Wingra Engineering, S.C.
Environmental Engineering Consultants

September 30, 2021

National Parks Conservation Association
Clean Air and Climate Program
Attn: Stephanie Kodish, Senior Director & Counsel
777 6th Street NW, Suite 700
Washington, DC 20001-3723

Subject: Four-Factor Reasonable Progress Analysis
Holcim - Florence Cement Plant
Florence, Colorado

Dear Ms. Kodish:

The National Parks Conservation Association requested the preparation of a Four-Factor Reasonable Progress Analysis for Holcim - Florence Cement Plant in Florence, Colorado. This analysis evaluates the feasibility of installing emission control equipment for air pollutants which are precursors to regional haze. The enclosed report describes the procedures and results of this analysis.

Should you have further questions, please contact me at (608) 255-5030.

Sincerely,

Wingra Engineering, S.C.

Steven Klafka

Steven Klafka, P.E., BCEE
Environmental Engineer

Enclosure

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Holcim - Florence Cement Plant
Florence, Colorado

Four-Factor Reasonable Progress Analysis

September 30, 2021

Prepared by:

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Wingra Engineering, S.C.

Madison, Wisconsin

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1.0 INTRODUCTION

The Colorado Department of Public Health and Environment (CDPHE) Air Pollution Control Division is updating its regional haze state implementation plan to improve visibility in certain national parks and wilderness areas in the state. These are referred to as Class I areas for implementation of air pollution protection regulations.

CDPHE is evaluating the retrofit of emission control technology at large industrial sources to make reasonable progress toward natural conditions in Class 1 areas. To determine the effectiveness of retrofitting emissions control technology, USEPA requires states to use a Four-Factor Reasonable Progress Analysis (FFA).

The four statutory factors included in an FFA are:

- Costs of compliance
- Time necessary for compliance
- Energy and non-air quality impacts of compliance
- Remaining useful life of any potentially affected sources

CDPHE has identified the Holcim - Florence Cement Plant located in Florence, Colorado as potentially having impacts on regional haze at surrounding Class I areas. CHPHE recently conducted its own FFA entitled, *Regional Haze Second 10-year Planning Period, Reasonable Progress Four-Factor Analysis of Control Options for Holcim Florence- Portland Cement Plant*, August 2021.

This report updates the CDPHE analysis by incorporating recent improvements in available air pollution control systems for cement kilns. The CDPHE analysis did not address these control methods.

2.0 FACILITY DESCRIPTION

Holcim - Florence Cement Plant is located at 3500 State Highway 120, Florence, Fremont County, Colorado. It manufactures Portland cement. This requires that a mixture of quarried materials, including limestone and clay, be heated at high temperatures in a rotary pre-heater/pre-calciner kiln. This kiln is the primary source of air pollution emissions at the plant and is identified as Emission Point 111 . The plant was recently issued draft air quality operating permit 96OPFR145 on August 30, 2021.

The kiln has a rated capacity of 5,950 tons per day and is fired with coal, natural gas and tire derived fuel. Currently, emissions are controlled using the following methods:

- Particulate Matter (PM) – Baghouse
- Sulfur Dioxide (SO_2) – Scrubbing inherent in the contact of SO_2 with the alkaline materials in the kiln and a wet scrubber following the baghouse.
- Nitrogen Oxides (NO_x) – Use of Selective Non-catalytic Reduction or SNCR by injection of ammonia into the high temperature areas of the kiln.

Allowable and uncontrolled emissions in units of tons per year (tpy) from the kiln are summarized in Table 1. Uncontrolled emissions for PM and NO_x are based on USEPA emission factors of 250 and 4.2 lbs/ton, respectively. For SO_2, it has been assumed that there is no difference between the allowable and uncontrolled emissions since the uncontrolled emissions are naturally controlled by the kiln.

Supporting calculations are provided in Appendix A.

Table 1 - Allowable and Uncontrolled Emissions from Holcim - Florence Cement Kiln (tpy)

Air Pollutant	PM_{10} (Total)	SO_2	NO_x	Total
Allowable	247.6	721.0	2,086.8	3,055.4
Uncontrolled	271,468.8	721.0	4,560.7	276,750.4

3.0 CDPHE FOUR-FACTOR ANALYSIS

The Four-Factor Analysis or FFA completed by CDPHE concluded that no emission control systems or methods are available for the Holcim kiln. No changes were made to the allowable emissions from the kiln or the plant. A copy of their draft analysis is provided in Appendix B.

For the control of NO_x, CDPHE evaluated the use of Selective Catalytic Reduction (SCR) to replace the current Selective Non-catalytic Reduction (SNCR). CDPHE estimated the current SNCR is achieving a NO_x emission reduction of 52.9%. SCR has been shown to provide NO_x emission reduction of 90% or more. SNCR requires the injection of ammonia in high temperatures (1,600 to 2,000°F) while SCR requires the injection of ammonia at lower temperatures (450 to 800°F) where control occurs in a ceramic catalyst. CDPHE rejected the use of SCR to attain greater NO_x emission reductions due to the likelihood of catalyst plugging by PM, mostly the condensable form, and the lack of experience on cement kilns.

For the control of PM, CDPHE determined that the existing baghouse provided state of the art capture of filterable PM and no better controls were available. The large amount of condensable PM could be minimized by tight control of the ammonia injection used by the SNCR control system for NO_x. CDPHE concluded in its FFA that: "Ammonia slip from the SNCR can react with chlorides and sulfates from the raw materials and coal to form condensable PM emissions."

For the control of SO_2, CDPHE did not evaluate control methods since actual emissions from the inherent scrubbing within the kiln and wet scrubber were already low.

4.0 OTHER AVAILABLE EMISSION CONTROL SYSTEMS

There are practical impediments to using a traditional SCR control system for the kiln due to potential plugging by PM emissions. However, the shortcomings of traditional SCR have been overcome with the availability of recently available catalytic ceramic filter systems. These systems are in use throughout the U.S., but with limited application at cement plants. There is greater application of these systems at cement plants in Europe. These systems combine the PM removal conducted by a baghouse with the NO_x removal of SCR. In its FFA, the CDPHE did not evaluate the use of ceramic filter systems.

The advantages of catalytic ceramic filter systems are as follows:

1. Injection of ammonia at low SCR filter temperatures rather than the high SNCR temperatures, thus avoiding the formation of condensable PM within the kiln.

2. More efficient usage of ammonia reducing ammonia slip.

3. Larger reductions in NO_x emissions, as the control efficiency is increased from 53% (estimated by CDPHE for Holcim) to greater than 90%.

4. Simultaneous capture PM emissions.

5. Simultaneous control of SO_2 emissions when combined with reagent injection.

There are two design alternatives for catalytic ceramic filters:

1. Stand-alone catalytic ceramic filter systems

2. Catalytic ceramic filter inserts for existing baghouses

Manufacturers of these filter systems include: Tri-Mer [1], GEA Bischoff [2], and Haldor Topsoe A/S[3]. All three firms were contacted for this study. They all cite the ability to control emissions in the cement industry. The first two firms offer catalytic ceramic filters. These catalytic ceramic filter systems combine into a single control device the traditional separate systems for each air pollutant, as the systems typically include a scrubber for SO_2 neutralization, baghouse for PM capture and SCR for NO_x control. Brochures for the catalytic ceramic filter control systems offered by these two firms are provided in Appendices C and D, respectively.

The last firm, Haldor Topsoe, produces both: 1) a catalytic filter candle (called TopFrax) and 2) a catalytic filter bag (called Cataflex). The filter candles are similar to those used inside the Tri-Mer and GEA systems. The catalytic filter bag, however, is a product that can be added to an existing

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[1] https://tri-mer.com/hot-gas-treatment/hot-gas-filtration.html

[2] https://www.gea.com/en/news/trade-press/2019/biscat-ceramic-catalyst-filter.jsp

[3] https://www.topsoe.com/products/catalysts/topfraxtm

baghouse. These catalytic filter bags have the advantage of reduced cost. They avoid the need for a separate stand-alone control system by instead inserting the catalytic filter bags into the fabric bags of the existing baghouse used to control PM emissions. Brochures for both the catalytic filter candles and bags provided by Haldor Topsoe are provided in Appendix E. Tri-Mer notes that it also has experience with the installation of catalytic filter bags on existing baghouses.

Tri-Mer has extensive experience in the U.S. using their catalytic filter control systems to simultaneously control PM, SO_2 and NO_x emissions from high temperature glass furnaces. Current installations in the U.S are summarized in Table 2.

Tri-Mer also has updated existing baghouses by replacing the fabric filter bags with catalytic ceramic filters. This approach modifies the baghouse to allow the control of NO_x emissions on the ceramic filter while continuing to capture PM emissions. With the addition of reagent injection, these new filters can also control SO_2 emissions.

Table 2 - Tri-Mer Filter Projects in U.S.

Company	Location	Glass Type
Durand	Millville, NJ	Tableware
Anchor	Monaca, PA	Mixed
AGC	Church Hill, TN	Flat
Gallo	Modesto, CA	Container
AGC	Hill, KS	Flat
Adagh	Dolton, IL	Container
Kohler	Kohler, WI	Specialty
Guardian	Carleton, MI	Flat
PG Corporation	L.A. Basin	Specialty
Cardinal FG	Mooresville, NC	Flat
Cardinal FG	Durant, OK	Flat

Haldor Topsoe worked with FLSmidth to install a ceramic filter system after a baghouse used on the cement kiln at Cemex Southeast LLC cement plant in Demopolis, Alabama. This ceramic filter system was used to control organic hazardous organic compound emissions.[4] Haldor Topsoe have also used their catalytic filter bags to control NO_x emissions from cement kilns in Europe.

Figure 1 provides a diagram of a stand-alone catalytic ceramic filter system offered by Tri-Mer.

Figure 2 shows the catalytic filter bag inserts (called Cataflex) offered by Haldor Topsoe.

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[4] https://www.cemex.com/documents/20143/49694544/IntegratedReport2019.pdf/4e1b2519-b75f-e61a-7cce-2a2f2f6f09dc

It is noteworthy that CDPHE recently completed an FFA for the Rocky Mountain Bottle Company which has a glass furnace equipped with the Tri-Mer system.

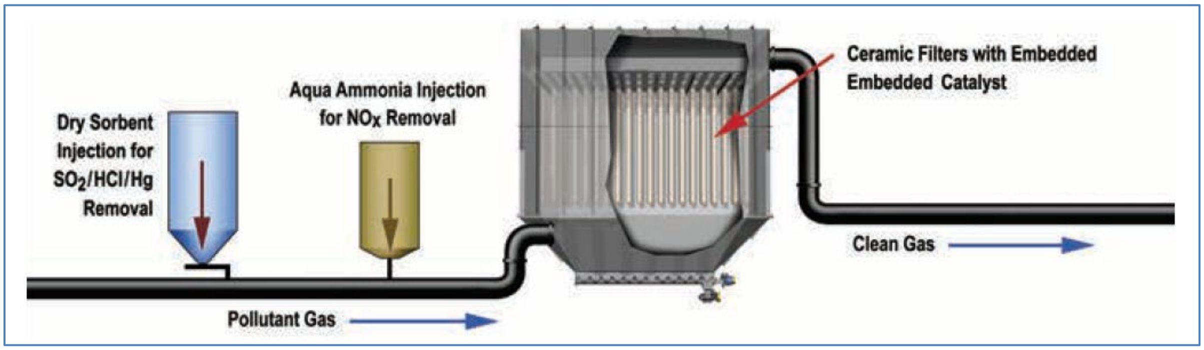

Figure 1 - Catalytic Ceramic Filter System

Figure 2 - Catalytic Filter Bag Insert

The configuration of the existing Holcim - Florence cement plant has been discussed with the three vendors. Potential emission control options include the following:

1. Insertion of catalytic filters into the existing baghouse.
2. Installation of a ceramic filter system after the existing baghouse.
3. Replacement of the existing baghouse with a stand-alone ceramic filter system.

The least expensive option is the first – installing catalytic filter bags into the fabric bags of the existing baghouse or replacing the fabric bags with ceramic filter elements. This approach would retain the footprint of the existing baghouse and stack with the least physical modifications.

The remaining two options would be more costly and require the purchase of a stand-alone ceramic filter system. For the second option, the existing baghouse and SNCR system would be retained. There would be less air pollution emissions to control and additional cost to reheat the flue gas to the catalyst operating temperature. For the third option, the existing baghouse and SNCR system would be removed. There would be more air pollution emissions to control and no need to reheat the flue gas.

5.0 COSTS OF COMPLIANCE

Cost estimates were developed for the following three emission control alternatives not considered by CDPHE in its FFA:

1. Replacement of the fabric filter bags of the existing baghouse with catalytic ceramic filter elements. This approach would add the control of NO_x emissions.
2. Installation of a stand-alone Tri-Mer catalytic ceramic filter system, while retaining the existing baghouse, SNCR and wet scrubber control systems. This approach would simultaneously control PM, SO_2 and NO_x emissions.
3. Replacement of the existing baghouse and wet scrubber with a stand-alone Tri-Mer catalytic ceramic filter system. This approach would simultaneously control PM, SO_2 and NO_x emissions

5.1 Cost of Catalytic Filters (Option #1)

Tri-Mer was provided with the design specifications of the existing cement kiln. These are the same as those used to develop the cost estimates for a stand-alone catalytic ceramic filter system, as discussed below.

Based on the design of the existing cement kiln and its air pollution control system, Tri-Mer prepared a proposal to replace the existing fabric filter bags in the baghouse with catalytic ceramic filter elements. This approach would continue to provide control of PM emissions, but add the ability to control NO_x emissions by 90% or more. If desired, the existing wet scrubber could be removed and reagent injection such as lime could be used to control SO_2 emissions. A copy of the Tri-Mer proposal is provided in Appendix F of this report.

Tri-Mer assumed the existing SNCR system would be discontinued so uncontrolled NO_x emissions would be controlled by the new filters. To achieve the required operating temperature of 550 °F, the exhaust flue gas of the cement kiln would no longer be cooled to a temperature required by the existing fabric bags.

Table 3 summarizes the cost estimate for Option #1. Tri-Mer estimates a cost effectiveness of $1,574 per ton of NO_x removed. This estimate is reasonable and falls within the range that has been accepted by regulatory agencies. If the removal of uncontrolled PM emissions is considered, the combined cost effectiveness is further reduced to $23 per ton of NO_x and PM removed.

Other benefits of this control option cited by Tri-Mer include the following:

- Minimal catalyst plugging
- Reduced ammonia slip
- Negligible catalyst deactivation

- Minor conversion of SO_2 to SO_3

Each of these addresses concerns raised by CDPHE for the use of SCR in its draft FFA.

5.2 Cost of Catalytic Ceramic Filter System (Options #2 and #3)

For typical Best Available Control Technology analyses, order-of-magnitude cost estimates are typically generated.[5] The cost estimate is improved if it is based on actual vendor quotations for the required equipment. Developing air pollution control cost estimates is a time-consuming process. Rather than request budget quotations from vendors, a cost estimate was developed from a 2015 proposal for a Tri-Mer catalytic ceramic filter system sized for a 700 tons per day flat glass plant. This system was eventually installed in North Carolina and continues to operate successfully. This glass plant cost estimate reflects the retrofit of a new control system at an existing industrial facility.

The capital, installation and operating costs were adjusted to reflect the differences between the glass plant and the cement kiln at the Holcim - Florence cement plant. Adjustments accounted for inflation, inlet air flow rates and uncontrolled emission rates of PM, SO_2 and NO_x. Supporting cost estimation calculations are provided in Appendix A.

If the existing baghouse and wet scrubber are retained for the first option, the exit temperature of the flue gas would be too low for the use of a catalytic reduction system. The cost estimates include the cost of natural gas to reheat the flue gas to the control system operating temperature of 550 °F.

If the existing baghouse and wet scrubber are removed and replaced with the catalytic filter system for the second option, it was assumed that operation of the cement plant gas cooler prior to the baghouse could instead be adjusted to increase the flue gas temperature to that required for the catalyst.

Table 3 summarizes the cost estimate for Options #2 and #3. Because the catalytic ceramic filter system is a multi-pollutant control technology, cost effectiveness was calculated based on the total expected emission reductions of NO_x alone, and for PM, SO_2 and NO_x combined.

For Option #2, adding a new ceramic catalytic filter system after the existing baghouse, wet scrubber and SNCR system, the estimated cost effectiveness to is $12,790 per ton for the removal of NO_x emissions. The cost effectiveness is $9,044 per ton for the removal of combined emissions of PM, SO_2 and NO_x. This is based on controlling the allowable emissions exiting the current baghouse and SNCR system.

For Option #3, replacement of the existing baghouse, wet scrubber and SNCR system with a new ceramic catalytic filter system, estimated cost effectiveness is $2,513 per ton for the removal of NO_x emissions. The cost effectiveness is $37 per ton for the removal of combined emissions of

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[5] USEPA, *Air Pollution Control Manual, Sixth Edition*, EPA/452/B-02-001 January 2002.

PM, SO_2 and NO_x. This is based on controlling the uncontrolled emissions exiting the current cement kiln.

This analysis for a stand-alone catalytic ceramic control system shows that Option #2 has a cost effectiveness value for all pollutants combined which is reasonable and falls within the range that has been accepted by regulatory agencies. Option #3 has cost effectiveness values for NO_x alone, or all pollutants combined, which are reasonable and falls within the range that has been accepted by regulatory agencies.

Table 3 - Cost Estimate for Catalytic Ceramic Filters for Holcim - Florence

Capital Costs	Option #1	Option #2	Option #3
Location of New Catalytic Filters	Replace Filters	After Baghouse	Replace Baghouse
Emissions Basis	Uncontrolled	Allowable	Uncontrolled
Basis	Tri-Mer Proposal	Scaled Quotation	Scaled Quotation
Combined Capital and Operating Costs			
Capital Costs	$31,250,800	$67,551,303	$67,551,303
Annual Capital Costs	$1,562,540	$4,646,179	$4,646,179
Annual Operating Costs	$4,900,000	$19,373,521	$5,670,501
Annual Capital and Operating Costs	$6,462,540	$24,019,699	$10,316,680
Inlet NO_x (tpy)	4,561	2,087	4,561
Inlet SO_2 (tpy)	721	721	721
Inlet PM (tpy)	271,469	248	271,469
Inlet NO_x, SO_2 and PM (tpy)	276,750	3,055	276,973
Outlet NO_x (tpy)	456	209	456
Outlet SO_2 (tpy)	721	180	180
Outlet PM (tpy)	131	10	131
Outlet NO_x, SO_2 and PM (tpy)	1,308	399	767
Removed NO_x (tpy)	4,105	1,878	4,105
Removed SO_2 (tpy)	0	541	541
Removed PM (tpy)	271,338	237	271,338
Removed NO_x, SO_2 and PM (tpy)	275,442	2,656	275,984
Cost Effectiveness ($ per ton of NO_x removed)	$1,574	$12,790	$2,513
Cost Effectiveness ($ per ton of total removed)	$23	$9,044	$37
Proposed Limitation for NO_x (lbs/ton of clinker) (30-day rolling average)	0.42	0.19	0.42
Proposed Limitation for SO_2 (lbs/ton of clinker) (30-day rolling average)	0.66	0.17	0.17
Proposed Limitation for PM (lbs/ton of clinker) (30-day rolling average)	0.12	0.01	0.12

6.0 TIME NECESSARY FOR COMPLIANCE

Based on prior projects, the time frame to obtain a quotation for a catalytic ceramic filter system or catalytic filter bags, issue a purchase order, complete engineering, construct and install the equipment is 12 months.

7.0 ENERGY AND NON-AIR QUALITY IMPACTS OF COMPLIANCE

Significant operating costs include electricity, ammonia reagent, hydrated lime reagent and labor. These costs are taken into account in the enclosed cost estimates. The cost estimates provided in this report incorporate electricity usage for control system fans.

The ammonia selected for the control of NO_x emissions is 19% aqueous ammonia. This is a less concentrated and safer alternative to anhydrous ammonia. This type of ammonia has no federal requirement to evaluate the potential impacts of an accidental release.

The calcium sulfate (i.e., gypsum) formed by the reaction of hydrated lime with SO_2 will be captured as dust by the ceramic filters. Calcium sulfate is a raw material in cement. It is possible the capture dust can be used as one of the ingredients in the production of cement and avoid landfilling.

8.0 REMAINING USEFUL LIFE OF ANY POTENTIALLY AFFECTED SOURCES

In its FFA, CDPHE concluded that Holcim has not announced a closure date for the Florence kiln, and CDPHE assumed that the cement kiln will remain in operation for at least 20 years.

9.0 CONCLUSIONS

The draft FFA prepared by CDPHE for the Holcim - Florence cement plant concluded there were no feasible control systems available to further reduce emissions. The use of catalytic ceramic filter systems was not considered by CDPHE. These systems are in operation in the U.S. and are suitable for cement kilns.

The enclosed estimates show that for the first option, replacement of the existing fabric filter bags with catalytic ceramic filter elements, the cost effectiveness would be $1,574 per ton for the removal of NO_x emissions.

For the second option, adding a new ceramic catalytic filter system after the existing baghouse and SNCR system, the estimated cost effectiveness to is $12,790 per ton for the removal of NO_x emissions. The cost effectiveness is $9,044 per ton for the removal of combined emissions of PM, SO_2 and NO_x. This is based on controlling the allowable emissions exiting the current baghouse and SNCR system.

For the third option, replacement of the existing baghouse and SNCR system with a new ceramic catalytic filter system, estimated cost effectiveness is $2,513 per ton for the removal of NO_x emissions. The cost effectiveness is $37 per ton for the removal of combined emissions of PM, SO_2 and NO_x. This is based on controlling the uncontrolled emissions exiting the current cement kiln.

Except for controlling only NO_x just with the first option, all of these cost effectiveness values represent a reasonable expenditure for the reduction of PM, SO_2, and NO_x emissions. There are no other impediments to the use of these control systems associated with time of installation, energy and non-air impacts, or the anticipated life of the existing cement plant.

Appendix A

Supporting Cost Calculations

Facility	Holcim Florence			Reference
	Portland Cement Plant			A
	Florence, Colorado			A
	Preheater/Precalciner Kiln			A
AIRS Point	111			A
Fuels	Coal, NG, TDF, Pet Coke			A
Capacity (tons per day)	5,950			A
Current Control for PM	Baghouse			A
Current Control for SO2	Inherent & Wet Scrubbing			A
Current Control for NOx	SNCR			A
Exhaust Flow Rate (acfm)	827,731			B
Exhaust Temperature (F)	166			B
Exhaust Moisture (%)	13.9			B
	Air Pollutant	Units	Emission	
Allowable	PM10 (Filterable)	(tpy)		
	PM10 (Condensable)	(tpy)		
	PM10 (Total)	(tpy)	247.6	A
	SO2	(tpy)	721.0	A
	NOx	(tpy)	2,086.8	A
Allowable	PM10 (Filterable)	(lbs/ton)		
	PM10 (Condensable)	(lbs/ton)		
	PM10 (Total)	(lbs/ton)	0.2	Calculated
	SO2	(lbs/ton)	0.7	Calculated
	NOx	(lbs/ton)	1.9	Calculated
Allowable	PM10 (Filterable)	(lbs/hr)		
	PM10 (Condensable)	(lbs/hr)		
	PM10 (Total)	(lbs/hr)	56.5	Calculated
	SO2	(lbs/hr)	164.6	Calculated
	NOx	(lbs/hr)	476.4	Calculated
Uncontrolled	PM10 (Filterable)	(lbs/ton)	250.0	C
	PM10 (Condensable)	(lbs/ton)	0.0	
	PM10 (Total)	(lbs/ton)	250.0	Calculated
	SO2	(lbs/ton)	0.7	D
	NOx	(lbs/ton)	4.2	A
Uncontrolled	PM10 (Filterable)	(lbs/hr)	61,979.2	Calculated
	PM10 (Condensable)	(lbs/hr)	0.0	Calculated
	PM10 (Total)	(lbs/hr)	61,979.2	Calculated
	SO2	(lbs/hr)	164.6	Calculated
	NOx	(lbs/hr)	1,041.3	Calculated

Uncontrolled	PM10 (Filterable)	(tpy)	271,468.8	Calculated
	PM10 (Condensable)	(tpy)	0.0	Calculated
	PM10 (Total)	(tpy)	271,468.8	Calculated
	SO2	(tpy)	721.0	Calculated
	NOx	(tpy)	4,560.7	Calculated

A - CDPHE, Four-Factor Analysis for Holcim Florence - Portland Cement Plant, August 2021

B - Compliance Stack Test Report, Lafarge Holcim Portland Plant, Test conducted on April 8, 2020, Flow rate increased from test rate of 5,470 tpd to capacity of 5,950 tpd.

C - USEPA, AP42, Table 11.6-2 - Emission Factors for Portland Cement Manufacturing, January 1995.

D - Uncontrolled SO2 assumed to be same as allowable due to use of inherent scrubbing within kiln.

Air Pollutant	PM10 (Total)	SO2	NOx	Total
Allowable	247.6	721.0	2,086.8	3,055.4
Uncontrolled	271,468.8	721.0	4,560.7	276,750.4

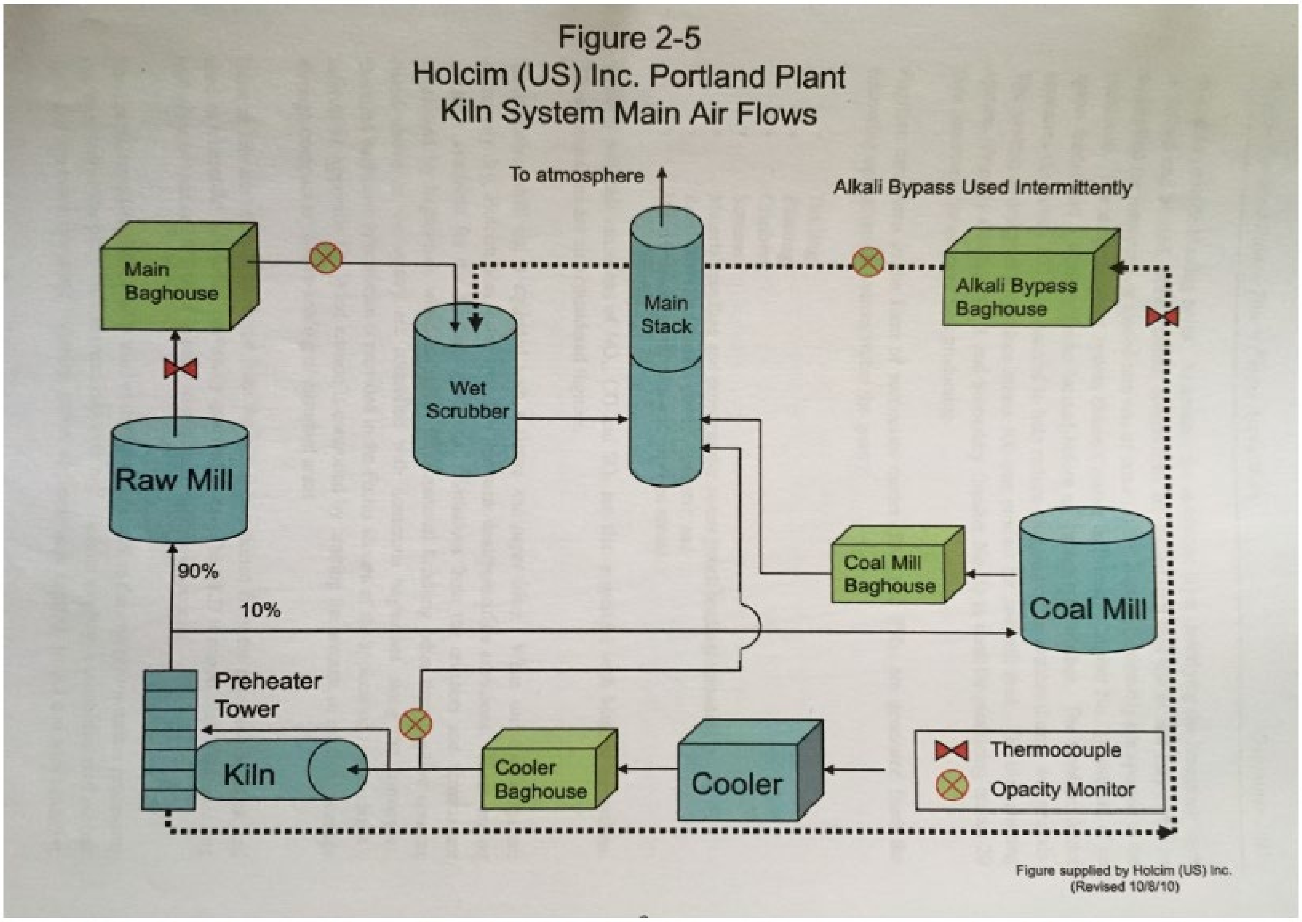

Figure 2-5
Holcim (US) Inc. Portland Plant
Kiln System Main Air Flows

Figure supplied by Holcim (US) Inc.
(Revised 10/8/10)

Source: CDPHE, PHolcim Portland Plant, Operating Permit No. 95OPFR145, Technical Review Document – Initial Operating Permit, August 30, 2021.

	Reference	Original (2015)		Original (2021)	Reference	Holcim Florence	Holcim Florence
Location of New Catalytic Filters						After Baghouse	Replace Baghouse
Emissions Basis		Potential		Potential		Allowable	Uncontrolled
Capacity (tpd)	Quotation	700		700	2021 CDPHE	5,950	5,950
Current Flow (acfm)					Permit Application	827,731	827,731
Current Temperature (deg F)					Permit Application	166	166
Inlet Flow (acfm)	Quotation	96,745		96,745	Calculated	1,335,477	1,335,477
Inlet Temperature (deg F)	Quotation	550		550	Calculated	550	550
Inlet Flow (scfm)							698,150
Inlet NOx (lbs/ton)	Quotation	18.0			Current Allowable	1.9	
Inlet SO2 (lbs/ton)	Quotation	4.0			Current Allowable	0.7	
Inlet PM (lbs/ton)	Quotation	1.2			Current Allowable	0.2	
Inlet NOx (tpy)	Calculated	2,299.5			Current Allowable	2,087	
Inlet SO2 (tpy)	Calculated	511.0			Current Allowable	721	
Inlet PM (tpy)	Calculated	153.3			Current Allowable	248	
NOx Removal (%)	IN vs OUT	90.0%			Same as Original	90.0%	
SO2 Removal (%)	IN vs OUT	75.0%			Same as Original	75.0%	
PM Removal (%)	IN vs OUT	95.8%			Same as Original	95.8%	
Outlet NOx (lbs/ton)	Quotation	1.8			Calculated	0.19	
Outlet SO2 (lbs/ton)	Quotation	1.0			Calculated	0.17	
Outlet PM (lbs/ton)	Quotation	0.1			Calculated	0.010	
Outlet NOx (tpy)	Calculated	230.0			Calculated	208.7	
Outlet SO2 (tpy)	Calculated	127.8			Calculated	180.3	
Outlet PM (tpy)	Calculated	6.4			Calculated	10.3	
Removed NOx (tpy)	Calculated	2,069.6			Calculated	1,878.1	
Removed SO2 (tpy)	Calculated	383.3			Calculated	540.8	
Removed PM (tpy)	Calculated	146.9			Calculated	237.3	
Removed NOx, SO2 and PM (tpy)	Calculated	2,599.7			Calculated	2,656.2	
Inlet NOx (lbs/ton)	Quotation	18.0		18.0	Uncontrolled (USEPA)		4.2
Inlet SO2 (lbs/ton)	Quotation	4.0		4.0	Current Allowable		0.7
Inlet PM (lbs/ton)	Quotation	1.2		1.2	Uncontrolled (USEPA)		250
Inlet NOx (tpy)	Calculated	2,299.5		2,299.5	Calculated		4,560.7
Inlet SO2 (tpy)	Calculated	511.0		511.0	Current Allowable		721.0
Inlet PM (tpy)	Calculated	153.3		153.3	Calculated		271,468.8
NOx Removal (%)	IN vs OUT	90.0%		90.0%	Same as Original		90.0%
SO2 Removal (%)	IN vs OUT	75.0%		75.0%	Same as Original		75.0%
PM Removal (%)	IN vs OUT	95.8%		95.8%	Same as Original		
Outlet NOx (lbs/ton)	Quotation	1.8		1.8	Calculated		0.42
Outlet SO2 (lbs/ton)	Quotation	1.0		1.0	Calculated		0.17
Outlet PM (lbs/ton)	Quotation	0.1		0.05	Calculated	Based on 0.005 gr/scf	0.12
Outlet NOx (tpy)	Calculated	230.0		230.0	Calculated		456.1
Outlet SO2 (tpy)	Calculated	127.8		127.8	Calculated		180.3
Outlet PM (tpy)	Calculated	6.4		6.4	Calculated		131.1
Removed NOx (tpy)	Calculated	2,069.6		2,069.6	Calculated		4,104.6
Removed SO2 (tpy)	Calculated	383.3		383.3	Calculated		540.8
Removed PM (tpy)	Calculated	146.9		146.9	Calculated		271,337.7
Removed NOx, SO2 and PM (tpy)	Calculated	2,599.7		2,599.7	Calculated		275,983.1
Capital Costs		Original (2015)	Inflation	Original (2021)	Adjustment Method	Holcim Florence	Holcim Florence
Location of New Catalytic Filters						After Baghouse	Replace Baghouse
Emissions Basis						Allowable	Uncontrolled
Complete System Equipment and Installation		$12,159,935	1.15	$13,983,925	Six-Tenths by Inlet Flow	$67,551,303	$67,551,303
Capital Recovery Factor (CRF)	CRF (20 yrs, 3.25%)	0.06878	CRF (20 yrs, 3.25%)		CRF (20 yrs, 3.25%)	0.06878	0.06878
Annualized Capital Cost		$836,360				$4,646,179	$4,646,179
Operating Costs							
Electricity		$188,953	1.15	$217,296	Ratio by Inlet Flow	$2,999,573	$2,999,573
19% Aqueous Ammonia		$665,665	1.15	$765,515	Ratio by Inlet NOx	$694,705.88	$1,518,271
Hydrated Lime		$361,810	1.15	$416,082	Ratio by Inlet SO2	$587,073.90	$587,074
Labor for Operation and Maintenance		$69,213	1.15	$79,595	Six-Tenths by Inlet Flow	$384,495	$384,495
Natural Gas for Reheating Flue Gas						$14,707,674	$0
Annual Operating Costs		$1,285,641				19,373,521	5,489,412
Combined Capital and Operating Costs							
Capital Costs		$12,159,935				$67,551,303	$67,551,303
Annual Capital Costs		$836,360				$4,646,179	$4,646,179
Annual Operating Costs		$1,285,641				$19,373,521	$5,489,412
Annual Capital and Operating Costs		$2,122,001				$24,019,699	$10,135,590
Inlet NOx (tpy)		2,300				2,087	4,561
Inlet SO2 (tpy)		511				721	721
Inlet PM (tpy)		153				248	271,469
Inlet NOx, SO2 and PM (tpy)		2,964				3,055	276,750
Outlet NOx (tpy)		230				209	456
Outlet SO2 (tpy)		128				180	180
Outlet PM (tpy)		6				10	131
Outlet NOx, SO2 and PM (tpy)		364				399	767
Removed NOx (tpy)		2,070				1,878	4,105
Removed SO2 (tpy)		383				541	541
Removed PM (tpy)		147				237	271,338
Removed NOx, SO2 and PM (tpy)		2,600				2,656	275,983
Cost Effectiveness ($ per ton of NOx removed)		$1,025				$12,789	$2,469
Cost Effectiveness ($ per ton of total removed)		$816				$9,043	$37

Notes:
Complete System Equipment and Installation includes: emission control system, controls, infrastructure, engineering design and project management, installation, services, batch recycle system, ammonia tank shelter.

Inflation multiplier from November 2015 to August 2021 = 1.15 - https://www.bls.gov/data/inflation_calculator.htm

Capital Recover Factor based on lifetime of operation and % interest from DOE, Four-Factor Analysis, https://ecology.wa.gov/Air-Climate/Air-quality/Air-quality-targets/Regional-haze

Natural Gas for Reheating Flue Gas to 550 F

Start Temp	(deg F)	166
Start Flow	(acfm)	827,731
Inlet Temp	(deg F)	550
Inlet Flow	(acfm)	1,335,477
Inlet Flow	(scfm)	698,150
Inlet Flow	(lbs/min)	52,361
Start h	(btu/lbs)	149.72

Inlet h	(btu/lbs)	243.48
Change h	(btu/lbs)	93.757
Fuel Required	(btu/hr)	294,554,069
Fuel Required	(therms/hr)	2945.5
Nat Gas	($/therm)	0.57
Nat Gas	($/yr)	$14,707,674

Capacity (tpd)	5,950	5,950	5,950
Combined Capital and Operating Costs	Option #1	Option #2	Option #3
Capital Costs	$31,250,800	$67,551,303	$67,551,303
Annual Capital Costs	$1,562,540	$4,646,179	$4,646,179
Annual Operating Costs	$4,900,000	$19,373,521	$5,670,501
Annual Capital and Operating Costs	$6,462,540	$24,019,699	$10,316,680
Inlet NO_x (tpy)	4,561	2,087	4,561
Inlet SO_2 (tpy)	721	721	721
Inlet PM (tpy)	271,469	248	271,469
Inlet NO_x, SO_2 and PM (tpy)	276,750	3,055	276,750
Outlet NO_x (tpy)	456	209	456
Outlet SO_2 (tpy)	180	180	180
Outlet PM (tpy)	131	10	131
Outlet NO_x, SO_2 and PM (tpy)	767	399	767
Removed NO_x (tpy)	4,105	1,878	4,105
Removed SO_2 (tpy)	541	540.75	540.75
Removed PM (tpy)	271,338	237	271,338
Removed NO_x, SO_2 and PM (tpy)	275,983	2,656	275,983
Cost Effectiveness ($ per ton of NO_x removed)	$1,574	$12,789	$2,513
Cost Effectiveness ($ per ton of total removed)	$23	$9,044	$37
Proposed Limitation for NOx	0.42	0.19	0.42
Proposed Limitation for SO2	0.17	0.17	0.17
Proposed Limitation for PM	0.12	0.01	0.12

Appendix B

CDPHE Four-Factor Analysis

Regional Haze Second 10-year Planning Period Reasonable Progress Four-Factor Analysis of Control Options for Holcim Florence – Portland Cement Plant

August 2021

For the second Regional Haze 10-year planning period, Colorado evaluated all stationary sources in the state with oxides of nitrogen (NO_x), sulfur dioxide (SO_2), and particulate matter (PM) emissions over 25 tons per year (TPY) statewide to determine which sources should be evaluated for potential additional emission controls depending on proximity to Class I areas (CIAs). Sources were included in the Reasonable Progress analysis if their total emissions of NO_x, SO_2, and PM, in TPY, divided by distance to the nearest CIA, in km, ("Q/d") was greater than 10, based on 2014 National Emissions Inventory (NEI) emissions. In Colorado, sources with a Q/d > 10 are considered potential contributors to CIA visibility impairment and are subject to the four-factor review process. In determining Reasonable Progress (RP) under the Regional Haze program, states must consider the four factors explicitly set forth in the Clean Air Act, which are:

(1) costs of compliance,
(2) time necessary for compliance,
(3) energy and non-air quality environmental impacts of compliance, and
(4) remaining useful life.

The Holcim cement plant has a Q/d = 20.53. Accordingly, the Holcim Florence plant is subject to the RP four-factor review process. Great Sand Dunes is the nearest Class I Area to Holcim and is approximately 75.4 km (46.8 miles) from the Florence Portland cement plant. Holcim was subject to a RP analysis during the first Regional Haze planning period.

For the purposes of evaluating RP, the Division elected to focus its analysis on those individual emission units with actual baseline emissions (2018-2020 average emissions) of NO_x, SO_2, or PM_{10} equal to or exceeding 10 TPY. The Division established a *de minimis* threshold to focus the technical emission control analysis on significant emission sources where potential controls could provide a meaningful improvement in visibility if emission controls are determined to be cost effective.

Prior to the application of the four statutory factors, the Division followed a process similar to assessing the application of the Best Available Control Technology (BACT), by identifying the available emissions control technologies and then determining if they were technically and economically feasible.

I. Source Description

Facility AIRS ID:	043-0001
Owner/Operator:	Holcim (US) Inc.
Source Type:	Portland Cement Manufacturing
SCC:	30500623 (Kiln), 30602009/10 (Drilling and Blasting), 30500617 (Finish Grinding Mill)
Kiln Type:	Preheater/Precalciner Kiln

The Holcim Portland plant manufactures Portland cement and is located in Fremont County on Highway 120 near the town of Florence, Colorado, approximately 20 kilometers southeast of Canon City, and 50 kilometers northwest of Pueblo, Colorado. The plant is located around 47 miles from Great Sand Dunes National Park. The facility is not located in a maintenance or non-attainment area for any NAAQS standards.

In May 2002, a newly constructed cement kiln at the Portland Plant commenced operation. This more energy-efficient 5-stage preheater/precalciner kiln replaced three older wet process kilns. As a result, Holcim was able to increase clinker production from approximately 800,000 tons of clinker per year to a permitted level of 1,873,898 tons of clinker per year, while reducing the level of NO_x, SO_2, and PM_{10} emissions on a pound per ton of clinker produced basis. As a part of this project, Holcim also installed a wet lime scrubber to reduce the emissions of sulfur oxides, SO_x. This new preheater/precalciner kiln is much more energy efficient than the modified long dry kiln at CEMEX Lyons and has comparable efficiency to the GCC Pueblo kiln preheater/precalciner kiln.

The dual string, 5-stage preheater/precalciner kiln system features a multi-stage combustion precalciner and a 17-foot diameter, 256-foot long rotary kiln. The kiln system is rated at 950 MMBtu/hour of fuel input with a nominal clinker production rate of 5,950 tons per day. The kiln is the main point source of SO_2, NO_x, and PM_{10} emissions, all of which are above the 10 TPY de minimis threshold. The quarry is permitted as a significant source of fugitive PM_{10} emissions. The actual NO_x emissions are below the 10 TPY de minimis threshold. The quarry's SO_2 permit limit is well below the 10 TPY threshold. PM_{10} emissions from the cement processing at the finishing mill also exceed the 10 TPY threshold. The kiln, quarry, and finishing mill were subject to RP analysis during the first Regional Haze implementation period.

Process Description:

The basic process of producing Portland cement plant involves producing a raw meal consisting of quarried materials, including limestone (primarily $CaCO_3$, calcium carbonate) and clay (which contains silicate minerals and aluminum oxides), along with other ingredients such as sand (primarily SiO_2, silicon dioxide) and scale (iron oxides). These raw meal ingredients are finely ground and mixed in various ratios depending on the desired final cement product. This raw meal is heated to very high temperatures in a rotary kiln to form alite ($Ca_3O \cdot SiO_4$) which clumps together in nodules called clinker, the primary component of Portland cement. In this heating process, NO_x is produced from the high combustion temperatures, SO_2 is produced from sulfur-containing compounds in the limestone and sulfur in the fuels (coal and pet-coke), and CO_2 is produced from the fuel combustion and the decomposition of calcium carbonate into calcium oxide and carbon dioxide ($CaCO_3 \rightarrow CaO + CO_2$). The clinker is cooled, combined with other products, such as gypsum ($CaSO_4 \cdot 2H_2O$), and ground to produce a specific Portland cement formulation.

In the case of the Holcim Florence facility, the process begins with extracting limestone and other raw materials from the co-located quarry. The limestone is excavated using blasting, then loaded into trucks with a front end loader. Limestone, translime, sandstone and occasionally other raw material components are off-loaded by truck or front-end loader into either Primary Crusher No.1 (old) or Primary Crusher No. 2 (new). If further size reduction is needed, the raw material is conveyed by belt to Secondary Crusher No. 1 where it is further reduced in size. Raw material exiting the crusher passes through a cross belt neutron analyzer during transport to the preblending hall. Chemical results from this analyzer are used to control the ratio of limestone, translime, and sandstone in the preblending piles. Two longitudinal preblending piles are fed by a traveling stacker. While one pile is being built, the other pile is reclaimed to a mill feed bin by a travelling reclaimer.

The ground material from the raw mill then goes to the blending silo where it is stored until being fed into the preheater/precalciner. Pulverized coal from the coal mill is also fed to the preheater/precalciner, where it is fired. Some process gases from the kiln are used to dry the coal, while the remaining gases pass through the in-line raw mill. This helps conserve energy and the in-line raw mill acts as a scrubber for SO_2 and ammonia. The Holcim Florence kiln is also permitted to fire several fuels including petroleum coke, natural gas, used oils, and alternative fuels such as tire derived fuel (TDF) and dried cellulose, which can also be used to offset the coal usage. The material leaving the preheater/precalciner is almost completely calcined as it enters the rotary kiln, which is located at a slight incline along its horizontal axis. The material travels towards the clinker discharge end where additional pulverized coal is fired for the clinkering process. The clinker is discharged from the kiln into the clinker cooler where it is cooled by air forced through the clinker bed by under-grate fans. Heated air from the clinker cooler is fed into the kiln as pre-heated combustion air, which improves the energy efficiency of the kiln. The cooled clinker is transferred to clinker storage silos near the finish mill. Finish mill additives, such as gypsum, are delivered via truck or rail and transferred to an additive storage silo near the finish mill. Clinker and additives from the clinker storage silo and additive silo are fed to the finish mill which grinds the material to a fine powder to produce Portland cement. The Portland cement is stored in product silos and shipped via railcar or truck.

Emissions from the kiln system (including preheater/precalciner), raw mill, coal mill, alkali bypass and clinker cooler are all routed through a common main stack for discharge to atmosphere. These emissions are currently controlled by fabric filters baghouses for PM control. Around 90% of kiln emissions are routed through the raw mill to dry the raw material and then pass through the main baghouse before exiting the stack. The remaining 10% of kiln emissions are routed through the coal mill and then through the coal mill baghouse before exiting through the stack. The kiln is equipped with an alkali bypass which is occasionally used to remove potassium and sodium to produce Low Alkali (LA) clinker. When in use, alkali bypass emissions are filtered by the alkali bypass baghouse. Clinker cooler emissions are filtered through a dedicated baghouse that exhausts through the main baghouse before the flow is split between the main stack (50% of flow), kiln (20%), and preheater/precalciner (30%). All SO_2 emissions passing through the kiln and preheater are scrubbed by the inherent cement manufacturing process. The raw mill provides additional SO_2 scrubbing. Lastly, SO_2 emissions from the main baghouse and alkali bypass baghouse are treated with a wet scrubber before exiting the main stack. The kiln system utilizes low-NO_x burners (LNB), a low-NO_x precalciner, and an SNCR to reduce NO_x emissions.

From an overall perspective, the manufacturing process may be viewed as two segments -- clinker production and cement production. The clinker storage allows the two processes to operate at different production rates. During periods of low demand for cement, clinker is accumulated. If cement is in high demand, the clinker production can be supplemented by purchase of clinker from other sources. The overall result is the clinker production can operate at a rather steady rate, while the cement production can operate in response to the current or projected demands.

For sources identified through the above screening process as potentially impacting western Class I Areas, a *de minimis* threshold was established to focus technical emission control analysis on significant emission units where potential controls could provide a meaningful improvement in visibility. Emission points may include point or fugitive emissions, or both. Identified sources were asked to submit relevant four-factor information for all emission points with 2018 - 2020 average actual baseline emissions of NO_x, SO_2, and PM_{10} equal to or exceeding 10 TPY. These points were evaluated to identify additional emissions controls to determine if additional emissions reductions are technically feasible and cost effective.

Holcim submitted a Four-Factor Analysis for the Quarry (AIRS 101), Kiln (AIRS 111), and Finish Mill (AIRS 115) the Division on September 30, 2019 with additional information submitted on March 19, 2020.

The emission points potentially subject to evaluation at Holcim Florence plant are shown in Table 1. Emission points with permitted emissions of less than 10 TPY of NO_x, SO_2 or PM_{10} were excluded.

Table 1: Holcim Emission Points

AIRS Point	Description	Emission Type
101	Raw Materials Extraction - Quarry Operations	Fugitive
111	Kiln	Point
115	Finish Mills - Cement Handling and Unloading	Point and Fugitive

Table 2 lists the permitted and actual emissions for all units with permitted or actual emissions over 10 TPY. The emissions listed for the Quarry (101), Kiln (111), and Finish Mills (115) are all averages of 2018-2020 averages as reported in the four factor analysis submitted by Holcim. This data was confirmed using APEN submittals and facility inspection reports.

Table 2: Holcim Permitted and Average Annual Emissions

Point	Permitted PM_{10} (TPY)	Actual PM_{10} (TPY)	Permitted SO_2 (TPY)	Actual SO_2 (TPY)	Permitted NO_x (TPY)	Actual NO_x (TPY)
101	67.3	53.9	*2.3*	*0.9*	19.4	*7.5*
111	247.6	34.5	721.0	362.5	2,086.8	1,538.7
115 *	34.3	19.8	*N/A*	*N/A*	*N/A*	*N/A*

*The finish mill only emits particulates. Thus, there are no SO_2 or NO_x permit limits or actual emissions.

As shown in Table 2, the actual SO_2 and NO_x emissions for the Quarry (101) are below the 10 TPY threshold, so these pollutants will not be analyzed for the quarry. This analysis will focus on the SO_2, PM_{10}, and NO_x emissions from the Kiln (111) and PM_{10} emissions from the Quarry (101) and Finish Mills (115). The kiln the primary source of visibility impairing pollutants including NO_x and SO_2. The finish mill system includes a combination of point and fugitive sources. The fugitive emissions result from material transfers, but these sources can be enclosed and controlled using baghouses, like point sources. The quarry emissions result from blasting and hauling of raw materials and alkali dust which are difficult to control fugitive sources of PM.

Applying the four factors discussed above to fugitive emission sources is more challenging than applying the same factors to stationary point sources of emissions. Fugitive emission sources are best controlled by work practices such as watering, reclamation, and vehicle speed limits. Fugitive emission reductions and associated costs are not as readily quantifiable or measured as those associated with the installation of emission control technologies on a point source, such as the kiln.

II. Source Controls

Kiln (AIRS 111)

The Holcim Florence kiln fires a combination of pipeline natural gas, low sulfur, high BTU coal, high BTU tire-derived fuel (TDF), and high BTU petroleum coke (pet coke). Holcim is also permitted to fire dried cellulose (55,000 TPY) and oil, including non-hazardous used oil (4,000 TPY), but has not fired either category of fuel during the 2018-2020 baseline period. Table 3 lists the average heat content of each fuel type along with the 2018-2020 average fuel usage.

Table 3: Fuel Usage and Specifications

	Fuel Heating Value *	2018-2020 Avg Fuel Usage **	Sulfur (% by weight)
Natural Gas	1,020 MMBtu/MMSCF	519 MMscf	Negligible
Coal	14,250 Btu/lb	56,334 TPY	0.5%
TDF	13,201 Btu/lb	34,373 TPY	2.0%
Pet Coke	16,661 Btu/lb	51,394 TPY	5.5%

* Fuel heating values are in MMBtu/MMscf for natural gas and Btu/lb for coal, TDF, and pet coke.
** Average fuel usage is MMscf/yr for natural gas and TPY for coal, TDF, and pet coke.

Table 4 depicts technical information for the Holcim Florence kiln.

Table 4: Florence Kiln RP-eligible Emission Controls and Reduction (%)

	Portland Cement Kiln
Placed in Service	2002
Description	Preheater/precalciner kiln with 5-stage, dual string preheater
Air Pollution Control Equipment	SO_2 - Wet Scrubber (2002), Inherent Scrubbing of the Cement Process in the Kiln and the In-line Raw Mill PM/PM_{10} - 4 Baghouses (Main, Clinker Cooler, Coal Mill, Alkali Bypass) (2002) NO_x - Low-NOx Burners (LNB), Low-NOx Precalciner, Staged Combustion, Selective Non-Catalytic Reduction (SNCR, January 2018)
Emissions Reduction (%)	SO_2 - 98.4% * PM / PM_{10} - 99.5% / 99.5% ** NO_x - 39.1% / 52.9% ***

*SO_2 reductions based on actual SO_2 emissions measured by CEMS and input sulfur content. The sulfur input to the kiln is estimated as (Annual tons coal * Weight fraction of sulfur in coal) + (Annual tons pet

coke * Weight fraction of sulfur in pet coke) + (Annual tons TDF * Weight fraction of sulfur in TDF) + (Annual tons of raw meal * Weight fraction of sulfur in raw meal).
**PM/PM10 reductions based on stack tests.
***The first number compares the 99th percentile of the 30-day emission rates from the RP analysis (4.97 lb/ton of clinker) to the 99th percentile of the 30-day emission rates from Jan 2018 - December 2020 (3.03 lb/ton of clinker), resulting in a 39.1% reduction. Both emission rates exclude a 10% reduction from firing TDF in order to try to isolate the SNCR reduction. The second number is based on the uncontrolled AP-42 emission factor for a preheater/precalciner kiln (4.2 lb/ton of clinker) compared to the 2018-2020 average 30-day emission rate (1.97 lb/ton of clinker).

The source has not announced a closure date for the kiln, so the Division will assume a remaining useful life of 20 years for any control cost analysis.

Finish Mills (AIRS 115)

The Finish Mill systems encompass the processing and unloading of final cement product. The system employ multiple baghouses to control particulate emissions. These control devices are summarized in Table 5.

Table 5: Finish Mills (Cement Handling & Unloading) Existing PM Controls

AIRS ID	Activity	Controls
115	115A - Finish Mill #2 Primary & Secondary Discharge	2 - Fabric Filter Baghouses
	115B - Elevator to Finish Mill #2 Air Separator	2 - Fabric Filter Baghouses
	115C - Finish Mill #2 Air Separator	2 - Fabric Filter Baghouses
	115D - Finish Mill #2 Cement Cooler Discharge	2 - Fabric Filter Baghouses
	115E - Cement Roller Press Feed Belt	Fabric Filter Baghouse
	115F - Cement Roller Press Feed Elevator	Fabric Filter Baghouse
	115G - Cement Roller Press System	Fabric Filter Baghouse
	115H - Cement Roller Press Statopol Elevator	Fabric Filter Baghouse
	115I - Cement Roller Press System	Fabric Filter Baghouse
	115J - Finish Mill #3 Air Slides	Fabric Filter Baghouse
	115K - Finish Mill #3 Conveyor/Elevator	Fabric Filter Baghouse
	115L -Finish Mill #3 Separator	Fabric Filter Baghouse
	115M - Finish Mill #3 Ball Mill	Fabric Filter Baghouse

III. Reasonable Progress Evaluation of Holcim Florence plant

a. SO_2

Step 1: Identify All Available Technologies

During the first 10-year planning period for Regional Haze, a Reasonable Progress (RP) analysis was completed for the Holcim Florence cement kiln that evaluated potential system upgrades, as well as emission limit tightening. The kiln was already utilizing a wet scrubber to provide flue gas desulfurization. Holcim estimated that the wet scrubber achieves over 90% SO_2 reductions across the control device. In addition, the cement manufacturing process achieves a high degree of SO_2 removal. Inside the rotary kiln, hot combustion gases come in contact with the limestone which produces free lime that reacts with the SO_2 in the gas stream. This process binds sulfur compounds in the clinker product, rather than emitting them into the atmosphere. EPA's AP-42 emission factor analysis for Portland cement kilns states that the process can remove more than 95% of sulfur, although high levels of pyrite may reduce this to 70%.[1] In its RP analysis, Holcim estimated that the combination of the kiln and the wet scrubber achieved an overall SO_2 removal efficiency of 98.3%. Based on a 90% wet scrubber efficiency, the kiln was reducing SO_2 by 83%, which falls within the lower half of the estimated range provided by EPA. Based on discussions with Holcim, along with data it provided on fuel and raw meal sulfur content, the Division believes that the primary source of sulfur for the Florence kiln is pyrite and other sulfur contaminants in the limestone, which represent over 86% of sulfur throughput for the kiln system. These sulfur contaminants reduce the inherent SO_2 removal in the kiln which accounts for the relatively high SO_2 emissions for a multi-stage preheater/precalciner kiln with top-tier SO_2 control provided by a wet scrubber. Over the 2018-2020 baseline period, the Holcim kiln had SO_2 emissions of 0.47 - 0.83 lb/ton of clinker, on an annual basis, with a three-year average of 0.63 lb/ton of clinker. In the Round 1 RP analysis, the Division calculated Holcim's average annual SO_2 emission rate at 0.5 lb/ton of clinker with a standard deviation of 0.26 lb/ton of clinker. The Florence kiln's 2018-2020 SO_2 emissions are in line with previous emissions and are achieved through the same combination of inherent SO_2 control of the process and the existing wet scrubber. This indicates Holcim's long-term compliance with the emission limits established during the first planning period.

The Division did not evaluate additional SO_2 control options during the first Regional Haze planning period because Holcim was already operating a wet scrubber, which is considered a top-tier control for SO_2 removal. RP was determined to be the combination of the inherent scrubbing of the cement process along with continued operation of the existing wet scrubber. However, the Division also evaluated emission limit tightening during the first planning period. The Division lowered the annual SO_2 limit from 1,006.5 TPY to 721.4 TPY. At the time, Holcim lacked an emission rate limit, and the Division established a new limit of 1.30 lb/ton of clinker, on a 30-day rolling average. The annual limit corresponds to an emission rate of 0.77 lb/ton of clinker, but this is not an enforceable limit. The lower annual limit and 30-day lb/ton of clinker emission rates were achievable without additional capital investment. Due to the high level of existing SO_2 control, Holcim did not review additional SO_2 control technology for the second planning period. The Division identified an additional control option, circulating fluidized bed absorbers (CFBA), which is discussed below.

EPA's August 2019 "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period" notes in Section II.B.3.f, that it may be reasonable for a state not to select a particular source for further analysis. The guidance specifically sources that are subject to and complying with recent NSPS requirements, sources that underwent recent

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[1] EPA. AP-42 Emission Factor for Portland Cement Manufacturing, page 6. January 1995.

BACT or LAER review, or sources that recently installed controls based on BART review during the first regional haze planning period. Although none of the specific exemptions listed in the guidance document apply to the Holcim Florence kiln, the existing wet scrubber achieves at least 90% SO_2 reductions, which is consistent with the NSPS alternate compliance method for new sources.[2]

Additionally, the Division reviewed EPA's RACT/BACT/LAER Clearinghouse (RBLC) for similar Portland cement kilns for the most recent 20 years and the EPA Menu of Control Measures for additional or improved potential control options. Most of the recently permitted kilns are multi-stage preheater/precalciner designs that are comparable to the Holcim Florence kiln. However, cement kiln emissions are highly dependent on fuel and raw material composition, in addition to the general kiln design. The RBLC determinations provide an indication of the achievable emission rates at Portland cement kilns which are subject to the latest NSPS. The lowest emission permitted emission rate listed in the RBLC was the Universal Cement Plant in Illinois which was permitted in 2010 at 0.4 lb/ton of clinker. As stated in the footnote above, newer cement kilns can comply with the current cement kiln NSPS either by meeting a 0.4 lb/ton of clinker SO_2 emission rate or by operating SO_2 controls that achieve 90% reductions. Illinois EPA deemed this to meet LAER and was achievable using a combination of the inherent sulfur removal of the process and a CFBA or equivalent. The Division was unable to identify any US cement plant, including the Universal Cement Plant in Illinois, that is currently using a CFBA. Other determinations range from 0.4 lb/ton to 1.0 lb/ton of clinker and utilized either the inherent sulfur control or the process, or the inherent sulfur control combined with lime injection. As stated earlier, the Holcim Florence plant currently operates with SO_2 emissions of 0.63 lb/ton of clinker, on an annual basis, and is subject to a 1.3 lb/ton limit, on a 30-day rolling average.

As discussed above, Portland cement kilns have two potential sources of sulfur: the fuel, which is generally coal, and the sulfide contaminants in the raw materials, such as pyrite in the limestone. This makes controlling sulfur emissions from cement kilns more challenging than coal-fired boilers where the sulfur content of the coal fuel is the only sulfur source. As a result, the Menu of Control Measures for reducing SO_2 emissions from Portland cement kilns is more extensive and includes: fuel substitution, raw material substitution, lime injection, and either wet or dry scrubbing. The RP analysis in the first Regional Haze planning period did not explore additional control options because the existing wet scrubber was determined be the highest performing add-on SO_2 control.

In the first round RP analysis, the Division estimated that the Holcim was providing 98.3% control of SO_2 emissions. Similarly, the Division estimated Holcim is currently reducing SO_2 emissions by 98.4%, as shown in Table 4. The Division evaluated the following potential controls to address the remaining SO_2 emissions:

- Fuel Substitution - Firing Tire-Derived Fuel (TDF)
- Raw Material Substitution
- Lime Addition to Kiln Feed
- Dry Sorbent Injection (DSI)
- Wet Scrubbers

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[2] See Cement Kiln NSPS 60.62(a)(4): "On and after the date on which the performance test required to be conducted by § 60.8 is completed, you may not discharge into the atmosphere from any kiln any gases which: Exceed 0.4 pounds of sulfur dioxide (SO_2) per ton of clinker on a 30-operating day rolling average if construction, reconstruction, or modification commences after June 16, 2008, unless you are demonstrating a 90 percent SO_2 emissions reduction measured across the SO_2 control device."

- Circulating Fluidized Bed Absorbers (CFBA)

Step 2: Eliminate Technically Infeasible Options

Fuel Substitution: Fuel substitution for Portland cement kilns involves firing a combination of fossil fuels and alternative fuels, such as non-hazardous waste and tire-derived fuel (TDF). In principal, converting a cement kiln to full natural gas combustion would significantly reduce SO_2 and PM_{10} emissions, but would not significantly reduce NO_x emissions. However, a natural gas flame in the main kiln burner may not sufficiently dissipate heat which can reduce clinker production and may require raw meal reformulation to maintain product quality. However, a natural gas flame in the main kiln burner may not sufficiently dissipate heat which can reduce clinker production and may require raw meal reformulation to maintain product quality.[3] The lower heat transfer of a natural gas flame in the main kiln can also lead to higher temperatures that increase thermal NO_x production.[4] Although few kilns use natural gas as the primary fuel, many kilns, including the Holcim Florence facility, fire natural gas at startup to minimize emissions while heating up the kiln, as required by NESHAP (MACT) requirements. Discussions with other Colorado kiln operators confirmed that operating a kiln entirely on natural gas may require extensive modifications to the kiln design and controls and result in lower production capacity. When used correctly, alternatives fuels with high energy content (Btu/lb), such as TDF, can help safely dispose of waste tires and reduce NO_x emissions from the kiln. However, the kiln operator needs to maintain proper combustion conditions to avoid emissions increases from firing TDF. Holcim is currently firing the kiln with low-sulfur coal, high-sulfur pet coke, natural gas for startup, and TDF, as indicated in Table 3.

In 2002, CEMEX conducted a stack test with the long-dry kiln firing a combination of coal and TDF. The stack tests suggested 40% reductions in SO_2 emissions from firing TDF without exceeding the standards for any other criteria pollutants or hazardous air pollutants.[5] However, the reductions are highly kiln dependent and also dependent on the fuel being replaced. Simulations for fuel switching at Lafarge's Brookfield cement plant in Nova Scotia indicated that switching from a 100% blend of high sulfur coal and pet coke (50-50 blend, 3.5% overall weight % sulfur) to 30% TDF and 70% coal/pet coke blend would reduce fuel SO_2 by 21%.[6] In contrast, EPA notes that TDF usage decreased SO_2 emissions around 20% for some kilns, but increased SO_2 emissions by a similar amount for other kilns. Overall, EPA expects a slight decrease in SO_2 emissions, depending on the kiln and type of fuel that is being replaced.[7]

As noted above, raw meal provides over 86% of the sulfur input to the Florence kiln, so increasing TDF from 0% to 30% of the fuel mix would only reduce sulfur input by approximately 3%. However, the Holcim Florence kiln is already utilizing a significant amount of TDF, approximately 22% of the fuel mix from 2018-2020, and the Division expects that real-

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[3] IEEE Cement Industry Technical Conference. "From coal to natural gas: Its impact on kiln production, Clinker quality and emissions." 2013.

[4] EPA. "Alternative Control Techniques Document Update - NO_x Emissions from New Cement Kilns" November 2007.

[5] BART Analysis for CEMEX Lyons Cement Plant. Page 6.

[6] Dalhousie University. "Use of scrap tires as an alternative fuel source at the Lafarge cement kiln, Brookfield, Nova Scotia, Canada" Page 23. July 21, 2015.

[7] EPA. "Air Emissions Data Summary for Portland Cement Pyroprocessing Operations Firing Tire-Derived Fuels" Page 24 of 33. 2008.

world SO_2 reductions would be less than 3%. Replacing high sulfur pet coke with TDF could decrease fuel SO_2, whereas replacing low sulfur coal with TDF could increase SO_2 emissions. Holcim did not provide cost or control estimates for replacing pet coke or coal with TDF. The Division notes that Holcim is permitted to fire approximately 20,000 more tons of TDF per year and the Division will continue to evaluate Holcim's permitted fuel mix and work with the company to ensure Holcim's fuel usage achieves cost effective reductions of SO_2, NO_x, PM, and HAP emissions. TDF is a technically feasible fuel option, but the Division expects additional increases in TDF firing would likely result in minimal SO_2 reductions and is not analyzing this option further.

Raw Material Substitution: As discussed previously, sulfur in the raw materials, primarily iron pyrite in the limestone, can oxidize in the kiln to form SO_2 according to the following reaction ($4FeS_2 + 11O_2 \rightarrow 2Fe_2O_3 + 8SO_2$). Sulfur in the raw materials represents the primary source of SO_2 generated in the Holcim Florence kiln. Holcim notes that the limestone sourced from the nearby quarry averages around 0.9% sulfur content, but pyrite levels are difficult to predict and lower sulfur limestone is not readily availability near the Florence facility. Furthermore, it stated that the additional SO_2 reductions would be minimal and would significantly increase costs. The Division recognizes that cement plants are built near a limestone source to minimize transportation costs that would make the facility economically infeasible. Even if lower sulfur limestone could be sourced at a reasonable cost, the increase in haze-forming pollutants from NO_x and PM emissions produced by the limestone delivery rail/truck could potentially offset SO_2 reductions in the kiln. Because raw material substitution would render most cement plants uneconomic, the Division considers this option infeasible.

Lime Addition to Kiln Feed: Calcium oxide (CaO), also known as lime, can be added to the raw meal to reduce sulfur dioxide emissions. The lime can react with the SO_2 released from the coal and limestone to produce calcium sulfite ($CaO + SO_2 \rightarrow CaSO_3$). The calcium sulfate can further react with oxygen to form calcium sulfate ($CaSO_3 + \frac{1}{2} O_2 \rightarrow CaSO_4$). These reactions can occur throughout the kiln and in the precalciner as long as the temperature and contact time are sufficient for the lime and SO_2 to react. The calcium sulfate is absorbed in the clinker which prevents the sulfur from being re-released as SO_2. Given the high degree of control achieved by the current wet scrubber system, which also utilizes lime, it's unlikely that injecting additional lime with the raw meal would significantly reduce SO_2 emissions. While it is technically feasible to add lime to the raw meal, the Division expects very little additional SO_2 reductions from this practice and is not considering this option further.

Dry Sorbent Injection (DSI): DSI involves injecting a finely ground sorbent into the gas stream of the kiln. The sorbent can be hydrated lime, sodium bicarbonate or Trona (soda ash). Water may be injected separately from the sorbent either downstream or upstream of the dry sorbent injection point to humidify the flue gas. When hydrated lime is used, the lime reacts to form calcium sulfate, similar to the reactions from lime addition that are described above. However, the DSI system can often achieve higher removal efficiencies than adding lime to the kiln feed because the sorbent particles and water droplets are more effectively distributed throughout the kiln and can better scavenge SO_2.

In the BART analysis for CEMEX, the Division estimated that DSI could further reduce SO_2 emissions by 50% over the baseline control inherent to the process. CEMEX went beyond the BART requirements and began operating a DSI system in 2016, which is currently achieving an 82% reduction from the baseline inherent SO_2 control provided by the cement production process. Despite the high level of SO_2 control from CEMEX's DSI system, the system's control efficiency is still below the 90% control efficiency of Holcim's wet scrubber. Because it is not technically feasible to operate a DSI system in series with a wet scrubber, the existing wet scrubber would need to be removed in order to install a DSI system. The Division does not consider it reasonable to replace a top tier SO_2 control with a lower performing alternative, and is eliminating this option from further consideration.

Wet Lime Scrubbing: Wet scrubbers must be located after the baghouse because the moist plume resulting from the wet scrubber system would create baghouse plugging issues if the scrubber is placed upstream of the baghouse. The flue gas passes through a sprayed aqueous solution of slaked lime ($Ca(OH)_2$) or limestone ($CaCO_3$). In either case, the calcium reacts with SO_2 to form calcium sulfite ($CaSO_3$) which remains in aqueous sludge that is typically dewatered and disposed of in a landfill. The calcium sulfite sludge may also be oxidized to form calcium sulfate that can be added to the finish mill in place of purchased gypsum. Wet lime scrubbing can achieve very high control efficiencies, in some cases over 95%.[8] The primary downside to wet lime scrubbing is the high water usage which is a precious commodity in the arid western US. Given Holcim's high baseline SO_2 emissions using the existing wet scrubber, the Division considers the increased water usage to be a valid trade-off to reduce visibility impairing SO_2 and acid gas emissions. As discussed above, Holcim estimates at least 90% control efficiency for its wet scrubber and the company did not identify any upgrades to the wet scrubber that would improve its performance. The Division notes that dry scrubbing is more common on US cement kilns because many newer kilns can meet the 0.4 lb/ton of clinker NSPS limit for SO_2 based on very low sulfur raw meal. The NSPS notes that a wet scrubber is likely required to meet the alternative 90% SO_2 control efficiency, but otherwise discusses dry scrubbers to meet the standards. Wet scrubbers are therefore fairly uncommon on US cement kilns and are considered the top tier SO_2 add-on control. The Division will not analyze changes to the wet scrubber in further detail.

Circulating Fluidized Bed Absorber (CFBA): The 2008 project summary for the Universal Cement plant in Chicago, Illinois proposed a combination of the inherent SO_2 control of the process and CFBA, or equivalent, as LAER for SO_2 control. CEMEX evaluated CFBA as a potential SO_2 control, so the Division evaluated the technology for Holcim's Florence kiln as well. Similar to other scrubbing technology, flue gas passes through a lime slurry. In the case of CFBA this reaction takes place in a reactor, typically a vertical cylinder. Flue gases enter the reactor at the bottom and flows upward, lime is sprayed into the reactor and reacts with the SO_2, HCl, and other acid gases in the flue gas and neutralizes the acid gases. The reactor includes an integral cyclone to collect solid particles from the flue gas, such as unreacted lime, reaction products, and cement kiln dust for recirculation back to the reactor. The solid particles that do not get recirculated from the integral cyclone are controlled by a downstream baghouse. In other industries, CBFA has achieved control efficiencies well above 90%. However, they have not been used in the cement industry. The Universal Cement project summary notes, "The CFBA is a cutting-edge technology, proven in other industries, that has shown great promise as an innovative means to control SO_2 in the cement industry." A draft construction permit for the Universal Cement plant was issued in August 2011.[9] In June 2013, Illinois EPA granted an 18-month extension to begin construction of the Universal Cement plant.[10] The Division was unable to find a final construction permit or Title V permit and

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[8] EPA. Air Pollution Control Fact Sheet - Flue Gas Desulfurization (FGD) Wet, Spray Dry, and Dry Scrubbers. 2003.

[9] Illinois EPA. Universal Cement Plant - Draft Permit. 2011.

[10] Transmission Hub. "Illinois gives coal-fired cement project an extra 18 months." June 26, 2013.

believes the Universal Cement plant was never constructed, and was unable to identify any other US cement kilns utilizing CFBA for SO_2 control. Given the lack of cement plants using CFBA, the Division considers the technology unavailable.

The Division concludes that raw material substitution and CBFA are not technically feasible. A DSI system is also not a suitable option because it would achieve lower control efficiency than the existing wet scrubber. Lastly, additional firing of TDF and injecting lime with the raw meal are not expected to yield meaningful reductions over the currently operating combination of the inherent scrubbing of the cement process and the existing wet scrubber. The Division did not identify any upgrades to the existing controls that will achieve significant SO_2 reductions. Therefore, there are no remaining technically feasible options other than the existing controls in operation for the Holcim Florence kiln.

Step 3: Evaluate Control Effectiveness of Each Remaining Technology

Stack SO_2 emissions from the Holcim Florence kiln are monitored with a CEMS. Although Holcim is not subject to the cement kiln NSPS, the 90% control efficiency provided by the wet scrubber meets the alternate compliance option for SO_2 emissions under the NSPS. Based on calculations of the stack SO_2 emissions versus the sulfur input from the fuel and raw meal, the Division estimates that the Holcim kiln and wet scrubber are providing 98.4% overall SO_2 control efficiency. No additional controls were identified that would provide significant SO_2 reductions.

Step 4: Evaluate Factors and Present Determination

Factor 1: Cost of Compliance

There are no associated costs of compliance since no options other than continuing proper operation of the kiln and the existing wet scrubber are considered technically feasible and cost-effective.

Factor 2: Time Necessary for Compliance

There is no additional time required for compliance since no options other than continuing proper operation of the kiln and the existing wet scrubber are considered technically feasible and cost-effective.

Factor 3: Energy and Non-Air Quality Impacts

As discussed earlier, the high water usage of the existing wet scrubber is the primary downside to this control technology. However, the Division has determined that this is the most effective control option for reducing the high SO_2 emissions generated by the sulfur in Holcim's raw materials. Replacing the high sulfur raw materials from the local quarry with lower sulfur materials from a distant source is not economically feasible for Holcim, or most other cement plants. Although increases in Holcim's clinker production could increase total water usage, the Division does not anticipate any changes in the existing controls that will increase the water consumption rate (gallons/ton of clinker). Similarly, the total energy consumption could increase as clinker production increases, but the energy consumption rate is not expected to change in future years.

Factor 4: Remaining Useful Life

Holcim has not announced a closure date for the Florence kiln or its associated limestone quarry. Therefore, the Division assumes that the kiln will remain in operation for at least 20 years. Because no additional control options are considered technically feasible and cost-effective, remaining useful life does not impact cost estimates for additional controls.

Determinations
Upgrades to the existing SO_2 control system were evaluated, and the state determined that meaningful upgrades to the system are not available. Because the kiln will remain in operation for 20 years or more, the Division also evaluated emission limit tightening. Holcim is currently operating a modern, energy-efficient preheater/precalciner kiln with top-tier wet scrubber SO_2 controls. The kiln's relatively high total SO_2 emissions are due to sulfur content in the raw meal, which is difficult to predict and control without significant imports of low sulfur material from distant sources. This control option is cost prohibitive and can result in offsetting emission increases from raw material deliveries. During the first Regional Haze planning period, the Division evaluated emission limit tightening and lowered the annual limit to 721.4 TPY. At the maximum permitted clinker production of 1,873,898 TPY, this corresponds to an annual average emission rate of 0.77 lb/ton of clinker, though this annual emission rate limit is not in Holcim's permit. In light of the inherent variability of sulfur content in both the coal and the raw materials, the Division established a higher 30-day rolling average SO_2 limit of 1.3 lb/ton of clinker. During the 2018-2020 baseline period, the Holcim kiln has complied with the 1.3 lb/ton of clinker emission rate limit and the 721.4 TPY annual limit. For establishing the NO_x limits during the first Regional Haze planning period, the Division set the NOx limit at the 99th of the 30-day rolling averages during the baseline period. Applying this approach to Holcim's SO_2 emissions results in a limit of 1.30 lb/ton of clinker, which is equal to the current limit. Because the Division has not identified any cost-effective SO_2 control options and the current limits allow for long-term compliance, it has determined that tighter emission limits are not practical.

Based upon its consideration of the four factors summarized herein and detailed in Appendix C, the Division recommends that SO_2 RP is the following:

1) The following existing SO_2 emission limits shall remain in effect for this planning period:
Kiln: 1.3 lb/ton of clinker (30-day rolling average)
721.4 TPY (12-month rolling average)

The state assumes that the RP emission limits can be achieved through continued operation and maintenance of the wet scrubber system and good operating practices for the kiln. The Division has determined that this emission rate is achievable without additional capital investment through the four-factor analysis.

b. Filterable Particulate Matter (PM10)

Step 1: Identify All Available Technologies

Quarry (AIRS 101)

Control techniques for fugitive dust generally involve watering, chemical stabilization, windbreaks, source enclosures, paving, and modified work practices which are effective options for reducing emissions. In most locations, windbreaks and enclosures are often impractical due to the size of the sources. Paving is often impractical due to cost, the weight of the equipment using the roads, and the temporary nature of many roads in industries such as mining and construction.

EPA's AP-42 and Menu of Control Measures for Portland Cement Manufacturing include several methods for limiting fugitive dust. These include the application of chemical stabilizers and dust suppressants, speed limitations on unpaved roads, gravel, and paving. A review of the RBLC and state permits also found provisions that require adequate soil moisture requirements and activity limitations to limit dust under windy conditions.

Wind erosion of open material stockpiles and exposed areas may generate dust emissions. Outdoor storage piles are common in mining operations and are typically left uncovered, due to the size of the piles and the need for frequent transfer of material into and out of the stockpiles. Dust is generated from material loading onto the pile, loadout from the pile, truck and loading equipment activity in the stockpile area, and wind. Dust emissions are most likely to occur when material is added to the pile. As the stockpile weathers, moisture causes the aggregation and cementation of fine particles to the surface of larger particles. Rainfall also soaks the interior of the pile which then dries very slowly. Common control measures for stockpiles include watering and the use of chemical dust suppressants. Enclosing or covering inactive piles can reduce wind erosion, but this is often impractical due to the size of the stockpiles.

Vehicle traffic on unpaved roads generates emissions of fugitive dust. Emissions at industrial sites are highly correlated with vehicle weight. Common controls fall into three main categories. Vehicle restrictions limit the speed, weight, or number of vehicles on the road. Surface improvements include measures such as paving or adding gravel to the unpaved road. Surface treatments include measures such as watering or treatment with chemical dust suppressants. Traffic controls are inexpensive and may provide moderate emission reduction, but are difficult to enforce. Paving is highly effective, but is costly and not feasible for many industrial roads travelled by heavy vehicles. Watering and chemical suppressants are applicable to most haul roads at moderate cost. Many chemical suppressants form a hardened crust on the road surface, binding particles together. Chemical suppressants are generally not cost effective in the case of temporary roads, which are common in mining operations.

Blasting to break up overburden and coal generates fugitive dust and emissions are uncontrolled. EPA's Menu of Control Measures does not include any controls for explosives blasting. A search of the RBLC and other Colorado permits found no controls other than limits on blasting frequency and quantity of explosive used.

Kiln (AIRS 111)

PM emissions from the kiln are currently controlled by four baghouses: the Main baghouse (421-BF1), the Coal Mill baghouse (L61-BF1), the Clinker Cooler baghouse (471-BF1), and the Alkali Bypass baghouse (4A1-BF1). Exhaust from all four baghouses flows out a common stack. Approximately 90% of the preheater/precalciner exhaust flows through the raw mill for drying and to provide additional ammonia and SO2 scrubbing. After passing through the raw mill, the gas flows through the Main baghouse, followed by the wet scrubber, and finally out the main stack. Approximately 10% of the preheater/precalciner exhaust is directed to the coal mill for coal drying and then filtered through the Coal Mill baghouse. The Coal Mill baghouse exhaust enters the cooler exhaust duct just prior to discharge through the main stack. Alkali bypass gases are filtered by the Alkali Bypass baghouse, scrubber by the wet scrubber, and exhausted out the common stack. The alkali bypass is used intermittently to produce low alkali clinker. Holcim is subject to the National Emission Standards for Hazardous Air Pollutants for Source Categories; Portland Cement Manufacturing Industry, 40 CFR Part 63 Subpart LLL. The NESHAP (MACT) establishes PM emissions limits that apply to the Florence kiln, coal mill, clinker cooler, and alkali bypass. Because the kiln, coal mill, clinker cooler, and alkali bypass share a common stack, Holcim tracks compliance with the NESHAP according to the alternative compliance standard given by 63.1343(b)(2) Equation 1. This equation establishes a PM limit based on the combined airflow through the kiln, coal mill, clinker cooler, and alkali bypass, rather than the fixed 0.07 lb/ton of clinker limit that applies to standalone kilns or clinker coolers. During the 2018-2020 baseline period, Holcim's annual PM_{10} emissions ranged from 0.037 to 0.090 lb/ton of clinker, with a three year average of 0.060 lb/ton of clinker.

EPA's August 2019 "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period" notes in Section II.B.3.f, that it may be reasonable for a state not to select a particular source for further analysis, specifically for the purpose of PM control measures, if the source is meeting a NESHAP standard promulgated since July 2013[11]. The most recent final rule was issued for 40 CFR Part 63 Subpart LLL in August 2017 and the 2019 facility inspection report states that Holcim is in compliance with the 2017 final rule.

The Division has reviewed the requirements of the NESHAP (MACT) for Portland cement production and evaluated the RACT/BACT/LAER clearinghouse database for other available particulate control options. Nearly all new kilns rely on baghouses for PM control, though some existing kilns rely on electrostatic precipitators (ESP). Baghouses are the preferred option as they can achieve control efficiencies well over 99%, compared to ESPs which typically have control efficiencies below 99%. As stated earlier, Holcim operates baghouses that provide over 99.5% control efficiency and ensure compliance with the alternative MACT PM standard. Holcim reports actual PM_{10} emissions from the common stack based on an emission factor established through a stack test. Based on stack testing, Holcim reports PM/PM_{10} control efficiency of 99.5% on its APEN submittals to the Division. The Division also notes that Holcim's maximum annual PM_{10} emissions were 52.68 TPY during the 2018-2020 baseline period, which is well below the 247.6 TPY permit limit. The Division has determined that the Holcim Florence kiln already has top tier PM controls and no new particulate control measures have been identified that would significantly improve upon the existing PM controls that are required to comply with the NESHAP.

Finish Mills (AIRS 115)

The finish mills (finish mills #2 and #3) produce the final Portland cement product by grinding the required proportions of clinker, gypsum, and additives to produce a specific cement product type. Finish mill #2 and #3 are fed from storage silos by conveyor belts. Clinker, gypsum, limestone, and/or other finish grinding additives are proportionately supplied to the finish mill feed belts from storage silos to obtain the desired chemical composition. Grinding aid is injected into the finish mills to aid the grinding process and produce a more flowable product. Finish Mill #3, which is a two-stage grinding system, is designed with a roller press and a ball mill to produce finished cement. Clinker, gypsum and other additives are transported to the roller press feed bin by belt conveyors and a bucket elevator. The product from the roller press is fed into a static separator with the coarse material returning to the press and the fines collected in cyclones and deposited into an intermediate bin which is used to feed the ball mill. The coarse material from the high efficiency separator is fed to a one-compartment ball mill, which is equipped with water spray and grinding aid systems. The product from the ball mill is combined with the product from the intermediate bin and fed to the high efficiency separator. The fines from the dynamic separator form a cement product and are collected in a baghouse. Part of the product passes through a cement cooler. The cooler product joins the non-cooled product and is then transported to the appropriate cement storage silo via belt, elevator, and airslide. The roller press, ball mill, and the separations processes are well controlled with additional baghouses. Each of these points calculate emissions based on an AP-42 emission factor. There is an annual PM10 limit of 34.3 TPY, but there is not an annual emission limit for each point. Based on the stack test results,

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[11] Guidance on Regional Haze State Implementation Plans for the Second Implementation Period, August 20, 2019.

Holcim reports PM/PM_{10} control efficiency of 99.5% on its APEN submittals to the Division. EPA notes that finish mill grinding circuits are typically controlled using fabric filter baghouses and only provides controlled emission factors based on baghouses, not on other potential controls such as Electrostatic Precipitators (ESPs).[12] The Division has determined that the Holcim Florence finish mill grinding system already has top-tier PM controls and no new particulate control measures have been identified that would significantly upon the existing fabric filter baghouses.

Step 2: Eliminate Technically Infeasible Options

Quarry (AIRS 101)

Enclosing or covering stockpiles is technically infeasible due to the size of the piles which cover multiple acres of surface area. The only potentially feasible additional control that could be applied to further reduce the fugitive dust emissions is paving of the haul roads. Plant entryway, truck service roads, and other traffic areas must be concreted or graveled and the Division evaluated this option for haul roads. At this location the haul roads are established, not temporary. Paving for vehicles of over 150 tons loaded weight is not technically practical as the weight of the vehicles breaks down the pavement in a short time. In recognition of the limited useful life of paving unpaved haul roads and the net air quality penalty associated with the need to continuously fix paved haul roads damaged by heavy truck traffic, the Division has determined that paving haul roads is not technically feasible.

Kiln (AIRS 111)

The Division has determined that the currently operating PM/PM_{10} controls on the kiln perform better than any of the identified control technologies. Therefore, there are no remaining technically feasible options other than the existing controls in operation for the Holcim Florence kiln.

Finish Mills (AIRS 115)

The Division has determined that the currently operating PM/PM_{10} controls on the finish mill grinding circuit perform better than any of the identified control technologies. Therefore, there are no remaining technically feasible options other than the existing controls in operation for the Holcim Florence finish mill grinding system.

Step 3: Evaluate Control Effectiveness of Each Remaining Technology

Quarry (AIRS 101)

Multiple strategies are used to control fugitive dust at the Florence quarry. The onsite quarry is the only local source of limestone for the Holcim Florence kiln, though the facility may blend small amount of raw materials that are delivered to the site.

Particulate emissions from blasting activity are managed using work practices. The facility permit currently includes annual limits on the quantity of explosives used. Also, blasting activities must be stopped if wind speeds are greater than or equal to 30 miles per hour, and the source operates a meteorological station to monitor wind speeds. In addition, the facility's Particulate Emissions Control Plan requires wet drilling and sequential blasting to limit fugitive dust generation and sleeve and paper filters to capture drilling dust.

The facility Particulate Emissions Control Plan specifies that visible emissions are not to exceed 20% opacity, and off-property transport of visible emissions is prohibited. Blasting

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[12] EPA. AP-42 Emission Factor for Portland Cement Manufacturing, pages 7 and 14. January 1995.

activities are subject to this prohibition of off-property transport. Various particulate control and opacity reduction measures are required depending for each specific mining activity.

Topsoil removed at the Florence quarry is generally dense and contains sufficient natural moisture to control emissions. Emissions from topsoil handling activities such as removal, loading, and hauling are controlled by watering if soil moisture is not adequate to limit emissions. Topsoil is removed early in the pit operation and is not disturbed again until it is returned to the pit during reclamation activities. Enclosure or covering of the inactive topsoil stockpiles is impractical due to the size of the stockpiles. Stockpiles are required to be compacted and revegetated within one year of placement. During reclamation, dust emissions from topsoil handling will be controlled by watering if soil moisture is not adequate to control fugitive dust emissions.

Overburden removed at the Florence quarry generally contains sufficient moisture to control emissions. If moisture is not adequate, watering is required to control fugitive dust emissions during overburden handling activities. Truck traffic during hauling and overburden unloading effectively compacts the pile. The active portion of the overburden stockpile is also watered as needed as material is being unloaded. Reclamation work and sequential extraction of material is required to keep the total disturbed area at any one time to a minimum. Enclosure or covering of the inactive out-of-pit overburden stockpile is not practical due to the size of the stockpile.

The Florence quarry applies multiple control strategies to limit fugitive dust emissions from unpaved roads. The quarry posts speed limits on mine roads and provide regular training to employees to follow posted speed limits. Vehicle speeds are restricted to a maximum of 35 miles per hour on all unpaved active haul roads for empty trucks. Vehicles reaching this speed are generally light duty pick-ups. Front end loaders, water trucks, and 150-ton haul trucks generally travel at much slower speeds. Loaded haul trucks are limited to 25 miles per hour. The roads are frequently maintained and vehicle traffic is limited to established roadways. Material hauling activities must utilize haul trucks with at least 150 ton capacity to minimize vehicle miles travelled. It is impractical to apply gravel to roads because the gravel would be depressed into the road within a period of a few days to a few weeks depending on soil conditions.

Additional control at the quarry is achieved on unpaved haul roads by applying chemical dust suppressant and watering as needed. Dust suppressant is applied in accordance with the manufacturer's recommendations to maintain a suitable surface crust that achieves 88% emission control. Holcim is required to water haul roads as needed to maintain sufficient soil moisture. Also, the facility must clean up any debris that could become airborne within four hours. In addition to the unpaved haul roads, disturbed surfaces at outdoor clinker areas are watered as needed to limit dust emissions.

The Florence quarry effectively controls fugitive dust using controls and work practices that are standard in mining operations. The Division has not identified any additional work practices or control measures to reduce fugitive emissions from the quarry.

Kiln (AIRS 111)

PM_{10} emissions and opacity from the Holcim kiln, clinker cooler, and alkali bypass are monitored with a CPMS and multiple COMS, and controlled with four baghouses. The latest full-facility inspection report from 2019 determined that the facility is meeting the 20% opacity MACT limits and the lb/ton of clinker limit calculated using Equation 1, which applies to commingled sources. Holcim also conducts stack tests on the kiln to establish the control efficiency for reporting emissions. Based on the stack tests, Holcim reports the baghouses achieve greater than 99.5% control efficiency. The Division has not identified any additional control measures to reduce PM emissions from the kiln.

Finish Mills (AIRS 115)

PM_{10} emissions from the Holcim finish mill emission points are reported based on AP-42 emission approved by the Division for the individual points. The system is also subject to 10% opacity MACT limits and compliance with the opacity standard is determined using a Method 22 visual examination. Holcim reports the baghouses achieve 99.5% control efficiency on the APENs submitted to the Division. The Division has not identified any additional control measures to reduce PM emissions from the finish mill system

Step 4: Evaluate Factors and Present Determination

Factor 1: Cost of Compliance

Quarry (AIRS 101)

There are no associated costs of compliance since no other options are considered technically feasible except continuing the current work practices to minimize fugitive dust emissions.

Kiln (AIRS 111)

There are no associated costs of compliance since no other options are considered technically feasible except for continuing operation of the existing PM controls on the kiln.

Finish Mills (AIRS 115)

There are no associated costs of compliance since no other options are considered technically feasible except for continuing operation of the existing PM controls on the finish mill grinding circuit.

Factor 2: Time Necessary for Compliance

Quarry (AIRS 101)

There is no additional time required for compliance since no other options are considered technically feasible except continuing the current work practices to minimize fugitive dust emissions.

Kiln (AIRS 111)

There is no additional time required for compliance since no other options are considered technically feasible except for continuing operation of the existing PM controls on the kiln.

Finish Mills (AIRS 115)

There is no additional time required for compliance since no other options are considered technically feasible except for continuing operation of the existing PM controls on the finish mill grinding circuit.

Factor 3: Energy and Non-Air Quality Impacts

Quarry (AIRS 101)

There are no specific energy and non-air quality impacts associated with continuing the current work practices at the Florence quarry.

Kiln (AIRS 111)

There are no specific energy and non-air quality impacts associated with the continued operation of the existing PM controls on the kiln.

Finish Mills (AIRS 115)

There are no specific energy and non-air quality impacts associated with the continued operation of the existing PM controls on the finish mill grinding system.

Factor 4: Remaining Useful Life

Quarry (AIRS 101)

Holcim has not announced a closure date for the Florence kiln or its quarry. Therefore, the Division assumes that mining will continue at the quarry for at least 20 years. Because no additional control options or work practices are considered technically feasible, remaining useful life does not impact cost estimates for additional controls.

Kiln (AIRS 111)

Holcim has not announced a closure date for the Florence kiln or its quarry. Therefore, the Division assumes that the kiln will remain in operation for at least 20 years. Because no additional control options are considered technically feasible, remaining useful life does not impact cost estimates for additional controls.

Finish Mills (AIRS 115)

Holcim has not announced a closure date for the Florence kiln or its associated quarry. Therefore, the Division assumes that the finish mill grinding system will remain in operation for at least 20 years. Because no additional control options are considered technically feasible, remaining useful life does not impact cost estimates for additional controls.

Determinations

Quarry (AIRS 101)

Based upon its consideration of the four factors summarized herein and detailed in Appendix C, the Division recommends that RP for PM_{10} is the following:

1) The following existing requirements for the quarry shall remain in effect for this planning period:
   - -Compliance with the current permit limits and provisions applicable to particulate control for mining activities and material handling and hauling
   - -Compliance with the facility Particulate Emissions Control Plan

2) The following existing PM_{10} emission limit shall remain in effect for this planning period:
   Quarry: 67.3 TPY

The state assumes that the RP emission limits can be achieved through continued compliance with the facility Particulate Emission Control Plan and other existing permit limits and provisions. The Division has determined that these emission limits are achievable without additional capital investment through the four-factor analysis.

Kiln (AIRS 111)

Based upon its consideration of the four factors summarized herein and detailed in Appendix C, the Division recommends that RP for PM_{10} is a combination of the following:

1) The following existing PM_{10} MACT limits shall remain in effect for this planning period:

Kiln: lb/ton of clinker limit determined by 40 CFR 63.1343(b)(2) Equation 1
246.3 TPY (12-month rolling total)

The state assumes that the RP emission limits can be achieved through continued operation and maintenance of the existing fabric filter baghouses. The Division has determined that these emission limits are achievable without additional capital investment through the four-factor analysis.

Finish Mills (AIRS 115)

Based upon its consideration of the four factors summarized herein and detailed in Appendix C, the Division recommends that RP for PM_{10} is complying with the following limit:

1) The following existing PM_{10} emission limit shall remain in effect for this planning period:
Finish Mill: 34.3 TPY

The state assumes that the RP emission limits can be achieved through continued operation and maintenance of the existing fabric filter baghouses. The Division has determined that this emissions limit is achievable without additional capital investment through the four-factor analysis.

c. *Nitrogen Oxides (NOx)*

Step 1: Identify All Available Technologies

In the first Regional Haze planning period, the Division evaluated multiple pre and post combustion controls as well as potential system upgrades, through the four-factor analysis. Based upon its consideration of the four factors (as discussed in the 2011 Regional Haze SIP), an RP determination for the Holcim Florence kiln recommended an emission rate limit of 2.73 lb/ton of clinker, on a 30-day rolling average. The facility could comply with this limit by utilizing an SNCR with 45% control efficiency. The Division also established an annual NO_x limit of 2,086.8 TPY, on a 12-month rolling average. The Division followed a complex process to estimate baseline emissions and potential SNCR reductions, as summarized below.

In order to establish the new limits, the Division first estimated the baseline emissions rate on an annual basis and a 30-day rolling average basis. The Holcim kiln was built with numerous NO_x reduction technologies such as low-NO_x burners (LNB), a low-NO_x precalciner, staged combustion, and an advanced process control system. These controls are fundamental to the kiln operation and are therefore included in the baseline emission rate. The Division first accounted for the inherent variability in cement kiln emissions. The annual baseline emission rate was based on the 5-year average annual rate plus one standard deviation, resulting in an annual baseline of 3.64 lb/ton of clinker. Because short-term emissions are much more variable, the Division used the 99th percentile of the 30-day emission rates to establish the 30-day emission rate baseline of 4.47 lb/ton of clinker. However, both of these emission rates include NO_x reductions from firing TDF. The Division conservatively estimated 10% NO_x reduction from firing TDF. Because TDF usage is not consistent, this reduction was removed to establish the annual and 30-day average baseline emission rates. After this adjustment, the annual baseline was estimated at 4.04 lb/ton of clinker and the 30-day baseline was 4.97 lb/ton of clinker.

Next, the Division estimated the potential emission reduction from SNCR. The Division initially assumed a 50% control efficiency for an SNCR on the Holcim kiln, similar to BART analysis for CEMEX. However, the Holcim kiln utilizes its alkali bypass intermittently with approximately 30% of kiln airflow directed through the bypass. Because of Holcim's kiln design, the SNCR would be unable to treat the bypass gas. The Division assumed approximately 10% of kiln air passed through the bypass without being treated by the SNCR. This resulted in an estimated 45% control efficiency and a controlled annual emission rate of 2.23 lb/ton of clinker and a controlled 30-day average limit of 2.73 lb/ton of clinker. The annual limit of 2,086.8 TPY was established by multiplying the 2.23 lb/ton emission rate by the permitted clinker production limit of 1,873,898 TPY.

Holcim installed the SNCR in 2018 and it has been operating continuously since January 2018. The Division utilized the 99th percentile of the 30-day emission rates from January 2018 through December 2020 to evaluate the SNCR control efficiency. During this 2018 period, the 99th percentile was 2.73 lb/ton of clinker, which includes reductions from firing TDF. Removing the 10% NO_x reduction from firing TDF results in a 99th percentile value of 3.03 lb/ton of clinker for 2018 versus 4.97 lb/ton of clinker for the initial planning period. As shown in Table 7 below, this indicates that the Holcim SNCR has reduced NO_x emissions by 39.1%. The kiln does not include flow monitors for the alkali bypass that allow the Division to accurately assess the average alkali bypass flow rate over time. Therefore, the Division cannot determine if higher usage of the alkali bypass accounts for the lower SNCR performance. The average of the 30-day emission rates for the Holcim Florence kiln are 1.98 lb/ton of clinker, which is comparable to the 2016-2018 average of 1.95 lb/ton for the GCC Pueblo kiln, but the NO_X emissions at the Florence kiln are more variable. The standard deviation of the 30-day emission rates for the Holcim Florence kiln is around 0.42 lb/ton of clinker compared to 0.21 lb/ton of clinker for the GCC Pueblo kiln.

Table 6: NO_x reduction from SNCR

	99th Percentile (w/ TDF) (lb/ton)	99th Percentile (w/o TDF) (lb/ton)	% Reduction from 1st Period
1st Planning Period	4.47	4.97	
Jan 2018 - Dec 2020	2.73	3.03	39.1%

The Division reviewed EPA's RACT/BACT/LAER Clearinghouse (RBLC) for similar Portland cement kilns for the most recent 20 years and the EPA Menu of Control Measures for additional or improved potential control options. Most of the recently permitted kilns are multi-stage preheater/precalciner designs that are comparable to the Holcim Florence kiln. However, cement kiln emissions are highly dependent on fuel and raw material composition, in addition to the general kiln design. The RBLC determinations provide an indication of the achievable emission rates at Portland cement kilns that are subject to the latest NSPS. The lowest emission permitted emission rate listed in the RBLC was the Universal Cement Plant in Illinois which was permitted in 2010 at 1.2 lb/ton of clinker. Illinois EPA deemed this to meet LAER and was achievable using a combination of staged combustion and SNCR. This facility was never constructed. The CEMEX North Brooksville Kiln 3 was permitted in 2007 at 1.5 lb/ton of clinker with SNCR or SCR or a combination of these two. The permit was withdrawn and this kiln was never constructed. Other determinations range from 1.5 lb/ton to 2.65 lb/ton of clinker and utilize SNCR, often combined with indirect firing, low-NO_x burners (LNB), and staged combustion, all of which are utilized in the Holcim Florence kiln.

The following NO_X controls were evaluated, if technically feasible, in the first planning period RP analysis:

-Water Injection
-Selective Non-Catalytic Reduction (SNCR)

-Selective Catalytic Reduction (SCR)

In the RP analysis, the Division concluded that SCR was technically infeasible given the lack of any US cement kilns utilizing SCR at the time. Water injection was considered feasible, but was expected to provide much lower NO_x reduction than SNCR. The Holcim kiln was already utilizing indirect firing with LNB, a low-NO_x precalciner, an advanced process control system, and firing TDF. The Division did not identify any upgrades to these existing controls that would achieve additional NO_x reductions. Ultimately, the Division selected SNCR to meet the RP control requirements and estimated it could reduce NO_X emissions by 45%. As discussed earlier, the SNCR on the Florence kiln is currently achieving around 39% NO_X control efficiency, as shown in Table 4.

The following kiln NO_x controls were considered, if technically feasible, for this second planning period:

-Fuel Substitution - Firing Tire-Derived Fuel (TDF)
-Selective Non-Catalytic Reduction (SNCR)
-Selective Catalytic Reduction (SCR)
-Hybrid SCR and SNCR

Step 2: Eliminate Technically Infeasible Options

Fuel Substitution: Fuel substitution for Portland cement kilns involves firing a combination of fossil fuels and alternative fuels, such as non-hazardous waste and tire-derived fuel (TDF). In principal, converting a cement kiln to full natural gas combustion would significantly reduce SO_2 and PM_{10} emissions, but would not significantly reduce NO_X emissions.[13] However, a natural gas flame in the main kiln burner may not sufficiently dissipate heat which can reduce clinker production and may require raw meal reformulation to maintain product quality.[14] The lower heat transfer of a natural gas flame in the main kiln can also lead to higher temperatures that increase thermal NO_x production.[15] Although few kilns use natural gas as the primary fuel, many kilns, including the Holcim Florence facility, fire natural gas at startup to minimize emissions while heating up the kiln. Discussions with other Colorado kiln operators confirmed that operating a kiln entirely on natural gas may require extensive modifications to the kiln design and controls and result in lower production capacity. When used correctly, alternatives fuels with high energy content (Btu/lb), such as TDF, can help safely dispose of waste tires and reduce NO_x emissions from the kiln. However, the kiln operator needs to maintain proper combustion conditions to avoid emissions increases from firing TDF. Holcim is currently firing the kiln with low-sulfur coal, high-sulfur pet coke, natural gas for startup, and TDF, as indicated in Table 3.

In 2002, CEMEX conducted a stack test with the long-dry kiln firing a combination of coal and TDF. The stack tests on this long-dry kiln suggested 24.4% reductions in NO_X emissions from firing TDF without exceeding the standards for any other criteria pollutants or hazardous air pollutants.[16] However, the reductions are highly kiln dependent and also dependent on the

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[13] EPA. "Alternative Control Techniques Document Update - NOx Emissions from New Cement Kilns." Page 44 of 129. November 2007.

[14] IEEE Cement Industry Technical Conference. "From coal to natural gas: Its impact on kiln production, Clinker quality and emissions." 2013.

[15] EPA. "Alternative Control Techniques Document Update - NO_x Emissions from New Cement Kilns" November 2007.

[16] BART Analysis for CEMEX Lyons Cement Plant. Page 21

fuel being replaced. Simulations for fuel switching at Lafarge's Brookfield cement plant in Nova Scotia indicated that switching from a 100% blend of high sulfur coal and pet coke (50-50 blend, 3.5% overall weight % sulfur) to 30% TDF and 70% coal/pet coke blend would reduce fuel NO_x by 23%.[17] In contrast, EPA expects that firing TDF can reduce NO_x emissions by 33% on average, but in rare cases kilns may see NO_x increases around 20% as well as increases of other criteria pollutants. Overall, the Division expects that firing TDF can reduce NO_x emissions.

Holcim is already permitted to fire TDF and has used large amounts of this alternative fuel when available. Colorado has the largest waste tire piles, known as monofills, in the country and combusting them at high heat in a cement kiln not only reduces NO_x emissions from the kiln, it can also reduce the likelihood of large uncontrolled, monofill fires that release thick black clouds of smoke due to poor combustion conditions.[18] In order to use these tires on a consistent basis, cement manufacturers need a nearby monofill and may require government incentives to cover the cost of shredding the tires and transporting them to the facility, especially if the monofill is far from the cement plant. Unlike the GCC facility, Holcim has secured a large, and fairly consistent supply of tires near the Florence area, but this supply is not guaranteed long term. Also, the usage of TDF may depend on funding for Colorado's waste tire program which has varied from year to year. Due to some uncertainty in the future supply of TDF for Holcim and the available government incentives to encourage its use, the Division considers it infeasible to mandate a minimum amount of annual TDF usage. Holcim is already permitted to use a significant amount of TDF as fuel and has been doing so in recent years. Therefore, a limit requiring a certain amount of TDF is not necessary. The Division will continue to work with Holcim to evaluate the facility's future use of TDF and look for opportunities to reduce kiln emissions and Colorado's large stockpile of waste tires. Given the current high usage of TDF, the Division expects minimal additional NO_x reductions from a small increase in TDF usage. Since TDF usage is currently permitted and utilized, when available, the Division will not analyze this option further.

SNCR: Fuel substitution, which is discussed above, affects the combustion process, while SNCR and SCR are post-combustion controls that treat the combustion products. Both controls inject an ammonia or urea reagent into the flue gas to convert NO_x to molecular nitrogen (N_2). These reactions require higher temperatures in an SNCR (1,600 to 2,000°F), compared to SCR (450 to 800°F), and provided lower control efficiency. SNCR systems typically have lower capital costs than an SCR, but the operating costs are higher due to high reagent use. SNCR design requirements and performance are discussed in more detail below.

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$
$$2\ NO_2 + 4\ NH_3 + O_2 \rightarrow 3\ N_2 + 6\ H_2O$$

Above this temperature range, the NH_3 is oxidized to NO_x, thereby increasing NO_x emissions. Below this temperature range, the reaction rate is too slow for completion and unreacted NH_3 may be emitted from the pyroprocess. This temperature window generally is available at some location within rotary kiln systems. The NH_3 could be delivered to the kiln system through the use of anhydrous NH_3, or an aqueous solution of ammonium hydroxide [$NH_3(aq)$]or urea [$CO(NH_2)_2$]. A concern about application of SNCR technology is the breakthrough of

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[17] Dalhousie University. "Use of scrap tires as an alternative fuel source at the Lafarge cement kiln, Brookfield, Nova Scotia, Canada" Page 23. July 21, 2015.

[18] Booth, Michael. "Colorado's tire dumps were supposed to be gone by now. They grew instead." Colorado Sun. January 19, 2021.

unreacted NH_3 as "ammonia slip" and its subsequent reaction in the atmosphere with SO_2, sulfur trioxide (SO_3), hydrogen chloride (HCl) and/or chlorine (Cl_2) to form a detached plume of PM_{10}-$PM_{2.5}$. In addition to reacting with SO_x and chloride emissions from the kiln, the unreacted ammonia could react with NO_x or SO_x from other sources to form visibility impairing ammonium nitrate or ammonium sulfate, respectively. As discussed earlier, the in-line raw mill at the Holcim Florence kiln is an important part of the emission control system that helps minimize unreacted ammonia emissions and the raw mill is operating when the kiln is operating, except for planned mill maintenance and unexpected mill malfunctions.

In the Holcim RP analysis, the Division expressed concern about requiring more than 50% NO_x reductions utilizing an SNCR due to potential ammonia slip. Short-term testing by Holcim indicated that an SNCR could reduce NO_x emissions by 60-80%, albeit with high ammonia slip. Considering the close proximity of the Holcim Florence plant to the Great Sand Dunes, any unreacted ammonia is available to react with oxides of nitrogen or sulfur to form ammonium nitrate or ammonium sulfate, respectively, which are the two largest components of US anthropogenic emissions that contribute to visibility impairment. Due to this concern, the Division estimated a 50% NO_x control using an SNCR unit on the Holcim kiln. As discussed earlier, in order to achieve the necessary temperature range for proper SNCR reactions, the SNCR injection points are located at the duct at stage 5 of the preheater tower, where it is unable to treat the alkali bypass flow. 0 - 30% of the kiln air can flow through the bypass, and the Division estimated a long-term average of 10% of the kiln gas stream would flow through the bypass. As a result, the SNCR would effectively achieve 45% control efficiency (50% control * 90% of airflow). The Division estimated the SNCR could achieve an average emission rate of 2.73 lb/ton of clinker, on a 30-day rolling average, with total annual emissions of 2,086.8 TPY, on a 12-month rolling basis.

The existing NO_x controls on the Holcim Florence kiln, which include an SNCR, currently achieve average 30-day NO_x emissions of 1.97 lb/ton of clinker, including the reductions from firing TDF. This represents a 39% reduction from the baseline emission from the first Regional Haze planning period and a 53% reduction in NO_x emissions, compared to an uncontrolled preheater/precalciner kiln. These results agree with EPA's SNCR performance data which indicates that the technology can achieve NO_x reductions of 20 - 90%, with 50% as a reasonable long-term reduction.[19] It's important to note that achieving high NO_x (>60%) control efficiencies with an SNCR often results in high ammonia slip, as discussed in EPA's ACT for NO_x emissions from cement kilns and confirmed by Holcim's short-term tests at the facility.[20] Ammonia slip from the SNCR can react with chlorides and sulfates from the raw materials and coal to form condensable PM emissions. Although the Holcim kiln is not subject to a condensable PM limit, unlike the newer GCC Pueblo facility, Holcim still operates the kiln to minimize both NO_x and condensable PM emissions, which can result in visible plumes. For Holcim, this mean operating the SNCR to limit excess ammonia injection and allowing the in-line raw mill to act as an additional scrubber for ammonia emissions, when the mill is operating. If the raw mill is shut down for maintenance or due to a malfunction, the SNCR continues to inject ammonia to minimize NOx emissions, but this can lead to a spike in ammonia emissions. Ammonia is very water soluble, so the wet scrubber should reduce excess ammonia, but a visible plume can still result if the wet scrubber cannot fully adsorb the ammonia. Based on previous opacity limit exceedances caused by plume emissions, the

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[19] EPA. National Emissions Standard for Hazardous Air Pollutants from the Portland Cement Manufacturing Industry - Cost Environmental Impact Data. August 6, 2010.

[20] EPA. "Alternative Control Techniques Document Update - NOx Emissions from New Cement Kilns." Page 17 of 129. November 2007.

Division believes that the wet scrubber may not be able to fully mitigate excess ammonia emissions. Given that the Holcim Florence plant is located in an ozone attainment area and less than 25 miles from the populated Pueblo community, the Division does not believe the potential NO_x reduction is a valid trade-off for likely increases in ammonia emissions. Therefore, it is not recommending SNCR operational changes, such as much higher ammonia injection rates, to maximize NO_x emissions at the cost of greater plume emissions.

The Division and Holcim have not identified any potential upgrades to the existing SNCR that would significantly improve its performance. The Division will continue to monitor the long-term performance of the SNCR and will work with Holcim to ensure the kiln achieves the maximum NO_x control at a reasonable cost without significant increases in PM or other emissions. SNCR changes will not be analyzed in further detail.

SCR: SCR systems are the most widely used post-combustion NO_x control technology for coal-fired and natural gas-fired boilers. However, the technology has seen very little use at US cement kilns. In SCR systems, vaporized ammonia (NH_3) injected into the flue gas stream acts as a reducing agent when passed over an appropriate amount of catalyst. The NO_x and ammonia react to form nitrogen and water vapor, as described in the equations in the SNCR section. The principal is similar to SNCR, which is currently installed at the Holcim Florence kiln, but the SCR catalyst reduces the required flue gas temperature necessary for the NO_x reducing reaction. An optimized SCR design will provide the maximum level of NO_x reduction while maintaining low ammonia slip that could harm health and impair visibility. Detached plumes are possible with SCR, but less common than with SNCR.

EPA's ACT for NO_x emissions from cement kilns discusses SCR control for cement kilns. The document notes the SCR operating range depends on the catalyst material, and can range from 450°F to 800°F for base metal catalysts, to over 1,100°F for precious metal catalysts, though these are typically much more expensive. There are numerous challenges to operating an SCR on a cement kiln, including plugging and erosion of the catalyst caused by the high dust produced in the kiln. According to Benson[21], alkali and alkaline-earth rich oxides (sodium, magnesium, calcium and potassium) have strong influence on catalyst deactivation (*See also* Nicosia *et al.*, 2008, and Strege *et al.*, 2008). Calcium, in the form of limestone, is a staple of cement production, though sodium, potassium, and magnesium levels are tightly controlled in the raw meal to prevent swelling or cracking of the concrete. Also, alkalies and sulfur can potentially poison the catalyst.[22] The relatively high levels of sulfur in the raw materials used at the Holcim facility suggest that sulfur and alkali levels could potentially impact the catalyst.

Two additional concerns for a potential SCR system at the Holcim Florence facility are dust and site-specific design requirements. SCR systems can often be installed on coal-fired boilers in a "high dust" configuration, upstream of the particulate control device. However, this may not be feasible for cement kilns, including the Holcim Florence kiln, due to the potential for catalyst plugging and erosion caused by the very high dust levels in a kiln. Therefore, the SCR would need to be installed in a "low dust" configuration, downstream of the baghouse. Unfortunately, the post-baghouse flue gas temperature has dropped below the ideal range for SCR operation and it would require reheating with a duct burner or heat exchanger using natural gas or coal. This reheating increases upfront capital costs for the system, ongoing

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[21] Benson, S. *et al.* "SCR catalyst performance in flue gases derived from subbituminous and lignite coals, Fuel Processing Technology, Vol. 86" (2005).

[22] Strege, J. et al., "SCR deactivation in a full-scale co-fired utility boiler, Fuel 87" (2008)

operating and maintenance costs for fuel and burner/heat exchanger maintenance, and results in additional NO_x emissions that increase inlet NO_x levels to the SCR system. Lastly, at the time of the BART analysis, three cement kilns in Europe had installed SCR systems. Two were newer preheater kilns and the third was a smaller, traveling grate kiln. Although these kilns could achieve 80-90% NO_x reductions, it was unclear how well these results would translate to US cement kilns. As noted in the CEMEX BART analysis, the technology transfer of SCR systems from the power plant industry to the Portland cement industry requires substantial research and pilot testing before the technology could be considered commercially available.[23] A search of the RBLC indicates that the CEMEX North Brooksville Kiln #3 selected SNCR, SCR, or a combination of the two technologies to meet BACT for NO_x control. However, this permit was withdrawn, and this kiln was never constructed. Due to a lack of any commercially available at the time, the Division concluded that SCR was not technically feasible for retrofit on existing cement kilns.

Since the first round RP analysis was conducted, there has been a single US cement kiln, the Lafarge Joppa Kiln 1 in Illinois that installed an SCR for NO_x Control.[24] Joppa Kiln 1 is a long dry kiln with LNB and an electrostatic precipitator (ESP) for PM control. The SCR is installed downstream of the ESP in a "low dust" arrangement. This SCR was required as part of 2010 consent decree (CD) with Lafarge that covered kilns at 13 facilities in 13 states.[25] Joppa Kiln 1 was the only kiln required to install an SCR. Lafarge was required to conduct a 12-month optimization study to determine the kiln's emission limit. After the optimization period, the emission limit was ultimately set at 3.21 lb/ton of clinker using the formula prescribed in the consent decree: Limit = $\mu = 1.645*\sigma$, where μ is the mean of the 30-day rolling averages during the 12-month optimization period and σ is the standard deviation of the 30-day rolling averages. According to the Final Demonstration Report for the SCR, the mean was 1.99 lb/ton of clinker and the standard deviation was 0.75 lb/ton of clinker, resulting in an 80% reduction in NO_x compared to the baseline levels.[26] The average 30-day emission rate from Joppa Kiln 1 (1.99 lb/ton of clinker) using LNB + SCR is slightly higher than the current emissions from the Holcim Florence kiln (1.97 lb/ton of clinker) with LNB + SNCR. Also, the NO_x emissions from Joppa Kiln 1 have much greater variability, as indicated by the standard deviation of 0.75 lb/ton of clinker, which is over 1.5 times larger than Holcim Florence's standard deviation of 0.42 lb/ton of clinker. In addition, cost information for the Joppa SCR is not publicly available, so it's not possible to compare the cost effectiveness to the existing SNCR at Holcim Florence.

Since the Joppa consent decree in January 2011, EPA has issued nine consent decrees against cement manufacturers, as shown in Table 7 below. This includes the CEMEX Lyons facility in Colorado. All of the facilities were required to install an SNCR to comply with NO_x limits, except for Essroc Logansport Kiln 1 and Kiln 2 in Indiana, which are both long wet kilns that are not comparable to Holcim Florence. Both Logansport kilns were required to conduct 4-month SCR pilot studies.[27] If the pilots were deemed successful, the kilns would operate the SCR going forward based on a NO_x limit established during the pilot studies. If the studies

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[23] Schreiber, R, *et al* "Evaluation of Suitability of Selective Catalytic Reduction and Selective Non-Catalytic Reduction for use in Portland Cement Industry", (2006)

[24] The Holcim Midlothian Kiln 1 installed an SCR in 2017 o-HAP control to comply with the Portland Cement MACT limits, not for NO_x control. This SCR is currently operating.

[25] EPA. Consent Decree: Lafarge North America, Inc, Lafarge Midwest, Inc, and Lafarge Building Materials, Inc. January 2010.

[26] LAFARGE - U.S. EPA Consent Decree Final Demonstration Report, Joppa Kiln 1. April 2015.

[27] EPA. Consent Decree: Essroc Cement Corp. December 2011.

were deemed unsuccessful, the kilns would install SNCR with a NO_x limit determined by EPA. "Success" for the SCR pilot studies included reducing NO_x by at least 80% while maintaining ammonia slip below 10 ppm without negatively impacting product quality or kiln reliability. Essroc completed these SCR studies and submitted the report to EPA, but EPA rejected them. Essroc filed for dispute resolution and, as a result, EPA required Essroc to run a second SCR study and submit the performance reports to EPA. Prior to the start of the second SCR study, EPA required Logansport Kiln 1 and Kiln 2 to establish tighter emission limits, but neither kiln was required to permanently install an SCR. Ultimately, EPA, Essroc, and the State of Indiana required Logansport Kiln 2 to install a water injection system with a NO_x limit of 4.75 lb/ton of clinker, on a 30-day rolling average. Logansport Kiln 1 was required to install a water injection system and an SNCR, and conduct a study to establish a NO_x emission limit that is no less stringent than 4.75 lb/ton of clinker. The Division was unable to obtain a copy of either the initial or second SCR pilot studies, but has concluded that neither Kiln 1 nor Kiln 2 is currently operating an SCR. This leaves the Joppa kiln as the only US cement kiln still operating an SCR for NO_x control. Table 7 demonstrates that the limit of 1.85 lb/ton of clinker imposed by the CEMEX Lyons consent decree matched the lowest emission limit set by consent decree up to April 2013. Although Holcim's 30-day limit of 2.73 lb/ton of clinker is higher than CEMEX's limit, the current requirements for the facilities are very different: the Holcim Florence facility is located in an attainment area whereas CEMEX is an ozone nonattainment area, Holcim's SNCR was installed for RP during the first Regional Haze planning period not due to a consent decree. Other than the Lafarge Joppa kiln 1 in Illinois, no US cement kilns have installed and continue to operate an SCR for NO_x control based on a consent decree. As discussed earlier, the Joppa kiln has a much higher emission limit and more NO_x emission variability than nearly all recent consent decrees, including Holcim Florence. All of the other consent decree limits are based on SNCR controls, as shown in Table 7.

Table 7: EPA Cement Manufacturer Consent Decrees after January 2010

Company Name	CD Date	# of Facilities Included in CD	# of Kilns Included in CD	NO_x Limit (Control Tech)
CEMEX Fairborn	Feb 2011	1	1	1.85 lb/ton (SNCR)
CalPortland	Dec 2011	1	1	2.5 lb/ton (SNCR)
Essroc (now Lehigh Cement)	Dec 2011	6	9	1.85 - 4.75 lb/ton (SNCR) *
CEMEX Lyons	Apr 2013	1	1	1.85 lb/ton (SNCR)
Ash Grove	June 2013	9	13	1.5 - 8 lb/ton (SNCR)
Holcim/ St. Lawrence	July 2013	1	1	1.8 lb/ton (SNCR)
CEMEX	July 2016	5	7	1.5 - 5.3 lb/ton (SNCR)
Lonestar/Buzzi	Aug 2016	1	1	1.5 - 2.9 lb/ton (SNCR) **
Lehigh	Dec 2019	11	14	1.5 - 8.2 lb/ton (SNCR)

* Essroc Logansport was required to conduct SCR pilot studies on Kilns 1 and 2. The pilot study reports were rejected by EPA and the source and EPA ultimately agreed to install water injection on both kilns. Kiln 1 was also required to install an SNCR. Both kilns have limits of 4.75 lb/ton of clinker.
** The two emission rates at the Lonestar facility are for firing waste (1.5 lb/ton) and not firing waste (2.9 lb/ton).

The Division also reviewed the RBLC to look for instances where SCR has been approved. As discussed earlier, the CEMEX North Brooksville Kiln 3 in Florida was permitted in 2007 with SNCR, SCR, or a combination of the two, but the permit was withdrawn and the kiln was never built. The only LAER determination listed in the RBLC was the Universal Cement plant in Illinois that was permitted at 1.2 lb/ton of clinker using staged combustion and SNCR, not SCR. LAER determinations seek the lowest achievable emission rate without consideration of cost, a more stringent standard than the Regional Haze RP determination for Holcim Florence, and SCR has not been selected as LAER for NO_x emissions from cement kilns. Under Regional Haze, states must consider cost of compliance when evaluating potential controls and the Division believes it is inappropriate to recommend essentially unproven technologies beyond LAER under Regional Haze.

The only existing US cement kiln with an operating SCR for NO_x control, the Lafarge Joppa Kiln 1, has very little publicly available information, including costs. Based on the information available to the Division, this SCR is achieving 80% control efficiency, which is higher than the 39% control efficiency of the Holcim Florence SNCR, but without additional cement kilns using SCR for NO_x control it is unclear whether the technology could consistently achieve 80% control efficiency at other facilities, such as Holcim Florence. SNCR technology has also been chosen over SCR under recent consent decrees, BACT, and LAER determinations. Given the limited potential NO_x reductions, unknown cost, and lack of SCR installations on comparable preheater/precalciner kilns, the Division still considers SCR technology infeasible for cement kilns and it will not be analyzed further.

Hybrid SNCR + SCR: As discussed in the SCR section, the Division does not consider SCR technically feasible for NO_x control at US cement plant, based on limited available information on the one operating US cement plant, Joppa Kiln 1. Holcim, GCC, and CEMEX each argued in their respective four-factor analyses, that SCR is not technically feasible for cement plants respective four factor. Despite this, Holcim's September 2019 four-factor analysis included a cost estimates for SCR installation which was intended for informational purposes. The cost estimate was developed using EPA's Control Cost Manual SCR spreadsheet. This is a standard cost estimation tool for coal, fuel oil, and natural gas-fired industrial and utility boilers, but EPA warns that these estimates may not be representative for other source categories, such as cement kilns. Holcim's cost estimate was based on a 0.99 lb/ton of clinker emission rate that could be achieved using the existing controls plus an add-on SCR. This combination of an SNCR + SCR is considered a Hybrid SNCR + SCR, which is unproven on production cement kilns in the US and Europe, as discussed below.

The goal of a hybrid SNCR+SCR system, such as Fuel Tech's ASCR technology, is to achieve similar reductions to a standalone SCR at lower capital costs. The hybrid system is designed to achieve high levels of NO_x reduction through the SNCR by using additional reagent injection nozzles to increase reagent injection rates. But these high ammonia injection rates result in higher ammonia slip. As discussed in the SNCR section, the short-term SNCR tests on the Holcim Florence kiln SNCR tests suggest that SNCR can achieve high levels of NO_x reduction, up to 60-80%, at the expense of high ammonia slip. This high level of ammonia slip is likely to produce detached plumes that impair visibility. A hybrid SNCR+SCR system seeks to address the ammonia slip by adding an “end-of-pipe” SCR to promote additional NO_x reducing reactions that consume the excess ammonia. Because the SNCR provides much of the NO_x reduction, the SCR catalyst can be smaller which should reduce capital costs. Locating the SCR downstream of the baghouse and wet scrubber could remove most of the PM and sulfur contaminants that can cause catalyst plugging, poisoning, deactivation, and erosion. This may reduce catalyst replacement and/or maintenance which would reduce ongoing costs. The disadvantage of an end-of-pipe SCR is that the flue gas will require reheating, likely using a duct burner that fires additional natural gas or coal. This additional reheating increases the NO_x concentrations into the SCR and may offset some of a hybrid system’s additional reductions. The flue gas may also require additional drying to reduce residual risk of catalyst plugging or deactivation. Alternatively, the SCR could be located between the baghouse and wet scrubber, but this significantly increases catalyst exposure to calcium sulfate that can deactivate the catalyst or ammonium bisulfate that can plug it. As discussed in the SCR section, it can be difficult to find a suitable location for an SCR catalyst on a cement kiln. It’s likely more difficult to find a location with the higher ammonia injection rates used in a hybrid system.

After SCR installations on cement kilns in German and Italy, there were discussions about achieving similar NO_x reductions using a hybrid SNCR + SCR system, which had been evaluated on a limited number of utility boilers. EPA’s ACT document for NO_x controls on cement kilns discusses these hybrid systems under the “developing technologies” section which states, “A possible control system to use in new cement kilns is a SNCR/SCR hybrid combination. This system has been used in the power industry (AES -Greenidge, NY) and at waste-to-energy plants (ASM Brescai, Italy).”[28] Despite this initial enthusiasm for the potential of hybrid systems, EPA’s 2019 update to the SNCR chapter of the cost control manual indicates that there has been limited additional deployment of hybrid SNCR+SCR systems, “Hybrid technology has been evaluated extensively in modeling and pilot-scale studies. Commercial applications in the U.S., however, have been rare. At least three coal-fired utility boilers have been equipped with hybrid technology for demonstrations or short-term commercial operation, though none are still operating.”[29]

Performance has been mixed in these limited trial runs. Some coal-fired and natural gas boilers have achieved up to 90% NO_x reductions, while other utilities have only achieved 40-75% reductions. In general, these systems have achieved greater reductions at low load, which is less beneficial for cement kilns which typically operate at high loads. The wide range of potential reductions suggest that extensive testing is necessary to determine if a hybrid system on a cement kiln could achieve better NO_x control than the industry-standard SNCR controls. Lastly, the Division highlights that none of the European cement kilns have hybrid controls. Although the Solnhofen facility in Germany has both SNCR and SCR systems, the systems do not operate simultaneously. Both the SNCR and SCR achieve 50% NO_x reductions compared to baseline emissions using low-NO_x burners and firing alternative fuels. The construction permit for the facility set a much lower emissions target for the SCR, but the facility has been unable to achieve this level of control.[30] The only existing guidance on the potential performance of a hybrid SNCR+SCR system is the limited-term trials on utility boilers and a waste to energy plant, and these controls are not currently operating. The technology

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[28] EPA. “Alternative Control Techniques Document Update - NO_x Emissions from New Cement Kilns” Page 107 of 129. November 2007.

[29] EPA. “Cost Control Manual - Selective Non-Catalytic Reduction (SNCR).” Page 34 of 71. April 2019.

[30] EPA. “Alternative Control Techniques Document Update - NO_x Emissions from New Cement Kilns” Pages 98-100 of 129. November 2007.

has not been tested on any cement kilns in Europe or the US. Based on this the Division considers hybrid SNCR+SCR systems technically infeasible for US cement kilns. Although Holcim's four-factor analysis estimated control efficiencies and costs for a hybrid SNCR+SCR system, the Division considers these estimates highly speculative and believes the facility would need to build a pilot plant to prove the technology before deploying it long-term on a production kiln. Technologies that include this type of R&D project are not considered reasonably available technology for the purposes of Regional Haze.

Step 3: Evaluate Control Effectiveness of Each Remaining Technology

Table 8 summarizes each available technology and technical feasibility for NO_x control on the Holcim Florence kiln. The Division has concluded that the existing SNCR and existing practice of firing TDF are the only technically feasible options for NO_x control on the Florence kiln. The Division did not identify any additional upgrades or modifications to these controls that would achieve additional reductions.

Table 8: Holcim Florence Kiln - NO_x Technology Options and Technical Feasibility

Technology	Emission Control Efficiency (%)	Technically Feasible? (Y = yes, N = no)
Baseline - SNCR (39% Control)	N/A	Y - installed
Fuel Substitution - Firing TDF	< 10%	Y - currently in use, further increases will not provide significant NOx reductions
SCR	N/A	N
Hybrid SNCR + SCR	N/A	N

Step 4: Evaluate Factors and Present Determination

Factor 1: Cost of Compliance

There are no associated costs of compliance since no other options are technically feasible and cost-effective other than continuing proper operation of the existing NOx controls and firing TDF, when available.

Factor 2: Time Necessary for Compliance

There is no additional time required for compliance since no other options are technically feasible and cost-effective other than continuing proper operation of the existing NOx controls and firing TDF, when available.

Factor 3: Energy and Non-Air Quality Impacts

As noted earlier, excess ammonia emissions can produce visible plumes if the ammonia is not adsorbed in the wet scrubber slurry. Since the Division is not proposing changes to the SNCR system, it does not anticipate any increase in the energy usage or ammonia emissions on a ton of clinker basis. However, Holcim is not currently operating at peak production capacity and production increases could increase the total energy usage and ammonia emissions. There are no additional energy and non-air quality impacts associated with the continued operation of the kiln and SNCR unit on the Holcim Florence kiln.

Factor 4: Remaining Useful Life

Holcim has not announced a closure date for the Florence kiln or its associated limestone quarry. Therefore, the Division assumes that the kiln will remain in operation for at least 20 years. Because no additional control options are considered technically feasible and cost-effective, remaining useful life does not impact cost estimates for additional controls.

Emission Limit Tightening: Although the Division did not identify any additional NO_x control measures, it also evaluated tightening emission limits for the Holcim Florence kiln. In establishing the short term NO_x limits for boilers, the Division adds a 15% buffer to the annual average emissions. However, cement kilns typically have greater emission variability than EGU boilers. Based on this variability, the Division set RP limits for the Holcim Florence cement kiln based on the 99th percentile of the 30-day rolling averages during the first Regional Haze planning period. Using this same metric with January 2018 – December 2020 emissions data results in a NO_x limit of 2.73 lb/ton of clinker for the Holcim Florence kiln, which is the current 30-day rolling average NO_x limit. For reference, the limit would be 2.80 lb/ton of clinker using the 15% buffer for boilers, which is less stringent than the existing 30-day average limit. In either case, the proposed emission rate is the same or less stringent than the existing emission rate. Therefore, the Division does not recommend tightening the NOx emission rate.

Determinations

Upgrades to the existing NO_x control system were evaluated, and the state determines that meaningful upgrades to the system are not available. Because the kiln will remain in operation for 20 years or more, the Division also evaluated emission limit tightening. The Holcim Florence kiln installed SNCR NO_x controls after the first Regional Haze planning period to meet the 30-day rolling average RP emission limit of 2.73 lb/ton of clinker. The Division recognizes the inherent variability in cement kiln emissions and will not recommend tighter limits unless they will achieve significant reductions while allowing long-term compliance. The Division has determined that a lower emission rate is likely not feasible without a counterproductive increase in other visibility impairing pollutants.

Based upon its consideration of the four factors summarized herein and detailed in Appendix C, the Division recommends that NO_x RP is complying with the following emission rate and annual limits:

1) The following existing NO_x emission limits shall remain in effect for this planning period:
Kiln: 2.73 lb/ton of clinker (30-day rolling average)
2,086.8 TPY (12-month rolling average)

The state assumes that the RP emission limits can be achieved through continued proper operation and maintenance of the kiln and existing NO_x controls and TDF usage, when available. The Division has determined that these emission limits are achievable without additional capital investment through the four-factor analysis.

Appendix C

Tri-Mer Brochure

Tri-Mer® CORPORATION

Technology Leader
multi-pollutant control

World's Largest Supplier of Ceramic Catalyst Filter Systems

Boiler MACT • CISWI MACT • Cement NESHAP

All-in-One Solution

Tri-Mer Ceramic Catalyst Filter Systems are state-of-the art for removing particulate (PM), SO2, HCl, mercury and heavy metals. Simultaneously, the ceramic catalyst filters destroy NOx, cement organic HAPs, and dioxins. Systems can be configured for any combination of the pollutants.

The system is completely dry, with no water consumption. Disposal of the dry collected waste is straightforward. Large gas flow volumes can be accommodated.

Particulate Control

Tri-Mer Ceramic Catalyst Filters are excellent at removing all sizes of particulate from gas sources above 300˚F, including PM10, PM2.5, and submicron. Typical outlet levels are less than 0.001 grains/dscf (2.0 mg/Nm^3) regardless of inlet loading.

NOx Control

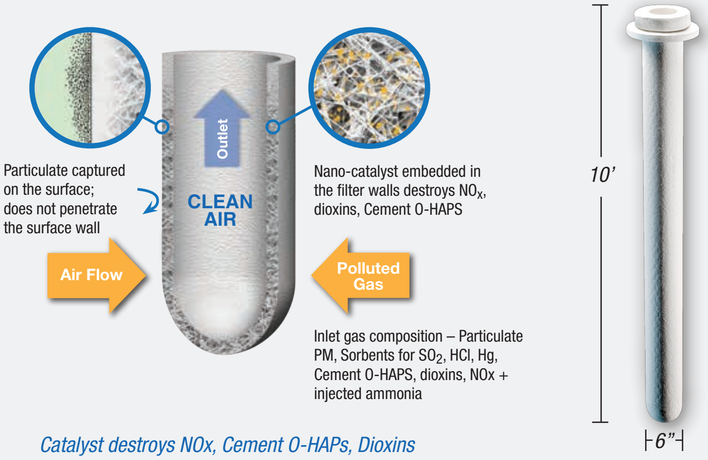
Catalytic filter tubes have nanobits of SCR catalyst embedded in the filter walls. Operating range is 350˚F to 950˚F. The exceptionally large reactive surface area of the micronized catalyst produces high NOx removal at temperatures notably lower than standard SCR. Good results start at 350˚F and improve to 95% removal at 450˚F and above (standard "big block" SCR requires 650˚F or higher for similar efficiency).

The unique structure of the filters captures process particulate on its outer surface, thus keeping it away from the nano-catalyst inside the filter walls. This prevents PM blinding and poisoning of the catalyst and greatly extends the catalyst life compared to standard SCR..

Cement O-HAPs and THC Control

Cement organic HAPS are also destroyed by the embedded catalyst. Good removal on the primary Cement O-HAPs occurs at temperatures over 400˚F, with excellent results on all Cement O-HAPS approaching 500˚F. Dioxins are also destroyed by the filters, typically with 95% efficiency or better at temperatures up to 500˚F.

Cut-away of Filter Tube with Embedded Nano-catalysts



Catalyst destroys NOx, Cement O-HAPs, Dioxins

SO2, HCl, Acid Gases, & Mercury Control

For dry scrubbing of acid gases, Tri-Mer filter systems use injection of hydrated lime or SBC upstream of the filters. Removal of SO2 is typically above 90% and HCl better than 97%. The approach for mercury depends on the Hg species in the gas. Activated carbon and other sorbents, some blended with the acid gas sorbents, are selected on a case-by-case basis.

www.tri-mer.com

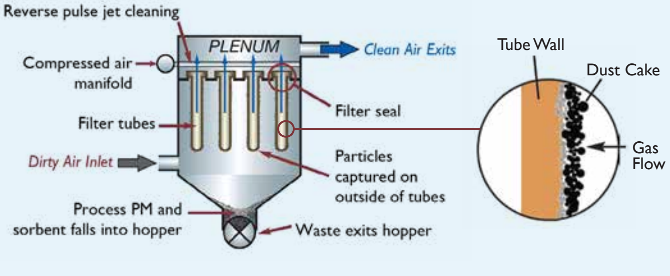
Boilers, Cement, Glass, Incinerators, Stationary Diesel

CERAMIC CATALYST Filter Systems

Controls PM, S02, HCl, Hg, NOx, Dioxins, Cement O-HAPs

Operation and Maintenance

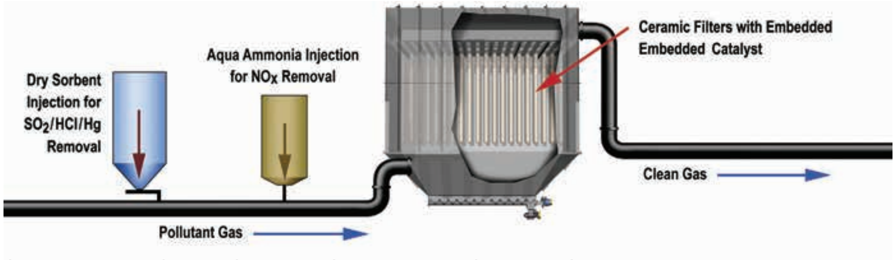
Tri-Mer's Ceramic Catalyst Filter System uses a baghouse configuration with a reverse pulse-jet cleaning action. The filters are back-flushed with air or inert gas. The design has been engineered for easy filter installation and maintenance. Filter tubes are manufactured in various sizes, the largest of which is 10' long and 6" in diameter, including an integral mounting flange. Filter life averages 5 to 10 years on most applications.



Reverse pulse-jet cleaning mechanism for the filter tubes. Filter tube wall is 3/4" thick with catalyst embedded inside.

Initial system cost is lower than competing options, with much better performance and flexibility. Pressure drop is 4" w.g. – lower than the total energy usage of multi-step systems.

Modular systems to treat any flow volume



Controls PM, S02, HCl, Hg, NOx, Dioxins, Cement O-HAPs

Tri-Mer's Ceramic Catalyst Filter System is the Low Cost Solution

Tri-Mer Corporation, a technology leader in air pollution control, provides turnkey engineering, manufacturing, installation, and service of its ceramic catalytic catalyst filter systems.

Tri-Mer Corporation
Factory and Headquarters
1400 Monroe St., Owosso, MI 48867

Primary Applications

- Boiler MACT compliance for coal, biomass, wood
- Cement NESHAP Organic HAPs
- Glass furnaces
- CISWI Incinerator MACT
- Stationary diesel for ships at dock
- Metal smelting, mineral processing
- Chemical production

More Applications

Air Pollution Control

- Medical waste
- Soil cleaning
- Foundry processes
- Energy production
- Fire testing
- Many specialized high temp applications

Product Collection/Recovery

- Titanium dioxide production
- Fumed silica production
- Catalyst manufacturing
- Platinum smelting
- Metal powder production
- Activated carbon production

Tri-Mer® CORPORATION Technology Leader *multi-pollutant control*

www.tri-mer.com

Appendix D

GEA Brochure

Hot gas filtration with ceramic candles

A multifunctional filter for the simultaneous removal of particulate, acid gases and NOx from flue gases

engineering for
a better world

gea.com

Discover the benefits of ceramic candle filters

GEA high temperature filters with ceramic elements remove particulates and are now available as BisCat ceramic filters with an embedded catalyst matrix allowing removal of NOx, dioxins, mercury and VOC. The filter elements are chemically inert and corrosion-resistant.

Emission control advantages

Ceramic filter elements show very low dust emissions < 2 mg/Nm³ and are thermally stable up to high operating temperatures. No cooling of flue gases is required and no thermal heat energy is wasted.

Filter elements are cleaned online during operation by means of separate, compressed air jet pulses. The filter elements are placed in a single or multi-compartment housing to handle large volumetric flow rates. This construction technique allows for maintenance of a single module while others continue to operate, without interruption of the process itself.

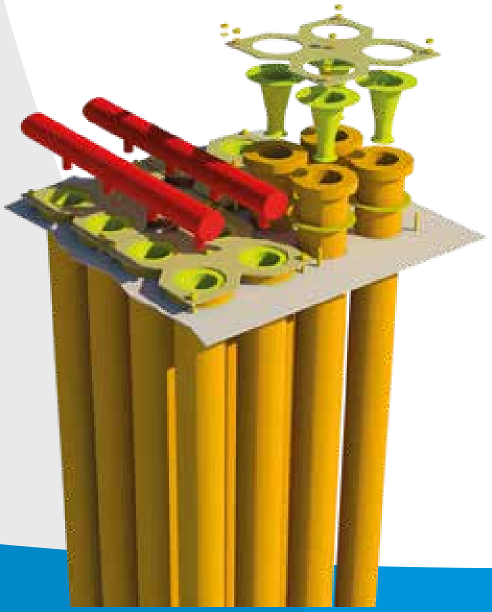
The injection of lime-based reagents allows for control of inorganic gaseous emissions like HF, HCl, SOx. The rigid candle structure enables surface filtration and forms a first layer of reactive dust for absorption processes.

BisCat ceramic catalyst filters

In addition to treating particulate and acid gases, the BisCat ceramic catalyst filters is enriched with a catalyst providing effective NOx removal by using upfront ammonia injection and replace a conventional selective catalyst reactor (SCR).

The BisCat filter solution is combining three process steps in one unit for advanced emission control:

- Dedusting
- Removal of acid components
- Reducing THC and NOx



Details of BisCat installation

CERAMIC FILTERS

- Low dust emissions
- High operating temperatures
- Excellent gas permeability
- Lightweight construction
- Long service lifetime

BISCAT

- Effective NOx removal
- Low differential pressure
- Single emission control unit
- Multi-pollutant performance

APPLICATIONS

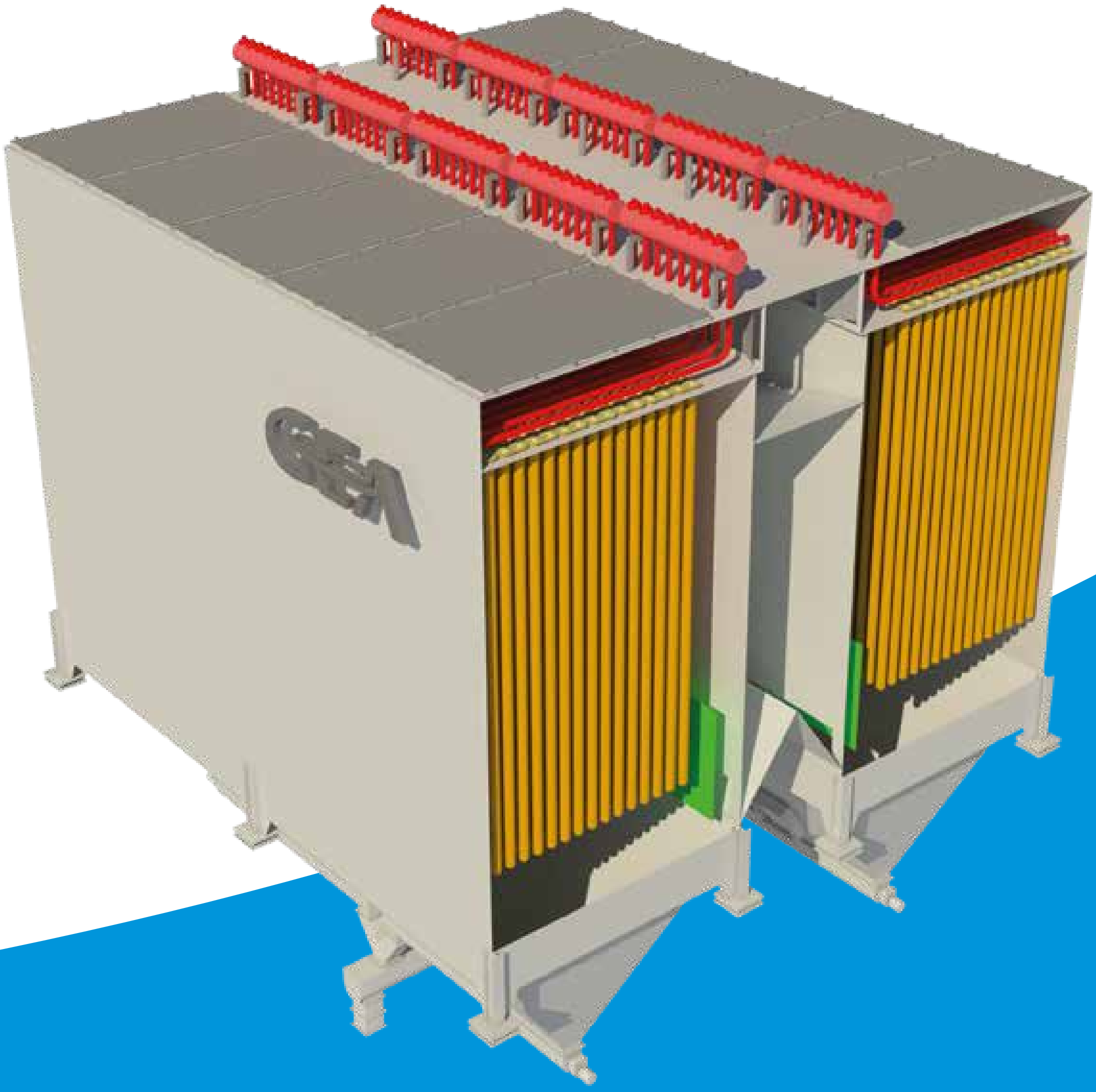
- Glass furnaces
- Cement kilns and coolers
- Incinerators
- Refineries
- Roasters

Special features of ceramic candle filters with pulse jet technology

- Low differential pressure
- Dust monitoring system (Broken Bag Detector) allows for safe operation with almost zero dust emission
- Low a/c ratio allows n-1 operation for longer periods
- Baffle plates protect candles from direct gas flow intake in raw gas compartment
- Clean gas dampers are designed for low differential pressure
- Candle installation period is short, due to easy and fast candle piece assembly
- Penthouse equipped with lifting devices to handle candles and clean gas compartment covers

The special GEA design allows for candle length of up to six meters. A downholder plate holds four candles in place to a common tubesheet. The intake nozzle protects candles from excessive abrasion by means of compressed air and the sealing between candle and head plate prevents from bypass gas.

Standard reverse pulse jet methods, commonly used in fabric filter baghouses, are used for ceramic filter cleaning. A pulse of compressed air is sent down in the center of the filter elements and cleans the accumulated dust from the outer surface of the tubes. The particulate falls into a lower hopper and is removed through an airlock device. Filters are cleaned on-line, with no need to isolate individual housings or sections.



BisCat system

engineering for
a better world

We live our values.

Excellence • Passion • Integrity • Responsibility • GEA-versity

GEA is a global technology company with multi-billion euro sales operations in more than 50 countries. Founded in 1881 the company is one of the largest providers of innovative equipment and process technology. GEA is listed in the STOXX® Europe 600 Index. In addition, the company is included in selected MSCI Global Sustainability Indexes.

GEA Germany
GEA Bischoff GmbH
Ruhrallee 311
45136 Essen, Germany

Tel +49 201 8948 0

gea.com/contact
gea.com

Appendix E

Haldor Topsoe Brochure

TopFrax™ catalytic filters

Remove gas emissions and dust in one single process

Breakthrough catalytic filters trap dust,
while removing NOx, dioxins, CO and VOCs

www.topsoe.com

HALDOR TOPSØE

Are regulators putting the **squeeze** on your business?

Topsoe’s new TopFrax™ catalytic filter makes compliance a whole lot more affordable

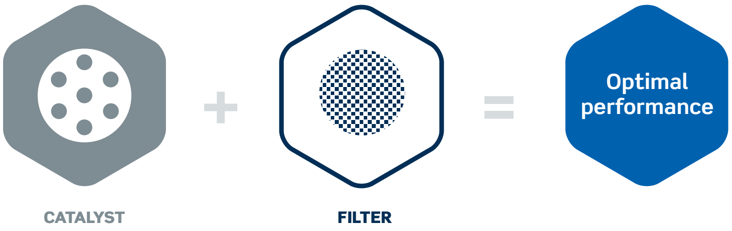
Authorities in many countries are tightening emissions standards by reducing particle permissible levels and adding new gases to the list of regulated components. Compliance is costly, requiring substantial investments in new abatement technologies.

At Topsoe, we hear producers calling not just for new technologies, but for innovation that makes compliance affordable. That’s what our TopFrax™ catalytic filter is all about.

Trap dust and remove pollutants
TopFrax™ are patent-pending catalyst-coated filters designed to treat off-gases in high-dust environments found in a wide range of industries and activities, including:

- Glass production
- Cement production
- Waste incineration
- Bio-mass boilers
- Steel production

Built on decades of leadership in filtration and catalysis, these breakthrough solutions can transform the economics of meeting regulatory emissions.



The fact that we both master catalysts and process technology gives us the “big picture” view it takes to ensure optimal performance

Remove gas emissions and dust **in one single process**

Upgrading is easy and affordable, if you use a candle system

Topsoe's catalytic filter is designed to give any facility the option of treating off-gases along with trapping dust. TopFrax™ is a catalytic ceramic candle solution that provides high removal performance efficiency at both high and low operating temperatures and with the resistance of sparks contained in off-gases.

TopFrax™ catalytic filter candle
The TopFrax™ catalytic filter candle consists of a high-temperature-resistant ceramic filter impregnated with carefully selected catalytic compounds. Benefits include:

- Simultaneous dust and multiple gaseous compounds removal in a single step
- No need for costly, space-demanding tail-end gas removal equipment
- Reinforced at flanges and bottom to enhance mechanical durability
- Catalytic ceramic filter accommodates temperatures as high as 400°C (752°F)
- No contact between catalyst and potentially harmful particles
- Exceptional resistance to catalyst poisoning
- Effective down to 180°C (356°F) operation
- Easy to install and handle

TopFrax™ ceramic catalytic filter

A broad spectrum of **regulated pollutants**

While the filters trap dust, the catalyst removes NOx, dioxins, CO and VOC

Dust
TopFrax™ effectively blocks particulates and dust particles at the filter surface the same way conventional filters do, ensuring full compliance with stringent emission standards.

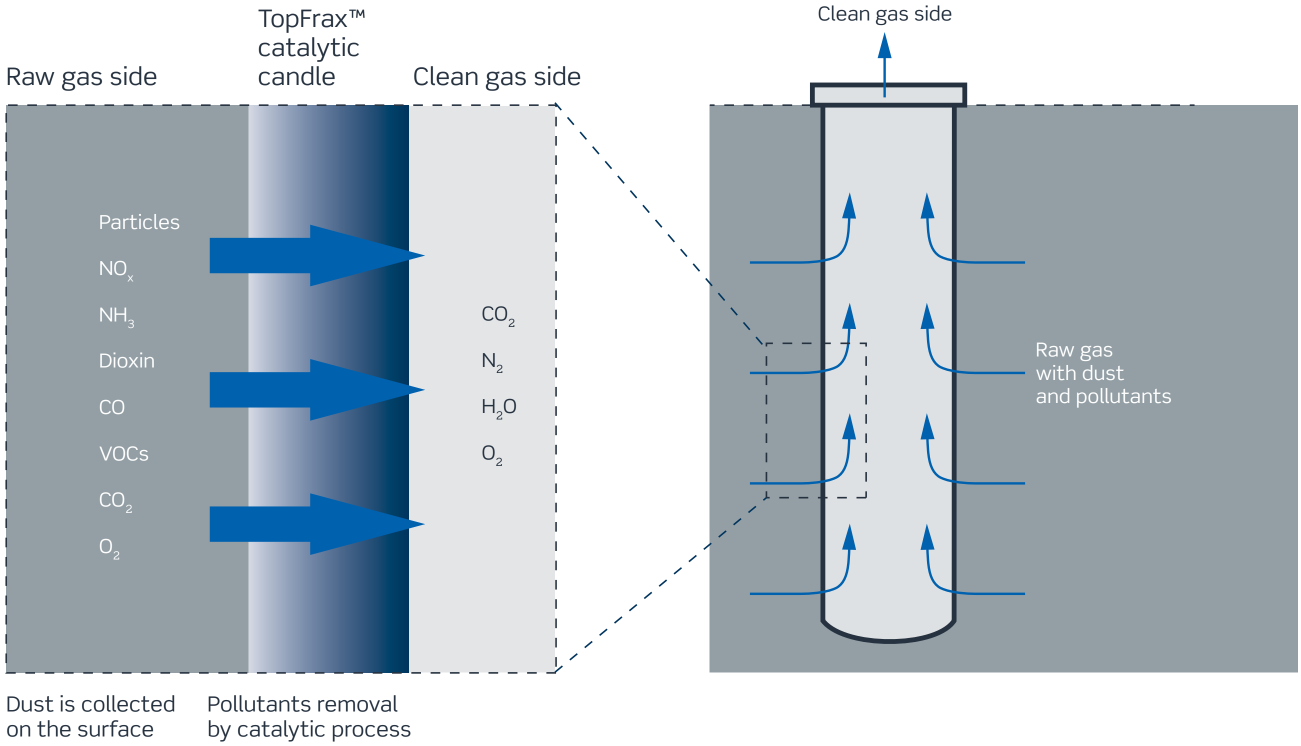
TopFrax™ candles are made from either refractory ceramics or fibers with low bio-persistance. Both products trap dust emissions (below $PM_{2.5}$) down to 1 mg/Nm^3.

NOx
TopFrax™ uses selective catalytic reduction (SCR) to remove NOx from off-gases, by utilizing ammonia to convert to harmless nitrogen and water

Dioxins
TopFrax™ also ensures compliance with limits on dioxins and furans, by treating more than 99% of these by converting them into harmless compounds and reducing their concentrations to below 0.1 ng/Nm^3, TEQ.

CO and VOCs
The catalytic sites on TopFrax™ candles also oxidize CO and volatile organic compounds into harmless CO_2 and H_2O.

The TopFrax™ oxidation version ensures optimal combustion of VOCs with no additional emission of CO.

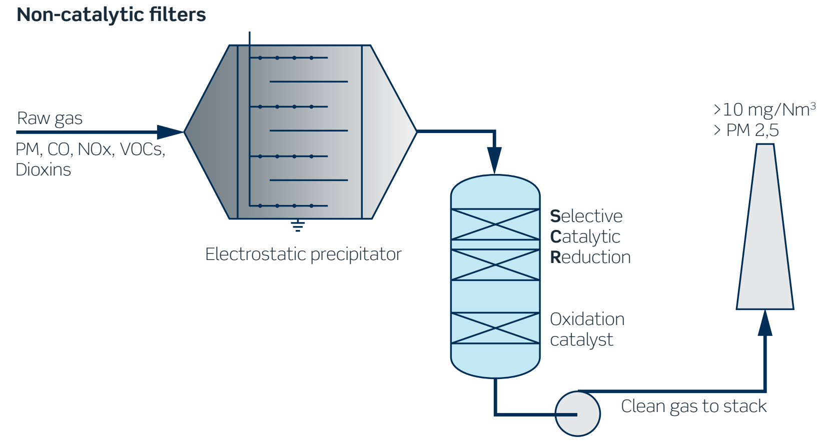


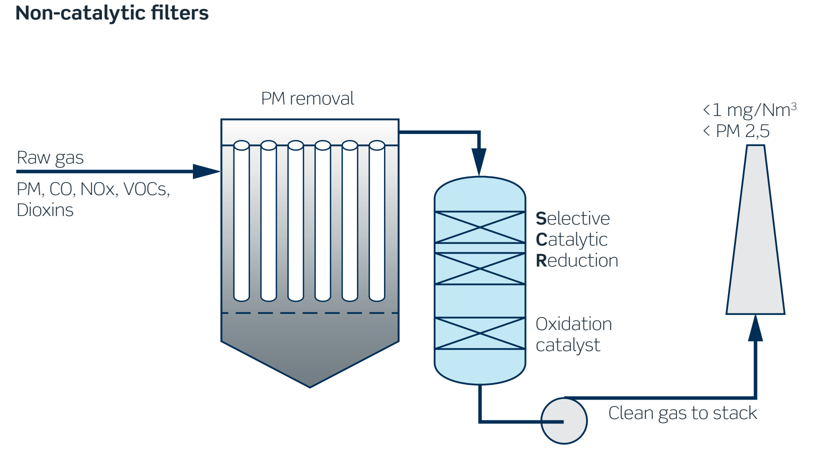
Cut technology costs

The Topsoe catalytic filter solution TopFrax™ can help you reduce capital expenditures compared to competing solutions relying on separate DeNOx and oxidation technologies

Filtration unit and tail end removal of NOx and VOC

Traditional solution based on separated technologies

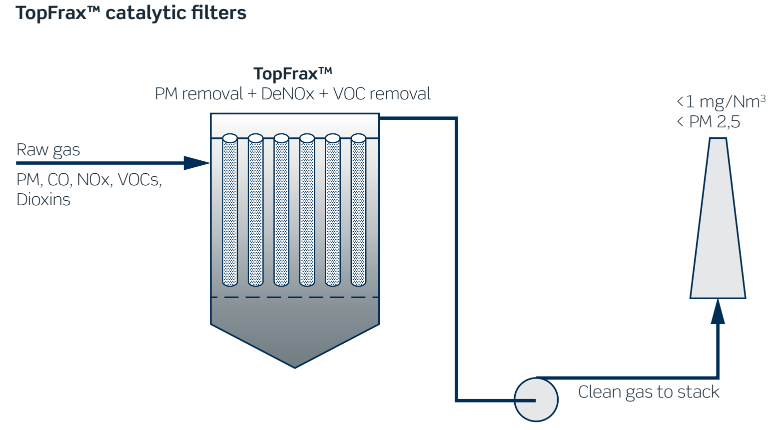

Non-catalytic filters


Non-catalytic filters

Catalytic filtration - integrated solution

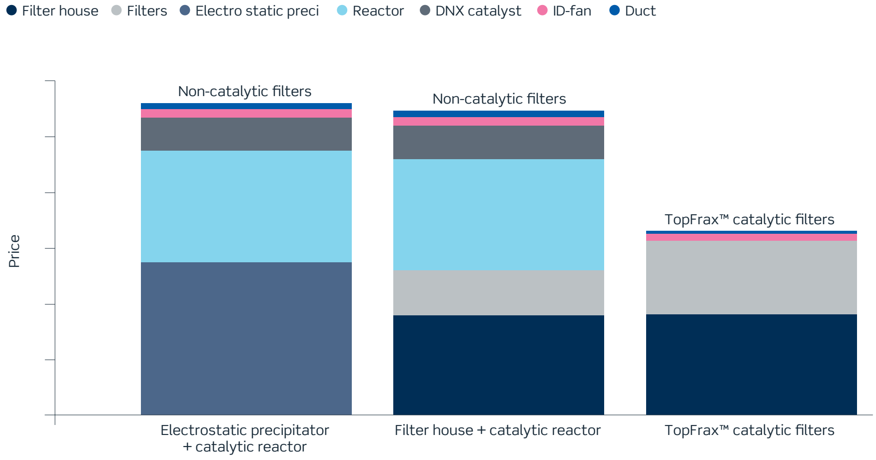
Catalytic filter solution:

- Lower CAPEX
- Less foot print
- Lower pressure drop
- Less maintenance
- Lower cost of ownership


TopFrax™ catalytic filters

Comparison of lump sum investment

CAPEX savings from installing catalytic filters.



Related technologies

Discover the full range of Topsoe catalysts and technologies for optimizing performance

Optimized performance often means ensuring that multiple technologies and components are tuned to each other. If you're not already using them, please consider these related offerings from Topsoe.

VOC

VOC removal
Regulatory pressure on VOC emissions has never been greater, and we can help you meet the challenge by removing VOCs from off-gases via low-temperature catalytic processes. Our solutions deliver reduction efficiencies exceeding 99%, without creating any secondary pollutants. Our catalysts remove VOCs from air and waste gas streams in an energy-efficient and environmentally friendly manner.

S

Sulfur removal
As emission regulations continue to get tighter around the world, optimal handling of sulfurous gases is becoming increasingly important. In addition to meeting regulatory requirements, we make sure our solutions also make financial sense. Due to their high availability, energy efficiency and flexibility, our sulfur removal systems deliver market-leading performance. They can even be used to convert otherwise costly waste into valuable commercial-grade sulfuric acid.

Why partner with **Haldor Topsoe**

The Topsoe advantage lies not just in individual solutions, but in how our solutions work together

When you partner with Haldor Topsoe, you partner not only with the world's experts in catalysis, surface science and emissions management. You also partner with a company that takes a uniquely holistic approach to your plant and your business.

When we look at your plant, we look at the big picture – and then apply the full breadth of our expertise to deliver a thoroughly tailored solution, where individual components work together to ensure environmental compliance at the lowest possible cost.

Haldor Topsoe is a world leader in catalysis and surface science, committed to helping our customers achieve optimal performance. We enable companies to get the most out of their processes and products, using the least possible energy and resources, in the most responsible way. We are headquartered in Denmark and do project development, R&D, engineering, production, and sales & service across the globe.

Get in touch today
www.topsoe.com/topfrax

Haldor Topsoe A/S, cvr 41853816 | CCM | 0224.2017/Rev.1

HALDOR TOPSØE

CataFlex™ catalytic filter bags

Remove pollutants and **trap** dust in one **single** step

Breakthrough catalytic filter bags trap dust,
while removing dioxins, NOx and NH_3

www.topsoe.com

HALDOR TOPSØE

Are regulators putting the **squeeze** on your business?

Topsoe's CataFlex™ catalytic filter bags make compliance a whole lot more affordable

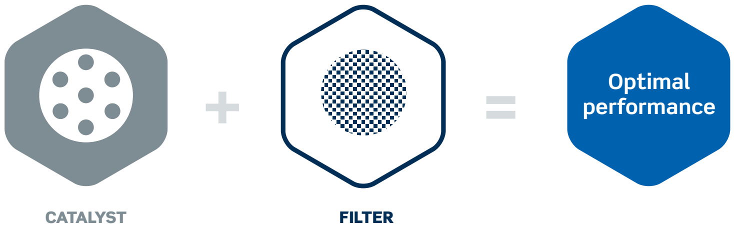
Authorities in many countries are tightening emissions standards by reducing permissible levels and adding new gases and particles to the list of regulated components. Compliance is costly, requiring substantial investments in new abatement technologies.

At Topsoe, we hear producers calling not just for new technologies, but for innovation that makes compliance affordable. That's what our CataFlex™ catalytic filter bags are all about.

Trap dust and remove pollutants
CataFlex™ are catalyst-coated filter bags designed to treat off-gases in high-dust environments found in a wide range of industries and activities, including:

- Waste incineration
- Biomass boilers
- Power plants
- Cement production
- Glass production
- Steel production

Built on decades of leadership in filtration and catalysis, these breakthrough solutions can transform the economics of meeting regulatory emissions.



The fact that we both master catalysts and process technology gives us the "big picture" view it takes to ensure optimal performance

Single step **removal** of dioxins, NOx and NH_3

Upgrading is easy and affordable

Topsoe's catalytic filter systems are designed to give any facility the option of treating off-gases along with trapping dust. CataFlex™ is the ideal choice for facilities already using a filter bag solution.

Designed for use in most industries that require flue gas cleaning, the CataFlex™ catalytic filter bag consists of a catalytic fabric layer installed inside a standard filter bag. Both the catalyst formula and the fabric material for the catalytic inner layer and the dust filtration layer are optimized according to the process requirements.

Benefits include:

- Removes dust and multiple gaseous compounds in a single step
- No need for costly, space-demanding tail-end SCR equipment
- Low pressure drop means no need for costly new ID fans or compressed air
- Accommodates operating temperatures up to 260°C (500°F)
- Bags can be inserted into existing filter houses for an affordable drop-in upgrade
- Life time and pressure drop is comparable to conventional fabric filters
- No contact between catalyst and potentially harmful particles
- Exceptional resistance to catalyst poisoning
- Length up to 10 m (32 ft)
- Longer outer bag lifetime

CataFlex™ catalytic filter bag

A broad spectrum of **regulated pollutants**

While the filters trap dust, the catalyst removes dioxins, NOx and NH_3

SEM image of CataFlex™

Outer layer

Dust
CataFlex™ effectively block particulates and dust particles on the outer layer which consist of a traditional dust filter bag, ensuring full compliance with the stringent emission standards.

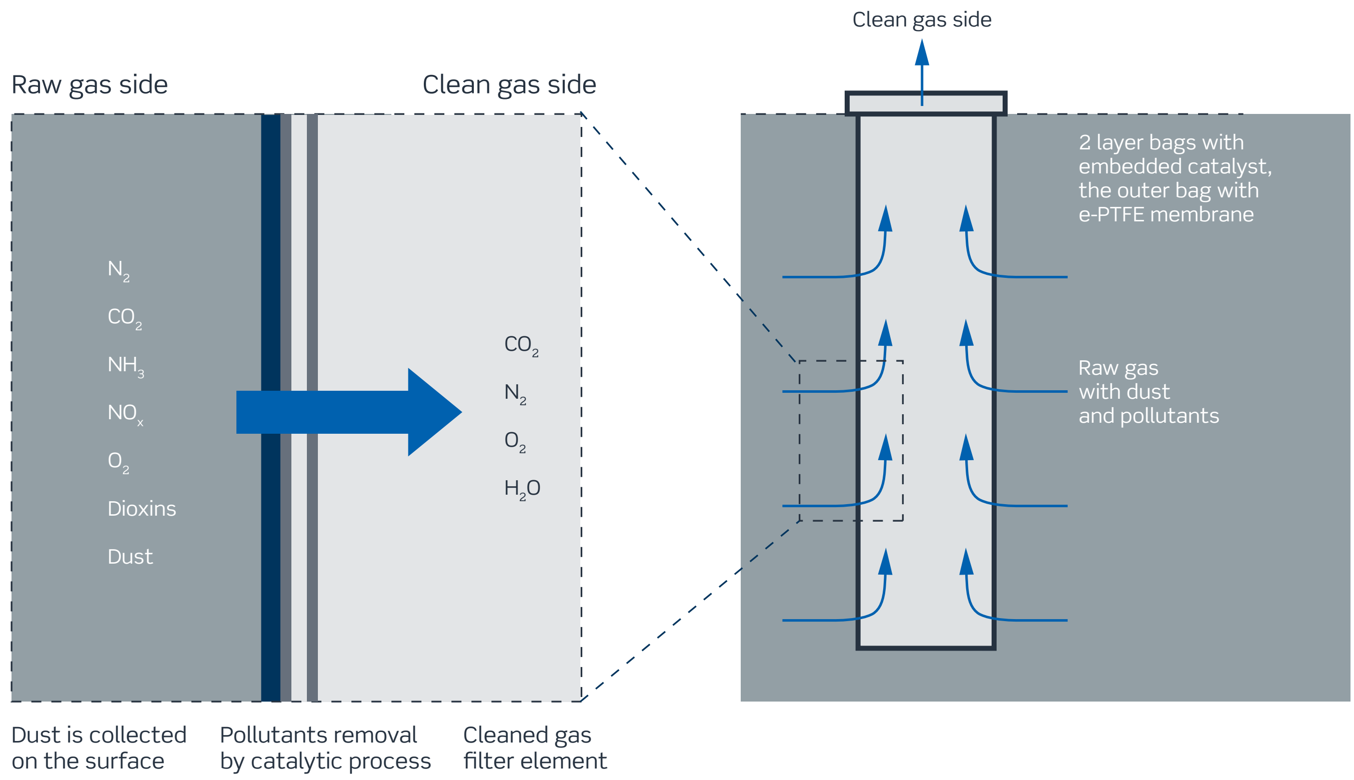
The outer layer of a CataFlex™ filter bag is a conventional filter bag which can be made by different fabrics and with and without PTFE membrane. CataFlex™ reduces dust emissions to below 1 mg/Nm^3.

Inner layer

Dioxins destruction
CataFlex™ ensure compliance with limits on dioxins and furans - destruction more than 99% of these by converting them into harmless compounds and reducing their concentrations to below 0.1 ng-TEQ/Nm^3.

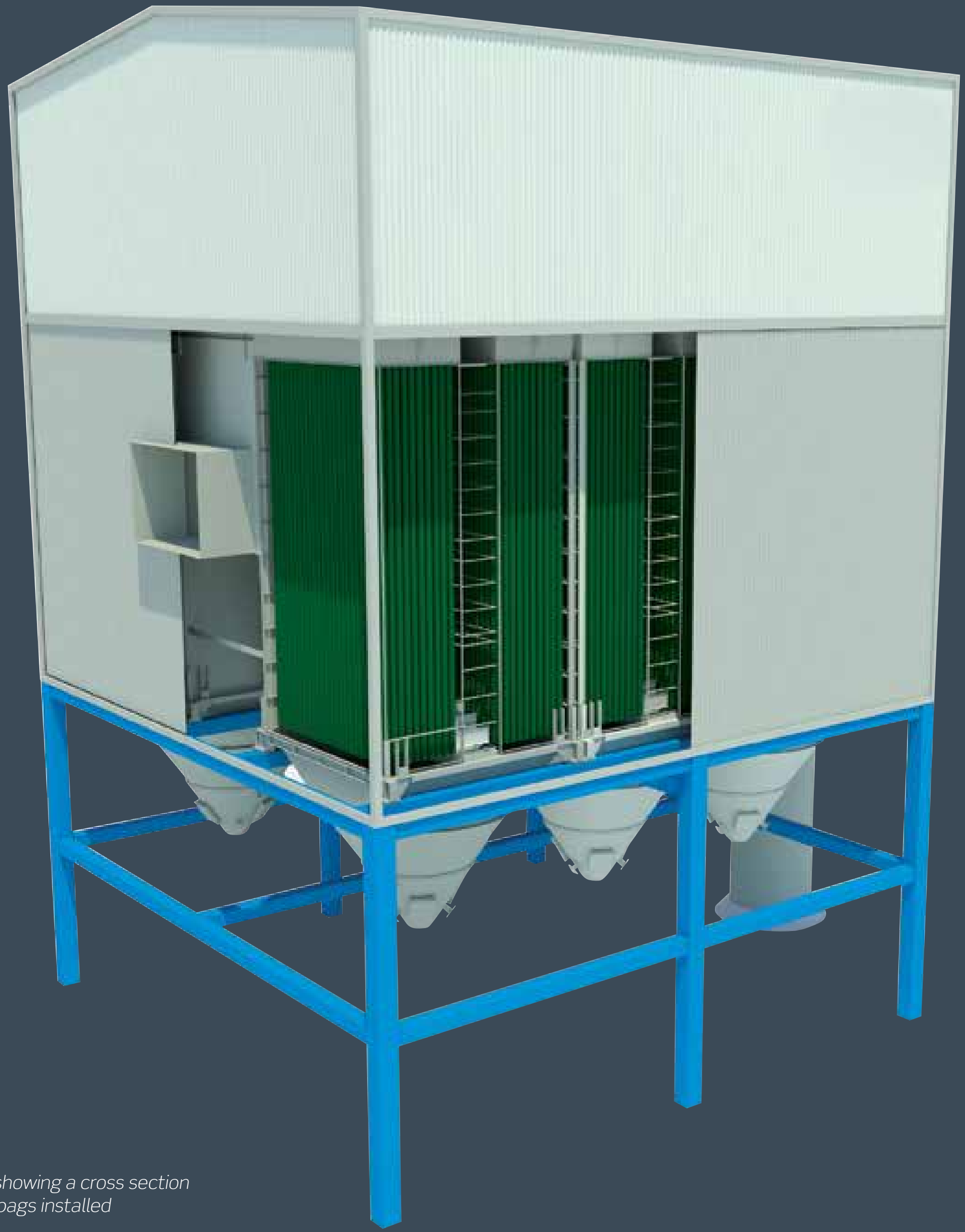
NOx
CataFlex™ use selective catalytic reduction (SCR) to remove NOx from off-gas, either by utilizing ammonia contained in the off-gas or via ammonia injection. The NOx is converted to harmless nitrogen and water.

NH_3
CataFlex™ eliminates any NH_3 slip from upstream selective non-catalytic reduction (SNCR) of NOx. This complies with NH_3 regulations and makes SNCR control easier.



Cut equipment **costs**

The Topsoe catalytic filter bag solution can help you reduce capital expenditures by up to 80% compared to competing solutions relying on separate dust removal and SCR technology.

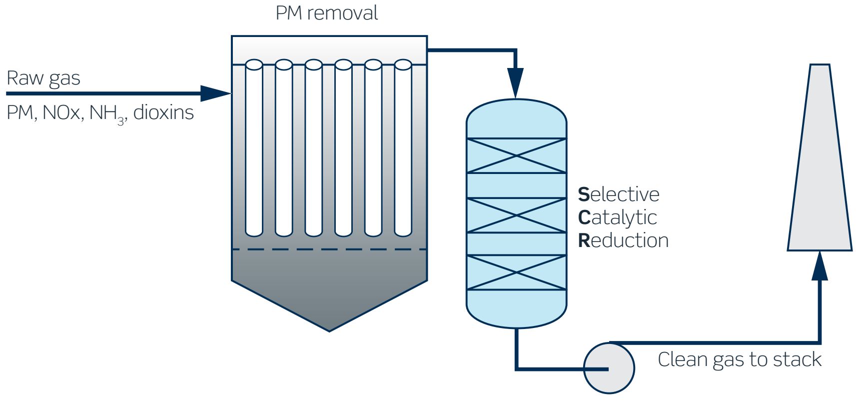


Typical fabric filter showing a cross section with catalytic filter bags installed

Filtration unit and tail end removal of NOx and NH_3

Traditional solution based on separated technologies

Non-catalytic filters

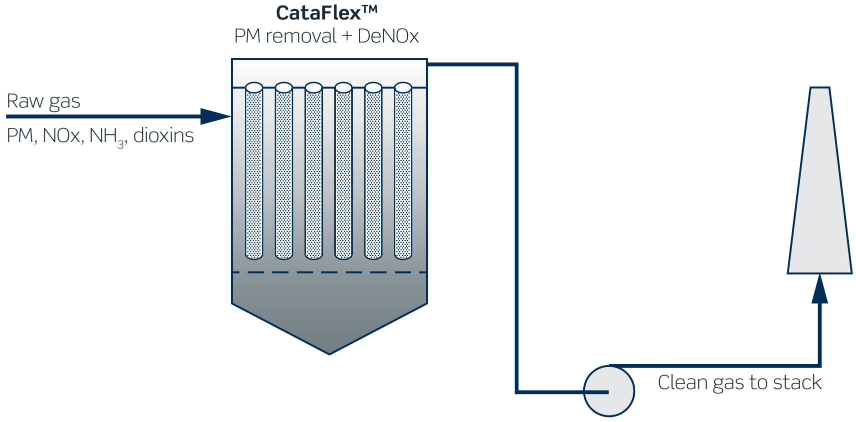


Catalytic filtration - integrated solution

Catalytic filter bag solution:

- Lower cost of ownership
- Less foot print
- Lower pressure drop
- Less maintenance

Catalytic filters



Related technologies

Discover the full range of Topsoe catalysts and technologies for optimizing performance

Optimized performance often means ensuring that multiple technologies and components are tuned to each other. If you're not already using them, please consider these related offerings from Topsoe.

S

Sulfur removal
As emission regulations continue to get tighter around the world, optimal handling of sulfurous gases is becoming increasingly important. In addition to meeting regulatory requirements, we make sure our solutions also make financial sense. Due to their high availability, energy efficiency and flexibility, our sulfur removal systems deliver market-leading performance. They can even be used to convert otherwise costly waste into valuable commercial-grade sulfuric acid.

VOC

VOC removal
Regulatory pressure on VOC emissions has never been greater, and we can help you meet the challenge by removing VOCs from off-gases via low-temperature catalytic processes. Our solutions deliver reduction efficiencies exceeding 99%, without creating any secondary pollutants. Our catalysts remove VOCs from air and waste gas streams in an energy-efficient and environmentally friendly manner.

Why partner with **Haldor Topsoe**

The Topsoe advantage lies not just in individual solutions, but in how our solutions work together

When you partner with Haldor Topsoe, you partner not only with the world's experts in catalysis, surface science and emissions management. You also partner with a company that takes a uniquely holistic approach to your plant and your business.

When we look at your plant, we look at the big picture – and then apply the full breadth of our expertise to deliver a thoroughly tailored solution, where individual components work together to maximize your plant's performance and your business success.

Haldor Topsoe is a world leader in catalysis and surface science. We are committed to helping our customers achieve optimal performance. We enable our customers to get the most out of their processes and products, using the least possible energy and resources, in the most responsible way. This focus on our customers' performance, backed by our reputation for reliability, makes sure we add the most value to our customers and the world.

Get in touch today
www.topsoe.com/Cataflex

Haldor Topsoe A/S, cvr 41853816 | GMC | 0268.2019/Rev.1

HALDOR TOPSØE

Appendix F

Tri-Mer Proposal

TECHNICAL FEASIBILITY ASSESSMENT

APPLICABILITY OF CERAMIC FILTERS FOR CEMENT PLANT POLLUTION CONTROL

REFERENCE NUMBER: **P-22.518**
REVISION: 0

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INTRODUCTION

In response to your recent request, we are pleased to provide Wingra Engineering with our initial assessment relating to the applicability of Ceramic Filter Technology at both the Holcim, Florence Site in Colorado, and the GCC, Pueblo Site in Colorado for multi-pollutant control.

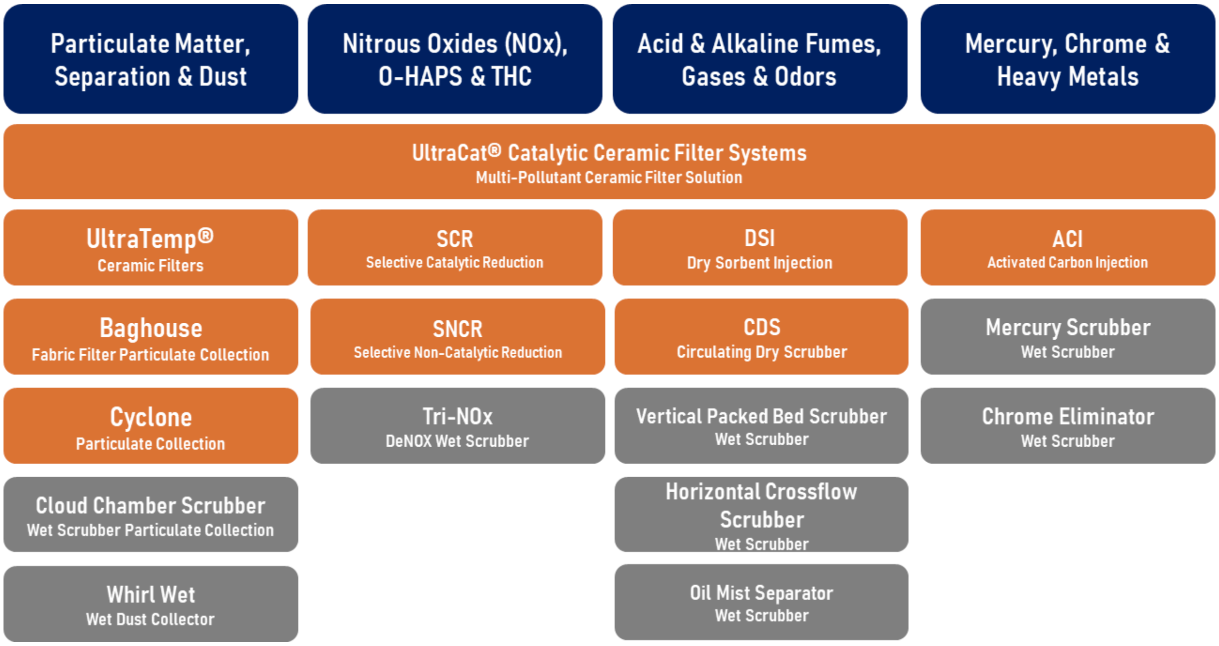
Ceramic Filter Technology has been utilized as a premier solution for Air Pollution Control (APC) for a number of decades, with Tri-Mer having installed over 75% of the ceramic filter systems operating across North America today. The technology has been enhanced considerably since the first US installation in the 2000's, with significant advancements in both the filter technology, and the overall multi-pollutant solution installed.

Across North America, while the technology has predominately been installed in the glass industry, it has wide applicability to a wide range of other industries. Specifically in respect to the cement industry, ceramic filter technology has been installed for the purposes of multi-pollutant reduction into a number of cement plants both in Europe and Asia, while there is also a major cement installation in the US.

Based on the initial information received, we expect that Tri-Mer's ceramic filter technology can be installed to both sites to fully achieve the requirements set forth in respect to both taking on the inlet conditions and operational requirements of both sites, while also meeting the legislative requirements for PM, NOx and SOx removal. Importantly, following our initial assessment, we fully expect Tri-Mer's proprietary ceramic filter technology – UltraCat® Catalytic Ceramic Filter Solution (UCF) - can be a cost-effective solution available to these plants.

OUR TECHNOLOGIES

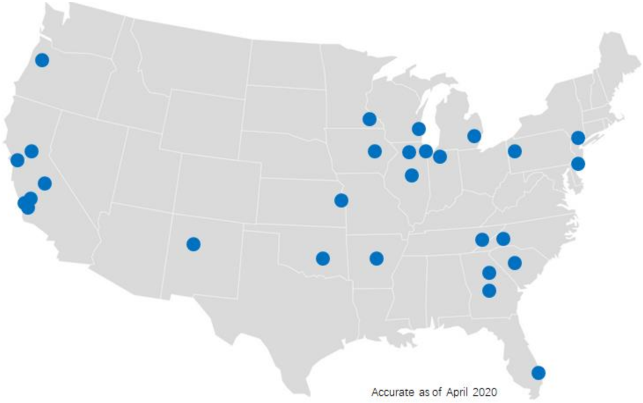
For over 60 years, TMC has developed an enviable reputation in the field of air pollution control. The business performed over 6,000 global installations, providing a wide range of technologies and solutions, to clients across most major industries. TMC has developed a large number of technologies in-house, and works with proven partners to allow for expanded scope where required.



Based in Owosso, Michigan, TMC is a full solution integrator, providing solutions that support our clients reduce almost all major air pollutants. The company headquarters include over 200,000 sq. ft. of state-of-the-art steel fabrication and manufacturing facilities. While our wide range of technologies and solutions provide the strong foundation for the business, it is our dedication to exceed your needs through full and flexible lifecycle services, that help to set us apart.

OUR EXPERIENCE

TMC is the global leader in designing and delivering high-efficiency ceramic filter technology. Through our proprietary UltraCat® Ceramic Filter systems, we have installed over 50,000 ceramic filters across over 40 installations in North America alone. The technology is proven to operate on all pre- and post-combustion processes, mitigating pollutants such as PM, SO_2, SO_3, HCl, O-HAPS, VOC, HF, and NO_x to higher removal rates than industry standard within a single system, while heavy metals, mercury, dioxins, and VOC O-HAPS can also be removed.



DESIGN PARAMETERS

To provide a basis to this assessment, our proposed solution has been evaluated based on the design and process details as outlined below:

Facility		Holcim Florence Portland Cement Plant Florence, Colorado Preheater/Precalciner Kiln	GCC Pueblo Pueblo Cement Plant Pueblo, Colorado Preheater/Precalciner Kiln
AIRS Point		111	039
Fuels		Coal, NG, TDF, Pet Coke	Coal, NG, TDF
Capacity	tons per day	5,950	3,750
Current Control for PM		Baghouse	Baghouse
Current Control for SO_2		Inherent & Wet Scrubbing	Inherent Scrubbing
Current Control for NOx		SNCR	SNCR
Exhaust Flow Rate (acfm)	acfm	827,731	306,708
Exhaust Temperature (°F)	°F	166	377
Exhaust Moisture (%)	vol.%	13.9	8.2
PM10 (Filterable)	(lbs/hr)	61,979.2	39,062.5
PM10 (Condensable)	(lbs/hr)	0.0	10,473.7
PM_{10} (Total)	(lbs/hr)	61,979.2	49,536.2
SO_2	(lbs/hr)	164.6	215.4
NOx	(lbs/hr)	1,041.3	656.3

DESIGN ASSUMPTIONS

Without gaining full access to full details regarding the operation and design of the existing systems in place at Holcim, Florence and GCC, Rio Grande, we have made the following assumptions, exclusions and clarifications within our overall assessment. Tri-Mer has the full capability to investigate, design and supply many of these elements within a full turnkey solution:

- Both cement plants use water quench system for adjustment of the flue gas temperature at baghouse inlet
- Adjustments to decreasing quench efficiency can be easily made in order to increase the flue gas temperature to about 550°F for 90% NOx removal efficiency. Tri-Mer is presently investigating capabilities to operate its UCF filters at lower temperature
- Existing baghouse is designed for 12' bag filters.
- Existing baghouse is designed for a face velocity at filter (air-to-cloth ratio) of 0.8 m/min (about 2.7 fpm)
- Typical operation temperature for the existing baghouse is limited to 425°F
- Existing infrastructure for online filter cleaning consists of pulse jet system and can be used for the cleaning of the UCF® filters, e.g. without any modifications to jet tubes, solenoid valves, tank volumes, available pressure and compressed air class 2 quality requirements.
- Existing ID-fans will be capable to handle additional volumetric flow and pressure drop requirements

OUR SOLUTION

With our extensive range of air pollution control technologies, our approach is always to identify the best technical fit for the specific project. As each project, client and site is unique, we ascertain the most appropriate technology and applicability of these technologies. For this assessment, we have evaluated ceramic filter technology only, and looked into the most economical option for the two sites.

Traditionally, ceramic filter technology is installed within its own filter housing (either UCF or UTF), both for brownfield and greenfield projects. More recently, where a baghouse is already installed and its design meets the flow and particulate requirements, we can utilize the existing baghouse and replace the existing filter bags with ceramic filters. This concept has been achieved outside of the US, while Tri-Mer has undertaken extensive design and capability assessments on other cement plants to ensure its applicability. Therefore, for both sites, our proposed Bag-to-Ceramic Filter Retrofit solution would include:

- Structural analysis of the existing baghouse with recommendations for structural improvement
- Engineering package and design of upgraded internals for the replacement of bag- with catalytically activated ceramic filters
- Engineering package with analysis of existing ID-fan capacity and if required, booster fan upgrade recommendations
- Upgrade equipment, both internal replacements and structural modifications
- Catalytically activated UCF replacement filters
- Aqua ammonia storage, dosing and injection system, utilizing a 30,000-gal tank for 7+ days holding capacity at GCC Rio Grande and a 4+ days holding capacity at Holcim Florence
- Mechanical and electrical installation
- Site supervision

EXPECTED SYSTEM PERFORMANCE

Tri-Mer's UltraCat® Catalytic Ceramic Filter Systems are proven to deliver some of the highest levels of pollutant reduction available from commercially proven technology. Based on the initial process information provided, we expect our solution to deliver the following:

Targeted Pollutant	Expected Performance[1]	Test Method
PM10	>99.9%	US EPA Test Method 5
PM2.5	>99.9%	US EPA Test Method 201A or 202
NOx	>90%	US EPA Test Method 7E
SOx	>90%	US EPA Test Method 8A
Ammonia Slip	<10ppm	US EPA Test Method CTM 027

Note: 1 Based on a 30 day rolling average

When considering both NOx and SOx, Tri-Mer have the capability to provide higher levels of performance should it be required through the additional of supplementary technology and solutions.

ESTIMATED COSTS

Utilizing the existing information provided, and aligned with our extensive experience in providing ceramic filter systems, we fully expect that our Bag-to-Ceramic Filter Retrofit would be one of the most cost-effective solutions to providing some of the highest levels of pollutant reduction available

	Holcim, Florence	**GCC, Pueblo**
Estimated Upfront Capital Investment Cost (US $)	$31,250,800	$8,999,200
Estimated Cost per ton NOx removed per annum[1] *(CapEx + 20 Year OpEx / ton NOx removed per year)*	$1,576/ton of NOx removed per annum	$800/ton of NOx removed per annum
Estimated Lifetime Cost[2] *CapEx + 20 Year OpEx*	USD $129,250,800	USD $41,399,200
Estimated Lifetime Cost per annum[2] *(CapEx + 20 Year OpEx / 20 years)*	USD $6,462,540 per annum	USD $2,069,960 per annum

<u>Note</u>:

[1] *the following base cost assumed: Power: US$44/MWh; Aqua ammonia (19 wt.%): US$1,200/ton; Maintenance: US$270,000/yr; Replacement Filters: Once every 10 years.*

[2] *Lifetime cost does not include any assumption to calculate NPV*

The estimated costs shown in the table below are preliminary, and we would require additional information to better ascertain the exact costs for each facility.

ADDED BENEFITS

In addition to the estimated costs, both capital and 20-year lifetime costs, the ceramic filter technology will provide a wide range of benefits to both facilities in comparison to utilizing the existing baghouse (with filter bags) and the installation of a new SCR:

1. **Minimal Footprint**

   Unlike a requirement to add an SCR, our proposed solution to retrofit the existing baghouse, will not require significant footprint to ensure that the site meets increased NOx mitigation. The only footprint that will be required would be for the ammonia storage and transport system to deliver the targeted levels of NOx, SOx and PM,

2. **Reduced Onsite Installation Labor**

   In alignment with the minimal footprint requirement, the proposed retrofit would significantly reduce the requirement for civil, mechanical installation, and electrical installation, reducing both the cost, complexity and the time taken to install the solution.

3. **Minimal Catalyst Plugging**

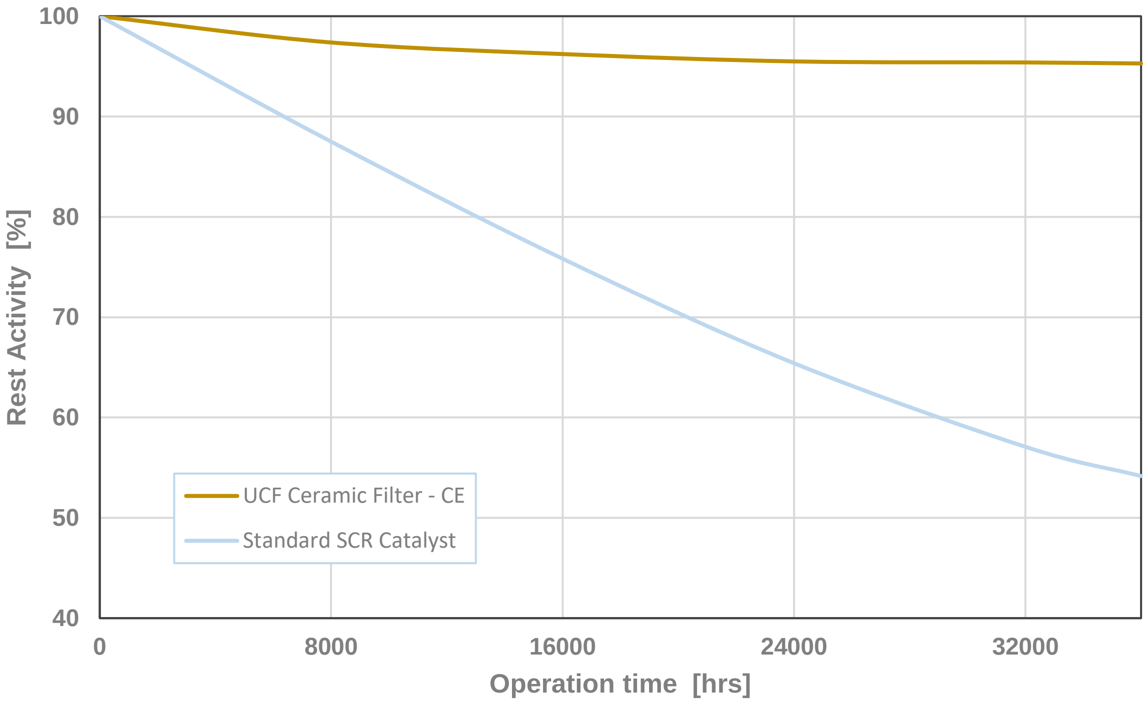
   The SCR DeNOx catalyst is finely distributed throughout the filter wall. Since the ceramic material of the filter is rigid, the filter does not inflate or otherwise change shape or form during jet pulse cleaning, unlike bag filters do. As a consequence, UCF filters always will maintain a residual filter cake as a barrier for any dust constituents, preventing active sites and pore system from being coated and plugged.

4. **Reduced Ammonia Slip**

   Field testing of ammonia slip in service with regenerative glass furnace, e.g. periodical flow reversal, typically show very low ammonia slip well below 10 ppm and even allow the use of ammonia slip monitoring for reliable filter breakage detection.

5. **Negligible Catalyst Deactivation**

   As noted in #3, unlike the catalyst provided within an SCR, the nano-catalyst embedded within the ceramic filter is protected by the ceramic filter and its filter cake. This will ensure that the catalyst is not poisoned and therefore deactivated in the same way as the SCR. Our experience estimates that a SCR catalyst would need to be replaced every 2-3 years, whereas a ceramic filter has no deactivation of the catalyst in a continuous operation for 10 years+.



6. **Temperature Consistency**
   As the existing Baghouse and proposed SCR require different operating temperatures, the installation of an SCR would require significant reheat, driving higher costs and CO2 as a result of this activity. The proposed ceramic filter technology has an optimal operating temperature range at about 550°F.

7. **Continuous Operation**
   Tri-Mer's ceramic filter technology is designed to allow for continuous operation with a capability to provide full redundancy. This will ensure that both cement plants will be able to operate for as long as required, without downtime or bypass associated with the SCR downstream of the Baghouse.

8. **Mitigation of SO_2 to SO_3 Conversion**
   While the UCF filter can excel a 90% NOx conversion at 550°F, SO2 to SO3 conversion at this temperature is expected to be minor.

9. **Experience**
   While the ceramic filter technology may be a relatively new concept to S-based cement plants, ceramic filters are used in a number of cement plants around the world. Tri-Mer work with the leading suppliers of ceramic filters who have the experience and knowledge of cement plant operation. Our knowledge about system design, together with their capabilities in filter technoligy, will ensure that our solution can meet the needs of these projects.

Last Page