SMAQMD BACT CLEARINGHOUSE

ACTIVE

CATEGORY Type: **PRINTING PROCESS**

BACT Category: < 6,371 LBS/YEAR UNCONTROLLED V

BACT Determination Number: 365	**BACT Determination Date:** 7/23/2024

Equipment Information

Permit Number: N/A -- Generic BACT Determination

Equipment Description: FLEXOGRAPHIC NON-HEATSET BOX FINISHING

Unit Size/Rating/Capacity: Minor Source BACT

Equipment Location:

BACT Determination Information

District Contact: Felix Trujillo Phone No.: (279) 207-1154 email: ftrujillo@airquality.org

ROCs	**Standard:**	See Comments
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	No Standard
	Technology Description:	
	Basis:	
SOx	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM10	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM2.5	**Standard:**	No Standard
	Technology Description:	
	Basis:	
CO	**Standard:**	No Standard
	Technology Description:	
	Basis:	
LEAD	**Standard:**	No Standard
	Technology Description:	
	Basis:	

Comments: Use of materials compliant with SMAQMD Rule 450 - Graphic Arts, use of inks with < 1.5 lbs VOC/gal, less water and exempt compounds; or use of UV/EB or water-based inks/coatings < 180 g VOC/L (1.5 lbs VOC/gal), less water and exempt compounds, and use of adhesives with a VOC content not exceeding 0.021 lb/gal, less water and exempt compounds. No VOC clean-up solvents with use of water-based inks/coatings. See BACT Determination Evaluation for T-BACT determination.

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	Basis:	
SOx	**Standard:**	No Standard
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PM10	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM2.5	**Standard:**	No Standard
	Technology Description:	
	Basis:	
CO	**Standard:**	No Standard
	Technology Description:	
	Basis:	
LEAD	**Standard:**	No Standard
	Technology Description:	
	Basis:	

Comments: Use of materials compliant with SMAQMD Rule 450 - Graphic Arts, use of inks with < 1.5 lbs VOC/gal, less water and exempt compounds; or use of UV/EB or water-based inks/coatings < 180 g VOC/L (1.5 lbs VOC/gal), less water and exempt compounds, and use of adhesives with a VOC content not exceeding 0.021 lb/gal, less water and exempt compounds. No VOC clean-up solvents with use of water-based inks/coatings. A VOC control device that has an overall system efficiency (collection and destruction) of at least 98.5% for VOC. See BACT determination evaluation for T-BACT

Printed: 7/23/2024

777 12th Street, Suite 300 SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT Sacramento, CA 95814

BEST AVAILABLE CONTROL TECHNOLOGY DETERMINATION

DETERMINATION NO.:	365 & 366
DATE:	7/23/24
ENGINEER:	Felix Trujillo, Jr.

Category/General Equip Description:	Printing Process
Equipment Specific Description:	Printing Press/Box Finishing - Flexographic – Non-Heatset
Equipment Size/Rating:	<6,371 lbs VOC/year (BACT #149) and ≥ 6,371 lbs VOC/year (BACT #176)
Previous BACT Det. No.:	149 & 176

A review of the District's permit database showed the District's only flexographic printing presses are for box finishing corrugated packaging operations. Therefore, this BACT determination will only apply to box finishing operations. The San Joaquin Valley Air Pollution Control District's graphic arts rule (Rule 4607) includes a category for flexographic specialty inks with VOC content limits that are higher than other flexographic inks. Sacramento Air Quality Management District's Rule 450 (Graphic Arts Operations) does not include a category for flexographic specialty inks. Therefore, SMAQMD Rule 450 is more stringent for these inks. The SMAQMD rule does not include any heat set flexographic printing operations. Therefore, this BACT will not address heat set flexographic printing operations.

BACT ANALYSIS

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

The following control technologies are currently employed as BACT for flexographic printing presses that are non-heatset by the following air pollution control districts:

United States Environmental Protection Agency (US EPA)

BACT
Source: EPA RACT/BACT/LAER Clearinghouse

A search of the EPA BACT Clearinghouse under Process Code 41.021 (Printing - Packaging) for a time period of 01/01/2014 to 05/03/24 resulted in the list down below for flexographic printing.

RBLC ID	Facility Name	Permit No.	Permit Date
WI-0297	Green Bay Packaging, Inc.	79-DMM-129	12/10/19
IL-0127	Winkpak Heat Seal Corporation	14040006	10/05/18
LA-0321	Graphic Packaging International, Inc.	PSD-LA-819	04/10/17
IA-0112	American Packaging Corporation	16-A-013-P	04/04/16

All of the above permits were based on PSD-BACT, which is based on a case-by-case basis and applied to major sources. This BACT will only apply to minor sources, therefore, these PSD BACTs will not be referenced under this BACT determination.

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

RULE REQUIREMENTS:
40 CFR 63 Subpart KK – National Emission Standards for the Printing and Publishing Industry

This regulation applies to facilities at which publication rotogravure, product and packaging rotogravure, or wide-web flexographic printing presses are operated and that are located at a plant site that is a major source of HAPs as defined in 40 CFR 63 Subpart A, §63.2. Although this NESHAP applies only to major sources of HAPs, it will be considered achieved in practice in the T-BACT evaluation for minor sources.

Subpart KK limits organic HAP emissions of product and packaging rotogravure or wide-web flexographic printing (capable of printing substrates greater than 18 inches in width) to the following:

§63.825(b) Each product and packaging rotogravure or wide-web flexographic printing affected source shall limit organic HAP emissions to no more than 5 percent of the organic HAP applied for the month; or to no more than 4 percent of the mass of inks, coatings, varnishes, adhesives, primers, solvents, reducers, thinners, and other materials applied for the month; or to no more than 20 percent of the mass of solids applied for the month; or to a calculated equivalent allowable mass based on the organic HAP and solids contents of the inks, coatings, varnishes, adhesives, primers, solvents, reducers, thinners, and other materials applied for the month.

California Air Resources Board (CARB)

BACT
Source: BACT Determination Tool
BACT Guideline Tool

CARB has revised their BACT Clearinghouse and it is now listed as the Technology Clearinghouse to comply with Assembly Bill 617 to establish and maintain a statewide Technology Clearinghouse. The Technology Clearinghouse includes two tools that relate to BACT. The BACT Determination Tool lists BACT determinations (contain limits that a specific piece of equipment (or process) has been required to meet within the district) from the California air districts and out of state agencies.

The BACT Guideline Tool lists guidelines (provide an overview of the limits that may be required when a source type is permitted) from the California air districts.

The BACT Determination Tool listed only one BACT determination from the SCAQMD under Application No. 377979 (6/27/01). This BACT is listed under the SCAQMD Major Source BACT category. This SMAQMD BACT will only apply to minor sources. Therefore, the SCAQMD BACT determination will not be referenced under this BACT determination.

The only BACTs that were listed under the BACT Guideline Tool were from the SJVAPCD, SCAQMD and BAAQMD. The referenced BACTs from these air districts are included in the BACT sections of these air districts under this BACT document. The BACT Guideline Tool also listed the now rescinded BACTs from the SJVAPCD, which are shown down below. These rescinded BACTs are no longer applicable and will not be referenced under this BACT determination.

BACT No.	Active Date	Title	Rescinded
4.7.4	9/22/06	Flexographic Printing – Corrugated Boxes, High End Graphics	8/16/23
4.7.5	2/25/98	Flexographic Printing – Heatset Inks on Low-Porosity Glossy Paper and Plastic Film	5/11/22
4.7.9	10/7/99	Flexographic Printer – High-End Graphics Printing on Clay Coated Paper	5/11/22
4.7.12	4/17/01	Flexographic Printing – High-End Graphics, Heat-Set Inks, on High-Porosity Material	8/16/23
4.7.14	11/9/04	Flexographic UV Printing – High-End Printing of Labels, Tags and Forms	8/16/23
4.7.15	9/22/06	Flexographic Printing – Corrugated Boxes, Low-End Graphics	8/16/23

RULE REQUIREMENTS:
None

Sacramento Metropolitan AQMD (SMAQMD)

BACT

Source: SMAQMD BACTs #'s 149 & 176 (12/22/17)

Flexographic Printing Press/Box Finishing That Are Non-Heatset (#149) Emitting < 8,683 Lbs Uncontrolled VOC Per Year	
VOC	Use of materials (as defined in SMAQMD Rule 450 – Graphic Arts) compliant with SMAQMD Rule 450, use of inks with a VOC content (less water and exempt compounds), use of adhesives with a VOC content (less water and exempt compounds) not exceeding 0.044 lb/gal, and no VOC clean-up solvents. (A)
NOx	No standard
SOx	No standard
PM10	No standard
PM2.5	No standard
CO	No standard

(A) The high-end and low-end graphics limits were derived from SJVAPCD BACT Guidelines 4.7.4 and 4.7.15, which were rescinded on 8/16/23 and are no longer applicable. Therefore, this BACT will re-evaluate the VOC content for inks and not refence the rescined BACTs and associated limits.

Flexographic Printing Press/Box Finishing That Are Non-Heatset (#176) Emitting ≥ 8,683 Lbs Uncontrolled VOC Per Year	
VOC	Use of materials (as defined in SMAQMD Rule 450 – Graphic Arts) compliant with SMAQMD Rule 450 – Graphic Arts, use of inks with a VOC content (less water and exempt compounds) of 0.3 lb/gal for low-end graphics, use of VOC content not exceeding 1.1 lb/gal (less water and exempt compounds) for high-end graphics, use of adhesives with a VOC content (less water and exempt compounds) not exceeding 0.044 lb/gal, no VOC clean-up solvents and a VOC control device that has an overall system efficiency (collection and destruction) of at least 98.5% for VOC. (A)
NOx	No standard
SOx	No standard
PM10	No standard
PM2.5	No standard
CO	No standard

(B) The high-end and low-end graphics limits were derived from SJVAPCD BACT Guidelines 4.7.4 and 4.7.15, which were rescinded on 8/16/23 and are no longer applicable. Therefore, this BACT will re-evaluate the VOC content for inks and not refence the rescined BACTs and associated limits.

The SMAQMD has a BACT trigger level of 0 lb/day.

T-BACT

T-BACT for Flexographic Printing Presses/Box Finishing that are Non-Heatset (#149) Emitting < 8,683 LBS Uncontrolled VOC per Year	
Pollutant	**Standard**
Organic HAP/VHAP (T-BACT)	Compliance with the flexographic printing presses/box finishing BACT VOC limits and HAP emission limits of Section 63.825(b) of 40 CFR 63 Subpart KK.

T-BACT for Flexographic Printing Presses/Box Finishing that are Non-Heatset (#176) Emitting ≥ 8,683 LBS Uncontrolled VOC per Year	
Pollutant	**Standard**
Organic HAP/VHAP (T-BACT)	Compliance with the flexographic printing presses/box finishing BACT VOC limits and HAP emission limits of Section 63.825(b) of 40 CFR 63 Subpart KK and a VOC control device that has an overall system efficiency (collection and destruction) of at least 98.5% for VOC.

RULE REQUIREMENTS:

Rule 450 – Graphic Arts Operations (10/23/2008)

MATERIAL TYPE	**VOC CONTENT LIMITS g/l (lb/gal) Less water and exempt compounds**
Printing Ink	300 (2.5)
Adhesive	150 (1.25)
Coating	300 (2.5)

VOC Content for Solvent Cleaning Materials:

Material Type	**VOC Content Limits g/l (lb/gal) Including Water and Exempt Compounds**
General (e.g., maintenance, repair, solvent, wipe) Cleaning	25 (0.21)
Application Equipment Cleaning	

Material Type	VOC Content Limits g/l (lb/gal) Including Water and Exempt Compounds
General (not specifically listed below)	25 (0.21)
Flexographic Printing	25 (0.21)
Specialty Flexographic Printing (A)	100 (0.83)
Ultraviolet/Electron Bean Inks (Except Screen Printing)	100 (0.83)

(A) Specialty flexographic printing applies to printing on polyethylene, polyester and foil substrates. This BACT applies to box finishing, which does not cover these types of substrates. Therefore, this limit does not apply.

Control Devices Control Efficiency:
Control Devices for flexographic Printing Presses must have an overall system efficiency of 67%.

South Coast AQMD (SCAQMD)

BACT
Source: SCAQMD BACT Guidelines for Non-Major Polluting Facilities, page 103

Printing (Graphic Arts) - Flexographic	
VOC	Inks with ≤ 1.5 lbs VOC/gal, less water and exempt compounds (1990); or use of UV/EB or water-based inks/coatings ≤ 180 g VOC/L. Compliance with AQMD rules 1130 and 1171 (2-2-2018)
NOx	No standard
SOx	No standard
PM10	No standard
PM2.5	No standard
CO	No standard

The SCAQMD has a BACT trigger level of 1 lb/day.

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

RULE REQUIREMENTS:

Reg XI, Rule 1130 – Graphic Arts (5/2/2014)

Graphic Art Material	VOC Content Limits g/l (lb/gal) Less water and exempt compounds
Adhesive	150 (1.25)
Coating	300 (2.5)
Flexographic Fluorescent Ink	300 (2.5)
Flexographic Ink: Non-Porous Substrate	300 (2.5)
Flexographic Ink: Porous Substrate	225 (1.9)

An emission control device must have a control efficiency of at least 95% and the emission collection system must have a collection efficiency of at least 90%.

Reg XI, Rule 1171 – Solvent Cleaning Operations (5/1/2009)

Solvent Cleaning Activity	VOC Limits g/l (lb/gal)
Cleaning of Coatings or Adhesives Application Equipment	25 (0.21)
Cleaning of Ink Application Equipment	
General	25 (0.21)
Flexographic Printing	25 (0.21))
Specialty Flexographic Printing (A)	100 (0.83)
Ultraviolet Ink/Electron Beam Ink Application Equipment (except screen printing)	100 (0.83)

(A) Specialty flexographic printing applies to printing on polyethylene, polyester and foil substrates. This BACT applies to box finishing, which does not cover these types of substrates. Therefore, this limit does not apply.

San Joaquin Valley APCD (SJVAPCD)

BACT

Source: SJVAPCD BACT Guideline 4.9.12 (9/22/06)

Corrugated Box Gluer	
VOC	Use of adhesives with a VOC content of 0.021 lb-VOC/gal (less water and exempt compounds)
NOx	No standard
SOx	No standard
PM10	No standard
PM2.5	No standard
CO	No standard

The SJVAPCD has a BACT trigger level of 2 lb/day.

RULE REQUIREMENTS:

Rule 4607 – Graphic Arts and Paper, Film, Foil and Fabric Coatings (12/18/2008)

VOC content limits for inks, coatings, and adhesives

Material	Grams of VOC per liter (lb/gal), less water and exempt compounds, as applied
Flexographic Ink on Porous Substrates	225 (1.88)
Inks	300 (2.5)
Coatings	300 (2.5)
Adhesives	150 (1.25)

VOC content limits for flexographic specialty ink

Material	Grams of VOC per liter (lb/gal), less water and exempt compounds, as applied
Metallic Ink	460 (3.8)
Matte Finish Ink	535 (4.5)
Metallic Ink and Matte Finish Ink on Flexible Package Printing	383 (3.2)

VOC content limits for solvent cleaning

Type of Solvent Cleaning Operation	Limit Grams of VOC/Liter of Material (lb/gal)
Product Cleaning During Manufacturing Process; or Surface Preparation for Coating, Ink, or Adhesive Application	25 (0.21)
Repair and Maintenance Cleaning	25 (0.21)
Cleaning of Coating or Adhesive Application Equipment	25 (0.21)
Cleaning of Ink Application Equipment	
General and Flexographic Printing	25 (0.21)
Cleaning of Ink Application Equipment	
Ultraviolet Ink/Electron Beam Ink Application Equipment (except screen printing)	100 (0.83)

Flexographic printing presses venting to a control device must have an overall capture and control efficiency of 75% on a mass basis.

San Diego County APCD (SDAPCD)

Source: NSR Requirements for BACT, page 45

Graphic Arts Operations (< 5 tons/year)	
VOC	1. Use of low VOC fountain solution (< 6% VOC by volume), 2. Capture & recycle blanket and roller tray wash, 3. Use of cleanup solvent which has either less than 200 g VOC/l or vapor pressure of less than 5 mm HG at 20^{O}C, and 4. Use of metering roll cleanup solvent which has either less than 100 g VOC/l or vapor pressure less than 10 mm HG at 20^{O}C, and 5. Use of inks which have a VOC content of less than 300 g/l (2.5 lb/gal)
NOx	No standard
SOx	No standard
PM10	No standard
PM2.5	No standard
CO	No standard

The SDCAPCD has a BACT trigger level of 10 lb/day. The applicant may choose to limit the potential to emit from the equipment to less than 10 lb/day for each pollutant in lieu of meeting the stated BACT requirement.

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

RULE REQUIREMENTS:

Regulation 4, Rule 67.16 – Graphic Arts Operations (Adopted 11/9/2011 & Effective 05/09/12)

a) Graphic arts materials, except adhesives, must contain < 300 g VOC/l (2.5 lb/gal)

b) Adhesives containing not more than 150 grams of VOC per liter (1.25 lb/gal), as applied, less water and less exempt compounds

c) Fountain solutions containing not more than 5% VOC by volume or fountain solutions containing not more than 8.5% VOC by volume refrigerated to a temperature below 60 degrees F

d) Cleaning material must have a VOC content less than 100 g/l or the total VOC vapor pressure of the cleaning material is 5mm of Hg at 20^{O}C or less.

Control devices must have a capture and control efficiency of 85% by weight.

Bay Area AQMD (BAAQMD)

Source: BAAQMD BACT Guidelines, Document #83.1, 06/20/95

Flexographic Printing Line	
VOC	Water reducible inks with either: < 1.5 lb VOC/gal coating or < 10% by volume VOC: and no VOC clean-up solvents
NOx	No standard
SOx	No standard
PM10	No standard
PM2.5	No standard
CO	No standard

The BAAQMD has a BACT trigger level of 10 lb/day.

T-BACT
This guideline also lists these standards as TBACT.

RULE REQUIREMENTS:

Reg 8, Rule 20 – Graphic Arts Printing and Coating Operations (11/19/2008)

Product	**Product Limit** **grams VOC per liter of product as applied, less water and exempt solvent** **(lbs/gal)**
	Less than:
Ink	300 (2.5)
Flexographic Ink Porous Substrate	225 (1.9)
Flexographic Ink Non-Porous Substrate	300 (2.5)
Coating	300 (2.5)
Adhesive	150 (1.25)
Web Splicing Adhesive	300 (2.5)

Cleaning Product Limits:

Equipment	**VOC g/l (lb/gal) including water**
For Press Equipment, except Other Press Parts	
Flexographic Press	25 (0.21)
Specialty Flexographic Press	100 (0.83)
Adhesive Application Equipment	25 (0.21)
Ultraviolet Ink Removal, Any Press Type	100 (0.83)
Other Press Parts	25 (0.21)

Emission control systems must have an overall efficiency of 75% on a mass basis.

Summary of Achieved in Practice Control Technologies

SUMMARY OF ACHIEVED IN PRACTICE CONTROL TECHNOLOGIES	
VOC	1. Use of inks with < 1.5 lbs VOC/gal, less water and exempt compounds; or use of UV/EB or water-based inks/coatings < 180 g VOC/L (1.5 lbs VOC/gal), less water and exempt compounds, and use of adhesives with a VOC content not exceeding 0.021 lb/gal, less water and exempt compounds. No VOC clean-up solvents with use of water-based inks/coatings. – [BAAQMD, SCAQMD, SJVAPCD] 2. Use of materials compliant with SCAQMD Rule 1130 and 1171, BAAQMD Regulation 8 Rule 20, SJVAPCD Rule 4607 or SMAQMD Rule 450. – [SCAQMD, SMAQMD, BAAQMD, SJVAPCD] 3. Use of materials compliant with SDCAPCD Rule 67.16. – [SDCAPCD]
NOx	No standard – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]
SOx	No standard – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]
PM10	No standard – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]
PM2.5	No standard – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]
CO	No standard – [SMAQMD, SCAQMD, SDCAPCD, BAAQMD, SJVAPCD]

Emission limits for inks, coatings, adhesives and solvent cleaning are consistent across SCAQMD Rule 1130 and 1171, SMAQMD Rule 450, BAAQMD Regulation 8 Rule 20 and SJVAPCD Rule 4607. The difference is the SJVAPCD Rule 4607 includes a category for flexographic specialty inks, with VOC content limits that are higher than for other flexographic inks, while the SMAQMD Rule 450 does not. Therefore, SMAQMD Rule 450 is more stringent for these inks. Also, the SCAQMD, BAAQMD and SJVAPCD rules separate the ink into porous (225 g/l) and non-porous (300 g/l) substrates, which the SMAQMD does not. For this application, the SCAQMD, BAAQMD and SJVAPCD rules would be more stringent for porous substrates. But this will not affect the selection of BACT for the ink, because the BACT limit will be set by the BAAQMD and SCAQMD BACTs. The BAAQMD BACT #83.1 has not been updated since 1995 and only shows the use of water-based inks with less than 1.5 lb VOC/gal and no VOC clean-up solvents. It has been shown that UV/EB inks are also low VOC emitting (https://www3.epa.gov/ttn/catc/cica/files/fuv-eb.pdf) and have been included on the SCAQMD BACT as an option in addition to the water-based inks and coatings. SMAQMD Rule 450 and SCAQMD Rule 1171 allow a higher VOC content for solvent cleaning for UV/EB inks, which will be addressed by compliance with Rule 450. The cleaning of the coatings will be addressed by the Flexographic Printing limit of Rule 450 (0.21 lb VOC/gal, including water and exempt compounds), since there is no specific limit for UV/EB coatings. Therefore, this BACT will combine the BACT requirements from the BAAQMD and SCAQMD.

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

BEST CONTROL TECHNOLOGIES ACHIEVED		
Pollutant	**Standard**	**Source**
VOC	Use of materials compliant with SMAQMD Rule 450 – Graphic Arts, use of inks with < 1.5 lbs VOC/gal, less water and exempt compounds; or use of UV/EB or water-based inks/coatings < 180 g VOC/L (1.5 lbs VOC/gal), less water and exempt compounds, and use of adhesives with a VOC content not exceeding 0.021 lb/gal, less water and exempt compounds. No VOC clean-up solvents with use of water-based inks/coatings.	BAAQMD, SCAQMD, SJVAPCD
NOx	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
SOx	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
PM10	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
PM2.5	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
CO	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD

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 2. Carbon adsorber
NOx	None
SOx	None
PM10	None

Pollutant	Technologically Feasible Alternatives
PM2.5	None
CO	None

VOCs: As shown above, thermal oxidation and carbon adsorption are technologically feasible. According to the BAAQMD BACT Guideline 83.1, an overall system efficiency (capture and control efficiencies combined) of 98.5% for VOCs is technologically feasible for these types of operations.

Cost Effectiveness 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)
VOC	25,300
NO_X	35,300
PM10	11,400
SO_X	18,300
CO	300

Cost Effectiveness Analysis Summary

The cost analysis was processed in accordance with the EPA OAQPS Air Pollution Control Cost Manual (Sixth Edition). The sales tax rate was based on the District's standard rate of 8.5% as approved on 10/17/16. The electricity (11.24 cents/kWh) and natural gas (6.41 dollars/1,000 cubic feet) rates were based on an industrial application as approved by the District on 10/17/16. 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 and addition of two percentage points and rounding up the next higher integer rate. The labor (Occupation Code 51-5112: Printing press operators) and maintenance (Occupation Code 49-9099: Installation, maintenance, and repair workers, all others) rates were based on data from the Bureau of Labor Statistics for California.

A. Carbon Adsorber:

As shown in Attachment B, the cost effectiveness for the add on carbon adsorber system to control VOC was calculated to be **$25,300.06/ton**. The following basic parameters were used in the analysis.

Equipment Life = 15 years

Total Capital Investment = $426,981

Direct Annual Cost = $11,548 per year

Indirect Annual Cost = $69,918 per year

Recovery Credit = - $2,071 per year

Total Annual Cost = $79,395 per year

VOC Removed = 3 tons per year

Cost of VOC Removal = $25,300.06 per ton reduced

A detailed calculation of the cost effectiveness for VOC removal with a carbon absorber is shown in Attachment B. **Uncontrolled** VOC emissions of **6,371 lb/year** or greater is the cost-effective threshold for control equipment using carbon absorption control technology.

B. Thermal Oxidizer:

Equipment Life = 20 years

Direct Cost = $1,750,236

Direct Annual Cost = $73,874 per year

Indirect Annual Cost = $241,345 per year

Total Annual Cost = $315,219 per year

VOC Removed = 8.9 tons per year

Cost of VOC Removal = $35,300 per ton reduced

A detailed calculation of the cost effectiveness for VOC removal with a thermal oxidizer is shown in Attachment B. **Uncontrolled** VOC emissions of **17,800 lb/year** or greater is the cost-effective threshold for control equipment using thermal oxidation control technology.

Conclusion: In this analysis, different emission operating levels are presented with the corresponding total cost per ton of VOC controlled using either a carbon adsorption control or a thermal oxidizer. Uncontrolled VOC emission level of 6,371 lb per year or greater must be reached in order for the carbon adsorption control option to be cost effective. Uncontrolled VOC emission level of 17,800 lb per year or greater must be reached in order for a thermal oxidizer to be cost effective. The emissions level for the cost effectiveness of controls is based on the District cost effective limit for VOC of $25,300 per ton controlled.

With EPA's cost data, the highest allowable uncontrolled emission rate to not require add-on control devices will be updated to 6,371 lb/year based on the cost of carbon adsorption.

C: SELECTION OF BACT

BACT FOR FLEXOGRAPHIC PRINTING PRESS/BOX FINISHING THAT ARE NON-HEATSET (#365) EMITTING < 6,371 LBS UNCONTROLLED VOC PER YEAR		
Pollutant	**Standard**	**Source**
VOC	Use of materials compliant with SMAQMD Rule 450 – Graphic Arts, use of inks with < 1.5 lbs VOC/gal, less water and exempt compounds; or use of UV/EB or water-based inks/coatings < 180 g VOC/L (1.5 lbs VOC/gal), less water and exempt compounds, and use of adhesives with a VOC content not exceeding 0.021 lb/gal, less water and exempt compounds. No VOC clean-up solvents with use of water-based inks/coatings.	SMAQMD, SCAQMD, BAAQMD
NOx	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
SOx	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
PM10	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
PM2.5	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
CO	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD

BACT FOR FLEXOGRAPHIC PRINTING PRESS/BOX FINISHING THAT ARE NON-HEATSET (#366) EMITTING ≥ 6,371 LBS UNCONTROLLED VOC PER YEAR		
Pollutant	**Standard**	**Source**
VOC	Use of materials compliant with SMAQMD Rule 450 – Graphic Arts, use of inks with < 1.5 lbs VOC/gal, less water and exempt compounds; or use of UV/EB or water-based inks/coatings < 180 g VOC/L (1.5 lbs VOC/gal), less water and exempt compounds, and use of adhesives with a VOC content not exceeding 0.021 lb/gal, less water and exempt compounds. No VOC clean-up solvents with use of water-based inks/coatings. A VOC control device that has an overall system efficiency (collection and destruction) of at least 98.5% for VOC.	SMAQMD, SCAQMD, BAAQMD
NOx	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
SOx	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
PM10	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
PM2.5	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD
CO	No standard	SMAQMD, SCAQMD, SJVAPCD, SDCAPCD, BAAQMD

D: SELECTION OF T-BACT

Toxics are in the form of VOCs and may also be exempt compounds. T-BACT for flexographic printing presses/box finishing operations was determined to be the following:

T-BACT FOR FLEXOGRAPHIC PRINTING PRESSES/BOX FINISHING THAT ARE NON-HEATSET (#365) EMITTING < 6,371 LBS UNCONTROLLED VOC PER YEAR		
Pollutant	**Standard**	**Source**
Organic HAP/VHAP (T-BACT)	1. Compliance with the flexographic printing presses/box finishing BACT VOC limits and HAP emission limits of Section 63.825(b) of 40 CFR 63 Subpart KK.	NESHAP 40 CFR 63 Subpart KK

T-BACT FOR FLEXOGRAPHIC PRINTING PRESSES/BOX FINISHING THAT ARE NON-HEATSET (#366) EMITTING ≥ 6,371 LBS UNCONTROLLED VOC PER YEAR		
Pollutant	**Standard**	**Source**
Organic HAP/VHAP (T-BACT)	1. Compliance with the flexographic printing presses/box finishing BACT VOC limits and HAP emission limits of Section 63.825(b) of 40 CFR 63 Subpart KK and a VOC control device that has an overall system efficiency (collection and destruction) of at least 98.5% for VOC.	NESHAP 40 CFR 63 Subpart KK BAAQMD BACT Guideline 83.1

Approved by: Brian F Krebs **Date:** 07-23-2024

Attachment A
Review of BACT Determination

ACTIVE SMAQMD BACT CLEARINGHOUSE

CATEGORY: **FLEXOGRAPHIC PRESS NON-HEATSET**

BACT Size: Minor Source BACT **PRINTING PRESS**

BACT Determination Number: 149	**BACT Determination Date:** 12/22/2017

Equipment Information

Permit Number: 24803
Equipment Description: PRINTING PRESS
Unit Size/Rating/Capacity: < 8,683 LBS/YEAR UNCONTROLLED VOC
Equipment Location: OFFICE OF STATE PUBLISHING
4225 PELL DR
SACRAMENTO, CA

BACT Determination Information

ROCs	**Standard:**	See Comments
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	No Standard
	Technology Description:	
	Basis:	
SOx	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM10	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM2.5	**Standard:**	No Standard
	Technology Description:	
	Basis:	
CO	**Standard:**	No Standard
	Technology Description:	
	Basis:	
LEAD	**Standard:**	No Standard
	Technology Description:	
	Basis:	

Comments: BACT: Use of material (as defined in SMAQMD Rule 450 - Graphic Arts) compliant with SMAQMD Rule 450, use of inks with a VOC content (less water and exempt compounds) of 0.3 lb/gal for low end graphics, use of ink with a VOC content not exceeding 1.1 lb/gal (less water and exempt compounds) for high-end graphics, use of adhesives with a VOC content (less water and exempt compounds) not exceeding 0.044 lb/gal and no VOC clean-up solvents. TBACT: Compliance with VOC BACT and HAP emission limits of Section 63.825(b) of 40 CFR 63 Subpart kk.

District Contact: Felix Trujillo Phone No.: (916)874-7357 email: jquok@airquality.org

Printed: 1/24/2018

CATEGORY: **FLEXOGRAPHIC PRESS NON-HEATSET**

BACT Size: **PRINTING PRESS**

BACT Determination Number: 176	**BACT Determination Date:** 12/22/2017

Equipment Information

Permit Number: 24803

Equipment Description: PRINTING PRESS

Unit Size/Rating/Capacity: ≥ 8,683 LBS/YEAR UNCONTROLLED VOC

Equipment Location: PACKAGE ONE
4225 PELL DR
SACRAMENTO, CA

BACT Determination Information

ROCs	**Standard:**	See comments
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	No Standard
	Technology Description:	
	Basis:	
SOx	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM10	**Standard:**	No Standard
	Technology Description:	
	Basis:	
PM2.5	**Standard:**	No Standard
	Technology Description:	
	Basis:	
CO	**Standard:**	No Standard
	Technology Description:	
	Basis:	
LEAD	**Standard:**	No Standard
	Technology Description:	
	Basis:	

Comments: BACT: Use of material (as defined in SMAQMD Rule 450 - Graphic Arts) compliant with SMAQMD Rule 450, use of inks with a VOC content (less water and exempt compounds) of 0.3 lb/gal for low end graphics, use of ink with a VOC content not exceeding 1.1 lb/gal (less water and exempt compounds) for high-end graphics, use of adhesives with a VOC content (less water and exempt compounds) not exceeding 0.044 lb/gal, no VOC clean-up solvents and a VOC control device that has an overall system efficiency (collection and destruction) of at least 98.5% for VOC. TBACT: Compliance with VOC

District Contact: Felix Trujillo Phone No.: (916) 874 - 7357 email: ftrujillo@airquality.org

San Joaquin Valley
Unified Air Pollution Control District

Best Available Control Technology (BACT) Guideline 4.9.12*

Last Update: 8/29/2018

Corrugated Box Gluer

Pollutant	Achieved in Practice or contained in the SIP	Technologically Feasible	Alternate Basic Equipment
VOC	Use of adhesives with a VOC content of 0.021 lb-VOC/gal (less water and exempt compounds)	1. VOC Capture and Thermal/Catalytic Oxidation 2. VOC Capture and Carbon Adsorption	

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 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**

10-20-2000 Rev. 0
12-5-2003 Rev. 1
7-14-2006 Rev. 2
2-2-2018 Rev. 3
2-1-2019 Rev. 4
9-2-2022 Rev. 5

Equipment or Process: Printing (Graphic Arts)

	Criteria Pollutants					
Subcategory	**VOC**	**NOx**	**SOx**	**CO**	**PM_{10}**	**Inorganic**
Flexographic	Inks with ≤ 1.5 Lbs VOC/Gal, Less Water and Less Exempt Compounds (1990); or use of UV/EB or water-based inks/coatings ≤ 180 g VOC/L. Compliance with Rules 1130 and 1171 (2-2-2018)					
Alternatively	For add-on control required by Rule 1130(c)(5) or other South Coast AQMD requirement: EPA M. 204 Permanent Total Enclosure (100% collection) vented to thermal oxidizer with 95% overall control efficiency; Combustion Chamber: Temp ≥ 1500°F[1], Retention Time > 0.3 seconds (2-2-2018)	Compliance with BACT requirements for Thermal Oxidizer		Compliance with BACT requirements for Thermal Oxidizer		
Letterpress	Compliance with Rules 1130 and 1171 (12-5-2003)					

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

BAY AREA AIR QUALITY MANAGEMENT DISTRICT
Best Available Control Technology (BACT) Guideline

Source Category

Source:	*Flexographic Printing Line*	Revision:	*2*
		Document #:	*83.1*
Class:	*All*	Date:	*06/20/95*

Determination

POLLUTANT	BACT 1. Technologically Feasible/ Cost Effective 2. Achieved in Practice	TYPICAL TECHNOLOGY
POC	1. Water reducible inks w/ <1 lb VOC/gal of coating and no VOC clean-up solvents. If cost-effective, capture and vent VOC to afterburner or carbon adsorption sytem w/ $\geq$ 98.5% destruction/recovery device efficiency, or VOC outlet $\leq$10 ppmv[a,b,T] 2. *Water reducible inks w/ either: <1.5 lb VOC/gal coating or <10% by volume VOC; and no VOC clean-up solvnets*[a,T]	1. *Low VOC Coatings and no VOC clean-up solvents; or BAAQMD approved Collection System and Abatement Device*[a,b,T] 2. *Low VOC Coatings and no VOC clean-up solvents*[a,T]
NOx	1. *n/a* 2. *n/a*	1. *n/a* 2. *n/a*
SO_2	1. *n/a* 2. *n/a*	1. *n/a* 2. *n/a*
CO	1. *n/a* 2. *n/a*	1. *n/a* 2. *n/a*
PM_{10}	1. *n/a* 2. *n/a*	1. *n/a* 2. *n/a*
NPOC	1. *Same as for POC above*[a,b,T] 2. *Same as for POC above*[a,b,T]	1. *Low or no NPOC Coatings and Solvents: or BAAQMD Approved Abatement System*[a,b,T] 2. *Low NPOC Coatings and Solvents*[a,T]

References

a. BAAQMD
b. For abatement devices, the following are acceptable: $\leq$10 ppmv at outlet; or $\geq$98.5% destruction/recovery efficiency if inlet VOC $\geq$2000 ppmv: or $\geq$97% efficiency if inlet VOC $\geq$200 to <2000 ppmv: or $\geq$90% efficiency if inlet VOC <200 ppmv.
T. TBACT

GRAPHIC ARTS OPERATDONS (< 5 tons/year)

Fee Schedule 27 N

The BACT Control Options which have been determined to be technologically feasible (T/F - demonstrated but not necessarily proven in field application) or have achieved the BACT emission rate limits in practice (A/P - demonstrated in use for the specific equipment category) are listed below. The BACT Control Options are listed in descending order of control stringency. If the top-listed T/F control option is proposed, no further analysis is required. If the first T/F control option is not chosen, then the applicant must review and determine the cost-effectiveness of each T/F control option in the order listed. The first control option determined to be cost-effective must be installed to meet the BACT requirement. A control option is considered cost-effective if the annualized cost of implementing that control option is equal to or less than the reference cost-effectiveness value for the same pollutant shown in Table 2-4. If none of the T/F control options are determined to be cost-effective, the applicant must propose the A/P control option, propose an alternative technology that meets the BACT emission rate limit or perform a full Top-down BACT Analysis as described in Section 4. The applicant is responsible for ensuring that the installed equipment meets the specified BACT Emission Rate Limit. (See Section 2 for further guidance.)

	VOC	NOx	SOx	PM
BACT Control Option	1. Use of low VOC fountain solution (< 5% VOC by volume), 2. Capture & recycle blanket and roller tray wash, 3. Use of cleanup solvent which has either less than 100 grams VOC per liter or vapor pressure of less than 5 mm HG at 20°C, 4. Use of metering roll cleanup solvent which has either less than 100 grams VOC per liter or vapor pressure of less than 5 mm HG at 20°C, and 5. Use of inks which have a VOC content of less than 225 grams per liter (1.9 lb/gal). (T/F) BACT emission rate limit not determined.	(N/A)	(N/A)	(N/A)
BACT Control Option	1. Use of low VOC fountain solution (< 6% VOC by volume), 2. Capture & recycle blanket and roller tray wash, 3. Use of cleanup solvent which has either less than 200 grams VOC per liter or vapor pressure of less than 5 mm HG at 20°C, and 4. Use of metering roll cleanup solvent which has either less than 100 grams VOC per liter or vapor pressure of less than 10 mm HG at 20°C, and 5. Use of inks which have a VOC content of less than 300 grams per liter (2.5 lb/gal). (A/P) BACT emission rate limit not determined.	(N/A)	(N/A)	(N/A)

The applicant may choose to limit the Potential to Emit (PTE) from the equipment to less than 10 pounds per day for each pollutant in lieu of meeting the stated BACT requirement.

Attachment B

Cost Effectiveness Analysis for Carbon Adsorption

Data Inputs

Select the type of carbon adsorber system: Fixed-Bed Carbon Adsorber with Steam Regeneration

For fixed-bed carbon adsorbers, provide the following information:

Select the type of operation: Continuous Operation

Select the type of material used to fabricate the carbon adsorber vessels: Stainless Steel, 304

Select the orientation for the adsorber vessels: Horizontal

Enter the design data for the proposed Fixed-Bed Carbon Adsorber with Steam Regeneration

Number of operating hours per year (Θ_s)	2,080	hours/year	
Waste Gas Flow Rate (Q)	10,000	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	3.063	lbs/hour	
Required VOC removal efficiency (E)	98.5	percent	
Superficial Bed Velocity (v_b)	75.00	ft/min	
Estimated equipment life of adsorber vessels and auxiliary Equipment (n)	15	Years*	* 15 years is a default equipment life. User should enter actual value, if known.
Estimated Carbon life (n)	5	Years	
Total Number of carbon beds (N_{total})	3	Beds*	* 3 beds is the default. User should enter actual number of beds, if known.
Number of carbon beds adsorbing VOC when system is operating (N_A)	2	Beds*	* 2 beds is the default. User should enter actual number of beds, if known.
Total time for adsorption (Θ_A)	12	hours*	* 12 hours is a default value. User should enter actual value, if known.
Total time for desorption (Θ_D)	5	hours*	* 5 hours is a default value. User should enter actual value, if known.
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	Toluene	
Partial Pressure of Toluene in waste gas stream	0.0104	psia
Parameter "k" for Toluene	0.551	**Note:** Typical values of "k" and "m" for some common VOCs are shown in Table A.
Parameter "m" for Toluene	0.110	

Enter the cost data for the carbon adsorber:

Desired dollar-year	2024			
CEPCI* for 2024	800.3	CEPCI value for 2024	390.6	1999
Annual Interest Rate (i)	7	percent (Current bank prime rate)		

* CEPCI is the Chemical Engineering Plant Cost Index. The use of CEPCI in this spreadsheet is not an endorsement of the index for purpose 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.

Electricity (P_{elec})	$0.1124	per kWh	
Steam (P_s)	$5.00	per 1,000 lbs*	* $5.00/1,000 lbs is a default value. User should enter actual value, if known.
Cooling Water (P_{cw})	$3.55	per 1,000 gallons of water*	* $3.55/1,000 gallons is a default value. User should enter actual value, if known.
Operator Labor Rate	$22.76	per hour	
Maintenance Labor Rate	$26.18	per hour	
Carbon Cost (CC)	$4.20	per lb	* $4.20/lb is a default value based on 2018 market price. User should enter actual value, if known.
Re-Sale Value of Recovered VOC (P_{voc})	$0.33	per lb*	* $0.33/lb is a default value for recovered toluene based on 2018 data. User should enter actual value of recovered
Disposal/Treatment Cost for Recovered VOC (D_{voc})	$0.00	per lb*	* $0/lb is a default value for disposal and/or treatment of recovered VOC/HAP. User should enter actual value, if known.

If known, enter any additional costs for site preparation and building construction/modification:

Site Preparation (SP) =	$0	* Default value. User should enter actual value, if known.
Buildings (Bldg) =	$0	* Default value. User should enter actual value, if known.
Equipment Costs for auxiliary equipment (e.g., ductwork, dampers, and stack) (EC_{aux}) =	$32,000	* Default value. User should enter actual value, if known.
Contingency Factor (CF)	10.0 percent*	* 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Data Sources for Default Values Used in Calculations:

Design Parameters

The following design parameters for the carbon adsorber 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.

Type of Carbon Adsorber:	**Fixed-Bed Carbon Adsorber with Steam Regeneration**
Name of VOC Controlled:	**Toluene**

Parameter	Equation	Calculated Value	Units
Quantity of Toluene Recovered:			
Quantity of Toluene Recovered (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	3.138	tons/year
Time required for Desorption (Θ_D) =		5	hours
Time for Adsorption (Θ_A) =		12	hours
Time Available for Desorption =	$\Theta_A (N_D/N_A) =$	6	hours
Adsorber Parameters:			
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.333	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.167	lb. VOC/lb. Carbon
Adjustment Factor for Adorber Vessel Material (F_m) =		1.0	(* Stainless Steel, 304)
Number of Bed Desorbing (N_D) =	$N_{total} - N_A =$	1	Bed
Number of Bed Adsorbing (N_A) =		2	Bed
Volumetric Flow Rate for each Vessel (Q') =	$Q/N_A =$	5,000	acfm/Bed
Carbon Bed Thickness (t_b) =	$(M_c'/\rho_b)/(Q'/v_b)$, where the density of carbon (pb) = 30 lb/sq.ft	0.06	ft.
Pressure Drop (ΔP_s) =	$t_b \times (0.03679 v_b + 1.107 \times 10^{-4} v_b^2) + 1 =$	1.19	inches
Cooling Fan Operating Time (Θ_{cf}) =	$0.4 \times \Theta_D \times (N_A \times \Theta_s)/\Theta_A =$	693	hours
Estimated Carbon Required:			
Estimated Carbon Consumption (M_c) for a continuously operated system =	$(m_{voc}/w_c) \times \Theta_A (1 + N_D/N_A) =$	331	lbs.
Carbon Required for each Vessel (M_c') =	$M_c/(N_A + N_D) =$	110	lbs./Bed
Estimated Adsorber Vessel Dimensions and Surface Area:			
Vessel Orientation =		Horizontal	
Vessel Diameter (D) =	$(0.127 \times M_c' \times v_b)/Q' =$	0.21	ft.
Vessel Length (L) =	$(7.87/Mc') \times (Q'/v_b)^2 =$	317.28	ft.
Surface Area of Adsorber Vessel (S) =	$\pi \times D \times (L+D/2) =$	209	sq.ft
Electricity Consumption:			
Electricity Consumed by the system fan (Q_{sf}) =	$(0.746 kW/hp) \times 2.5 \times 10^{-4} \times Q \times \Delta P_s \times \Theta_s =$	4,602	kWh/year
Electricity Consumed by the cooling fan (Q_{cf}) =	$(0.746 kW/hp) \times 2.5 \times 10^{-4} \times Q_{cf} \times \Delta P_s \times \Theta_{cf} =$	460	kWh/year
Electricity Consumed by the Cooling Water Fan (Q_{cwf}) =	$(0.746 kW/hp) \times [2.52 \times 10^{-4} \times 100/\eta] \times [\Theta_{cwp}/(0.6 \times \Theta_D \times N_A \times \Theta_D/\Theta_A) \times 60 \text{ mins/hour}] =$	132	kWh/year
Total Estimated Electricity Consumption (Q_{Elec}) =	Qsf + Qcf + Qcsf =	5,194	kWh/year
Steam Consumption:			
Total Steam Consumption (Q_{Steam}) =	$= 3.5 \times M_{voc} \times \Theta_s =$	22,301	lbs./year
Cooling Water Consumption:			
Total Cooling Water Consumption (Q_{cw}) =	$= 3.43 \times C_s/P_s =$	76,494	gallons/year
Capital Recovery Factor:			
Capital Recovery Factor for adsorber vessels and auxiliary equipment (CFRabsorber)=	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Equipment Life and i = Interest Rate	0.1098	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.2439	

Cost Estimate

Capital Costs

Estimated capital costs for a Fixed-Bed Carbon Adsorber with Steam Regeneration with the following characteristics:

VOC Controlled/Recovered =	Toluene
Adsorber Vessel Orientation =	Horizontal
Operating Schedule =	Continuous Operation

Total Capital Investment (TCI) (in 2024 dollars)

Parameter	Equation	Cost
Costs for Each Carbon Adsorber Vessel (C_v) =	$271 \times F_m \times S^{0.778}$ =	$35,499
Total Cost for All Carbon Adsorber Vessels and Carbon(EC_{Adsorb}) =	$5.82 \times Q^{-0.133} \times [C_c + (N_A + N_D) \times C_v]$ =	$184,453
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$32,000
Total Purchased Equipment Costs for Carbon Adsorber (A) =	= $EC_{Adsorb} + EC_{aux}$ =	$216,453
Instrumentation =	0.10 × A =	Included in A
Sales taxes =	0.085 × A =	$18,398
Freight =	0.05 × A =	$10,823
	Total Purchased Equipment Costs (B) =	$245,674

Direct Installation Costs (in 2024 dollars)

Parameter	Equation	Cost
Foundations and Supports =	0.08 × B =	$19,654
Handling and Erection =	0.14 × B =	$34,394
Electrical =	0.04 × B =	$9,827
Piping =	0.02 × B =	$4,913
Insulation =	0.01 × B =	$2,457
Painting =	0.01 × B =	$2,457
Site Preparation (SP) =		$0
Buildings (Bldg) =		$0
	Total Direct Costs (DC) = B + (0.3 × B) + SP + Bldg =	$319,376

Total Indirect Installation Costs (in 2024 dollars)

Parameter	Equation	Cost
Engineering =	0.10 × B =	$24,567
Construction and field expenses =	0.05 × B =	$12,284
Contractor fees =	0.10 × B =	$24,567
Start-up =	0.02 × B =	$4,913
Performance test =	0.01 × B =	$2,457
	Total Indirect Costs (IC) =	$68,789
Contingency Cost (C) =	CF(IC+DC)=	$38,816
Total Capital Investment (TCI) =	**DC + IC + C = (1.28 × B) + SP + Bldg. + C =**	**$426,981** in 2024 dollars

Annual Costs

Direct Annual Costs

Parameter	Equation	Cost
Annual Electricity Cost =	$Q_{Elec} \times P_{elec}$ =	$584
Annual Steam Cost (C_s) =	$3.50 \times m_{voc} \times \Theta_s \times P_s$ =	$112
Annual Cooling Water Cost (C_{cs}) =	$3.43 \times C_s/P_s \times P_{wc}$ =	$272
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$2,959
	Supervisor = 15% of Operator	$444
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$3,403
	Materials = 100% of maintenance labor	$3,403
Carbon Replacement Costs:	Labor = $CRF_{carbon} \times (\text{Labor Rate} \times M_c)/CRR$ =	$6
	Carbon = $CRF_{carbon} \times CC \times M_c \times 1.08$ =	$366
Direct Annual Costs (DAC) =		**$11,548** in 2024 dollars

Indirect Annual Costs

Parameter	Equation	Cost
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$6,126
Administrative Charges	= 2% of TCI	$8,540
Property Taxes	= 1% of TCI	$4,270
Insurance	= 1% of TCI	$4,270
Capital Recovery	= $CRF_{Adsorber} \times (TCI - [(1.08 \times CC \times M_c) + (LR \times M_c/CRR)]$ =	$46,713
Indirect Annual Costs (IAC) =		**$69,918** in 2024 dollars

Recovered Solvent Credit/Disposal Costs

Disposal Cost

Parameter	Equation	Cost
VOC Disposal/Treatment Costs (*Disposal* $_{cost}$)	$= m_{voc} \times \Theta_s \times D_{voc} \times E$ =	$0

VOC Recovery Credit

Parameter	Equation	Cost
Annual Recovery Credit for Condensate (RC)	$= m_{voc} \times \Theta_s \times P_{voc} \times E$ =	$2,071
Total Annual Cost (TAC) =	**DAC + IAC + C + Disposal $_{Cost}$ - RC =**	**$79,395** in 2024 dollars

Cost Effectiveness

Cost Effectiveness

Parameter	Equation	Cost	
Total Annual Cost =	TAC =	$79,395	per year in 2024 dollars
Annual Quantity of VOC Removed/Recovered =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	3	tons/year
Cost Effectiveness =	Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =	$25,300.06	per ton of pollutants removed/recovered in 2024 dollars

Attachment C

Cost Effectiveness Analysis for Thermal Oxidizers

Data Inputs

Select the type of oxidizer: Regenerative 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
Toluene	2,001	11,000	4,274	92.14

Note: The lower explosion limit (LEL), heat of combustion and molecular weight for some commonly used VOC/HAP are provided in the table below. In addition, the heat of combustion to be entered in column D is a lower heating value (LHV), not a higher heating value (HHV).

Enter the design data for the proposed oxidizer:

Percent Energy Recovery (HR) = 70 percent

Number of operating hours/year	2,080	hours/year	
Inlet volumetric flow rate(Q_{wi}) at 77°F and 1 atm.	20,000	scfm*	* 20,000 scfm is a default volumetric flow rate. User should enter actual value, if known.
Pressure drop (ΔP)	19	inches of water	* 19 inches of water is a default pressure drop for thermal oxidizers. User should 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})	77	°F	
Operating Temperature (T_{fi})	1,900	°F	* Note: Default value for Tfi is 2000°F for thermal regenerative oxidizers. Use actual value if known. Tfi for regenerative oxidizers typically between 1800 and 2000°F.
Destruction and Removal Efficiency (DRE)	98.5	percent	
Estimated Equipment Life	20	Years*	* 20 years is the typical equipment life. User should enter actual value, if known.
Heat Loss (η)	1	percent*	* 1 percent is a default value for the heat loss. User should enter actual value, if known. Heat loss is typically between 0.2 and 1.5%.

Enter the cost data:

Desired dollar-year	2024				
CEPCI* for 2024	800.3	Enter the CEPCI value for 2024	536.4	2016 CEPCI	*Enter dollar year first.
Annual Interest Rate (i)	7.00	%			
Electricity ($Cost_{elect}$)	0.1124	$/kWh			
Natural Gas Fuel Cost ($Cost_{fuel}$)	0.00975	$/scf			
Operator Labor Rate	$22.76	per hour			
Maintenance Labor rate	$26.18	per hour			
Contingency Factor (CF)	10.0	Percent			* 10 percent of the total capital investment F45is 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:

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)
Toluene	2,001	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	2,001	0

Constants used in calculations:

		Value	Units
Temperature of auxiliary fuel (T_{af}) =	Reference Temperature (T_{ref}) =	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	Value	Units
Sum of volume fraction of combustible components =	$= (\sum x_i) =$	2,001	ppmv		
Lower Explosive Limit of waste gas (LEL_{mix})	$= [\sum((x_i)/((\sum x_i) \times LEL_i))]^{-1} =$	11,000	ppmv		
	Where x_i is the volume fraction and LEL_i the lower explosive limit for each combustible component in the waste gas.				
% LEL_{mix}	= (Total Combustible Conc. In Mixture/LEL_{mix}) × 100 =	18.19	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 Entry Tab) =	20,000	scfm		
Oxygen Content of gas stream	$= 100 - (\sum x_i \times 100/10^6) =$	20.86	percent		
Fan Power Consumption (FP)	$= [(1.17 \times 10^{-4}) \times Q_{wi} \times \Delta P]/\varepsilon$	74.1	kW		
Q_{wo}	$\approx Q_{wi} =$	20,000	scfm		
Operating temperature of oxidizer (T_{fi})	(From Data Entry Tab)	1,900	°F		
Temperature of waste gas at outlet to preheater (T_{wo})	$=$ Heat Recovery $\times (T_{fi} - T_{wi}) + T_{wi} =$	1,353	°F	Note: this temperature is relevant for incinerators, but not for	
Temperature of flue gas exiting the regenerative oxidizer (T_{fo})	$= T_{fi} - 0.95(T_{fi} - T_{wi}) =$	168	°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.	8.55	Btu/scf	115.7	Btu/lb
Estimated Auxiliary Fuel Flow (Q_{af}) at 77 °F and 1 atm.	(Calculated using Equation 2.45 in Appendix B)	-155.58	scfm	Note: Negative value for calculated Qaf indicates that the waste gas is sufficient to support combustion.	
Auxiliary fuel Energy Input =		0	Btu/min		
Minimum Energy required for combustion stabilization =	$= 5\% \times$ Total Energy Input $= 0.05 \times \rho_{fi} \times Q_{fi} \times C_{pmf} \times (T_{fi} - T_{ref}) =$	33,410	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.)		No		Note: Additional auxiliary fuel equivalent to 5% of total energy input is required to stabilize combustion.	
Auxiliary fuel flow (Qaf) (adjusted for fuel required for combustion stabilization)at 77°F and 1 atm. =		38	scfm		
Total Volumetric Throughput (Q_{tot}) at 77 °F and 1 atm.	$= Q_{fi} = Q_{wo} + Q_o + Q_{af} = Q_{wi} + Q_{af} =$	20,038	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	0.0944

Cost Estimate

Direct Costs		
Total Purchased equipment costs (in 2024 dollars)		
Incinerator + auxiliary equipment[a] (A) =		
Equipment Costs (EC) for Regenerative Oxidizer	=(2.204 x 100,000 + 11.57 Qtot) x (2024 CEPI/1999 CEPCI) =	$815,417 in 2024 dollars
Instrumentation[b] =	0.10 × A =	$81,542
Sales taxes =	0.085 × A =	$69,310
Freight =	0.05 × A =	$40,771
	Total Purchased equipment costs (B) =	$1,007,040 in 2024 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 2024 dollars)		
Foundations and Supports =	0.08 × B =	$80,563
Handling and Erection =	0.14 × B =	$140,986
Electrical =	0.04 × B =	$40,282
Piping =	0.02 × B =	$20,141
Insulation for Ductwork =	0.01 × B =	$10,070
Painting =	0.01 × B =	$10,070
Site Preparation (SP) =		$0
Buildings (Bldg) =		$0
	Total Direct Installaton Costs =	$302,112
Total Direct Costs (DC) =	B + C + SP + Bldg =	$1,309,153 in 2024 dollars

Total Indirect Installation Costs (in 2024 dollars)		
Engineering =	0.10 × B =	$100,704
Construction and field expenses =	0.05 × B =	$50,352
Contractor fees =	0.10 × B =	$100,704
Start-up =	0.02 × B =	$20,141
Performance test =	0.01 × B =	$10,070
	Total Indirect Costs (IC) =	$281,971
Continency Cost (C) =	CF(IC+DC)=	$159,112
Total Capital Investment =	**DC + IC +C =**	**$1,750,236 in 2024 dollars**

Direct Annual Costs		
Annual Electricity Cost	= Annual Electricity Usage × Operating Hours/year × Electricity Price =	$17,324
Annual Fuel Costs for Natural Gas	= $Cost_{fuel}$ × Fuel Usage Rate × 60 min/hr × Operating hours/year	$46,341
Operating Labor	Operator = 0.5hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$2,959
	Supervisor = 15% of Operator	$444
Maintenance Costs	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$3,403
	Materials = 100% of maintenance labor	$3,403
Direct Annual Costs (DC) =		**$73,874 in 2024 dollars**

Indirect Annual Costs		
Overhead	= 60% of sum of operating, supervisor, maintenance labor and maintenance materials	$6,126
Administrative Charges	= 2% of TCI	$35,005
Property Taxes	= 1% of TCI	$17,502
Insurance	= 1% of TCI	$17,502
Capital Recovery	= CRF[TCI-1.08(cat. Cost)]	$165,210
Indirect Annual Costs (IC) =		**$241,345 in 2024 dollars**
Total Annual Cost =	**DC + IC =**	**$315,219 in 2024 dollars**

Cost Effectiveness

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

Total Annual Cost (TAC) =	$315,219 per year in 2024 dollars
VOC/HAP Pollutants Destroyed =	8.9 tons/year
Cost Effectiveness =	$35,300 per ton of pollutants removed in 2024 dollars