APPENDIX A-3

Source ID# 089-00310

W. R. Grace & Co.

NOx RACT Study

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PROtect℠

August 2, 2024

Indiana Department of Environmental Management
Office of Air Quality, Programs Branch
100 North Senate Avenue, IGCN 1003
Indianapolis, IN 46204-2251

RE: Reasonably Available Control Technology (RACT) Case-By-Case Review

To Whom It May Concern,

PROtect, LLC (PROtect) is writing on behalf of W. R. Grace & Co. ("Grace" or "the Company") regarding the sodium silicate manufacturing facility located in Lake County at 5215 Kennedy Ave, East Chicago, Indiana. Attached is a RACT Case-By-Case Review for the facility under the 2015 National Ambient Air Quality Standard (NAAQS) for ozone. The analysis follows the steps outlined by the Indiana Department of Environmental Management (IDEM).

Please contact me at (920) 621-8293 if you have any questions regarding this analysis.

Sincerely,

Mitch Lagerstrom

Mitch Lagerstrom
Director of Environmental Services
PROtect, LLC

CASE-BY-CASE REASONABLY AVAILABLE CONTROL TECHNOLOGY REVIEW

Background

The case-by-case Reasonably Available Control Technology (RACT) review is conducted in pursuant to the requirements of the Clean Air Act (CAA) and its associated regulations. The CAA mandates that state implication plans (SIPs) include RACT provisions to control emission of certain pollutants, particularly those contributing to ozone formation, such as volatile organic compounds (VOCs) and nitrogen oxides (NO_X). Under this regulatory framework, facilities in non-attainment areas for ozone and other criterial pollutants must implement RACT to achieve and maintain National Ambient Air Quality Standards (NAAQS).

The facility operates under Part 70 Operating Permit No. T089-19927-00310 and Standard Industrial Classification Code 2819. Grace is providing this Case-By-Case RACT review as requested in an email from the Indiana Department of Environmental Management (IDEM) [1] as Lake County is currently moderate non-attainment for the 2015 NAAQS for ozone. Within the email, IDEM requested five steps be completed to provide an acceptable process for conducting this case-by-case RACT review. The following outlines each requested step and subsequent analysis.

1. Identify and describe the emission units subject to NO_X RACT review, including the size or capacity of each affected unit and the types of fuel combusted or the types and quantities of materials processed or produced.

The following emission units are subject to site-specific NOX RACT limitations at OAC 3745-110-03(P):

- Sodium Silicate Furnace (EU-01) – Natural gas fired unit with potential NO_X emissions of 141.1 tons per year, heat input of 25 mmBtu/hr, and capacity 9,600 pounds of raw material per hour. SCC: 30501402.
- Three Stone Johnston Boilers (EU-02, EU-03, and EU-04) – Natural gas fired units with potential NO_X emissions of 43.2 tons per year (combined), heat input of 33.5 mmBtu/hr each, constructed in March 1986. These units may be subject to a presumptive NO_X emission limit of 0.08 lb/mmBtu.

[1] Email from Ms. Jean Boling (IDEM Environmental Engineer) to Ms. Julie Kendall (Grace EHS Manager) on June 19, 2024.

The following sources operate less than 500 hours per year and are therefore exempt from the NO_X RACT regulations under OAC 3745-110-03(K)(2). Due to these units being exempt from the regulations, the following units are not considered in the remainder of this NO_X RACT study:

- EVC Backup Generator (EU-05) – Natural gas fired engine with a maximum heat input of 0.5 mmBtu/hr.
- Powerhouse Backup Generator (EU-06) – Natural gas fired engine with a maximum heat input of 0.5 mmBtu/hr.
- Back-Up Emergency Generator (EU-26) – Natural gas fired engine installed in 2015 with a maximum capacity of 47 horsepower.

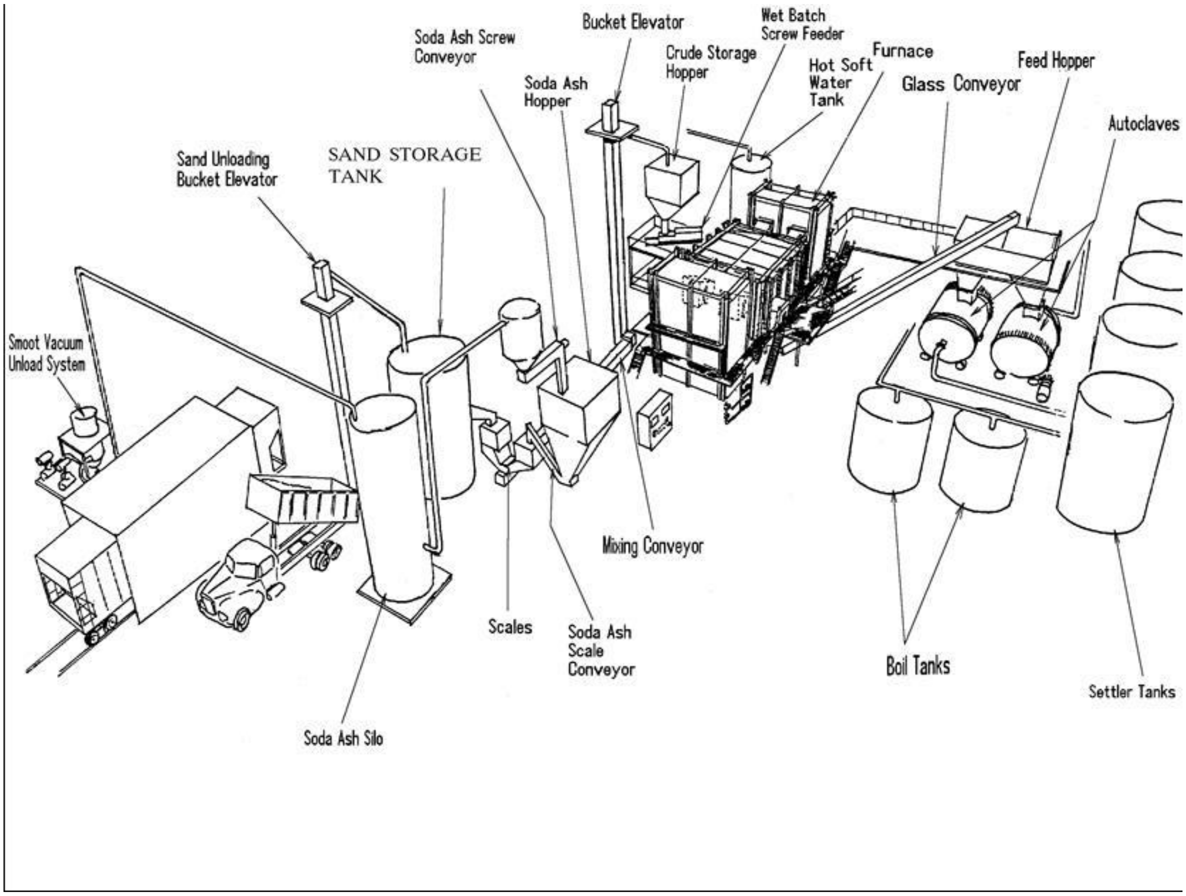
The generators have a combined NO_X emission limit of 1.38 tons per year.

Process Description

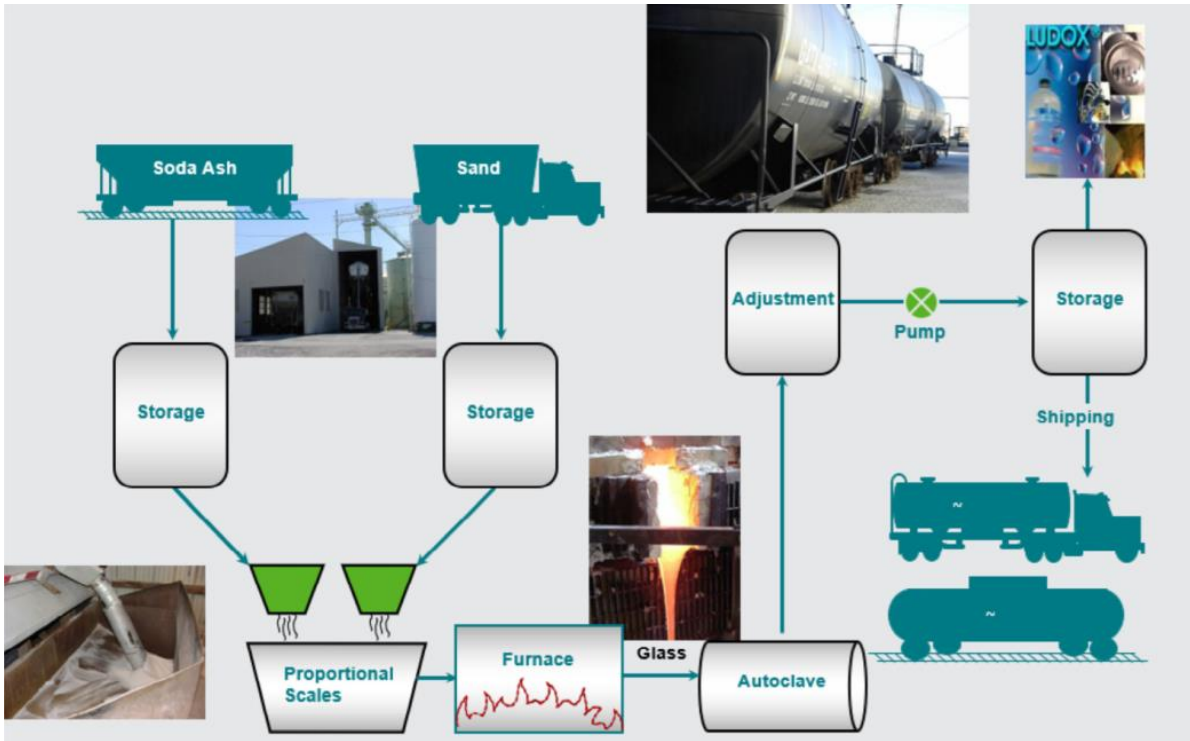
Sodium silicate is manufactured from a combination of sand and soda ash. Each raw material is weighed by scales and dropped into a mixing screw conveyor. Using a bucket elevator the material is transferred to a feed hopper. Material leaves the feed hopper and is moistened in a wet batch feeder; it is then continuously fed into the sodium silicate furnace where it is fused. The resulting molten glass discharges onto a glass conveyor and is sprayed with water to cool and fracture.

Sodium silicate solution is prepared in an autoclave, where the glass is dissolved in hot, soft water (and caustic with some grades) under 80 - 90 psig steam pressure. The resulting solution is pumped into settler tanks where final adjustments to specific grades are made. From the settler tank, the final product is transferred to applicable storage tanks to await final distribution to customers or enter the Ludox process.

Process Diagram



Process Flow Diagram



2. Identify the existing and proposed available control technologies and compare the effectiveness of them. Available control options are air pollution control technologies or techniques with a reasonable potential for application to the source. When considering available controls, evaluate both add on controls and possible changes in process and/or raw materials to reduce emissions.

Higher NO_X emissions from a glass furnace are largely due to higher combustion temperatures generating more thermal NO_X. Thermal NO_X is formed when nitrogen and oxygen in the combustion air combine at high temperatures with NO_X formation increasing significantly above 2,800°F.[2] Temperatures within a glass furnace generally are within the range of 2,700 – 3,100°F.[3]

Grace's Sodium Silicate Furnace do not currently incorporate any technology that reduces NO_X emissions. Five technologies were evaluated in this case-by-case RACT review for the Sodium Silicate Furnace, three are combustion modifications and the other two are post combustion modifications. The combustion modifications evaluated were Flue Gas Recirculation (FGR), Low NO_X Burners (LNBs), and Oxy-Firing; post combustion modifications evaluated include Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR).

Similarly, the natural gas fired boilers do not currently incorporate any technology that reduces NO_X emissions. Technologies evaluated for the boilers include two combustion modifications and two post combustion modifications. Combustion modifications include LNGs and FGR; post combustion modifications include SCR and SNCR.

Combustion Modifications

Flue Gas Recirculation involves recirculating about 8-10% of the flue gas back into the burner. Adding non-reactive gases into the burner reduces the concentration of oxygen in the combustion process, reducing available oxygen in the burner, slowing down reactions in the combustion chamber. Reducing available oxygen and slowing down reactions in the combustion chamber reduces both the rate that nitrogen bonds with oxygen and the peak flame temperature, both yielding an overall reduction in NO_X emissions.[4]

LNBs stage the combustion process in different zones. The first stage is fuel rich, and the second stage is air rich. Each stage control fuel and air mixing reducing the peak flame temperature, thereby reducing NO_X emissions.[5]

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[2] "How Is NO_X Formed." *CleanBoiler.Org*, cleanboiler.org/workshop/how-is-nox-formed/#:~:text=Thermal%20NOx%20is%20formed%20when,2%2C800%C2%B0F%20flame%20temperature. Accessed 15 July 2024.

[3] "Glass Melting." *Glass Melting - an Overview | ScienceDirect Topics*, www.sciencedirect.com/topics/chemistry/glass-melting. Accessed 15 July 2024.

[4] EPA, 1994: *"Alternative Control Techniques Document-- NO_X Emissions from Glass Manufacturing"* U.S. Environmental Protection Agency, Emission Standards Division, Office of Air and Radiation, Research Triangle Park, NC, June 1994. EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[5] Ibid, 5-10.

Oxy-Firing reduces the amount of nitrogen entering the combustion chamber, reducing NO_X formation. Nitrogen will still enter the combustion chamber with the oxygen, fuel, and through air infiltration through leaks in the furnace. Therefore, NO_X formation is not eliminated with Oxy-Firing. NO_X reductions from Oxy-Firing are achieved above certain oxygen concentrations. Increasing Oxygen concentration from 21 percent to 60 percent in the ambient air demonstrates a typical increase in NO_X formation. Emissions of NO_X decrease dramatically when inlet oxygen concentration is above 90 percent. Several installations of this technology have been made to glass furnaces with varying results. Poorer results are seen in furnaces with more air leaks.[6]

Post-Combustion Modifications

SNCR technology is based on the non-catalyzed chemical reaction between ammonia and NO_X, reducing it to nitrogen and water. The reagent is injected into the post combustion gas stream at temperatures between 1,600 – 2,400°F. Two reagents are commonly used, ammonia and urea. Optimum temperatures for each reagent are different. The optimum range for ammonia is 1,600 – 2,000°F with peak removal occurring at 1,750°F. The temperature range for urea is 1,650 – 2,100°F, with peak removal occurring at 1,850°F. NO_X reduction is favored over other chemical reactions within the temperature range in the presence of oxygen. The heat from the furnace provides the energy needed for the reduction reaction. The reaction mechanisms using ammonia as the reagent are:

$$2NO + 2NH_3 + \tfrac{1}{2}O_2 \rightarrow 2N_2 + 3H_2O$$

$$2NO + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$$

The reaction mechanisms using urea as the reagent are:

$$2NO + CO(NH_2)_2 + \frac{1}{2}O_2 \rightarrow 2N_2 + CO_2 + 2H_2O$$

$$2NO_2 + 2CO(NH_2)_2 + O_2 \rightarrow 3N_2 + 2CO_2 + 4H_2O$$

The primary byproduct formed using either reagent is nitrous oxide. Nitrous oxide is both an ozone depleting substance and a greenhouse gas. The amount of nitrous oxide formed depends on several factors including which reagent is used (urea produces more), the reagent feed rate and temperature. Higher levels of nitrous oxide formation correlates with increased NO_X reductions.[7]

SCR is similar to SNCR, the primary difference is the metal catalyst used with SCR. The introduction of the catalyst does two things: it drops the activation energy of the reactions allowing the reactions to occur at lower temperatures and increases the reduction of NO_X emissions. The introduction of the catalyst also increases capital and operating cost. The primary components of an SCR are ammonia storage and delivery, ammonia injection grid, and the catalyst.

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[6] Ibid, 5-24.

[7] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. Chapter 1 Selective Non-Catalytic Reduction. 2019. At 1-11. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024.

3. Evaluate the technical feasibility of the available control options identified and eliminate technically infeasible options.

There are limitations with using FGR on glass melt furnaces. Glass furnaces need to reach high temperatures that require combustion air preheating, this can make FGR infeasible. As a result, FGR was not further evaluated for application at Grace's East Chicago facility.[8] FGR is technically feasible for the natural gas fired boilers. However, the manufacturer of the boiler indicated that the vintage of these boilers makes a retrofit more complex. Therefore, they will not perform FGR retrofits for these units and could not provide a cost estimate but was confident that other vendors would be able to perform this service. As a result, a cost estimate using EPA data was developed for these units to install FGR.

The other combustion modifications, LNBs and Oxy-Firing, have both been used on glass furnaces and were found to be technically feasible. However, given the age of the furnace (over 100 years) at the East Chicago facility air infiltration through furnace leaks is a significant concern with using Oxy-Firing. As stated previously, these leaks would allow nitrogen from the ambient air into the furnace, generating thermal NO_X due to high temperatures within the unit. LNBs and Oxy-Firing are technically feasible for the natural gas fired boilers, however cost estimate information for Oxy-Firing were not readily available for this analysis.

SNCR is technically feasible for both the sodium silicate furnace and natural gas fired boilers, however, as previously stated there are environmental impacts that need to be considered. SNCR creates nitrous oxide which is both an ozone depleting substance and a greenhouse gas. Furthermore, particulates like ammonium sulfate salts (ammonium sulfate and ammonium bisulfate) form as trace amounts of sulfur in the fuel and larger amounts of sulfur from the decomposition of sulfates in the batch are formed downstream of the reagent injection.[9] SNCR has the effect of increasing emissions of ozone depleting substances, greenhouse gases, and particulate matter.[10]

Concerns regarding plugging and/or poisoning of catalysts for a glass furnace have led to the installation of particulate control upstream of an SCR. The United States Environmental Protection Agency (USEPA) has indicated that baghouses have been used within the glass manufacturing industry, but fabric corrosion requires careful temperature control. The only other particulate control with cost data readily available is an electrostatic precipitator (ESP).[11] Therefore, the cost of a baghouse and an ESP were each evaluated to be installed with an SCR to determine if any are economically feasible. SCR is technically feasible for the natural gas fired boilers without particulate control and is included in this analysis.

4. Rank the remaining control technologies by control effectiveness: the final list of control technologies should include the baseline emissions of NO_X pre-control, the post control emissions, the control efficiency of each option, and the economic impacts of each control option.

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[8] EPA, 5-2.
[9] "Glass Manufacturing." *Compilation of Air Pollutant Emissions Factors from Stationary Sources (AP-42) Chapter 11 Section 15,* USEPA, Oct. 1986, www.epa.gov/sites/default/files/2020-10/documents/c11s15.pdf. Accessed 16 July 2024.
[10] Sorrels, 1-19.
[11] Glass Manufacturing, 11.15-4.

Baseline emissions of NO_X pre-control were established through a stack test in 2003 and past emission inventories.

Table 1: NO_X Pre-Control Emissions for Sodium Silicate Furnace

NO_X Emission Rate	Units	Basis
764.60	lb/day	2021 Average NO_X Emission Rate
764.60	lb/day	2022 Average NO_X Emission Rate
728.16	lb/day	2023 Average NO_X Emission Rate
139.54	tons/yr	2021 Annual NO_X Emissions
139.54	tons/yr	2022 Annual NO_X Emissions
132.89	tons/yr	2023 Annual NO_X Emissions

Stack testing has not been performed on the natural gas fired boilers. Emission inventories for these units have utilized EPA's AP-42 emission factors.

Table 2: NO_X Pre-Control Emissions for Natural Gas Fired Boilers

NO_X Emission Rate (per unit)	Units	Basis
5.8	tons/yr	2021 Annual NO_X Emissions
5.7	tons/yr	2022 Annual NO_X Emissions
4.98	tons/yr	2023 Annual NO_X Emissions

Sodium silicate production over the past three years is presented in Table 3.

Table 3: Sodium Silicate Production

Year	Sodium Silicate Production (tons/yr)	Average Sodium Silicate Production (tons/day)
2021	32,063	87.84
2022	28,556	78.24
2023	25,030	68.57

Calendar years 2021 and 2022 are the most representative of past and future operation. Therefore, the average daily production rate of 83.04 tons/day and annual NO_X emissions of 139.54 tons/yr are used as the baseline in this analysis and 5.75 tons/yr of NO_X emissions for the natural gas fired boilers. The need to control particulate emissions upstream of an SCR necessitates that baseline emissions of particulate matter also be established.

The focus of this RACT analysis is NO_X controls. PM-10 is only reviewed for air pollution control equipment where particulate control is appropriate. Therefore, the cost evaluation of PM-10 controls will use potential emissions of 26.28 tons/year as the baseline to be conservative.

The control efficiency of each control device is generally established through USEPA published information.

Table 4: Control Efficiencies for Sodium Silicate Furnace

Control Device	Control Efficiency	Source
LNBs	40%	Alternative Control Techniques[12]
Oxy-Firing	85%	Alternative Control Techniques[13]
SNCR	35%*	Alternative Control Techniques[14]
SCR	75%	Alternative Control Techniques[15] CoST[16]
ESP	95%	CoST[17]
Baghouse	99%	CoST[18]

* Note the source provides a range of 30-40%, 35% was chosen.

Similarly, the control efficiencies for the natural gas fired boilers were also established through EPA published information.

[12] EPA, 6-3.
[13] Ibid, 6-4.
[14] Ibid, 6-8.
[15] Ibid, 6-7.
[16] *Control Measure AT-A-GLANCE Report. Control Measure: Selective Catalytic Reduction; Glass Manufacturing – Pressed.* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[17] *Control Measure AT-A-GLANCE Report. Control Measure: Electrostatic Precipitator ICI Boilers and Heaters Gas and Oil (PESPICIGAS).* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[18] *Control Measure AT-A-GLANCE Report. Control Measure: Fabric Filter ICI Boilers and Heaters Gas and Oil (PFFICIGAS).* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

Table 5: Control Efficiencies for Natural Gas Fired Boilers

Control Device	Control Efficiency	Source
LNBs	61%*	CoST[19]
FGR	61%*	CoST[20]
LNBs + FGR	61%	CoST[21]
SNCR	35%	CoST [22]
SCR	90%	CoST[23]

*Note the control efficiency is for LNBs and FGR together, but costs can be speciated. Therefore, the same control efficiency is used for individual controls to be conservative.

Post control emissions are calculated based on the potential annual emissions and referenced control efficiencies.

Table 6: Post-Control Potential Emissions for Sodium Silicate Furnace

Control Device (Pollutant)	Pollutant	Pre-Control Baseline Emissions (tons/yr)	Control Efficiency	Emissions Removed (tons/yr)	Post-Control Potential Emissions (tons/yr)
LNBs	NO_X	139.54	40%	55.8	83.7
Oxy-Firing	NO_X	139.54	85%	118.6	20.9
SNCR	NO_X	139.54	35%	48.8	90.7
SCR	NO_X	139.54	75%	104.7	34.9
ESP	PM-10	26.28	95%	25.0	1.3
Baghouse	PM-10	26.28	99%	26.0	0.3

Post control emissions for the Natural Gas Fired Boilers is also established. All values in Table 6 are per boiler.

[19] *Control Measure AT-A-GLANCE Report. Control Measure: Low NOx Burner and Flue Gas Recirculation; ICI Boilers - Gas (NLNBFIBG).* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[20] Ibid.
[21] Ibid.
[22] *Control Measure AT-A-GLANCE Report. Control Measure: Selective Non-Catalytic Reduction; ICI Boilers - Gas (NSNCRICBG).* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[23] *Control Measure AT-A-GLANCE Report. Control Measure: Selective Catalytic Reduction; ICI Boilers - Gas (NSCRICBG).* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

Table 7: Post-Control Potential Emissions for Natural Gas Fired Boilers

Control Device (Pollutant)	Pollutant	Pre-Control Baseline Emissions (tons/yr)	Control Efficiency	Emissions Removed (tons/yr)	Post-Control Potential Emissions (tons/yr)
LNBs	NO_X	5.75	61%*	3.51	2.24
FGR	NO_X	5.75	61%*	3.51	2.24
LNBs + FGR	NO_X	5.75	61%	3.51	2.24
SNCR	NO_X	5.75	35%	2.01	3.74
SCR	PM-10	5.75	90%	5.18	0.58

* Control efficiency was only listed for LNBs with FGR and not separate, in order to be conservative this control efficiency was used for each individual control.

Finally, the economic impact of each control option was reviewed based on the emissions removed and EPA cost data to determine the economic impact of each control option in dollars per ton removed. Different EPA publications were used to complete this review with a preference for costs specific to the glass manufacturing industry. As a result, EPA's Cost Control Manual was not used to estimate the cost of each control for the Sodium Silicate Furnace as it is limited to only SNCR and SCR control costs and the Total Capital Investment (TCI) and Total Annual Costs criteria is for far larger industrial gas-fired units (>250 mmBtu/hr for SNCR and >205 mmBtu/hr for SCR). However, the Cost Control Manual was used for SCR and SNCR for the Natural Gas Fired Boilers because a better cost tool has not been developed for these sources. The cost breakdown structure primarily for capital investment was used in lieu of simply listing the TCI, including this breakdown does not affect the total TCI or the Total Annualized Cost (TAC).

Sodium Silicate Furnace Cost Analysis

LNBs Costs

The cost of LNBs was developed from the Alternative Control Techniques Document-- NO_X Emissions from Glass Manufacturing.[24] This publication provides a table of capital cost, annualized cost, NO_X reduction, and cost effectiveness values for a range of plant sizes. Cost data from Table 6-3 are provided in Table 8.

Table 8: Costs and Cost Effectiveness of Retrofit LNBs for Glass Furnace

Plant Size (tons/day)	Capital Cost ($\$10^3$)	Annualized Cost ($\$10^3$/yr)	NO_X Reduction (ton NO_X/yr)	Cost Effectiveness ($/ton NO_X Removed)
50	265	123	73	1,680
250	695	320	167	1,920
750	1,340	621	790	790

Using the data in this table, the capital cost for the East Chicago plant was calculated using interpolation based on the 50 ton/day and 250 ton/day plant sizes. All dollar values in the referenced document are in

[24] EPA, 6-4.

1994 dollars. The Chemical Engineering Plant Cost Index (CEPCI) for 1994[25] and 2024[26] were used to update these values to 2024 dollars.

TCI (Dollar values are $\$10^3$/yr)

$$\left(\$265 + \left(83.04\,\frac{tons}{day} - 50\frac{tons}{day}\right) \times \frac{(\$695 - \$265)}{\left(250\frac{tons}{day} - 50\,\frac{tons}{day}\right)}\right) \times \frac{799.1}{368.1} = \$729$$

This value is then used to calculate the TAC. Footnote b of Table 6-3 of Alternative Control Techniques Document-- NO_X Emissions from Glass Manufacturing indicates that the TAC is 46.2% of the TCI.

TAC (Dollar values are $\$10^3$/yr)

$$\$729\ \times 46.2\% = \$337$$

This value is then divided by the 40% NO_X reduction value of 55.8 tons/yr to determine the cost effectiveness of the control.

$$\frac{\frac{\$337{,}026}{yr}}{55.8\,\frac{tons}{yr}} = \frac{\$6{,}038}{ton\ NOx\ Removed}$$

Attachment 1 contains the Excel spreadsheet calculations for LNBs. However, these additions do not affect the TCI or TAC calculations.

<u>Oxy-Firing Costs</u>

The same source and a similar calculation methodology was used to develop costs for Oxy-Firing. Cost data from Table 6-4 of Alternative Control Techniques Document-- NO_X Emissions from Glass Manufacturing are provided in Table 9.

Table 9: Costs and Cost Effectiveness of Oxy-Firing for Glass Furnace

Plant Size (tons/day)	Capital Cost ($\$10^3$)	Annualized Cost ($\$10^3$/yr)	NO_X Reduction (ton NOx/yr)	Cost Effectiveness ($/ton NO_X Removed)
50	1,930	706	160	4,400
250	5,070	1,860	359	5,300
750	9,810	3,590	1,670	2,150

[25] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.
[26] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

Using the data in this table, the capital cost for the East Chicago plant was calculated using interpolation based on the 50 ton/day and 250 ton/day plant sizes. All dollar values in the referenced document are in 1994 dollars. CEPCI for 1994[27] and 2024[28] were used to update these values to 2024 dollars.

TCI (Dollar values are $\$10^3$/yr)

$$\left(\$1{,}930+\left(83.04\,\frac{tons}{day}-50\frac{tons}{day}\right)\times\frac{(\$5{,}070-\$1{,}930)}{\left(250\frac{tons}{day}-50\frac{tons}{day}\right)}\right)\times\frac{799.1}{368.1}=\$5{,}316$$

Interpolation was also used to calculate the TAC.

TAC (Dollar values are $\$10^3$/yr)

$$\left(\$706+\left(83.04\,\frac{tons}{day}-50\frac{tons}{day}\right)\times\frac{(\$1{,}860-\$706)}{\left(250\frac{tons}{day}-50\frac{tons}{day}\right)}\right)\times\frac{799.1}{368.1}=\$1{,}946$$

This value is then divided by the 85% NO_X reduction value of 118.6 tons/yr to determine the cost effectiveness of the control.

$$\frac{\frac{\$1{,}946{,}497}{yr}}{118.6\,\frac{tons}{yr}}=\frac{\$16{,}411}{ton\ NOx\ Removed}$$

Attachment 2 contains the Excel spreadsheet calculations for Oxy-Firing. Note that additional costs were included based on capital project experience. However, these additions do not affect the TCI or TAC calculations presented above.

<u>SNCR Costs</u>

The same source and calculation methodology was used to develop costs for SNCR. Cost data from Table 6-8 from Alternative Control Techniques Document-- NO_X Emissions from Glass Manufacturing are provided in Table 10.

Table 10: Costs and Cost Effectiveness of SNCR for Glass Furnace

Plant Size (tons/day)	Capital Cost ($\$10^3$)	Annualized Cost ($\$10^3$/yr)	NO_X Reduction (ton NO_X/yr)	Cost Effectiveness ($/ton NO_X Removed)
50	310	130	70	1,770
250	810	340	170	2,000
750	1,560	660	790	830

[27] Engineering Practice STRUCTURE of the CECPI.
[28] Maxwell.

Using the data in this table, the capital cost for the East Chicago plant was calculated using interpolation based on the 50 ton/day and 250 ton/day plant sizes. All dollar values in the referenced document are in 1994 dollars. CEPCI for 1994[29] and 2024[30] were used to update these values to 2024 dollars.

TCI (Dollar values are $\$10^3$/yr)

$$\left(\$310+\left(83.04\,\frac{tons}{day}-50\frac{tons}{day}\right)\times\frac{(\$810-\$310)}{\left(250\frac{tons}{day}-50\frac{tons}{day}\right)}\right)\times\frac{799.1}{368.1}=\$852$$

Interpolation was also used to calculate the TAC.

TAC (Dollar values are $\$10^3$/yr)

$$\left(\$130+\left(83.04\,\frac{tons}{day}-50\frac{tons}{day}\right)\times\frac{(\$340-\$130)}{\left(250\frac{tons}{day}-50\frac{tons}{day}\right)}\right)\times\frac{799.1}{368.1}=\$358$$

This value is then divided by the 35% NO_X reduction value of 48.8 tons/yr to determine the cost effectiveness of the control.

$$\frac{\frac{\$358{,}526}{yr}}{48.8\,\frac{tons}{yr}}=\frac{\$7{,}321}{ton\ NOx\ Removed}$$

Attachment 3 contains the Excel spreadsheet calculations for Oxy-Firing. Note that additional costs were included based on capital project experience and EPA's Cost Control Manual. However, these additions do not affect the TCI or TAC calculations.

SCR Costs

Again, the same source and calculation methodology was used to develop costs for SCR. Cost data from Table 6-7 from Alternative Control Techniques Document-- NO_X Emissions from Glass Manufacturing are provided in Table 11.

Table 11: Costs and Cost Effectiveness of SCR for Glass Furnace

Plant Size (tons/day)	Capital Cost ($\$10^3$)	Annualized Cost ($\$10^3$/yr)	NO_X Reduction (ton NOx/yr)	Cost Effectiveness ($/ton NO_X Removed)
50	530	400	140	2,950
250	1,390	770	310	2,460
750	2,690	1,200	1,490	810

[29] Engineering Practice STRUCTURE of the CECPI.
[30] Maxwell.

Using the data in this table, the capital cost for the East Chicago plant was calculated using interpolation based on the 50 ton/day and 250 ton/day plant sizes. All dollar values in the referenced document are in 1994 dollars. CEPCI for 1994[31] and 2024[32] were used to update these values to 2024 dollars.

TCI (Dollar values are $\$10^3$/yr)

$$\left(\$528 + \left(83.04\,\frac{tons}{day} - 50\frac{tons}{day}\right) \times \frac{(\$1{,}388 - \$528)}{\left(250\frac{tons}{day} - 50\frac{tons}{day}\right)}\right) \times \frac{799.1}{368.1} = \$1{,}455$$

Interpolation was also used to calculate the TAC.

TAC (Dollar values are $\$10^3$/yr)

$$\left(\$400 + \left(83.04\,\frac{tons}{day} - 50\frac{tons}{day}\right) \times \frac{(\$770 - \$400)}{\left(250\frac{tons}{day} - 50\frac{tons}{day}\right)}\right) \times \frac{799.1}{368.1} = \$1{,}001$$

This value is then divided by the 85% NO_X reduction value of 104.7 tons/yr to determine the cost effectiveness of the control.

$$\frac{\frac{\$1{,}001{,}044}{yr}}{104.7\,\frac{tons}{yr}} = \frac{\$9{,}565}{ton\ NOx\ Removed}$$

Attachment 4 contains the Excel spreadsheet calculations for SCR. Note that additional costs were included based on capital project experience and EPA's Cost Control Manual. However, these additions do not affect the TCI or TAC calculations. As stated previously, SCR needs an upstream particulate control to ensure that plugging and poisoning of the catalyst from particulate matter is avoided.

ESP Cost

USEPA's CoST tool was used to estimate the TCI and TAC for an ESP. This tool contains a capital cost constant and capital cost multiplier that are used to estimate TCI. Additionally, the measured exhaust flow rate from the 2003 stack test was used to perform the calculation. Equation 35 from the Control Strategy Tool (CoST) Cost Equations Documentation was used. This value is in 2017 dollars, CEPCI for 2017 and 2024[33] were used to update these values to 2024 dollars.

TCI

$$\left(\frac{\$90.3}{ACFM} \times 28{,}084\ ACFM + \$17{,}107\right) \times \frac{799.1}{567.5} = \$3{,}595{,}024$$

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[31] Engineering Practice STRUCTURE of the CECPI.
[32] Maxwell.
[33] Ibid.

Then equation 36 was used to estimate O&M costs and the same CEPCI values were used to update the values to 2024 dollars.

O&M Costs

$$\left(\frac{\$6.30}{ACFM} \times 28{,}084\ ACFM + \$3{,}883{,}000\right) \times \frac{799.1}{567.5} = \$5{,}653{,}445$$

The total annualized cost was calculated based on a 20-year equipment lift listed in CoST and the prime bank loan rate of 8.5%, providing a Capital Recovery Factor of 0.1057. This provided a TAC of $6,033,334 and was then used to calculate the cost effectiveness of an ESP.

$$\frac{\frac{\$6{,}033{,}334}{yr}}{25.0\,\frac{tons}{yr}} = \frac{\$241{,}662}{ton\ PM-10\ Removed}$$

Adding the annualized cost of installing an ESP in addition to an SCR the cost effectiveness of this scenario was calculated.

$$\frac{\frac{\$7{,}034{,}378}{yr}}{104.7\,\frac{tons}{yr}} = \frac{\$67{,}215}{ton\ NOx\ Removed}$$

A copy of the calculations spreadsheet for an ESP is included in Attachment 5 and the Control Measure AT-A-GLANCE Report for an ESP is included in Attachment 6.

<u>Baghouse</u>

USEPA's CoST tool was again used to estimate the TCI and TAC for a baghouse. This tool contains a capital cost constant and capital cost multiplier that are used to estimate TCI. Additionally, the measured exhaust flow rate from the 2003 stack test was used to perform the calculation. Equation 35 from the Control Strategy Tool (CoST) Cost Equations Documentation was used. This value is in 2017 dollars, CEPCI for 2017 and 2024[34] were used to update these values to 2024 dollars.

TCI

$$\left(\frac{\$20.9}{ACFM} \times 28{,}084\ ACFM + \$5{,}238\right) \times \frac{799.1}{567.5} = \$833{,}871$$

Then equation 36 was used to estimate O&M costs and the same CEPCI values were used to update the values to 2024 dollars.

[34] Ibid.

O&M Costs

$$\left(\frac{\$2.20}{ACFM} \times 28{,}084\ ACFM + \$830{,}000\right) \times \frac{799.1}{567.5} = \$1{,}255{,}727$$

The total annualized cost was calculated based on a 20-year equipment lift listed in CoST and the prime bank loan rate of 8.5%, providing a Capital Recovery Factor of 0.1057. This provided a TAC of $1,318,629 and was then used to calculate the cost effectiveness of a baghouse.

$$\frac{\frac{\$1{,}255{,}727}{yr}}{26.0\ \frac{tons}{yr}} = \frac{\$51{,}652}{ton\ PM - 10\ Removed}$$

Adding the annualized cost of installing a baghouse in addition to an SCR the cost effectiveness of this scenario was calculated.

$$\frac{\frac{\$2{,}344{,}887}{yr}}{104.7\ \frac{tons}{yr}} = \frac{\$22{,}406}{ton\ NOx\ Removed}$$

A copy of the calculations spreadsheet for a baghouse is included in Attachment 7 and the Control Measure AT-A-GLANCE Report for a baghouse is included in Attachment 8.

The cost-effectiveness of the evaluated controls are ranked from most cost-effective to least cost effective.

Table 12: Costs and Cost Effectiveness of NO_X RACT Controls for Sodium Silicate Furnace

NO_X Emission Control	TCI	TAC ($/yr)	NO_X Reduction (ton NOx/yr)	Cost Effectiveness ($/ton NO_X Removed)
LNBs	$729,493	$337,026	55.8	$6,038
SNCR	$852,286	$357,526	48.8	$7,321
Oxy-Firing	$5,315,888	$1,946,497	118.6	$16,411
SCR + Baghouse	$2,288,994	$2,344,887	104.7	$22,406
SCR + ESP	$5,050,147	$7,034,378	104.7	$67,215

Natural Gas Fired Boilers Cost Analysis

LNB and FGR Costs

The cost of LNB and FGR was developed from EPA's CoST tool.[35] This tool provides a formula to calculate both TCI and TAC. Equipment cost of a LNB was provided by the boiler manufacturer, Johnston Boilers. The vendor indicated equipment cost would be $450,000. Installed cost is estimated after adding tax, engineering expenses, and contingency at $601,875. O&M costs were estimated using EPA's CoST tool. This tool distinguishes between LNB and FGR costs except for the O&M Cost Constant. Therefore, this value was split between the two control devices to estimate the cost of each. Cost data provided is in 2008 dollars, CEPCI was used to update the cost data to 2024 dollars.

$$\left[\frac{\$389{,}766.80}{2}+\left(\frac{\$218.40}{mmBtu}\times 33.5\,\frac{mmBtu}{hr}^{0.65}\right)\right]\times\frac{799.1}{575.4}=\$273{,}622$$

This value is then added to the annualized TCI cost using an equipment life of 15 years[36] and an interest rate of 8.5%, providing a TAC of $346,100. Dividing this value by the NO_X removed to determine the cost effectiveness of LNBs for the Natural Gas Fired Boilers.

$$\frac{\frac{\$346{,}100}{yr}}{3.51\,\frac{tons}{yr}}=\frac{\$98{,}674}{ton\ NOx\ Removed}$$

A copy of the calculations spreadsheet for LNBs is included in Attachment 9 and the Control Measure AT-A-GLANCE Report for a baghouse is included in Attachment 10.

The cost of FGR was developed from the same CoST tool as LNB. This tool provides a formula to calculate both TCI and TAC. TCI was calculated first,

$$\left(\frac{\$86{,}330.02}{mmBtu}\times 33.5\,\frac{mmBtu}{hr}^{0.228}\right)\times\frac{799.1}{575.4}=\$119{,}896$$

Similar to LNBs, O&M costs were estimated using EPA's CoST tool. The tool includes an emissions cost multiplier for FGR

$$\left[\frac{\$389{,}766.80}{2}+\left(\frac{\$3{,}453.20}{mmBtu}\times 33.5\,\frac{mmBtu}{hr}^{0.228}\right)+\left(\frac{\$19.3}{acfm}\times 11{,}754\,acfm\right)\right]\times\frac{799.1}{575.4}=\$286{,}579$$

[35] *Control Measure AT-A-GLANCE Report. Control Measure: Low NOx Burner and Flue Gas Recirculation; ICI Boilers - Gas (NLNBFIBG).* Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
36 Ibid.

This value is then added to the annualized TCI cost using an equipment life of 15 years[37] and an interest rate of 8.5%, providing a TAC of \$301,017. Dividing this value by the NO_X removed to determine the cost effectiveness of LNBs for the Natural Gas Fired Boilers.

$$\frac{\frac{\$301{,}017}{yr}}{3.51\,\frac{tons}{yr}} = \frac{\$85{,}821}{ton\ NOx\ Removed}$$

A copy of the calculations spreadsheet for FGR is included in Attachment 11.

LNB and FGR costs as a combined installation are also provided as the CoST tool is more appropriate for this scenario. The TCI and TAC from each scenario are combined providing a TCI of \$868,870 and TAC of \$664,831, the cost effectiveness of LNBs and FGR together for the Natural Gas Fired Boilers is determined by dividing the TAC by the NO_X removed.

$$\frac{\frac{\$664{,}831}{yr}}{3.51\,\frac{tons}{yr}} = \frac{\$189{,}545}{ton\ NOx\ Removed}$$

A copy of the calculations spreadsheet for LNBs and FGR combined is included in Attachment 12.

SNCR

The cost of SNCR was calculated using the most recent version of EPA's Cost Control Manual.[38] This tool provides a number of formulas to calculate both TCI and TAC. A summary of the calculations with references to the equations used is contained in Attachment 13. CEPCI was used to update from 2016 dollars to 2024 dollars. This analysis provided a TCI of \$1,103, 664 and a TAC of \$155,702. This was used to calculate the cost effectiveness of SNCR.

$$\frac{\frac{\$155{,}702}{yr}}{2.01\,\frac{tons}{yr}} = \frac{\$77{,}368}{ton\ NOx\ Removed}$$

SCR

The cost of SCR was also calculated using the most recent version of EPA's Cost Control Manual.[39] This tool provides a number of formulas to calculate both TCI and TAC. A summary of the calculations with references to the equations used is contained in Attachment 14. Note that an equation from the most recent Cost Control Manual was used to calculate TCI, a better cost breakdown was provided by an earlier version of the Cost Control Manual. That manual was used to back calculate indirect costs, direct costs, and equipment costs; however, this had no impact on the TCI calculation. CEPCI was used to update from

[37] Ibid.
[38] Sorrels.
[39] Sorrels.

2016 dollars to 2024 dollars. This analysis provided a TCI of $3,110,221 and a TAC of $562,397. This was used to calculate the cost effectiveness of SNCR.

$$\frac{\frac{\$562{,}397}{yr}}{5.18\,\frac{tons}{yr}} = \frac{\$108{,}676}{ton\ NOx\ Removed}$$

The cost-effectiveness of the evaluated controls are ranked from most cost-effective to least cost effective.

Table 13: Costs and Cost Effectiveness of NO_X RACT Controls for Natural Gas Fired Boilers

NO_X Emission Control	TCI	TAC ($/yr)	NO_X Reduction (ton NOx/yr)	Cost Effectiveness ($/ton NO_X Removed)
SNCR	$1,103,664	$155,702	2.01	$77,368
FGR	$119,896	$301,017	3.51	$85,821
LNBs	$601,875	$346,100	3.51	$98,674
SCR	$3,110,221	$562,397	5.18	$108,676
LNBs + FGR	$868,870	$664,831	3.51	$189,545

5. Identify RACT.

All NO_X control options are above generally acceptable RACT benchmarks for cost effectiveness for both the Sodium Silicate Furnace and the Natural Gas Fired Boilers. For example, Ohio uses a benchmark of $5,000/ton[40] and Pennsylvania uses a benchmark of $3,750/ton.[41]

Grace identifies no new control for the Sodium Silicate Furnace as RACT for the 2015 Ozone NAAQS. Grace proposes a RACT emission limit of 13.28 lbs NO_X/ton of sodium silicate produced in the furnace. This emission rate is the result of the 2003 stack test with 20% added for compliance margin.

Grace also identifies no new control for the Natural Gas Fired Boilers as RACT for the 2015 Ozone NAAQS. IDEM is in the process of developing regulations for the Ozone RACT, the Ohio EPA threshold of 20 mmBtu/hr for RACT [OAC §3745-110-03(K)(1)] is too low. The threshold should be based on a higher heat input or potential annual NO_X emissions for an individual boiler.

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[40] Payton, Amanda. *Business Impact Analysis*. 22 June 2021. https://www.registerofohio.state.oh.us/servlet/RooBusinessPDF?ruleActionId=597890&docTypeId=14. Accessed 18 July 2024.

[41] *Additional RACT Requirements for Major Sources of NO_X and VOCs for the 2015 Ozone NAAQS*. 7 Aug. 2021, at 31 files.dep.state.pa.us/PublicParticipation/Public%20Participation%20Center/PubPartCenterPortalFiles/Environmental%20Quality%20Board/2022/August%209,%202022/01_7-561_RACT%203_Final/04_7-561_RACT%20III_Final_CRD.pdf. Accessed 18 July 2024.

Attachment 1 – RACT Cost Spreadsheet LNBs (Furnace)

RACT Cost - LNB

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment	545,415	Calculated from TCI
Sales Tax (7% of purchased equipment costs)	38,179	Indiana sales tax
TOTAL DIRECT COSTS (TDC)	583,594	
INDIRECT INSTALLATION COSTS		
Engineering Costs (5% of PEC)	29,180	Calculated from TCI
Contingency (20% of TDC)	116,719	Calculated from TCI
TOTAL INDIRECT COSTS	145,899	
TOTAL CAPITAL INVESTMENT (TCI)	**729,493**	1
Annual O&M Cost	**51,401**	Calculated from TAC
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
3 Equipment Life (years)		1
8.5% Interest Rate (%)		2
Capital Recovery Factor	0.3915	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**729,493**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**285,625**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	**337,026**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**139.5**	
TONS OF NOx REMOVED PER YEAR	**55.8**	
Assuming 40% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING ($ per ton of NOx removed)	**6,038**	1, 3, 4

[1] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[2] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[3] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 2 – RACT Cost Spreadsheet Oxy-Firing (Furnace)

RACT Cost - Oxy-Firing

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment	3,974,496	Calculated from TCI
Sales Tax (7% of purchased equipment costs)	278,215	Indiana sales tax
Subtotal-Purchased Equipment Costs (PEC)	4,252,710	
TOTAL DIRECT COSTS (TDC)	**4,252,710**	Calculated from TCI
INDIRECT INSTALLATION COSTS		
Engineering Costs (5% of PEC)	212,636	Calculated from TCI
Contingency (20% of TDC)	850,542	Calculated from TCI
TOTAL INDIRECT COSTS	1,063,178	
TOTAL CAPITAL INVESTMENT (TCI)	**5,315,888**	1 - Table 6-3
37.74 $/ton Glass		Calculated from TAC
82.5 tons/day of Glass		
365 Annual operating days	1,136,315	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
10 Equipment Life (years)		2
8.5% Interest Rate (%)		3
Capital Recovery Factor	0.1524	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**5,315,888**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**810,182**	
TOTAL ANNUALIZED COST (TAC) **(Total annual O&M cost and annualized capital cost)**	**1,946,497**	1 - Table 6-3
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**139.5**	
TONS OF NOx REMOVED PER YEAR	**118.6**	
Assuming 85% Removal		1 - Table 6-3
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS **($ per ton of NOx removed)**	**16,411**	1, 4, 5

[1] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[2] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[2a] Oxygen Enriched Air Staging a Cost-effective Method For Reducing NOx Emissions. Industrial Technologies. April 2002. Available at: http://www1.eere.energy.gov/manufacturing/resources/glass/pdfs/airstaging.pdf

[2b] Saint-Gobain Containers Inc. Clean Air Act Settlement (https://www.epa.gov/enforcement/saintgobain-containers-inc-clean-air-act-settlement) required the installation of OEAS on glassfurnaces

[2b] Owens-Brockway Glass Container Inc. Clean Air Act Settlement (https://www.epa.gov/enforcement/owens-brockway-glass-container-inc-settlement) required the installation of OEAS on glass furnaces.

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[4] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[5] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

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Attachment 3 – RACT Cost Spreadsheet SNCR (Furnace)

RACT Cost - SNCR

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
SNCR	541,856	Calculated from TCI
Sales Tax (7% of purchased equipment costs)	37,930	Indiana sales tax
Subtotal-Purchased Equipment Costs (PEC)	579,786	
INDIRECT INSTALLATION COSTS		
Engineering, Construction Management, Installation, Labor, and Contractors	173,936	Calculated from TCI
Project Contingency (15% of TDC)	86,968	Calculated from TCI
Preproduction Cost (2% of TDC)	11,596	Calculated from TCI
TOTAL INDIRECT COSTS	272,500	
TOTAL CAPITAL INVESTMENT (TCI)	**852,286**	1
TOTAL ANNUAL DIRECT AND INDIRECT COSTS	267,464	Calculated from TAC
TOTAL ANNUAL COSTS	**267,464**	Calculated from TAC
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		2
8.5% Interest Rate (%)		3
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**852,286**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**90,062**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**	**357,526**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**139.5**	
TONS OF NOx REMOVED PER YEAR	**48.8**	
Assuming 35% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING **($ per ton of Nox removed)**	**7,321**	1, 4, 5

[1] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[2] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[4] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[5] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 4 – RACT Cost Spreadsheet SCR (Furnace)

RACT Cost - SCR

COST COMPONENT				COST	REFERENCE
DIRECT COSTS					
Purchased Equipment Costs					
	SCR			516,678	Calculated from TCI
	Sales Tax (7% of purchased equipment costs)			36,167	Indiana sales tax
Subtotal-Purchased Equipment Costs (PEC)				552,846	
Balance of Plant Costs (BoP)				486,528	1 - Equation 2.36
h_{scr}		57	ft		
$m_{reagent}$		13.6	lb/hr		
F(new)		0			
QB		25	mmBtu/hr		
$Vol_{catalyst}$		142.4	cuft		
TOTAL DIRECT COSTS (TDC)				1,039,374	
INDIRECT INSTALLATION COSTS					
	General Facilities (5% of TDC)			51,969	1 - Table 2.5
	Engineering and Home Office Fees (10% of TDC)			103,937	1 - Table 2.5
	Contingency (5% of TDC)			51,969	1 - Table 2.5
PROJECT CONTINGENCY					
	Contingency (15% of TDC)			187,087	1 - Table 2.5
	Preproduction Cost (2% of TDC)			20,787	1 - Table 2.5
	Inventory Capital				
TOTAL INDIRECT COSTS				415,749	
TOTAL CAPITAL INVESTMENT (TCI)				**1,455,123**	2
DIRECT AND INDIRECT ANNUAL COSTS				847,280	Calculated from TAC
TOTAL ANNUAL COSTS				**847,280**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)					
	20	Equipment Life (years)			3
	8.5%	Interest Rate (%)			4
	Capital Recovery Factor			0.1057	
CAPITAL RECOVERY COSTS					
	TOTAL CAPITAL REQUIREMENT			**1,455,123**	
	TOTAL ANNUALIZED CAPITAL REQUIREMENT			**153,764**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**				**1,001,044**	2
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE				**139.5**	
TONS OF NOx REMOVED PER YEAR				**104.7**	
Assuming		75%	Removal		3
COST-EFFECTIVENESS					
	ENVIRONMENTAL BASIS EPA Nox EMISSIONS FROM GLASS MANUFACTURING **($ per ton of NOx removed)**			**9,565**	2, 5, 6

[1] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[2] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[3] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2019. Chapter 2 Selective Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024

[4] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[5] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[6] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 5 – RACT Cost Spreadsheet ESP (Furnace)

RACT Cost - ESP

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost	1,235,658	Calculated from TCI
Sales Tax (7% of equipment costs)	86,496	Based on Indiana sales tax
Instrumentation (10% of equipment cost)	123,566	2 - Table 3.16
Freight (5% of equipment costs)	49,426	2 - Table 3.16
Subtotal-Purchased Equipment Costs (PEC)	1,495,146	
Direct Installation Costs		
Installation/Foundation (4% of PEC)	49,426	2 - Table 3.16
Handling & Erection (50% of PEC)	617,829	2 - Table 3.16
Electrical (8% of PEC)	98,853	2 - Table 3.16
Piping (1% of PEC)	12,357	2 - Table 3.16
Insulation and ductwork (2% of PEC)	24,713	2 - Table 3.16
Painting (2% of PEC)	24,713	2 - Table 3.16
Subtotal-Direct Installation Costs	827,891	
TOTAL DIRECT COSTS (TDC)	2,323,037	
INDIRECT INSTALLATION COSTS		
Engineering Costs (20% of PEC)	299,029	2 - Table 3.16
Construction and field expenses (20% of PEC)	299,029	2 - Table 3.16
Contractor fees (10% of PEC)	149,515	2 - Table 3.16
Start-up (1% of PEC)	14,951	2 - Table 3.16
Performance test (1% of PEC)	14,951	2 - Table 3.16
Model study (2% of PEC)	29,903	2 - Table 3.16
Contingency (3% of TDC)	464,607	2 - Table 3.16
TOTAL INDIRECT COSTS	1,271,987	
TCI Calculations		
$90.30 Capital Cost Multiplier ($/acfm)		1
28,084 acfm (stack test)		Stack Test
$17,107 Capital Cost Constant		1
799.1 CEPCI 2024		3
567.5 CEPCI 2017		3
3,595,024 TCI		1
TOTAL CAPITAL INVESTMENT (TCI)	**3,595,024**	1 - Equation 35
DIRECT ANNUAL COSTS		
Total O&M Cost	**5,653,445**	1 - Equation 36
$6.30 O&M Cost Multiplier ($/acfm)		
$3,838,000 O&M Cost Constant		
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		1
8.5% Interest Rate (%)		4
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**3,595,024**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**379,890**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**	**6,033,334**	
BASELINE POTENTIAL PM-10 EMISSIONS (TPY) FROM GLASS FURNACE	**26.3**	
TONS OF PM-10 REMOVED PER YEAR	**25.0**	
Assuming 95% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS **($ per ton of PM-10 removed)**	**241,662**	1, 3

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[1a] GDIT, 2019: General Dynamics Information Technology, "CoST PM25 Control Measures Report," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 2019.

[2] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[3] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 6 – Control Measure AT-A-GLANCE Report for an ESP

Control Measure AT-A-GLANCE Report

Control Measure: Electrostatic Precipitator ICI Boilers and Heaters Gas and Oil (PESPICIGAS)

Summary:

Control Measure Name: Electrostatic Precipitator ICI Boilers and Heaters Gas and Oil
Abbreviation: PESPICIGAS
Description: This measure includes all types of electrostatic precipitators (ESP). Cost and cost effectiveness values were developed for combustion processes using natural gas, process gas, residual oil or distillate oil as the fuel source.
Class: Known
Pollutant: PM25-PRI
Equipment Life: 20.0 years
Control Technology: Electrostatic Precipitator-All Types
Source Group: ICI Boilers and Heaters - Gas and Oil
Sectors: ptnonipm
Months: All Months

Affected Pollutants, and their Control Efficiencies and Costs:

Pollutant:	PM25-PRI
Locale:	
Effective Date:	N/A
Cost Year:	2017
CPT:	$17,107
Ref Yr CPT:	$16,149
Control Efficiency:	95
Min Emis:	N/A
Max Emis:	N/A
Rule Effectiveness:	100.0
Rule Penetration:	100.0
Equation Type:	Type 8
Cap Ann Ratio:	N/A
Details:	
Existing Measure:	
Existing NEI Dev:	0

Cost Equations:

Name: Type 8

Description: Non-EGU PM

Inventory Fields: stack_flow_rate, stack_velocity, stack_diameter

Formula: Capital Cost = Capital Cost Multiplier x Exhaust Flowrate (acfm) + Capital Cost Constant
O&M Cost = O&M Cost Multiplier x Exhaust Flowrate (acfm) + O&M Cost Constant

Variable Name	Value
Pollutant	PM25-PRI
Cost Year	2017
Capital Cost Multiplier ($/acfm)	90.3
O&M Cost Multiplier ($/acfm)	6.3
Unused	104894
Unused	243000
Unused	7206
Capital Cost Constant ($)	17107
O&M Cost Constant ($)	3883000

Affected SCCs:

Code	Description
10200401	External Combustion Boilers; Industrial; Residual Oil; Grade 6 oil
10200402	External Combustion Boilers; Industrial; Residual Oil; 10-100 Million BTU/hr
10200403	External Combustion Boilers; Industrial; Residual Oil; < 10 Million BTU/hr
10200404	External Combustion Boilers; Industrial; Residual Oil; Grade 5 Oil
10200405	External Combustion Boilers; Industrial; Residual Oil; Cogeneration
10200406	External Combustion Boilers; Industrial; Residual Oil; Boiler > 100 Million BTU/hr
10200501	External Combustion Boilers; Industrial; Distillate Oil - Grades 1 and 2; Boiler
10200502	External Combustion Boilers; Industrial; Distillate Oil; 10-100 Million BTU/hr **
10200503	External Combustion Boilers; Industrial; Distillate Oil; < 10 Million BTU/hr **
10200504	External Combustion Boilers; Industrial; Distillate Oil; Grade 4 Oil
10200505	External Combustion Boilers; Industrial; Distillate Oil; Cogeneration
10200506	External Combustion Boilers; Industrial; Distillate Oil; Boiler > 100 Million BTU/hr
10200601	External Combustion Boilers; Industrial; Natural Gas; > 100 Million BTU/hr
10200602	External Combustion Boilers; Industrial; Natural Gas; 10-100 Million BTU/hr
10200603	External Combustion Boilers; Industrial; Natural Gas; < 10 Million BTU/hr
10200604	External Combustion Boilers; Industrial; Natural Gas; Cogeneration
10200701	External Combustion Boilers; Industrial; Process Gas; Petroleum Refinery Gas
10200704	External Combustion Boilers; Industrial; Process Gas; Blast Furnace Gas
10200707	External Combustion Boilers; Industrial; Process Gas; Coke Oven Gas
10200710	External Combustion Boilers; Industrial; Process Gas; Cogeneration
10200711	External Combustion Boilers; Industrial; Process Gas; Landfill Gas
10200799	External Combustion Boilers; Industrial; Process Gas; Other: Specify in Comments
10201001	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane
10201002	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Propane

10201003	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane/Propane Mixture: Specify Percent Butane in Comments
10201301	External Combustion Boilers; Industrial; Liquid Waste; Specify Waste Material in Comments
10201302	External Combustion Boilers; Industrial; Liquid Waste; Waste Oil
10201303	External Combustion Boilers; Industrial; Liquid Waste; Salable Animal Fat
10201401	External Combustion Boilers; Industrial; CO Boiler; Natural Gas
10201402	External Combustion Boilers; Industrial; CO Boiler; Process Gas
10201403	External Combustion Boilers; Industrial; CO Boiler; Distillate Oil
10201501	External Combustion Boilers; Industrial; Tire-derived Fuel; Boiler, Stoker
10201601	External Combustion Boilers; Industrial; Methanol; Industrial Boiler
10201701	External Combustion Boilers; Industrial; Gasoline; Industrial Boiler
10300401	External Combustion Boilers; Commercial/Institutional; Residual Oil - Grade 6; Boiler
10300402	External Combustion Boilers; Commercial/Institutional; Residual Oil; 10-100 Million BTU/hr **
10300403	External Combustion Boilers; Commercial/Institutional; Residual Oil; < 10 Million BTU/hr **
10300404	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 5 Oil
10300501	External Combustion Boilers; Commercial/Institutional; Distillate Oil - Grades 1 and 2; Boiler
10300502	External Combustion Boilers; Commercial/Institutional; Distillate Oil; 10-100 Million BTU/hr **
10300503	External Combustion Boilers; Commercial/Institutional; Distillate Oil; < 10 Million BTU/hr **
10300504	External Combustion Boilers; Commercial/Institutional; Distillate Oil; Grade 4 Oil
10300601	External Combustion Boilers; Commercial/Institutional; Natural Gas; > 100 Million BTU/hr
10300602	External Combustion Boilers; Commercial/Institutional; Natural Gas; 10-100 Million BTU/hr
10300603	External Combustion Boilers; Commercial/Institutional; Natural Gas; < 10 Million BTU/hr
10300701	External Combustion Boilers; Commercial/Institutional; Process Gas; POTW Digester Gas-fired Boiler
10300799	External Combustion Boilers; Commercial/Institutional; Process Gas; Other Not Classified
10300811	External Combustion Boilers; Commercial/Institutional; Landfill Gas; Landfill Gas
10301001	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane
10301002	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Propane
10301003	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane/Propane Mixture: Specify Percent Butane in Comments
10301301	External Combustion Boilers; Commercial/Institutional; Liquid Waste; Specify Waste Material in Comments
10301302	External Combustion Boilers; Commercial/Institutional; Liquid Waste; Waste Oil
10500105	External Combustion; Space Heaters; Industrial; Distillate Oil
10500106	External Combustion; Space Heaters; Industrial; Natural Gas
10500110	External Combustion; Space Heaters; Industrial; Liquified Petroleum Gas (LPG)
10500113	External Combustion; Space Heaters; Industrial; Waste Oil: Air Atomized Burner
10500114	External Combustion; Space Heaters; Industrial; Waste Oil: Vaporizing Burner
10500205	External Combustion; Space Heaters; Commercial/Institutional; Distillate Oil
10500206	External Combustion; Space Heaters; Commercial/Institutional; Natural Gas

10500210	External Combustion; Space Heaters; Commercial/Institutional; Liquified Petroleum Gas (LPG)
10500213	External Combustion; Space Heaters; Commercial/Institutional; Waste Oil: Air Atomized Burner
10500214	External Combustion; Space Heaters; Commercial/Institutional; Waste Oil: Vaporizing Burner
30100306	Industrial Processes; Chemical Manufacturing; Ammonia Production; Primary Reformer: Natural Gas Fired
30190001	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30190002	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Residual Oil: Process Heaters
30190003	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Natural Gas: Process Heaters
30190004	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Process Gas: Process Heaters
30190011	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Distillate Oil (No. 2): Incinerators
30190012	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Residual Oil: Incinerators
30190013	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Natural Gas: Incinerators
30190014	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Process Gas: Incinerators
30190099	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Specify in Comments Field
30200115	Industrial Processes; Food and Agriculture; Alfalfa Dehydration; Gas-fired, Single-Pass Dryer Cyclone
30205020	Industrial Processes; Food and Agriculture; Ethanol Production; Natural Gas Combustion from Dryer
30205021	Industrial Processes; Food and Agriculture; Ethanol Production; Natural Gas Combustion from Thermal Oxidizer
30290001	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30290003	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Natural Gas: Process Heaters
30290005	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Liquified Petroleum Gas (LPG): Process Heaters
30291001	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Broiling Food: Natural Gas
30390001	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30390002	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Residual Oil: Process Heaters
30390003	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Natural Gas: Process Heaters
30390004	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Process Gas: Process Heaters
30390013	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Natural Gas: Incinerators
30390014	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Process Gas: Incinerators
30490001	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30490002	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Residual Oil: Process Heaters
30490003	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Natural Gas: Process Heaters

30490004	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Process Gas: Process Heaters
30490013	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Natural Gas: Incinerators
30490014	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Process Gas: Incinerators
30590001	Industrial Processes; Mineral Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30590002	Industrial Processes; Mineral Products; Fuel Fired Equipment; Residual Oil: Process Heaters
30590003	Industrial Processes; Mineral Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30590005	Industrial Processes; Mineral Products; Fuel Fired Equipment; Liquified Petroleum Gas (LPG): Process Heaters
30590013	Industrial Processes; Mineral Products; Fuel Fired Equipment; Natural Gas: Incinerators
30600101	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired **
30600102	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired **
30600103	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired
30600104	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired
30600105	Industrial Processes; Petroleum Industry; Process Heaters; Natural Gas-fired
30600106	Industrial Processes; Petroleum Industry; Process Heaters; Process Gas-fired
30600107	Industrial Processes; Petroleum Industry; Process Heaters; LPG-fired
30600108	Industrial Processes; Petroleum Industry; Process Heaters; Landfill Gas-fired
30600111	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired (No. 6 Oil) : 100 Million Btu Capacity
30600203	The SCC entry is not found in the reference.scc table
30600204	The SCC entry is not found in the reference.scc table
30600205	The SCC entry is not found in the reference.scc table
30609901	Industrial Processes; Petroleum Industry; Incinerators; Distillate Oil (No. 2)
30609902	Industrial Processes; Petroleum Industry; Incinerators; Residual Oil
30609903	Industrial Processes; Petroleum Industry; Incinerators; Natural Gas
30609904	Industrial Processes; Petroleum Industry; Incinerators; Process Gas
30609905	Industrial Processes; Petroleum Industry; Incinerators; Liquified Petroleum Gas
30890001	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30890003	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30890004	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Liquified Petroleum Gas (LPG): Process Heaters
30890013	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Natural Gas: Incinerators
30990001	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30990003	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30990011	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Distillate Oil (No. 2): Incinerators

30990013	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Natural Gas: Incinerators
31000401	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2)
31000402	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil
31000403	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil
31000404	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas
31000405	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas
31000411	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2): Steam Generators
31000412	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil: Steam Generators
31000413	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil: Steam Generators
31000414	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas: Steam Generators
31000415	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas: Steam Generators
31390001	Industrial Processes; Electrical Equipment; Process Heaters; Distillate Oil (No. 2)
31390002	Industrial Processes; Electrical Equipment; Process Heaters; Residual Oil
31390003	Industrial Processes; Electrical Equipment; Process Heaters; Natural Gas
39000402	Industrial Processes; In-process Fuel Use; Residual Oil; Cement Kiln/Dryer
39000403	Industrial Processes; In-process Fuel Use; Residual Oil; Lime Kiln
39000499	Industrial Processes; In-process Fuel Use; Residual Oil; General
39000501	Industrial Processes; In-process Fuel Use; Distillate Oil; Asphalt Dryer **
39000502	Industrial Processes; In-process Fuel Use; Distillate Oil; Cement Kiln/Dryer
39000503	Industrial Processes; In-process Fuel Use; Distillate Oil; Lime Kiln
39000598	Industrial Processes; In-process Fuel Use; Distillate Oil; Grade 4 Oil: General
39000599	Industrial Processes; In-process Fuel Use; Distillate Oil; General
39000602	Industrial Processes; In-process Fuel Use; Natural Gas; Cement Kiln/Dryer
39000603	Industrial Processes; In-process Fuel Use; Natural Gas; Lime Kiln
39000605	Industrial Processes; In-process Fuel Use; Natural Gas; Metal Melting **
39000699	Industrial Processes; In-process Fuel Use; Natural Gas; General
39000701	Industrial Processes; In-process Fuel Use; Process Gas; Coke Oven or Blast Furnace
39000702	Industrial Processes; In-process Fuel Use; Process Gas; Coke Oven Gas
39000797	Industrial Processes; In-process Fuel Use; Process Gas; General
39001099	Industrial Processes; In-process Fuel Use; Liquified Petroleum Gas; General
39001399	Industrial Processes; In-process Fuel Use; Liquid Waste; General
39900501	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Distillate Oil
39900601	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Natural Gas
39900701	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Process Gas
39900711	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Refinery Gas

39900721	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Digester Gas
39900801	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Landfill Gas
39901001	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; LPG
39990001	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Distillate Oil (No. 2): Process Heaters
39990002	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Residual Oil: Process Heaters
39990003	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Natural Gas: Process Heaters
39990004	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Process Gas: Process Heaters
39990013	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Natural Gas: Incinerators
39990014	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Process Gas: Incinerators
40201001	Petroleum and Solvent Evaporation; Surface Coating Operations; Coating Oven Heater; Natural Gas
40201002	Petroleum and Solvent Evaporation; Surface Coating Operations; Coating Oven Heater; Distillate Oil
40201004	Petroleum and Solvent Evaporation; Surface Coating Operations; Coating Oven Heater; Liquified Petroleum Gas (LPG)
40290011	Petroleum and Solvent Evaporation; Surface Coating Operations; Fuel Fired Equipment; Distillate Oil: Incinerator/Afterburner
40290013	Petroleum and Solvent Evaporation; Surface Coating Operations; Fuel Fired Equipment; Natural Gas: Incinerator/Afterburner
49090011	Petroleum and Solvent Evaporation; Organic Solvent Evaporation; Fuel Fired Equipment; Distillate Oil (No. 2): Incinerators
49090013	Petroleum and Solvent Evaporation; Organic Solvent Evaporation; Fuel Fired Equipment; Natural Gas: Incinerators
49090015	Petroleum and Solvent Evaporation; Organic Solvent Evaporation; Fuel Fired Equipment; Recovered Solvents: Miscellaneous Incinerators
50190005	Waste Disposal; Solid Waste Disposal - Government; Auxillary Fuel/No Emissions; Distillate Oil
50190006	Waste Disposal; Solid Waste Disposal - Government; Auxillary Fuel/No Emissions; Natural Gas
50190010	Waste Disposal; Solid Waste Disposal - Government; Auxillary Fuel/No Emissions; Liquified Petroleum Gas (LPG)
50290005	Waste Disposal; Solid Waste Disposal - Commercial/Institutional; Auxillary Fuel/No Emissions; Distillate Oil
50290006	Waste Disposal; Solid Waste Disposal - Commercial/Institutional; Auxillary Fuel/No Emissions; Natural Gas
50290010	Waste Disposal; Solid Waste Disposal - Commercial/Institutional; Auxillary Fuel/No Emissions; Liquified Petroleum Gas (LPG)
50390005	Waste Disposal; Solid Waste Disposal - Industrial; Auxillary Fuel/No Emissions; Distillate Oil
50390006	Waste Disposal; Solid Waste Disposal - Industrial; Auxillary Fuel/No Emissions; Natural Gas

References:

- GDIT, 2019: General Dynamics Information Technology, "CoST PM25 Control Measures Report," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 2019.

Other information:

CE_NOTES:	CE from GDIT 2019 (Table 7)
CPT_NOTES:	CPT from GDIT 2019 supplemental table (cmdb_PMupdates_20191001_efficiencies_revised_20200511.csv)
EQUATION_NOTES:	Equation parameters from GDIT 2019 (cmdb_PMupdates_20191001_equations_revised_20200511.csv)

Attachment 7 – RACT Cost Spreadsheet Baghouse (Furnace)

RACT Cost - Baghouse

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment Cost	280,840	Calculated from TCI
Sales Tax (7% of equipment costs)	19,659	Based on Indiana sales tax
Instrumentation (10% of equipment cost)	28,084	2 - Table 3.16
Freight (5% of equipment costs)	11,234	2 - Table 3.16
Subtotal-Purchased Equipment Costs (PEC)	339,817	
Direct Installation Costs		
Support/Foundation (4% of PEC)	11,234	2 - Table 3.16
Handling & Erection (50% of PEC)	140,420	2 - Table 3.16
Electrical (8% of PEC)	22,467	2 - Table 3.16
Piping (1% of PEC)	2,808	2 - Table 3.16
Insulation and ductwork (7% of PEC)	19,659	2 - Table 3.16
Painting (4% of PEC)	11,234	2 - Table 3.16
Subtotal-Direct Installation Costs	207,822	
TOTAL DIRECT COSTS (TDC)	547,639	
INDIRECT INSTALLATION COSTS		
Engineering Costs (10% of PEC)	67,963	2 - Table 1.9
Construction and field expenses (20% of PEC)	67,963	2 - Table 1.9
Contractor fees (10% of PEC)	33,982	2 - Table 1.9
Start-up (1% of PEC)	3,398	2 - Table 1.9
Performance test (1% of PEC)	3,398	2 - Table 1.9
Contingency (3% of TDC)	109,528	2 - Table 1.9
TOTAL INDIRECT COSTS	286,232	
TCI		
$20.90 Capital Cost Multiplier ($/acfm)		1
28,084 acfm (stack test)		Stack Test
$5,238 Capital Cost Constant		1
799.1 CEPCI 2024		3
567.5 CEPCI 2017		3
833,871 TCI		1
TOTAL CAPITAL INVESTMENT (TCI)	**833,871**	1 - Equation 35
DIRECT ANNUAL COSTS		
Total O&M Cost	**1,255,727**	1 - Equation 36
$2.20 O&M Cost Multiplier ($/acfm)		
$830,000 O&M Cost Constant		
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		1
8.5% Interest Rate (%)		4
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**833,871**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**88,116**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	**1,343,843**	
BASELINE POTENTIAL PM-10 EMISSIONS (TPY) FROM GLASS FURNACE	**26.3**	
TONS OF PM-10 REMOVED PER YEAR	**26.0**	
Assuming 99% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS ($ per ton of PM-10 removed)	**51,652**	1, 3

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[2] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[3] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 8 – Control Measure AT-A-GLANCE Report for a Baghouse

Control Measure AT-A-GLANCE Report

Control Measure: Fabric Filter ICI Boilers and Heaters Gas and Oil (PFFICIGAS)

Summary:

Control Measure Name: Fabric Filter ICI Boilers and Heaters Gas and Oil

Abbreviation: PFFICIGAS

Description: This measure includes all types of fabric filters (FF). Cost and cost effectiveness values were developed for combustion processes using natural gas, process gas, residual oil or distillate oil as the fuel source.

Class: Known

Pollutant: PM25-PRI

Equipment Life: 20.0 years

Control Technology: Fabric Filter-All Types

Source Group: ICI Boilers and Heaters - Gas and Oil

Sectors: ptnonipm

Months: All Months

Affected Pollutants, and their Control Efficiencies and Costs:

Pollutant:	PM25-PRI
Locale:	
Effective Date:	N/A
Cost Year:	2017
CPT:	$5,238
Ref Yr CPT:	$4,945
Control Efficiency:	99
Min Emis:	N/A
Max Emis:	N/A
Rule Effectiveness:	100.0
Rule Penetration:	100.0
Equation Type:	Type 8
Cap Ann Ratio:	N/A
Details:	
Existing Measure:	
Existing NEI Dev:	0

Cost Equations:

Name: Type 8

Description: Non-EGU PM

Inventory Fields: stack_flow_rate, stack_velocity, stack_diameter

Formula: Capital Cost = Capital Cost Multiplier x Exhaust Flowrate (acfm) + Capital Cost Constant
O&M Cost = O&M Cost Multiplier x Exhaust Flowrate (acfm) + O&M Cost Constant

Variable Name	Value
Pollutant	PM25-PRI
Cost Year	2017
Capital Cost Multiplier ($/acfm)	20.9
O&M Cost Multiplier ($/acfm)	2.2
Unused	22663
Unused	264000
Unused	3151
Capital Cost Constant ($)	5238
O&M Cost Constant ($)	830000

Affected SCCs:

Code	Description
10200401	External Combustion Boilers; Industrial; Residual Oil; Grade 6 oil
10200402	External Combustion Boilers; Industrial; Residual Oil; 10-100 Million BTU/hr
10200403	External Combustion Boilers; Industrial; Residual Oil; < 10 Million BTU/hr
10200404	External Combustion Boilers; Industrial; Residual Oil; Grade 5 Oil
10200405	External Combustion Boilers; Industrial; Residual Oil; Cogeneration
10200406	External Combustion Boilers; Industrial; Residual Oil; Boiler > 100 Million BTU/hr
10200501	External Combustion Boilers; Industrial; Distillate Oil - Grades 1 and 2; Boiler
10200502	External Combustion Boilers; Industrial; Distillate Oil; 10-100 Million BTU/hr **
10200503	External Combustion Boilers; Industrial; Distillate Oil; < 10 Million BTU/hr **
10200504	External Combustion Boilers; Industrial; Distillate Oil; Grade 4 Oil
10200505	External Combustion Boilers; Industrial; Distillate Oil; Cogeneration
10200506	External Combustion Boilers; Industrial; Distillate Oil; Boiler > 100 Million BTU/hr
10200601	External Combustion Boilers; Industrial; Natural Gas; > 100 Million BTU/hr
10200602	External Combustion Boilers; Industrial; Natural Gas; 10-100 Million BTU/hr
10200603	External Combustion Boilers; Industrial; Natural Gas; < 10 Million BTU/hr
10200604	External Combustion Boilers; Industrial; Natural Gas; Cogeneration
10200701	External Combustion Boilers; Industrial; Process Gas; Petroleum Refinery Gas
10200704	External Combustion Boilers; Industrial; Process Gas; Blast Furnace Gas
10200707	External Combustion Boilers; Industrial; Process Gas; Coke Oven Gas
10200710	External Combustion Boilers; Industrial; Process Gas; Cogeneration
10200711	External Combustion Boilers; Industrial; Process Gas; Landfill Gas
10200799	External Combustion Boilers; Industrial; Process Gas; Other: Specify in Comments
10201001	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane
10201002	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Propane

10201003	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane/Propane Mixture: Specify Percent Butane in Comments
10201301	External Combustion Boilers; Industrial; Liquid Waste; Specify Waste Material in Comments
10201302	External Combustion Boilers; Industrial; Liquid Waste; Waste Oil
10201303	External Combustion Boilers; Industrial; Liquid Waste; Salable Animal Fat
10201401	External Combustion Boilers; Industrial; CO Boiler; Natural Gas
10201402	External Combustion Boilers; Industrial; CO Boiler; Process Gas
10201403	External Combustion Boilers; Industrial; CO Boiler; Distillate Oil
10201501	External Combustion Boilers; Industrial; Tire-derived Fuel; Boiler, Stoker
10201601	External Combustion Boilers; Industrial; Methanol; Industrial Boiler
10201701	External Combustion Boilers; Industrial; Gasoline; Industrial Boiler
10300401	External Combustion Boilers; Commercial/Institutional; Residual Oil - Grade 6; Boiler
10300402	External Combustion Boilers; Commercial/Institutional; Residual Oil; 10-100 Million BTU/hr **
10300403	External Combustion Boilers; Commercial/Institutional; Residual Oil; < 10 Million BTU/hr **
10300404	External Combustion Boilers; Commercial/Institutional; Residual Oil; Grade 5 Oil
10300501	External Combustion Boilers; Commercial/Institutional; Distillate Oil - Grades 1 and 2; Boiler
10300502	External Combustion Boilers; Commercial/Institutional; Distillate Oil; 10-100 Million BTU/hr **
10300503	External Combustion Boilers; Commercial/Institutional; Distillate Oil; < 10 Million BTU/hr **
10300504	External Combustion Boilers; Commercial/Institutional; Distillate Oil; Grade 4 Oil
10300601	External Combustion Boilers; Commercial/Institutional; Natural Gas; > 100 Million BTU/hr
10300602	External Combustion Boilers; Commercial/Institutional; Natural Gas; 10-100 Million BTU/hr
10300603	External Combustion Boilers; Commercial/Institutional; Natural Gas; < 10 Million BTU/hr
10300701	External Combustion Boilers; Commercial/Institutional; Process Gas; POTW Digester Gas-fired Boiler
10300799	External Combustion Boilers; Commercial/Institutional; Process Gas; Other Not Classified
10300811	External Combustion Boilers; Commercial/Institutional; Landfill Gas; Landfill Gas
10301001	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane
10301002	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Propane
10301003	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane/Propane Mixture: Specify Percent Butane in Comments
10301301	External Combustion Boilers; Commercial/Institutional; Liquid Waste; Specify Waste Material in Comments
10301302	External Combustion Boilers; Commercial/Institutional; Liquid Waste; Waste Oil
10500105	External Combustion; Space Heaters; Industrial; Distillate Oil
10500106	External Combustion; Space Heaters; Industrial; Natural Gas
10500110	External Combustion; Space Heaters; Industrial; Liquified Petroleum Gas (LPG)
10500113	External Combustion; Space Heaters; Industrial; Waste Oil: Air Atomized Burner
10500114	External Combustion; Space Heaters; Industrial; Waste Oil: Vaporizing Burner
10500205	External Combustion; Space Heaters; Commercial/Institutional; Distillate Oil
10500206	External Combustion; Space Heaters; Commercial/Institutional; Natural Gas

10500210	External Combustion; Space Heaters; Commercial/Institutional; Liquified Petroleum Gas (LPG)
10500213	External Combustion; Space Heaters; Commercial/Institutional; Waste Oil: Air Atomized Burner
10500214	External Combustion; Space Heaters; Commercial/Institutional; Waste Oil: Vaporizing Burner
30100306	Industrial Processes; Chemical Manufacturing; Ammonia Production; Primary Reformer: Natural Gas Fired
30190001	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30190002	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Residual Oil: Process Heaters
30190003	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Natural Gas: Process Heaters
30190004	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Process Gas: Process Heaters
30190011	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Distillate Oil (No. 2): Incinerators
30190012	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Residual Oil: Incinerators
30190013	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Natural Gas: Incinerators
30190014	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Process Gas: Incinerators
30190099	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Specify in Comments Field
30200115	Industrial Processes; Food and Agriculture; Alfalfa Dehydration; Gas-fired, Single-Pass Dryer Cyclone
30205020	Industrial Processes; Food and Agriculture; Ethanol Production; Natural Gas Combustion from Dryer
30205021	Industrial Processes; Food and Agriculture; Ethanol Production; Natural Gas Combustion from Thermal Oxidizer
30290001	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30290003	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Natural Gas: Process Heaters
30290005	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Liquified Petroleum Gas (LPG): Process Heaters
30291001	Industrial Processes; Food and Agriculture; Fuel Fired Equipment; Broiling Food: Natural Gas
30390001	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30390002	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Residual Oil: Process Heaters
30390003	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Natural Gas: Process Heaters
30390004	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Process Gas: Process Heaters
30390013	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Natural Gas: Incinerators
30390014	Industrial Processes; Primary Metal Production; Fuel Fired Equipment; Process Gas: Incinerators
30490001	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30490002	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Residual Oil: Process Heaters
30490003	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Natural Gas: Process Heaters

30490004	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Process Gas: Process Heaters
30490013	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Natural Gas: Incinerators
30490014	Industrial Processes; Secondary Metal Production; Fuel Fired Equipment; Process Gas: Incinerators
30590001	Industrial Processes; Mineral Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30590002	Industrial Processes; Mineral Products; Fuel Fired Equipment; Residual Oil: Process Heaters
30590003	Industrial Processes; Mineral Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30590005	Industrial Processes; Mineral Products; Fuel Fired Equipment; Liquified Petroleum Gas (LPG): Process Heaters
30590013	Industrial Processes; Mineral Products; Fuel Fired Equipment; Natural Gas: Incinerators
30600101	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired **
30600102	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired **
30600103	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired
30600104	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired
30600105	Industrial Processes; Petroleum Industry; Process Heaters; Natural Gas-fired
30600106	Industrial Processes; Petroleum Industry; Process Heaters; Process Gas-fired
30600107	Industrial Processes; Petroleum Industry; Process Heaters; LPG-fired
30600108	Industrial Processes; Petroleum Industry; Process Heaters; Landfill Gas-fired
30600111	Industrial Processes; Petroleum Industry; Process Heaters; Oil-fired (No. 6 Oil) : 100 Million Btu Capacity
30600203	The SCC entry is not found in the reference.scc table
30600204	The SCC entry is not found in the reference.scc table
30600205	The SCC entry is not found in the reference.scc table
30609901	Industrial Processes; Petroleum Industry; Incinerators; Distillate Oil (No. 2)
30609902	Industrial Processes; Petroleum Industry; Incinerators; Residual Oil
30609903	Industrial Processes; Petroleum Industry; Incinerators; Natural Gas
30609904	Industrial Processes; Petroleum Industry; Incinerators; Process Gas
30609905	Industrial Processes; Petroleum Industry; Incinerators; Liquified Petroleum Gas
30890001	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30890003	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30890004	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Liquified Petroleum Gas (LPG): Process Heaters
30890013	Industrial Processes; Rubber and Miscellaneous Plastics Products; Fuel Fired Equipment; Natural Gas: Incinerators
30990001	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Distillate Oil (No. 2): Process Heaters
30990003	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30990011	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Distillate Oil (No. 2): Incinerators

30990013	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Natural Gas: Incinerators
31000401	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2)
31000402	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil
31000403	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil
31000404	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas
31000405	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas
31000411	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2): Steam Generators
31000412	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil: Steam Generators
31000413	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil: Steam Generators
31000414	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas: Steam Generators
31000415	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas: Steam Generators
31390001	Industrial Processes; Electrical Equipment; Process Heaters; Distillate Oil (No. 2)
31390002	Industrial Processes; Electrical Equipment; Process Heaters; Residual Oil
31390003	Industrial Processes; Electrical Equipment; Process Heaters; Natural Gas
39000402	Industrial Processes; In-process Fuel Use; Residual Oil; Cement Kiln/Dryer
39000403	Industrial Processes; In-process Fuel Use; Residual Oil; Lime Kiln
39000499	Industrial Processes; In-process Fuel Use; Residual Oil; General
39000501	Industrial Processes; In-process Fuel Use; Distillate Oil; Asphalt Dryer **
39000502	Industrial Processes; In-process Fuel Use; Distillate Oil; Cement Kiln/Dryer
39000503	Industrial Processes; In-process Fuel Use; Distillate Oil; Lime Kiln
39000598	Industrial Processes; In-process Fuel Use; Distillate Oil; Grade 4 Oil: General
39000599	Industrial Processes; In-process Fuel Use; Distillate Oil; General
39000602	Industrial Processes; In-process Fuel Use; Natural Gas; Cement Kiln/Dryer
39000603	Industrial Processes; In-process Fuel Use; Natural Gas; Lime Kiln
39000605	Industrial Processes; In-process Fuel Use; Natural Gas; Metal Melting **
39000699	Industrial Processes; In-process Fuel Use; Natural Gas; General
39000701	Industrial Processes; In-process Fuel Use; Process Gas; Coke Oven or Blast Furnace
39000702	Industrial Processes; In-process Fuel Use; Process Gas; Coke Oven Gas
39000797	Industrial Processes; In-process Fuel Use; Process Gas; General
39001099	Industrial Processes; In-process Fuel Use; Liquified Petroleum Gas; General
39001399	Industrial Processes; In-process Fuel Use; Liquid Waste; General
39900501	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Distillate Oil
39900601	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Natural Gas
39900701	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Process Gas
39900711	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Refinery Gas

39900721	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Digester Gas
39900801	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Landfill Gas
39901001	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; LPG
39990001	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Distillate Oil (No. 2): Process Heaters
39990002	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Residual Oil: Process Heaters
39990003	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Natural Gas: Process Heaters
39990004	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Process Gas: Process Heaters
39990013	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Natural Gas: Incinerators
39990014	Industrial Processes; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Process Gas: Incinerators
40201001	Petroleum and Solvent Evaporation; Surface Coating Operations; Coating Oven Heater; Natural Gas
40201002	Petroleum and Solvent Evaporation; Surface Coating Operations; Coating Oven Heater; Distillate Oil
40201004	Petroleum and Solvent Evaporation; Surface Coating Operations; Coating Oven Heater; Liquified Petroleum Gas (LPG)
40290011	Petroleum and Solvent Evaporation; Surface Coating Operations; Fuel Fired Equipment; Distillate Oil: Incinerator/Afterburner
40290013	Petroleum and Solvent Evaporation; Surface Coating Operations; Fuel Fired Equipment; Natural Gas: Incinerator/Afterburner
49090011	Petroleum and Solvent Evaporation; Organic Solvent Evaporation; Fuel Fired Equipment; Distillate Oil (No. 2): Incinerators
49090013	Petroleum and Solvent Evaporation; Organic Solvent Evaporation; Fuel Fired Equipment; Natural Gas: Incinerators
49090015	Petroleum and Solvent Evaporation; Organic Solvent Evaporation; Fuel Fired Equipment; Recovered Solvents: Miscellaneous Incinerators
50190005	Waste Disposal; Solid Waste Disposal - Government; Auxillary Fuel/No Emissions; Distillate Oil
50190006	Waste Disposal; Solid Waste Disposal - Government; Auxillary Fuel/No Emissions; Natural Gas
50190010	Waste Disposal; Solid Waste Disposal - Government; Auxillary Fuel/No Emissions; Liquified Petroleum Gas (LPG)
50290005	Waste Disposal; Solid Waste Disposal - Commercial/Institutional; Auxillary Fuel/No Emissions; Distillate Oil
50290006	Waste Disposal; Solid Waste Disposal - Commercial/Institutional; Auxillary Fuel/No Emissions; Natural Gas
50290010	Waste Disposal; Solid Waste Disposal - Commercial/Institutional; Auxillary Fuel/No Emissions; Liquified Petroleum Gas (LPG)
50390005	Waste Disposal; Solid Waste Disposal - Industrial; Auxillary Fuel/No Emissions; Distillate Oil
50390006	Waste Disposal; Solid Waste Disposal - Industrial; Auxillary Fuel/No Emissions; Natural Gas

References:

- GDIT, 2019: General Dynamics Information Technology, "CoST PM25 Control Measures Report," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 2019.

Other information:

CE_NOTES:	CE from GDIT 2019 (Table 7)
CPT_NOTES:	CPT from GDIT 2019 supplemental table (cmdb_PMupdates_20191001_efficiencies_revised_20200511.csv)
EQUATION_NOTES:	Equation parameters from GDIT 2019 (cmdb_PMupdates_20191001_equations_revised_20200511.csv)

Attachment 9 – RACT Cost Spreadsheet for LNBs (Boiler)

RACT Cost Estimate - LNB Boiler

COST COMPONENT		COST	REFERENCE
DIRECT COSTS			
Purchased Equipment Costs			
Equipment		450,000	Estimate from vendor
Sales Tax (7% of purchased equipment costs)		31,500	Indiana sales tax
TOTAL DIRECT COSTS (TDC)		481,500	
INDIRECT INSTALLATION COSTS			
Engineering Costs (5% of TDC)		24,075	Estimate
Contingency (20% of TDC)		96,300	Estimate
TOTAL INDIRECT COSTS		120,375	
TOTAL CAPITAL INVESTMENT (TCI)		**601,875**	
Total O&M Cost		**273,622**	1 - Equation 48
$218.40	O&M Cost Multiplier LNBs ($/mmBtu)		
0.65	O&M Cost Exponent LNBs		
$194,883	O&M Cost Constant		
799.1	CEPCI 2024		2
575.4	CEPCI 2008		2
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)			
15	Equipment Life (years)		1
8.5%	Interest Rate (%)		2
Capital Recovery Factor		0.1204	
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		**601,875**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT		**72,478**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)		**346,100**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER		**5.75**	
TONS OF NOx REMOVED PER YEAR		**3.51**	
Assuming 61% Removal			1
COST-EFFECTIVENESS			
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING ($ per ton of NOx removed)		**98,674**	1

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[2] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 10 – Control Measure AT-A-GLANCE Report for LNBs and FGR

Control Measure AT-A-GLANCE Report

Control Measure: Low NOx Burner and Flue Gas Recirculation; ICI Boilers - Gas (NLNBFIBG)

Summary:

Control Measure Name: Low NOx Burner and Flue Gas Recirculation; ICI Boilers - Gas

Abbreviation: NLNBFIBG

Description: Application: This control is the use of low NOx burner (LNB) technology and flue gas recirculation (FGR) to reduce NOx emissions. LNBs reduce the amount of NOx created from reaction between fuel nitrogen and oxygen by lowering the temperature of one combustion zone and reducing the amount of oxygen available in another.

Discussion: LNBs are designed to "stage" combustion so that two combustion zones are created, one fuel-rich combustion and one at a lower temperature. Staging techniques are usually used by LNB to supply excess air to cool the combustion process or to reduce available oxygen in the flame zone. Staged-air LNBs create a fuel-rich reducing primary combustion zone and a fuel-lean secondary combustion zone. Staged-fuel LNBs create a lean combustion zone that is relatively cool due to the presence of excess air, which acts as a heat sink to lower combustion temperatures (EPA, 2002).

Class: Known

Pollutant: NOX

Equipment Life: 15.0 years

Control Technology: Low NOx Burner and Flue Gas Recirculation

Source Group: ICI Boilers - Gas

Sectors: ptnonipm

Months: All Months

Affected Pollutants, and their Control Efficiencies and Costs:

Pollutant:	NOX	NOX	NOX
Locale:			
Effective Date:	N/A	N/A	N/A
Cost Year:	2008	2008	2008
CPT:	$6,266	$11,782	$22,003
Ref Yr CPT:	$6,762	$12,715	$23,746
Control Efficiency:	61	61	61
Min Emis:	100.0	50.0	25.0
Max Emis:	N/A	100.0	50.0
Rule Effectiveness:	100.0	100.0	100.0
Rule Penetration:	100.0	100.0	100.0
Equation Type:	Type 13	Type 13	Type 13
Cap Ann Ratio:	N/A	N/A	N/A
Details:			
Existing Measure:			
Existing NEI Dev:	0	0	0

Cost Equations:

Name: Type 13

Description: ICI Boiler Cost Equations

Inventory Fields: design_capacity, design_capacity_unit_numerator, design_capacity_unit_denominator, stack_flow_rate, stack_velocity, stack_diameter

Formula: Capital Cost = var1*input1^var2+var3*input1^var4
O&M Cost = var5+var6*input1^var7+var8*input1^var9+var10*input3+var11*input2

where

input1 = boiler size in MMBtu/hr
input2 = boiler emissions in ton/yr
input3 = boiler exhaust flowrate in ft3/sec
var1 = Capital cost size multiplier No.1
var2 = Capital cost exponent No. 1
var3 = Capital cost size multiplier No.2
var4 = Capital cost exponent No. 2
var5 = O&M known costs
var6 = O&M cost size multiplier No.1
var7 = O&M cost size exponent No. 1
var8 = O&M cost size multiplier No. 2
var9 = O&M cost size exponent No. 2
var10 = O&M cost flowrate multiplier
var11 = O&M cost emissions multiplier

Variable Name	Value
Pollutant	NOX
Cost Year	2008
Capital Cost Size Multiplier No. 1	5460.27
Capital Cost Exponent No. 1	0.65
Capital Cost Size Multiplier No. 2	86330.02
Capital Cost Exponent No. 2	0.228
O&M Known Costs	389766.8
O&M Cost Size Multiplier No. 1	218.4
O&M Cost Exponent No. 1	0.65
O&M Cost Size Multiplier No. 2	3453.2
O&M Cost Exponent No. 2	0.228
O&M Flowrate Multiplier	19.3
O&M Emissions Multiplier	0

Affected SCCs:

Code	Description
10200601	External Combustion Boilers; Industrial; Natural Gas; > 100 Million BTU/hr
10200602	External Combustion Boilers; Industrial; Natural Gas; 10-100 Million BTU/hr
10200603	External Combustion Boilers; Industrial; Natural Gas; < 10 Million BTU/hr
10200604	External Combustion Boilers; Industrial; Natural Gas; Cogeneration
10200701	External Combustion Boilers; Industrial; Process Gas; Petroleum Refinery Gas

10200704	External Combustion Boilers; Industrial; Process Gas; Blast Furnace Gas
10200707	External Combustion Boilers; Industrial; Process Gas; Coke Oven Gas
10200710	External Combustion Boilers; Industrial; Process Gas; Cogeneration
10200799	External Combustion Boilers; Industrial; Process Gas; Other: Specify in Comments
10201001	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Butane
10201002	External Combustion Boilers; Industrial; Liquified Petroleum Gas (LPG); Propane
10201401	External Combustion Boilers; Industrial; CO Boiler; Natural Gas
10201402	External Combustion Boilers; Industrial; CO Boiler; Process Gas
10300601	External Combustion Boilers; Commercial/Institutional; Natural Gas; > 100 Million BTU/hr
10300602	External Combustion Boilers; Commercial/Institutional; Natural Gas; 10-100 Million BTU/hr
10300603	External Combustion Boilers; Commercial/Institutional; Natural Gas; < 10 Million BTU/hr
10300701	External Combustion Boilers; Commercial/Institutional; Process Gas; POTW Digester Gas-fired Boiler
10300799	External Combustion Boilers; Commercial/Institutional; Process Gas; Other Not Classified
10300811	External Combustion Boilers; Commercial/Institutional; Landfill Gas; Landfill Gas
10301001	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Butane
10301002	External Combustion Boilers; Commercial/Institutional; Liquified Petroleum Gas (LPG); Propane
30600203	The SCC entry is not found in the reference.scc table
30600204	The SCC entry is not found in the reference.scc table

References:

- Bodnarik, Andy. September 29, 2011. Personal Communication with Andy Bodnarik of Ozone Transport Commission to Bryan Lange of ERG.
- MACTEC Engineering and Consulting, Inc. March 30, 2005. Midwest Regional Planning Organization - Boiler Best Available Retrofit Technology Engineering Analysis
- Ozone Transport Commission & Lake Michigan Air Directors Consortium. May 25, 2010. Draft - Evaluation of Control Options for Industrial, Commercial and Institutional Boilers, Technical Support Document.
- Northeast States for Coordinated Air Use Management. November 2008 (revised January 2009). Applicability and Feasibility of NOx, SO2, and PM Emissions Control Technologies for Industrial, Commercial, and Institutional Boilers.
- EPA, 2018: U.S. EPA, Control Strategy Tool Cost Equations Document
- ERG, 2010: Evaluation and Development of NOx Control Technologies Cost Equations for Industrial/Commercial/Institutional Boilers
- EPA, 2000: U.S. Environmental Protection Agency, Office of Research and Development, "Coal Utility Environmental Cost (CUECost) Version 3.0" [computer program], February 2000.

Other information:

CE_NOTES: CE is midpoint of potential control efficiency (50-72) noted in MACTEC 2005b

COST_BASIS:	The original cost information was from model plant data in the Alternative Control Techniques (ACT) Document -- NOx Emissions from Industrial/Commercial/Institutional Boilers (EPA, 1994d). Appendices D and E of ICI boiler ACT Document have detailed tables of scaled cost-effectivness numbers and cost-effectivness numbers for retrofit controls.
CPT_NOTES:	Median CE for LNB+FGR on gas fuel type sources in relevant emissions range in Equation 13 - CMDB Changes - Measures with No Default CPT - FINAL 2017_04_06.docx (Table 5)
EFFICIENCY_TABLE_NOTES:	Threshold should be in terms of capacity but is in terms of minemiss/maxemiss because we will have emissions data for ICI boilers, but will not always have capacity data.
EQUATION_NOTES:	Equation parameters from ERG 2010 (Table 4 and Table 7A)

Attachment 11 – RACT Cost Spreadsheet for FGR (Boiler)

RACT Cost Estimate - FGR Boiler

COST COMPONENT		COST	REFERENCE
DIRECT COSTS			
Purchased Equipment Costs			
Equipment		89,642	Calculated from TCI
Sales Tax (7% of purchased equipment costs)		6,275	Indiana sales tax
TOTAL DIRECT COSTS (TDC)		95,917	
INDIRECT INSTALLATION COSTS			
Engineering Costs (5% of PEC)		4,796	Estimate
Contingency (20% of TDC)		19,183	Estimate
TOTAL INDIRECT COSTS		23,979	
$86,330.02	Capital Cost Multiplier ($/mmBtu)	**86,332**	1
0.228	Capital Cost Exponent	**119,896**	
33.5	Heat Input (mmBtu/hr)		
799.1	CEPCI 2024		2
575.4	CEPCI 2008		2
TOTAL CAPITAL INVESTMENT (TCI)		**119,896**	1
Total O&M Cost		**286,579**	1 - Equation 48
$3,453.20	O&M Cost Multiplier ($/mmBtu)		
0.228	O&M Cost Exponent		
$194,883	O&M Cost Constant		
$19.30	O&M Emissions Cost Multiplier ($/acfm)		
11,754	acfm		
Annual O&M Cost		**286,579**	1
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)			
15	Equipment Life (years)		1
8.5%	Interest Rate (%)		3
Capital Recovery Factor		0.1204	
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		**119,896**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT		**14,438**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**		**301,017**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER		**5.75**	
TONS OF NOx REMOVED PER YEAR		**3.51**	
Assuming 61% Removal			1
COST-EFFECTIVENESS			
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING **($ per ton of NOx removed)**		**85,821**	1

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[2] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

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Attachment 12 – RACT Cost Spreadsheet for LNBs and FGR (Boiler)

RACT Cost Estimate - LNBs + FGR

COST COMPONENT		COST	REFERENCE
DIRECT COSTS			
Purchased Equipment Costs			
	Equipment	649,623	Vendor Estimate for LNB and 1 for FGR
	Sales Tax (7% of purchased equipment costs)	45,474	Indiana sales tax
TOTAL DIRECT COSTS (TDC)		695,096	
INDIRECT INSTALLATION COSTS			
	Engineering Costs (5% of PEC)	34,755	Estimate
	Contingency (20% of TDC)	139,019	Estimate
TOTAL INDIRECT COSTS		173,774	
For FGR			
$86,330.02	Capital Cost Multiplier ($/mmBtu)	**192,253**	1
0.228	Capital Cost Exponent	**266,995**	
33.5	Heat Input (mmBtu/hr)		
799.1	CEPCI 2024		2
575.4	CEPCI 2008		2
TOTAL CAPITAL INVESTMENT (TCI)		**868,870**	1
Total O&M Cost		**560,201**	1 - Equation 48
$218.40	O&M Cost Multiplier LNBs ($/mmBtu)		
0.65	O&M Cost Exponent LNBs		
$3,453.20	O&M Cost Multiplier FGR ($/mmBtu)		
0.228	O&M Cost Exponent FGR		
$389,767	O&M Cost Constant		
$19.30	O&M Emissions Cost Multiplier ($/acfm)		
11,754	acfm		
Annual O&M Cost		**560,201**	1
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)			
15	Equipment Life (years)		1
8.5%	Interest Rate (%)		3
	Capital Recovery Factor	0.1204	
CAPITAL RECOVERY COSTS			
	TOTAL CAPITAL REQUIREMENT	**868,870**	
	TOTAL ANNUALIZED CAPITAL REQUIREMENT	**104,630**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)		**664,831**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER		**5.75**	
TONS OF NOx REMOVED PER YEAR		**3.51**	
Assuming 61% Removal			1
COST-EFFECTIVENESS			
	ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING ($ per ton of NOx removed)	**189,545**	1

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[2] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.
[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 13 – RACT Cost Spreadsheet for SNCR (Boiler)

RACT Cost Estimate -SNCR Boiler

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
SNCR	367,818	1 - Equation 1.36
ELEVF 1.02		1 - Equation 1.22
Sales Tax (7% of purchased equipment costs)	25,747	Indiana sales tax
Subtotal-Purchased Equipment Costs (PEC)	393,566	
Balance of Plant Costs	455,407	1 - Equation 1.37
NPHR 8.2 mmBtu/MW		
QB 33.5 mmBtu/hr		
NOx Removed 0.5 lb/hr		
CEPCI 2016 541.7		3
CEPCI 2024 799.1		3
TOTAL INDIRECT COSTS	254,692	Calculated from TCI
TOTAL CAPITAL INVESTMENT (TCI)	**1,103,664**	1 - Equation 1.35
DIRECT ANNUAL COSTS		
Maintenance Materials and Labor (1.5% of TCI)	16,555	1 - Equation 1.39
Reagent Cost	15,316	1 - Equation 1.40
qsol 0.5 gal/hr		1 - Equation 1.20
reag cost $2.45 $/gal		
t op 8,760 hr/yr		
Power	5,900	1 - Equation 1.42
Consumption 0.20 kW		1 - Equation 1.43
Cost $0.0676 $/kWh		
Water	119	1 - Equation 1.46
q water 2.2		1 - Equation 1.44
Water Cost $0.0042 $/gal		
Fuel	690	1 - Equation 1.49
Delta Fuel 0.019 mmBtu/hr		1 - Equation 1.47
Fuel Cost $2.87 $/mmBtu		
TOTAL DIRECT ANNUAL COSTS	38,580	
Administrative $497 (3% of Maintenance Cost)	497	1 - Equation 1.52
TOTAL INDIRECT ANNUAL COSTS	497	1 - Equation 2.54
TOTAL ANNUAL COSTS	**39,077**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		1
8.5% Interest Rate (%)		2
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**1,103,664**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**116,625**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	**155,702**	
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**5.75**	
TONS OF NOx REMOVED PER YEAR	**2.01**	
Assuming 35% Removal		4
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA COST CONTROL MANUAL ($ per ton of NOx removed)	**77,368**	1

[1] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. Chapter 1 Selective Non-Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024

[2] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[3] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

Attachment 14 – RACT Cost Spreadsheet for SCR (Boiler)

RACT Cost - SCR Boiler

COST COMPONENT				COST	REFERENCE
DIRECT COSTS					
Purchased Equipment Costs					
	SCR			1,528,271	Calculated from TCI
	Sales Tax (7% of purchased equipment costs)			106,979	Indiana sales tax
Subtotal-Purchased Equipment Costs (PEC)				1,635,250	
Balance of Plant Costs (BoP)				864,947	1 - Equation 2.36
h_{scr}	57	ft			1 - Equation 2.31
$m_{reagent}$	1.0	lb/hr			1 - Equation 2.32
F(new)	0				
QB	33.5	mmBtu/hr			
$Vol_{catalyst}$	190.8	cuft			1 - Equation 2.19
TOTAL DIRECT COSTS (TDC)				2,500,197	
INDIRECT INSTALLATION COSTS					
	General Facilities (5% of TDC)			125,010	1 - Table 2.5
	Engineering and Home Office Fees (10% of TDC)			250,020	1 - Table 2.5
	Contingency (5% of TDC)			125,010	1 - Table 2.5
PROJECT CONTINGENCY					
	Contingency (15% of TDC)			450,035	1 - Table 2.5
	Preproduction Cost (2% of TDC)			50,004	1 - Table 2.5
TOTAL INDIRECT COSTS				1,000,079	
TCI					
ELEVF	1.02				2 - Equation 2.39a
RF	1.5	(design based on >205 mmBtu/hr unit, therefore high RF)			
CEPCI 2016	541.7				4
CEPCI 2024	799.1				4
TOTAL CAPITAL INVESTMENT (TCI)				**3,110,221**	2 - Equation 2.53
DIRECT ANNUAL COSTS					
Maintenance Materials and Labor (0.5% of TCI)				15,551	2 - Equation 2.57
Replacement Catalyst (24,000 hour Service Life - Reference 2)				149,141	2 - Equation 2.67
NRF	1.13	mmBtu/MW			
$cc_{replacement}$	$290	$/cuft			
Reagent Cost				11,584	2 - Equation 2.58
qsol	0.5	gal/hr			2 - Equations 2.35 - 2.37
reag cost	$2.45	$/gal			
t op	8,760	hr/yr			
Power				10,201	2 - Equation 2.62
Consumption	17.23	kW			2 - Equation 2.60
Cost	$0.0676	$/kWh			
t op	8,760	hr/yr			
Catalyst Disposal (Estimated as 6% of TCI, Amortized Over 3 Year Period)				38,412	2
$	98,115	* Capital Recovery Factor (0.3915 for n = 3 & i = 8.5%)			3
TOTAL DIRECT ANNUAL COSTS				224,888	
Administrative				8,848	2 - Equation 2.69
Operating Days	365	days/yr			
Operator Time	4	hr/day			
Operator Rate	$60	$/hr			
TOTAL INDIRECT ANNUAL COSTS				8,848	2 - Equation 2.54
TOTAL ANNUAL COSTS				**233,737**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)					
	20	Equipment Life (years)			2
	8.5%	Interest Rate (%)			3
	Capital Recovery Factor			0.1057	
CAPITAL RECOVERY COSTS					
	TOTAL CAPITAL REQUIREMENT			**3,110,221**	
	TOTAL ANNUALIZED CAPITAL REQUIREMENT			**328,660**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)				**562,397**	2
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE				**5.75**	
TONS OF NOx REMOVED PER YEAR				**5.18**	
Assuming	90%	Removal			2
COST-EFFECTIVENESS					
	ENVIRONMENTAL BASIS EPA Nox EMISSIONS FROM GLASS MANUFACTURING ($ per ton of NOx removed)			**108,676**	2, 4, 5

[1] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[2] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2019. Chapter 2 Selective Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[4] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[5] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

PROtect[SM]

September 10, 2024

Indiana Department of Environmental Management
Office of Air Quality, Programs Branch
100 North Senate Avenue, IGCN 1003
Indianapolis, IN 46204-2251

RE: Reasonably Available Control Technology (RACT) Response to Comments

To Whom It May Concern,

PROtect, LLC (PROtect) is writing on behalf of W. R. Grace & Co. ("Grace" or "the Company") regarding the sodium silicate manufacturing facility located in Lake County at 5215 Kennedy Ave, East Chicago, Indiana. Attached is Grace's response to the Indiana Department of Environmental Management's (IDEM) comments.

Please contact me at (920) 621-8293 if you have any questions regarding this analysis.

Sincerely,

Mitch Lagerstrom

Mitch Lagerstrom
Director of Environmental Services
PROtect, LLC

RESPONSES TO IDEM COMMENTS ON RACT REVIEW

Following are Grace's responses to IDEM comments on the case-by-case RACT analysis.

Potential to Emit Comment

1. The review's Background states the sodium silicate furnace (EU-01) has a NOx Potential to Emit of 141.1 tons per year. This is the value used in recently issued air permits. However, the actual NOx emission rate demonstrated by the furnace indicates this Potential to Emit value is erroneously low.

   The PTE based on the 2003 stack test was first calculated by W. R. Grace to be 202.19 tons/yr, and was shown as 211.3 tons/yr in the initial Title V permit T089-19927-00310 and in the first TV Renewal application. Please see Virtual File Cabinet (VFC) document 39353104 page 13, and VFC document 65291090 pages 70 and 71. As I noted in an April email, I have found no explanation for the change in PTE calculations used in the TV Renewals. Unfortunately, I also did not find IDEM OAQ's full PTE calculations for the furnace included in the initial TV Technical Support Document, just the PTE Summary tables, so I don't know how the 211.3 tons/year was determined.

   Using the demonstrated NOx emission factor for the furnace, 1,929.47 lbs/MMCF, and the permitted capacity, I calculate the **PTE** to be **201.2 tons/year**.

   (25 MMBtu/hr) x (1 CF/1050 Btu) x (1,929.427 lbs/MMCF) x (8,760 hrs/yr) x (1 ton/2,000 lbs)

Response

Grace agrees that the PTE included in recent permits is too low, but believes that the correct PTE should not be based on a stack test result without factoring in adequate compliance margin.

Past Actual Emissions Comment

2. The average actual emissions value used for the sodium silicate furnace control cost analysis is 139.54 tons/year. This is the average of the annual emissions reported for the furnace for 2021 and 2022. However, as Ms. Kendall and I discussed in April, although the emissions statements show the NOx emission factor is taken from the stack test, dividing the reported tons of NOx by the reported natural gas throughput results in inconsistent lb/MMCF values from year to year.

Further examination of the annual emissions statements shows that the same NOx emissions have been reported for the furnace for multiple years, even though the gas usage has varied. I have prepared a table with the Reported NOx Emissions and gas throughput values available in the VFC, and included a Calculated NOx Emissions value for each year based on the reported gas values and the 2003 stack test result. Please see the last page of these comments for the table.

The repeated use of the same annual NOx emissions values despite the variance in the gas usage casts doubt on the validity of the reported NOx values. If the Calculated NOx Emissions values are used, the **average actual or baseline emissions result for 2021 and 2022 is 153.87 tons/year**.

Response

Grace agrees with IDEM's comment, the cost effectiveness calculations were revised to include the correct baseline NO_X emissions of 153.87 tons/year. The revised cost effectiveness calculations are attached to this response.

<u>SNCR Control Efficiency Comment</u>

3. In the Table 4 footnote, the RACT submittal says EPA's 1994 *"Alternative Control Techniques Document – NOx Emissions from Glass Manufacturing"* provides a control efficiency range of 30-40% for SNCR, and 35% was chosen for the current review. Footnote 14 on the same page of the submittal specifically references page 6-8 of that ACT document. However, the ACT page 6-8 Table 6-8 and Table 6-9 footnotes regarding "Two actual installations at 40 and 30 percent control, respectively" appear to be relevant to only the 750 tons/day plant size lines of those tables.

   The 1994 ACT (Table 2-2 NOx Emission Reductions for Various Technologies) and the 2023 EPA Final Non-EGU Sectors TSD Revised (Table 5.B: List of NOx Controls Available for Glass Manufacturing Furnaces) both show **40%** as the SNCR Control Efficiency for glass furnaces.
   https://www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf
   https://www.epa.gov/system/files/documents/2023-03/Final%20Non-EGU%20Sectors%20TSD.pdf

   Therefore, please provide additional documentation to support the use of 35% control efficiency for SNCR or revise the SNCR control efficiency in the RACT submittal to 40% to be consistent with the SNCR Control Efficiency for glass furnaces in the EPA documents.

Response

Urea-based SNCR installations are more common than ammonia-based systems. Even though ammonia-based systems are more effective at reducing NO_X emissions, urea has other advantages over ammonia as it is nontoxic and less volatile than ammonia[1] ("Although installation of urea-based systems is more common than ammonia-based deployments, operating data reveal higher NO_X reductions occur with ammonia reagent."[2])

EPA has further documented that the boiler/furnace size is less important for control efficiency than the reagent used. ("[N]early all ammonia-based systems have reduction efficiencies greater than 40 percent, while several urea-based systems have lower reduction efficiencies.[3] […] [E]fficiencies for utility boilers range from 20 percent to over 60 percent with most between 20 percent and 35 percent. […] [E]fficiencies for the larger utility boilers are comparable to those for smaller utility boilers."[4]) Companies chose to use urea as a reagent instead of ammonia in part due to the toxicity of ammonia and the requirements to develop a program compliant with 29 CFR §1910.119 (Process Safety Management of Highly Hazardous Chemicals) and/or 40 CFR Part 68 (Chemical Accident Prevention Provisions) for Extremely Hazardous Substances (EHS).

If a company chooses to utilize ammonia in a concentration (<20%) and/or quantity (<10,000 lbs) that is below the thresholds in the OSHA and EPA regulations, they are still required to develop a program under §112(r)(1) of the Clean Air Act (CAA) also known as the General Duty Clause (GDC). EHS are not defined in the CAA; however, the Senate Report for the CAA amendments notes that the CAA GDC applies to any chemical where, "[…] short-term exposures associated with releases to the air cause death, injury or property damage due to its toxicity, reactivity, flammability, volatility, or corrosivity."[5] Note that the CAA does not contain concentration or quantity thresholds for chemicals that meet these criteria. Anhydrous and commercially available concentrations of aqueous ammonia (19% and 29%) are toxic, flammable (at concentrations of 16-25% in the air), corrosive (to skin, eyes, and respiratory system), and volatile.[6]

Therefore, Grace believes that using 35% control efficiency is appropriate for a urea-based SNCR control system. It would be appropriate to use 40% control efficiency for an ammonia-based system, but as EPA noted, "[…] urea-based systems have lower reduction efficiencies". The Company would choose to use urea instead of ammonia as the reagent for a SNCR to limit employee exposure to a toxic chemical and to avoid the requirement to develop a program under

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[1] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. Chapter 1 Selective Non-Catalytic Reduction. 2019. At 1-13. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 20 August 2024.
[2] Ibid, 1-1.
[3] Ibid, 1-1.
[4] Ibid, 1-4.
[5] Senate Committee on Environment and Public Works, Clean Air Act Amendments of 1989, Senate Report No. 228, 101st Congress, 1st Session 211 (1989) - "Senate Report".
[6] *Lsbindustries.com*, 2024, lsbindustries.com/wp-content/uploads/2020/11/Aqua-Ammonia-5-19.9.pdf. Accessed 21 Aug. 2024.

29 CFR §1910.119 (Process Safety Management of Highly Hazardous Chemicals), 40 CFR Part 68 (Chemical Accident Prevention Provisions), and/or §112(r)(1) of the CAA.

Indiana State Sales Tax Comment

4. Based on the Indiana Department of Revenue's rule 45 IAC 2.2-5-70 Environmental Quality Control Equipment, and consultation with the OAQ Permits Branch Chief, Jenny Acker, I believe the 7.5% state tax should be removed from the control cost calculations. (Indiana Administrative Code | Rule 45 IAC 2.2-5 - Exempt Transactions of a Retail Merchant | Casetext)

   "Sec. 70. (a) The state gross retail tax does not apply to sales of tangible personal property which constitutes, is incorporated into, or is consumed in the operation of, a device, facility, or structure predominately used and acquired for the purpose of complying with any state, local or federal environmental qaulity [sic.] statutes, regulations or standards; and the person acquiring the property is engaged in the business of manufacturing, processing, refining, mining, or agriculture.

Response

Grace agrees with IDEM's position that state sales tax does not apply to the purchase and installation of air pollution control technology. However, the calculation methodology directly calculates the Total Capital Investment (TCI) and then back calculated the purchased equipment cost, state tax, and other values. As a result, removing the state income tax increases the purchased equipment cost to arrive at the calculated TCI and does not change the cost effectiveness of the control.

Production Days

IDEM has indicated that RACT should be based on production time instead of the number of days the furnace was firing natural gas. Grace had reviewed past operations and determined that the furnace was producing sodium silicate 361 days in 2022 and 351 days in 2021. The Company noticed that the production rates for 2021 and 2022 were incorrect, both have been revised to reflect the correct production rates. These changes are summarized in Table 1,

Table 1: Sodium Silicate Production

Year	Sodium Silicate Production (tons/yr)	Days of Operation	Daily Production (tons/day)	NO_X Emissions (lb/day)
2021	28,835	351	82.15	883.5
2022	29,379	361	81.38	844.4

Catalytic Ceramic Filter System (CCF)

IDEM has request review of a multi-pollutant control technology that has been employed at other sodium silicate furnaces. CCF is a dry system for simultaneously controlling multiple pollutants, including PM, SO_X, and NO_X. CCFs are embedded with nanobits of NO_X catalyst dispersed within the filter walls. Vendors of the CCF technology like Tri-Mer have guaranteed NO_X reductions of 80%. Similar to Selective Catalytic Reduction (SCR) operation the technology requires injection of ammonia upstream of the catalyst.

IDEM has provided cost estimates from the South Coast Air Quality Management District (SCAQMD) for a sodium silicate furnace in Southern California. This provides a basis to estimate capital costs associated with this technology. In order to establish a cost estimate for Grace's furnace the manufacturer (Tri-Mer) was contacted. The vendor indicated the size of the system is dependent upon the exhaust flow rate and the influent NO_X concentration. The unit in Southern California is larger than the furnace in East Chicago, but the influent exhaust NO_X concentration is much lower. Therefore, Grace does not have a basis to revise the capital cost estimate and Tri-Mer indicated there is no straightforward way to quickly estimate capital costs.

Tri-Mer provided additional clarity for both capital and operational cost assumptions used for the furnace in Southern California. Additionally, EPA estimation techniques for SCR operation were also utilized to estimate operating costs for items like reagent usage, which is based on stoichiometry rather than catalyst technology, and electrical consumption. The following is a summary of substantive changes from the SCAQMD cost analysis and calculations shown for items that result in significant annual cost; specifically filter replacement and reagent usage.

Equipment Life

SCAQMD utilized a 20-year equipment life to annualize capital costs. Tri-Mer indicated that none of its installations of CCF have been in operation for 20 years and that they would utilize a 20-year equipment life as a basis to annualize the capital cost. Therefore, a 20-year equipment life was utilized for this analysis instead of 25-years.

Filter Replacement Frequency and Cost

Tri-Mer indicated that the individual filters are guaranteed for one year of operation, but that it would be appropriate to assume replacement every two years. Individual filters are $500 each, the unit in Southern California has 800 filters installed, the cost to replace these filters every two years is,

$$\frac{\$500}{Filter} \times 800\ Filters = \$400{,}000$$

The annualized cost assumes replacement every two years at the prime bank loan rate of 8.5%, providing a capital recovery factor of 0.5646,

$$\$400{,}000 \times 0.5646 = \$225{,}840\ per\ year$$

Disposal Costs

Tri-Mer stated that the filters cannot be reused/refurbished, are hazardous waste, and are ten feet long. The filters will not fit within standard shipping containers like a drum, requiring special packaging and handling. Therefore, additional costs are incurred every two years to dispose of the filters, similar to SCR catalysts. Through experience with SCR disposal costs, these costs are substantial and can represent approximately 5% of the purchased equipment cost.

Reagent Costs

Reagent cost was found to be the most significant portion of annual operating costs. Using equation 2.58 of EPA's Cost Control Manual for an SCR the ammonia injection rate of 19% aqueous ammonia,

$$\frac{1.86779\frac{lb}{mmBtu} \times 25\frac{mmBtu}{hr} \times 80\% \times 1.05 \times 17.03\frac{lb\ NH_3}{lbmol}}{46.01\frac{lb\ NO_2}{lbmol} \times 19\%\ NH_3} = 76.4\ \frac{lb\ NH_3}{hr}$$

The cost for 19% aqueous ammonia was calculated from a 2018 bid received by the City of High Point, North Carolina.[7] This bid shows the cost to be $1,100 per ton of aqueous ammonia, or $0.55 per pound. Accounting for inflation increases this value to $0.73 per pound in 2024 dollars. Using the calculated injection rate and cost per pound, annual reagent costs would be,

$$76.4\ \frac{lb\ NH_3}{hr} \times \$0.73\ \frac{NH_3}{lb} \times 8{,}760\ \frac{hr}{yr} = \$487{,}792\ per\ year$$

Table 2 incorporates the CCF technology. The spreadsheet calculation is included in Attachment 15.

Table 2: Costs and Cost Effectiveness of NO_X RACT Controls for Sodium Silicate Furnace

NO_X Emission Control	TCI	TAC ($/yr)	NO_X Reduction (ton NOx/yr)	Cost Effectiveness ($/ton NO_X Removed)
LNBs	$723,565	$334,287	61.5	$5,431
SNCR	$845,394	$354,631	53.9	$6,585
CCF	$2,850,469	$1,103,466	123.1	$8,963
Oxy-Firing	$5,272,603	$1,930,589	130.8	$14,761
SCR + Baghouse	$2,277,148	$2,339,786	115.4	$60,282
SCR + ESP	$5,038,301	$7,029,277	115.4	$250,292

Table 3 summarizes the results of the changes summarized in this response for the Natural Gas Fired Boilers.

Table 3: Costs and Cost Effectiveness of NO_X RACT Controls for Natural Gas Fired Boilers

NO_X Emission Control	TCI	TAC ($/yr)	NO_X Reduction (ton NOx/yr)	Cost Effectiveness ($/ton NO_X Removed)
SNCR	$1,070,193	$163,026	2.01	$81,007
FGR	$119,896	$301,017	3.51	$85,821
LNBs	$562,500	$341,358	3.51	$97,322
SCR	$3,110,221	$588,485	5.18	$113,717
LNBs + FGR	$812,028	$657,986	3.51	$187,594

[7] Invitation to bid: https://www.highpointnc.gov/DocumentCenter/View/9559/ITB4036-022718-Ammonia-Hydroxide
Bid response: https://www.highpointnc.gov/DocumentCenter/View/9762/BT4036-022718?bidId=

RACT

Grace proposes to install LNBs on the sodium silicate furnace to meet RACT. LNBs can be installed by June 2026, within 20 months from now. Grace believes it is reasonable to establish a RACT limit after securing a vendor guaranteed NO_X emission rate. The Company will continue to communicate with IDEM throughout the procurement process, providing updates on the installation timeline and vendor guarantees.

Attachment 1 – RACT Cost Spreadsheet LNBs (Furnace)

RACT Cost - LNB

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment	578,852	Calculated from TCI
TOTAL DIRECT COSTS (TDC)	578,852	
INDIRECT INSTALLATION COSTS		
Engineering Costs (5% of PEC)	28,943	Calculated from TCI
Contingency (20% of TDC)	115,770	Calculated from TCI
TOTAL INDIRECT COSTS	144,713	
TOTAL CAPITAL INVESTMENT (TCI)	**723,565**	1
Annual O&M Cost	**50,983**	Calculated from TAC
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
3 Equipment Life (years)		1
8.5% Interest Rate (%)		2
Capital Recovery Factor	0.3915	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**723,565**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**283,304**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**	**334,287**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**153.9**	
TONS OF NOx REMOVED PER YEAR	**61.5**	
Assuming 40% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING **($ per ton of NOx removed)**	**5,431**	1, 3, 4

[1] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[2] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[3] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 2 – RACT Cost Spreadsheet Oxy-Firing (Furnace)

RACT Cost - Oxy-Firing

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment	4,218,082	Calculated from TCI
Subtotal-Purchased Equipment Costs (PEC)	4,218,082	
TOTAL DIRECT COSTS (TDC)	**4,218,082**	Calculated from TCI
INDIRECT INSTALLATION COSTS		
Engineering Costs (5% of PEC)	210,904	Calculated from TCI
Contingency (20% of TDC)	843,616	Calculated from TCI
TOTAL INDIRECT COSTS	1,054,521	
TOTAL CAPITAL INVESTMENT (TCI)	**5,272,603**	1 - Table 6-3
36.23 $/ton Glass		Calculated from TAC
85.2 tons/day of Glass		
365 Annual operating days	1,127,004	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
10 Equipment Life (years)		2
8.5% Interest Rate (%)		3
Capital Recovery Factor	0.1524	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**5,272,603**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**803,585**	
TOTAL ANNUALIZED COST (TAC) **(Total annual O&M cost and annualized capital cost)**	**1,930,589**	1 - Table 6-3
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**153.9**	
TONS OF NOx REMOVED PER YEAR	**130.8**	
Assuming 85% Removal		1 - Table 6-3
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS		
($ per ton of NOx removed)	**14,761**	1, 4, 5

[1] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[2] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[2a] Oxygen Enriched Air Staging a Cost-effective Method For Reducing NOx Emissions. Industrial Technologies. April 2002. Available at: http://www1.eere.energy.gov/manufacturing/resources/glass/pdfs/airstaging.pdf

[2b] Saint-Gobain Containers Inc. Clean Air Act Settlement (https://www.epa.gov/enforcement/saintgobain-containers-inc-clean-air-act-settlement) required the installation of OEAS on glassfurnaces

[2b] Owens-Brockway Glass Container Inc. Clean Air Act Settlement (https://www.epa.gov/enforcement/owens-brockway-glass-container-inc-settlement) required the installation of OEAS on glass furnaces.

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[4] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[5] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 3 – RACT Cost Spreadsheet SNCR (Furnace)

RACT Cost - SNCR

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
SNCR	575,098	Calculated from TCI
Subtotal-Purchased Equipment Costs (PEC)	575,098	
INDIRECT INSTALLATION COSTS		
Engineering, Construction Management, Installation, Labor, and Contractors	172,529	Calculated from TCI
Project Contingency (15% of TDC)	86,265	Calculated from TCI
Preproduction Cost (2% of TDC)	11,502	Calculated from TCI
TOTAL INDIRECT COSTS	270,296	
TOTAL CAPITAL INVESTMENT (TCI)	**845,394**	1
TOTAL ANNUAL DIRECT AND INDIRECT COSTS	265,297	Calculated from TAC
TOTAL ANNUAL COSTS	**265,297**	Calculated from TAC
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		2
8.5% Interest Rate (%)		3
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**845,394**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**89,334**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**	**354,631**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**153.9**	
TONS OF NOx REMOVED PER YEAR	**53.9**	
Assuming 35% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING **($ per ton of Nox removed)**	**6,585**	1, 4, 5

[1] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994.
US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[2] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[4] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[5] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 4 – RACT Cost Spreadsheet SCR (Furnace)

RACT Cost - SCR

COST COMPONENT			COST	REFERENCE
DIRECT COSTS				
Purchased Equipment Costs				
SCR			544,384	Calculated from TCI
Subtotal-Purchased Equipment Costs (PEC)			544,384	
Balance of Plant Costs (BoP)			486,528	1 - Equation 2.36
h_{scr}	57	ft		
$m_{reagent}$	13.6	lb/hr		
F(new)	0			
QB	25	mmBtu/hr		
$Vol_{catalyst}$	142.4	cuft		
TOTAL DIRECT COSTS (TDC)			1,030,912	
INDIRECT INSTALLATION COSTS				
General Facilities (5% of TDC)			51,546	1 - Table 2.5
Engineering and Home Office Fees (10% of TDC)			103,091	1 - Table 2.5
Contingency (5% of TDC)			51,546	1 - Table 2.5
PROJECT CONTINGENCY				
Contingency (15% of TDC)			185,564	1 - Table 2.5
Preproduction Cost (2% of TDC)			20,618	1 - Table 2.5
Inventory Capital				
TOTAL INDIRECT COSTS			412,365	
TOTAL CAPITAL INVESTMENT (TCI)			**1,443,277**	2
DIRECT AND INDIRECT ANNUAL COSTS			843,431	Calculated from TAC
TOTAL ANNUAL COSTS			**843,431**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)				
	20	Equipment Life (years)		3
	8.5%	Interest Rate (%)		4
Capital Recovery Factor			0.1057	
CAPITAL RECOVERY COSTS				
TOTAL CAPITAL REQUIREMENT			**1,443,277**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT			**152,512**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)			**995,943**	2
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE			**153.9**	
TONS OF NOx REMOVED PER YEAR			**115.4**	
Assuming	75%	Removal		3
COST-EFFECTIVENESS				
ENVIRONMENTAL BASIS EPA Nox EMISSIONS FROM GLASS MANUFACTURING ($ per ton of NOx removed)			**8,630**	2, 5, 6

[1] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[2] EPA, 1994: U.S. Environmental Protection Agency, Emissions Standard Division, Office of Air Quality Planning and Standards, "Alternative Control Techniques Document-- NOx Emissions from Glass Manufacturing," EPA,-453/R-94-037, Research Triangle Park, NC, June 1994. US EPA, www3.epa.gov/airquality/ctg_act/199406_nox_epa453_r-94-037_glass_manufacturing.pdf. Accessed 9 July 2024.

[3] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2019. Chapter 2 Selective Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024

[4] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[5] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[6] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

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Attachment 5 – RACT Cost Spreadsheet ESP (Furnace)

RACT Cost - ESP

COST COMPONENT	COST	REFERENCE	
DIRECT COSTS			
Purchased Equipment Costs			
Equipment Cost	1,289,648	Calculated from TCI	
Instrumentation (10% of equipment cost)	128,965	2 - Table 3.16	
Freight (5% of equipment costs)	51,586	2 - Table 3.16	
Subtotal-Purchased Equipment Costs (PEC)	1,470,199		
Direct Installation Costs			
Installation/Foundation (4% of PEC)	51,586	2 - Table 3.16	
Handling & Erection (50% of PEC)	644,824	2 - Table 3.16	
Electrical (8% of PEC)	103,172	2 - Table 3.16	
Piping (1% of PEC)	12,896	2 - Table 3.16	
Insulation and ductwork (2% of PEC)	25,793	2 - Table 3.16	
Painting (2% of PEC)	25,793	2 - Table 3.16	
Subtotal-Direct Installation Costs	864,064		
TOTAL DIRECT COSTS (TDC)	2,334,264		
INDIRECT INSTALLATION COSTS			
Engineering Costs (20% of PEC)	294,040	2 - Table 3.16	
Construction and field expenses (20% of PEC)	294,040	2 - Table 3.16	
Contractor fees (10% of PEC)	147,020	2 - Table 3.16	
Start-up (1% of PEC)	14,702	2 - Table 3.16	
Performance test (1% of PEC)	14,702	2 - Table 3.16	
Model study (2% of PEC)	29,404	2 - Table 3.16	
Contingency (3% of TDC)	466,853	2 - Table 3.16	
TOTAL INDIRECT COSTS	1,260,760		
TCI Calculations			
$90.30 Capital Cost Multiplier ($/acfm)		1	
28,084 acfm (stack test)		Stack Test	
$17,107 Capital Cost Constant		1	
799.1 CEPCI 2024		3	
567.5 CEPCI 2017		3	
3,595,024 TCI		1	
TOTAL CAPITAL INVESTMENT (TCI)	**3,595,024**	1 - Equation 35	5,038,301
DIRECT ANNUAL COSTS			
Total O&M Cost	**5,653,445**	1 - Equation 36	
$6.30 O&M Cost Multiplier ($/acfm)			
$3,838,000 O&M Cost Constant			
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)			
20 Equipment Life (years)		1	
8.5% Interest Rate (%)		4	
Capital Recovery Factor	0.1057		
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT	**3,595,024**		
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**379,890**		
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	**6,033,334**		7,029,277
BASELINE POTENTIAL PM-10 EMISSIONS (TPY) FROM GLASS FURNACE	**26.3**		
TONS OF PM-10 REMOVED PER YEAR	**25.0**		
Assuming 95% Removal		1	
COST-EFFECTIVENESS			
ENVIRONMENTAL BASIS			
($ per ton of PM-10 removed)	**241,662**	1, 3	250,292

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[1a] GDIT, 2019: General Dynamics Information Technology, "CoST PM25 Control Measures Report," prepared for U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, October 2019.

[2] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[3] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 6 – RACT Cost Spreadsheet for LNBs (Boiler)

RACT Cost Estimate - LNB Boiler

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
Equipment	450,000	Estimate from vendor
TOTAL DIRECT COSTS (TDC)	450,000	
INDIRECT INSTALLATION COSTS		
Engineering Costs (5% of TDC)	22,500	Estimate
Contingency (20% of TDC)	90,000	Estimate
TOTAL INDIRECT COSTS	112,500	
TOTAL CAPITAL INVESTMENT (TCI)	**562,500**	
Total O&M Cost	**273,622**	1 - Equation 48
$218.40 O&M Cost Multiplier LNBs ($/mmBtu)		
0.65 O&M Cost Exponent LNBs		
$194,883 O&M Cost Constant		
799.1 CEPCI 2024		2
575.4 CEPCI 2008		2
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
15 Equipment Life (years)		1
8.5% Interest Rate (%)		2
Capital Recovery Factor	0.1204	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**562,500**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**67,737**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	**341,358**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER	**5.75**	
TONS OF NOx REMOVED PER YEAR	**3.51**	
Assuming 61% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM BOILER ($ per ton of NOx removed)	**97,322**	1

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[2] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

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Attachment 7 – RACT Cost Spreadsheet for FGR (Boiler)

RACT Cost Estimate - FGR Boiler

COST COMPONENT		COST	REFERENCE
DIRECT COSTS			
Purchased Equipment Costs			
Equipment		89,642	Calculated from TCI
TOTAL DIRECT COSTS (TDC)		89,642	
INDIRECT INSTALLATION COSTS			
Engineering Costs (5% of PEC)		4,482	Estimate
Contingency (20% of TDC)		17,928	Estimate
TOTAL INDIRECT COSTS		22,410	
$86,330.02	Capital Cost Multiplier ($/mmBtu)	**86,332**	1
0.228	Capital Cost Exponent	**119,896**	
33.5	Heat Input (mmBtu/hr)		
799.1	CEPCI 2024		2
575.4	CEPCI 2008		2
TOTAL CAPITAL INVESTMENT (TCI)		**119,896**	1
Total O&M Cost		**286,579**	1 - Equation 48
$3,453.20	O&M Cost Multiplier ($/mmBtu)		
0.228	O&M Cost Exponent		
$194,883	O&M Cost Constant		
$19.30	O&M Emissions Cost Multiplier ($/acfm)		
11,754	acfm		
Annual O&M Cost		**286,579**	1
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)			
15	Equipment Life (years)		1
8.5%	Interest Rate (%)		3
Capital Recovery Factor		0.1204	
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		**119,896**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT		**14,438**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)		**301,017**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER		**5.75**	
TONS OF NOx REMOVED PER YEAR		**3.51**	
Assuming 61% Removal			1
COST-EFFECTIVENESS			
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM BOILER ($ per ton of NOx removed)		**85,821**	1

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

[2] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 8 – RACT Cost Spreadsheet for LNBs and FGR (Boiler)

RACT Cost Estimate - LNBs + FGR

COST COMPONENT		COST	REFERENCE
DIRECT COSTS			
Purchased Equipment Costs			
Equipment		649,623	Vendor Estimate for LNB and 1 for FGR
TOTAL DIRECT COSTS (TDC)		649,623	
INDIRECT INSTALLATION COSTS			
Engineering Costs (5% of PEC)		32,481	Estimate
Contingency (20% of TDC)		129,925	Estimate
TOTAL INDIRECT COSTS		162,406	
For FGR			
$86,330.02	Capital Cost Multiplier ($/mmBtu)	**192,253**	1
0.228	Capital Cost Exponent	**266,995**	
33.5	Heat Input (mmBtu/hr)		
799.1	CEPCI 2024		2
575.4	CEPCI 2008		2
TOTAL CAPITAL INVESTMENT (TCI)		**812,028**	1
Total O&M Cost		**560,201**	1 - Equation 48
$218.40	O&M Cost Multiplier LNBs ($/mmBtu)		
0.65	O&M Cost Exponent LNBs		
$3,453.20	O&M Cost Multiplier FGR ($/mmBtu)		
0.228	O&M Cost Exponent FGR		
$389,767	O&M Cost Constant		
$19.30	O&M Emissions Cost Multiplier ($/acfm)		
11,754	acfm		
Annual O&M Cost		**560,201**	1
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)			
15	Equipment Life (years)		1
8.5%	Interest Rate (%)		3
Capital Recovery Factor		0.1204	
CAPITAL RECOVERY COSTS			
TOTAL CAPITAL REQUIREMENT		**812,028**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT		**97,785**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)		**657,986**	1
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER		**5.75**	
TONS OF NOx REMOVED PER YEAR		**3.51**	
Assuming 61% Removal			1
COST-EFFECTIVENESS			
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM BOILER ($ per ton of NOx removed)		**187,594**	1

[1] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.
[2] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.
[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

Attachment 9 – RACT Cost Spreadsheet for SNCR (Boiler)

RACT Cost Estimate -SNCR Boiler

COST COMPONENT			COST	REFERENCE
DIRECT COSTS				
Purchased Equipment Costs				
	SNCR		367,818	1 - Equation 1.36
ELEVF	1.02			1 - Equation 1.22
Subtotal-Purchased Equipment Costs (PEC)			367,818	
Balance of Plant Costs			455,407	1 - Equation 1.37
NPHR	8.2	mmBtu/MW		
QB	33.5	mmBtu/hr		
NOx Removed	0.5	lb/hr		
CEPCI 2016	541.7			3
CEPCI 2024	799.1			3
TOTAL INDIRECT COSTS			246,968	Calculated from TCI
TOTAL CAPITAL INVESTMENT (TCI)			**1,070,193**	1 - Equation 1.35
DIRECT ANNUAL COSTS				
Maintenance Materials and Labor (1.5% of TCI)			16,053	1 - Equation 1.39
Reagent Cost			35,369	1 - Equation 1.40
qsol	0.5	gal/hr		1 - Equation 1.20
reag cost	$5.66	$/gal		
t op	8,760	hr/yr		
Power			5,900	1 - Equation 1.42
Consumption	0.20	kW		1 - Equation 1.43
Cost	$0.0676	$/kWh		
Water			119	1 - Equation 1.46
q water	2.2			1 - Equation 1.44
Water Cost	$0.0042	$/gal		
Fuel			690	1 - Equation 1.49
Delta Fuel	0.019	mmBtu/hr		1 - Equation 1.47
Fuel Cost	$2.87	$/mmBtu		
TOTAL DIRECT ANNUAL COSTS			58,131	
Administrative	$482	(3% of Maintenance Cost)	482	1 - Equation 1.52
TOTAL INDIRECT ANNUAL COSTS			482	1 - Equation 2.54
TOTAL ANNUAL COSTS			**58,613**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)				
	20	Equipment Life (years)		1
	8.5%	Interest Rate (%)		2
	Capital Recovery Factor		0.1057	
CAPITAL RECOVERY COSTS				
	TOTAL CAPITAL REQUIREMENT		**1,070,193**	
	TOTAL ANNUALIZED CAPITAL REQUIREMENT		**113,088**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**			**171,701**	
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM BOILER			**5.75**	
TONS OF NOx REMOVED PER YEAR			**2.01**	
Assuming	35%	Removal		4
COST-EFFECTIVENESS				
	ENVIRONMENTAL BASIS EPA COST CONTROL MANUAL **($ per ton of NOx removed)**		**85,317**	1

[1] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. Chapter 1 Selective Non-Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024

[2] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[3] Maxwell, Charles. "Cost Indices – Towering Skills." Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[4] Control Measure AT-A-GLANCE Report. Control Strategy Tool (CoST) Cost Equations Documentation. 7 Sept. 2023. https://www.epa.gov/system/files/documents/2023-10/control-strategy-tool-cost-cost-equations-documentation.pdf. Accessed July 8, 2024.

Attachment 10 – RACT Cost Spreadsheet for SCR (Boiler)

RACT Cost - SCR Boiler

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
SCR	1,356,640	Calculated from TCI
Subtotal-Purchased Equipment Costs (PEC)	1,356,640	
Balance of Plant Costs (BoP)	864,947	1 - Equation 2.36
h_{scr} 57 ft		1 - Equation 2.31
$m_{reagent}$ 1.0 lb/hr		1 - Equation 2.32
F(new) 0		
QB 33.5 mmBtu/hr		
$Vol_{catalyst}$ 190.8 cuft		1 - Equation 2.19
TOTAL DIRECT COSTS (TDC)	2,221,586	
INDIRECT INSTALLATION COSTS		
General Facilities (5% of TDC)	111,079	1 - Table 2.5
Engineering and Home Office Fees (10% of TDC)	222,159	1 - Table 2.5
Contingency (5% of TDC)	111,079	1 - Table 2.5
PROJECT CONTINGENCY		
Contingency (15% of TDC)	399,886	1 - Table 2.5
Preproduction Cost (2% of TDC)	44,432	1 - Table 2.5
TOTAL INDIRECT COSTS	888,635	
TCI		
ELEVF 1.02		2 - Equation 2.39a
RF 1.5 (design based on >205 mmBtu/hr unit, therefore high RF)		
CEPCI 2016 541.7		4
CEPCI 2024 799.1		4
TOTAL CAPITAL INVESTMENT (TCI)	**3,110,221**	2 - Equation 2.53
DIRECT ANNUAL COSTS		
Maintenance Materials and Labor (0.5% of TCI)	15,551	2 - Equation 2.57
Replacement Catalyst (24,000 hour Service Life - Reference 2)	149,141	2 - Equation 2.67
NRF 1.13 mmBtu/MW		
$cc_{replacement}$ $290 $/cuft		
Reagent Cost	39,370	2 - Equation 2.58
qsol 6.2 lb/hr		2 - Equations 2.35 - 2.37
reag cost $0.73 $/lb		
t op 8,760 hr/yr		
Power	15,048	2 - Equation 2.62
Consumption 17.23 kW		2 - Equation 2.60
Cost $0.0997 $/kWh		
t op 8,760 hr/yr		
Catalyst Disposal (Estimated as 6% of TCI, Amortized Over 3 Year Period)	31,867	2
$ 81,398 * Capital Recovery Factor (0.3915 for n = 3 & i = 8.5%)		3
TOTAL DIRECT ANNUAL COSTS	250,977	
Administrative	8,848	2 - Equation 2.69
Operating Days 365 days/yr		
Operator Time 4 hr/day		
Operator Rate $60 $/hr		
TOTAL INDIRECT ANNUAL COSTS	8,848	2 - Equation 2.54
TOTAL ANNUAL COSTS	**259,825**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		2
8.5% Interest Rate (%)		3
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**3,110,221**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**328,660**	
TOTAL ANNUALIZED COST **(Total annual O&M cost and annualized capital cost)**	**588,485**	2
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**5.75**	
TONS OF NOx REMOVED PER YEAR	**5.18**	
Assuming 90% Removal		2
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA Nox EMISSIONS FROM GLASS MANUFACTURING **($ per ton of NOx removed)**	**113,717**	2, 4, 5

[1] EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2002. https://www.epa.gov/sites/default/files/2020-07/documents/c_allchs.pdf. Accessed 9 July 2024

[2] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2019. Chapter 2 Selective Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024

[3] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

[4] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.

[5] Engineering Practice STRUCTURE of the CECPI. https://www.chemengonline.com/Assets/File/CEPCI_2002.pdf. Accessed July 11, 2024.

Attachment 11 – RACT Cost Spreadsheet for CCF (Furnace)

COST COMPONENT	COST	REFERENCE
DIRECT COSTS		
Purchased Equipment Costs		
CCF	1,952,376	Calculated from TCI
Subtotal-Purchased Equipment Costs (PEC)	1,952,376	
Installation Costs (40% of PEC)	780,950	Calculated from TCI
TOTAL INDIRECT AND DIRECT COSTS	780,950	
799.1 CEPCI 2024		3
556.8 CEPCI 2015		3
Project Contingency (15% of Direct and Indirect Costs)	117,143	
TOTAL CAPITAL INVESTMENT (TCI)	**2,850,469**	1
DIRECT ANNUAL COSTS		
Maintenance Materials and Labor (0.5% of TCI)	14,252	2 - Equation 2.57
Replacement Catalyst (Every Two Years), Capital Recovery Factor (0.5646 for n = 2 & i = 8.5%)	225,840	
$cc_{replacement}$ $500 $/Filter		Vendor
800 Filters		Vendor
Reagent Cost	487,792	2 - Equation 2.58
qsol 76.4 lb/hr		2 - Equations 2.35 - 2.37
reag cost $0.73 $/lb		3
t op 8,760 hr/yr		
Power	10,925	2 - Equation 2.62
Consumption 12.85 kW		2 - Equation 2.60
Cost $0.0970 $/kWh		
t op 8,760 hr/yr		
Catalyst Disposal (Estimated as 5% of equipment cost the same as an SCR, Amortized Over Two Years)	55,116	Vendor
$ 97,619 * Capital Recovery Factor (0.5646 for n = 2 & i = 8.5%)		4
TOTAL DIRECT ANNUAL COSTS	793,925	
Administrative	8,329	2 - Equation 2.69
Operating Days 365 days/yr		
Operator Time 4 hr/day		
Operator Rate $60 $/hr		
TOTAL INDIRECT ANNUAL COSTS	8,329	2 - Equation 2.54
DIRECT AND INDIRECT ANNUAL COSTS	802,254	
TOTAL ANNUAL COSTS	**802,254**	
CAPITAL RECOVERY FACTOR, CFR = (i * (1+i)n)/((1+i)n - 1)		
20 Equipment Life (years)		Vendor
8.5% Interest Rate (%)		3
Capital Recovery Factor	0.1057	
CAPITAL RECOVERY COSTS		
TOTAL CAPITAL REQUIREMENT	**2,850,469**	
TOTAL ANNUALIZED CAPITAL REQUIREMENT	**301,212**	
TOTAL ANNUALIZED COST (Total annual O&M cost and annualized capital cost)	**1,103,466**	
BASELINE POTENTIAL NOx EMISSIONS (TPY) FROM GLASS FURNACE	**153.9**	
TONS OF NOx REMOVED PER YEAR	**123.1**	
Assuming 80% Removal		1
COST-EFFECTIVENESS		
ENVIRONMENTAL BASIS EPA NOx EMISSIONS FROM GLASS MANUFACTURING ($ per ton of NOx removed)	**8,963**	1, 2

[1] Clark, Christina, et al. NOX RECLAIM BARCT INDEPENDENT EVALUATION of COST ANALYSIS PERFORMED by SCAQMD STAFF for BARCT in the NON-REFINERY SECTOR. South Coast Air Quality Management District, 26 Nov. 2014, at 13.
[2] Sorrels, John, et al. EPA AIR POLLUTION CONTROL COST MANUAL Sixth Edition. 2019. Chapter 2 Selective Catalytic Reduction. 2019. https://www.epa.gov/sites/production/files/2017-12/documents/scrcostmanualchapter7thedition_2016revisions2017.pdf. Accessed 9 July 2024
[3] Maxwell, Charles. “Cost Indices – Towering Skills.” Toweringskills.com, 28 May 2020, toweringskills.com/financial-analysis/cost-indices/. Accessed July 11, 2024.
[4] Bank Prime Loan Rate. https://www.federalreserve.gov/releases/h15/

From: Cordell, Vickie K
To: Boling, Jean; ACKER, JENNY
Cc: Logan, Douglas A; JOHNSON, JANUSZ
Subject: W R Grace LNB as RACT
Date: Wednesday, September 4, 2024 1:48:44 PM

I talked to Grace's primary NOx RACT consultant, Mitch Lagerstrom at PROtect, and told him that IDEM is happy to accept low-NOx burners as the control technology for Grace's sodium silicate furnace. Although they can't make the burner switch during this fall's outage, they are sure it will take less than two years to complete the project. In further discussions with the vendor they learned that the downtime and lost production for the burner replacement will be significantly less than they had been anticipating, so that alleviated their last big concern. I told him that I will look into wording options for stating the installation deadline in the SIP, and that I have seen numerous instances of control being required within one year from final issuance of the RACT rule. If the rule is final in May 2025 as expected then that would be about 20 months from now. He thought they'd be OK with that.

He asked if the final RACT rule will have to have an emission limit. They've seen 7 lb/ton for similar furnaces, but they aren't 100% sure they can meet that all the time and won't know until they stack test after the change. They're thinking they'd like 8 lbs/ton of sodium silicate produced. I told him I'll see if EPA has accepted a limit that high for a sodium silicate furnace. He noted their last NOx test result (2003 test) was 10.6 lb/ton; a 40% reduction would be 6.36 lb/ton. (We did not discuss averaging.)

He asked if we need to include start up/shut down language now, or can it wait until permitting? I told him I'll look into that, too, and the EPA has been much more restrictive regarding SU/SD in recent years, but I do understand that the refractory takes time to heat up after a shutdown before they can start making product.

Vickie

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From:	Cordell, Vickie K
To:	Boling, Jean; ACKER, JENNY; DELONEY, SCOTT; Engdahl, Seth M
Cc:	Logan, Douglas A; JOHNSON, JANUSZ
Subject:	NOx Limit for W. R. Grace sodium silicate furnace
Date:	Thursday, September 12, 2024 1:11:18 PM
Attachments:	RACT Response to Comments WR Grace 09102024.pdf Rule 1117 - Comparison of Emission Limits for Various Furnaces.docx

To all,

W. R. Grace's revised RACT submittal (RACT Response to Comments, attached) agrees to add low-NOx burners but does not specify an emission limit.

Their consultant, Mitch Lagerstom at PROtect, said that they were thinking that if they HAVE to have a limit, they would go with 8.0 lb/ton of product. They have seen 7.0 lb/ton of glass online for glass furnaces but until the stack test after the LNB installation they won't know if they can reliably meet that. He noted their previous furnace NOx test result (from 2003) was 10.6 lb/ton. If the LNB retrofit results in 40% NOx reduction as expected, 10.6 x 0.6 = 6.36 lb NOx/ton of sodium silicate produced. Rebricking the furnace this fall should reduce air infiltration which could reduce thermal NOx formation, too.

Rather than setting a numeric limit at this time, could we include language "Test and set limit based on installation of Low-NOX Burners" as shown in the Federal ''Good Neighbor Plan'' for reheat furnaces at Iron and Steel Mills in Table I.B–4? If we set a value now at 8.0 then we might end up with an overly generous limit but if we set it at 7.0 then they'd probably object, and we might be able to go even lower after the stack test.

The highest glass furnace NOx limit in the Final Good Neighbor Rule is 7.0 lb/ton with a rolling 30-day average for flat glass. I have attached a list of NOx limits for glass furnaces including sodium silicate furnaces that was compiled by the California South Coast Air Quality Management District for their NOx RACT Rule 1117 development.
What does everyone think of the "to be determined" idea? I am happy to provide more detail on NOx limits found in other state rules and permits for sodium silicate furnaces, if desired.

Sincerely,

Vickie Cordell

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Site	Operation	NOx Limit	Other conditions	Control Device
PQ Corporation Baltimore, MD	Sodium silicate melting furnace, EU-3	• 5.73 lbs NOx/ton produced	• Production limited to 54,000 tons/yr (147.9 tpd) • No CEMS, emission factor based on production • Verification by source testing	Low-NOx burners
PQ Corporation Chester, PA	Sodium silicate melting furnace, #4 50.75 MMBtu/hr	• 6.0 lbs NOx/ton produced, 30-day rolling average • 69.6 lbs/hr – 4-hour average, rolling by 1 hour • 275.0 tons/yr on a 12-month rolling basis	• Production limited to 11.6 tons/hr (278.4 tpd) • CEMS required • Idling (I) defined as less than 25% of permitted production capacity • NOx not counted during S/U, S/D & I • Maintenance limited to 144 hours per calendar year • S/D starts when production drops below 25% permitted limit, no more than 20 days allowed	Low-NOx burners (Combustion Tec, Model No. Britefire 0308)
PQ Corporation St. Louis, MO	Sodium silicate melting furnace, EP3 32.7 MMBtu/hr	N/A		None
Guardian Glass DeWitt, IA	Glass melting furnace, MF1	• 80% reduction across SCR • If inlet to SCR < 8.0 lbs NOx/ton produced, then exit limit is 1.6 lbs NOx/ton produced, 30-day rolling average	• CEMS before and after SCR • Abnormally low production rate (ALPR) defined as 35% of permitted production rate	SCR

		• 8,357 lb NOx/day, block average when control device S/D or bypassed	• NOx not counted in reduction calculation during S/U, S/D & ALPR • Maintenance limited to 144 hours per calendar year	
Guardian Industries Kingsburg, CA (San Joaquin Valley APCD)	Flat Glass Manufacturing 212 MMBtu/hr	• 3.7 lb/ton glass pulled, 24 block average • 3.2 lb/ton glass pulled, rolling 30-day average • NOx emissions during idling shall not exceed 6,440 lbs/day (?) • NH3 limited to 10 ppmvd @8% O2, rolling 24-hour average	• Glass pull rate limited to 700 tons/day • CEMS required • Idling (I) defined as less than 25% of permitted production capacity • NOx not counted during S/U, S/D & I • Maintenance limited to 144 hours per calendar year • CEMS required • S/D starts when production drops below 25% permitted limit, no more than 20 days allowed	• Scrubber • ESP • SCR
Gallo Glass Company Modesto, CA (San Joaquin Valley APCD)	Glass Manufacturing 90 MMBtu/hr	• 1.3 lb/ton, rolling 30-day average	•	• Scrubber/ESP and/or • Trimer Ceramic Filter system
Owens-Brockway Vernon, CA (South Coast AQMD)	Glass Melting Furnace – B 68 MMBtu/hr	• 1.5 lbs/ton glass pulled • NH3 limited to 5 ppmvd, averaged over 60 minutes, rolling 1-hour average	• Glass pull rate limited to 400 tons/day • If APCD bypassed, pull rate limited to 50 tons/day	Tri-mer SCR
	Glass Melting Furnace – C 68 MMBtu/hr	• 1.5 lbs/ton glass pulled • NH3 limited to 5 ppmvd, averaged over 60 minutes, rolling 1-hour average	• Glass pull rate limited to 332tons/day • If APCD bypassed, pull rate limited to 50 tons/day	Tri-mer SCR
PQ Corporation South Gate, CA	Sodium silicate melting furnace, 56.6 MMBtu/hr	• No permitted limit	• Glass pull rate limited to 263 tons/day	Tri-mer SCR

(South Coast AQMD)		• NH3 limited to 10 ppmvd @ 10% O2		

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