPA, MD-0036]

<u>For rich-burn engines ≥ 50 BHP using fossil derived gaseous fuel or gasoline</u>
1. 250 ppmvd @ 15% O_2 [SDAPCD]
(1.53 g/bhp for naturally aspirated engines)
(1.47 g/bhp for turbocharged engines)
<u>For lean-burn engines ≥ 50 BHP using gaseous fuel</u>
1. 250 ppmvd @ 15% O_2 [SDAPCD]
(1.53 g/bhp for naturally aspirated engines)
(1.47 g/bhp for turbocharged engines)

<u>For Emergency Gas-Fired IC engines <132 BHP, Rich Burn</u>
1. Positive crankcase ventilation [SJVUAPCD]
<u>For Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn</u>
1. Positive crankcase ventilation [SJVUAPCD]
2. Natural gas, LPG, or propane as fuel [SJVUAPCD]
<u>For Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn</u>
1. ≤ 1.0 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) [SJVUAPCD]</td></tr>
<tr><td>NOx</td><td><u>For Spark Ignition, Emergency Standby Engines ≥ 50 BHP</u>
1. 1.0 g/bhp-hr [BAAQMD]
2. 1.5 g/bhp-hr [SCAQMD]
3. 85% control efficiency, 3-way catalyst with air-to-fuel ratio controller [SMAQMD]
(1.56 g/bhp-hr for rich burn engines)
4. Lean burn technology or equivalent [BAAQMD]

<u>For Spark Ignition, Emergency Standby Engines ≥ 500 BHP</u>
1. 0.5 g/bhp-hr[(B)] [EPA, MI-0390]</td></tr>
</table>

NOx	For rich-burn engines ≥ 50 BHP using fossil derived gaseous fuel or gasoline 1. 25 ppmvd @ 15% O_2 OR 96% NOx weight reduction [SDAPCD] (0.44 g/bhp-hr for naturally aspirated engines) (0.42 g/bhp-hr for turbocharged engines) For lean-burn engines ≥ 50 BHP using gaseous fuel 1. 65 ppmvd @ 15% O_2 OR 90% NOx weight reduction [SDAPCD] (1.14 g/bhp-hr for naturally aspirated engines) (1.10 g/bhp-hr for turbocharged engines) For Emergency Gas-Fired IC engines <132 BHP, Rich Burn 1. No achieved in practice standard [SJVUAPCD] For Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn 1. Natural gas, LPG, or propane as fuel [SJVUAPCD] For Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn 1. ≤ 1.0 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) [SJVUAPCD]
SOx	For Spark Ignition, Emergency Standby Engines ≥ 50 BHP 1. Natural gas or propane fuel [SMAQMD] 2. Natural gas fuel [BAAQMD] 3. Use of clean fuels[C] [SCAQMD] For Emergency Gas-Fired IC engines <132 BHP, Rich Burn 1. No standard [SJVUAPCD] For Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn 1. Natural gas, LPG, or propane as fuel [SJVUAPCD] For Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn 1. No standard [SJVUAPCD]
PM10	For Spark Ignition, Emergency Standby Engines ≥ 50 BHP 1. Natural gas or propane fuel [SMAQMD] 2. Natural gas fuel [BAAQMD] 3. Use of clean fuels[C] [SCAQMD] For Spark Ignition, Emergency Standby Engines ≥ 500 BHP 1. 0.0099 lb/MMBtu [EPA, MD-0036] For Emergency Gas-Fired IC engines <132 BHP, Rich Burn 1. Positive crankcase ventilation [SJVUAPCD] For Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn 1. Positive crankcase ventilation [SJVUAPCD] 2. Natural gas, LPG, or propane as fuel [SJVUAPCD] For Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn 1. Natural gas fuel [SJVUAPCD]
PM2.5	1. No Standard [SMAQMD, SCAQMD, SJVUAPCD, SDAPCD, BAAQMD]
CO	For Spark Ignition, Emergency Standby Engines ≥ 50 BHP 1. 2.0 g/bhp-hr [SCAQMD] 2. 85% control efficiency, 3-way catalyst with air-to-fuel ratio controller [SMAQMD] (2.56 g/bhp-hr for rich burn engines) 3. 2.75 g/bhp-hr [BAAQMD] 4. Lean burn technology or equivalent [BAAQMD]

CO	For Spark Ignition, Emergency Standby Engines ≥ 500 BHP 1. 1.5 g/bhp-hr [EPA, MD-0036] For rich-burn engines ≥ 50 BHP using fossil derived gaseous fuel or gasoline 1. 4,500 ppmvd @ 15% O_2 [SDAPCD] (48.4 g/bhp-hr for naturally aspirated engines) (46.4 g/bhp-hr for turbocharged engines) For lean-burn engines ≥ 50 BHP using gaseous fuel 1. 4,500 ppmvd @ 15% O_2 [SDAPCD] (48.4 g/bhp-hr for naturally aspirated engines) (46.4 g/bhp-hr for turbocharged engines) For Emergency Gas-Fired IC engines <132 BHP, Rich Burn 1. No achieved in practice standard [SJVUAPCD] For Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn 1. Natural gas, LPG, or propane as fuel [SJVUAPCD] For Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn 1. ≤ 2.75 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) [SJVUAPCD]
VHAP[D] (T-BACT)	For Spark Ignition, Emergency Standby Engines ≥ 50 BHP 1. 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller [SMAQMD] (0.29 g/bhp-hr for rich burn engines) 2. 1.0 g/bhp-hr [BAAQMD] 3. 1.5 g/bhp-hr [SCAQMD] 4. Lean burn technology or equivalent [BAAQMD] For Spark Ignition, Emergency Standby Engines ≥ 500 BHP 1. 0.6 g/bhp-hr[A] [EPA, MD-0036] For rich-burn engines ≥ 50 BHP using fossil derived gaseous fuel or gasoline 1. 250 ppmvd @ 15% O_2 [SDAPCD & ARB] (1.53 g/bhp for naturally aspirated engines) (1.47 g/bhp for turbocharged engines) For lean-burn engines ≥ 50 BHP using gaseous fuel 1. 250 ppmvd @ 15% O_2 [SDAPCD & ARB] (1.53 g/bhp for naturally aspirated engines) (1.47 g/bhp for turbocharged engines) For Emergency Gas-Fired IC engines <132 BHP, Rich Burn 1. Positive crankcase ventilation [SJVUAPCD] For Emergency Gas-Fired IC engine ≥132 BHP, Rich Burn 1. Positive crankcase ventilation [SJVUAPCD] 2. Natural gas, LPG, or propane as fuel [SJVUAPCD] For Emergency Gas-Fired IC engine ≥250 BHP, Lean Burn 1. ≤ 1.0 g/bhp-hr (Lean burn natural gas fired engine, or equivalent emissions) [SJVUAPCD]

(A) MD-0036 was a BACT Determination for a 1,085 BHP engine. This determination did not identify if the engine was lean or rich burn.

(B) MI-0390 was a BACT Determination for a 1,818 BHP engine. This determination did not identify if the engine was lean or rich burn.

(C) Clean fuels is defined as one that produces air emissions equivalent to or lower than natural gas for NOx, SOx, ROG, and fine particulate matter (PM10).

(D) A full list of the volatile hazardous air pollutants (VHAP) from natural gas combustion can be found in AP-42, Section 3.2 Natural Gas-fired Reciprocating Engines, Tables 3.2-1, 3.2-2, and 3.2-3.

The following control technologies have been identified as the most stringent, achieved in practice control technologies:

BEST CONTROL TECHNOLOGIES ACHIEVED		
Pollutant	**Standard**	**Source**
VOC	**<u>For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas)</u>**	
	<u>Lean Burn</u> 1.0 g/bhp-hr	BAAQMD
	<u>Rich Burn</u> 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller (0.29 g/bhp-hr for rich burn engines)[A]	SMAQMD
	<u>For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas)</u>	
	<u>Lean Burn</u> 0.6 g/bhp-hr	EPA, MD-0036
	<u>Rich Burn</u> 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller (0.29 g/bhp-hr for rich burn engines)[A]	SMAQMD
NOx	**<u>For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas and rich-burn)</u>**	
	<u>Lean Burn</u> 1.0 g/bhp-hr	BAAQMD
	<u>Rich Burn</u> 25 ppmvd @ 15% O_2 OR 96% weight reduction (0.44 g/bhp-hr for naturally aspirated engines) (0.42 g/bhp-hr for turbocharged engines)	SDAPCD (Rule 69.4.1)
	<u>For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas and rich-burn)</u>	
	<u>Lean Burn</u> 0.5 g/bhp-hr	EPA, MI-0390
	<u>Rich Burn</u> 25 ppmvd @ 15% O_2 OR 96% weight reduction (0.44 g/bhp-hr for naturally aspirated engines) (0.42 g/bhp-hr for turbocharged engines)	SDAPCD (Rule 69.4.1)

BEST CONTROL TECHNOLOGIES ACHIEVED		
Pollutant	**Standard**	**Source**
SOx	**For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas)** Natural gas or equivalent fuel **For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas)** Natural gas or equivalent fuel	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD
PM10	**For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas)** Natural gas or equivalent fuel **For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas)** 0.0099 lb/MMBtu	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD EPA (MD-0036)
PM2.5[(A)]	**For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas)** Natural gas or equivalent fuel **For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas)** 0.0099 lb/MMBtu	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD EPA (MD-0036)
CO	**For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas)** 2.0 g/bhp-hr **For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas)** 1.5 g/bhp-hr	SCAQMD EPA (MD-0036)
VHAP	**For gaseous or propane/LPG fired emergency IC Engines < 500 BHP (excluding biogas)** Lean Burn 1.0 g/bhp-hr Rich Burn 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller (0.29 g/bhp-hr for rich burn engines)[(A)] **For gaseous or propane/LPG fired emergency IC Engines ≥ 500 BHP (excluding biogas)** Lean Burn 0.6 g/bhp-hr Rich Burn 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller (0.29 g/bhp-hr for rich burn engines)[(A)]	BAAQMD SMAQMD EPA, MD-0036 SMAQMD

(A) All PM is expected to be less than 1.0 micrometer in diameter and therefore PM10 BACT is equivalent to PM2.5 BACT.

B. TECHNOLOGICALLY FEASIBLE AND COST EFFECTIVE (Rule 202, §205.1.b.):

Technologically Feasible Alternatives:

Any alternative basic equipment, fuel, process, emission control device or technique, singly or in combination, determined to be technologically feasible by the Air Pollution Control Officer.

SJVUAPCD's BACT determination lists 3-way catalysts for rich burn emergency gas-fired engines as technologically feasible. However this BACT determination was last updated in 1996, and other districts have determined that 3-way catalysts are now achieved in practice. SMAQMD's BACT determination lists 3-way catalysts as achieved in practice for standby spark ignited engines.

During the most recent rulemaking for updates to the Airborne Toxic Control Measure for Stationary Compression Ignition Engines (Title 17, Cal. Code. Regs., §93115 to §93115.15), ARB conducted a cost effectiveness analysis to determine if selective catalytic reduction (SCR) was technologically feasible and cost effective for emergency use applications. (Initial Statement of Reasons for Proposed Rulemaking: Proposed Amendments to the Airborne Toxic Control Measure for Stationary Compression Ignition Engines, Appendix B, September 2010). Although the analysis was for stationary compression ignition engines, the listed SCR challenges due to the operational nature of emergency standby engines is also applicable for stationary spark ignition engines.

The analysis concluded that SCR may be technologically feasible, but had some additional challenges. Because standby engines routinely operate only for scheduled maintenance and testing, the engines do not operate more than 15-30 minutes, and do operate at no or low load. Because of this the exhaust would not likely reach the temperature (260 °C to 540 °C) required for the catalyst to operate. To circumvent this problem, the engine would need to be operated with higher loads and in many cases for longer periods of time. This could be a challenge for most emergency standby applications as most businesses do not have load banks in house and would have to create a larger load on the engine to get the catalyst up to operational temperature.
Urea handling and maintenance is also an important consideration. Urea crystallization in the lines can cause damage to the SCR system and to the engine itself. Crystallization in the lines is more likely in emergency standby engines due to their periodic and low hours of usage. Urea also has a shelf life of approximately two years. This could increase the cost of operating a SCR for emergency standby engines since the low number of annual hours of operation experienced by most emergency standby engines could lead to urea expiration. The urea would then have to be drained and replaced, creating an extra maintenance step and an increased cost to the end user.

ARB staff determined that while, SCR systems may be technically feasible, there are significant operational hurdles to overcome before routine use of SCR on emergency standby engines is practical. This is because the majority of operating hours for emergency standby engines occur during short 15 to 30 minute maintenance and testing checks are at low engine loads. In most cases, the temperature needed for the SCR catalyst to function will not be reached during this operation and the SCR will not provide the expected NOx reductions.

The table below shows the technologically feasible alternatives identified as capable of reducing emissions beyond the levels determined to be "Achieved in Practice" as per Rule 202, §205.1.a.

VOC	No other technologically feasible option identified
NOx	Selective Catalytic Reduction
SOx	No other technologically feasible option identified
PM10	No other technologically feasible option identified
PM2.5	No other technologically feasible option identified
CO	No other technologically feasible option identified

All identified control technologies are considered achieved in practice.

Cost Effective Determination:

After identifying the technologically feasible control options, a cost analysis is performed to take into consideration economic impacts for all technologically feasible controls identified.

Maximum Cost per Ton of Air Pollutants Controlled

1. A control technology is considered to be cost-effective if the cost of controlling one ton of that air pollutant is less than the limits specified below (except coating operations):

Pollutant	Maximum Cost ($/ton)
ROG	17,500
NO_X	24,500
PM_{10}	11,400
SO_X	18,300
CO	TBD if BACT triggered

Cost Effectiveness Analysis Summary

SCR:

As shown in Attachment C, the cost effectiveness for the add on SCR system to control NOx to a 96% weight reduction was calculated to be **$162,913.75/ton** for a 499 bhp engine and **$129,580.57/ton** for a 1000 bhp engine (see attached Engine Cost Effectiveness Analysis). The following basic parameters were used in the analysis.

499 BHP Engine

NOx Control Level = 0.02356 lb/MMBtu (96% weight reduction)

NOx Baseline Level = 0.589 lb/MMBtu (160 ppmv @ 15% O2 per Subpart JJJJ)

Engine Rating = 499 BHP (4.8 MMBtu/hr)

Equipment Life = 20 years

Direct Cost = $139,848.01

Direct Annual Cost = $3,449.03 per year

Indirect Annual Cost = $18,659.28 per year

Total Annual Cost = $22,108.31 per year

NOx Removed = 0.14 tons per year

Cost of NOx Removal = $162,913.75 per ton reduced

1,000 BHP Engine

NOx Control Level = 0.02356 lb/MMBtu (96% weight reduction)

NOx Baseline Level = 0.589 lb/MMBtu (160 ppmv @ 15% O2 per Subpart JJJJ)

Engine Rating = 1,000 BHP (4.8 MMBtu/hr)

Equipment Life = 20 years

Direct Cost = $220,942.20

Direct Annual Cost = $5,657.54 per year

Indirect Annual Cost = $29,512.08 per year

Total Annual Cost = $35,169 .62 per year

NOx Removed = 0.27 tons per year

Cost of NOx Removal = $129,580.57 per ton reduced

Therefore, the add-on SCR system is considered not cost effective for either engine size and is eliminated.

C. SELECTION OF BACT/T-BACT:

Based on the above analysis, BACT for VOC, NOx, SOx, PM10, and CO will remain at what is currently achieved in practice and BACT for PM2.5 will be set to be the same as for PM10.

Volatile hazardous air pollutants (VHAP) are the primary driver for health risks associated with gaseous fueled engines. VHAPs are emitted as VOC, and the same control technologies that control VOC also control VHAPs. Therefore, the BACT for VOC and T-BACT for VHAPs are the same.

Table 1: BACT FOR SPARK IGNITED I.C. ENGINES, STANDBY, GASEOUS-FUELED (EXCLUDING BIOGAS) <500 BHP		
Pollutant	**Standard**	**Source**
VOC	Lean Burn 1.0 g/bhp-hr Rich Burn 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller (0.29 g/bhp-hr for rich burn engines)[(A)]	BAAQMD SMAQMD
NOx	Lean-Burn: 1.0 g/bhp-hr Rich Burn: 25 ppmvd @ 15% O_2 OR 96% weight reduction (0.44 g/bhp-hr for naturally aspirated engines) (0.42 g/bhp-hr for turbocharged engines)	BAAQMD SDAPCD (Rule 69.4.1) & ARB
SOx	Natural gas or equivalent fuel	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD
PM10	Natural gas or equivalent fuel	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD
PM2.5	Natural gas or equivalent fuel	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD
CO	2.0 g/bhp-hr	SCAQMD

(A) Control efficiency conversion to g/bhp-hr is based on uncontrolled emission factors from AP-42, Table 3.2-3 (7/00), and engine brake-specific fuel consumption (BSFC) from SBC*APCD Piston IC Engine Technical Reference Document*, Table 6 (11/1/02).

Table 2: T-BACT FOR SPARK IGNITED I.C. ENGINES, STANDBY, GASEOUS-FUELED (EXCLUDING BIOGAS) <500 BHP		
Pollutant	**Standard**	**Source**
VHAP[(A)]	1.0 g/bhp-hr	BAAQMD

(A) A full list of the volatile hazardous air pollutants (VHAP) from natural gas combustion can be found in AP-42, Section 3.2 Natural Gas-fired Reciprocating Engines, Tables 3.2-1, 3.2-2, and 3.2-3.

Table 3: BACT FOR SPARK IGNITED I.C. ENGINES, STANDBY, GASEOUS-FUELED (EXCLUDING BIOGAS) ≥500 BHP		
Pollutant	**Standard**	**Source**
VOC	Lean Burn 0.6 g/bhp-hr Rich Burn 50% Control efficiency, 3-way catalyst with air-to-fuel ratio controller (0.29 g/bhp-hr for rich burn engines)[(A)]	EPA, MD-0036 SMAQMD
NOx	Lean-Burn: 0.5 g/bhp-hr Rich-Burn: 25 ppmvd @ 15% O_2 OR 96% weight reduction (0.44 g/bhp-hr for naturally aspirated engines) (0.42 g/bhp-hr for turbocharged engines)	EPA (MI-0390) SDAPCD (Rule 69.4.1) & ARB
SOx	Natural gas or equivalent fuel	SMAQMD, SCAQMD, SJVUAPCD, and BAAQMD
PM10	0.0099 lb/MMBtu	EPA (MD-0036)
PM2.5	0.0099 lb/MMBtu	EPA (MD-0036)
CO	1.5 g/p-hr	EPA (MD-0036)

Table 4: T-BACT FOR SPARK IGNITED I.C. ENGINES, STANDBY, GASEOUS-FUELED ≥500 BHP		
Pollutant	**Standard**	**Source**
VHAP[(A)]	0.6 g/bhp-hr	EPA (MD-0036)

(A) A full list of the volatile hazardous air pollutants (VHAP) from natural gas combustion can be found in AP-42, Section 3.2 Natural Gas-fired Reciprocating Engines, Tables 3.2-1, 3.2-2, and 3.2-3.

REVIEWED BY: ______________________ **DATE:** ______________________

APPROVED BY: ______________________ **DATE:** ______________________

Attachment A

Review of BACT Determinations published by EPA

List of BACT determinations published in EPA's RACT/BACT/LAER Clearinghouse (RBLC) for Natural Gas (includes propane & liquefied petroleum gas) I.C. Engines ≤ 500 BHP & > 500 BHP

RBLC#	Permit Date[A]	Process Code [B], [C]	Engine Burn Type	Rating	Pollutant	Standard	Case-By-Case Basis
LA-0256	12/06/2011	17.130	Not Listed	1,818 BHP	PM10	0.01 lb/hr	BACT-PSD, Operating Permit[D]
LA-0256	12/06/2011	17.130	Not Listed	1,818 BHP	PM2.5	0.01 lb/hr	BACT-PSD, Operating Permit[D]
LA-0256	12/06/2011	17.130	Not Listed	1,818 BHP	PM (TSP)	0.01 lb/hr	BACT-PSD, Operating Permit[D]
LA-0257	12/06/2011	17.130	Not Listed	2,012 BHP	CO	4.0 lb/bhp-r	BACT-PSD[E]
LA-0257	12/06/2011	17.130	Not Listed	2,012 BHP	NOx	2.0 g/bhp-hr	BACT-PSD[E]
LA-0257	12/06/2011	17.130	Not Listed	2,012 BHP	PM (TPM)	N/A	BACT-PSD
LA-0257	12/06/2011	17.130	Not Listed	2,012 BHP	VOC	1.0 g/bhp-r	BACT-PSD[E]
CA-1192	6/21/2011	17.130	Not Listed	860 BHP (550.0 KW)	CO	N/A	BACT-PSD[F]
CA-1192	6/21/2011	17.130	Not Listed	860 BHP (550.0 KW)	NOx	N/A	BACT-PSD[F]
CA-1192	6/21/2011	17.130	Not Listed	860 BHP (550.0 KW)	PM (TPM)	N/A	BACT-PSD[F]
CA-1192	6/21/2011	17.130	Not Listed	860 BHP (550.0 KW)	PM (PM10)	N/A	BACT-PSD[F]
MI-0390	10/14/2010	17.130	Not Listed	1818 BHP	NOx	0.5 g/bhp-hr	BACT-PSD, NSPS, NESHAP
LA-0232	6/24/2008	17.130	Not Listed	838 BHP	NOx	4.8 lb/hr	BACT-PSD, Operating Permit
LA-0232	6/24/2008	17.130	Not Listed	838 BHP	VOC	1.39 lb/hr	BACT-PSD, Operating Permit
MD-0036	3/10/2006	17.130	Not Listed	1,085 BHP (770KW)	CO	1.5 g/bhp-hr	BACT-PSD
MD-0036	3/10/2006	17.130	Not Listed	1,085 BHP (770KW)	NOx	2.0 g/bhp-hr	BACT-PSD
MD-0036	3/10/2006	17.130	Not Listed	1,085 BHP (770KW)	PM (FPM10)	0.0099 lb/MMBtu	BACT-PSD[G]

RBLC#	Permit Date[A]	Process Code [B], [C]	Engine Burn Type	Rating	Pollutant	Standard	Case-By-Case Basis
MD-0036	3/10/2006	17.130	Not Listed	1,085 BHP (770 KW)	VOC	0.6 g/hp-hr	LAER
IA-0102	2/1/2012	17.230	Not Listed	225 KW	VOC	0.66 lb/hr	BACT-PSD[H]
WA-0316	6/14/2006	17.230	Not Listed	450 KW	NOx	82 g/hr	BACT-PSD[I]
NV-0048	5/16/2006	17.230	Not Listed	771 BHP (575 KW)	CO	2.0 g/bhp-hr	Other Case-by-Case, SIP, Operating Permit
NV-0048	5/16/2006	17.230	Not Listed	771 BHP (575 KW)	NOx	21.5 g/bhp-hr	Other Case-by-Case, SIP, Operating Permit
NV-0048	5/16/2006	17.230	Not Listed	771 BHP (575 KW)	PM (FPM10)	0.0410 g/bhp-hr	Other Case-by-Case, SIP, Operating Permit
NV-0048	5/16/2006	17.230	Not Listed	771 BHP (575 KW)	SOx	0.0052 g/bhp-hr	Other Case-by-Case, SIP, Operating Permit
NV-0048	5/16/2006	17.230	Not Listed	771 BHP (575 KW)	VOC	0.23 g/bhp-hr	Other Case-by-Case, SIP, Operating Permit

(A) Due to the large number of entries only determinations made (based on Permit Date) entered since 01/01/2005 are included in the above table.

(B) Process Code 17.130 includes Large Internal Combustion Engines (> 500 BHP) fueled using natural gas (includes propane and liquid petroleum gas).

(C) Process Code 17.230 includes Small Internal Combustion Engines (≤ 500 BHP) fueled using natural gas (includes propane and liquid petroleum gas).

(D) BACT was determined to be use of natural gas fuel and good combustion practices. Emission limits for PM10, PM2.5, and PM (TSP) were determined to be <0.01 lb/hr and was established by Louisiana Department of Environmental Quality Permit PSD-LA-754 for Westlake Vinyls Company, LP.

(E) Emission Limits are based on 40 CFR Part 60 Subpart JJJJ – Standards of Performance for Stationary Spark Ignition Internal Combustion Engines. (NSPS, Subpart IIII)

(F) The Ninth Circuit Court of Appeals issued a decision on 8/12/2014 that vacated the permit decision and remanded it to EPA. Therefore, this BACT determination has not yet been achieved in practice. Source: EPA Region IX, Avenal Energy Product.

(G) Emission limit for PM is based on AP-42 PM condensable emission factor for natural gas-fired reciprocating engines.

(H) BACT was determined to be good combustion practices. Emission limit for VOC was determined to be 0.66 lb/hr and was established by Iowa Department of Natural Resources; Air Quality Bureau, Title V Permit 03-TV-025R2 (page 133) for Alcoa, Inc.

(I) BACT was determined to be non-selective catalytic reduction. Emission limit for NOx was determined to be ≤82 g/hr and was established by Washington State Department of Ecology; Air Quality Program, Permit PSD-01-09 Amendment 6 for Northwest Pipeline Corporation

= Not enough information provided to determine if engine is used for standby purposes.

= Not applicable to this determination. Equipment has not yet been achieved in practice or is for a specific purpose outside of the scope of this determination.

= Selected as the most stringent BACT determination achieved in practice.

Attachment B

Review of BACT Determinations published by ARB

List of BACT determinations published in ARB's BACT Clearinghouse for ICE: Spark Ignition, Natural Gas & ICE: Emergency, Spark Ignition:

Capacity	**Source**	**Date**	**Engine Burn Type**	**NOx**	**VOC**	**CO**	**PM10**	**SOx**
528 BHP	MBUAPCD	10/13/2005	Rich Burn	0.07 g/bhp-hr(A)	N/A	N/A	N/A	N/A
93 BHP	SCAQMD	10/06/2000	Rich Burn	0.15 g/bhp-hr(B)	0.15 g/bhp-hr	0.6 g/bhp-hr	N/A	N/A
1334 BHP	SCAQMD	12/7/1999	Rich Burn	1.5 g/bhp-hr(B)	1.5 g/bhp-hr(B)	2.0 g/bhp-hr(B)	N/A	N/A
750 BHP	SCAQMD(C)	N/A	Rich Burn	0.15 g/bhp-hr(B)	0.15 g/bhp-hr(B)	0.6 g/bhp-hr(B)	N/A	N/A
310 BHP	SMAQMD(D)	10/22/2004	Rich Burn	2.13 g/bhp-hr(A)	0.0449(A)	1.6 g/bhp-hr(A)	0.152 g/bhp-hr	0.002 g/bhp-hr

(A) Add-on control – 3-way catalytic converter,
(B) Add-on control – 3-way catalytic converter and air/fuel ratio controller
(C) SCAQMD is reconsidering the BACT requirement for future applications of this type. Source: SCAQMD Application No. 359876
(D) Emission limits are based on emissions for the specific engine and is not a standard for gaseous emergency standby engines

[light blue] = Not enough information to determine if engine is for standby purposes

[yellow] = Selected as the most stringent BACT determination achieved in practice.

Attachment C

Cost Effectiveness Calculations

ENGINE SCR COST EFFECTIVENESS CALCULATION

EPA AIR POLLUTION CONTROL COST MANUAL, Sixth Edition, EPA/452/B-02-001, January 2002

Section 4.2 - NOx Post-Combustion, Chapter 2 - Selective Catalytic Reduction

Cost Effectiveness =	**$ 162,913.75**	**$/ton**

Equipment

Engine rating (499 bhp)	4.8	mmBTU/hr
Engine Operating hours	100	hours
Engine capacity factor	1	
SCR Operating Days	365	days
Total Capacity Factor	1	
Baseline Nox (160 PPM @ 15% O2 per Subpart JJJJ)	0.589	lb/mmBTU
SCR Nox (96% weight reduction)	0.02356	lb/mmBTU
Ammonia Slip	10	ppm
Ammonia Stochiometric Ratio	1.05	
Stored Ammonia Conc	29	%
Ammonia Storage days	90	days
Sulfur Content	0.005	%
Pressure drop for SCR Ductwork	3	inches W.G.
Pressure drop for each Catalyst Layer	1	inches W.G.
Temperature at SCR Inlet	650	degrees F
Cost year	1998	
Equipment Life	20	years
Annual interest Rate	7	%
Catalyst cost, Initial	240	$/ft2
Catalyst cost, replacement	290	$/ft2
Electrical Power cost	0.05	$/KWh
Ammonia Cost	0.101	$/lb
Catalyst Life	24000	hr
Catalyst Layers	2 full, 1 empty	

Engine Calculations

Q_B	4.8	mmBTU/hr

$q_{flue\ gas}$	1710.371508	acfm
N_{NOx}	0.96	

SCR Reactor Calculations

$Vol_{Catalyst}$	14.47935815	ft3
$A_{Catalyst}$	1.781636988	ft2
A_{SCR}	2.048882536	ft2
l=w=	1.431391818	ft
n_{layer}	3	
h_{layer}	3.708998943	
n_{total}	4	
h_{SCR}	51.83599577	ft

Reagent Calculations

$m_{reagent}$	1.098773675	lb/hr
m_{sol}	3.788874742	lb/hr
q_{sol}	0.50615307	gph
Tank Volume	1093.290632	gal

Cost Estimation

Direct Costs

DC	$	139,848.01	

Indirect Costs

General Facilities	$	6,992.40	
Engineering and home office fees	$	13,984.80	
Process Contingency	$	6,992.40	
Total Indirect Installation Costs	$	27,969.60	
Project Contingency	$	25,172.64	
Total Plant Cost	$	192,990.25	
Preproduction Cost	$	3,859.80	
Inventory Capital	$	826.58	
Total Capital Investment	$	197,676.63	

Direct Annual Costs

Maintenance Costs	$	2,965.15	per yr
Power		2.04898176	KW
Annual Electricity	$	10.24	per yr

Reagent Solution Cost	$	38.27	per yr

Catalyst Replacement

FWF		0.311051666	
Annual Catalyst Replacement	$	435.37	per yr
Total Variable Direct Cost	$	483.88	per yr
Total Direct Annual Cost	$	3,449.03	per yr
CRF		0.094392926	
Indirect Annual Cost	$	18,659.28	per yr
Total annual Cost	$	22,108.31	per yr
Nox Removed		0.14	tons
Cost of Nox removal	$	162,913.75	per ton

ENGINE SCR COST EFFECTIVENESS CALCULATION

EPA AIR POLLUTION CONTROL COST MANUAL, Sixth Edition, EPA/452/B-02-001, January 2002

Section 4.2 - NOx Post-Combustion, Chapter 2 - Selective Catalytic Reduction

Cost Effectiveness = $ 129,580.57 $/ton

Equipment

Engine rating (1000 bhp)	9.6	mmBTU/hr
Engine Operating hours	100	hours
Engine capacity factor	1	
SCR Operating Days	365	days
Total Capacity Factor	1	
Baseline Nox (160 PPM @ 15% O2 per Subpart JJJJ)	0.589	lb/mmBTU
SCR Nox (96% weight reduction)	0.02356	lb/mmBTU
Ammonia Slip	10	ppm
Ammonia Stochiometric Ratio	1.05	
Stored Ammonia Conc	29	%
Ammonia Storage days	90	days
Sulfur Content	0.005	%
Pressure drop for SCR Ductwork	3	inches W.G.
Pressure drop for each Catalyst Layer	1	inches W.G.
Temperature at SCR Inlet	650	degrees F
Cost year	1998	
Equipment Life	20	years
Annual interest Rate	7	%
Catalyst cost, Initial	240	$/ft2
Catalyst cost, replacement	290	$/ft2
Electrical Power cost	0.05	$/KWh
Ammonia Cost	0.101	$/lb
Catalyst Life	24000	hr
Catalyst Layers	2 full, 1 empty	

Engine Calculations

Q_B	9.6	mmBTU/hr

$q_{flue\ gas}$	3420.743017	acfm
N_{NOx}	0.96	

SCR Reactor Calculations

$Vol_{Catalyst}$	28.9587163	ft3
$A_{Catalyst}$	3.563273976	ft2
A_{SCR}	4.097765072	ft2
l=w=	2.024293722	ft
n_{layer}	3	
h_{layer}	3.708998943	
n_{total}	4	
h_{SCR}	51.83599577	ft

Reagent Calculations

$m_{reagent}$	2.197547351	lb/hr
m_{sol}	7.577749485	lb/hr
q_{sol}	1.012306141	gph
Tank Volume	2186.581265	gal

Cost Estimation

Direct Costs

DC	$	220,942.20	

Indirect Costs

General Facilities	$	11,047.11	
Engineering and home office fees	$	22,094.22	
Process Contingency	$	11,047.11	
Total Indirect Installation Costs	$	44,188.44	
Project Contingency	$	39,769.60	
Total Plant Cost	$	304,900.24	
Preproduction Cost	$	6,098.00	
Inventory Capital	$	1,653.16	
Total Capital Investment	$	312,651.41	

Direct Annual Costs

Maintenance Costs	$	4,689.77	per yr
Power		4.09796352	KW
Annual Electricity	$	20.49	per yr

Reagent Solution Cost	$	76.54	per yr

Catalyst Replacement

FWF		0.311051666	
Annual Catalyst Replacement	$	870.74	per yr
Total Variable Direct Cost	$	967.77	per yr
Total Direct Annual Cost	$	5,657.54	per yr
CRF		0.094392926	
Indirect Annual Cost	$	29,512.08	per yr
Total annual Cost	$	35,169.62	per yr
Nox Removed		0.27	tons
Cost of Nox removal	$	129,580.57	per ton