CATEGORY: **MISCELLANEOUS**

BACT Size: Minor Source BACT **TEST STAND**

BACT Determination Number:	181	**BACT Determination Date:**	**8/21/2018**

Equipment Information

Permit Number: 25520

Equipment Description: TEST STAND

EXPIRED

Unit Size/Rating/Capacity: Jet A Fuel

Equipment Location: COMPOSITE ENGINEERING INC, A KRATOS CO
5381 RALEY BLVD
SACRAMENTO, CA

BACT Determination Information

ROCs	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
SOx	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
PM10	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
PM2.5	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
CO	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
LEAD	**Standard:**	
	Technology Description:	
	Basis:	

Comments: T-BACT will be determined on a case by case basis.

District Contact: Jeff Quok Phone No.: (916) 874-4863 email: jquok@airquality.org

777 12th Street, Third Floor

SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

Sacramento, CA 95814

BEST AVAILABLE CONTROL TECHNOLOGY DETERMINATION

DETERMINATION NO.: 181

DATE: 8/21/18

ENGINEER: Jeffrey Quok

EXPIRED

Category/General Equip Description: Turbine Engine Test Cell

Equipment Specific Description: Drone Turbine Engine Test Cell (Jet A Fuel)

Equipment Size/Rating: Minor Source BACT

Previous BACT Det. No.: N/A

This BACT/T-BACT determination will be made for drone turbine engine test cell using Jet A fuel.

This BACT was determined under the project for A/C 25520 (Composite Engineering Inc. Kratos Company).

BACT/T-BACT ANALYSIS

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

The following control technologies are currently employed as BACT for drone engine/turbine test cell by the following air pollution control districts:

District/ Agency	Best Available Control Technology (BACT) Requirements	
US EPA	**BACT** Source: EPA RACT/BACT/LAER Clearinghouse RBLC#: VA-0303 For Engine/Turbine Test Cells	
	VOC	Good combustion practices
	NOx	Good combustion practices
	SOx	No standard
	PM10	No standard
	PM2.5	No standard
	CO	Good combustion practices

District/ Agency	Best Available Control Technology (BACT) Requirements
US EPA	**T-BACT** There are no T-BACT standards published in the clearinghouse for this category. **RULE REQUIREMENTS**: 40 CFR 63 Subpart PPPPP – National Emission Standards for Hazardous Air Pollutants for Engine Test Cells/Stands (5/27/03) This regulation applies engine test cells/stands located at major sources of hazardous air pollutants (HAP) emissions. An engine test cell/stand is any apparatus used for testing uninstalled stationary or uninstalled mobile (motive) engines. [40 CFR §63.9285] Any portion of the affected source used exclusively for testing combustion turbine engines does not have to meet the requirements of this subpart. [40 CFR §63.9290(d)(1)] Therefore, this regulation will not apply for this BACT determination.
ARB	**BACT** Source: ARB BACT Clearinghouse There are no BACT standards published in the clearinghouse for this category. **T-BACT** There are no T-BACT standards published in the clearinghouse for this category. **RULE REQUIREMENTS**: None.
SMAQMD	**BACT** Source: SMAQMD BACT Clearinghouse There are no BACT standards published in the clearinghouse for this category. **T-BACT** There are no T-BACT standards published in the clearinghouse for this category. **RULE REQUIREMENTS**: None.

<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, pg 78
<table>
<tr><th colspan="2">For Jet Engine Test Facility – Performance Testing</th></tr>
<tr><td>VOC</td><td>No standard</td></tr>
<tr><td>NOx</td><td>No standard</td></tr>
<tr><td>SOx</td><td>No standard</td></tr>
<tr><td>PM10</td><td>No standard</td></tr>
<tr><td>PM2.5</td><td>No standard</td></tr>
<tr><td>CO</td><td>No standard</td></tr>
</table>
<u>T-BACT</u>
There are no T-BACT standards published in the clearinghouse for this category.

<u>RULE REQUIREMENTS</u>:
Rule 1470 – Requirements for Stationary Diesel-Fueled Internal Combustion and Other Compression Ignition Engines (Amended 5/4/12)
This rule applies to any person who owns or operates a stationary CI engine with a rated horsepower greater than 50 bhp. However, engine test cells and test stands for testing CI engines, or CI engine components are exempt for the requirements of this rule.
</td></tr>
<tr><td>San Diego County APCD</td><td>
<u>BACT</u>
Source: NSR Requirements for BACT

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

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

<u>RULE REQUIREMENTS</u>:
None.
</td></tr>
<tr><td>Bay Area AQMD</td><td>
<u>BACT</u>
Source: BAAQMD BACT Guideline

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

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

<u>RULE REQUIREMENTS</u>:
None.
</td></tr>
</table>

<table>
<tr><td>District/ Agency</td><td>Best Available Control Technology (BACT) Requirements</td></tr>
<tr><td>San Joaquin Valley APCD</td><td><u>BACT</u>
Source: SJVUAPCD BACT Clearinghouse, Guideline 8.3.12

<table>
<tr><td colspan="2">For Helicopter Engine Test Cell</td></tr>
<tr><td>VOC</td><td>Good combustion practices(A)</td></tr>
<tr><td>NOx</td><td>Good combustion practices(A)</td></tr>
<tr><td>SOx</td><td>Good combustion practices(A)</td></tr>
<tr><td>PM10</td><td>Good combustion practices(A)</td></tr>
<tr><td>PM2.5</td><td>No standard</td></tr>
<tr><td>CO</td><td>Good combustion practices(A)</td></tr>
</table>
(A) Use of JP-8 fuel is also listed as BACT, however fuel is specific to the type of engine being tested and won't be considered BACT for all test cells/stands.

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

<u>RULE REQUIREMENTS</u>:
None.</td></tr>
</table>

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

SUMMARY OF ACHIEVED IN PRACTICE CONTROL TECHNOLOGIES	
Pollutant	**Standard**
VOC	Good combustion practices [EPA, SJVAPCD]
NOx	Good combustion practices [EPA, SJVAPCD]
SOx	Good combustion practices [SJVAPCD]
PM10	Good combustion practices [SJVAPCD]
PM2.5	N/A – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD, ARB, EPA]
CO	Good combustion practices [EPA, SJVAPCD]
VOC (T-BACT)	N/A – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD, ARB, EPA]

Although there is no recorded achieved in practice BACT for PM2.5, because the majority of the PM from combustion sources is PM2.5, it will be assumed that the PM10 BACT standard can also be achieved for PM2.5.

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

BEST CONTROL TECHNOLOGIES ACHIEVED		
Pollutant	**Standard**	**Source**
VOC	Good combustion practices	EPA, SJVUAPCD
NOx	Good combustion practices	EPA, SJVUAPCD
SOx	Good combustion practices	SJVUAPCD
PM10	Good combustion practices	SJVUAPCD
PM2.5	Good combustion practices	SMAQMD
CO	Good combustion practices	EPA, SJVUAPCD
VOC (T-BACT)	No Standard	SMAQMD, SCAQMD, SJVUAPCD, SDCAPCD, BAAQMD, EPA, ARB

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.

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.

Pollutant	Technologically Feasible Alternatives
VOC	1. Thermal Oxidizer
NOx	No other technologically feasible option identified
SOx	No other technologically feasible option identified
PM10	No other technologically feasible option identified
PM2.5	No other technologically feasible option identified
CO	1. Thermal Oxidizer
VOC (T-BACT)	1. Thermal Oxidizer

VOC & CO Control Technology

Thermal Oxidizer

Thermal oxidizers require a chamber temperature between 1200°F to 2000°F to enable the oxidation reaction and require sufficient flow velocities to promote mixing between the combustion products and the burner. Thermal oxidizers control both VOC and CO emissions.

NOx Control Technology

Selective Catalytic Reduction (SCR) with Ammonia Injection
Ammonia (NH_3) is injected to react with NO to form nitrogen and water. The required catalyst temperature is 500°F to 700°F. Proper operation depends on many factors including correct stoichiometric ratio of ammonia to NO, reaction temperature, exhaust gas flow rate, and condition of catalyst.

SCR technology has been used for stationary gas turbine applications for power plants. However, the exhaust gas characteristics of power plant turbines are much different than test cells. While power plant turbines have steady exhaust gas characteristics; engine testing requires the engine to operate over a range of speeds which results in significantly variable exhaust stack gas temperatures and flow rates. For SCR to be effective the system would need to automatically adjust the level of augmentation air to adjust the exhaust temperature and flow to a suitable temperature for the catalyst. A burner may also need to be installed to keep the exhaust gas temperature at the catalysts operating temperature, which would also create additional NOx emissions. The NH_3 injection system must track NOx emission rates in order to maintain the proper NOx to NH_3 ratio. These rapid and frequent changes in engine output will place demand on the SCR controller not found in current installations where SCR is used. Therefore, SCR is not technologically feasible for engine test stand applications.

Selective Non-Catalytic Reduction (SNCR)
SNCR uses injection of chemicals such as ammonia or urea to the exhaust gases, for non-catalytic reactions that result in formation of nitrogen and water. The desired reaction for NOx reduction occurs in the temperature range of 1,800°F to 2,000°F.

Test cell exhaust stack gas temperatures are significantly below the 1,800°F to 2,000°F range where SNCR is viable. In order to raise the temperature of the exhaust gas a burner would be needed. Due to the high temperature requirements, a burner would potentially create more NOx which would offset the NOx reduction of the SNCR system. Therefore, SNCR is not technologically feasible for engine test stand applications.

PM10 Control Technology

Venturi Scrubber

SCAQMD BACT Guideline lists a venturi scrubber with water spray as BACT for experimental high altitude testing. However, for performance testing SCAQMD does not list a control technology achieved in practice.

The BACT for experimental high altitude testing was based on a determination made in 1988 and is based on older engine technology. Older jet engines do not incorporate technological features such as the reduced emission combustors or advanced fuel injection, which increase combustion efficiency. Combustion efficiency is directly proportional to the pressure ratio developed in the engine. The pressure ratio of older engines ranges from 12 to 15, compared with the pressure ratio range of 20 to 25 of the technologically advanced engines.

Technologically advanced engines, which operate at a higher pressure ratio, are characterized by a higher thermodynamic efficiency and better fuel atomization. These characteristics, combined with better mixing of fuel with the combustion air, results in higher combustion efficiency, lower particulate emissions, and smaller particle size. Older engines with lower pressure ratio, lower degree of atomization, and lower combustion efficiency result in a larger particle size distribution.

Venturi Scrubbers remove particulate matter from the gas stream using a liquid spray. Venturi scrubbers accelerate the gas stream to atomize the scrubbing liquid and to improve gas-liquid contact.

Efficiency of venturi scrubbers are dependent on particle size and inlet dust concentration. Scrubber efficiency increases as particle size increases. Collection efficiency of small particles (less than 1 micrometer) is expected to be low. Collection efficiency for scrubbers have been found to be directly proportional to the inlet dust concentration; efficiency increases with the increase of dust loading.

The dust loading per unit volume of jet engine exhaust is much lower than what is encountered from a majority of stationary combustion sources. Therefore, lower scrubber efficiency is expected. For improved efficiency, the exhaust gas velocity must be increased, which will result in higher pressure drop. This pressure drop will affect the calibration of the engine test stand. Therefore, this control option is considered technologically infeasible for engine test stand applications.

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

The cost analysis was processed in accordance with the EPA OAQPS Air Pollution Control Cost Manual (Sixth Edition, EPA/452/B-02-001), except that for VOC Destruction Controls, the updated chapter was used (November 2017). The sales tax rate was based on the District’s standard rate of 8.25%. The electricity (13.80 cents/kWh) and natural gas (8.04 dollars/1,000 cubic feet) rates were based on a commercial application as approved by the District. The life of the equipment was based on the EPA cost manual recommendation. The interest rate was based on the previous 6-month average interest rate on United States Treasury Securities (based on the life of the equipment) and addition of two percentage points and rounding up to the next higher integer rate. The labor (Occupation Code 17-3021: Aerospace engineering and operation technicians) and maintenance (Occupation Code 49-9099: Installation, maintenance, and repair workers, all other) rates were based on data from the Bureau of Labor Statistics.

Thermal Oxidizer: As shown in Attachment B, the cost effectiveness for the add-on thermal oxidizer system to control VOC was calculated to be **$1,623,663/ton**. The following basic parameters were used in the analysis.

Equipment Life = 10 years

Total Capital Investment = $894,773

Direct Annual Cost = $12,505 per year

Indirect Annual Cost = $107,754 per year

Total Annual Cost = $120,258 per year

VOC Removed = 0.1 tons per year

Cost of VOC Removal = $1,623,663 per ton reduced

The annualized cost of a thermal oxidizer exceeds the cost effectiveness threshold of $17,500 per ton of VOC reduced. Therefore, thermal oxidizer is therefore eliminated from consideration for BACT.

C. SELECTION OF BACT:

Since no technologically feasible controls were identified, BACT for VOC, NOx, SOx, PM10, PM2.5, and CO will remain at what is currently achieved in practice.

TABLE 1: BACT FOR TURBINE ENGINE TEST CELLS (JET A FUEL)		
Pollutant	**Standard**	**Source**
VOC	Good combustion practices	EPA, SJVUAPCD
NOx	Good combustion practices	EPA, SJVUAPCD
SOx	Good combustion practices	SJVUAPCD
PM10	Good combustion practices	SJVUAPCD
PM2.5	Good combustion practices	SMAQMD
CO	Good combustion practices	EPA, SJVUAPCD

D. SELECTION OF T-BACT:

For this category of equipment T-BACT will be determined on a case by case basis.

REVIEWED BY: ______________________ **DATE:** ______________

APPROVED BY: [signature] **DATE:** 8/21/18

Attachment A
Review of BACT Determinations published by EPA

List of BACT determinations published in EPA's RACT/BACT/LAER Clearinghouse (RBLC) for glycol dehydrators:

RBLC#	Permit Date	Process Code (A), (B), (C), (D)	Equipment	Pollutant	Standard (E)	Case-By-Case Basis
TX-0699	12/16/2014	15.190	Turbine Test Cell	NOx	Good combustion practices	LAER
OH-0355	05/07/2013	17.110	Test Cell for Aircraft Engines and Turbines (Jet fuel, diesel fuel, biofuels, and gaseous fuels)	CO	No controls feasible, 5.1 lb/MMBtu, 99.9 tons/year for 2 test cells and 4 preheaters	N/A
				NOx	No controls feasible, 1.7 lb/MMBtu, 92 tons/year	LAER
				PM10	No controls feasible, 0.038 lb/MMBtu, 9.9 tons/year for 2 test cells and 4 preheaters	N/A
				SO2	No controls feasible, 0.11 lb/MMBtu, 24.9 tons/year for 2 test cells and 4 preheaters	N/A
				VOC	No controls feasible, 0.7 lb/MMBtu, 39.9 tons/year for 2 test cells and 4 preheaters	N/A
OH-0355	05/07/2013	17.110	Test Cell for Aircraft Engines and Turbines (Jet fuel, diesel fuel, biofuels, and gaseous fuels)	CO	No controls feasible, 7.3 lb/MMBtu, 99.9 tons/year for 2 test cells and 4 preheaters	N/A
				NOx	No controls feasible, 4.4 lb/MMBtu, 80 tons/year	LAER
				PM10	No controls feasible, 0.038 lb/MMBtu, 9.9 tons/year for 2 test cells and 4 preheaters	N/A
				SO2	No controls feasible, 0.11 lb/MMBtu, 24.9 tons/year for 2 test cells and 4 preheaters	N/A

RBLC#	Permit Date	Process Code (A), (B), (C), (D)	Equipment	Pollutant	Standard (E)	Case-By-Case Basis
				VOC	No controls feasible, 0.7 lb/MMBtu, 39.9 tons/year for 2 test cells and 4 preheaters	N/A
MA-0038	03/13/2008	16.100	Engine Test Cell	NO2	67.2 tons/month, 157 tons/year	BACT-PSD
OK-0121	04/25/2007	19.900	Jet Engine Test Cells	CO	No controls feasible, 169.39 tons/year	BACT-PSD
				NOx	No controls feasible, 323.13 tons/year	BACT-PSD
				PM10	No controls feasible, 27.6 tons/year	BACT-PSD
				VOC	No controls feasible, 135.46 tons/year	BACT-PSD
VA-0303	01/10/2007	15.190	Engine Test Cells	CO	Good combustion practices, 135 tons/year	N/A
				NO2	Good combustion practices, 4.7 tons/year	N/A
				VOC	Good combustion practices, 90.1 tons/year	N/A

(A) Process code 15.190 is for Large Combustion Turbines >25MW, liquid fuel & liquid fuel mixtures
(B) Process code 16.100 is for Small Combustion Turbines ≤25MW, simple cycle
(C) Process code 17.110 is for Internal Combustion Engines, Fuel oil (ASTM # 1,2, includes kerosene, aviation, diesel fuel)
(D) Process code 19.900 is for Miscellaneous Combustion, other mis. Combustion.
(E) Emission limits listed in these standards are specific to the facility operation.
[yellow highlight] = Selected as the most stringent BACT determination achieved in practice.

Attachment B
BACT Determinations from Various Districts

10-20-2000 Rev. 0

Equipment or Process: Jet Engine Test Facility

	Criteria Pollutants					
Subcategory/ Rating/Size	VOC	NOx	SOx	CO	PM_{10}	Inorganic
Experimental High Altitude Testing					Venturi Scrubber with Water Spray in Exhaust (1988)	
Experimental Sea Level (Low Altitude) Testing[1]						
Performance Testing[1]						

1) At the date of the last revision for this category, there was no Achieved In Practice BACT Determination for this subcategory. Technologically Feasible options listed in historic SCAQMD BACT Guidelines for this subcategory require cost effective analyses before they can be listed in these current Guidelines.

* Means those facilities that are not major polluting facilities as defined by Rule 1302 - Definitions

San Joaquin Valley
Unified Air Pollution Control District

Best Available Control Technology (BACT) Guideline 8.3.12*

Last Update: 9/24/2001

Helicopter Engine Test Cell

Pollutant	Achieved in Practice or contained in the SIP	Technologically Feasible	Alternate Basic Equipment
VOC	Use of JP-8 fuel and good combustion practices.		
SOx	Use of JP-8 fuel and good combustion practices.		
PM10	Use of JP-8 fuel and good combustion practices.		
NOx	Use of JP-8 fuel and good combustion practices.		

BACT is the most stringent control technique for the emissions unit and class of source. Control techniques that are not achieved in practice or contained in s a state implementation plan must be cost effective as well as feasible. Economic analysis to demonstrate cost effectiveness is required for all determinations that are not achieved in practice or contained in an EPA approved State Implementation Plan.

***This is a Summary Page for this Class of Source**

Technology Transfer Network
Clean Air Technology Center - RACT/BACT/LAER Clearinghouse

Pollutant Information

Click on the Process Information button to see more information about the process associated with this pollutant.
Or click on the Process List button to return to the list of processes.

RBLC Home | New Search | Search Results | Facility Information | Process List | Process Information | Pollutant Information

Help

FINAL

RBLC ID: VA-0303
Corporate/Company: STIHL INCORPORATED
Facility Name: STIHL INCORPORATED
Process: ENGINE TEST CELLS

Pollutant: Volatile Organic Compounds (VOC)
CAS Number: VOC

Pollutant Group(s): Volatile Organic Compounds (VOC),
Substance Registry System: Volatile Organic Compounds (VOC)

Pollution Prevention/**A**dd-on Control Equipment/**B**oth/**N**o Controls Feasible: P

P2/Add-on Description: GOOD COMBUSTION PRACTICES

Test Method: Unspecified

EPA/OAR Methods | All Other Methods

Percent Efficiency:	0
Compliance Verified:	Unknown
EMISSION LIMITS:	
Case-by-Case Basis:	N/A
Other Applicable Requirements:	SIP , OPERATING PERMIT
Other Factors Influence Decision:	Unknown
Emission Limit 1:	90.1000 T/YR
Emission Limit 2:	0
Standard Emission Limit:	0
COST DATA:	
Cost Verified?	No
Dollar Year Used in Cost Estimates:	
Cost Effectiveness:	0 $/ton
Incremental Cost Effectiveness:	0 $/ton
Pollutant Notes:	

Pollutant Information

Help
FINAL

RBLC ID: VA-0303
Corporate/Company: STIHL INCORPORATED
Facility Name: STIHL INCORPORATED
Process: ENGINE TEST CELLS

Pollutant: Nitrogen Dioxide (NO2)
CAS Number: 10102-44-0

Pollutant Group(s): InOrganic Compounds, Oxides of Nitrogen (NOx),
Substance Registry System: Nitrogen Dioxide (NO2)

Pollution Prevention/**A**dd-on Control Equipment/**B**oth/**N**o Controls Feasible: P

P2/Add-on Description: GOOD COMBUSTION PRACTICES

Test Method: Unspecified

EPA/OAR Methods | All Other Methods

Percent Efficiency:	0
Compliance Verified:	Unknown
EMISSION LIMITS:	
Case-by-Case Basis:	N/A
Other Applicable Requirements:	SIP , OPERATING PERMIT
Other Factors Influence Decision:	Unknown
Emission Limit 1:	4.7000 T/YR
Emission Limit 2:	0
Standard Emission Limit:	0
COST DATA:	
Cost Verified?	No
Dollar Year Used in Cost Estimates:	
Cost Effectiveness:	0 $/ton
Incremental Cost Effectiveness:	0 $/ton
Pollutant Notes:	

Pollutant Information

FINAL

RBLC ID: VA-0303
Corporate/Company: STIHL INCORPORATED
Facility Name: STIHL INCORPORATED
Process: ENGINE TEST CELLS

Pollutant: Carbon Monoxide
CAS Number: 630-08-0

Pollutant Group(s): InOrganic Compounds,
Substance Registry System: Carbon Monoxide

Pollution Prevention/**A**dd-on Control Equipment/**B**oth/**N**o Controls Feasible: P
P2/Add-on Description: GOOD COMBUSTION PRACTICES

Test Method: Unspecified

EPA/OAR Methods | All Other Methods

Percent Efficiency: 0
Compliance Verified: Unknown
EMISSION LIMITS:
Case-by-Case Basis: N/A
Other Applicable Requirements: OPERATING PERMIT , SIP
Other Factors Influence Decision: Unknown
Emission Limit 1: 135.0000 T/YR
Emission Limit 2: 0
Standard Emission Limit: 135.0000 T/YR
COST DATA:
Cost Verified? No
Dollar Year Used in Cost Estimates:
Cost Effectiveness: 0 $/ton
Incremental Cost Effectiveness: 0 $/ton
Pollutant Notes:

Attachment C

Cost Effectiveness Determination for Thermal Oxidizers

For Thermal and Catalytic Oxidizers

U.S. Environmental Protection Agency
Air Economics Group
Health and Environmental Impacts Division
Office of Air Quality Planning and Standards
(January 2018)

This spreadsheet allows users to estimate the capital and annualized costs for installing and operating oxidizers. Oxidizers control volatile organic compounds (VOCs) and hazardous air pollutants (HAP) from industrial waste gas streams by oxidizing organic compounds to carbon dioxide and water. If the waste gas contains chlorinated or sulfonated organic compounds, HCl and SO_2 will be generated, which may require acid gas controls, such as a wet scrubber. There are two major types of oxidizers: thermal and catalytic oxidizers.

The calculation methodologies used in this spreadsheet are those presented in the U.S. EPA's Air Pollution Control Cost Manual. This spreadsheet is intended to be used in combination with the Control Cost Manual. For a detailed description of the oxidizer control technology and cost methodology, see Section 3.2, Chapter 2 (Incinerators and Oxidizers) of the Air Pollution Control Cost Manual (as updated in 2016). Additional controls may be necessary for some industrial waste gas streams (e.g., chlorinated and sulfur-containing organic compounds that produce acid gases when oxidized). Costs for additional control technologies can be estimated using the methods provided in other chapters of the cost manual. A copy of the Control Cost Manual is available on the U.S. EPA's "Clean Air Technology Center" website at: http://www3.epa.gov/ttn/catc/products.html#cccinfo.

The spreadsheet can be used to estimate capital and annualized costs for the following types of oxidizers:

Incinerator Type	Total Waste Gas Flowrate (scfm)
Thermal Recuperative	500 - 50,000
Thermal Regenerative	10,000 - 100,000
Fixed-Bed/Monolith Catalytic	2,000 - 50,000
Fluid-Bed Catalytic	2,000 - 25,000

Installation costs for a given incinerator could deviate significantly from costs generated using this spreadsheet depending on the site conditions.

Note: This spreadsheet is designed to calculate the design parameters and costs for thermal and catalytic oxidizers used to control waste gas streams that have an oxygen content of at least 20%. If the oxygen content is less than 20%, the waste stream parameters should be adjusted to include auxiliary air sufficient to increase the oxygen content of the waste gas stream above 20%.

Instructions

Step 1: Please select on the ***Data Inputs*** tab and click on the ***Reset Form*** button. This will reset the inlet flow rate, pressure drop, fan efficiency, inlet temperature, control efficiency, interest rate, labor rates, electricity and natural gas prices, and the contingency factor to default factors. All other data entry fields will be blank.

Step 2: Select the type of oxidizer from the options provided in the pull down menu. The operating temperature will be set to a default value of 2000°F for a regenerative thermal oxidizer, 1600°F for a recuperative thermal oxidizer and 900°F for a catalytic oxidizer. If you select a catalytic oxidizer, the catalyst life, catalyst unit cost, and space velocity factor will be set to default values. You may use site-specific values instead of the default values; however, you should document the source of each value you use.

Step 3: Complete all of the cells highlighted in yellow. As noted above, some of the highlighted cells are pre-populated with default values based on 2016 data. Users should document the source of all values entered in accordance with the recommendations provided in the Control Cost Manual. Use of actual values other than the default values in this spreadsheet, if appropriately documented, is acceptable.

Step 4: Once all of the data fields are complete, select the Design Parameters tab to see the calculated design parameters and the Cost Estimate tab to view the calculated cost data for the installation and operation of the oxidizer. If the %LEL for the waste gas exceeds 25%, the spreadsheet adjusts the concentrations and waste gas flow rate to account for the dilution air needed to reduce the %LEL of the waste gas below the 25% threshold. If the oxygen content is less than 20%, auxiliary air must be added.

Data Inputs

Select the type of oxidizer: Recuperative Thermal Oxidizer

Enter the following information for your emission source:

Composition of Inlet Gas Stream				
Pollutant Name	**Concentration (ppmv)**	**Lower Explosive Limit (LEL) (ppmv)***	**Heat of Combustion (Btu/scf)**	**Molecular Weight**
Propane	13.7	21,000	2,353	44.09

Note: The lower explosion limit (LEL), heat of combustion and molecular weight for some commonly used VOC/HAP are provided in the table below.

Enter the design data for the proposed oxidizer:

Number of operating hours/year	54	hours/year	
Inlet volumetric flow rate(Q_{wi}) at 77°F and 1 atm.	32,505	scfm	
Inlet volumetric flow rate(Q_{wi}) (actual conditions)	32,505	acfm	
Pressure drop (ΔP)	23	inches of water*	* 23 inches of water is the default pressure drop for thermal oxidizers; 19 inches of water is the default pressure drop for catalytic oxidizers. Enter actual value, if known.
Motor/Fan Efficiency (ε)	60	percent*	* 60% is a default fan efficiency. User should enter actual value, if known.
Inlet Waste Gas Temperature (T_{wi})	100	°F*	* 100°F is a default temperature. User should enter actual value, if known.
Operating Temperature (T_{fi})	1,600	°F	* Note: Default value for Tfi is 1600°F for thermal recuperative oxidizers. Use actual value if known.
Destruction and Removal Efficiency (DRE)	90	percent	
Estimated Equipment Life	20	Years*	* 20 years is the typical equipment life. User should enter actual value, if known.

Percent Energy Recovery (HR) = 70 percent

Enter the cost data:

Desired dollar-year	2017			
CEPCI* for 2017	567.5	Enter the CEPCI	390.6	1999

		value for 2017		CEPCI
Annual Interest Rate (i)	5	Percent		
Electricity ($Cost_{elect}$)	0.13	$/kWh		
Natural Gas Fuel Cost ($Cost_{fuel}$)	0.0080 4	$/scf		
Operator Labor Rate	$33.45	per hour		
Maintenance Labor rate	$21.21	per hour		
Contingency Factor (CF)	10.0	Percent		

* 10 percent is a default value for construction contingencies. User may enter values between 5 and 15 percent.

* CEPCI is the Chemical Engineering Plant Cost Escalation/De-escalation Index. The use of CEPCI in this spreadsheet is not an endorsement of the index for purposes of cost escalation or de-escalation, but is there merely to allow for availability of a well-known cost index to spreadsheet users. Use of other well-known cost indexes (e.g., M&S) is acceptable.

Data Sources for Default Values Used in Calculations:

Parameters for Common Compounds:

Compound	LEL (ppmv)	Heat of Combustion (Btu/scf)	Molecular Weight
Methane*	50,000	911	16.04
Ethane	30,000	1,631	30.07

Propane	21,000	2,353	44.09
Butane	19,000	3,101	58.12
Pentane	14,000	3,709	72.15
Hexane	11,000	4,404	86.17
Octane	10,000	5,796	114.23
Nonane	8,000	6,493	128.25
Decane	8,000	7,190	142.28
Ethylene**	27,000	1,499	28.05
Propylene	20,000	2,182	42.08
Cyclohexane	13,000	4,180	84.16
Benzene**	14,000	3,475	78.11
Toluene**	11,000	4,274	92.13
Methyl Chloride (Chloromethane)**	82,500	705	50.49
Footnotes * Greenhouse gas. ** Hazardous air pollutant.			

Data Element	Default Value	Sources for Default Values used in the calculation . . .	If you used your own site-specific values, please enter the value used and the reference source . . .	Recommended data sources for site-specific information
Electricity Cost ($/kWh)	0.13	$/kWh		Plant's utility bill or use U.S. Energy Information Administration (EIA) data for most recent year. Available at http://www.eia.gov/electricity/data.cfm#sales.

Fuel Cost ($/MMBtu)	8.04	$/1000 cu.ft.		Check with fuel supplier or use U.S. Energy Information Administration (EIA) data for most recent year." Available at Available at http://www.eia.gov/dnav/ng/hist/n3035us3A.htm.
Operator Labor ($/hour)	33.45	Bureau of Labor Statistics, May 2016 National Occupational Employment and Wage Estimates – United States, May 2016 (https://www.bls.gov/oes/current/oes_nat.htm). Hourly rates for operators based on data for aerospace engineering and operation technicians (17-3021).		Use plant-specific labor rate.
Maintenance Labor ($/hour)	21.21	Bureau of Labor Statistics, May 2016 National Occupational Employment and Wage Estimates – United States, May 2016 (https://www.bls.gov/oes/current/oes_nat.htm). Hourly rates for maintenance workers based on installation, maintenance, and repair workers, all other (49-9099).		Use plant-specific labor rate.

Design Parameters

The following design parameters for the oxidizer were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.

Composition of Inlet Gas Stream		
Pollutant Name	**Concentration in Waste Stream (ppmv) From Data Inputs Tab**	**Adjusted Concentration with Dilution Air (ppmv)**
Propane	14	NA
0	0	NA
0	0	NA
0	0	NA
0	0	NA
0	0	NA
0	0	NA
0	0	NA
0	0	NA
0	0	NA
Total	14	0

Constants used in calculations:

Temperature of auxiliary fuel (T_{af}) =	54	77.0	°F
Density of auxiliary Fuel at 77 °F (ρ_{af}) =		0.0408	lb/ft^3
Heat Input of auxiliary fuel ($-\Delta h_{caf}$) =		21,502	Btu/lb
Density of waste gas at 77 °F (ρ_{wi}) =		0.0739	lb/ft^3

Mean Heat Capacity of Air (C_{pmair}) (For thermal oxidizers) 0.255 Btu/lb °F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Sum of volume fraction of combustible components =	$= (\sum x_i) =$	13.7	ppmv		
Lower Explosive Limit of waste gas (LEL_{mix})	$= [\sum((x_j)/((\sum x_i) \times LEL_j))]^{-1} =$ Where x_j is the volume fraction and LEL_j the lower explosive limit for each combustible component in the waste gas.	21,000	ppmv		
% LEL_{mix}	= (Total Combustible Conc. In Mixture/LEL_{mix}) × 100 =	0.07	percent	* Note: Since the LEL of the waste gas stream is below 25%, no dilution air is needed.	
Dilution Factor	$= (LEL_{mix} \times 0.249)/(\sum x_i) =$	Not applicable			
Lower Explosive Limit (LEL) of waste gas after addition of dilution air	= (Total Adjusted Conc. With Dilution Air/LEL_{mix}) × 100 =	Not Applicable			
Inlet volumetric flow rate(Qwi) at 77°F and 1 atm.	(From Data Inputs Tab) =	32,505	scfm		
Oxygen Content of gas stream	$= 100 - (\sum x_j \times 100/10^6) \times 0.209 =$	20.90	percent		
Fan Power Consumption (FP)	$= [(1.17 \times 10^{-4}) \times Q_{wi} \times \Delta P]/\varepsilon$	145.8	kW		
Q_{wo}	$\approx Q_{wi} =$	32,505	scfm		
Operating temperature of oxidizer (T_{fi})	(From Data Inputs Tab)	1,600	°F		
Temperature of waste gas at outlet to preheater (T_{wo})	$=$ Heat Recovery $\times (T_{fi} - T_{wi}) + T_{wi} =$	1,150	°F		
Temperature of flue gas exiting the oxidizer (T_{fo})	$= T_{fi} - T_{wo} + T_{wi} =$	550	°F		

Heat Input of waste gas ($-\Delta h_{cwi}$)	$= \sum (-\Delta h_{ci}) x_i$ Where ($-\Delta h_{ci}$) is the heat of combustion and x_i the fraction of component "i" at 77 °F.	0.03 Btu/scf	0.4 Btu/lb
Estimated Auxiliary Fuel Flow (Q_{af}) at 77 °F and 1 atm.	(Calculated using Equation 2.21 in Chapter 2 of the Cost Manual)	427.85 scfm	
Auxiliary fuel Energy Input =		375,343 Btu/min	
Minimum Energy required for combustion stabilization =	$= 5\% \times \text{Total Energy Input} = 0.05 \times \rho_{fi} \times Q_{fi} \times C_{pmfi} \times (T_{fi} - T_{ref}) =$	47,259 Btu/min	
Is the calculated auxiliary fuel sufficient to stabilize combustion? (Note: If the auxiliary fuel energy input > 5% of Total Energy Input, then the auxilary fuel is sufficient.)		Yes	
Auxiliary fuel flow (Qaf) at 77°F and 1 atm. =		428 scfm	
Total Volumetric Throughput (Q_{tot}) at 77 °F and 1 atm.	$= Q_{fi} = Q_{wo} + Q_a + Q_{af} = Q_{wi} + Q_{af} =$	32,933 scfm	

Capital Recovery Factor:

Parameter	Equation	Calculated Value
Capital Recovery Factor (CRF) =	$i(1+i)^n/(1+i)^n - 1 =$ Where n = Equipment Life and i= Interest Rate	0.0802

Cost Estimate

Direct Costs

Total Purchased equipment costs (in 2017 dollars)

Incinerator + auxiliary equipment[a] (A) =			
Equipment Costs (EC) for Recuperative Thermal Oxidizer	= (21,342 x Qtot^(0.25)) x (2017 CEPI/1999 CEPCI) =	$417,711	in 2017 dollars
Instrumentation[b] =	0.10 × A =	$41,771	
Sales taxes =	0.0825 × A =	$34,461	
Freight =	0.05 × A =	$20,886	
	Total Purchased equipment costs (B) =	$514,829	in 2017 dollars

Footnotes

a - Auxiliary equipment includes equipment (e.g., duct work) normally not included with unit furnished by incinerator vendor.

b - Includes the instrumentation and controls furnished by the incinerator vendor.

Direct Installation Costs (in 2017 dollars)

Foundations and Supports =	0.08 × B =	$41,186	
Handling and Erection =	54	$72,076	
Electrical =	0.04 × B =	$20,593	
Piping =	0.02 × B =	$10,297	
Insulation for Ductwork =	0.01 × B =	$5,148	
Painting =	0.01 × B =	$5,148	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct Installation Costs =	$154,449	
Total Direct Costs (DC) =	Total Purchase Equipment Costs (B) + Total Direct Installation Costs =	$669,278	in 2017 dollars

Total Indirect Installation Costs (in 2017 dollars)

Engineering =	0.10 × B =	$51,483	
Construction and field expenses =	0.05 × B =	$25,741	
Contractor fees =	0.10 × B =	$51,483	
Start-up =	0.02 × B =	$10,297	
Performance test =	0.01 × B =	$5,148	
	Total Indirect Costs (IC) =	$144,152	
Continency Cost (C) =	CF(IC+DC)=	$81,343	
Total Capital Investment =	**DC + IC +C =**	**$894,773**	**in 2017 dollars**
Direct Annual Costs			
Annual Electricity Cost	= Fan Power Consumption × Operating Hours/year × Electricity Price =	$1,086	
Annual Fuel Costs for Natural Gas	= $Cost_{fuel}$ × Fuel Usage Rate × 60 min/hr × Operating hours/year	$11,145	
Operating Labor	Operator = 0.5hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$113	
	Supervisor = 15% of Operator	$17	
Maintenance Costs	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$72	
	Materials = 100% of maintenance labor	$72	
Direct Annual Costs (DC) =		**$12,505**	**in 2017 dollars**
Indirect Annual Costs			
Overhead	= 60% of sum of operating, supervisor, maintenance labor and maintenance materials	$164	
Administrative Charges	= 2% of TCI	$17,895	
Property Taxes	= 1% of TCI	$8,948	
Insurance	= 1% of TCI	$8,948	
Capital Recovery	= CRF x TCI	$71,799	

Indirect Annual Costs (IC) =		**$107,754**	**in 2017 dollars**
Total Annual Cost =	**DC + IC =**	**$120,258**	**in 2017 dollars**

Cost Effectiveness

Cost Effectiveness = (Total Annual Cost)/(Annual Quantity of VOC/HAP Pollutants Destroyed)

Total Annual Cost (TAC) =	$120,258	per year in 2017 dollars
VOC/HAP Pollutants Destroyed =	0.1	tons/year
Cost Effectiveness =	$1,623,663	per ton of pollutants removed in 2017 dollars