NEVILLE® Neville Chemical Company 2800 Neville Road, Pittsburgh PA 15225-1496

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December 5, 2022

Ms. JoAnn Truchan, MPM, P.E.
Section Chief, Engineering
Allegheny County Health Department
301 39th Street, Building #7
Pittsburgh, PA 15201-1811
AQPermits@AlleghenyCounty.US

RE: Reasonably Available Control Technology (RACT III) Evaluation

Dear Ms. Truchan,

Neville Chemical Company is submitting an updated Reasonably Available Control Technology (RACT III) Evaluation for the Neville Island facility as required by changes to 25 Pa. Code §§129.111 – 129.115.

If you have any questions regarding this report, please feel free to contact me directly at 412-777-4201 or by e-mail at dkokoski@nevchem.com.

Sincerely,

Daniel D. Kokoski
Vice President of Manufacturing

DDK/dld

Enclosure

cc: Helen Gurvich, Air Quality Engineer at Helen.Gurvich@AlleghenyCounty.US

VOC RACT III Evaluation
Neville Chemical Company – Pittsburgh, PA

1. INTRODUCTION

The Neville Chemical Company (Neville) facility located in Neville Township, Allegheny County, Pennsylvania, is classified as a major stationary source of volatile organic compounds (VOC) emissions. As such, the facility is subject to the Reasonably Available Control Technology (RACT III) rules enacted in Pennsylvania on November 12, 2022, outlined in 25 Pa. Code §§129.111 – 129.115. The RACT III rule requires all existing major facilities of NOx and VOC emissions to assess the need to install new or additional emission controls, or implement work practice measures to reduce emissions of those two pollutants. This document contains Neville's RACT III evaluation of VOC-emitting sources, to be submitted to Allegheny County Health Department (ACHD), Air Quality Control.

Supporting documents for this evaluation include:

Attachment A – RACT III Applicability Tables
Attachment B – Economic Analysis Tables

2. RACT III SOURCE APPLICABILITY EVALUATION

The tables included in Attachment 1 form the basis of the RACT III applicability evaluation of all VOC-emitting sources at the Neville facility. These tables include:

- Table 1, sorted by RACT III classification, lists all of the VOC sources and includes the source potential to emit (PTE), and the determination of applicability to RACT III.
- Table 2 contains the same information as Table 1, but is sorted by Source ID.
- Table 3 lists all of the storage tanks at the facility, their individual capacities, and an indication of whether they are subject to the RACT III rule.
- Table 4 provides a summary of the sources found to be 'Exempt' from the RACT III requirements, due to having a potential to emit (PTE) of less than one (1) ton/year.
- Table 5 summarizes all the sources classified as 'Presumptive'. These sources have a PTE of greater than 1 ton/year but less than 2.7 tons/year.
- Table 6 shows all of the sources subject to 'Case-by-Case' technical and economic evaluation, per section §129.114 of the RACT III rules. This table also provides Neville's determination of technically-feasible control options for each of these sources.
- Table 7 contains the RACT III economic evaluation results for each case-by-case source that was determined to have technically-feasible control options.
- For reference, Table 8 contains the economic evaluation results that ACHD used for determining economic feasibility under the RACT II requirements. Note that control options as low as $6,700 per ton of VOC controlled were determined by ACHD to be infeasible.

3. TECHNICAL FEASIBILITY OF CONTROLLING CASE-BY-CASE SOURCES

As noted above, Table 6 in Attachment 1 includes a determination of technical feasibility of various options for controlling VOC emissions from the case-by-case sources. Following are additional explanations for the technical feasibility determinations.

3.1 Rotary Concentrator Feasibility

While doing research for this RACT III evaluation, it was discovered that Rotary Concentrators, using zeolite for adsorption, are not suitable for controlling any of the processes at Neville. Per TANN Corporation, a vendor of zeolite concentrators, the presence of certain pollutants in the emission streams, such as styrene and methylene chloride, will lead to adverse fouling of the adsorption media, thus shortening its life. TANN recommended not using this control technology. Therefore, Neville considers Rotary Concentrator technology to be not technically feasible for the sources at this facility.

3.2 Oxidation Control Feasibility

Under this RACT III analysis, the technical feasibility of the various oxidation control options was re-examined and is now determined based on the cost correlation equation restrictions noted in USEPA's *Air Pollution Control Cost Manual*, 7th Edition, Section 3.2, Chapter 2. The exhaust flow rate ranges that coincide with each oxidation option are noted in the table below. What this means is that the USEPA manual's capital cost equations are not applicable beyond these flow rate ranges.

Table 2.9: Scope of Cost Correlations

Incinerator Type	Total (Flue) Gas Flowrate, scfm	Figure Number
Thermal – Recuperative	500[a] – 50,000	2.4
Thermal – Regenerative	10,000 – 100,000	2.5
Fixed-Bed Catalytic	2,000 – 50,000	2.6
Fluid-Bed Catalytic	2,000 – 25,000	2.7

[a]Although Figure 2.4 covers the 1,000 to 50,000 scfm range, the correlation is valid for the 500 to 50,000 scfm range.

3.3 Product Loading Capture and Loading Feasibility

Table 6 in Attachment 1 states that capture and control of the Product Loading stations is technically feasible, and the cost analysis assumes all of the loading stations can be captured and routed to a single control device. In reality, the three (3) railcar and six (6) tank truck loading stations are located in various spots within the facility, such that connecting all of these sources to a common control device is not practically feasible.

3.4 Resin Kettles Capture and Control Feasibility

Table 6 in Attachment 1 also states that capture and control of the Packaging Center's resin kettles is technically feasible. Neville has concerns regarding installation of a capture system for the kettles due to the complexity required for safe operation.

The system would require a significant amount of instrumentation, long duct runs requiring additional structural support in areas where space is tight, all ducting would require insulation, flame/denotation arresters would be required, a control system would be required, plus the operating temperatures of a refrigerated condenser could cause the entire system to plug up with ice due to steam being required to clear resin lines. It is Neville's opinion that design and implementation of such a collection system would require extensive and unreasonable costs. Based on engineering judgment, Neville estimates that these additional costs could easily be in the $250,000 to $400,000 range. To be conservative, the economic evaluation tables for the resin kettles use the mid-point of this range to represent auxiliary equipment and installation costs.

3.5 Wastewater Conveyance System Capture and Control Feasibility

It has been determined that capture and control of the Wastewater Conveyance System (P014) is not technically feasible. The wastewater conveyance system is a facility-wide collection and transport system that is mainly underground. The system includes hundreds of manholes and catch basins where fugitive emissions can escape. There is no reasonable or feasible method to capture all of these fugitive emission points. Therefore, control of the conveyance system is not feasible.

3.6 Resin Rework Tanks

Neville has not operated the Resin Rework Tanks (P015) over the past couple of years and has decided to permanently shut down this source. As noted in Section 5 below, Neville is proposing to remove this source from the facility's Title V permit. Therefore, further technical and economic evaluation of this source is not required.

3.7 VOC Control Technology Search

A search was conducted for VOC technologies that may have been developed subsequent to the evaluation conducted under the RACT II requirements. No "newer" technologies were found during this search. Some of the sites utilized for this search included the following:

- www.epa.gov
  - Ground-level Ozone Pollution
  - Controlling Air Pollution from the Oil and Natural Gas Industry
  - Air Pollution Control Technology Fact Sheet
  - NSCEP
- www.dep.pa.gpv
  - Control Technique Guidelines
- Choosing the Right VOC Emission Control Technology | Products Finishing (pfonline.com)

4. ECONOMIC ANALYSIS

An economic analysis of all technically feasible control options for the case-by-case sources was conducted. A summary of the results is provided in Table 6 of Attachment 1. The detailed cost analysis tables are provided in Attachment 2. All control cost analyses were conducted pursuant to procedures provided in USEPA's *Air Pollution Control Cost Manual*, 7th Edition (the most recent edition).

Every technically feasible control option for every source exceeds the RACT III "screening threshold" value of $12,000 per ton of VOC removed. Control options with costs above this threshold are automatically considered to be economically infeasible. It is Neville's contention that it is not economically feasible to install additional controls on any of the Case-by-Case VOC sources.

5. PROPOSED RACT III

The only change being requested by Neville is the removal of the Resin Rework (P015) operation from the Title V permit. The permanent shutdown of this source results in a potential VOC emission reduction of 16.24 tpy. Neville proposes that no other additional VOC reductions are necessary to satisfy the RACT III requirements.

ATTACHMENT 1
RACT III Applicability Tables

Table 1 **Summary of Facility VOC Sources and RACT III Classification - Sorted by Classification**
Neville Chemical Company - Pittsburgh, PA

Source ID	Description	VOC PTE [1] (TPY)	RACT III Classification
D001	Tanks 174, 1001, 1002, 1017	3.08	Not Applicable [2]
D002	Tanks 9, 12-14, 69, 80, 85, 178, 273-278, 307-309, 314-315, 342, 8501, 8503, 3 Still Wash Tank	2.26	Not Applicable [2]
D003	Tanks 601, 2108	2.71	Not Applicable [2]
D004	Tanks 176, 177, 205, 206, 1014, 2104, 2109	1.65	Not Applicable [2]
D005	Tanks 76, 252, 60SC	0.04	Not Applicable [2]
D006	Tanks 1- 2, 4, 10, 68, 81, 100, 102, 108, 112, 202-204, 302-303	0.84	Not Applicable [2]
D007	Tanks 82-83	0.15	Not Applicable [2]
D008	Tank 1008	0.02	Not Applicable [2]
D009	Tanks 1012, 1015, 5003, 6101-6102, 8502, 8504-8506	1.92	Not Applicable [2]
D010	Tanks 135, 304-305, 312-313, 316-317, 320, 330-334	18.31	Not Applicable [2]
D011	Tanks 271-272, 341, 2105-2106	3.32	Not Applicable [2]
G004	Tank Cleaning and Painting	3.75	Not Applicable [3]
B001	No.15 Still Process Heater	0.21	Exempt [4]
B002	No.16 Still Process Heater	0.17	Exempt [4]
B003	No.18 Still Process Heater	0.20	Exempt [4]
B004	No.19 Still Process Heater	0.21	Exempt [4]
B006	No. 3 Continuous Still Process Heater	0.14	Exempt [4]
B009	No. 2 Packaging Center Heater	0.14	Exempt [4]
B010	No. 3 Packaging Center Heater	0.11	Exempt [4]
B011	No. 5 Packaging Center Heater	0.08	Exempt [4]
B012	Boiler #8	0.80	Exempt [4]
B015	Heat Polymerization Unit #43: Process Heater	0.21	Exempt [4]
D005	9 Agitator (storage tank)	< 1 tpy	Exempt [4]
D006	Tank 145	< 1 tpy	Exempt [4]
N/A	Eight (8) Emergency Generators	0.71	Exempt [4]
P001	Heat Polymerization Still #15	0.58	Exempt [4]
P001	Heat Polymerization Still #16	0.80	Exempt [4]
P001	Heat Polymerization Still #18	0.85	Exempt [4]
P001	Heat Polymerization Still #19	0.80	Exempt [4]
P001	Heat Polymerization Still #43	0.80	Exempt [4]
P001	Thermal Oxidizer Fuel Consumption	0.51	Exempt [4]
P016	Final Product Loading: Barge Loading	0.78	Exempt [4]
B013	Boiler #6	1.34	Presumptive [5]
G002	Parts Washing	2.00	Presumptive [5]
G003	R&D Lab Hoods	2.00	Presumptive [5]
P008	Continuous Still #3	2.56	Presumptive [5]
P012	No.3 Packaging Center: Pouring Station	1.88	Presumptive [5]
P014	Wastewater Treatment System: Equalization Tank	1.79	Presumptive [5]
P014	Wastewater Treatment System: Biological Treatment Aeration Tanks	1.37	Presumptive [5]
P014	Wastewater Treatment System: Surge Tank	1.89	Presumptive [5]
P017	Groundwater Remediation System	1.51	Presumptive [5]
P006	Unit 20-21	9.71	Case-by-case
P011	No. 2 Packaging Center: Drain Kettles	15.57	Case-by-case
P011	No. 2 Packaging Center: Flaking Belt	8.14	Case-by-case
P012	No. 3 Packaging Center: Drain Kettles	21.79	Case-by-case
P012	No. 3 Packaging Center: Pastillating Belt	6.69	Case-by-case
P013	No. 5 Packaging Center: Drain Kettles	14.00	Case-by-case
P013	No. 5 Packaging Center: Flaking Belt	7.32	Case-by-case
P014	Wastewater Treatment System: 3 Batch Tanks	10.28	Case-by-case
P014	Wastewater Conveyance System	3.36	Case-by-case
P015	Resin Rework Tanks	16.24	Case-by-case
P016	Final Product Loading: Final Product Tankcar & Tankwagon Loading	18.24	Case-by-case

[1] VOC PTE taken from ACHD's draft Title V Renewal OP, dated 4/14/2022.

[2] Storage tanks with capacity of 2000 gallons or more are Not Applicable to RACT III due to being subject to ACHD storage tank regulations at 2105.12.

[3] Not applicable to RACT III due to being subject to ACHD surface coating regulations at 2105.10.

[4] Exempt from RACT III due to emissions less than 1 tpy, per PADEP regulation 129.111(c).

[5] Subject to applicable Presumptive RACT requirements, per PADEP regulation 129.112.

[6] Sources with VOC emissions of 2.7 tpy or greater are subject to case-by-case analysis requirements, per PADEP regulation 129.114.

Table 2 **Summary of Facility VOC Sources and RACT III Classification - Sorted by Source ID**
Neville Chemical Company - Pittsburgh, PA

Source ID	Description	VOC PTE* (TPY)	RACT III Classification
B001	No.15 Still Process Heater	0.21	Exempt
B002	No.16 Still Process Heater	0.17	Exempt
B003	No.18 Still Process Heater	0.20	Exempt
B004	No.19 Still Process Heater	0.21	Exempt
B006	No. 3 Continuous Still Process Heater	0.14	Exempt
B009	No. 2 Packaging Center Heater	0.14	Exempt
B010	No. 3 Packaging Center Heater	0.11	Exempt
B011	No. 5 Packaging Center Heater	0.08	Exempt
B012	Boiler #8	0.80	Exempt
B013	Boiler #6	1.34	Presumptive
B015	Heat Polymerization Unit #43: Process Heater	0.21	Exempt
D001	Tanks 174, 1001, 1002, 1017	3.08	Not Applicable
D002	Tanks 9, 12-14, 69, 80, 85, 178, 273-278, 307-309, 314-315, 342, 8501, 8503, 3 Still Wash Tank	2.26	Not Applicable
D003	Tanks 601, 2108	2.71	Not Applicable
D004	Tanks 176, 177, 205, 206, 1014, 2104, 2109	1.65	Not Applicable
D005	Tanks 76, 252, 60SC	0.04	Not Applicable
D005	9 Agitator (storage tank)	< 1 tpy	Exempt
D006	Tanks 1- 2, 4, 10, 68, 81, 100, 102, 108, 112, 202-204, 302-303	0.84	Not Applicable
D006	Tank 145	< 1 tpy	Exempt
D007	Tanks 82-83	0.15	Not Applicable
D008	Tank 1008	0.02	Not Applicable
D009	Tanks 1012, 1015, 5003, 6101-6102, 8502, 8504-8506	1.92	Not Applicable
D010	Tanks 135, 304-305, 312-313, 316-317, 320, 330-334	18.31	Not Applicable
D011	Tanks 271-272, 341, 2105-2106	3.32	Not Applicable
G002	Parts Washing	2.00	Presumptive
G003	R&D Lab Hoods	2.00	Presumptive
G004	Tank Cleaning and Painting	3.75	Not Applicable
P001	Heat Polymerization Still #15	0.58	Exempt
P001	Heat Polymerization Still #16	0.80	Exempt
P001	Heat Polymerization Still #18	0.85	Exempt
P001	Heat Polymerization Still #19	0.80	Exempt
P001	Heat Polymerization Still #43	0.80	Exempt
P001	Thermal Oxidizer Fuel Consumption	0.51	Exempt
P006	Unit 20-21	9.71	Case-by-case
P008	Continuous Still #3	2.56	Presumptive
P011	No. 2 Packaging Center: Drain Kettles	15.57	Case-by-case
P011	No. 2 Packaging Center: Flaking Belt	8.14	Case-by-case
P012	No. 3 Packaging Center: Drain Kettles	21.79	Case-by-case
P012	No. 3 Packaging Center: Pastillating Belt	6.69	Case-by-case
P012	No.3 Packaging Center: Pouring Station	1.88	Presumptive
P013	No. 5 Packaging Center: Drain Kettles	14.00	Case-by-case
P013	No. 5 Packaging Center: Flaking Belt	7.32	Case-by-case
P014	Wastewater Treatment System: 3 Batch Tanks	10.28	Case-by-case
P014	Wastewater Conveyance System	3.36	Case-by-case
P014	Wastewater Treatment System: Equalization Tank	1.79	Presumptive
P014	Wastewater Treatment System: Biological Treatment Aeration Tanks	1.37	Presumptive
P014	Wastewater Treatment System: Surge Tank	1.89	Presumptive
P015	Resin Rework Tanks	16.24	Case-by-case
P016	Final Product Loading: Final Product Tankcar & Tankwagon Loading	18.24	Case-by-case
P016	Final Product Loading: Barge Loading	0.78	Exempt
P017	Groundwater Remediation System	1.51	Presumptive
N/A	Eight (8) Emergency Generators	0.71	Exempt

* VOC PTE taken from ACHD's draft Title V Renewal OP, dated 4/14/2022

Table 3 List of Storage Tanks and Capacities
Neville Chemical Company - Pittsburgh, PA

Material Category	Category ID	Tank ID#	Capacity (gallons)	RACT III Classification *
Catalytic & Misc Poly Oil	D001	174	20,350	Not Applicable
Catalytic & Misc Poly Oil	D001	1001	100,980	Not Applicable
Catalytic & Misc Poly Oil	D001	1002	100,980	Not Applicable
Catalytic & Misc Poly Oil	D001	1017	100,980	Not Applicable
Distillates, Low VP	D002	9	2,256	Not Applicable
Distillates, Low VP	D002	12	19,320	Not Applicable
Distillates, Low VP	D002	13	20,305	Not Applicable
Distillates, Low VP	D002	14	20,305	Not Applicable
Distillates, Low VP	D002	3 Still Wash	3,900	Not Applicable
Distillates, Low VP	D002	69	9,568	Not Applicable
Distillates, Low VP	D002	80	15,100	Not Applicable
Distillates, Low VP	D002	85	3,900	Not Applicable
Distillates, Low VP	D002	178	16,120	Not Applicable
Distillates, Low VP	D002	273	26,004	Not Applicable
Distillates, Low VP	D002	274	24,004	Not Applicable
Distillates, Low VP	D002	275	26,004	Not Applicable
Distillates, Low VP	D002	276	26,004	Not Applicable
Distillates, Low VP	D002	277	26,004	Not Applicable
Distillates, Low VP	D002	278	26,004	Not Applicable
Distillates, Low VP	D002	307	30,050	Not Applicable
Distillates, Low VP	D002	308	30,050	Not Applicable
Distillates, Low VP	D002	309	30,050	Not Applicable
Distillates, Low VP	D002	314	30,050	Not Applicable
Distillates, Low VP	D002	315	30,050	Not Applicable
Distillates, Low VP	D002	342	34,000	Not Applicable
Distillates, Low VP	D002	8501	845,968	Not Applicable
Distillates, Low VP	D002	8503	845,968	Not Applicable
Distillates, Mid VP	D003	601	60,914	Not Applicable
Distillates, Mid VP	D003	2108	217,336	Not Applicable
Heat Poly Charge Stock	D004	176	16,120	Not Applicable
Heat Poly Charge Stock	D004	177	16,120	Not Applicable
Heat Poly Charge Stock	D004	205	20,305	Not Applicable
Heat Poly Charge Stock	D004	206	20,305	Not Applicable
Heat Poly Charge Stock	D004	1014	100,651	Not Applicable
Heat Poly Charge Stock	D004	2104	217,336	Not Applicable
Heat Poly Charge Stock	D004	2109	217,336	Not Applicable
Miscellaneous	D005	76	7,614	Not Applicable
Miscellaneous	D005	252	24,052	Not Applicable
Miscellaneous	D005	60SC	6,016	Not Applicable
Miscellaneous	D005	9 Agitator	1,980	Exempt
Napthenic/Ink/Veg Oils	D006	1	19,320	Not Applicable
Napthenic/Ink/Veg Oils	D006	2	19,320	Not Applicable
Napthenic/Ink/Veg Oils	D006	4	17,626	Not Applicable
Napthenic/Ink/Veg Oils	D006	10	20,850	Not Applicable
Napthenic/Ink/Veg Oils	D006	68	9,568	Not Applicable
Napthenic/Ink/Veg Oils	D006	81	10,000	Not Applicable
Napthenic/Ink/Veg Oils	D006	100	10,450	Not Applicable
Napthenic/Ink/Veg Oils	D006	102	10,000	Not Applicable

Table 3 **List of Storage Tanks and Capacities**
Neville Chemical Company - Pittsburgh, PA

Material Category	Category ID	Tank ID#	Capacity (gallons)	RACT III Classification *
Napthenic/Ink/Veg Oils	D006	108	10,450	Not Applicable
Napthenic/Ink/Veg Oils	D006	112	9,107	Not Applicable
Napthenic/Ink/Veg Oils	D006	145	1,763	Exempt
Napthenic/Ink/Veg Oils	D006	202	20,082	Not Applicable
Napthenic/Ink/Veg Oils	D006	203	20,082	Not Applicable
Napthenic/Ink/Veg Oils	D006	204	20,082	Not Applicable
Napthenic/Ink/Veg Oils	D006	302	30,050	Not Applicable
Napthenic/Ink/Veg Oils	D006	303	30,050	Not Applicable
NEVCHEM LR	D007	83	10,000	Not Applicable
NEVCHEM LR	D007	82	10,000	Not Applicable
Recovered Oil	D008	1008	100,980	Not Applicable
Resin Former	D009	1012	100,651	Not Applicable
Resin Former	D009	1015	100,980	Not Applicable
Resin Former	D009	5003	497,277	Not Applicable
Resin Former	D009	6301	630,000	Not Applicable
Resin Former	D009	6302	630,000	Not Applicable
Resin Former	D009	8502	845,968	Not Applicable
Resin Former	D009	8504	845,968	Not Applicable
Resin Former	D009	8505	845,968	Not Applicable
Resin Former	D009	8506	845,968	Not Applicable
Resin Solutions	D010	135	2,010	Not Applicable
Resin Solutions	D010	304	30,050	Not Applicable
Resin Solutions	D010	305	30,050	Not Applicable
Resin Solutions	D010	312	30,050	Not Applicable
Resin Solutions	D010	313	30,050	Not Applicable
Resin Solutions	D010	316	30,050	Not Applicable
Resin Solutions	D010	317	30,050	Not Applicable
Resin Solutions	D010	320	22,438	Not Applicable
Resin Solutions	D010	330	30,913	Not Applicable
Resin Solutions	D010	331	30,913	Not Applicable
Resin Solutions	D010	332	30,913	Not Applicable
Resin Solutions	D010	333	30,913	Not Applicable
Resin Solutions	D010	334	30,913	Not Applicable
Unit 20-21 Feed Blend	D011	271	26,004	Not Applicable
Unit 20-21 Feed Blend	D011	272	26,004	Not Applicable
Unit 20-21 Feed Blend	D011	341	34,000	Not Applicable
Unit 20-21 Feed Blend	D011	2105	217,336	Not Applicable
Unit 20-21 Feed Blend	D011	2106	217,336	Not Applicable

* Storage tanks with capacity of 2000 gallons or more are 'Not Applicable' to RACT III due to being subject to ACHD storage tank regulations at 2105.12. The tanks in this list marked as "Exempt" have emissions of less than 1 tpy.

Table 4 **Facility Sources Exempt from RACT III (PA Code 129.111(c) [< 1 TPY VOC])**
Neville Chemical Company - Pittsburgh, PA

Source ID	Description	VOC PTE (TPY)
P001	Heat Polymerization Still #15	0.58
P001	Heat Polymerization Still #16	0.80
P001	Heat Polymerization Still #18	0.85
P001	Heat Polymerization Still #19	0.80
P001	Heat Polymerization Still #43	0.80
P001	Thermal Oxidizer Fuel Consumption	0.51
P016	Final Product Loading: Barge Loading	0.78
B001	No.15 Still Process Heater	0.21
B002	No.16 Still Process Heater	0.17
B003	No.18 Still Process Heater	0.20
B004	No.19 Still Process Heater	0.21
B006	No. 3 Continuous Still Process Heater	0.14
B009	No. 2 Packaging Center Heater	0.14
B010	No. 3 Packaging Center Heater	0.11
B011	No. 5 Packaging Center Heater	0.08
B012	Boiler #8	0.80
B015	Heat Polymerization Unit #43: Process Heater	0.21
N/A	Eight (8) Emergency Generators	0.71
D005	9 Agitator (storage tank)	< 1 tpy

Table 5 Facility Sources Subject to Presumptive RACT III (PA Code 129.112)
Neville Chemical Company - Pittsburgh, PA

Source ID	Description	VOC PTE (TPY)	Basis for Presumptive	Presumptive RACT Requirement
P008	Continuous Still #3	2.56	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
P012	No.3 Packaging Center: Pouring Station	1.88	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
P014	Wastewater Treatment System: Equalization Tank	1.79	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
P014	Wastewater Treatment System: Biological Treatment Aeration Tanks	1.37	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
P014	Wastewater Treatment System: Surge Tank	1.89	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
P017	Groundwater Remediation System	1.51	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
B013	Boiler #6	1.34	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
G002	Parts Washing	2.00	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices
G003	R&D Lab Hoods	2.00	1 ≤ TPY < 2.7	Install, maintain and operate the source in accordance with the manufacturer's specifications and with good operating practices

Table 6 **Facility Sources Subject to Case-by-Case RACT III (PA Code 129.114) & Technical Feasibility of Controls**
Neville Chemical Company - Pittsburgh, PA

Source ID	Description	VOC PTE (TPY)	Exhaust Flow (acfm)	Technically Feasible Controls
P006	Unit 20-21	9.71	100	Condensation; Adsorption
P011	No. 2 Packaging Center: Drain Kettles	15.57	200	Condensation; Adsorption
P011	No. 2 Packaging Center: Flaking Belt	8.14	4,850	Recuperative, Regenerative & Catalytic Oxidation; Adsorption
P012	No. 3 Packaging Center: Drain Kettles	21.79	200	Condensation; Adsorption
P012	No. 3 Packaging Center: Pastillating Belt	6.69	9,700	Recuperative, Regenerative & Catalytic Oxidation; Adsorption
P013	No. 5 Packaging Center: Drain Kettles	14.00	75	Condensation; Adsorption
P013	No. 5 Packaging Center: Flaking Belt	7.32	4,850	Recuperative, Regenerative & Catalytic Oxidation; Adsorption
P014	Wastewater Treatment System: 3 Batch Tanks	10.28	300	Recuperative Oxidation; Condensation; Adsorption
P014	Wastewater Conveyance System	3.36	Fugitive	None - see Section 3 of *VOC RACT III Evaluation* report
P015	Resin Rework Tanks	16.24	150	None - operation is shut down and is proposed to be removed from the permit
P016	Final Product Loading: Final Product Tankcar & Tankwagon Loading	18.24	1,000	Recuperative Oxidation; Condensation; Adsorption

Flow Rate basis for Technical Feasibility:

Control Type	Minimum Flow Rate, cfm*
Recuperative Oxidation	500
Regenerative Oxidation	5000
Catalytic Oxidation	2000
Carbon Adsorption	None
Vapor Condensation	None

* Per EPA's OAQPS Control Cost Manual, 7th Edition, Section 3.2, Chapter 2

Table 7 **VOC Control Costs of Technically Feasible Control Options for Case-by-Case RACT III Sources**
Neville Chemical Company - Pittsburgh, PA

Control Option		P006 (Unit 20-21)	P011 (2PC Kettles)	P011 (2PC Flaking Belt)	P012 (3PC Kettles)	P012 (3PC Pastillating	P013 (5PC Kettles)	P013 (5PC Flaking Belt)	P014 (WWT Batch Tanks)	P016 (Product Loading)
Recuperative Oxidation (98%)	tpy VOC Removed			7.82		6.43		7.03	9.9	17.5
	Annual Cost			$430,406		$687,412		$430,406	$195,078	$240,097
	$/ton	**N/A**	**N/A**	**$55,056**	**N/A**	**$106,989**	**N/A**	**$61,223**	**$19,759**	**$13,706**
Regenerative Oxidation (98%)	tpy VOC Removed			7.82		6.43		7.03		
	Annual Cost			$318,638		$436,938		$318,638		
	$/ton	**N/A**	**N/A**	**$40,759**	**N/A**	**$68,005**	**N/A**	**$45,325**	**N/A**	**N/A**
Catalytic Oxidation (98%)	tpy VOC Removed			7.82		6.43		7.03		
	Annual Cost			$283,493		$409,670		$283,493		
	$/ton	**N/A**	**N/A**	**$36,263**	**N/A**	**$63,761**	**N/A**	**$40,325**	**N/A**	**N/A**
Concentrator/ Oxidation (98%)	tpy VOC Removed									
	Annual Cost									
	$/ton	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
Carbon Adsorption (95%)	tpy VOC Removed	9.24	14.77	7.74	20.68	6.37	13.32	6.95	9.78	16.64
	Annual Cost	$217,619	$327,190	$197,490	$377,512	$187,426	$302,791	$197,490	$217,619	$288,069
	$/ton	**$23,558**	**$22,150**	**$25,517**	**$18,255**	**$29,440**	**$22,740**	**$28,420**	**$22,255**	**$17,308**
Condensation (90%)	tpy VOC Removed	8.70	13.90		19.30		12.70		9.00	16.00
	Annual Cost	$155,687	$244,588		$238,858		$189,941		$174,553	$303,291
	$/ton	**$17,870**	**$17,355**	**N/A**	**$12,185**	**N/A**	**$15,206**	**N/A**	**$19,325**	**$18,938**
	Minimum $/ton:	**$17,870**	**$17,355**	**$25,517**	**$12,185**	**$29,440**	**$15,206**	**$28,420**	**$19,325**	**$13,706**

N/A - the control type is not technically feasible for this process (see Table 6)

Table 8 **ACHD's VOC Control Cost Comparisons for Case-by-Case RACT II Sources***
Neville Chemical Company - Pittsburgh, PA

Control Option		P007 (Unit 21)	P009 (stills #3 & 4)	P011 (2PC resin kettles)	P011 (2PC belt, packaging)	P012 (3PC resin kettles)	P012 (3PC pastillating	P013 (5PC resin kettles)	P013 (5PC belt, packaging)	P014 (WW conveyance	P014 (WWT batch tanks)	P015 (rework tanks)	P016 (product loading)
Regenerative Oxidation (98%)	tpy VOC Removed	6.1	13.6	15.2	7.8	21.3	6.6	13.7	7.2	3.3	10.1	16.2	17.9
	Annual Cost	$262,000	$218,000	$157,000	$80,000	$243,000	$516,000	$141,000	$74,000	$64,000	$197,000	$165,000	$160,000
	$/ton	$42,900	$16,000	$10,300	$10,300	$11,400	$78,200	$10,300	$10,300	$19,500	$19,500	$10,200	$8,940
Catalytic Oxidation (98%)	tpy VOC Removed	6.1	13.6	15.2	7.8	21.3	6.6	13.7	7.2	3.3	10.1	16.2	17.9
	Annual Cost	$183,000	$140,000	$114,000	$58,500	$162,000	$312,000	$103,000	$54,000	$45,000	$137,000	$159,000	$154,000
	$/ton	$30,000	$10,300	$7,500	$7,500	$7,600	$47,200	$7,500	$7,500	$13,600	$13,600	$9,790	$8,590
Concentrator/ Oxidation (98%)	tpy VOC Removed	6.1	13.6	15.2	7.8	21.3	6.6	13.7	7.2	3.3	10.1	16.2	17.9
	Annual Cost	$185,000	$185,000	$102,000	$52,000	$162,000	$222,000	$92,000	$48,000	$46,000	$139,000	$168,000	$168,000
	$/ton	$30,400	$13,600	$6,700	$6,700	$7,600	$33,600	$6,700	$6,700	$13,800	$13,800	$10,400	$9,390
Carbon Adsorption (95%)	tpy VOC Removed	6.1	13.6	15.2	7.8	21.3	6.6	13.7	7.2	3.3	10.1	16.2	17.9
	Annual Cost	$256,000	$260,000	$181,000	$93,000	$213,000	$183,000	$163,000	$86,000	$64,000	$196,000	$266,000	$261,000
	$/ton	$42,000	$19,100	$11,900	$11,900	$10,000	$27,700	$11,900	$11,900	$19,400	$19,400	$16,400	$14,600
Condensation (90%)	tpy VOC Removed	5.6	12.5	14.0	7.3	19.6	6.0	12.6	6.6	3.0	9.3	14.9	16.4
	Annual Cost	$372,000	$217,000	$370,000	$193,000	$425,000	$846,000	$333,000	$174,000	$100,000	$305,000	$297,000	$290,000
	$/ton	$66,500	$17,400	$26,400	$26,400	$21,700	$141,000	$26,400	$26,400	$30,200	$30,200	$19,900	$17,700
	Minimum $/ton:	**$30,000**	**$10,300**	**$6,700**	**$6,700**	**$7,600**	**$27,700**	**$6,700**	**$6,700**	**$13,600**	**$13,600**	**$9,790**	**$8,590**

* These values were taken from ACHD's Technical Support Document associated with the Title V Permit 0006c Amendment, issued April 23, 2020.

ATTACHMENT 2
Economic Analysis Tables

Oxidation Cost Tables

Table 1. **Cost Summary of RACT III VOC Oxidation Control Options**
Neville Chemical Company - Pittsburgh, PA

Source Name: **#2 PC Flaking Belt**
Source ID: **P011**

1a. - Ranking of VOC Oxidation Control Options, by Reduction Efficiency

Ranking	Control Technology	Destruction Efficiency (%)	Capture Efficiency (%)	Reduction [1] Efficiency (%)	Inlet VOC Emissions (tons/year)	VOC Reduction (tons/year)
1.	Recuperative Thermal Oxidizer	98.0	98.0	96.0	8.14	7.82
2.	Catalytic Oxidizer	98.0	98.0	96.0	8.14	7.82
3.	Regenerative Thermal Oxidizer	98.0	98.0	96.0	8.14	7.82

1b. - Ranking of Annual Control Costs per Ton of Pollutant Reduced

Ranking	Control Technology	Capital Cost ($)	Capital Recovery Cost ($/year)	Capital-Only Control Cost ($/ton/yr)	Total Annualized Cost ($/year)	**VOC Control Cost ($/ton/yr)**
1.	Catalytic Oxidizer	442,043	34,939	4,469	283,493	**36,263**
2.	Regenerative Thermal Oxidizer	726,001	58,256	7,452	318,638	**40,759**
3.	Recuperative Thermal Oxidizer	455,893	36,582	4,679	430,406	**55,056**

[1] Overall reduction based on product of Control efficiency and Capture efficiency

Table 2. INPUT PARAMETERS FOR CONTROL TECHNOLOGY ANALYSIS
Neville Chemical Company - Pittsburgh, PA

Emissions Data

VOC emissions, tpy:	8.14
Operating hours per year:	8,760

Collection System Data

Units Controlled	Expected Capture Eff.		Expected Air Flow, cfm
Fume Hood Exhaust Fan	98%		4,850
		Total:	4,850

Total length of collection ductwork, ft	100	estimated
Ductwork diameter, inches	30	

Control System Data

	Removal Efficiency, %	Heat Recovery, %
Recuperative Thermal Oxidizer	98	50
Catalytic Oxidizer (fixed bed)	98	50
Regenerative Thermal Oxidizer (RTO)	98	85

Auxiliary Equipment and Costs

	Cost	
Ductwork to collect fumes	15,435	(see Table 6)
Other equipment	0	
Total Auxiliary Equipment Costs:	15,435	

Facility-specific Economic Data

Operator labor cost, $/hr	45.00
Maintenance labor cost, $/hr	45.00
Electricity cost, $/kwh	0.10
Natural Gas cost, $/mcf	8.00
Debt Interest rate, fraction	0.05

Other Economic Data

Taxes, insurance, admin, fraction	0.05	EPA spreadsheet*
Catalyst cost, $/ft3	350	EPA spreadsheet*
Catalyst life (years):	4	EPA spreadsheet*
Control system life (years):	20	EPA spreadsheet*
Operating labor factor (hr/sh):	0.5	EPA spreadsheet*
Maintenance labor factor (hr/sh):	0.5	EPA spreadsheet*
CEPCI (cost inflation factor)	832.6	Final value for June 2022

(Chemical Engineering Plant Cost Index, updated monthly in "Chemical Engineering Magazine")

* USEPA-developed spreadsheet, named: US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm
(available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution)

Table 3. Total Annual Cost Spreadsheet - Recuperative Thermal Oxidizer
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	4,850	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.5	
Waste gas heat content (BTU/scf):	5.0	conservative estimate
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.26	air
Combustion temperature (oF):	1,400	
Preheat temperature (oF):	735	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	11.0	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	2.305	Equation 2.21
(scfm):	56.5	
Total Gas Flowrate (scfm):	4,907	

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
Incinerator:		
@ 0 % heat recovery:	0	Equation 2.29
@ 35 % heat recovery:	0	Equation 2.30
@ 50 % heat recovery:	142,991	Equation 2.31
@ 70 % heat recovery:	0	Equation 2.32
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	158,426	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	337,699	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	364,714	Table 2.8
Total Capital Investment (TCI = 1.25B):	**455,893**	Table 2.8

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	237,596	
Electricity	9,260	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	22,795	Table 2.10
Capital recovery	36,582	Table 2.10
Total Annual Cost	**430,406**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 4. **Total Annual Cost Spreadsheet - Regenerative Thermal Oxidizer**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	2016	
Reference Date CEPCI value*	541.7	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	1.54	

INPUT PARAMETERS

Exhaust Gas flowrate (scfm):	4,850	
Reference temperature (oF):	77	
Waste gas inlet temperature, Tw_i (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.85	
Waste gas heat content, annual avg. (BTU/scf):	5.00	
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.255	air
Combustion temperature (oF):	1,800	
Temperature leaving heat exchanger, Tw_o (oF):	1541	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	30.4	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Requirement:	(lb/min):	0.724	Equation 2.45
	(scfm):	17.74	
	(mcf/yr):	9,325.5	
Total Maximum Exhaust Gas Flowrate:	(scfm):	4,868	

CALCULATED CAPITAL COSTS

Oxidizer Equipment Cost (EC):		
@ 85% heat recovery:	334,451	Equation 2.33
@ 95% heat recovery:	0	Equation 2.33
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	349,886	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	537,779	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	580,801	Table 2.8
Total Capital Investment (TCI = 1.25B):	**726,001**	Table 2.8

ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	74,604	
Electricity	25,305	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	36,300	Table 2.10
Capital recovery	58,256	Table 2.10
Total Annual Cost	**318,638**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 5. Total Annual Cost Spreadsheet - Catalytic Oxidizer (Fixed Bed)
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	4,850	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.50	
Waste gas heat content (BTU/scf):	5.0	
Waste gas heat content (BTU/lb):	67.66	
Gas heat capacity (BTU/lb-oF):	0.255	air
Combustion temperature (oF):	850	
Preheat temperature (oF):	460	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	13.0	Table 2.11

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	0.869	Equation 2.21
(scfm):	21.3	
Total Gas Flowrate (scfm):	4,871	
Catalyst Volume (ft3):	9.4	Equation 2.28

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
@ 0 % heat recovery:	0	Equation 2.34
@ 35 % heat recovery:	0	Equation 2.35
@ 50 % heat recovery:	138,178	Equation 2.36
@ 70 % heat recovery:	0	Equation 2.37
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	153,612	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	327,439	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	353,634	Table 2.8
Total Capital Investment (TCI = 1.25B):	**442,043**	Table 2.8

ANNUAL COST INPUTS

Operating factor (hr/yr):	8760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Catalyst price ($/ft3):	650
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Catalyst life (years):	4
Capital recovery factor (system):	0.0802
Capital recovery factor (catalyst):	0.2820
Taxes, insurance, admin. factor:	0.05

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	89,553	
Electricity	10,858	Equation 2.42
Catalyst replacement	1,868	Table 2.10
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	22,102	Table 2.10
Capital recovery	34,939	
Total Annual Cost	**283,493**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 6. Total Annual Cost Spreadsheet - Straight Ductwork For Routing To Controls
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:		2016	
Reference Date CEPCI value*		541.7	
Most recent CEPCI value**		832.6	Final value for June 2022
Cost Escalation Factor		1.54	

INPUT PARAMETERS				
Inlet stream flowrate (acfm):		1,617	per exhaust fan	
Duct velocity (ft/min)		329		5.5 ft/sec
Duct length (ft)		33	per exhaust fan	
Material of construction		Galv. CS sh.		
Insulation thickness (in.)		1		
Duct design		Circ.-spiral		
Cost equation parameters	a:	2.560		
	b:	0.937		
Cost equation form		1		
Control system installation factor		1.5		
(if no system, enter '0')				
Fan-motor combined efficiency (fraction)		0.60		

DESIGN PARAMETERS	
Number of exhaust fans	3
Duct diameter (in.)	30.00
Pressure drop (in. w.c.)	0.002

CALCULATED CAPITAL COSTS	
Equipment Cost ($)--base	2,066
Equipment Cost ($)--escalated	3,176
Purchased Equipment Cost ($)	3,430
Total Capital Investment per Exhaust Fan($)	5,145
Overall Total Capital Investment($):	**15,435**

ANNUAL COST INPUTS	
Operating factor (hours/year):	8760
Electricity price ($/kWhr):	0.100
Annual interest rate (fractional):	0.05
Ductwork economic life (years):	20
Capital recovery factor (system):	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)
Electricity	1
Taxes, insurance, administrative	257
Capital recovery	413
Total Annual Cost	**671**

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.
** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 1. **Cost Summary of RACT III VOC Oxidation Control Options**
Neville Chemical Company - Pittsburgh, PA

Source Name: **#3 PC Pastillating Belt**
Source ID: **P012**

1a. - Ranking of VOC Oxidation Control Options, by Reduction Efficiency

Ranking	Control Technology	Destruction Efficiency (%)	Capture Efficiency (%)	Reduction [1] Efficiency (%)	Inlet VOC Emissions (tons/year)	VOC Reduction (tons/year)
1.	Recuperative Thermal Oxidizer	98.0	98.0	96.0	6.69	6.43
2.	Catalytic Oxidizer	98.0	98.0	96.0	6.69	6.43
3.	Regenerative Thermal Oxidizer	98.0	98.0	96.0	6.69	6.43

1b. - Ranking of Annual Control Costs per Ton of Pollutant Reduced

Ranking	Control Technology	Capital Cost ($)	Capital Recovery Cost ($/year)	Capital-Only Control Cost ($/ton/yr)	Total Annualized Cost ($/year)	**VOC Control Cost ($/ton/yr)**
1.	Catalytic Oxidizer	629,610	49,459	7,698	409,670	**63,761**
2.	Regenerative Thermal Oxidizer	867,205	69,587	10,830	436,938	**68,005**
3.	Recuperative Thermal Oxidizer	533,815	42,835	6,667	687,412	**106,989**

[1] Overall reduction based on product of Control efficiency and Capture efficiency

Table 2. INPUT PARAMETERS FOR CONTROL TECHNOLOGY ANALYSIS
Neville Chemical Company - Pittsburgh, PA

Emissions Data

VOC emissions, tpy:	6.69
Operating hours per year:	8,760

Collection System Data

Units Controlled	Expected Capture Eff.	Expected Air Flow, cfm
Fume Hood Exhaust Fan	98%	9,700
	Total:	9,700

Total length of collection ductwork, ft	100	estimated
Ductwork diameter, inches	30	

Control System Data

	Removal Efficiency, %	Heat Recovery, %
Recuperative Thermal Oxidizer	98	50
Catalytic Oxidizer (fixed bed)	98	50
Regenerative Thermal Oxidizer (RTO)	98	85

Auxiliary Equipment and Costs

	Cost	
Ductwork to collect fumes	15,435	(see Table 6)
Other equipment	0	
Total Auxiliary Equipment Costs:	15,435	

Facility-specific Economic Data

Operator labor cost, $/hr	45.00
Maintenance labor cost, $/hr	45.00
Electricity cost, $/kwh	0.10
Natural Gas cost, $/mcf	8.00
Debt Interest rate, fraction	0.05

Other Economic Data

Taxes, insurance, admin, fraction	0.05	EPA spreadsheet*
Catalyst cost, $/ft3	350	EPA spreadsheet*
Catalyst life (years):	4	EPA spreadsheet*
Control system life (years):	20	EPA spreadsheet*
Operating labor factor (hr/sh):	0.5	EPA spreadsheet*
Maintenance labor factor (hr/sh):	0.5	EPA spreadsheet*
CEPCI (cost inflation factor)	832.6	Final value for June 2022

(Chemical Engineering Plant Cost Index, updated monthly in "Chemical Engineering Magazine")

* USEPA-developed spreadsheet, named: US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm
(available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution)

Table 3. **Total Annual Cost Spreadsheet - Recuperative Thermal Oxidizer**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	9,700	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.5	
Waste gas heat content (BTU/scf):	5.0	conservative estimate
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.26	air
Combustion temperature (oF):	1,400	
Preheat temperature (oF):	735	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	11.0	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	4.611	Equation 2.21
(scfm):	113.0	
Total Gas Flowrate (scfm):	9,813	

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
Incinerator:		
@ 0 % heat recovery:	0	Equation 2.29
@ 35 % heat recovery:	0	Equation 2.30
@ 50 % heat recovery:	170,069	Equation 2.31
@ 70 % heat recovery:	0	Equation 2.32
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	185,504	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	395,419	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	427,052	Table 2.8
Total Capital Investment (TCI = 1.25B):	**533,815**	Table 2.8

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	475,193	
Electricity	18,521	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	26,691	Table 2.10
Capital recovery	42,835	Table 2.10
Total Annual Cost	**687,412**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 4. Total Annual Cost Spreadsheet - Regenerative Thermal Oxidizer
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	2016	
Reference Date CEPCI value*	541.7	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	1.54	

INPUT PARAMETERS

Exhaust Gas flowrate (scfm):	9,700	
Reference temperature (oF):	77	
Waste gas inlet temperature, Tw_i (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.85	
Waste gas heat content, annual avg. (BTU/scf):	5.00	
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.255	air
Combustion temperature (oF):	1,800	
Temperature leaving heat exchanger, Tw_o (oF):	1541	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	30.4	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Requirement:	(lb/min):	1.448	Equation 2.45
	(scfm):	35.49	
	(mcf/yr):	18,651.0	
Total Maximum Exhaust Gas Flowrate:	(scfm):	9,735	

CALCULATED CAPITAL COSTS

Oxidizer Equipment Cost (EC):		
@ 85% heat recovery:	402,502	Equation 2.33
@ 95% heat recovery:	0	Equation 2.33
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	417,937	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	642,374	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	693,764	Table 2.8
Total Capital Investment (TCI = 1.25B):	**867,205**	Table 2.8

ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	149,208	
Electricity	50,610	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	43,360	Table 2.10
Capital recovery	69,587	Table 2.10
Total Annual Cost	**436,938**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 5. Total Annual Cost Spreadsheet - Catalytic Oxidizer (Fixed Bed)
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS		
Gas flowrate (scfm):	9,700	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.50	
Waste gas heat content (BTU/scf):	5.0	
Waste gas heat content (BTU/lb):	67.66	
Gas heat capacity (BTU/lb-oF):	0.255	air
Combustion temperature (oF):	850	
Preheat temperature (oF):	460	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	13.0	Table 2.11

ANNUAL COST INPUTS	
Operating factor (hr/yr):	8760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Catalyst price ($/ft3):	650
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Catalyst life (years):	4
Capital recovery factor (system):	0.0802
Capital recovery factor (catalyst):	0.2820
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES		
Auxiliary Fuel Reqrmnt (lb/min):	1.738	Equation 2.21
(scfm):	42.6	
Total Gas Flowrate (scfm):	9,743	
Catalyst Volume (ft3):	18.9	Equation 2.28

CALCULATED CAPITAL COSTS		
Equipment Costs ($):		
@ 0 % heat recovery:	0	Equation 2.34
@ 35 % heat recovery:	0	Equation 2.35
@ 50 % heat recovery:	203,359	Equation 2.36
@ 70 % heat recovery:	0	Equation 2.37
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	218,793	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	466,378	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	503,688	Table 2.8
Total Capital Investment (TCI = 1.25B):	**629,610**	Table 2.8

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	179,106	
Electricity	21,716	Equation 2.42
Catalyst replacement	3,735	Table 2.10
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	31,481	Table 2.10
Capital recovery	49,459	
Total Annual Cost	**409,670**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 6. **Total Annual Cost Spreadsheet - Straight Ductwork For Routing To Controls**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:		2016	
Reference Date CEPCI value*		541.7	
Most recent CEPCI value**		832.6	Final value for June 2022
Cost Escalation Factor		1.54	

INPUT PARAMETERS					
Inlet stream flowrate (acfm):		3,233	per exhaust fan		
Duct velocity (ft/min)		658		11.0	ft/sec
Duct length (ft)		33	per exhaust fan		
Material of construction		Galv. CS sh.			
Insulation thickness (in.)		1			
Duct design		Circ.-spiral			
Cost equation parameters	a:	2.560			
	b:	0.937			
Cost equation form		1			
Control system installation factor		1.5			
(if no system, enter '0')					
Fan-motor combined efficiency (fraction)		0.60			
DESIGN PARAMETERS					
Number of exhaust fans		3			
Duct diameter (in.)		30.00			
Pressure drop (in. w.c.)		0.007			
CALCULATED CAPITAL COSTS					
Equipment Cost ($)--base		2,066			
Equipment Cost ($)--escalated		3,176			
Purchased Equipment Cost ($)		3,430			
Total Capital Investment per Exhaust Fan($)		5,145			
Overall Total Capital Investment($):		**15,435**			

ANNUAL COST INPUTS	
Operating factor (hours/year):	8760
Electricity price ($/kWhr):	0.100
Annual interest rate (fractional):	0.05
Ductwork economic life (years):	20
Capital recovery factor (system):	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)
Electricity	4
Taxes, insurance, administrative	257
Capital recovery	413
Total Annual Cost	**674**

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.
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Table 1. **Cost Summary of RACT III VOC Oxidation Control Options**
Neville Chemical Company - Pittsburgh, PA

Source Name: **#5 PC Flaking Belt**
Source ID: **P013**

1a. - Ranking of VOC Oxidation Control Options, by Reduction Efficiency

Ranking	Control Technology	Destruction Efficiency (%)	Capture Efficiency (%)	Reduction [1] Efficiency (%)	Inlet VOC Emissions (tons/year)	VOC Reduction (tons/year)
1.	Recuperative Thermal Oxidizer	98.0	98.0	96.0	7.32	7.03
2.	Catalytic Oxidizer	98.0	98.0	96.0	7.32	7.03
3.	Regenerative Thermal Oxidizer	98.0	98.0	96.0	7.32	7.03

1b. - Ranking of Annual Control Costs per Ton of Pollutant Reduced

Ranking	Control Technology	Capital Cost ($)	Capital Recovery Cost ($/year)	Capital-Only Control Cost ($/ton/yr)	Total Annualized Cost ($/year)	**VOC Control Cost ($/ton/yr)**
1.	Catalytic Oxidizer	442,043	34,939	4,970	283,493	**40,325**
2.	Regenerative Thermal Oxidizer	726,001	58,256	8,287	318,638	**45,325**
3.	Recuperative Thermal Oxidizer	455,893	36,582	5,204	430,406	**61,223**

[1] Overall reduction based on product of Control efficiency and Capture efficiency

Table 2. INPUT PARAMETERS FOR CONTROL TECHNOLOGY ANALYSIS
Neville Chemical Company - Pittsburgh, PA

Emissions Data

VOC emissions, tpy:	7.32
Operating hours per year:	8,760

Collection System Data

Units Controlled	Expected Capture Eff.		Expected Air Flow, cfm
Fume Hood Exhaust Fan	98%		4,850
		Total:	4,850

Total length of collection ductwork, ft	100	estimated
Ductwork diameter, inches	30	

Control System Data

	Removal Efficiency, %	Heat Recovery, %
Recuperative Thermal Oxidizer	98	50
Catalytic Oxidizer (fixed bed)	98	50
Regenerative Thermal Oxidizer (RTO)	98	85

Auxiliary Equipment and Costs

	Cost	
Ductwork to collect fumes	15,435	(see Table 6)
Other equipment	0	
Total Auxiliary Equipment Costs:	15,435	

Facility-specific Economic Data

Operator labor cost, $/hr	45.00
Maintenance labor cost, $/hr	45.00
Electricity cost, $/kwh	0.10
Natural Gas cost, $/mcf	8.00
Debt Interest rate, fraction	0.05

Other Economic Data

Taxes, insurance, admin, fraction	0.05	EPA spreadsheet*
Catalyst cost, $/ft3	350	EPA spreadsheet*
Catalyst life (years):	4	EPA spreadsheet*
Control system life (years):	20	EPA spreadsheet*
Operating labor factor (hr/sh):	0.5	EPA spreadsheet*
Maintenance labor factor (hr/sh):	0.5	EPA spreadsheet*
CEPCI (cost inflation factor)	832.6	Final value for June 2022

(Chemical Engineering Plant Cost Index, updated monthly in "Chemical Engineering Magazine")

* USEPA-developed spreadsheet, named: US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm
(available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution)

Table 3. **Total Annual Cost Spreadsheet - Recuperative Thermal Oxidizer**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	4,850	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.5	
Waste gas heat content (BTU/scf):	5.0	conservative estimate
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.26	air
Combustion temperature (oF):	1,400	
Preheat temperature (oF):	735	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	11.0	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	2.305	Equation 2.21
(scfm):	56.5	
Total Gas Flowrate (scfm):	4,907	

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
Incinerator:		
@ 0 % heat recovery:	0	Equation 2.29
@ 35 % heat recovery:	0	Equation 2.30
@ 50 % heat recovery:	142,991	Equation 2.31
@ 70 % heat recovery:	0	Equation 2.32
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	158,426	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	337,699	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	364,714	Table 2.8
Total Capital Investment (TCI = 1.25B):	**455,893**	Table 2.8

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	237,596	
Electricity	9,260	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	22,795	Table 2.10
Capital recovery	36,582	Table 2.10
Total Annual Cost	**430,406**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

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Table 4. **Total Annual Cost Spreadsheet - Regenerative Thermal Oxidizer**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	2016	
Reference Date CEPCI value*	541.7	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	1.54	

INPUT PARAMETERS

Exhaust Gas flowrate (scfm):	4,850	
Reference temperature (oF):	77	
Waste gas inlet temperature, Tw_i (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.85	
Waste gas heat content, annual avg. (BTU/scf):	5.00	
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.255	air
Combustion temperature (oF):	1,800	
Temperature leaving heat exchanger, Tw_o (oF):	1541	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	30.4	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Requirement:	(lb/min):	0.724	Equation 2.45
	(scfm):	17.74	
	(mcf/yr):	9,325.5	
Total Maximum Exhaust Gas Flowrate:	(scfm):	4,868	

CALCULATED CAPITAL COSTS

Oxidizer Equipment Cost (EC):		
@ 85% heat recovery:	334,451	Equation 2.33
@ 95% heat recovery:	0	Equation 2.33
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	349,886	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	537,779	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	580,801	Table 2.8
Total Capital Investment (TCI = 1.25B):	**726,001**	Table 2.8

ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	74,604	
Electricity	25,305	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	36,300	Table 2.10
Capital recovery	58,256	Table 2.10
Total Annual Cost	**318,638**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

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Table 5. Total Annual Cost Spreadsheet - Catalytic Oxidizer (Fixed Bed)
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	4,850	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.50	
Waste gas heat content (BTU/scf):	5.0	
Waste gas heat content (BTU/lb):	67.66	
Gas heat capacity (BTU/lb-oF):	0.255	air
Combustion temperature (oF):	850	
Preheat temperature (oF):	460	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	13.0	Table 2.11

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	0.869	Equation 2.21
(scfm):	21.3	
Total Gas Flowrate (scfm):	4,871	
Catalyst Volume (ft3):	9.4	Equation 2.28

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
@ 0 % heat recovery:	0	Equation 2.34
@ 35 % heat recovery:	0	Equation 2.35
@ 50 % heat recovery:	138,178	Equation 2.36
@ 70 % heat recovery:	0	Equation 2.37
Other equipment (see Table 2):	15,435	
Total Equipment Cost--base:	153,612	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	327,439	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	353,634	Table 2.8
Total Capital Investment (TCI = 1.25B):	**442,043**	Table 2.8

ANNUAL COST INPUTS

Operating factor (hr/yr):	8760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Catalyst price ($/ft3):	650
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Catalyst life (years):	4
Capital recovery factor (system):	0.0802
Capital recovery factor (catalyst):	0.2820
Taxes, insurance, admin. factor:	0.05

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	89,553	
Electricity	10,858	Equation 2.42
Catalyst replacement	1,868	Table 2.10
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	22,102	Table 2.10
Capital recovery	34,939	
Total Annual Cost	**283,493**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

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Table 6. **Total Annual Cost Spreadsheet - Straight Ductwork For Routing To Controls**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	2016		
Reference Date CEPCI value*	541.7		
Most recent CEPCI value**	832.6	Final value for June 2022	
Cost Escalation Factor	1.54		

INPUT PARAMETERS				
Inlet stream flowrate (acfm):		1,617	per exhaust fan	
Duct velocity (ft/min)		329		5.5 ft/sec
Duct length (ft)		33	per exhaust fan	
Material of construction		Galv. CS sh.		
Insulation thickness (in.)		1		
Duct design		Circ.-spiral		
Cost equation parameters	a:	2.560		
	b:	0.937		
Cost equation form		1		
Control system installation factor		1.5		
(if no system, enter '0')				
Fan-motor combined efficiency (fraction)		0.60		

DESIGN PARAMETERS	
Number of exhaust fans	3
Duct diameter (in.)	30.00
Pressure drop (in. w.c.)	0.002

CALCULATED CAPITAL COSTS	
Equipment Cost ($)--base	2,066
Equipment Cost ($)--escalated	3,176
Purchased Equipment Cost ($)	3,430
Total Capital Investment per Exhaust Fan($)	5,145
Overall Total Capital Investment($):	**15,435**

ANNUAL COST INPUTS	
Operating factor (hours/year):	8760
Electricity price ($/kWhr):	0.100
Annual interest rate (fractional):	0.05
Ductwork economic life (years):	20
Capital recovery factor (system):	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)
Electricity	1
Taxes, insurance, administrative	257
Capital recovery	413
Total Annual Cost	**671**

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.
** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 1. **Cost Summary of RACT III VOC Oxidation Control Options**
Neville Chemical Company - Pittsburgh, PA

Source Name: **WWT Batch Tanks**
Source ID: **P014**

1a. - Ranking of VOC Oxidation Control Options, by Reduction Efficiency

Ranking	Control Technology	Destruction Efficiency (%)	Capture Efficiency (%)	Reduction [1] Efficiency (%)	Inlet VOC Emissions (tons/year)	VOC Reduction (tons/year)
1.	Recuperative Thermal Oxidizer	98.0	98.0	96.0	10.28	9.87
2.	Catalytic Oxidizer	Not Technically Feasible			N/A	N/A
3.	Regenerative Thermal Oxidizer	Not Technically Feasible			N/A	N/A

1b. - Ranking of Annual Control Costs per Ton of Pollutant Reduced

Ranking	Control Technology	Capital Cost ($)	Capital Recovery Cost ($/year)	Capital-Only Control Cost ($/ton/yr)	Total Annualized Cost ($/year)	**VOC Control Cost ($/ton/yr)**
1.	Recuperative Thermal Oxidizer	427,169	34,277	3,472	195,078	**19,759**
2.	Catalytic Oxidizer	Not Technically Feasible				**N/A**
3.	Regenerative Thermal Oxidizer	Not Technically Feasible				**N/A**

[1] Overall reduction based on product of Control efficiency and Capture efficiency

Table 2. INPUT PARAMETERS FOR CONTROL TECHNOLOGY ANALYSIS
Neville Chemical Company - Pittsburgh, PA

Emissions Data

VOC emissions, tpy:	10.28
Operating hours per year:	8,760

Collection System Data

Units Controlled	Expected Capture Eff.		Expected Air Flow, cfm
Batch Tanks (3)	98%		300
		Total:	300

Total length of collection ductwork, ft	500	estimated
Ductwork diameter, inches	30	

Facility-specific Economic Data

Operator labor cost, $/hr	45.00
Maintenance labor cost, $/hr	45.00
Electricity cost, $/kwh	0.10
Natural Gas cost, $/mcf	8.00
Debt Interest rate, fraction	0.05

Other Economic Data

Taxes, insurance, admin, fraction	0.05	EPA spreadsheet*
Catalyst cost, $/ft3	350	EPA spreadsheet*
Catalyst life (years):	4	EPA spreadsheet*
Control system life (years):	20	EPA spreadsheet*
Operating labor factor (hr/sh):	0.5	EPA spreadsheet*
Maintenance labor factor (hr/sh):	0.5	EPA spreadsheet*
CEPCI (cost inflation factor)	832.6	Final value for June 2022

(Chemical Engineering Plant Cost Index, updated monthly in "Chemical Engineering Magazine")

Control System Data (typical)

	Removal Efficiency, %	Heat Recovery, %
Recuperative Thermal Oxidizer	98	50
Catalytic Oxidizer (fixed bed)	98	50
Regenerative Thermal Oxidizer (RTO)	98	85

Auxiliary Equipment and Costs

	Cost	
Ductwork to collect fumes	77,173	(see Table 7)
Other equipment	0	
Total Auxiliary Equipment Costs:	77,173	

* USEPA-developed spreadsheet, named: US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm
(available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution)

Table 3. **Total Annual Cost Spreadsheet - Recuperative Thermal Oxidizer**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	300	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.5	
Waste gas heat content (BTU/scf):	5.0	conservative estimate
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.26	air
Combustion temperature (oF):	1,400	
Preheat temperature (oF):	735	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	11.0	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	0.143	Equation 2.21
(scfm):	3.5	
Total Gas Flowrate (scfm):	303	

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
Incinerator:		
@ 0 % heat recovery:	0	Equation 2.29
@ 35 % heat recovery:	0	Equation 2.30
@ 50 % heat recovery:	71,271	Equation 2.31
@ 70 % heat recovery:	0	Equation 2.32
Other equipment (see Table 2):	77,173	
Total Equipment Cost--base:	148,444	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	316,422	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	341,735	Table 2.8
Total Capital Investment (TCI = 1.25B):	**427,169**	Table 2.8

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	14,697	
Electricity	573	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	21,358	Table 2.10
Capital recovery	34,277	Table 2.10
Total Annual Cost	**195,078**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 4. Total Annual Cost Spreadsheet - Straight Ductwork For Routing To Controls
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	2016		
Reference Date CEPCI value*	541.7		
Most recent CEPCI value**	832.6	Final value for June 2022	
Cost Escalation Factor	1.54		

INPUT PARAMETERS				
Inlet stream flowrate (acfm):		100	per exhaust fan	
Duct velocity (ft/min)		20		0.3 ft/sec
Duct length (ft)		167	per exhaust fan	
Material of construction		Galv. CS sh.		
Insulation thickness (in.)		1		
Duct design		Circ.-spiral		
Cost equation parameters	a:	2.560		
	b:	0.937		
Cost equation form		1		
Control system installation factor		1.5		
(if no system, enter '0')				
Fan-motor combined efficiency (fraction)		0.60		
DESIGN PARAMETERS				
Number of exhaust fans		3		
Duct diameter (in.)		30.00		
Pressure drop (in. w.c.)		0.000		
CALCULATED CAPITAL COSTS				
Equipment Cost ($)--base		10,331		
Equipment Cost ($)--escalated		15,879		
Purchased Equipment Cost ($)		17,150		
Total Capital Investment per Exhaust Fan($)		25,724		
Overall Total Capital Investment($):		**77,173**		

ANNUAL COST INPUTS	
Operating factor (hours/year):	8760
Electricity price ($/kWhr):	0.100
Annual interest rate (fractional):	0.05
Ductwork economic life (years):	20
Capital recovery factor (system):	0.0802
Taxes, insurance, admin. factor:	0.05
CALCULATED ANNUAL COSTS	
Item	Cost ($/yr)
Electricity	0
Taxes, insurance, administrative	1,286
Capital recovery	2,064
Total Annual Cost	**3,350**

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.
** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 1. **Cost Summary of RACT III VOC Oxidation Control Options**
Neville Chemical Company - Pittsburgh, PA

Source Name: **Product Loading**
Source ID: **P016**

1a. - Ranking of VOC Oxidation Control Options, by Reduction Efficiency

Ranking	Control Technology	Destruction Efficiency (%)	Capture Efficiency (%)	Reduction [1] Efficiency (%)	Inlet VOC Emissions (tons/year)	VOC Reduction (tons/year)
1.	Recuperative Thermal Oxidizer	98.0	98.0	96.0	18.24	17.52
2.	Catalytic Oxidizer	Not Technically Feasible			N/A	N/A
3.	Regenerative Thermal Oxidizer	Not Technically Feasible			N/A	N/A

1b. - Ranking of Annual Control Costs per Ton of Pollutant Reduced

Ranking	Control Technology	Capital Cost ($)	Capital Recovery Cost ($/year)	Capital-Only Control Cost ($/ton/yr)	Total Annualized Cost ($/year)	**VOC Control Cost ($/ton/yr)**
1.	Recuperative Thermal Oxidizer	499,264	40,062	2,287	240,097	**13,706**
2.	Catalytic Oxidizer	Not Technically Feasible				**N/A**
3.	Regenerative Thermal Oxidizer	Not Technically Feasible				**N/A**

[1] Overall reduction based on product of Control efficiency and Capture efficiency

Table 2. **INPUT PARAMETERS FOR CONTROL TECHNOLOGY ANALYSIS**
Neville Chemical Company - Pittsburgh, PA

Emissions Data

VOC emissions, tpy:	18.24
Operating hours per year:	8,760

Collection System Data

Units Controlled	Expected Capture Eff.	Expected Air Flow, cfm
Product Loading	98%	1,000
	Total:	1,000

Total length of collection ductwork, ft	500	estimated
Ductwork diameter, inches	30	

Facility-specific Economic Data

Operator labor cost, $/hr	45.00
Maintenance labor cost, $/hr	45.00
Electricity cost, $/kwh	0.10
Natural Gas cost, $/mcf	8.00
Debt Interest rate, fraction	0.05

Other Economic Data

Taxes, insurance, admin, fraction	0.05	EPA spreadsheet*
Catalyst cost, $/ft3	350	EPA spreadsheet*
Catalyst life (years):	4	EPA spreadsheet*
Control system life (years):	20	EPA spreadsheet*
Operating labor factor (hr/sh):	0.5	EPA spreadsheet*
Maintenance labor factor (hr/sh):	0.5	EPA spreadsheet*
CEPCI (cost inflation factor)	832.6	Final value for June 2022

(Chemical Engineering Plant Cost Index, updated monthly in "Chemical Engineering Magazine")

Control System Data (typical)

	Removal Efficiency, %	Heat Recovery, %
Recuperative Thermal Oxidizer	98	50
Catalytic Oxidizer (fixed bed)	98	50
Regenerative Thermal Oxidizer (RTO)	98	85

Auxiliary Equipment and Costs

	Cost	
Ductwork to collect fumes	77,173	(see Table 7)
Other equipment	0	
Total Auxiliary Equipment Costs:	77,173	

* USEPA-developed spreadsheet, named: US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm
(available at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution)

Table 3. **Total Annual Cost Spreadsheet - Recuperative Thermal Oxidizer**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	1999	
Reference Date CEPCI value*	390.6	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	2.13	

INPUT PARAMETERS

Gas flowrate (scfm):	1,000	
Reference temperature (oF):	77	
Inlet gas temperature (oF):	70	
Inlet gas density (lb/scf):	0.0739	air
Primary heat recovery (fraction):	0.5	
Waste gas heat content (BTU/scf):	5.0	conservative estimate
Waste gas heat content (BTU/lb):	68	
Gas heat capacity (BTU/lb-oF):	0.26	air
Combustion temperature (oF):	1,400	
Preheat temperature (oF):	735	Equation 2.18
Fuel heat of combustion (BTU/lb):	21,502	methane
Fuel density (lb/ft3):	0.0408	methane
Pressure drop (in. w.c.):	11.0	Table 2.11

ANNUAL COST INPUTS

Operating factor (hr/yr):	8,760
Operating labor rate ($/hr):	45.00
Maintenance labor rate ($/hr):	45.00
Operating labor factor (hr/sh):	0.50
Maintenance labor factor (hr/sh):	0.50
Electricity price ($/kwh):	0.100
Natural gas price ($/mscf):	8.00
Annual interest rate (fraction):	0.05
Control system life (years):	20
Capital recovery factor:	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED UTILITY USAGES

Auxiliary Fuel Reqrmnt (lb/min):	0.475	Equation 2.21
(scfm):	11.7	
Total Gas Flowrate (scfm):	1,012	

CALCULATED CAPITAL COSTS

Equipment Costs ($):		
Incinerator:		
@ 0 % heat recovery:	0	Equation 2.29
@ 35 % heat recovery:	0	Equation 2.30
@ 50 % heat recovery:	96,324	Equation 2.31
@ 70 % heat recovery:	0	Equation 2.32
Other equipment (see Table 2):	77,173	
Total Equipment Cost--base:	173,497	Sum of EC and auxiliary equipment
Total Equipment Cost--escalated (A):	369,825	Base cost times escalation factor
Purchased Equipment Cost (B = 1.08A):	399,411	Table 2.8
Total Capital Investment (TCI = 1.25B):	**499,264**	Table 2.8

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)	
Operating labor	24,638	
Supervisory labor	3,696	Table 2.10
Maintenance labor	24,638	
Maintenance materials	24,638	Table 2.10, equals maintenance labor cost
Natural gas	48,989	
Electricity	1,909	Equation 2.42
Overhead	46,565	Table 2.10
Taxes, insurance, administrative	24,963	Table 2.10
Capital recovery	40,062	Table 2.10
Total Annual Cost	**240,097**	

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.

** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Table 4. **Total Annual Cost Spreadsheet - Straight Ductwork For Routing To Controls**
Neville Chemical Company - Pittsburgh, PA

COST REFERENCE DATE*:	2016	
Reference Date CEPCI value*	541.7	
Most recent CEPCI value**	832.6	Final value for June 2022
Cost Escalation Factor	1.54	

INPUT PARAMETERS

Inlet stream flowrate (acfm):		333	per exhaust fan	
Duct velocity (ft/min)		68		1.1 ft/sec
Duct length (ft)		167	per exhaust fan	
Material of construction		Galv. CS sh.		
Insulation thickness (in.)		1		
Duct design		Circ.-spiral		
Cost equation parameters	a:	2.560		
	b:	0.937		
Cost equation form		1		
Control system installation factor		1.5		
(if no system, enter '0')				
Fan-motor combined efficiency (fraction)		0.60		

DESIGN PARAMETERS

Number of exhaust fans	3
Duct diameter (in.)	30.00
Pressure drop (in. w.c.)	0.001

CALCULATED CAPITAL COSTS

Equipment Cost ($)--base	10,331
Equipment Cost ($)--escalated	15,879
Purchased Equipment Cost ($)	17,150
Total Capital Investment per Exhaust Fan($)	25,724
Overall Total Capital Investment($):	**77,173**

ANNUAL COST INPUTS

Operating factor (hours/year):	8760
Electricity price ($/kWhr):	0.100
Annual interest rate (fractional):	0.05
Ductwork economic life (years):	20
Capital recovery factor (system):	0.0802
Taxes, insurance, admin. factor:	0.05

CALCULATED ANNUAL COSTS

Item	Cost ($/yr)
Electricity	0
Taxes, insurance, administrative	1,286
Capital recovery	2,064
Total Annual Cost	**3,350**

* Reference date and corresponding CEPCI value taken from USEPA cost estimating spreadsheet 'US EPA_OAQPS_IncineratorsOxidizers_Calc_Sheet_september_2022.xlsm' , based on OAQPS Cost Manual, 7th Edition.
** Chemical Engineering Plant Cost Index (CEPCI) values are published in *Chemical Engineering* monthly journals

Carbon Adsorption Tables

Source Name and ID:	Unit 20-21 (P006)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system:	Carbon Canister Adsorber with Carbon Replacement
For fixed-bed carbon adsorbers, provide the following information:	
Select the type of operation:	Not Applicable
Select the type of material used to fabricate the carbon adsorber vessels:	Not Applicable
Select the orientation for the adsorber vessels:	Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	100	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	2.220	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$15,000	
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **Unit 20-21 (P006)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	9.237	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	24,993	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	9	canisters
Total Quantity of Carbon Required for 9 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	27,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: Unit 20-21 (P006)
Facility Name: Neville Chemical Company

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	Equation	Cost	
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$183,627	
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$15,000	
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$198,627	
Instrumentation =	0.10 × A =	$19,863	
Sales taxes =	0.03 × A =	$5,959	
Freight =	0.05 × A =	$9,931	
	Total Purchased Equipment Costs (B) =	**$234,380**	

Installation Costs (in 2022 dollars:)

Parameter	Equation	Cost	
Direct and Indirect Installation =	0.20 × B =	$18,750	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$18,750	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$25,313	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$278,443**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	Equation	Cost	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$1,724	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$65,866	
	Direct Annual Costs (DAC) =	**$145,198**	**in 2022 dollars**

Indirect Annual Costs

Parameter	Equation	Cost	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$5,569	
Property Taxes	= 1% of TCI	$2,784	
Insurance	= 1% of TCI	$2,784	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$14,718	
	Indirect Annual Costs (IAC) =	**$72,420**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$217,619**	**in 2022 dollars**

Cost Effectiveness

Parameter	Equation	Cost	
Total Annual Cost =	TAC =	$217,619	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	9.24	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$23,558**	per ton of pollutants removed

Source Name and ID:	2PC Flaking Belt (P011)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system: Carbon Canister Adsorber with Carbon Replacement

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

Select the type of operation: Not Applicable

Select the type of material used to fabricate the carbon adsorber vessels: Not Applicable

Select the orientation for the adsorber vessels: Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	4,850	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	1.860	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$15,000	
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **2PC Flaking Belt (P011)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	7.739	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	20,940	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	7	canisters
Total Quantity of Carbon Required for 7 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	21,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: **2PC Flaking Belt (P011)**
Facility Name: **Neville Chemical Company**

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	Equation	Cost	
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$142,821	
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$15,000	
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$157,821	
Instrumentation =	0.10 × A =	$15,782	
Sales taxes =	0.03 × A =	$4,735	
Freight =	0.05 × A =	$7,891	
	Total Purchased Equipment Costs (B) =	**$186,229**	

Installation Costs (in 2022 dollars:)

Parameter	Equation	Cost	
Direct and Indirect Installation =	0.20 × B =	$14,898	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$14,898	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$20,113	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$221,240**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	Equation	Cost	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$1,341	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$51,229	
	Direct Annual Costs (DAC) =	**$130,178**	**in 2022 dollars**

Indirect Annual Costs

Parameter	Equation	Cost	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$4,425	
Property Taxes	= 1% of TCI	$2,212	
Insurance	= 1% of TCI	$2,212	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$11,897	
	Indirect Annual Costs (IAC) =	**$67,312**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$197,490**	**in 2022 dollars**

Cost Effectiveness

Parameter	Equation	Cost	
Total Annual Cost =	TAC =	$197,490	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	7.74	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$25,517**	per ton of pollutants removed

Source Name and ID:	2PC Resin Kettles (P011)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system:	Carbon Canister Adsorber with Carbon Replacement
For fixed-bed carbon adsorbers, provide the following information:	
Select the type of operation:	Not Applicable
Select the type of material used to fabricate the carbon adsorber vessels:	Not Applicable
Select the orientation for the adsorber vessels:	Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	200	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	3.550	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$325,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation
Contingency Factor (CF)	10.0	percent* — * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **2PC Resin Kettles (P011)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	14.772	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	39,966	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	14	canisters
Total Quantity of Carbon Required for 14 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	42,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: **2PC Resin Kettles (P011)**
Facility Name: **Neville Chemical Company**

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	**Equation**	**Cost**	
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$285,642	
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$325,000	
Total Purchased Equipment Costs for Carbon Adsorber (A) =	EC_{Adsorb} + EC_{aux} =	$610,642	
Instrumentation =	0.10 × A =	$61,064	
Sales taxes =	0.03 × A =	$18,319	
Freight =	0.05 × A =	$30,532	
	Total Purchased Equipment Costs (B) =	**$720,558**	

Installation Costs (in 2022 dollars:)

Parameter	**Equation**	**Cost**	
Direct and Indirect Installation =	0.20 × B =	$57,645	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$57,645	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$77,820	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$856,022**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	**Equation**	**Cost**	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$2,682	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$102,458	
	Direct Annual Costs (DAC) =	**$182,748**	**in 2022 dollars**

Indirect Annual Costs

Parameter	**Equation**	**Cost**	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$17,120	
Property Taxes	= 1% of TCI	$8,560	
Insurance	= 1% of TCI	$8,560	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$63,636	
	Indirect Annual Costs (IAC) =	**$144,442**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$327,190**	**in 2022 dollars**

Cost Effectiveness

Parameter	**Equation**	**Cost**	
Total Annual Cost =	TAC =	$327,190	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	14.77	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$22,150**	per ton of pollutants removed

Source Name and ID:	3PC Flaking Belt (P012)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system: Carbon Canister Adsorber with Carbon Replacement

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

Select the type of operation: Not Applicable

Select the type of material used to fabricate the carbon adsorber vessels: Not Applicable

Select the orientation for the adsorber vessels: Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	9,700	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	1.530	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$15,000	
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **3PC Flaking Belt (P012)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	6.366	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	17,225	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	6	canisters
Total Quantity of Carbon Required for 6 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	18,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: **3PC Flaking Belt (P012)**
Facility Name: **Neville Chemical Company**

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	Equation	Cost	
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$122,418	
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$15,000	
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$137,418	
Instrumentation =	0.10 × A =	$13,742	
Sales taxes =	0.03 × A =	$4,123	
Freight =	0.05 × A =	$6,871	
	Total Purchased Equipment Costs (B) =	**$162,153**	

Installation Costs (in 2022 dollars:)

Parameter	Equation	Cost	
Direct and Indirect Installation =	0.20 × B =	$12,972	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$12,972	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$17,513	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$192,638**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	Equation	Cost	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$1,149	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$43,911	
	Direct Annual Costs (DAC) =	**$122,668**	**in 2022 dollars**

Indirect Annual Costs

Parameter	Equation	Cost	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$3,853	
Property Taxes	= 1% of TCI	$1,926	
Insurance	= 1% of TCI	$1,926	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$10,487	
	Indirect Annual Costs (IAC) =	**$64,758**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$187,426**	**in 2022 dollars**

Cost Effectiveness

Parameter	Equation	Cost	
Total Annual Cost =	TAC =	$187,426	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	6.37	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$29,440**	per ton of pollutants removed

Source Name and ID:	3PC Resin Kettles (P012)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system: Carbon Canister Adsorber with Carbon Replacement

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

Select the type of operation: Not Applicable

Select the type of material used to fabricate the carbon adsorber vessels: Not Applicable

Select the orientation for the adsorber vessels: Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	200	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	4.970	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$325,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **3PC Resin Kettles (P012)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	20.680	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	55,952	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	19	canisters
Total Quantity of Carbon Required for 19 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	57,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: 3PC Resin Kettles (P012)
Facility Name: Neville Chemical Company

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	**Equation**	**Cost**
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$387,657
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$325,000
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$712,657
Instrumentation =	0.10 × A =	$71,266
Sales taxes =	0.03 × A =	$21,380
Freight =	0.05 × A =	$35,633
	Total Purchased Equipment Costs (B) =	**$840,935**

Installation Costs (in 2022 dollars:)

Parameter	**Equation**	**Cost**	
Direct and Indirect Installation =	0.20 × B =	$67,275	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$67,275	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$90,821	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$999,031**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	**Equation**	**Cost**	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$3,640	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$139,051	
	Direct Annual Costs (DAC) =	**$220,298**	**in 2022 dollars**

Indirect Annual Costs

Parameter	**Equation**	**Cost**	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$19,981	
Property Taxes	= 1% of TCI	$9,990	
Insurance	= 1% of TCI	$9,990	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$70,687	
	Indirect Annual Costs (IAC) =	**$157,214**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$377,512**	**in 2022 dollars**

Cost Effectiveness

Parameter	**Equation**	**Cost**	
Total Annual Cost =	TAC =	$377,512	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	20.68	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$18,255**	per ton of pollutants removed

Source Name and ID:	3PC Resin Kettles (P012)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system? Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	200	scfm (at 77 °F; 1 atm)		
Inlet stream temperature (T_{in})	375	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.00153			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh		
Operator Labor Rate	$45.00	per hour		
Maintenance Labor Rate	$45.00	per hour		
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb		
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.	

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) and Ductwork =	$325,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation		
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.		
Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID:	5PC Flaking Belt (P013)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system:	Carbon Canister Adsorber with Carbon Replacement
For fixed-bed carbon adsorbers, provide the following information:	
Select the type of operation:	Not Applicable
Select the type of material used to fabricate the carbon adsorber vessels:	Not Applicable
Select the orientation for the adsorber vessels:	Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	4,850	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	1.670	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$15,000	
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **5PC Flaking Belt (P013)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	6.949	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	18,801	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	7	canisters
Total Quantity of Carbon Required for 7 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	21,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: 5PC Flaking Belt (P013)
Facility Name: Neville Chemical Company

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	Equation	Cost	
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$142,821	
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$15,000	
Total Purchased Equipment Costs for Carbon Adsorber (A) =	EC_{Adsorb} + EC_{aux} =	$157,821	
Instrumentation =	0.10 × A =	$15,782	
Sales taxes =	0.03 × A =	$4,735	
Freight =	0.05 × A =	$7,891	
	Total Purchased Equipment Costs (B) =	**$186,229**	

Installation Costs (in 2022 dollars:)

Parameter	Equation	Cost	
Direct and Indirect Installation =	0.20 × B =	$14,898	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$14,898	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$20,113	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$221,240**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	Equation	Cost	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$1,341	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$51,229	
	Direct Annual Costs (DAC) =	**$130,178**	**in 2022 dollars**

Indirect Annual Costs

Parameter	Equation	Cost	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$4,425	
Property Taxes	= 1% of TCI	$2,212	
Insurance	= 1% of TCI	$2,212	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$11,897	
	Indirect Annual Costs (IAC) =	**$67,312**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$197,490**	**in 2022 dollars**

Cost Effectiveness

Parameter	Equation	Cost	
Total Annual Cost =	TAC =	$197,490	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	6.95	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$28,420**	per ton of pollutants removed

Source Name and ID:	5PC Resin Kettles (P013)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system:	Carbon Canister Adsorber with Carbon Replacement
For fixed-bed carbon adsorbers, provide the following information:	
Select the type of operation:	Not Applicable
Select the type of material used to fabricate the carbon adsorber vessels:	Not Applicable
Select the orientation for the adsorber vessels:	Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	75	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	3.200	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$250,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **5PC Resin Kettles (P013)**
Facility Name: **Neville Chemical Company**

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: **Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled: **m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	13.315	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	36,025	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	13	canisters
Total Quantity of Carbon Required for 13 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	39,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: 5PC Resin Kettles (P013)
Facility Name: Neville Chemical Company

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	Equation	Cost
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$265,239
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$250,000
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$515,239
Instrumentation =	0.10 × A =	$51,524
Sales taxes =	0.03 × A =	$15,457
Freight =	0.05 × A =	$25,762
	Total Purchased Equipment Costs (B) =	**$607,982**

Installation Costs (in 2022 dollars:)

Parameter	Equation	Cost	
Direct and Indirect Installation =	0.20 × B =	$48,639	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$48,639	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$65,662	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$722,283**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	Equation	Cost	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$2,490	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$95,140	
	Direct Annual Costs (DAC) =	**$175,238**	**in 2022 dollars**

Indirect Annual Costs

Parameter	Equation	Cost	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$14,446	
Property Taxes	= 1% of TCI	$7,223	
Insurance	= 1% of TCI	$7,223	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$52,097	
	Indirect Annual Costs (IAC) =	**$127,553**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$302,791**	**in 2022 dollars**

Cost Effectiveness

Parameter	Equation	Cost	
Total Annual Cost =	TAC =	$302,791	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	13.32	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$22,740**	per ton of pollutants removed

Source Name and ID:	WWT Batch Tanks (P014)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system:	Carbon Canister Adsorber with Carbon Replacement
For fixed-bed carbon adsorbers, provide the following information:	
Select the type of operation:	Not Applicable
Select the type of material used to fabricate the carbon adsorber vessels:	Not Applicable
Select the orientation for the adsorber vessels:	Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	300	acfm*	assumed 100 cfm per each of three batch tanks
VOC Emission Rate (m_{voc})	2.350	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$15,000	
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **WWT Batch Tanks (P014)**
Facility Name: **Neville Chemical Company**

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:	**Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled:	**m-Xylene**

Parameter	**Equation**	**Calculated Value**	**Units**
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	9.778	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	26,456	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	9	canisters
Total Quantity of Carbon Required for 9 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	27,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: WWT Batch Tanks (P014)
Facility Name: Neville Chemical Company

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	**Equation**	**Cost**	
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$183,627	
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$15,000	
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$198,627	
Instrumentation =	0.10 × A =	$19,863	
Sales taxes =	0.03 × A =	$5,959	
Freight =	0.05 × A =	$9,931	
	Total Purchased Equipment Costs (B) =	**$234,380**	

Installation Costs (in 2022 dollars:)

Parameter	**Equation**	**Cost**	
Direct and Indirect Installation =	0.20 × B =	$18,750	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$18,750	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$25,313	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$278,443**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	**Equation**	**Cost**	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$1,724	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$65,866	
	Direct Annual Costs (DAC) =	**$145,198**	**in 2022 dollars**

Indirect Annual Costs

Parameter	**Equation**	**Cost**	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$5,569	
Property Taxes	= 1% of TCI	$2,784	
Insurance	= 1% of TCI	$2,784	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$14,718	
	Indirect Annual Costs (IAC) =	**$72,420**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$217,619**	**in 2022 dollars**

Cost Effectiveness

Parameter	**Equation**	**Cost**	
Total Annual Cost =	TAC =	$217,619	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	9.78	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$22,255**	per ton of pollutants removed

Source Name and ID:	Product Loading (P016)
Facility Name:	Neville Chemical Company

Data Inputs

Select the type of carbon adsorber system: Carbon Canister Adsorber with Carbon Replacement

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

Select the type of operation:	Not Applicable
Select the type of material used to fabricate the carbon adsorber vessels:	Not Applicable
Select the orientation for the adsorber vessels:	Not Applicable

Enter the design data for the proposed Carbon Canister Adsorber with Carbon Replacement

Number of operating hours per year (Θ_s)	8,760	hours/year	
Waste Gas Flow Rate (Q)	1,000	acfm*	*acfm is actual cubic feet/min
VOC Emission Rate (m_{voc})	4.000	lbs/hour	
Required VOC removal efficiency (E)	95	percent	
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)	2	Years	
Estimated Carbon Replacement Rate (CRR)	379	lbs/hour*	* 379 lbs./hour is a default value. User should enter actual value, if known.
Carbon Canister Size	3000	lbs carbon per canister*	* 3000 lbs of carbon per canister is a default value. User should enter prefered canister size, if known.

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene	
Partial Pressure of m-Xylene in waste gas stream	0.005	psia
Parameter "k" for m-Xylene	0.708	**Note:**
Parameter "m" for m-Xylene	0.113	Typical values of "k" and "m" for some common VOCs are shown in Table A.

Enter the cost data for the carbon adsorber:

Desired dollar-year	2022			
CEPCI* for 2022	833	CEPCI value for 2022	567.5	2018
Annual Interest Rate (i)	5	percent*	* 5 percent is a default value. User should enter current prime bank 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.

Carbon Canister Cost	$20,403	per canister (in 2022 dollar	Note: Typical costs for carbon canisters are shown in Table B.
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	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.

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}) =	$15,000	
Contingency Factor (CF)	10.0	percent* * 10 percent is a default value. The contingency factor should be between 5 and 15 percent.

Source Name and ID: **Product Loading (P016)**
Facility Name: **Neville Chemical Company**

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:	**Carbon Canister Adsorber with Carbon Replacement**
Name of VOC Controlled:	**m-Xylene**

Parameter	Equation	Calculated Value	Units
Quantity of m-Xylene Removed:			
Quantity of m-Xylene Removed (Wvoc) =	$W_{voc} = m_{voc} \times \Theta_s \times E =$	16.644	tons/year
Number of times canister(s) replaced per year =	$\Theta_s / \Theta_A =$	2	
Adsorber Parameters for Carbon Canisters:			
Time for Adsorption (Θ_A) =	*Number of operating hours before carbon canister replacement =*	4,380	hours
Equilibrium Capacity at the Inlet ($W_{e(max)}$) =	$k \times P^m =$	0.389	lb. VOC/lb. Carbon
Working Capacity (w_c) =	$0.5 \times w_{e(max)} =$	0.195	lb. VOC/lb. Carbon
Estimated Total Carbon Required (M_c) =	$(m_{voc}/w_c) \times \Theta_A =$	45,032	lbs.
Number of Carbon Canisters Required =	M_c/Carbon Canister Capacity	16	canisters
Total Quantity of Carbon Required for 16 Canisters =	Number of Carbon Canisters * Carbon Capacity per Canister =	48,000	lbs.
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	0.0963	
Capital Recovery Factor for carbon (CRF_{Carbon}) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1] =$ Where n = Carbon Life and i = Interest Rate	0.5378	

Source Name and ID: **Product Loading (P016)**
Facility Name: **Neville Chemical Company**

Cost Estimate

Capital Costs

Estimated capital costs for a Carbon Canister Adsorber with Carbon Replacement with the following characteristics:

VOC Controlled/Recovered = m-Xylene
Adsorber Vessel Orientation = Not Applicable
Operating Schedule = Not Applicable

Total Capital Investment (TCI) (in 2022 dollars:)

Parameter	**Equation**	**Cost**
Total Cost for All Carbon Adsorber Canisters (EC_{Adsorb}) =	Canister Cost x Number of Canisters Required =	$326,448
Auxiliary Equipment (EC_{aux}) =	(Based on design costs or estimated using methods provided in Section 2)	$15,000
Total Purchased Equipment Costs for Carbon Adsorber (A) =	$EC_{Adsorb} + EC_{aux}$ =	$341,448
Instrumentation =	0.10 × A =	$34,145
Sales taxes =	0.03 × A =	$10,243
Freight =	0.05 × A =	$17,072
	Total Purchased Equipment Costs (B) =	**$402,909**

Installation Costs (in 2022 dollars:)

Parameter	**Equation**	**Cost**	
Direct and Indirect Installation =	0.20 × B =	$32,233	
Site Preparation (SP) =		$0	
Buildings (Bldg) =		$0	
	Total Direct and Indirect Installation Costs =	$32,233	
Contingency Cost (C) =	CF x (Purchase Equipment Cost + Installation costs) =	$43,514	
	Total Capital Investment (TCI) = Purchace Equipment + Installation + Contingency Costs =	**$478,655**	**in 2022 dollars**

Annual Costs

Direct Annual Costs

Parameter	**Equation**	**Cost**	
Operating Labor Costs:	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	
	Supervisor = 15% of Operator	$3,696	
Maintenance Costs:	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	
	Materials = 100% of maintenance labor	$24,638	
Carbon Replacement Costs:	Labor = CFR_{carbon} [Labor Rate × T_C/CRR] =	$3,065	
	Carbon = CRF_{carbon}[CC x T_c x 1.08] =	$117,095	
	Direct Annual Costs (DAC) =	**$197,768**	**in 2022 dollars**

Indirect Annual Costs

Parameter	**Equation**	**Cost**	
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	
Administrative Charges	= 2% of TCI	$9,573	
Property Taxes	= 1% of TCI	$4,787	
Insurance	= 1% of TCI	$4,787	
Capital Recovery	= $CRF_{Adsorber}$ × [TCI - [(1.08 *CC *Tc) + (LR*Tc/CRR)] =	$24,589	
	Indirect Annual Costs (IAC) =	**$90,300**	**in 2022 dollars**
	Total Annual Cost (TAC) = DAC + IAC =	**$288,069**	**in 2022 dollars**

Cost Effectiveness

Parameter	**Equation**	**Cost**	
Total Annual Cost =	TAC =	$288,069	per year in 2022 dollars
Annual Quantity of VOC Removed =	$W_{voc} = m_{voc} \times \Theta_s \times E$ =	16.64	tons/year
Cost Effectiveness =	**Total Annual Cost (TAC) / Annual Quantity of VOC Removed/Recovered =**	**$17,308**	per ton of pollutants removed

Condensation Cost Tables

Source Name and ID:	Unit 20-21 (P006)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system?	Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	100	scfm (at 77 °F; 1 atm)*		
Inlet stream temperature (T_{in})	80	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.0014			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh	
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	per hour	
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb	
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.

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) and Ductwork =	$25,000			
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.		
Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID: **Unit 20-21 (P006)**
Facility Name: **Neville Chemical Company**

Design Parameters

The following design parameters for the condenser 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.

VOC	VOC volume Fraction of waste stream entering the condenser ($Y_{voc,in}$)	Heat Capacity ($C_{p,voc}$) (Btu/lb.-mole-°F)	Heat of Condensation (ΔH_{ref}) (Btu/lb.-mole)
m-Xylene	0.00136	43.82	15360

Parameter	Equation		Calculated Value	Units
Partial Pressure of m-Xylene VOC in Exit Stream (Pvoc) =	$760 \times (M_{voc,out} / (M_{in} - M_{voc, recovered}))$ =	$760 \times [Y_{voc,in} \times (1 - \eta)] / [1 - (\eta \times Y_{voc,in})]$ =	0.1	mmHg
Estimated Condensation Temperature for m-Xylene (Tcon) =	$((B / (A - \log(P_{voc})) - C) \times 1.8 + 32$ =		-25.9	°F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Quantities of VOC in Inlet and Outlet streams:					
Moles of VOC in the inlet stream ($M_{voc,in}$) =	$(Q_{in} / 392) \times (Y_{voc,in}) \times 60$ =	0.021	lb.-moles/hour	2.21	lb/hour
Moles of VOC in the outlet stream ($M_{voc,out}$) =	$M_{voc,in} \times (1 - \eta)$ =	0.002	lb.-moles/hour		
Quantity of VOC Recovered:					
Moles of VOC Recovered ($M_{voc, recovered}$) =	$M_{voc,in} \times \eta$ =	0.019	lb.-moles/hour		
Quantity of VOC Recovered (W_{voc}) =	$M_{voc, recovered} \times MW_{voc}$ =	1.99	lb./operating hour	8.71	Tons/year
Calculation of Enthalpy of Condensation:					
Critical Temperature for VOC (T_c) =		1111	°R		
Reference Temperature for Heat of Condensation (T_1) =		742	°R		
Condensation Temperature (T_2) =	$T_{con} + 459.67$ =	434	°R		
Enthalpy of condensation of VOC (ΔHvoc) at -25.9 °F =	$\Delta H_{ref} \times [(1 - T_2 / T_c) / (1 - T_1 / T_c)]^{0.38}$ =	19,340	Btu/lb.-mole		
Calculation of Condenser Heat Load:					
Heat capacity of air ($C_{p, air}$) =		6.95	Btu/lb.-mole-°F @ 77 °F and 1 atm.		
Mean Temperature (T_{mean}) =	$(T_{in} + T_{con}) / 2$ =	27	°F		
Enthalpy change associated with the condensed VOC (ΔH_{con}) =	$M_{voc,recovered} \times [\Delta H_{voc} + C_{p,voc} (T_{in} - T_{con})]$=	449	Btu/hour		
Enthalpy change associated with the uncondensed VOC (ΔH_{uncon}) =	$M_{voc,out} \times C_{p,voc} \times (T_{in} - T_{con})$ =	10	Btu/hour		
Enthalpy change associated with the non-condensable air (ΔHnoncon) =	$[((Q_{in} / 392) \times 60) - M_{voc,in}] \times C_{p,air} \times (T_{in} - T_{con})$ =	11,255	Btu/hour		
Condenser Heat Load (H_{load}) =	$\Delta H_{con} + \Delta H_{uncon} + \Delta H_{noncon}$ =	11,714	Btu/hour		
Calculation of Surface Area:					
Temperature of coolant entering the condenser ($T_{cool,in}$) =	T_{con} - 15 °F =	-40.9	°F		
Temperature of coolant exiting the condenser ($T_{cool,out}$) =	$T_{cool,in}$ + 25 °F =	-15.9	°F		
Logarithmic mean temperature difference (ΔT_{lm}) =	$\frac{[(T_{in} - T_{cool,out}) - (T_{con} - T_{cool,in})]}{[\ln\{(T_{in} - T_{cool, out})/(T_{con} - T_{cool,in})\}]}$	43.6	°F		
Condenser Surface Area (A_{con}) =	$H_{load} / (U \times \Delta T_{lm})$ =	13.4	ft²		
Calculation of Coolant Flow Rate and Refrigeration Capacity:					
Coolant Flow Rate (W_{cool}) =	$H_{load} / (C_{p,cool} \times (T_{cool,out} - T_{cool,in}))$ =	721	lb./hour		
Refrigeration Capacity (R) =	H_{load} / 12,000 Btu/ton =	0.98	Tons/hour		
Calculation of Electricity Consumption:					
Estimated Electricity Consumption (E) =	$2.7411 \times \exp(-0.015 \times T_{con})$ =	4.05	kW/ton		
Capital Recovery Factor:					
Capital Recovery Factor (CRF) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1]$ = Where n = Equipment Life and i = Interest Rate	0.0963			

Source Name and ID: Unit 20-21 (P006)
Facility Name: Neville Chemical Company

Control Cost Estimate

Capital Costs

VOC Controlled/Recovered =	m-Xylene
Refrigeration Capacity (R) =	0.98 tons/hour
Condensation Temperature for Waste Stream (T_{con}) =	-26 °F

Total Capital Investment (TCI) (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Equipment Costs for Single Stage Refrigeration Unit (ECr):	1.611 × exp[9.83 - 0.014 × Tcon + 0.34 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =	$61,741	
Equipment Costs for Multistage Refrigeration Unit (ECr):	1.611 × exp[9.73 - 0.012 × Tcon + 0.58 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =		$52,734
Other Equipment Costs for a Packaged Solvent Recovery System (ECp):	1.25 × ECr =	$77,176	$13,184
Costs for Refrigerated Condenser (A) =	ECp + ECr =	$138,917	$65,918
Instrumentation =	0.10 × A =	Included in A	Included in A
Sales taxes =	0.03 × A =	$4,168	$1,978
Freight =	0.05 × A =	$6,946	$3,296
	Total Purchased Equipment Costs (B) =	**$150,031**	$71,191

Direct Installation Costs (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Foundations and Supports =	0.14 × B =	Not applicable	Not applicable
Handling and Erection =	0.08 × B =	Not applicable	Not applicable
Electrical =	0.08 × B =	Not applicable	Not applicable
Piping =	0.02 × B =	Not applicable	Not applicable
Insulation =	0.10 × B =	Not applicable	Not applicable
Painting =	0.01 × B =	Not applicable	Not applicable
Site Preparation (SP) =		$0	$0
Buildings (Bldg) =		$25,000	$25,000
	Total Direct Costs (DC) = B + (0.43 × B) + SP + Bldg =	$175,031	$96,191
	Total Capital Investment (TCI) = Direct Costs + Contingency = (1.15 × DC) =	**$201,285**	**$110,620**

Annual Costs

Direct Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Annual Electricity Cost =	$(R / \eta_{Comp}) \times E \times \Theta_s \times p_e$ =	$4,070	$4,070
Operating Labor =	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	$24,638
	Supervisor = 15% of Operator	$3,696	$3,696
Maintenance Costs =	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	$24,638
	Materials = 100% of maintenance labor	$24,638	$24,638
	Direct Annual Costs (DAC) =	**$81,678**	**$81,678**

Indirect Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	$46,565
Administrative Charges	= 2% of TCI	$4,026	$2,212
Property Taxes	= 1% of TCI	$2,013	$1,106
Insurance	= 1% of TCI	$2,013	$1,106
Capital Recovery	= CRF × TCI	$19,392	$10,657
	Indirect Annual Costs (IAC) =	**$74,009**	**$61,647**

VOC Recovery Credit

Parameter	Equation	Single Stage	Multi-Stage
Annual Recovery Credit for Condensate (RC)	= $W_{voc} \times Credit \times \Theta_s$ =	$0	$0
	Total Annual Cost (TAC) = DAC + IAC - RC =	**$155,687**	**$143,325**

Cost Effectiveness

Parameter	Equation	Single Stage	Multi-Stage
Total Annual Cost =	TAC =	$155,687	$143,325
Annual Quantity of VOC Removed/Recovered =	W_{voc} =	8.7	8.7
Cost Effectiveness =	**Total Annual Cost/Annual Quantity of VOC Removed/Recovered =**	**$17,870**	**$16,451**

Source Name and ID:	2PC Resin Kettles (P011)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system? Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	200	scfm (at 77 °F; 1 atm)		
Inlet stream temperature (T_{in})	375	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.00110			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh	
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	per hour	
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb	
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.

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) and Ductwork =	$325,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.

Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID: 2PC Resin Kettles (P011)
Facility Name: Neville Chemical Company

Design Parameters

The following design parameters for the condenser 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.

VOC	VOC volume Fraction of waste stream entering the condenser ($Y_{voc,in}$)	Heat Capacity ($C_{p,voc}$) (Btu/lb.-mole-°F)	Heat of Condensation (ΔH_{ref}) (Btu/lb.-mole)
m-Xylene	0.00110	43.82	15360

Parameter	Equation		Calculated Value	Units
Partial Pressure of m-Xylene VOC in Exit Stream (Pvoc) =	$760 \times (M_{voc,out} / (M_{in} - M_{voc, recovered}))$ =	$760 \times [Y_{voc,in} \times (1 - \eta)] / [1 - (\eta \times Y_{voc,in})]$ =	0.1	mmHg
Estimated Condensation Temperature for m-Xylene (Tcon) =	$((B / (A - \log (P_{voc})) - C) \times 1.8 + 32$ =		-29.7	°F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Quantities of VOC in Inlet and Outlet streams:					
Moles of VOC in the inlet stream ($M_{voc,in}$) =	$(Q_{in} / 392) \times (Y_{voc,in}) \times 60$ =	0.034	lb.-moles/hour	3.58	lb/hour
Moles of VOC in the outlet stream ($M_{voc,out}$) =	$M_{voc,in} \times (1 - \eta)$ =	0.003	lb.-moles/hour		
Quantity of VOC Recovered:					
Moles of VOC Recovered ($M_{voc, recovered}$) =	$M_{voc,in} \times \eta$ =	0.030	lb.-moles/hour		
Quantity of VOC Recovered (W_{voc}) =	$M_{voc, recovered} \times MW_{voc}$ =	3.22	lb./operating hour	14.09	Tons/year
Calculation of Enthalpy of Condensation:					
Critical Temperature for VOC (T_c) =		1111	°R		
Reference Temperature for Heat of Condensation (T_1) =		742	°R		
Condensation Temperature (T_2) =	$T_{con} + 459.67$ =	430	°R		
Enthalpy of condensation of VOC (ΔHvoc) at -29.7 °F =	$\Delta H_{ref} \times [(1 - T_2 / T_c) / (1 - T_1 / T_c)]^{0.38}$ =	19,381	Btu/lb.-mole		
Calculation of Condenser Heat Load:					
Heat capacity of air ($C_{p, air}$) =		6.95	Btu/lb.-mole-°F @ 77 °F and 1 atm.		
Mean Temperature (T_{mean}) =	$(T_{in} + T_{con}) / 2$ =	173	°F		
Enthalpy change associated with the condensed VOC (ΔH_{con}) =	$M_{voc,recovered} \times [\Delta H_{voc} + C_{p,voc} (T_{in} - T_{con})]$=	1,125	Btu/hour		
Enthalpy change associated with the uncondensed VOC (ΔH_{uncon}) =	$M_{voc,out} \times C_{p,voc} \times (T_{in} - T_{con})$ =	60	Btu/hour		
Enthalpy change associated with the non-condensable air (ΔHnoncon) =	$[((Q_{in} / 392) \times 60) - M_{voc,in}] \times C_{p,air} \times (T_{in} - T_{con})$ =	86,008	Btu/hour		
Condenser Heat Load (H_{load}) =	$\Delta H_{con} + \Delta H_{uncon} + \Delta H_{noncon}$ =	87,193	Btu/hour		
Calculation of Surface Area:					
Temperature of coolant entering the condenser ($T_{cool,in}$) =	T_{con} - 15 °F =	-44.7	°F		
Temperature of coolant exiting the condenser ($T_{cool,out}$) =	$T_{cool,in}$ + 25 °F =	-19.7	°F		
Logarithmic mean temperature difference (ΔT_{lm}) =	$\frac{[(T_{in} - T_{cool,out}) - (T_{con} - T_{cool,in})]}{[\ln\{(T_{in} - T_{cool, out})/(T_{con} - T_{cool,in})\}]}$ =	116.1	°F		
Condenser Surface Area (A_{con}) =	$H_{load} / (U \times \Delta T_{lm})$ =	37.5	ft²		
Calculation of Coolant Flow Rate and Refrigeration Capacity:					
Coolant Flow Rate (W_{cool}) =	$H_{load} / (C_{p,cool} \times (T_{cool,out} - T_{cool,in}))$ =	5,366	lb./hour		
Refrigeration Capacity (R) =	H_{load} / 12,000 Btu/ton =	7.27	Tons/hour		
Calculation of Electricity Consumption:					
Estimated Electricity Consumption (E) =	$2.7411 \times \exp(-0.015 \times T_{con})$ =	4.28	kW/ton		
Capital Recovery Factor:					
Capital Recovery Factor (CRF) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1]$ = Where n = Equipment Life and i = Interest Rate	0.0963			

Source Name and ID: **2PC Resin Kettles (P011)**
Facility Name: **Neville Chemical Company**

Control Cost Estimate

Capital Costs

VOC Controlled/Recovered =	m-Xylene
Refrigeration Capacity (R) =	7.27 tons/hour
Condensation Temperature for Waste Stream (T_{con}) =	-30 °F

Total Capital Investment (TCI) (in 2022 dollars)

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Equipment Costs for Single Stage Refrigeration Unit (ECr):	1.611 × exp[9.83 - 0.014 × Tcon + 0.34 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =	$128,769	
Equipment Costs for Multistage Refrigeration Unit (ECr):	1.611 × exp[9.73 - 0.012 × Tcon + 0.58 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =		$176,723
Other Equipment Costs for a Packaged Solvent Recovery System (ECp):	1.25 × ECr =	$160,961	$44,181
Costs for Refrigerated Condenser (A) =	ECp + ECr =	$289,730	$220,903
Instrumentation =	0.10 × A =	Included in A	Included in A
Sales taxes =	0.03 × A =	$8,692	$6,627
Freight =	0.05 × A =	$14,487	$11,045
	Total Purchased Equipment Costs (B) =	**$312,908**	$238,575

Direct Installation Costs (in 2022 dollars)

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Foundations and Supports =	0.14 × B =	Not applicable	Not applicable
Handling and Erection =	0.08 × B =	Not applicable	Not applicable
Electrical =	0.08 × B =	Not applicable	Not applicable
Piping =	0.02 × B =	Not applicable	Not applicable
Insulation =	0.10 × B =	Not applicable	Not applicable
Painting =	0.01 × B =	Not applicable	Not applicable
Site Preparation (SP) =		$0	$0
Buildings (Bldg) =		$325,000	$325,000
	Total Direct Costs (DC) = B + (0.43 × B) + SP + Bldg =	$637,908	$563,575
	Total Capital Investment (TCI) = Direct Costs + Contingency = (1.15 × DC) =	**$733,595**	**$648,112**

Annual Costs

Direct Annual Costs

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Annual Electricity Cost =	$(R / \eta_{Comp}) \times E \times \Theta_s \times p_e$ =	$32,050	$32,050
Operating Labor =	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	$24,638
	Supervisor = 15% of Operator	$3,696	$3,696
Maintenance Costs =	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	$24,638
	Materials = 100% of maintenance labor	$24,638	$24,638
	Direct Annual Costs (DAC) =	**$109,658**	**$109,658**

Indirect Annual Costs

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	$46,565
Administrative Charges	= 2% of TCI	$14,672	$12,962
Property Taxes	= 1% of TCI	$7,336	$6,481
Insurance	= 1% of TCI	$7,336	$6,481
Capital Recovery	= CRF × TCI	$70,676	$62,441
	Indirect Annual Costs (IAC) =	**$146,585**	**$134,930**

VOC Recovery Credit

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Annual Recovery Credit for Condensate (RC)	= $W_{voc} \times$ Credit $\times \Theta_s$ =	$0	$0
	Total Annual Cost (TAC) = DAC + IAC - RC =	**$256,243**	**$244,588**

Cost Effectiveness

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Total Annual Cost =	TAC =	$256,243	$244,588
Annual Quantity of VOC Removed/Recovered =	W_{voc} =	14.1	14.1
Cost Effectiveness =	**Total Annual Cost/Annual Quantity of VOC Removed/Recovered =**	**$18,182**	**$17,355**

Source Name and ID:	3PC Resin Kettles (P012)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system?	Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	200	scfm (at 77 °F; 1 atm)		
Inlet stream temperature (T_{in})	375	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.00153			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh	
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	per hour	
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb	
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.

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) and Ductwork =	$325,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation		
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.		
Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID: **3PC Resin Kettles (P012)**
Facility Name: **Neville Chemical Company**

Design Parameters

The following design parameters for the condenser 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.

VOC	VOC volume Fraction of waste stream entering the condenser ($Y_{voc,in}$)	Heat Capacity ($C_{p,voc}$) (Btu/lb.-mole-°F)	Heat of Condensation (ΔH_{ref}) (Btu/lb.-mole)
m-Xylene	0.00153	43.82	15360

Parameter	Equation		Calculated Value	Units
Partial Pressure of m-Xylene VOC in Exit Stream (Pvoc) =	$760 \times (M_{voc,out} / (M_{in} - M_{voc,recovered}))$ =	$760 \times [Y_{voc,in} \times (1 - \eta)] / [1 - (\eta \times Y_{voc,in})]$ =	0.1	mmHg
Estimated Condensation Temperature for m-Xylene (Tcon) =	$((B / (A - \log(P_{voc}))) - C) \times 1.8 + 32$ =		-23.8	°F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Quantities of VOC in Inlet and Outlet streams:					
Moles of VOC in the inlet stream ($M_{voc,in}$) =	$(Q_{in} / 392) \times (Y_{voc,in}) \times 60$ =	0.047	lb.-moles/hour	4.97	lb/hour
Moles of VOC in the outlet stream ($M_{voc,out}$) =	$M_{voc,in} \times (1 - \eta)$ =	0.005	lb.-moles/hour		
Quantity of VOC Recovered:					
Moles of VOC Recovered ($M_{voc,recovered}$) =	$M_{voc,in} \times \eta$ =	0.042	lb.-moles/hour		
Quantity of VOC Recovered (W_{voc}) =	$M_{voc,recovered} \times MW_{voc}$ =	4.48	lb./operating hour	19.60	Tons/year
Calculation of Enthalpy of Condensation:					
Critical Temperature for VOC (T_c) =		1111	°R		
Reference Temperature for Heat of Condensation (T_1) =		742	°R		
Condensation Temperature (T_2) =	$T_{con} + 459.67$ =	436	°R		
Enthalpy of condensation of VOC (ΔHvoc) at -23.8 °F =	$\Delta H_{ref} \times [(1 - T_2 / T_c) / (1 - T_1 / T_c)]^{0.38}$ =	19,317	Btu/lb.-mole		
Calculation of Condenser Heat Load:					
Heat capacity of air ($C_{p,air}$) =		6.95	Btu/lb.-mole-°F @ 77 °F and 1 atm.		
Mean Temperature (T_{mean}) =	$(T_{in} + T_{con}) / 2$ =	176	°F		
Enthalpy change associated with the condensed VOC (ΔH_{con}) =	$M_{voc,recovered} \times [\Delta H_{voc} + C_{p,voc} (T_{in} - T_{con})]$=	1,551	Btu/hour		
Enthalpy change associated with the uncondensed VOC (ΔH_{uncon}) =	$M_{voc,out} \times C_{p,voc} \times (T_{in} - T_{con})$ =	82	Btu/hour		
Enthalpy change associated with the non-condensable air (ΔHnoncon) =	$[((Q_{in} / 392) \times 60) - M_{voc,in}] \times C_{p,air} \times (T_{in} - T_{con})$ =	84,722	Btu/hour		
Condenser Heat Load (H_{load}) =	$\Delta H_{con} + \Delta H_{uncon} + \Delta H_{noncon}$ =	86,355	Btu/hour		
Calculation of Surface Area:					
Temperature of coolant entering the condenser ($T_{cool,in}$) =	T_{con} - 15 °F =	-38.8	°F		
Temperature of coolant exiting the condenser ($T_{cool,out}$) =	$T_{cool,in}$ + 25 °F =	-13.8	°F		
Logarithmic mean temperature difference (ΔT_{lm}) =	$\frac{[(T_{in} - T_{cool,out}) - (T_{con} - T_{cool,in})]}{[\ln\{(T_{in} - T_{cool,out})/(T_{con} - T_{cool,in})\}]}$	114.8	°F		
Condenser Surface Area (A_{con}) =	$H_{load} / (U \times \Delta T_{lm})$ =	37.6	ft²		
Calculation of Coolant Flow Rate and Refrigeration Capacity:					
Coolant Flow Rate (W_{cool}) =	$H_{load} / (C_{p,cool} \times (T_{cool,out} - T_{cool,in}))$ =	5,314	lb./hour		
Refrigeration Capacity (R) =	H_{load} / 12,000 Btu/ton =	7.20	Tons/hour		
Calculation of Electricity Consumption:					
Estimated Electricity Consumption (E) =	$2.7411 \times \exp(-0.015 \times T_{con})$ =	3.92	kW/ton		
Capital Recovery Factor:					
Capital Recovery Factor (CRF) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1]$ = Where n = Equipment Life and i = Interest Rate	0.0963			

Source Name and ID: 3PC Resin Kettles (P012)
Facility Name: Neville Chemical Company

Control Cost Estimate

Capital Costs

VOC Controlled/Recovered =	m-Xylene
Refrigeration Capacity (R) =	7.2 tons/hour
Condensation Temperature for Waste Stream (T_{con}) =	-24 °F

Total Capital Investment (TCI) (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Equipment Costs for Single Stage Refrigeration Unit (ECr):	1.611 × exp[9.83 - 0.014 × Tcon + 0.34 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =	$118,206	
Equipment Costs for Multistage Refrigeration Unit (ECr):	1.611 × exp[9.73 - 0.012 × Tcon + 0.58 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =		$163,765
Other Equipment Costs for a Packaged Solvent Recovery System (ECp):	1.25 × ECr =	$147,758	$40,941
Costs for Refrigerated Condenser (A) =	ECp + ECr =	$265,964	$204,706
Instrumentation =	0.10 × A =	Included in A	Included in A
Sales taxes =	0.03 × A =	$7,979	$6,141
Freight =	0.05 × A =	$13,298	$10,235
	Total Purchased Equipment Costs (B) =	**$287,241**	$221,083

Direct Installation Costs (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Foundations and Supports =	0.14 × B =	Not applicable	Not applicable
Handling and Erection =	0.08 × B =	Not applicable	Not applicable
Electrical =	0.08 × B =	Not applicable	Not applicable
Piping =	0.02 × B =	Not applicable	Not applicable
Insulation =	0.10 × B =	Not applicable	Not applicable
Painting =	0.01 × B =	Not applicable	Not applicable
Site Preparation (SP) =		$0	$0
Buildings (Bldg) =		$325,000	$325,000
	Total Direct Costs (DC) = B + (0.43 × B) + SP + Bldg =	$612,241	$546,083
	Total Capital Investment (TCI) = Direct Costs + Contingency = (1.15 × DC) =	**$704,077**	**$627,995**

Annual Costs

Direct Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Annual Electricity Cost =	$(R / \eta_{Comp}) \times E \times \Theta_s \times p_e$ =	$29,062	$29,062
Operating Labor =	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	$24,638
	Supervisor = 15% of Operator	$3,696	$3,696
Maintenance Costs =	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	$24,638
	Materials = 100% of maintenance labor	$24,638	$24,638
	Direct Annual Costs (DAC) =	**$106,671**	**$106,671**

Indirect Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	$46,565
Administrative Charges	= 2% of TCI	$14,082	$12,560
Property Taxes	= 1% of TCI	$7,041	$6,280
Insurance	= 1% of TCI	$7,041	$6,280
Capital Recovery	= CRF × TCI	$67,832	$60,503
	Indirect Annual Costs (IAC) =	**$142,560**	**$132,187**

VOC Recovery Credit

Parameter	Equation	Single Stage	Multi-Stage
Annual Recovery Credit for Condensate (RC)	$= W_{voc} \times Credit \times \Theta_s$ =	$0	$0
	Total Annual Cost (TAC) = DAC + IAC - RC =	**$249,231**	**$238,858**

Cost Effectiveness

Parameter	Equation	Single Stage	Multi-Stage
Total Annual Cost =	TAC =	$249,231	$238,858
Annual Quantity of VOC Removed/Recovered =	W_{voc} =	19.6	19.6
Cost Effectiveness =	**Total Annual Cost/Annual Quantity of VOC Removed/Recovered =**	**$12,714**	**$12,185**

Source Name and ID:	5PC Resin Kettles (P013)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system? Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	75	scfm (at 77 °F; 1 atm)		
Inlet stream temperature (T_{in})	375	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.00260			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh	
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	per hour	
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb	
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.

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) and Ductwork =	$250,000	Neville estimate - see Section 3.4 of *VOC RACT III Evaluation* for an explanation
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.

Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID: **5PC Resin Kettles (P013)**
Facility Name: **Neville Chemical Company**

Design Parameters

The following design parameters for the condenser 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.

VOC	VOC volume Fraction of waste stream entering the condenser ($Y_{voc,in}$)	Heat Capacity ($C_{p,voc}$) (Btu/lb.-mole-°F)	Heat of Condensation (ΔH_{ref}) (Btu/lb.-mole)
m-Xylene	0.00260	43.82	15360

Parameter	Equation		Calculated Value	Units
Partial Pressure of m-Xylene VOC in Exit Stream (Pvoc) =	$760 \times (M_{voc,out} / (M_{in} - M_{voc,\ recovered}))$ =	$760 \times [Y_{voc,in} \times (1 - \eta)] / [1 - (\eta \times Y_{voc,in})]$ =	0.2	mmHg
Estimated Condensation Temperature for m-Xylene (Tcon) =	$((B / (A - \log (P_{voc}))) - C) \times 1.8 + 32$ =		-13.9	°F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Quantities of VOC in Inlet and Outlet streams:					
Moles of VOC in the inlet stream ($M_{voc,in}$) =	$(Q_{in} / 392) \times (Y_{voc,in}) \times 60$ =	0.030	lb.-moles/hour	3.17	lb/hour
Moles of VOC in the outlet stream ($M_{voc,out}$) =	$M_{voc,in} \times (1 - \eta)$ =	0.003	lb.-moles/hour		
Quantity of VOC Recovered:					
Moles of VOC Recovered ($M_{voc,\ recovered}$) =	$M_{voc,in} \times \eta$ =	0.027	lb.-moles/hour		
Quantity of VOC Recovered (W_{voc}) =	$M_{voc,\ recovered} \times MW_{voc}$ =	2.85	lb./operating hour	12.49	Tons/year
Calculation of Enthalpy of Condensation:					
Critical Temperature for VOC (T_c) =		1111	°R		
Reference Temperature for Heat of Condensation (T_1) =		742	°R		
Condensation Temperature (T_2) =	$T_{con} + 459.67$ =	446	°R		
Enthalpy of condensation of VOC (ΔHvoc) at -13.9 °F =	$\Delta H_{ref} \times [(1 - T_2 / T_c) / (1 - T_1 / T_c)]^{0.38}$ =	19,209	Btu/lb.-mole		
Calculation of Condenser Heat Load:					
Heat capacity of air ($C_{p,\ air}$) =		6.95	Btu/lb.-mole-°F @ 77 °F and 1 atm.		
Mean Temperature (T_{mean}) =	$(T_{in} + T_{con}) / 2$ =	181	°F		
Enthalpy change associated with the condensed VOC (ΔH_{con}) =	$M_{voc,recovered} \times [\Delta H_{voc} + C_{p,voc} (T_{in} - T_{con})]$=	974	Btu/hour		
Enthalpy change associated with the uncondensed VOC (ΔH_{uncon}) =	$M_{voc,out} \times C_{p,voc} \times (T_{in} - T_{con})$ =	51	Btu/hour		
Enthalpy change associated with the non-condensable air (ΔHnoncon) =	$[((Q_{in} / 392) \times 60) - M_{voc,in}] \times C_{p,air} \times (T_{in} - T_{con})$ =	30,948	Btu/hour		
Condenser Heat Load (H_{load}) =	$\Delta H_{con} + \Delta H_{uncon} + \Delta H_{noncon}$ =	31,973	Btu/hour		
Calculation of Surface Area:					
Temperature of coolant entering the condenser ($T_{cool,in}$) =	T_{con} - 15 °F =	-28.9	°F		
Temperature of coolant exiting the condenser ($T_{cool,out}$) =	$T_{cool,in}$ + 25 °F =	-3.9	°F		
Logarithmic mean temperature difference (ΔT_{lm}) =	$\frac{[(T_{in} - T_{cool,out}) - (T_{con} - T_{cool,in})]}{[\ln\{(T_{in} - T_{cool,\ out})/(T_{con} - T_{cool,in})\}]}$	112.7	°F		
Condenser Surface Area (A_{con}) =	$H_{load} / (U \times \Delta T_{lm})$ =	14.2	ft²		
Calculation of Coolant Flow Rate and Refrigeration Capacity:					
Coolant Flow Rate (W_{cool}) =	$H_{load} / (C_{p,cool} \times (T_{cool,out} - T_{cool,in}))$ =	1,968	lb./hour		
Refrigeration Capacity (R) =	H_{load} / 12,000 Btu/ton =	2.66	Tons/hour		
Calculation of Electricity Consumption:					
Estimated Electricity Consumption (E) =	$2.7411 \times \exp(-0.015 \times T_{con})$ =	3.38	kW/ton		
Capital Recovery Factor:					
Capital Recovery Factor (CRF) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1]$ = Where n = Equipment Life and i = Interest Rate	0.0963			

Source Name and ID: 5PC Resin Kettles (P013)
Facility Name: Neville Chemical Company

Control Cost Estimate

Capital Costs

VOC Controlled/Recovered =	m-Xylene
Refrigeration Capacity (R) =	2.66 tons/hour
Condensation Temperature for Waste Stream (T_{con}) =	-14 °F

Total Capital Investment (TCI) (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Equipment Costs for Single Stage Refrigeration Unit (ECr):	1.611 × exp[9.83 - 0.014 × Tcon + 0.34 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =	$73,394	
Equipment Costs for Multistage Refrigeration Unit (ECr):	1.611 × exp[9.73 - 0.012 × Tcon + 0.58 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =		$81,712
Other Equipment Costs for a Packaged Solvent Recovery System (ECp):	1.25 × ECr =	$91,742	$20,428
Costs for Refrigerated Condenser (A) =	ECp + ECr =	$165,135	$102,140
Instrumentation =	0.10 × A =	Included in A	Included in A
Sales taxes =	0.03 × A =	$4,954	$3,064
Freight =	0.05 × A =	$8,257	$5,107
	Total Purchased Equipment Costs (B) =	**$178,346**	$110,311

Direct Installation Costs (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Foundations and Supports =	0.14 × B =	Not applicable	Not applicable
Handling and Erection =	0.08 × B =	Not applicable	Not applicable
Electrical =	0.08 × B =	Not applicable	Not applicable
Piping =	0.02 × B =	Not applicable	Not applicable
Insulation =	0.10 × B =	Not applicable	Not applicable
Painting =	0.01 × B =	Not applicable	Not applicable
Site Preparation (SP) =		$0	$0
Buildings (Bldg) =		$250,000	$250,000
	Total Direct Costs (DC) = B + (0.43 × B) + SP + Bldg =	$428,346	$360,311
	Total Capital Investment (TCI) = Direct Costs + Contingency = (1.15 × DC) =	**$492,598**	**$414,358**

Annual Costs

Direct Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Annual Electricity Cost =	$(R / \eta_{Comp}) \times E \times \Theta_s \times p_e$ =	$9,274	$9,274
Operating Labor =	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	$24,638	$24,638
	Supervisor = 15% of Operator	$3,696	$3,696
Maintenance Costs =	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	$24,638	$24,638
	Materials = 100% of maintenance labor	$24,638	$24,638
	Direct Annual Costs (DAC) =	**$86,882**	**$86,882**

Indirect Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	$46,565	$46,565
Administrative Charges	= 2% of TCI	$9,852	$8,287
Property Taxes	= 1% of TCI	$4,926	$4,144
Insurance	= 1% of TCI	$4,926	$4,144
Capital Recovery	= CRF × TCI	$47,458	$39,920
	Indirect Annual Costs (IAC) =	**$113,727**	**$103,059**

VOC Recovery Credit

Parameter	Equation	Single Stage	Multi-Stage
Annual Recovery Credit for Condensate (RC)	= $W_{voc} \times \text{Credit} \times \Theta_s$ =	$0	$0
	Total Annual Cost (TAC) = DAC + IAC - RC =	**$200,609**	**$189,941**

Cost Effectiveness

Parameter	Equation	Single Stage	Multi-Stage
Total Annual Cost =	TAC =	$200,609	$189,941
Annual Quantity of VOC Removed/Recovered =	W_{voc} =	12.5	12.5
Cost Effectiveness =	**Total Annual Cost/Annual Quantity of VOC Removed/Recovered =**	**$16,059**	**$15,206**

Source Name and ID:	WWT Batch Tanks (P014)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system? Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	300	scfm (at 77 °F; 1 atm)	assumed 100 cfm per each of the three batch tanks	
Inlet stream temperature (T_{in})	80	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.00047			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh	
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	per hour	
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb	
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.

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) and Ductwork =	$25,000	
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.

Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID: WWT Batch Tanks (P014)
Facility Name: Neville Chemical Company

Design Parameters

The following design parameters for the condenser 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.

VOC	VOC volume Fraction of waste stream entering the condenser ($Y_{voc,in}$)	Heat Capacity ($C_{p,voc}$) (Btu/lb.-mole-°F)	Heat of Condensation (ΔH_{ref}) (Btu/lb.-mole)
m-Xylene	0.00047	43.82	15360

Parameter	Equation		Calculated Value	Units
Partial Pressure of m-Xylene VOC in Exit Stream (Pvoc) =	$760 \times (M_{voc,out} / (M_{in} - M_{voc,\ recovered}))$ =	$760 \times [Y_{voc,in} \times (1 - \eta)] / [1 - (\eta \times Y_{voc,in})]$ =	0.0	mmHg
Estimated Condensation Temperature for m-Xylene (Tcon) =	$((B / (A - \log(P_{voc}))) - C) \times 1.8 + 32$ =		-43.9	°F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Quantities of VOC in Inlet and Outlet streams:					
Moles of VOC in the inlet stream ($M_{voc,in}$) =	$(Q_{in} / 392) \times (Y_{voc,in}) \times 60$ =	0.022	lb.-moles/hour	2.29	lb/hour
Moles of VOC in the outlet stream ($M_{voc,out}$) =	$M_{voc,in} \times (1 - \eta)$ =	0.002	lb.-moles/hour		
Quantity of VOC Recovered:					
Moles of VOC Recovered ($M_{voc,\ recovered}$) =	$M_{voc,in} \times \eta$ =	0.019	lb.-moles/hour		
Quantity of VOC Recovered (W_{voc}) =	$M_{voc,\ recovered} \times MW_{voc}$ =	2.06	lb./operating hour	9.03	Tons/year
Calculation of Enthalpy of Condensation:					
Critical Temperature for VOC (T_c) =		1111	°R		
Reference Temperature for Heat of Condensation (T_1) =		742	°R		
Condensation Temperature (T_2) =	$T_{con} + 459.67$ =	416	°R		
Enthalpy of condensation of VOC (ΔHvoc) at -43.9 °F =	$\Delta H_{ref} \times [(1 - T_2 / T_c) / (1 - T_1 / T_c)]^{0.38}$ =	19,534	Btu/lb.-mole		
Calculation of Condenser Heat Load:					
Heat capacity of air ($C_{p,\ air}$) =		6.95	Btu/lb.-mole-°F @ 77 °F and 1 atm.		
Mean Temperature (T_{mean}) =	$(T_{in} + T_{con}) / 2$ =	18	°F		
Enthalpy change associated with the condensed VOC (ΔH_{con}) =	$M_{voc,recovered} \times [\Delta H_{voc} + C_{p,voc} (T_{in} - T_{con})]$=	485	Btu/hour		
Enthalpy change associated with the uncondensed VOC (ΔH_{uncon}) =	$M_{voc,out} \times C_{p,voc} \times (T_{in} - T_{con})$ =	12	Btu/hour		
Enthalpy change associated with the non-condensable air (ΔHnoncon) =	$[((Q_{in} / 392) \times 60) - M_{voc,in}] \times C_{p,air} \times (T_{in} - T_{con})$ =	39,531	Btu/hour		
Condenser Heat Load (H_{load}) =	$\Delta H_{con} + \Delta H_{uncon} + \Delta H_{noncon}$ =	40,028	Btu/hour		
Calculation of Surface Area:					
Temperature of coolant entering the condenser ($T_{cool,in}$) =	T_{con} - 15 °F =	-58.9	°F		
Temperature of coolant exiting the condenser ($T_{cool,out}$) =	$T_{cool,in}$ + 25 °F =	-33.9	°F		
Logarithmic mean temperature difference (ΔT_{lm}) =	$\frac{[(T_{in} - T_{cool,out}) - (T_{con} - T_{cool,in})]}{[\ln\{(T_{in} - T_{cool,\ out})/(T_{con} - T_{cool,in})\}]}$ =	48.8	°F		
Condenser Surface Area (A_{con}) =	$H_{load} / (U \times \Delta T_{lm})$ =	41.0	ft²		
Calculation of Coolant Flow Rate and Refrigeration Capacity:					
Coolant Flow Rate (W_{cool}) =	$H_{load} / (C_{p,cool} \times (T_{cool,out} - T_{cool,in}))$ =	2,463	lb./hour		
Refrigeration Capacity (R) =	H_{load} / 12,000 Btu/ton =	3.34	Tons/hour		
Calculation of Electricity Consumption:					
Estimated Electricity Consumption (E) =	$2.7411 \times \exp(-0.015 \times T_{con})$ =	5.30	kW/ton		
Capital Recovery Factor:					
Capital Recovery Factor (CRF) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1]$ = Where n = Equipment Life and i = Interest Rate	0.0963			

Source Name and ID: WWT Batch Tanks (P014)
Facility Name: Neville Chemical Company

Control Cost Estimate

Capital Costs

VOC Controlled/Recovered =	m-Xylene
Refrigeration Capacity (R) =	3.34 tons/hour
Condensation Temperature for Waste Stream (T_{con}) =	-44 °F

Total Capital Investment (TCI) (in 2022 dollars)

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Equipment Costs for Single Stage Refrigeration Unit (ECr):	1.611 × exp[9.83 - 0.014 × Tcon + 0.34 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =	Not applicable*	
Equipment Costs for Multistage Refrigeration Unit (ECr):	1.611 × exp[9.73 - 0.012 × Tcon + 0.58 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =		$133,449
Other Equipment Costs for a Packaged Solvent Recovery System (ECp):	1.25 × ECr =	Not applicable	$33,362
Costs for Refrigerated Condenser (A) =	ECp + ECr =	Not applicable	$166,812
Instrumentation =	0.10 × A =	Included in A	Included in A
Sales taxes =	0.03 × A =	Not applicable	$5,004
Freight =	0.05 × A =	Not applicable	$8,341
	Total Purchased Equipment Costs (B) =	**Not applicable**	$180,157

Direct Installation Costs (in 2022 dollars)

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Foundations and Supports =	0.14 × B =	Not applicable	Not applicable
Handling and Erection =	0.08 × B =	Not applicable	Not applicable
Electrical =	0.08 × B =	Not applicable	Not applicable
Piping =	0.02 × B =	Not applicable	Not applicable
Insulation =	0.10 × B =	Not applicable	Not applicable
Painting =	0.01 × B =	Not applicable	Not applicable
Site Preparation (SP) =		Not applicable	$0
Buildings (Bldg) =		Not applicable	$25,000
	Total Direct Costs (DC) = B + (0.43 × B) + SP + Bldg =	Not applicable	$205,157
	Total Capital Investment (TCI) = Direct Costs + Contingency = (1.15 × DC) =	**Not applicable**	**$235,930**

Annual Costs

Direct Annual Costs

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Annual Electricity Cost =	$(R / \eta_{Comp}) \times E \times \Theta_s \times p_e$ =	Not applicable	$18,213
Operating Labor =	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	Not applicable	$24,638
	Supervisor = 15% of Operator	Not applicable	$3,696
Maintenance Costs =	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	Not applicable	$24,638
	Materials = 100% of maintenance labor	Not applicable	$24,638
	Direct Annual Costs (DAC) =	**Not applicable**	**$95,821**

Indirect Annual Costs

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	Not applicable	$46,565
Administrative Charges	= 2% of TCI	Not applicable	$4,719
Property Taxes	= 1% of TCI	Not applicable	$2,359
Insurance	= 1% of TCI	Not applicable	$2,359
Capital Recovery	= CRF × TCI	Not applicable	$22,730
	Indirect Annual Costs (IAC) =	**Not applicable**	**$78,732**

VOC Recovery Credit

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Annual Recovery Credit for Condensate (RC)	$= W_{voc} \times Credit \times \Theta_s$ =	Not applicable	$0
	Total Annual Cost (TAC) = DAC + IAC - RC =	**Not applicable**	**$174,553**

Cost Effectiveness

Parameter	**Equation**	**Single Stage**	**Multi-Stage**
Total Annual Cost =	TAC =	Not applicable	$174,553
Annual Quantity of VOC Removed/Recovered =	W_{voc} =	Not applicable	9.0
Cost Effectiveness =	**Total Annual Cost/Annual Quantity of VOC Removed/Recovered =**	**Not applicable**	**$19,325**

Source Name and ID:	Product Loading to Tankcars and Tankwagons (P016)
Facility Name:	Neville Chemical Company

Data Inputs

Is the condenser a packaged, custom or gasoline vapor recovery system?	Packaged Condenser System

Enter the design data for the proposed condenser:

Number of operating hours per year and per day (Θ_s)	8,760	hours/year	24	hours/day
Volumetric flow rate of the waste stream (Q_{in})	1,000	scfm (at 77 °F; 1 atm)		
Inlet stream temperature (T_{in})	120	°F		
Required VOC removal efficiency (η)	90	%*	* 90% is a default control efficiency. Enter actual value, if known.	
Specific heat of the coolant ($C_{p,cool}$)	0.65	Btu/lb-mole-°F*	* 0.65 Btu/lb-mole-°F is a default value. Enter actual value, if known.	
Estimated equipment life (n)	15	Years*	* 15 years is a default equipment life. Enter actual value, if known.	
Overall heat transfer coefficient (U)	20	Btu/hour-ft²-°F*	* 20 Btu/hour-ft²-°F is a default coefficient. Enter actual value, if known.	
Mechanical efficiency of compressor (η_{comp})	85	%*	* 85% is a default value. Enter actual value, if known.	

Enter the Characteristics of the VOC/HAP:

Name of VOC/HAP	m-Xylene			
Molecular Weight of m-Xylene (MW)	106.17	lb./mole		
Density of m-Xylene	9.6	lb./gallon		
Heat Capacity of m-Xylene (Cp,voc)	43.82	Btu/lb.-mole-°F		
Heat of Condensation of m-Xylene (ΔHref)	15,360	Btu/lb.-mole		
Boiling Point of m-Xylene	282	°F		
Antoine Equation Constants for m-Xylene	**A**	**B**	**C**	
	7.00908	1462.266	215.11	based on degrees C and mmHg
Critical Temperature for m-Xylene	1111	°R		
Volume Fraction of m-Xylene in waste stream entering the condenser (Yvoc,in)	0.0003			

Enter the cost data for the condenser:

Electricity ($Cost_{elect}$)	$0.1000	per kWh	
Operator Labor Rate	$45.00	per hour	
Maintenance Labor Rate	$45.00	per hour	
Re-Sale Value of Recovered VOC (Credit)	$0.00	per lb	
Contingency Factor (CF)	10.0	percent*	* 10 percent is a default value.

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) and Ductwork =	$25,000			
Equipment Costs for auxiliary equipment for custom condenser systems (EC_{aux}) =	$0	* Default value. User should enter actual value, if known.		
Desired dollar-year	2022			
CEPCI* for 2022	833	Enter the CEPCI value for 2022	576.1	2014 CEPCI
Annual Interest Rate (i)	5.00	% (Default value is 4.25%)		

* 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.

Source Name and ID: **Product Loading to Tankcars and Tankwagons (P016)**
Facility Name: **Neville Chemical Company**

Design Parameters

The following design parameters for the condenser 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.

VOC	VOC volume Fraction of waste stream entering the condenser ($Y_{voc,in}$)	Heat Capacity ($C_{p,voc}$) (Btu/lb.-mole-°F)	Heat of Condensation (ΔH_{ref}) (Btu/lb.-mole)
m-Xylene	0.00025	43.82	15360

Parameter	Equation		Calculated Value	Units
Partial Pressure of m-Xylene VOC in Exit Stream (Pvoc) =	$760 \times (M_{voc,out} / (M_{in} - M_{voc, recovered}))$ =	$760 \times [Y_{voc,in} \times (1 - \eta)] / [1 - (\eta \times Y_{voc,in})]$ =	0.0	mmHg
Estimated Condensation Temperature for m-Xylene (Tcon) =	$((B / (A - \log (P_{voc})) - C) \times 1.8 + 32$ =		-53.7	°F

Parameter	Equation	Calculated Value	Units	Calculated Value	Units
Quantities of VOC in Inlet and Outlet streams:					
Moles of VOC in the inlet stream ($M_{voc,in}$) =	$(Q_{in} / 392) \times (Y_{voc,in}) \times 60$ =	0.038	lb.-moles/hour	4.06	lb/hour
Moles of VOC in the outlet stream ($M_{voc,out}$) =	$M_{voc,in} \times (1 - \eta)$ =	0.004	lb.-moles/hour		
Quantity of VOC Recovered:					
Moles of VOC Recovered ($M_{voc, recovered}$) =	$M_{voc,in} \times \eta$ =	0.034	lb.-moles/hour		
Quantity of VOC Recovered (W_{voc}) =	$M_{voc, recovered} \times MW_{voc}$ =	3.66	lb./operating hour	16.01	Tons/year
Calculation of Enthalpy of Condensation:					
Critical Temperature for VOC (T_c) =		1111	°R		
Reference Temperature for Heat of Condensation (T_1) =		742	°R		
Condensation Temperature (T_2) =	$T_{con} + 459.67$ =	406	°R		
Enthalpy of condensation of VOC (ΔHvoc) at -53.7 °F =	$\Delta H_{ref} \times [(1 - T_2 / T_c) / (1 - T_1 / T_c)]^{0.38}$ =	19,638	Btu/lb.-mole		
Calculation of Condenser Heat Load:					
Heat capacity of air ($C_{p, air}$) =		6.95	Btu/lb.-mole-°F @ 77 °F and 1 atm.		
Mean Temperature (T_{mean}) =	$(T_{in} + T_{con}) / 2$ =	33	°F		
Enthalpy change associated with the condensed VOC (ΔH_{con}) =	$M_{voc,recovered} \times [\Delta H_{voc} + C_{p,voc} (T_{in} - T_{con})]$=	938	Btu/hour		
Enthalpy change associated with the uncondensed VOC (ΔH_{uncon}) =	$M_{voc,out} \times C_{p,voc} \times (T_{in} - T_{con})$ =	29	Btu/hour		
Enthalpy change associated with the non-condensable air (ΔHnoncon) =	$[((Q_{in} / 392) \times 60) - M_{voc,in}] \times C_{p,air} \times (T_{in} - T_{con})$ =	184,740	Btu/hour		
Condenser Heat Load (H_{load}) =	$\Delta H_{con} + \Delta H_{uncon} + \Delta H_{noncon}$ =	185,707	Btu/hour		
Calculation of Surface Area:					
Temperature of coolant entering the condenser ($T_{cool,in}$) =	T_{con} - 15 °F =	-68.7	°F		
Temperature of coolant exiting the condenser ($T_{cool,out}$) =	$T_{cool,in}$ + 25 °F =	-43.7	°F		
Logarithmic mean temperature difference (ΔT_{lm}) =	$\frac{[(T_{in} - T_{cool,out}) - (T_{con} - T_{cool,in})]}{[\ln\{(T_{in} - T_{cool, out})/(T_{con} - T_{cool,in})\}]}$	62.2	°F		
Condenser Surface Area (A_{con}) =	$H_{load} / (U \times \Delta T_{lm})$ =	149.2	ft²		
Calculation of Coolant Flow Rate and Refrigeration Capacity:					
Coolant Flow Rate (W_{cool}) =	$H_{load} / (C_{p,cool} \times (T_{cool,out} - T_{cool,in}))$ =	11,428	lb./hour		
Refrigeration Capacity (R) =	H_{load} / 12,000 Btu/ton =	15.48	Tons/hour		
Calculation of Electricity Consumption:					
Estimated Electricity Consumption (E) =	$2.7411 \times \exp(-0.015 \times T_{con})$ =	6.13	kW/ton		
Capital Recovery Factor:					
Capital Recovery Factor (CRF) =	$[i \times (1 + i)^n] / [(1 + i)^n - 1]$ = Where n = Equipment Life and i = Interest Rate	0.0963			

Source Name and ID: Product Loading to Tankcars and Tankwagons (P016)
Facility Name: Neville Chemical Company

Control Cost Estimate

Capital Costs

VOC Controlled/Recovered =	m-Xylene
Refrigeration Capacity (R) =	15.48 tons/hour
Condensation Temperature for Waste Stream (T_{con}) =	-54 °F

Total Capital Investment (TCI) (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Equipment Costs for Single Stage Refrigeration Unit (ECr):	1.611 × exp[9.26 - 0.007 × Tcon + 0.627 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =	Not applicable*	
Equipment Costs for Multistage Refrigeration Unit (ECr):	1.611 × exp[9.73 - 0.012 × Tcon + 0.58 × ln(R)] × [2022 CEPCI / 2014 CEPCI] =		$365,446
Other Equipment Costs for a Packaged Solvent Recovery System (ECp):	1.25 × ECr =	Not applicable	$91,362
Costs for Refrigerated Condenser (A) =	ECp + ECr =	Not applicable	$456,808
Instrumentation =	0.10 × A =	Included in A	Included in A
Sales taxes =	0.03 × A =	Not applicable	$13,704
Freight =	0.05 × A =	Not applicable	$22,840
	Total Purchased Equipment Costs (B) =	**Not applicable**	$493,353

Direct Installation Costs (in 2022 dollars)

Parameter	Equation	Single Stage	Multi-Stage
Foundations and Supports =	0.14 × B =	Not applicable	Not applicable
Handling and Erection =	0.08 × B =	Not applicable	Not applicable
Electrical =	0.08 × B =	Not applicable	Not applicable
Piping =	0.02 × B =	Not applicable	Not applicable
Insulation =	0.10 × B =	Not applicable	Not applicable
Painting =	0.01 × B =	Not applicable	Not applicable
Site Preparation (SP) =		Not applicable	$0
Buildings (Bldg) =		Not applicable	$25,000
	Total Direct Costs (DC) = B + (0.43 × B) + SP + Bldg =	Not applicable	$518,353
	Total Capital Investment (TCI) = Direct Costs + Contingency = (1.15 × DC) =	**Not applicable**	**$596,105**

Annual Costs

Direct Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Annual Electricity Cost =	$(R / \eta_{Comp}) \times E \times \Theta_s \times p_e$ =	Not applicable	$97,844
Operating Labor =	Operator = 0.5 hours/shift × Labor Rate × (Operating hours/8 hours/shift)	Not applicable	$24,638
	Supervisor = 15% of Operator	Not applicable	$3,696
Maintenance Costs =	Labor = 0.5 hours/shift × Labor Rate × (Operating Hours/8 hours/shift)	Not applicable	$24,638
	Materials = 100% of maintenance labor	Not applicable	$24,638
	Direct Annual Costs (DAC) =	**Not applicable**	**$175,452**

Indirect Annual Costs

Parameter	Equation	Single Stage	Multi-Stage
Overhead	= 60% of sum of operator, supervisor, maintenance labor Plus maintenance materials	Not applicable	$46,565
Administrative Charges	= 2% of TCI	Not applicable	$11,922
Property Taxes	= 1% of TCI	Not applicable	$5,961
Insurance	= 1% of TCI	Not applicable	$5,961
Capital Recovery	= CRF × TCI	Not applicable	$57,430
	Indirect Annual Costs (IAC) =	**Not applicable**	**$127,839**

VOC Recovery Credit

Parameter	Equation	Single Stage	Multi-Stage
Annual Recovery Credit for Condensate (RC)	= $W_{voc} \times$ Credit $\times \Theta_s$ =	Not applicable	$0
	Total Annual Cost (TAC) = DAC + IAC - RC =	**Not applicable**	**$303,291**

Cost Effectiveness

Parameter	Equation	Single Stage	Multi-Stage
Total Annual Cost =	TAC =	Not applicable	$303,291
Annual Quantity of VOC Removed/Recovered =	W_{voc} =	Not applicable	16.0
Cost Effectiveness =	**Total Annual Cost/Annual Quantity of VOC Removed/Recovered =**	**Not applicable**	**$18,938**