

## **Appendix 9E**

### **St Mary's Cement BART Technical Analysis**



**BART Application for Regional Haze**

**for**

**St Marys Cement Inc. (US)  
Portland Cement Manufacturing Plant  
Charlevoix, Michigan**

**December 28, 2006**

**Prepared By:  
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Project No. 16-060416**



Mr. Asadullah Khan, Senior Environmental Engineer  
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AQD – Strategic Development Unit  
P.O. Box 30260  
Lansing, MI 48909

Dear Mr. Khan:

December 21, 2006

Pursuant to your letter dated August 9, 2006, referencing the federal Regional Haze program, found at 40 CFR Part 51, Subpart P, requiring best available retrofit technology (BART), enclosed is a detailed engineering plan representing BART, as it would apply to the existing in-line kiln system located at the St Marys Cement Inc. (U.S.) (SMC) plant in Charlevoix, Michigan. The AQD had identified the in-line kiln system as a BART eligible source at SMC's plant. The deadline for submitting this plan is December 31, 2006.

The enclosed engineering plan addresses the available control technologies for particulate matter (PM), nitrogen oxides (NO<sub>x</sub>), and sulfur dioxide (SO<sub>2</sub>), and summarizes SMC's findings for BART, as it would apply to these air contaminants from the in-line kiln system.

SMC has recently implemented new control technologies for the in-line kiln system. These new controls consist of low-NO<sub>x</sub> burners (identified as an indirect firing system or "IDF") for the kiln and pre-calciner, and a new state-of-the-art baghouse control device for PM routed to the main stack. The baghouse replaced the existing main stack electrostatic precipitator, and the IDF replaced the existing solid fuel firing system. These new control technologies are identified and explained further in the enclosed engineering plan.

We authorize NTH Consultants, Ltd. to serve as our agent in responding to your questions concerning the engineering plan. Should you have any questions concerning the plan, please contact them at 517-484-6900.

Sincerely,

**Dirk A. Cox**

Dirk A. Cox  
Operations Manager

Enclosure

cc: Mr. Delbert Rector – NTH  
Mr. David Ferrier – NTH  
Mr. Courtney Schmidt – SMC  
Fred Dindoffer, Esq., Bodman



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## 1.0 EXECUTIVE SUMMARY

On March 27, 2006, the Michigan Department of Environmental Quality, Air Quality Division sent a letter informing St Marys Cement (SMC) that their Charlevoix facility was subject to the requirements for Best Available Retrofit Technology (BART). SMC held a subsequent meeting on June 12, 2006, with their consultant, NTH Consultants, Ltd, and the AQD to discuss the implications of being subject to the requirements of BART. A preliminary outline of the BART analysis was submitted to the MDEQ-AQD at the end of August 2006.

The emission unit identified as being subject to the BART requirements is the line kiln and pre-calciner. The AQD has identified nitrogen oxides (NO<sub>x</sub>) and sulfur dioxide (SO<sub>2</sub>) as the visibility-impairing pollutants of concern. SMC is including particulate matter with an aerodynamic diameter of less than 10 microns (PM<sub>10</sub>) in its BART application, since this pollutant is also identified in Appendix Y (Guidance for BART Determinations) of 40 CFR Part 51.

The AQD has performed an analysis to determine whether there is a potential for SMC to have a significant impact on various Class I areas. Under EPA guidelines, BART is required if the impacts exceed 21 days per three years of greater than 0.5 deciview, which represents a 98<sup>th</sup> percentile of probability. MDEQ has used actual emissions from 2004 and 7 days per year of greater than 0.5 deciview as a basis for determining whether Michigan sources should be subject to BART. Based on the Y2003 & Y2004 actual reported emissions, the AQD determined that SMC does have an impact that exceeds the requirements for a de minimus impact of 0.5 deciview more than 7 days per year. Visibility modeling using CALPUFF showed that there are 10 days in 2002 based on potential-to-emit emissions where the impacts of PM<sub>10</sub>, NO<sub>x</sub> and SO<sub>2</sub> showed greater than 0.5 deciview. The highest impact was predicted to be 5.257 deciviews.

Recent CALPUFF modeling indicates that there are still visibility impacts that exceed 0.5 deciview for more than 7 days in a year, which is based on the current allowed emissions for PM, SO<sub>2</sub>, and NO<sub>x</sub>, in SMC's current Permit to Install, identified as No. 700-77H. PM is considered to be PM<sub>10</sub> for purposes of this application.



Table 1 below describes the BART-eligible emissions unit, BART technology, affected pollutant, emission limits, averaging times, visibility improvement, and mostly affected Class I area.

**Table 1 – Summary of Proposed BART**

<b>BART Emissions Unit</b>	<b>Proposed BART</b>	<b>Pollutant</b>	<b>BART Limit</b>	<b>Emissions Averaging Time</b>	<b>Visibility Benefit</b>	<b>Class I Area(s) Impacted</b>
Kiln System	Baghouse on Main Stack	PM <sub>10</sub>	0.30 lb/ton raw feed	Stack Test Protocol	None	Mostly Seney NWR
	IDF & Pre-Calciner	NO <sub>x</sub>	6.5 lb/ton clinker	30-day rolling average	None	Mostly Seney NWR
	Alkaline exhaust gas	SO <sub>2</sub>	4404 tons/year <sup>1</sup>	12-month rolling	None	Mostly Seney NWR

<sup>1</sup> The SO<sub>2</sub> emission limit is based on 8760 hours/year of continuous operation.

The remaining portion of this document demonstrates why the above technology and resulting emission limits represents BART. For NO<sub>x</sub>, the recently installed indirect firing system (IDF) with the use of a pre-calciner represents BART. Regarding PM<sub>10</sub>, SMC recently replaced the main stack ESP with a new baghouse, and the BART Guidance in Appendix Y of 40 CFR Part 51 allows the use of the MACT standard to represent BART.

SO<sub>2</sub> emissions are primarily attributed to the sulfur content of the raw material, not the sulfur content of the fuel. SO<sub>2</sub> emissions are currently much lower than the allowed rate because the limestone and shale currently being mined from the quarry have lower than historical sulfur content. The quarry still contains considerable raw material with sulfur content similar to what has been historically used. SMC cannot commit to using only the lower sulfur raw materials in the quarry, as that would greatly limit the future production capacity of the plant.



## 2.0 INTRODUCTION

SMC became the operator of the Charlevoix Plant on April 1, 2005, after it was purchased from CEMEX. The facility is located at 16000 Bells Bay Road, Charlevoix, Michigan, on 1300+ acres. The existing plant is a portland cement manufacturing facility that consists of quarry operations, crushing systems, raw feed receiving and storage areas, raw mill systems, fuel receiving and storage areas, a preheater/precalciner (or flash furnace), kiln, clinker cooler, clinker storage systems, finish mill systems, and a cement storage and shipping facility. The manufacture of Portland cement primarily involves crushing, grinding and blending of limestone and other raw materials into a chemically proportioned mixture which is then heated in a flash furnace (or precalciner) followed by a rotary kiln at extremely high temperatures (2800 degrees Fahrenheit) to produce pellets about one half to 2 inches in diameter. The pellets, known as clinker, are cooled and ground in ball mills together with 5% to 10% gypsum to produce the final product, Portland cement.

The BART eligible emission unit at SMC is the existing kiln system, which consists of the precalciner and horizontal kiln. The kiln system uses fuels to achieve the necessary temperature to convert raw materials into clinker. The primary fuels are coal and petcoke. The other fuels being used are propane and oil for startup purposes, and oil fuel is used in the event that solid fuels (coal and petcoke) are unavailable. The kiln system cannot operate at continuous full production when using oil fuel.

The remaining sources of  $\text{NO}_x$  and  $\text{SO}_2$  are small heaters/boilers for hot water heating (bathrooms and showers), and cold weather heating of various buildings (such as the main office and other on-site buildings that require heating).

### **Nitrogen Oxides ( $\text{NO}_x$ )**

$\text{NO}_x$  are present in the flue gas in two forms: thermal  $\text{NO}_x$  and fuel  $\text{NO}_x$ . Thermal  $\text{NO}_x$  forms when nitrogen and oxygen molecules in the combustion air are disassociated at peak flame temperatures and recombined into oxides of nitrogen (primarily NO). Fuel  $\text{NO}_x$  is formed when the nitrogen in the fuel (fuel-bound nitrogen) is combined with oxygen in the combustion air to form  $\text{NO}_x$ .



Current control technologies for emissions of NO<sub>x</sub> from cement kilns include the following:

- Selective catalytic reduction (SCR)
- Mid-kiln firing;
- Biosolids injection;
- CemStar™;
- Low NO<sub>x</sub> burners;
- Use of a pre-calciner; and,
- Selective non-catalytic reduction (SNCR).

### ***Selective Catalytic Reduction***

Although a report published by MACTEC in 2005 identified selective catalytic reduction (SCR) as a viable option, this option has never been proven in the United States and has only one (1) application worldwide.

In a letter to the Midwest Regional Planning Organization in response to the MACTEC report titled *Cement Best Available Retrofit Technology (BART) Engineering Analysis*, the Portland Cement Association (PCA) described the use of SCR at Portland cement plants as follows:

“Given the uncertainty in control efficiency, the still evolving application to cement kilns and excessive cost of installation and operation, SCR should not be considered as a BART (Best Available Retrofit Technology) control.”

Finally, MACTEC retracted their earlier analysis saying:

“After reviewing available literature, we agree that SCR technology has limited applicability and is not likely to be considered reasonably available or BART.”

### ***Mid-Kiln Firing***

Mid-kiln firing involves modifying the horizontal kiln to accept a certain portion of the kiln's total heat input approximately half way down the kiln. This type of modification is generally done when a kiln would be firing tire-derived fuel (TDF). Literature cautions the use of mid-kiln firing for short



kilns, which SMC currently operates. SMC has ruled this technology out due to mid-kiln firing being not technically feasible for SMC's short kiln.

### ***Biosolids***

Biosolids, in the form of dewatered sewage sludge, are injected into the mixing chamber of the pre-calciner, and works identical to a SNCR system. Heating of the mix with biosolids releases ammonia, which reacts with the nitric oxide (NO) from the pre-calciner to act like a SNCR unit. This requires an enormous amount of available sewage sludge. This type of control is best implemented in an area that is highly populated to provide a continuous supply of sewage sludge. Charlevoix is not a large enough metropolis to supply the necessary amounts of sludge on a continuous basis.

Introducing moisture into a cement kiln system's exhaust gas has detrimental effects due to the entrained water causing the cement-like dust to coagulate and stick to the internal equipment, which then needs to be removed causing lost production and incurring additional maintenance. This is discussed further under the NO<sub>x</sub> and SO<sub>2</sub> discussions in Section 4.0. Both SNCR for NO<sub>x</sub> control and dry flue gas desulfurization for SO<sub>2</sub> control involve adding a moist, or wet, reagent into the exhaust gas where the entrained cement dust becomes sticky and adheres to the internal sides of the equipment.

### ***CemStar™***

CemStar™ employs the use of iron or steel slag to reduce NO<sub>x</sub> formation. Since the slag requires less heat input, less fuel is needed to produce clinker. Less heat input means less fuel consumption, and, therefore, less NO<sub>x</sub> formation. Slag is also a cheaper raw material. SMC currently uses iron or steel slag in their process. Although the use of the slag requires that the chemistry of the slag be compatible as a raw material, SMC has been, and will continue to use, iron or steel slag whenever they can due to the lower energy costs for making clinker, and the cheaper cost of a raw material. However, the availability of slag is sporadic, and cannot be consistently depended upon as a continuous NO<sub>x</sub> control technology.



### ***Low NO<sub>x</sub> Burners***

Low NO<sub>x</sub> burners incorporate a design feature that reduces the formation of NO<sub>x</sub>. Through proper design and good combustion practices the formation of NO<sub>x</sub> can be limited by controlling the peak combustion temperature, gas residence time in the peak temperature, and the air to fuel ratio. The recently installed indirect firing system (IDF) reduces the available combustion air thereby reducing the formation of NO<sub>x</sub> in the flame zone where temperatures exist to prompt the formation of NO<sub>x</sub>. The MDEQ-AQD recognizes the fact that an IDF system is considered to be a low NO<sub>x</sub> burner. See Rule 801(1)(c).

### ***Pre-Calciner Kiln System***

SMC utilizes a pre-calciner system that further reduces the emissions of NO<sub>x</sub>, as compared to other systems used in the Portland cement industry. In a typical pre-calciner kiln, almost 40 to 50 percent of the fuel is burned at a lower temperature, which reduces thermal NO<sub>x</sub> formation.

### ***Selective Non-Catalytic Reduction (SNCR)***

SNCR involves injecting a nitrogen based compound, typically ammonia or urea solution, into the exhaust gas stream at a point where optimum temperature(s) exist to prompt the reaction of the ammonia or urea solution with the NO<sub>x</sub> in the exhaust gas to form elemental nitrogen and water. Control efficiencies vary depending on the amount of available ammonia or urea solution, and the residence time to allow the reaction to proceed. SNCR systems are typically located in the breeching between the exhaust end of the kiln and where the exhaust gases from the kiln enter the pre-calciner. Some cement plants have incorporated the use of SNCR to control potential NO<sub>x</sub> emissions.

Therefore, the use of using SNCR as an additional control technology is explored further in Section 4.0.

### ***Sulfur Dioxide (SO<sub>2</sub>)***

Sulfur dioxide (SO<sub>2</sub>) emissions are primarily determined by the content of the sulfur in the raw materials. Kilns that use raw materials with little or no volatile sulfur have relatively low SO<sub>2</sub> emissions. Conversely, kilns that use raw materials with larger amounts of sulfur can expect to have larger amounts of SO<sub>2</sub> emissions. Since this facility is located next to their own quarry, there



is little choice in the use of raw materials. However, SMC has made it a practice of selecting the lowest available sulfur content raw materials from their quarry.

Additionally, sulfur in the fuels fed to the kiln system will not lead to significant SO<sub>2</sub> emissions, due to the strong alkaline nature in the sintering zone, the calcination zone and in the lower stage of the preheater. Depending on the process and the source of the sulfur, SO<sub>2</sub> absorption, in the kiln itself, ranges from about 70 percent to more than 95 percent.

SMC also utilizes a baghouse to control the emissions at the kiln. The dust collected in this baghouse forms a highly alkaline layer on the bags further aiding the reduction of SO<sub>2</sub>.

A study by MACTEC Engineering and Consulting, Inc. in 2005 identified advanced flue gas desulfurization (AFGD), dry FGD (or dry scrubbing), and wet FGD (or wet scrubbing) as viable control options for SO<sub>2</sub> emissions from Portland cement factories. Therefore, these control options will undergo further evaluation in Section 4.0.

#### **Particulate Matter (PM)**

BART for PM is not necessary according to Appendix Y of 40 CFR Part 51, because the MACT standard for Portland cement plants (40 CFR Part 63, Subpart LLL, and also known as the "Portland Cement MACT") includes a PM emission limit of 0.30 lb PM/ton of raw feed for the kiln system. The Appendix Y guidance indicates that the states can rely on the MACT standards for an affected pollutant (such as VOC and PM) to satisfy the BART requirement for that pollutant.

Nonetheless, SMC has recently replaced the main stack ESP with a state-of-the-art baghouse.

Therefore, a BART analysis for PM has not been done since SMC complies with the PM emission limit in the Portland Cement MACT.



### **3.0 EMISSION CONDITIONS AND VISIBILITY IMPACTS FOR THE BART-ELIGIBLE KILN SYSTEM**

The following Tables 2 through 4 provides data as requested by the MDEQ-Air Quality Division. Table 2 lists the conditions for modeling input data. Table 3 contains the basis for 24-hour emissions data in Table 2. Table 4 presents the visibility modeling results.

A site plan is included in Appendix A. The CALPUFF modeling results are contained in Appendix H.



Table 2 – Modeling Input Data

Emission Unit ID	24-Hour Actual Emissions (Lbs)		Stack ID	UTM Easting Location	UTM Northing Location	UTM Zone	Stack Height <sup>1</sup> (Feet Above Ground)	Ground Elevation (Feet Above Mean Sea Level)	Exit Diameters (Inches)	Exhaust Gas Flow (ACFM)	Exhaust Temp (°F)
	SO <sub>2</sub>	NO <sub>x</sub>									
Kiln System	2520	1179.7	96	Main	5019500	16	323	626.6	132	499,890	220
	280	131.1	10.7	Bypass	5019300	16	225	626.6	78	110,700	224

<sup>1</sup> The stack heights and diameters have not been changed, nor will they be in the near future.

Table 3 – Basis for 24-Hour Emissions Data in Table 2

Emission Unit ID	Basis for 24-Hour SO <sub>2</sub> Emissions	Basis for 24-Hour NO <sub>x</sub> Emissions	Basis for 24-Hour PM <sub>10</sub> Emissions
Kiln System	Proposed BART Emissions	Proposed BART Emissions	Proposed BART Emissions

Table 4 – Visibility Modeling Results

Emission Unit ID	Class I Area with Greatest Impact	2002		2003		2004		2002-2004 Combined	
		Modeled 98 <sup>th</sup> Percentile Value	No. Of Days Exceeding 0.5 Deciview	Modeled 98 <sup>th</sup> Percentile Value	No. Of Days Exceeding 0.5 Deciview	Modeled 98 <sup>th</sup> Percentile Value	No. Of Days Exceeding 0.5 Deciview	Modeled 98 <sup>th</sup> Percentile Value	No. Of Days Exceeding 0.5 Deciview
Kiln System	Seney NWR	5.26	30	3.64	39	2.48	62	5.26	131



#### 4.0 BART ANALYSIS FOR THE AFFECTED EMISSION UNIT (KILN SYSTEM)

Appendix Y of 40 CFR Part 51 contains the requirements for making a BART determination. This guidance identifies various sources of information when researching available control alternatives. SMC has included a copy of the results of a RACT/BACT/LAER Clearinghouse database search, and is included in Appendix E. Appendix F contains the basis for the NO<sub>x</sub> SNCR control alternative. Appendix G contains the costs for wet and dry flue gas desulfurization (see Table IV-5 on page 4-21).

#### 4.1 NITROGEN OXIDES (NO<sub>x</sub>)

NO<sub>x</sub> is one of the precursors that can cause visibility impacts at the various federally designated Class I areas. Therefore, SMC has undertaken a review of various control technologies that could be implemented to reduce NO<sub>x</sub> emissions from their kiln system. This evaluation takes into consideration the pre-calciner and short kiln, with the control that SMC has recently implemented that includes the IDF.

##### *Low NO<sub>x</sub> Burners*

Low NO<sub>x</sub> burners are designed to reduce the formation of thermal NO<sub>x</sub>. This results in early ignition, especially of the volatile compounds in the fuel, in an oxygen-deficient atmosphere, and then complete combustion is achieved with additional air later on in the combustion process. This reduces the flame temperature where NO<sub>x</sub> is formed, which in turn reduces the formation of NO<sub>x</sub>.

Michigan Rule 801(1)(c) recognizes the use of an IDF as meeting the requirements for a low NO<sub>x</sub> burner. IDFs are being used by the cement industry to increase their kiln system's thermal efficiency and reduce air pollution. In November 2005, SMC submitted a permit application for a revision to Permit No. 700-77A requesting approval for the installation of the use of an IDF for their kiln. The AQD issued the permit on February 9, 2006. SMC has installed this equipment, completed a trial operation, and is currently demonstrating successful operation of this new equipment.



Furthermore, Rule 801(4)(e)(i) allows the use of a low NO<sub>x</sub> burner in cement kiln systems to achieve reductions of NO<sub>x</sub> emissions for the ozone control period.

### ***Selective Non-catalytic Reduction***

Selective non-catalytic reduction (SNCR) involves injecting ammonia or urea into the exhaust to react with NO<sub>x</sub> to form nitrogen and water. The injection must take place at a point where the exhaust temperatures are between 1600 and 2000 °F, and has sufficient retention for the injected agents to achieve the proper reaction. SNCR results in the buildup of ammonium bisulfite scale, which is very significant for sulfur-containing raw materials and fuels. SNCR systems also appear to convert some NO to N<sub>2</sub>O. Additionally, if the temperatures are above or below the appropriate temperature window unconverted ammonia is emitted (referred to as ammonia-slip). The ammonia that slips out can then form aerosols of ammonia chlorides and ammonia sulfates. These can become visible as a white plume above the exhaust stack.

A report in 2005 titled, *Interim White Paper - Midwest RPO Candidate Control Measures, Source Category: Cement Kilns*, from the Midwest Regional Planning Organization describes the use of SNCR by saying “SNCR technology has the potential to offer significant reductions on some precalciner kilns.” In other words, there is simply not enough data at this time to warrant the use of SNCR. Furthermore, SMC currently has an SNCR system installed at their facility that has been fraught with problems, due to plugging in the breeching to the pre-calciner.

SMC uses a SNCR system to meet the requirements of Rule 801(4)(e), which is currently used to control NO<sub>x</sub> emissions only during the ozone season. The existing SNCR causes buildup of materials inside the ductwork between the kiln and pre-calciner, which is the optimal place for the urea/NO<sub>x</sub> reaction to occur thereby reducing NO<sub>x</sub> emissions. This SNCR system achieves approximately 10% reduction of NO<sub>x</sub> emissions. Whenever a wet substance, such as the liquid urea, is introduced into a cement process, it causes the cement material in the exhaust gases from the kiln to become sticky, and adheres to the sides of the ductwork between the kiln and pre-calciner. Air cannons are used to help reduce the buildup. The entire breeching would need to have many air cannons to remove the buildup that occurs along the length of the breeching. The breeching surface area is approximately 1150 square feet, and each air cannon is only effective for an approximate six square-foot area. This would mean an additional 181 air cannons to help



reduce the build-up of materials on the sides of the breeching. These additional air cannons would require additional air compressor(s), which also requires additional electricity expense, and additional cooling water that would require treatment before discharge into surface waters (like Lake Michigan). The buildup reduces airflow through the kiln system, which involves eventual manually removing the buildup, and reduces production as the buildup continues. Manually removing the buildup requires the shutdown of the kiln, meaning a costly loss of one day's production. Air cannons are not entirely effective in removing all of the buildup. Therefore, installing extra air cannons would be costly and would only reduce the frequency, but not eliminate the need, for shutdowns.

The SNCR unit that is currently in place is not adequate for continuous operation, and would require the installation of another SNCR system that would be designed to achieve reliable annual service.

The cement plants that have incorporated SNCR technology also have state-of-the-art pre-calciner equipment that make the use of a SNCR system effective. EPA's RACT/BACT/LAER Clearinghouse (RBLC) (attached as Appendix E) shows which plants have the SNCR technology. Replacing the existing pre-calciner to be able to use SNCR would be extraordinarily expense, and is not considered BART.

Another issue is weather conditions. The winter weather in Charlevoix, MI experiences hard freezing temperatures that would cause solidification of the urea tank, pumps, and piping. With a 40% urea mixture, the temperature needs to be approximately 100°F to prevent the mixture from hardening. With the use of the existing SNCR during the warmer late spring/summer months, and with the heat of the kiln system, urea flow is not a problem. However, extensive heating lines would need to be installed to prevent solidification of the urea tank, pumps, and piping during the colder months of fall, winter and early spring. This results in higher installation and operating costs to install and maintain a SNCR system and keep it operating on an annual basis.

Nonetheless, a cost analysis for implementing a SNCR control system is included as Appendix B. The cost per ton of controlled NO<sub>x</sub> is \$7,568 per ton, which is judged to be cost prohibitive to represent BART for SMC's kiln system.



Based on the above, SMC has determined that the continued use of, or replacement of, a SNCR system to achieve some control of the NO<sub>x</sub> emissions is not feasible.

### ***Proposed BART***

SMC is proposing a BART emission limit for NO<sub>x</sub> of 6.5 lb NO<sub>x</sub>/ton-clinker, based on a 30-day rolling average, and represents a reduction of 15% from the current non-ozone season limit of 7.67 lb/ton clinker. A limit of 6.5 lb NO<sub>x</sub>/ton clinker would also result in a reduction of approximately 9.5% on an annual basis. This limit would be applicable continuously, except during startups, shutdowns, and malfunctions. During startups, shutdowns and malfunctions, there is no clinker being produced that would warrant having a normalized emission limit. This emission limit is well within the accepted range of BACT determinations as found within the RBLC. SMC will attain this emission limit through the use of using iron or steel slag whenever possible, a low NO<sub>x</sub> burner via their recently installed IDF, a pre-calciner and kiln system, and good combustion practices. For the reasons stated above, SNCR is not considered a viable option at this time. Furthermore, SMC has previously implemented SNCR at this facility and had several issues with the technology. The original intent for the SNCR was to meet the ozone season emission limit for NO<sub>x</sub>. The SNCR was installed prior to the installation of the indirect firing system, and was necessary to reduce the NO<sub>x</sub> emissions during the ozone season. During the non-ozone season, the SNCR was not used.

## **4.2 SULFUR DIOXIDE (SO<sub>2</sub>)**

SO<sub>2</sub> is formed from the introduction of raw materials that contain sulfur into the hot zones of the pre-calciner. SO<sub>2</sub> from the combustion of fuel(s) are easily absorbed into the raw materials and clinker due to their highly alkaline nature.

Portland cement plants are typically located adjacent to quarries that are used as raw material. Quarries generally vary in sulfur content depending on the location. As an example, quarries in the northern portion of the United States have higher sulfur content than those quarries in the southern portion of the United States. An individual quarry's sulfur content can also vary from seam to seam, which makes it impossible to guarantee that the raw feed will always be low in



sulfur content. SMC is currently using lower sulfur raw feed from the quarry, but it cannot be assumed that the quarry will continue to provide lower sulfur content raw materials. And, as stated previously, SMC cannot guarantee that the higher sulfur raw materials will never be used.

The following discusses different SO<sub>2</sub> control technologies, and how they may, or may not, be used at SMC's plant to reduce SO<sub>2</sub> emissions.

#### ***Advanced Flue Gas Desulfurization (AFGD)***

The AFGD process accomplishes SO<sub>2</sub> removal in a single absorber, which performs three functions: pre-quenching the flue gas, absorption of SO<sub>2</sub>, and oxidation into gypsum.

However, as the Portland Cement Association (PCA) points out in a letter dated October 2005, this technology cannot be considered technically feasible at this time because there is a substantial lack of data demonstrating its effectiveness. In their own study, MACTEC acknowledges that there are currently no known installations of AFGD at Portland cement facilities. Furthermore, in March 2006, MACTEC responded to the PCA letter and agreed that the advanced FGD system was a U.S. Department of Energy demonstration project (*Advanced Flue Gas Desulfurization (AFGD) Demonstration Project A DOE Assessment*, August 2001) and asserted that it was questionable whether it is even technically feasible. Therefore, this technology cannot be considered a viable option for SMC.

#### ***Wet Flue Gas Desulfurization (Wet Scrubbing)***

Wet FGD utilizes gas absorption technology to remove SO<sub>2</sub> in the waste gas. The absorbent can be a slurry of calcium carbonate, hydroxide or oxide. The slurry is injected counter current to the exhaust gas and collected in a recycle tank at the bottom of the scrubber where it is oxidized with air to form a dehydrate of calcium sulfate. Finally, dehydrate is separated and used as gypsum in cement milling and the water is returned to the scrubber.

In the United States, wet scrubbers have been demonstrated successfully in the utility industry; however, they require more care when used for a Portland cement facility. Calcium sulfate scaling and cementitious buildup occur when a wet scrubber is applied to the exhaust gas from a cement kiln. These can be avoided if these systems are installed downstream of a high efficiency



particulate control device, however, any malfunction of the particulate control device can pose adverse problems for a wet scrubber. From the RBLC, only two (2) plants are currently utilizing wet scrubbers. One of the plants, Continental Cement Company, LLC, of Missouri, has an emission limit of 12 lb SO<sub>2</sub>/ton-clinker. The other plant, Lehigh Cement Company of Iowa, has a very small emission limit, and most likely due to being a new plant.

Furthermore, wet FGD processes generate significant amounts of solid waste and require additional care for solids disposal.

A cost analysis for a wet FGD control system is contained in Appendix C. The cost per ton of controlled SO<sub>2</sub> is \$9,258 per ton, which is judged to be cost prohibitive to represent BART for SMC's kiln system.

#### ***Dry Flue Gas Desulfurization (Dry Scrubbing)***

Dry scrubbing systems spray lime slurry into an absorption tower where SO<sub>2</sub> chemically reacts with the lime and is absorbed by the slurry. The liquid-to-gas ratio is such that the water evaporates before the droplets reach the bottom of the tower. The dry solids are carried out with the gas and collected through a control device such as a fabric filter or ESP. Exhaust gases that exit at or near the adiabatic saturation temperatures can create problems with this control technology as listed below:

- Significant plugging and corrosion problems in the downstream particulate control device, duct work, and induced draft fan.
- The lime slurry would not dry properly, and it would plug up the dust collection system. Injecting an aqueous solution into the cement making process' exhaust gas stream has detrimental effects because there is cement dust in the exhaust gas. This causes the entrained cement dust to stick to the sides of the ductwork, which causes operational downtime and maintenance issues to remove the material sticking to the ductwork.

These types of issues are probably why, as of 2001, there was only one SO<sub>2</sub> dry scrubber in operation at a cement plant in Europe (and possibly worldwide), at the HCB-Untervaz plant in



Switzerland. Since this technology does not have a proven track record in the Portland cement industry, it cannot be considered a viable option.

Nonetheless, a cost analysis for implementing a dry FGD control system is included as Appendix D. The cost per ton of controlled SO<sub>2</sub> is \$8,988 per ton, which is judged to be cost prohibitive to represent BART for SMC's kiln system.

***Proposed BART***

Due to the highly alkaline environment within the kiln, thus creating its own natural scrubbing process, SMC believes no additional controls are necessary. Furthermore, SMC already employs a method of selecting the lowest available sulfur content raw materials. While three other control options were explored, none of these options are considered to be viable options for SMC, even based on SMC's potential to emit from their most recent Permit to Install. One of these options is considered technically infeasible (AFGD), another is not economically justified (dry scrubber), and the third option would only marginally reduce the already minimal SO<sub>2</sub> emissions while generating solid wastes with excessive costs that do not warrant being considered BART. SMC will continue to manage the raw feed from the quarry to minimize sulfur input to the kiln system, but cannot guarantee that the quarry will continue to produce lower sulfur content materials.

**BART Summary**

Table 5 presents the emission rates as a result of applying BART for SMC.



**Table 5 – Post-Control Emission Rates for the In-Line Kiln System**

<b>Pollutant</b>	<b>Control Technology</b>	<b>Maximum 24-Hour Emissions (lbs)</b>	<b>Percent Reduction</b>
NO <sub>x</sub>	IDF & Pre-Calciner	31,460	15.3 <sup>1</sup>
SO <sub>2</sub>	Use of low sulfur raw feed, as available <sup>2</sup>	67,200	None
PM <sub>10</sub>	Baghouse on Main Stack & ESP on Bypass Stack	2,561	None

<sup>1</sup> This is based on a reduction from 7.67 lb NO<sub>x</sub>/ton clinker to 6.5 lb NO<sub>x</sub>/ton clinker.

<sup>2</sup> SMC will make every attempt to use lower sulfur raw materials, but cannot guarantee it at all times in the future.





**Appendix A**  
**Facility Site Map**



**CEMEX INC.  
CHARLEVOIX, MICHIGAN**

DATE OF PHOTOGRAPHY: 11/20/2003

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GeoEye-1/2004





## **Appendix B**

### **SNCR NO<sub>x</sub> Control Cost**

**CAPITAL COSTS**

**Direct Costs**  
**Purchased Equipment Costs(1)**

SNCR	1,371,630		
Instrumentation	137,163		
Freight	68,582		
<b>Purchased Equipment Cost, PEC (B)</b>	<b>1,577,375</b>		

**Direct Installation Costs**

Foundations & supports	189,285		
Handling & erection	630,950		
Electrical	15,774		
Piping	473,212		
Insulation	15,774		
Painting	15,774		
<b>Direct Installation Costs</b>	<b>1,340,768</b>		

**Site Preparation, as required**  
**Buildings, as required**

Site Specific			
Site Specific			
<b>Total Direct Costs, DC</b>	<b>2,918,143</b>		

**Indirect Costs**

Engineering	157,737		
Construction and field expenses	157,737		
Contractor fees	157,737		
Start-up	15,774		
Performance test	15,774		
Contingencies	47,321		
<b>Total Indirect Costs, IC</b>	<b>552,081</b>		

**Total Capital Investment = DC + IC**

<b>Total Capital Investment = DC + IC</b>	<b>3,470,224</b>		
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Cost is from the Environ Report contained in Appendix F. \$400,000 of this is retro-fit capital to winterize the system to prevent solution freezing  
EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual

EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual  
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EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual  
EPA Air Pollution Control Cost Manual

**ANNUAL COSTS**

**Direct Annual Costs, DC**

<b>Operating Labor</b>				
Operator	\$25.38	1/2 hr per shift, 8000 hr/yr	12,600	EPA Air Pollution Control Cost Manual
Supervisor	15%	of operator	1,904	
<b>Operating Materials</b>				
Reagent (Urea) 1.06 \$/gal, 180 gal/hr, 8000 hr/yr, 60 lb/lbmole, 40 wt% Urea			1,440,000	
Catalyst NA -				
<b>Maintenance</b>				
Labor	\$17.77	1/2 hr per shift, 8760 hr/yr	8,756	EPA Air Pollution Control Cost Manual
Materials		100% of maintenance labor	45,990	
Electricity - 0.07 \$/kW-hr, 100 kW, 6570 hr/yr (for heating urea solution in cooler season)				
Clean out cementic build up on sides of ducting - 5 events/year, 1 day per event, \$40/ton cement lost revenue, 4840 tpd lost cement production, \$193,600 per day lost revenue.				
<b>Total Direct Annual Costs, DC</b>			968,000	This is based on past history of clean-out while using a SNCR for the ozone system.
			<b>2,486,096</b>	

**Indirect Annual Costs**

Overhead	60%	of total labor and material costs	883,264	EPA Air Pollution Control Cost Manual
Administrative Charges	2%	of Total Capital Investment	69,404	EPA Air Pollution Control Cost Manual
Property tax (Not allowed in Michigan)	0%	of Total Capital Investment	0	EPA Air Pollution Control Cost Manual
Insurance	1%	of Total Capital Investment	34,702	EPA Air Pollution Control Cost Manual
Capital Recovery 14.24% for a 10 - year equipment life and a 7% interest rate	1.4%		494,160	
<b>Total Indirect Annual Costs, IC</b>			<b>1,481,530</b>	

**Total Annual Costs = DC + IC**

**3,967,626**

**Pollutant Removed (tons/yr)**

524

\$242.9      \$741 tpy (reduced to 8000 hr/yr operation) with a 10% control efficiency, 10% control efficiency is obtained from SMC, and is based on actual results.

**Cost per ton of NOx removed**

**\$7,568**





## **Appendix C**

### **Wet FGD Control Cost**

Appendix C

**CAPITAL COST**

**Total Capital Investment (Includes all costs associated with direct equipment, engineering, freight, & ancillary costs)** **\$19,132,278**

Based on \$10.83 per ton of clinker. "Assessment of Control Options for BART-Eligible Sources", March 2005. See Appendix G. This cost is based on Y2002.

**ANNUAL COST**

**Total Indirect Annual Costs** **\$14,380,124**

Based on \$8.14 per ton of clinker. "Assessment of Control Options for BART-Eligible Sources", March 2005. See Appendix G. This cost is based on Y2002.

**Total Annual Costs (Capital Cost + Annual Cost)** **\$33,512,402**

**Pollutant Removed (tons/yr)** **3,620**

4021.9 4022 tpy (reduced to 8000 hr/yr operation) with a 90% control efficiency.

**Cost per ton of SO<sub>2</sub> removed** **\$9,258**





## **Appendix D**

### **Dry FGD Control Cost**

Appendix D

**CAPITAL COST**

Total Capital Investment (Includes all costs associated with direct equipment, engineering, freight, & ancillary costs) **\$19,361,936**

Based on \$10.96 per ton of clinker. "Assessment of Control Options for BART-Eligible Sources", March 2005. See Appendix G. This cost is based on Y2002.

**ANNUAL COST**

Total Indirect Annual Costs **\$9,557,306**

Based on \$5.41 per ton of clinker. "Assessment of Control Options for BART-Eligible Sources", March 2005. See Appendix G. This cost is based on Y2002.

**Total Annual Costs (Capital Cost + Annual Cost) \$28,919,242**

Pollutant Removed (tons/yr) **3,218**

4021.9 4022 tpy (reduced to 8000 hr/yr operation) with a 80% control efficiency.

**Cost per ton of SO<sub>2</sub> removed \$8,988**





## **Appendix E**

### **RBLC Search Results**

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FILE ID	FACILITY NAME	FACILITY STATE	FACILITY CONTACT	PERMIT DATE	FACILITY DESCRIPTION	OTHER PERMITTING INFORMATION	PROCESS NAME	FUEL	THRU PUT	THRU PUT UNIT	PROCESS NOTES	POLLUTANT	CTRL DESC	EMIS LIMIT1	EMIS LIMIT1 UNIT	EMIS LIMIT1 (t/ton of clinker)	ENIS LIMIT1 AVGTIME CONDITION	CASE-BY-CASE BASIS
VA-0272	ROANOKE CEMENT	VA	ROBERT OMER	6/13/2003	CEMENT MANUFACTURING FACILITY	#5 LIME KILN - BECAUSE OF THE HIGHER ORGANIC CONTENT OF THE AVAILABLE ROCK RAW MATERIAL CAUSING GREATER CO EMISSIONS, THE CO LIMIT FROM THE #5 LIME KILN SYSTEM WAS INCREASED FROM 1296 TONS/YR TO 1800 TONS/YR. THE SHORT TERM CO LIMIT HAS NOT CHANGED. NO PHYSICAL CHANGES WERE MADE AT THE FACILITY.	LIME KILN	COAL	1300000	T/YR		NO2	GOOD COMBUSTIONS PRACTICES AND A CONTINUOUS EMISSION MONITORING SYSTEM	982	LB/H			BACT-PSD
SD-0003	GCC DACOTAH	SD	GENE NELSON	4/10/2003	GCC DACOTAH QUARRYS LIMESTONE, SAND, AND GYPSUM IN THE SURROUNDING AREA TO PROVIDE RAW MATERIALS FOR ITS PORTLAND CEMENT PLANT. OTHER RAW MATERIALS SUCH AS IRON AND SHALE ARE SHIPPED IN BY TRUCK FROM OTHER AREAS. COAL IS USED AS THE HEAT SOURCE AND IS SHI	GCC Dacotah owns and operates a limestone quarry and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per day. The permit also requires emissions monitoring and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per day.	ROTARY KILN #6	CLINKER	2250	T/D	Rotary kiln #6 burns coal as a heat source. Approximately 35% of the coal is burned in the preheater/precalciner and the remaining 65% of the coal is burned in the main burner of the kiln. The emission limits for NOx, SO2, and CO are for the entire kiln system. The kiln system has three emission points (1 - Rotary kiln #6, 2 - Alkali bypass and alkali waste to waste bin transfer system, and 3 - Coal Mill) Compliance with the SO2, CO, and NOx emission limits will be based on continuous emission monitoring systems.	NOX	PREHEATER/PRECALCINATOR SYSTEM	2267	T/YR	5.52		BACT-PSD
SD-0003	GCC DACOTAH	SD	GENE NELSON	4/10/2003	GCC DACOTAH QUARRYS LIMESTONE, SAND, AND GYPSUM IN THE SURROUNDING AREA TO PROVIDE RAW MATERIALS FOR ITS PORTLAND CEMENT PLANT. OTHER RAW MATERIALS SUCH AS IRON AND SHALE ARE SHIPPED IN BY TRUCK FROM OTHER AREAS. COAL IS USED AS THE HEAT SOURCE AND IS SHI	GCC Dacotah owns and operates a limestone quarry and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per day. The permit also requires emissions monitoring and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per day.	MATERIAL TRANSFER, ALKALI	CLINKER	2250	T/D	Process is alkali bypass and alkali waste to waste bin transfer. The emission limits for NOx, SO2, and CO are for the entire kiln system. The kiln system has three emission points (1 - Rotary kiln #6, 2 - Alkali bypass and alkali waste to waste bin transfer system, and 3 - Coal Mill) Compliance with the SO2, CO, and NOx emission limits will be based on continuous emission monitoring systems.	NOX		2267	T/YR	5.52		BACT-PSD
FL-0271	BRANFORD CEMENT PLANT (SUWANNE)	FL	JOE HORTON	3/30/2006	THE FACILITY IS A PORTLAND CEMENT MANUFACTURING PLANT WITH ONE LINE (KILN NO. 1) AND ALL ITS ASSOCIATED CEMENT MANUFACTURING EQUIPMENT UNITS PERMITTED IN 1998. THIS PROJECT IS FOR THE CONSTRUCTION OF A NEW LINE (KILN NO. 2) THAT WILL INCLUDE A CLINKER AND CEMENT HANDLING STORAGE, COAL MILL AND COAL TRANSFER SYSTEM, DRY PROCESS PREHEATER/PRECALCINER, ROTARY KILN WITH AN IN-LINE RAW MILL, RAW MATERIAL HANDLING AND STORAGE. CHANGES TO THE EXISTING FACILITY WILL INCLUDE INCREASED PRODUCTION FOR THE PRIMARY CRUSHER, RAW MATERIALS PROCESSING AND INCREASED MATERIAL BEING TRANSPORTED THROUGHOUT THE PROCESS.	THIS PERMIT IS IN THE DRAFT PHASE	KILN WITH LINE RAW MILL WITH SNCR AND BAGHOUSE	COAL	127	T/H drinker		NOX	SNCR	1.95	LB/TON CLINKER	1.95	CEMS 30 DAYS ROLLING AVERAGE	BACT-PSD
FL-0286	BROOKSVILLE CEMENT PLANT (FCS)	FL	CHARLES ALLEN	12/20/2004	THIS FACILITY WILL CONSIST OF A PORTLAND CEMENT PLANT AND ASSOCIATED QUARRY AND RAW MATERIAL AND CEMENT HANDLING OPERATIONS. THE PLANT WILL COMBINE RAW MATERIALS AND UTILIZE A PREHEATER/PRECALCINER KILN WITH IN-LINE RAW MILL TO PRODUCE CLINKER. THE CLINKER WILL BE MILLED AND COMBINED WITH GYPSUM TO PRODUCE PORTLAND CEMENT. THIS PROJECT IS A NEW CEMENT MANUFACTURING LINE. NEW EMISSIONS UNITS FOR THE PROJECT INCLUDE A RAW MILL SYSTEM, DRY PROCESS PREHEATER/PRECALCINER KILN SYSTEM, CLINKER HANDLING SYSTEM, FINISH GRINDING OPERATIONS, TWO CEMENT LOADOUT SILOS, AND COAL HANDLING AND GRINDING OPERATIONS.	SNCR INSTALLED FOR NOX CONTROL. NOX EMISSIONS WILL NOT EXCEED 2.4 LB/TON OF CLINKER FOR THE FIRST 180 DAYS AFTER INITIAL STARTUP. EMISSIONS LISTED IN POLLUTANT SECTION ARE FOR AFTER THE 1ST YEAR OF OPERATION.	125 TPH CLINKER KILN AND ASSOCIATED EQUIPMENT	COAL			KILN THROUGHPUT SHALL NOT EXCEED 2800 TON PER DAY CLINKER AND 125 TPH CLINKER	NOX	SNCR	1.95	LB/TON CLINKER	1.95	30 DAY	BACT-PSD
FL-0267	THOMPSON S. BAKER CEMENT PLANT (FR)	FL	CHRIS HORNER	11/5/2004	THIS FACILITY CONSISTS OF A PORTLAND CEMENT PLANT AND ASSOCIATED QUARRY, RAW MATERIAL AND CEMENT HANDLING OPERATIONS. THE PLANT WILL COMBINE RAW MATERIALS AND UTILIZE A PREHEATER/PRECALCINER KILN WITH IN-LINE RAW MILL TO PRODUCE CLINKER. THE CLINKER WILL BE MILLED AND COMBINED WITH GYPSUM TO PRODUCE PORTLAND CEMENT. THIS PROJECT IS TO ADD A NEW 125 TPH CLINKER KILN AND ALL ASSOCIATED ANCILLARY EQUIPMENT.	SNCR ADDED FOR NOX CONTROL. NOX EMISSIONS RATE WILL BE 2.45 LB/TON CLINKER FOR THE FIRST 180 DAYS AFTER INITIAL START UP. NOX EMISSIONS LISTED IN THE POLLUTANT SECTION ARE FOR AFTER THE INITIAL YEAR AFTER STARTUP.	IN LINE KILN/RAW MILL WITH ESP AND SNCR	COAL				NOX	SNCR	1.95	LB/TON CLINKER	1.95	30 DAY	BACT-PSD
MS-0071	HOLCIM (US) INC.	MS	JAMES BOYD	8/20/2004	THIS IS A WET PROCESS CEMENT (PORTLAND) MANUFACTURING PLANT. THE PROJECT UNDER REVIEW WAS		PORTLAND CEMENT MANUFACTURING	COAL	650000	TON CLINKERY R		NOX	GOOD COMBUSTION PRACTICE	10	LB/T	10.00		BACT-PSD

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ELCID	FACILITY NAME	FACILITY STATE	FACILITY CONTACT	PERMIT DATE	FACILITY DESCRIPTION	OTHER PERMITTING INFORMATION	PROCESS NAME	FUEL	THRUPUT	THRUPUT UNIT	PROCESS NOTES	POLLUTANT	CTRL DESC	EMIS LIMIT1	EMIS UNIT	EMIS LIMIT1 (lb/ton of clinker)	EMIS LIMIT1 AVERAGE CONDITION	CASE-BY-CASE BASIS
LA-0070	LEHIGH CEMENT COMPANY - MASON CITY PLANT	IA	RITA DUNN	12/11/2003	PLEASE NOTE THAT A WET SCRUBBER WAS ADDED FOR BACT WHICH RESULTS IN A NET DECREASE IN PLANT EMISSIONS OF SO2 OF AROUND 5,400 TONS/YR. THE TABLE BELOW DOES NOT ALLOW NEGATIVE NUMBERS.	PROJECT NUMBER 2003-490 AND 05-282. THE PERMIT NUMBER LISTED ABOVE IS THE FACILITY'S PLANT NUMBER.	KILN/CALCINER/PREHEATER	COAL	150	T/H	Throughput is 1 clinker/h	NOX	SNCR, LOW NOX BURNERS, COMBUSTION CONTROLS, AND PROPER KILN DESIGN.	2.85	LB/T	2.85	LB/TON OF CLINKER	BACT-PSD
SD-0003	GCC DACOTAH	SD	GENE NELSON	4/10/2003	GCC DACOTAH QUARRYS LIMESTONE SAND AND GYPSUM IN THE SURROUNDING AREA TO PROVIDE RAW MATERIALS FOR ITS PORTLAND CEMENT PLANT. OTHER RAW MATERIALS SUCH AS IRON AND SHALE ARE SHIPPED IN BY TRUCK FROM OTHER AREAS. COAL IS USED AS THE HEAT SOURCE AND IS SHI	GCC Dacotah owns and operates a limestone quarry and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per year. Facility Number 01-0577-18026. BACT evaluation was not performed for the kiln because it was determined that no physical or operational change was made to the kiln. This project involved: replacing the raw mill; and constructing new feed equipment for the kiln (fuel & raw materials). The new replacement equipment was more efficient than previous equipment, & resulted in increased throughput for the kiln. This triggered review for NOx and VOC for the kiln only. No new pollutant limits for the replacement equipment. Facility limits listed here are the change in limits from the previous project.	COAL MILL	COAL	20	T/H	The emission limits for NOx, SO2, and CO are for the entire kiln system. The kiln system has three emission points (1 - Rotary kiln #6, 2 - Alkali bypass and alkali waste to waste bin transfer system, and 3 - Coal Mill) Compliance with the SO2, CO, and NOx emission limits will be based on continuous emission monitoring systems.	NOX	PREHEATER/PRECALCINATOR SYSTEM	5.52	T/YR	2267		BACT-PSD
AL-0003	HOLCIM (US) INC.	AL	TRAVIS OSBORNE	2/14/2003	PORTLAND CEMENT MANUFACTURING	FACTORY NUMBER 01-0577-18026. BACT evaluation was not performed for the kiln because it was determined that no physical or operational change was made to the kiln. This project involved: replacing the raw mill; and constructing new feed equipment for the kiln (fuel & raw materials). The new replacement equipment was more efficient than previous equipment, & resulted in increased throughput for the kiln. This triggered review for NOx and VOC for the kiln only. No new pollutant limits for the replacement equipment. Facility limits listed here are the change in limits from the previous project.	KILN SYSTEM (CALCINING KILN, PREHEATER/PRECALCINATOR)	COAL	390	T/H	Throughput is process capacity. Added efficiency increased throughput, and triggered review for NOx & VOC for the kiln only.	NOX		1.76	T/YR	2998		Other Case-by-Case
MD-0059	CONTINENTAL CEMENT COMPANY, LLC	MD	JERRY EPPERSON	9/24/2002	CONTINENTAL CEMENT COMPANY INTENDS TO REPLACE ITS EXISTING CEMENT KILN WITH A NEW, LARGER CAPACITY CEMENT KILN. THE NEW KILN IS DESIGNED TO INCREASE ANNUAL PRODUCTION OF CLINKER FROM 0.6 MILLION TONS TO 1.6 MILLION TONS. THE NEW OPERATIONS WILL INCLUDE A	CONDUCTED FOR THIS PROJECT WHICH DETERMINED THAT THE NET EMISSION INCREASE FOR THE PROJECT WOULD NOT EXCEED THE SIGNIFICANT LEVEL FOR ANY AIR POLLUTANT. HOWEVER, FOR THE NET EMISSIONS INCREASE TO BE LESS THAN THE SIGNIFICANCE LEVEL, STRINGENT CONTROLS ARE MADE A PART OF THE PERMIT. THESE CONTROLS INCLUDE THE USE OF FABRIC FILTERS (FOR PM10 CONTROL), A WET SCRUBBER AND LOW SULFUR COAL FOR CONTROL OF SULFUR OXIDES, LOW-NOX BURNERS AND SELECTIVE NON-CATALYTIC REDUCTION (SNCR) FOR CONTROL OF NITROGEN OXIDES, A PYROCLON (OR SIMILAR TYPE UNIT) AND A THERMAL OXIDIZER FOR CONTROL OF CARBON MONOXIDE EMISSIONS, AND A THERMAL OXIDIZER FOR CONTROL OF VOC EMISSIONS. THE CONTROLS AND RESULTANT EMISSIONS LIMITATIONS ARE SUCH THAT WE URGE OTHER AGENCIES PERMITTING AGENCIES TO PERMITTING THE PROJECT.	ROTARY KILN	COAL	183	T/H	Emissions from the rotary kiln and the pyroprocessing system are routed through the same controls. Thus, emission limits for the kiln and pyroprocessing system are the same. The pyroprocessing system transforms raw materials into clinker. The clinker is then introduced to the rotary kiln. The pyroprocessing system is fueled with liquid hazardous waste and coal as backup, 722.4 mmbtu/h, compliance verified by calculations.	NOX	SELECTIVE NON-CATALYTIC REDUCTION, LOW NOX BURNERS, TOP AIR FLOUT.	8	LB/T	8.00	lb/ton clinker, 30-day rolling avg	Other Case-by-Case
LA-0052	LAFARGE CORPORATION	IA	SCOTT NIELSON	7/1/2002		THIS PROJECT WAS TO ALLOW THE SOURCE TO INCREASE THE CAPACITY OF ITS PREHEATER/PRECALCINER KILN SYSTEM FROM 3050 TONS OF CLINKER PER DAY TO 3488 TONS OF CLINKER PER DAY. THE LATEST MODIFICATION WAS TO allow waste oil as a fuel, to amend the CO BACT limit and to write a PSD permit for the clinker cooler which was not permitted under the previous project number (PN 95-464).	CEMENT MANUFACTURING PREHEATER/PRECALCINER KILN	COAL	3488	T/D	COMPLIANCE WILL BE DETERMINED AFTER MODIFICATION. CEM FOR NOX, SOX AND OPAQTY. KILN IS LIMITED TO USING FUEL OIL, NATURAL GAS, COAL, AND CORE AS FUELS. IN ADDITION TO CLAY AND STONE, THE KILN IS ALLOWED TO USE THE FOLLOWING SUPPLEMENTAL MATERIALS IN LIMITED QUANTITIES: COAL COMBUSTION RESIDUE, FOUNDRY BY-PRODUCTS, HYDROCARBON CONTAINING SOILS, REFINERY BY-PRODUCTS, AND OILS AND GREASES. THERE ARE MULTIPLE POLLUTANT ENTRIES FOR TSP AND SO2 BECAUSE THEY HAVE DIFFERENT BASES FOR THEIR EMISSION LIMITS. STACK TESTING WAS	NOX	GOOD COMBUSTION PRACTICES	2546	T/YR	4.00		BACT-PSD

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ELCID	FACILITY NAME	FACILITY STATE	FACILITY CONTACT	PERMIT DATE	FACILITY DESCRIPTION	OTHER PERMITTING INFORMATION	PROCESS NAME	FUEL	THRUPTUT	THRUPTUT UNIT	PROCESS NOTES	POLLUTANT	CTRL DESC	EMIS LIMIT1	EMIS LIMIT1 UNIT	EMIS LIMIT1 (lb/ton of clinker)	EMISLIMIT1 AVERAGE CONDITION	CASE-BY-CASE BASIS
MD-0027	LEHIGH PORTLAND CEMENT COMPANY	MD	DAVID ROUSH	6/8/2000	PORTLAND CEMENT MANUFACTURING PLANT	EPA ID: 24-13-00012. LEHIGH PORTLAND CEMENT COMPANY'S UNION BRIDGE MODERNIZATION PROJECT INCLUDES THE INSTALLATION OF A 5 STAGE PREHEATER/PRECALCINER PYROPROCESSING UNIT TO REPLACE FOUR EXISTING LONG DRY KILNS. ADDITIONAL PLANT-WIDE EMISSIONS: LEAO = 0.5 T/YR; FLUORIDE = 2.0 T/YR.	CEMENT MANUFACTURING PREHEATER/PRECALCINER KILN	COAL	2214000	T/YR	THE PERMITS REQUIRE THE COMPANY TO CONDUCT STACK EMISSIONS TESTS AND OPERATE CEMS FOR COMPLIANCE DETERMINATION. THROUGHPUT IS CLINKER PRODUCT	NOX	A 5-STAGE PREHEATER/PRECALCINER PYROPROCESSING PLANT IS SELECTED FOR NOX EMISSION ABATEMENT. ANY ADDITIONAL NOX EMISSIONS CONTROL HAS BEEN DETERMINED TO BE EITHER:	4871	T/YR	4.40		Other Case-by-Case
MI-0087	HOLNAM, INC.	MI	MICHELLE FERGUSON	3/20/2000	PORTLAND CEMENT PLANT.	EPA ID: MID-008039500. AIRS ID: MI-0066824; M/SRN: B1743. ACTUAL START-UP DATE IS NOT AVAILABLE. CEMENT PLANT OPERATING SINCE 1960. SINCE APPROX. 1990, WET PROCESS CEMENT PLANT HAS BEEN USING CARBON INJECTION FOR THE CONTROL OF ORGANICS. PERMIT MOD 60-71L ALLOWS FOR CESSATION OF CARBON BAGHOUSES FOLLOWED BY SLURRY SCRUBBERS. THEN RTO. THIS POLLUTION CONTROL PROJECT IS NOT SUBJECT TO PSD. AND NOT A MAJOR MODIFICATION. THIS PERMIT SOURCE IS AUTHORIZED TO BURN TIRE CHIPS, UP TO ABOUT 21% OF HEAT INPUT, ON A PERMANENT BASIS. DURING TRIAL BURNS UNDER EARLIER PERMIT #69-71L STACK TESTS WERE CONDUCTED AND BECAME A BASIS FOR MUCH OF EMISSION LIMITS HEREIN.	CEMENT KILNS, WET PROCESS (2)	COAL	100	T/H FEED	MOST COMPLIANCE WILL BE DEMONSTRATED BY CEMS. AGENCY CAN INVOKE STACK TEST. CONVERSION TO PARTIAL TDF IS EXPECTED TO HAVE LITTLE EFFECT ON TOTAL PM EMISSIONS. PER APRIL 1997 TEST BURN.	NOX	CURRENT EXISTING LIMIT DOES NOT REFLECT POTENTIAL 30% REMOVAL IN SLURRY-SCRUBBER. SOME GENERATION OF NO2 BY NATURAL GAS COMBUSTION IN RTOS.	6	LB/T	6.00		Other Case-by-Case
WA-0307	PORTLAND CEMENT CLINKERING PLANT	WA		10/2/2001	MODIFICATION TO PORTLAND CEMENT PLANT PER AMENDMENTS TO ORDERS OF APPROVAL 3382 & 7381. CHANGING THE ORIGINAL PSD, AND REQUIRING AN UPDATED PSD BY PUGET SOUND CLEAN AIR AGENCY. THE MODIFICATION DELETED THE BACT LIMIT FROM THE PSD AND MOVED THE LIMIT TO A NONATTAINMENT PERMIT. THE AREA CHANGED STATUS BETWEEN INITIAL ISSUANCE OF THE PSD AND THE AMENDMENT.	INFORMATION ENTERED FOR AMENDMENT 3 OF PERMIT PSD-90-03. PLEASE REFER TO RBLIC ENTRY WA-0024 FOR THE ORIGINAL PERMIT INFORMATION.	KILN EXHAUST STACK				NO FUEL OR THROUGHPUT STATED IN THE PERMIT. NO MENTION OF EMISSION LIMITS FOR PM10 IN THE PERMIT. HOWEVER IT STATED THAT PM10 WILL BE SUBJECT TO LAER	NOX	NONE INDICATED	650	PPM @ 10% O2		24-H AV	BACT-PSD
TX-0355	PORTLAND CEMENT MANUFACTURING PLANT	TX	LARRY ALEXANDER	6/29/2001	THIS PORTLAND CEMENT MANUFACTURING PLANT USES THE DRY PROCESS AND A SINGLE KILN. THE RAW MATERIALS ARE FINELY GROUND AND BLENDED IN A DRY STATE PRIOR TO BEING FED THROUGH THE PREHEATER/CALCINER TOWER LOCATED AT THE FEED-END OF THE ROTARY CEMENT KILN. IN T	THIS PROJECT WAS SUBMITTED TO RECONCILE A PSD RETROACTIVE REVIEW FOR CO. ADDITIONAL STATE PERMITTING ACTIONS WILL INCLUDE AN AMENDMENT FOR INCREASED EMISSION ALLOWABLES FOR CO, VOC, HCL AND H2SO4. THERE IS NO NEW CONSTRUCTION AS A RESULT OF THIS AMENDMENT	GRINDING/PREHEATING KILN, K-19				ADDITIONAL APPLICABLE SCC CODES: 30500622 & 30500613. EMISSION RATES FOR THE KILN ARE BASED ON A MAXIMUM CLINKER PRODUCTION OF 124 T/H. THE TWO GRINDING MILLS SHALL NOT EXCEED A PRODUCTION OF 240 T/H COMBINED OF PROCESSED MATERIAL. EMISSIONS FROM K-19 MUST COMPLY WITH NSPS SUBPART F.	NOX	NONE INDICATED	660	LB/H	2.64		Other Case-by-Case
CO-0043	RIO GRANDE PORTLAND CEMENT CORP.	CO	BRIAN MCGILL	9/25/2000	MANUFACTURE OF PORTLAND CEMENT (DRY PROCESS)	CLINKER PRODUCTION: 950,000 T/YR; FINISHED CEMENT: 1,000,000 T/YR; COAL CONSUMED: 122,500 T/YR. RAW MATERIALS QUARRIES ADJACENT TO PLANT. CONTINUOUS EMISSION MONITOR FOR SO2, CO, NOX, CONTINUOUS OPACITY MONITORS. CEMENT KILN SUBJECT TO MACT. PLANTWIDE EMISSIONS (IN T/YR) INCLUDE: FILTERABLE PM = 165.4, PM10 F1.T = 148, PM10 F2.T = 49.7, PM FUGITIVE = 42.7, PM10 FUGITIVE = 17.6, AND PB = 0.038. DIVISION DID NOT DETERMINE BACT EMISSION LIMIT BASED ON STANDARD UNITS. LIMITS IN STANDARD UNITS HAVE BEEN CALCULATED USING THROUGHPUT AND LB/H LIMITS.	PREHEATER/PRECALCINER, KILN		950000	T/YR	THROUGHPUT IS CEMENT CLINKER. PYROPROCESSING OF CRUDE IN A 5-STAGE PREHEATER/PRECALCINER AND CLINKERING ROTARY KILN TO PRODUCE CEMENT CLINKER. PM10 EMISSIONS ROUTED THROUGH THE KILN & CLINKER BAGHOUSE. THIS IS ENTERED AS A SEPARATE PROCESS IN THIS DETERMINATION. BACT DETERMINATIONS FOR CO, NOX, PM, PM10 AND SOX	NOX	MULTI-STAGE COMBUSTION AND RECIRCULATION. EMISSION LIMIT IN LB/T OF CLINKER. LB/T LIMIT IS 12. MO ROLLING AVG.	2.32	LB/T	2.32		BACT-PSD
SD-0003	GCC DACOTAH	SD	GENE NELSON	4/10/2003	GCC DACOTAH QUARRYS LIMESTONE, SAND, AND GYPSUM IN THE SURROUNDING AREA TO PROVIDE RAW MATERIALS FOR ITS PORTLAND CEMENT PLANT. OTHER RAW MATERIALS SUCH AS IRON AND SHALE ARE SHIPPED IN BY TRUCK FROM OTHER AREAS. COAL IS USED AS THE HEAT SOURCE AND IS SHI	GCC Dacotah owns and operates a limestone quarry and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per day.	ROTARY KILN #6	CLINKER	2250	T/D	Rotary kiln #6 burns coal as a heat source. Approximately 35% of the coal is burned in the preheater/precalciner and the remaining 65% of the coal is burned in the main burner of the kiln. The emission limits for NOX, SO2, and CO are for the entire kiln system. The kiln system has three emission points (1 - Rotary kiln #6, 2 - Alkali bypass and alkali waste to waste bin transfer system, and 3 - Coal Mill). Compliance with the SO2, CO, and NOX emission limits will be based on continuous emission monitoring systems.	SO2	INHERENT SCRUBBER EFFECT OF PROCESSING LIMESTONE	632	LB/H	6.74		BACT-PSD

PLANT ID	FACILITY NAME	FACILITY STATE	FACILITY CONTACT	PERMIT DATE	FACILITY DESCRIPTION	OTHER PERMITTING INFORMATION	PROCESS NAME	FUEL	THRUPUT	THRUPUT UNIT	PROCESS NOTES	POLLUTANT	CTRL. DESC	EMIS LIMIT1	EMIS LIMIT1 UNIT	EMIS LIMIT1 (lb/ton of clinker)	EMIS LIMIT1 AVGTIME CONDITION	CASE-BY-CASE BASIS
263	GCC DACOTAH	SD	GENE NELSON	4/10/2003	GCC DACOTAH QUARRIES LIMESTONE, SAND, AND GYPSUM IN THE SURROUNDING AREA TO PROVIDE RAW MATERIALS FOR ITS PORTLAND CEMENT PLANT. OTHER RAW MATERIALS SUCH AS IRON AND SHALE ARE SHIPPED IN BY TRUCK FROM OTHER AREAS. COAL IS USED AS THE HEAT SOURCE AND IS SHIPPED IN BY TRUCK FROM OTHER AREAS.	GCC DACOTAH QUARRIES OPERATES A PORTLAND CEMENT PLANT AND PORTLAND CEMENT MANUFACTURING FACILITY IN Rapid City, South Dakota. GCC Dakota submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1998 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per hour.	MATERIAL TRANSFER, ALKALI	CLINKER	2250	T/D	Process is alkali bypass and alkali waste to waste bin transfer. The emission limits for NOx, SO2, and CO are for the entire kiln system. The kiln system has three emission points (1 - Rotary Kiln #6, 2 - Alkali bypass and alkali waste to waste bin transfer system, and 3 - Coal Mill) Compliance with the SO2, CO, and NOx emission limits will be based on continuous emission monitoring systems.	SO2	INHERENT SCRUBBING EFFECT OF PROCESSING LIMESTONE	632	LBH	6.74		BACT-PSD
271	BRANFORD CEMENT PLANT (SUWANNEE)	FL	JOE HORTON	3/30/2006	THE FACILITY IS A PORTLAND CEMENT MANUFACTURING PLANT WITH ONE LINE (KILN NO.1) AND ALL ITS ASSOCIATED CEMENT MANUFACTURING EQUIPMENT UNITS PERMITTED IN 1988. THIS PROJECT IS FOR THE CONSTRUCTION OF A NEW LINE (KILN NO.2) THAT WILL INCLUDE A CLINKER AND CEMENT HANDLING/STORAGE COAL MILL AND COAL TRANSFER SYSTEM, DRY PROCESS PRE-HEATER/PRECALCINER ROTARY KILN WITH AN IN-LINE RAW MILL, RAW MATERIAL HANDLING AND STORAGE CHANGES TO THE EXISTING FACILITY WILL INCLUDE INCREASED PRODUCTION FOR THE PRIMARY CRUSHER, RAW MATERIALS PROCESSING AND INCREASED MATERIAL BEING TRANSPORTED THROUGHOUT THE PROCESS.	THIS PERMIT IS IN THE DRAFT PHASE	KILN W/IN LINE RAW MILL W/ SNCR AND BAGHOUSE	COAL	127	T/H clinker		SO2	RAW MATERIALS AND PROCESS CONTROL	0.2	LB/TON CLINKER	0.20	CEMS 24 HR ROLLING AVERAGE	BACT-PSD
268	BROOKSVILLE CEMENT PLANT (FCS)	FL	CHARLES ALLEN	12/20/2004	THIS FACILITY WILL CONSIST OF A PORTLAND CEMENT PLANT AND ASSOCIATED QUARRY, AND RAW MATERIAL AND CEMENT HANDLING OPERATIONS. THE PLANT WILL COMBINE RAW MATERIALS AND UTILIZE A PRE-HEATER/PRECALCINER KILN WITH IN-LINE RAW MILL TO PRODUCE CLINKER. THE CLINKER WILL BE MILLED AND COMBINED WITH GYPSUM TO PRODUCE PORTLAND CEMENT. THIS PROJECT IS A NEW CEMENT MANUFACTURING LINE. NEW EMISSIONS UNITS FOR THE PROJECT INCLUDE A RAW MILL SYSTEM, DRY PROCESS PRE-HEATER/PRECALCINER KILN SYSTEM, CLINKER HANDLING SYSTEM, FINISH GRINDING OPERATIONS, TWO CEMENT LOADOUT SILOS, AND COAL HANDLING AND GRINDING OPERATIONS.	SNCR INSTALLED FOR NOX CONTROL. NOX EMISSIONS WILL NOT EXCEED 2.4 LB/TON OF CLINKER FOR THE FIRST 180 DAYS AFTER INITIAL STARTUP. EMISSIONS LISTED IN POLLUTANT SECTION ARE FOR AFTER THE 1ST YEAR OF OPERATION.	125 TPH CLINKER KILN AND ASSOCIATED EQUIPMENT	COAL			KILN THROUGHPUT SHALL NOT EXCEED 2800 TON PER DAY CLINKER AND 125 TPH CLINKER.	SO2	PROCESS CONTROL AND RAW MATERIALS	0.23	LB/TON CLINKER	0.23	24-HR	BACT-PSD
267	THOMPSON S. BAKER-CEMENT PLANT (FRI)	FL	CHRIS HORNER	11/5/2004	THIS FACILITY CONSISTS OF A PORTLAND CEMENT PLANT AND ASSOCIATED QUARRY, RAW MATERIAL AND CEMENT HANDLING OPERATIONS. THE PLANT WILL COMBINE RAW MATERIALS AND UTILIZE A PRE-HEATER/PRECALCINER KILN WITH IN-LINE RAW MILL TO PRODUCE CLINKER. THE CLINKER WILL BE MILLED AND COMBINED WITH GYPSUM TO PRODUCE PORTLAND CEMENT. THIS PROJECT IS TO ADD A NEW 125 TPH CLINKER KILN AND ALL ASSOCIATED ANCILLARY EQUIPMENT.	SNCR ADDED FOR NOX CONTROL. NOX EMISSIONS RATE WILL BE 2.45 LB/TON CLINKER FOR THE FIRST 180 DAYS AFTER INITIAL STARTUP. NOX EMISSIONS LISTED IN THE POLLUTANT SECTION ARE FOR AFTER THE INITIAL YEAR AFTER STARTUP.	IN LINE KILN/RAW MILL WITH ESP AND SNCR	COAL				SO2	PROCESS CONTROL AND RAW MATERIALS IN FLORIDA	0.28	LB/TON CLINKER	0.28	24 HR	
270	LEHIGH CEMENT COMPANY - MASON CITY PLANT	IA	RITA DUNN	12/11/2003	PLEASE NOTE THAT A WET SCRUBBER WAS ADDED FOR BACT WHICH RESULTS IN A NET DECREASE IN PLANT EMISSIONS OF SO2 OF AROUND 5,400 TONS/YR. THE TABLE BELOW DOES NOT ALLOW NEGATIVE NUMBERS.	PROJECT NUMBER 2003-490 AND 05-282. THE PERMIT NUMBER LISTED ABOVE IS THE FACILITY'S PLANT NUMBER.	KILN/CLINKER/PREHEATER	COAL	150	T/H	Throughput is 1 clinker/h	SO2	WET SCRUBBER	1.01	LB/T	1.01	LB/TON OF CLINKER	BACT-PSD

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ICID	FACILITY NAME	FACILITY STATE	FACILITY CONTACT	PERMIT DATE	FACILITY DESCRIPTION	OTHER PERMITTING INFORMATION	PROCESS NAME	FUEL	THRUPTUT	THRUPTUT UNIT	PROCESS NOTES	POLLUTANT	CTRL. DESC	EMIS LIMIT1	EMIS LIMIT1 UNIT	EMIS LIMIT1 (lb/ton of clinker)	EMISLIMIT1 AVGTIME CONDITION	CASE-BY-CASE BASIS				
2A-272	ROANOKE CEMENT	VA	ROBERT OMER	6/13/2003	CEMENT MANUFACTURING FACILITY	#6 LIME KILN - BECAUSE OF THE HIGHER ORGANIC CONTENT OF THE AVAILABLE ROCK RAW MATERIAL CAUSING GREATER CO EMISSIONS, THE CO LIMIT FROM THE #6 LIME KILN SYSTEM WAS INCREASED FROM 1296 TONS/YR TO 1950 TONS/YR. THE SHORT TERM CO LIMIT HAS NOT CHANGED. NO PHYSICAL CHANGES WERE MADE AT THE FACILITY. GCC Dacotah owns and operates a limestone quarry and portland cement manufacturing facility in Rapid City, South Dakota. GCC Dacotah submitted a Prevention of Significant Deterioration permit application for a modification that occurred in 1996 to rotary kiln #6. Rotary kiln #6 burns coal to produce heat, which transforms limestone and other raw materials into clinker. Gypsum is added to the clinker and ground to produce portland cement. The modification increased the production capacity of rotary kiln #6 from 1,650 to 2,250 tons of clinker per year.	LIME KILN	COAL	1300000	TYR	The emission limits for NOx, SO2, and CO are for the entire kiln system. The kiln system has three emission points (1 - Rotary kiln #6, 2 - Alkali bypass and alkali waste to waste bin transfer system, and 3 - Coal Mill) Compliance with the SO2, CO, and NOx emission limits will be based on continuous emission monitoring systems.	SO2	LOW SULFUR FUEL GOOD COMBUSTION PRACTICES AND CONTINUOUS EMISSION MONITORING SYSTEM.	950	LBH	6.40		BACT-PSD				
2D-303	GCC DACOTAH	SD	GENE NELSON	4/10/2003	GCC DACOTAH QUARRYS LIMESTONE, SAND, AND GYPSUM IN THE SURROUNDING AREA TO PROVIDE RAW MATERIALS FOR ITS PORTLAND CEMENT PLANT. OTHER RAW MATERIALS SUCH AS IRON AND SHALE ARE SHIPPED IN BY TRUCK FROM OTHER AREAS. COAL IS USED AS THE HEAT SOURCE AND IS SHI		COAL MILL	COAL	20	TH		SO2	INHERENT SCRUBBER EFFECT OF PROCESSING LIMESTONE	632	LBH	31.60		BACT-PSD				
2L-200	CEMEX, INC.	AL	MIKE GANDY	9/13/2002	PORTLAND CEMENT MANUFACTURING	AIRS Facility Number: 01-094-00002 CEMEX manufactures portland cement. This facility operates one kiln system, controlled by an ESP.	KILN, CEMENT	COAL	230	TH		SO2	DRY SCRUBBER EQUIVALENT-NOT AN ADD ON CONTROL. LIME IS GENERATED FROM LIMESTONE IN FEED AND COMES INTO CONTACT WITH SO2 AND SOME SO2 CAPTURED IN WASTE KILN DUST. ALTERNATE EMISSION LIMIT IS NAAQS, ALSO SO2 EMISSION CONTROL.	160	LBH	0.70		BACT-PSD				
2A-0052	LAFARGE CORPORATION	IA	SCOTT NIELSON	7/1/2002		THIS PROJECT WAS TO ALLOW THE SOURCE TO INCREASE THE CAPACITY OF ITS PRE-HEATER/PRECALCINER KILN SYSTEM FROM 3050 TONS OF CLINKER PER DAY TO 3488 TONS OF CLINKER PER DAY. The latest modification was to allow waste oil as a fuel, to amend the CO BACT limit and to write a PSD permit for the clinker cooler which was not permitted under the previous project number (PN 96-464).	CEMENT MANUFACTURING G. PRE-HEATER/PR E-CALCINER KILN	COAL	3488	T/D	COMPLIANCE WILL BE DETERMINED AFTER MODIFICATION. CEM FOR NOX, SOX AND OPACITY. KILN IS LIMITED TO USING FUEL OIL, NATURAL GAS, COAL, AND COKE AS FUELS. IN ADDITION TO CLAY AND STONE, THE KILN IS ALLOWED TO USE THE FOLLOWING SUPPLEMENTAL MATERIALS IN LIMITED QUANTITIES: COAL COMBUSTION RESIDUE, FOUNDRY BY-PRODUCTS, HYDROCARBON AND OILS AND GREASES. THERE ARE MULTIPLE POLLUTANT ENTRIES FOR TSP AND SO2 BECAUSE THEY HAVE DIFFERENT BASES FOR THEIR EMISSION LIMITS. STACK TESTING WAS PERFORMED FOR TSP, PM10, CO AND DIF.	SO2				4850	TONS/YR	7.62		BACT-PSD		
2D-2027	LEHIGH PORTLAND CEMENT COMPANY	MD	DAVID ROUSH	6/8/2000	PORTLAND CEMENT MANUFACTURING PLANT	EPA ID: 24-13-00012, LEHIGH PORTLAND CEMENT COMPANY'S UNION BRIDGE MODERNIZATION PROJECT INCLUDES THE INSTALLATION OF A 5 STAGE PRE-HEATER/PRECALCINER PYROPROCESSING UNIT TO REPLACE FOUR EXISTING LONG DRY KILNS. ADDITIONAL PLANT-WIDE EMISSIONS: LEAD = 0.5 TYR, FLUORIDE = 2.0 TYR	CEMENT MANUFACTURING G. PRE-HEATER/PR E-CALCINER KILN	COAL	2214000	TYR	THE PERMITS REQUIRE THE COMPANY TO CONDUCT STACK EMISSIONS TESTS AND OPERATE CEMS FOR COMPLIANCE DETERMINATION. THROUGHPUT IS CLINKER PRODUCT	SO2					1041	TYR	0.94		RACT	
2L-207	HOLNAM, INC.	MI	MICHELLE FERGUSON	3/20/2000	PORTLAND CEMENT PLANT.	EPA ID: 24-05-003600; AIRS ID: MI 0036524; MI SRN: 81743. ACTUAL START-UP DATE IS NOT AVAILABLE. CEMENT PLANT OPERATING SINCE 1960. SINCE APPROX. 1960, WET PROCESS CEMENT PLANT HAS BEEN USING CARBON INJECTION FOR THE CONTROL OF ORGANICS. PERMIT MOD 60-71L ALLOWS FOR CESSATION OF CARBON; BAGHOUSES FOLLOWED BY POLLUTION CONTROL PROJECT IS NOT SUBJECT TO PSD, AND NOT A MAJOR MODIFICATION. THIS PERMIT SOURCE IS AUTHORIZED TO BURN TIRE CHIPS, UP TO ABOUT 21% OF HEAT INPUT, ON A PERMANENT BASIS. DURING TRIAL BURNS, UNDER EARLIER PERMIT #60-71L, STACK TESTS WERE CONDUCTED AND BECAME A BASIS FOR MUCH OF EMISSION LIMITS. HEREIN	CEMENT KILNS, WET PROCESS (2)	COAL	100	T/H FEED	MOST COMPLIANCE WILL BE DEMONSTRATED BY CEMS. AGENCY CAN INVOKE STACK TEST. CONVERSION TO PARTIAL TDF IS EXPECTED TO HAVE LITTLE EFFECT ON TOTAL PM EMISSIONS, PER APRIL 1997 TEST BURN.	SO2						21.7	LB/T	21.70		Other Case-by-Case
2A-207	PORTLAND CEMENT CLINKERING PLANT	WA		10/5/2001	MODIFICATION TO PORTLAND CEMENT PLANT PER AMENDMENTS TO ORDERS OF APPROVAL 3382 & 7381, CHANGING THE ORIGINAL PSD, AND REQUIRING AN UPDATED PSD BY PUGET SOUND CLEAN AIR AGENCY. THE MODIFICATION DELETED THE BACT LIMIT FROM THE PSD AND MOVED THE LIMIT TO A NONATTAINMENT PERMIT. THE AREA CHANGED STATUS BETWEEN INITIAL ISSUANCE OF THE PSD AND THE AMENDMENT.	INFORMATION ENTERED FOR AMENDMENT 3 OF PERMIT PSD-90-03. PLEASE REFER TO RBLC ENTRY WA-0024 FOR THE ORIGINAL PERMIT INFORMATION.	KILN EXHAUST STACK				NO FUEL OR THROUGHPUT STATED IN THE PERMIT. NO MENTION OF EMISSION LIMITS FOR PM10 IN THE PERMIT. HOWEVER IT STATED THAT PM10 WILL BE SUBJECT TO LAER.	SO2	DURING KILN PRE-HEATING PERIOD, SHUTDOWN, AND DURING MAINTENANCE OF THE BAGHOUSE ONLY NAT GAS WILL BE BURNED. AND SULFUR RINGS SHALL BE REMOVED IF THE RING WAS THE CAUSE OF THE SHUTDOWN.	180	PPM @ 10% O2		1-H AV		BACT-PSD			

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RBLCID	FACILITY NAME	FACILITY STATE	FACILITY CONTACT	PERMIT DATE	FACILITY DESCRIPTION	OTHER PERMITTING INFORMATION	PROCESS NAME	FUEL	THRUPUT	THRUPUT UNIT	PROCESS NOTES	POLLUTANT	CTRL DESC	EMIS LIMIT1	EMIS LIMIT1 UNIT	EMIS LIMIT1 (lb/ton of clinker)	EMIS LIMIT1 AVERAGE CONDITION	CASE-BY-CASE BASIS
TX-0355	PORTLAND CEMENT MANUFACTURING PLANT	TX	LARRY ALEXANDER	6/29/2001	THIS PORTLAND CEMENT MANUFACTURING PLANT USES THE DRY PROCESS AND A SINGLE KILN. THE RAW MATERIALS ARE FINELY GROUND AND BLENDED IN A DRY STATE PRIOR TO BEING FED THROUGH THE PREHEATER/CLINKER TOWER LOCATED AT THE FEED-END OF THE ROTARY CEMENT KILN. IN T	THIS PROJECT WAS SUBMITTED TO RECONCILE A PSD RETROACTIVE REVIEW FOR CO. ADDITIONAL STATE PERMITTING ACTIONS WILL INCLUDE AN AMENDMENT FOR INCREASES IN EMISSION ALLOWABLES FOR CO, VOC, HCL AND H2SO4. THERE IS NO NEW CONSTRUCTION AS A RESULT OF THIS AMENDMENT.	GRINDING/ PREHEATING/ KILN, K-19				ADDITIONAL APPLICABLE SCC CODES: 30500622 & 30500613. EMISSION RATES FOR THE KILN ARE BASED ON A MAXIMUM CLINKER PRODUCTION OF 124 T/H. THE TWO GRINDING MILLS SHALL NOT EXCEED A PRODUCTION OF 240 T/H COMBINED OF PROCESSED MATERIAL. EMISSIONS FROM K-19 MUST COMPLY WITH NSP'S SUBPART F.	SO2	NONE INDICATED	20	LBH			Other Case-by-Case
CO-0043	RIO GRANDE PORTLAND CEMENT CORP.	CO	BRIAN MCGILL	9/25/2000	MANUFACTURE OF PORTLAND CEMENT (DRY PROCESS)	CLINKER PRODUCTION: 950,000 T/YR; FINISHED CEMENT: 1,000,000 T/YR; COAL CONSUMED: 122,500 T/YR. RAW MATERIALS QUARRIES ADJACENT TO PLANT. CONTINUOUS EMISSION MONITOR FOR SO2, CO, NOX, CONTINUOUS OPACITY MONITORS. CEMENT KILN SUBJECT TO MACT. PLANTWIDE EMISSIONS (IN T/YR) INCLUDE: FILTERABLE PM = 155.4, PM10 F1LT = 148, PM/ALL PM10 = 49.7, PM FUGITIVE = 42.7, PM10 FUGITIVE = 17.8, AND PB = 0.038. DIVISION DID NOT DETERMINE BACT EMISSION LIMIT BASED ON STANDARD UNITS. LIMITS IN STANDARD UNITS HAVE BEEN CALCULATED USING THROUGHPUT AND LBH LIMITS. A NET EMISSIONS INCREASE ANALYSIS WAS CONDUCTED FOR THIS PROJECT WHICH DETERMINED THAT THE NET EMISSION INCREASE FOR THE PROJECT WOULD NOT EXCEED THE SIGNIFICANT LEVEL FOR ANY AIR POLLUTANT. HOWEVER, FOR THE NET EMISSIONS INCREASE TO BE LESS THAN THE SIGNIFICANCE LEVEL, STRINGENT CONTROLS ARE MADE A PART OF THE PERMIT. THESE CONTROLS INCLUDE THE USE OF FABRIC FILTERS (FOR PM10 CONTROL), A WET SCRUBBER AND LOW-SULFUR COAL FOR CONTROL OF SULFUR OXIDES, LOW-NOX BURNERS AND SELECTIVE NON-CATALYTIC REDUCTION (SNCR) FOR CONTROL OF NITROGEN OXIDES, A PYROCLON (OR SIMILAR TYPE UNIT) AND A THERMAL OXIDIZER FOR CONTROL OF CARBON MONOXIDE EMISSIONS, AND A THERMAL OXIDIZER FOR CONTROL OF VOC EMISSIONS. THE CONTROLS AND RESULTANT EMISSIONS LIMITATIONS ARE SUCH THAT WE URGE OTHER AGENCIES PERMITTING CEMENT KILNS TO EXAMINE THESE	PREHEATER/PR ECALCINER, KILN		950000	T/YR	THROUGHPUT IS CEMENT CLINKER. PYROPROCESSING OF CRUDE IN A 5-STAGE PREHEATER/PRECALCINER AND CLINKER ROTARY KILN TO PRODUCE CEMENT CLINKER. PM10 EMISSIONS RATED THROUGH THE KILN & CLINKER BAGHOUSE. THIS IS ENTERED AS A SEPARATE PROCESS IN THIS DETERMINATION BACT DETERMINATIONS FOR CO, NOX, PM, PM10 AND SOX.	SO2	RAW MATERIALS QUARRY WILL BE MANAGED FOR OPTIMUM SULFUR CONTENTS. SO2 WILL BE ABSORBED IN 5-STAGE PRECALCINER/PR EHEATER/KILN AND RAW MILL. EMISSION LIMIT IN LB/T OF CLINKER, 12.40 ROLLING	1.99	LB/T	1.99		BACT-PSD
MO-0058	CONTINENTAL CEMENT COMPANY, LLC	MO	JERRY EPPERSON	9/24/2002	CONTINENTAL CEMENT COMPANY INTENDS TO REPLACE ITS EXISTING CEMENT KILN WITH A NEW, LARGER CAPACITY CEMENT KILN. THE NEW KILN IS DESIGNED TO INCREASE ANNUAL PRODUCTION OF CLINKER FROM 0.6 MILLION TONS TO 1.6 MILLION TONS. THE NEW OPERATIONS WILL INCLUDE A	A NET EMISSIONS INCREASE ANALYSIS WAS CONDUCTED FOR THIS PROJECT WHICH DETERMINED THAT THE NET EMISSION INCREASE FOR THE PROJECT WOULD NOT EXCEED THE SIGNIFICANT LEVEL FOR ANY AIR POLLUTANT. HOWEVER, FOR THE NET EMISSIONS INCREASE TO BE LESS THAN THE SIGNIFICANCE LEVEL, STRINGENT CONTROLS ARE MADE A PART OF THE PERMIT. THESE CONTROLS INCLUDE THE USE OF FABRIC FILTERS (FOR PM10 CONTROL), A WET SCRUBBER AND LOW-SULFUR COAL FOR CONTROL OF SULFUR OXIDES, LOW-NOX BURNERS AND SELECTIVE NON-CATALYTIC REDUCTION (SNCR) FOR CONTROL OF NITROGEN OXIDES, A PYROCLON (OR SIMILAR TYPE UNIT) AND A THERMAL OXIDIZER FOR CONTROL OF CARBON MONOXIDE EMISSIONS, AND A THERMAL OXIDIZER FOR CONTROL OF VOC EMISSIONS. THE CONTROLS AND RESULTANT EMISSIONS LIMITATIONS ARE SUCH THAT WE URGE OTHER AGENCIES PERMITTING CEMENT KILNS TO EXAMINE THESE	ROTARY KILN	COAL	183	T/H	Emissions from the rotary kiln and the pyroprocessing system are routed through the same controls. Thus, emission limits for the kiln and pyroprocessing system are the same. The pyroprocessing system transforms raw materials into clinker. The clinker is then introduced to the rotary kiln. The pyroprocessing system is fueled with liquid hazardous waste and coal as backup. 722.4 mmbtu/h. compliance verified by calculations.	SOX	WET SCRUBBER	12	LB/T	12.00	1bt clinker, 3-hr rolling avg	Other Case-by-Case





**Appendix F**

**Final Report, Environ International Corporation,  
Evaluation of Potential Control Technologies for Oxides of Nitrogen from  
Point Sources in Ellis County, Texas, June 2004**



**Final Report****HARC Project H-28**

Evaluation of Potential Control Technologies for Oxides of Nitrogen  
from Point Sources in Ellis County, Texas

Prepared for

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June 2004

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## SUMMARY

### INTRODUCTION

The objective of this project was to conduct a comprehensive review of all currently available technologies that could be employed for reducing NO<sub>x</sub> emissions from existing major point sources in Ellis County, Texas. Ellis County had NO<sub>x</sub> emissions in 2000 of 57 tons per day (tpd), with Point Sources contributing about 60% of those emissions. The Dallas area had 20 days over the 8-hour ozone standard in 2003, with a peak 8-hour value of 130 ppb. Because Ellis County has the potential to impact the air quality in the Dallas area, this report assesses technologies available to reduce emissions from major sources of NO<sub>x</sub> in Ellis County. The study also includes estimates for the initial capital expenditure and annual operating costs for technologies that could be practically implemented to further reduce emissions. These costs were compared with NO<sub>x</sub> controls being required of other industries and other sectors in the Dallas-Fort Worth (DFW) area.

### GENERAL APPROACH

This evaluation includes an identification of the source categories that produce the largest quantities of oxides of Nitrogen (NO<sub>x</sub>) emissions from stationary point sources. To determine the potential for potential new strategies, the baseline of current control and the technical feasibility of making additional emission reductions beyond current requirements were evaluated. Within the limits of available data and information, estimates of the quantity and cost-effectiveness of these reductions are provided.

The cost estimates were based on both the capital and operating costs to achieve reductions beyond those required under current regulation. For comparative purposes, cost-effectiveness (dollars per pound of NO<sub>x</sub> reduced) was calculated. The cost-effectiveness was calculated using certification data, published data from other reports, and data from vendors and other manufacturers of emission control and process equipment. The methodologies used in this report are based on the EPA Air Pollution Control Cost Manual, Fifth Edition

The control technology and costs are compared with the level of controls and costs of NO<sub>x</sub> controls being required of other sources and other sectors in the DFW area (to the degree that such data is published and readily available).

### EMISSION SOURCES

Based on a preliminary evaluation of the major sources of NO<sub>x</sub> in Ellis County, the following categories of point sources were reviewed:

- Cement Kilns
- Power Plants
- Fiberglass Plants
- Steel Industry
- Glass Container Industry
- Natural Gas Transmission

Due to limited resources and the need to focus on the highest priority sources, this analysis focused on the five largest facilities, which comprise most of the NOx emissions in Ellis County. Therefore, additional sources were not addressed. The 2002 emissions inventory of the TCEQ was the primary source for determining emissions from these sources<sup>1</sup>. Annual 2002 emissions from these five plants, based on TCEQ data<sup>2</sup>, were as follows:

**Table S-1. Summary of NOx Emissions from Cement Plants and Power Plants.**

Facility	2002 NO <sub>x</sub> (tons/yr)
Ash Grove Cement	2,572
TXI Operations	4,221
Holcim Texas	4,175
Midlothian Energy	721
Ennis Tractebel Power	89

The cement plants collectively produced more than 90% of 2002 NOx emissions from these five plants. In addition, the two power plants have advanced NOx control systems in place. The technology used for controlling NOx emissions is Selective Catalytic Reduction (SCR), which is in place on all the turbines at the two energy facilities. Accordingly, it was concluded that these plants have limited potential for further reductions. Given the limited resources for this analysis, it was decided to focus exclusively on the cement plants.

## **CEMENT PLANT OPERATIONS AND EQUIPMENT IN ELLIS COUNTY**

There are seven wet process kilns operating in Ellis County. Three of these kilns are operated by Ash Grove Cement (formerly North Texas Cement Company) and four wet process kilns are operated by TXI Operations. Three dry process kilns are in operation in Ellis County, one at TXO Operations and two at Holcim Texas. In the wet process kilns, slurry is introduced into the feed end but first must undergo a simultaneous heating and drying process. The wet process kilns tend to be older kilns and less conducive to methods used to control NOx emissions. The dry process kilns in Ellis County utilize a dry feed rather than a slurry and represent a newer technology referred to as preheater/precalciner kilns. These kilns have a larger capacity and have higher energy efficiency. These kilns are also more conducive to advance NOx controls.

Kilns in Ellis County have employed or propose to install a variety of controls to reduce NOx emissions. These controls include process modifications, mid-kiln firing and the installation of low-NOx burners. Process modifications, which reduce NOx emission without the installation of specific control equipment, include the ChemStar process. The processes and control equipment for reducing NOx emissions at the three cement plants in Ellis County is described in full detail in this report. Table S-2 summarizes the technologies in place and the 2002 NOx emissions from each of the kiln operations in Ellis County.

<sup>1</sup> Information provided by Russell Nettles of the TCEQ Emissions Inventory group included 2002 Contaminant Summary Reports, and other detailed reports on each of the five facilities

<sup>2</sup> See Sections 2 and 3 for additional background on emissions estimates.

The Ash Grove Cement and TXI plants predominantly use wet process kilns. In 2002 wet process kilns, for which control options are more limited, produced about 45% of all cement plant NOx emissions.

**Table S-2. Control technology used in Ellis County cement plants.**

Company Name	Unit	Process	Current NOx Control Technology <sup>4</sup>	2002 NOx Emissions (tons/yr)
Ash Grove Cement <sup>1</sup>	Kiln 1	Wet Process	ChemStar, MKF (tires) <sup>3</sup>	823.9
Ash Grove Cement	Kiln 2	Wet Process	ChemStar, MKF (tires) <sup>3</sup>	829.2
Ash Grove Cement	Kiln 3	Wet Process	ChemStar, MKF (tires) <sup>3</sup>	918.6
<b>Plant Total</b>				<b>2,571.7</b>
TXI Operations, L.P.	Kiln 1	Wet Process	ChemStar, LNB	1,010.2
TXI Operations, L.P.	Kiln 2	Wet Process	ChemStar, LNB	24.3
TXI Operations, L.P.	Kiln 3	Wet Process	ChemStar, LNB	375.6
TXI Operations, L.P.	Kiln 4	Wet Process	ChemStar, LNB	988.4
TXI Operations, L.P.	Kiln 5	Dry Process <sup>2</sup>	LNB	1,822.7
<b>Plant Total</b>				<b>4,221.2</b>
Holcim Texas L.P.	Kiln 1	Dry Process <sup>2</sup>	LNB	1,909.7
Holcim Texas L.P.	Kiln 2	Dry Process <sup>2</sup>	LNB	2,265.1
<b>Plant Total</b>				<b>4,174.8</b>

<sup>1</sup> Formerly North Texas Cement Company.

<sup>2</sup> Precalciner Kiln.

<sup>3</sup> TNRCC confirmed that North Texas Cement (Ash Grove) meets the criteria of having mid-kiln firing and low NOx-burners. Letter from Richard L. Hughes, September 20, 2000.

<sup>4</sup> MKF is Mid-Kiln Firing, LNB is Low-NOx Burners

## AVAILABLE CONTROL TECHNOLOGY AND COSTS

The evaluation of potential controls for the cement plants in Ellis County is based on the experience of other plants in the U.S. and Europe as reported in the literature. For the purposes of this report, the term "technically feasible" applies to a control method or technology has been applied to other cement kilns, has been demonstrated to be successful in reducing NOx emissions, and appears to be feasible for similar equipment and processes in use in Ellis County.

Several technologies are available to control NOx emissions from cement kilns. A full discussion of each technology is included in this analysis. Again, the purpose of this study is to guide the reader in making a "first cut" assessment of the potential for emissions reductions through the use of the technologies discussed herein, and provide some insight on next steps that may be considered.

The capital and operating costs were estimated for each of the control technologies that were deemed technically feasible in Task 3 and repeated here in Section 3. In addition, we have performed a rough estimate of the cost and cost-effectiveness of Selective Catalytic Reduction (SCR), even though it was classified as "potentially feasible". Because the ChemStar process is used on each of the wet kilns in Ellis County, this cost of this process was not estimated. Furthermore, because low-NOx burners are used in the wet kilns at TXI Operations, the cost for this technology was also not estimated.

In order to make the analysis more relevant to the Portland Cement facilities in Ellis County, we applied various technologies to specific kilns and did so with consideration of the equipment and NO<sub>x</sub> control methods that are already in place at each kiln. Although estimates are not provided for all technologies at each kiln, the general cost and cost-effectiveness ranges would generally apply to all kilns. The exception is where a particular technology is not applicable to a particular kiln, i.e., the application of SNCR to wet kilns. All assumptions and costs identified with this analysis are included in the cost evaluation sheets contained in Section 4 of this report.

Because this report relied on TCEQ permitting information for the facilities, some information on the costs of controls was based on assumptions that were necessary because certain information was not available from the TCEQ for the specific kilns in operation in Ellis County. For example, we were able to obtain, from TCEQ, material throughput in tons of clinker processed per year for the Ash Grove kilns and the Holcim kilns but not the kilns at TXI Operations. We were also not able to obtain information on the amount and types of fuel used for the kilns at each of the three plants. Assumptions for these parameters as well as assumptions on specific equipment such as the use of direct-fired burners at the wet kilns were also made. Further assessments should be made with facility participation, and TCEQ documented information.

Table S-3 summarizes the discussion of available control technologies as well as the costs associated with each technology.

**Table S-3. Available control technologies and Costs for Cement Plants in Ellis County.**

Control Technology	Kiln Type	NO <sub>x</sub> Reduction (Percent)	Capital Cost	Operating Cost	Cost-EFF. (\$/ton)
Mid-Kiln Firing <sup>1</sup>	Wet Process	28 - 59	\$3,228,000	(758,000) <sup>1</sup>	(\$650 - \$3,685)
Bio Solids Injection <sup>1</sup>	Dry Process <sup>2</sup>	15 - 30	\$947,000 - \$1,246,000	(\$483,000) <sup>1</sup> - (\$493,000)	(\$568) - (\$1,325)
SNCR	Dry Process <sup>2</sup>	10 - 50	\$3,651,000 - \$3,949,000	\$872,000 - \$1,770,000	\$1,022 - \$12,197
SCR	Dry Process <sup>2</sup>	80 - 95	\$27,685,000 - \$29,773,000	\$5,108,000 - \$7,023,000	\$3,849 - \$6,696

Notes:

<sup>1</sup> Operating costs show a savings from tipping fees and/or fuel savings.

<sup>2</sup> Dry process kilns in Ellis County are all preheater/precalciner kilns.

## SUMMARY

Technology for controlling NO<sub>x</sub> emissions in Ellis County is available and has the potential to significantly reduce emissions. With the exception of SCR, all the technologies identified in Table S-3 have been applied to cement plants in the U.S. It is important to note that specific technologies may not apply to a particular installation such as an older wet process kiln. Further, depending on the configuration and age of the unit, retrofit costs can increase above the costs identified in this report. With respect to SCR, this technology has been successfully applied to a specific application in Germany. A full discussion of this technology is included in this report. We have performed a rough estimate of the cost and cost-effectiveness of Selective Catalytic Reduction (SCR), even though it was classified as "potentially feasible". A technology referred to as LoTOx shows some promise, but has not been applied in a cement kiln operation. We recommend that this technology be further investigated.

This report addresses nearly all of the comments received from reviewers on the interim reports prepared for this study. However, we could not respond substantively to three specific comments because they were beyond the scope of this present project. First, comments received on the Task 2 report (Section 2 of this Report) suggested that we include the date of construction and initial startup dates for each of the cement kilns because several of the wet kilns are older configurations and less conducive to the installation of retrofit control equipment. However, that information was not available at the time of this report from the TCEQ. Second, the point was made that we should include the emission rates per ton of clinker for comparison purposes with the other clean plants in Europe. As discussed in the report, the annual clinker production was not available for all the wet kilns so we were not able to provide a comparison of the rates per ton of clinker produced. Lastly, although briefly discussed in this report, we did not investigate the issue raised by manufacturers regarding the iron ore content of the limestone, or the sulfur content of the limestone or some other aspect of the limestone which may prevent them from operating SNCR/SCR systems efficiently. Again, we did not have fuel use or fuel specification information to provide this type of analysis. We suggest that all three of these areas be further investigated. In addition, we highly recommend that any follow-on work on this project include actual site visits. This would allow onsite investigation of the operations and equipment in place as well as provide detailed information on configuration of the kilns. All of this information would provide further analyses for the TCEQ and assist in dealing with issues associated with the installation of further emission control equipment.

While this report identified potential technologies and the associated costs, it should be viewed as a preliminary evaluation to be used for further evaluation at specific sites. At this level of analysis, where detailed information on plant design, equipment and operations is not available, conclusions on technical feasibility are necessarily preliminary and have significant uncertainty. Therefore, the analysis and conclusions must be considered preliminary, since they are based on general information about the facilities in Ellis County and do not involve a detailed engineering analysis of specific plant equipment or operations. Detailed assessment of the actual emissions reductions likely from these facilities would require substantial equipment vendor interaction and plant engineering design. While we have done a preliminary engineering "scoping" assessment, including some very limited vendor discussions, this cannot replace the much more complex and costly process of actual engineering design.

Since cost-effectiveness calculations apply cost estimates to the range of emission reductions estimated in this report, all the uncertainties and limitations with emission reduction estimates that were described in the report apply equally to the cost-effectiveness numbers in this report.

At these levels of analysis, the capital cost estimates do not address specific retrofit considerations for the Ellis County plants. There was not enough information available to uncover potential hidden costs of a specific installation on a specific unit. EPA guidance notes that a retrofit factor of up to 50% of the capital cost of the control system can be justified on a case-by-case basis, but that it is also important to avoid over-estimates (Control Cost Manual, p. 2-28). Since this study has no means of developing a retrofit factor for each technology-unit combination, we have chosen to apply an across the board contingency factor of 20%. Specific considerations for retrofit requirements are identified in the discussion for each control technology. The contingency factor may or may not be adequate to cover plant and unit specific issues.

In summary, these estimates should be considered rough estimates of the actual cost-effectiveness of control should these control methods be applied to Ellis County cement plants.

## 1. INTRODUCTION AND GENERAL APPROACH

### INTRODUCTION

#### Objective of Study

The objective of this study was to conduct a comprehensive review of all currently available technologies that could be employed for reducing NOx emissions from existing major point sources in Ellis County, Texas. Ellis County had NOx emissions in 2000 of 57 tons per day (tpd), with Point Sources contributing about 60% of those emissions. The Dallas area had 20 days over the 8-hour ozone standard in 2003, with a peak 8-hour value of 130 ppb. To address this problem, we evaluated technologies available to reduce emissions from major sources of NOx in Ellis County. The study includes an analysis of current control methods to reduce NOx emissions as well as estimates for the initial capital expenditure and annual operating costs for technologies that could be practically implemented to further reduce emissions. These costs are compared with NOx controls being required of other industries and other sectors in the Dallas-Fort Worth (DFW) area.

#### Definition of the Problem

Ozone is created in the atmosphere by the chemical reaction of reactive organic gases (ROG) and oxides of nitrogen (NOx). The Dallas/Fort Worth (DFW) area Consolidated Metropolitan Statistical Area (CSMA) consists of 12 counties: Denton, Collin, Dallas, Tarrant, Johnson, Ellis, Kaufman, Parker, Rockwall, Hunt, Hood, and Henderson. Four of these counties (Denton, Collin, Dallas, and Tarrant) are nonattainment for the one-hour ozone standard. The DFW area is classified as a "serious" ozone nonattainment area by the Environmental Protection Agency (EPA) for the one-hour standard. The DFW portion of the SIP was adopted by the Texas Commission on Environmental Quality (TCEQ) in April 2000. EPA proposed to approve the SIP in January 2000, but several key funding and court decisions since that time have prevented full approval of the SIP. The court decision also affected the decision to extend until November 15, 2007 the deadline to attain the one-hour ozone standard. EPA has however, approved 13 of the 19 TCEQ rules implementing the 2000 SIP. In July 2003, TCEQ submitted to EPA its proposal for the boundaries of a new 8-hour ozone standard nonattainment area, which included seven counties of the CMSA. EPA has since responded that it believes the entire 12 county CMSA should form the 8-hour nonattainment area. A final decision will be made by April 15, 2004. Meanwhile, TCEQ is working on an early 8-hour SIP and mid-course review to check progress toward attainment. A proposed SIP is tentatively scheduled for April 2004 and the final in October 2004. It is for this early 8-hour, transitional SIP that this Ellis County NOx emission inventory and control measure evaluation is being developed.

As part of this SIP, the importance of local NOx reductions as well as the transport of ozone and its precursors from the Houston/Galveston area were taken into account. According to the projected inventory, the four county DFW ozone non-attainment area will emit 501 tons per day (tpd) of NOx by 2007, not counting the necessary control strategy reductions. In order to reach the attainment goal of 321 tpd, the four-county area will have to reduce NOx by 180 tpd. Additional reductions of about 49 tpd from nine neighboring counties in the CSMA will contribute towards attainment.

On March 5, 2003, the TCEQ adopted further changes to the DFW portion of the SIP which included revisions to the NOx control strategy for cement Kilns in DFW. As noted above, the next major SIP submittal for the DFW area will be for the mid-course review in 2004. This mid-course review will involve an evaluation of all modeling, inventory data and other tools to develop the attainment demonstration. Re-evaluation of existing control measures and, if needed, adoption of new strategies will also occur during the mid-course review.

## **GENERAL APPROACH**

The first task was to identify the source categories that produce the largest quantities of oxides of Nitrogen (NOx) emissions from stationary point sources. Second, the baseline of current control levels were determined. Third, we evaluated the technical feasibility potential of making additional emission reductions beyond current requirements. Fourth, within the limits of available data and information, we provide estimates of the quantity and cost-effectiveness of these reductions. These costs include both initial capital costs and operating costs. Throughout this study, we coordinated with the Houston Advanced Research Center (HARC) and the Texas Commission on Environmental Quality (TCEQ) at each stage. Information for the study was obtained from numerous sources including the Air Permits and Technical Analysis Divisions of the TCEQ, regulators other states, regulators from Europe, control equipment vendors as well as information from numerous reports, emission tests and data from sources in Ellis County and other areas.

For each of the categories discussed below, there are several elements of the analysis that are common to the evaluation. These two categories are the Evaluation of Cost, and the Comparison of Emissions and Cost to Other Sources in the DFW area.

### **Evaluation of Cost**

The cost estimates were based on both the capital and operating costs to achieve reductions beyond those required under current regulation. The local regulatory authorities were consulted to obtain information of regulatory requirements, the status of their implementation, and information on individual sources. For comparative purposes, cost-effectiveness (dollars per pound of NOx reduced) are calculated. The cost-effectiveness was calculated using certification data, published data from other reports, and data from vendors and other manufacturers of emission control and process equipment.

### **Comparison of Emissions and Cost to Other Sources in the DFW Area**

To place the NOx controls and cost in perspective, the control technology and costs are compared with the level of controls and costs of NOx controls being required of other sources and other sectors in the DFW area (to the degree that such data is published and readily available).

## **EMISSION SOURCE CATEGORIES**

Based on a preliminary evaluation of the major sources of NO<sub>x</sub> in Ellis County, we identified the following categories of point sources to evaluate: It should be noted that the list is identified in the order of priority that our evaluations were conducted.

- Cement Kilns
- Power Plants
- Fiberglass Plants
- Steel Industry
- Glass Container Industry
- Natural Gas Transmission

According to the current TCEQ emissions inventory (2001 updates for point sources) the categories identified above produce the largest quantities of oxides of Nitrogen (NO<sub>x</sub>) emissions from stationary point sources in Ellis County. Five (5) specific facilities account for 96% of the point source emissions in Ellis County. The goal of this study was to evaluate the technical feasibility potential of making additional emission reductions beyond current requirements.

## **EVALUATION OF POINT SOURCE CATEGORIES**

The following discussion presents an overview of the background and technical approach used to evaluate NO<sub>x</sub> emissions associated with each emission inventory category listed above.

### **Cement Kilns**

Three large cement plants are located in Ellis County. These three plants (TXI Midlothian, Holcim Midlothian, and NTCC Midlothian) are all located within a few square miles of each other and comprise the single largest source of NO<sub>x</sub> emissions in North Texas. There are a total of 10 kilns in operation at these three plants. Because of the magnitude of the emissions, and the proximity of the emissions to the DFW current non-attainment region, considerable public debate has centered on this emissions category and these sources.

### Existing Emissions

Based on the year 2002 Emissions Inventory, the Ellis County cement plants emitted nearly 11,000 tons of NO<sub>x</sub>. The specific emissions are as follows:

- North Texas Cement Company – 2,572 tpy
- TXI Operations – 4,221 tpy
- Holcim Texas – 4,175 tpy

We evaluated the current emissions from each of the three cement plants. The emissions inventory of the TCEQ was the primary source for determining emissions from these cement plants. Information provided by the TCEQ included specific information about each source

including specific current emissions, facility operating conditions, fuel use, emission abatement devices and material throughput. In addition, we obtained all current permits and any written permit conditions on the operation of each facility. In addition, we obtained from TCEQ, a copy of any emission source test results that were available from some operations.

In addition to facility emissions, we also reviewed the control requirements currently in place by reviewing the current TCEQ regulations and federal requirements that are applicable to these sources. This included all recently adopted regulations. Information was also obtained from the TCEQ on individual sources, including emission rates, the type of fuel and equipment in use, installed control equipment, other information related to the level of control that is currently in place and the operating factors (amount of time the source operates on an annual basis).

### Evaluation of Available Control Technology

Once the baseline control requirements for priority categories was established, we determined whether additional emission reductions are technically feasible and could be made cost-effectively. Several technologies are available to control NO<sub>x</sub> from cement kilns. These include the application of selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR) technologies. In addition, we looked at other technologies that are currently in use at cement kilns in the U.S and Europe. Our analysis included a review of available documents from other states and control agencies with air quality problems. States such as Iowa, Florida, New York, Missouri and California, which have recently permitted or are in the process of permitting cement kilns provided valuable information in evaluating the potential for additional NO<sub>x</sub> controls in Ellis County.

ENVIRON has completed numerous studies for the TCEQ and regional planning areas in Texas that will contain useful information on control measure effectiveness. Areas that have been evaluated include North Central Texas, Tyler-Longview-Marshall, and the Houston-Galveston region. We also plan to examine recent development efforts in Texas related to cement kiln emissions technology assessments.

### Technical References

The following sources of information were used for this evaluation:

1. 2002 Emissions Inventory Guidelines, Technical Analysis Division, Texas Commission on Environmental Quality, December 2002.
2. Emissions Inventory Forms for Specific Cement Kilns, Texas Commission on Environmental Quality, Russell Nettles, and TCEQ.
3. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, AP-42 Fifth Edition, January 1995 and subsequent updates, United States Environmental Protection Agency.
4. Applicable Permits for Specific Cement Kilns, Texas Commission on Environmental Quality, Randy Hamilton, TCEQ.
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11. Evaluation of Attainment Control Strategies for the Dallas-Fort Worth State Implementation Plan, ENVIRON International Corporation, October 2000.
12. Air Quality Planning Documents, for the South Coast Air Quality Management District (SCAQMD), the Ventura County Air Pollution Control District and the San Joaquin Valley Unified Air Pollution Control District, California.
13. Status Report on NO<sub>x</sub> Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines, Technologies and Cost Effectiveness, Northeast States for Coordinated Air Use Management, December 2000.
14. AirControlNET, A Control Strategy and Costing Tool, E.H. Pechan & Associates, October 2003.
15. Manufacturers test data or product information.
16. U.S. EPA Reasonably Available Control Technology (RACT) documents and Control Technology Guidance (CTG) documents.
17. California Air Resources Board (CARB) Best Available Control Technology/Best Available Retrofit Control Technology (RACT/BARCT) documents.
18. Standards identified by CARB as "Achievable Performance Standards."
19. Environmental Protection Agency, Acid Rain Database for NO<sub>x</sub>, BACT/LAER Guidelines.
20. Individual Experts Contacted:
  - Tom Lugar, KWH Catalysts, Inc.
  - Chris Roling, Iowa Department of Natural Resources
  - Al Linero, Florida Department of Environmental Protection
  - Joe Hower, ENVIRON Corporation
  - Anne McQueen, ENVIRON Corporation

### **Power Plants**

Two power plants are located in Ellis County that are major sources of NO<sub>x</sub>. These two plants (Midlothian Energy and Ennis Tractebel) employ simple cycle gas turbines and combined cycle gas turbines to generate electricity.

### Existing Emissions

Based on the year 2002 Emissions Inventory, the Ellis County these two plants had the following emissions:

Midlothian Energy – 721 tpy  
Ennis Tractebel – 89 tpy

The NO<sub>x</sub> emissions for Ennis Tractebel were zero in the year 2000/2001, as this plant only came on line a year and a half ago. The ENVIRON team evaluated the current emissions from each of the two power plants. The emissions inventory and operating permits from TCEQ were the primary source for determining emissions from these sources. Information provided by the TCEQ included specific information about each source including specific current emissions, facility operating conditions, fuel use, emission abatement devices and material throughput.

In addition to facility emissions, we also reviewed the control requirements currently in place by reviewing the current TCEQ regulations and federal requirements that are applicable to these categories. This included all recently adopted regulations as well as emission rates, the type of fuel and equipment in use, installed control equipment, other information related to the level of control that is currently in place and the operating factors (amount of time the source operates on an annual basis).

### Evaluation of Available Control Technology

Once the baseline control requirements for these two plants was established, we evaluated whether additional emission reductions are technically feasible and can be made cost-effectively. Several technologies are available to control NO<sub>x</sub> from power plants. Turbines that are currently controlled with Dry Low NO<sub>x</sub> Combustors (DLNC) can achieve an additional 20% control by the additional application of Selective Catalytic Control (SCR). SCR control techniques have been widely used in simple cycle gas turbines and almost exclusively in combined cycle gas turbines. However SCR retrofits will often require the use of additional space at a facility for control equipment and support equipment, such as ammonia storage tanks. There are many applications of SCR for both oil and gas fired units operating successfully in the U.S. and elsewhere in the world. Reductions of 85 percent to 90 percent are achievable. Again, add-on control equipment can sometimes be difficult depending on the space limitations at a given facility, or at a given unit. To make this determination, we conducted a review of available documents from other states and control agencies with air quality problems. Regulations that are currently in place in many areas of California and elsewhere with severe air quality problems also provide information on the potential for reductions of NO<sub>x</sub> emissions beyond that required in Ellis County. The air quality planning documents include those for the South Coast Air Quality Management District (SCAQMD), the Bay Area Air Quality Management District (BAAQMD), the Ventura County Air Pollution Control District, and the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD). One of the key sources of information is a compilation of RACT/BACT/LAER in California as well as a review of the Best Available Retrofit Control Technology (BARCT) documents developed by California Districts, ARB and the EPA (including that addressed through the U.S. EPA AirControlNET).

### Technical References

The following sources of information were used for this evaluation:

1. 2002 Emissions Inventory Guidelines, Technical Analysis Division, Texas Commission on Environmental Quality, December 2002.
2. Emissions Inventory Forms for Specific Power Plants, Texas Commission on Environmental Quality, Russell Nettles, TCEQ.
3. Compilation of Air Pollutant Emission Factors, Volume 1: Stationary Point and Area Sources, AP-42 Fifth Edition, January 1995 and subsequent updates, United States Environmental Protection Agency.
4. Applicable Permits for Specific Power Plants, Texas Commission on Environmental Quality, Randy Hamilton, TCEQ.
5. Guidance for Power Plant Siting and Best Available Control Technology, California Air Resources Board, September 1999.
6. Guidance for the Permitting of Electrical Generation Technologies, California Air Resources Board, July 2002.
7. Regulation to Establish a Distributed Generation Certification Program, California Air Resources Board, September 2001.
8. Status Report on NO<sub>x</sub> Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines, Technologies and Cost Effectiveness, Northeast States for Coordinated Air Use Management, December 2000.
9. Dallas-Fort Worth Attainment Demonstration SIP Emission Reduction Control Strategies.
10. Analysis of Emission Reduction Control Measures for Attaining the 8-Hour Ozone NAAQS in the Tyler/Longview/Marshall Near Nonattainment Area, ENVIRON International Corporation, September 9, 2002.
11. Evaluation of Attainment Control Strategies for the Dallas-Fort Worth State Implementation Plan, ENVIRON International Corporation, October 2000.
12. Air Quality Planning Documents, for the South Coast Air Quality Management District (SCAQMD), the Ventura County Air Pollution Control District and the San Joaquin Valley Unified Air Pollution Control District, California.
13. AirControlNET, A Control Strategy and Costing Tool, E.H. Pechan & Associates, October 2003.
14. Manufacturers test data or product information.
15. U.S. EPA Reasonably Available Control Technology (RACT) documents and Control Technology Guidance (CTG) documents.
16. California Air Resources Board (CARB) Best Available Control Technology/Best Available Retrofit Control Technology (RACT/BARCT) documents.
17. Standards identified by CARB as "Achievable Performance Standards."
18. Environmental Protection Agency, Acid Rain Database for NO<sub>x</sub>, BACT/LAER Guidelines.

### **OTHER NO<sub>x</sub> EMISSION SOURCES IN ELLIS COUNTY**

The focus of this study was the three cement plants and two major power plants. These five plants comprise, by far, most of the NO<sub>x</sub> emission in Ellis County. Because of this, and because we wanted to expend analytical resources for this study with productively, additional sources

were not addressed at that same level of detail. Following is a summary of these sources, the NOx emissions from these sources and an identification of potential NOx control methods. Additional assessment may be warranted to determine, especially in light of the ozone attainment challenge, if emissions reductions from these sources is cost effective.

### **Fiberglass**

This category includes facilities that manufacture fiberglass for insulation and other purposes. Ellis County has one major facility in this category: the Owens-Corning Waxahachie Plant. This plant includes a glass melting furnace, curing oven, facing oven and other associated equipment used in the fiberglass manufacturing process such as fiberizing and forming equipment, incinerators and boilers. Most of this equipment is fired with natural gas.

Owens-Corning Waxahachie Plant – 580 tpy

Operations that result in emission of NOx include the furnace associated with the fiberglass forming and the curing oven to drive off moisture and cure the binders. Several technologies are available to control NOx from fiberglass plants. These include the use of natural gas for the furnaces and ovens as well as low-NOx burners in the ovens and boilers.

### **Steel**

There is one major source of NOx emissions from the steelmaking process. This is the Chaparral Steel Midlothian facility. This facility employs an electric arc furnace (EAF), which is used to produce carbon and alloy steels. Several furnaces are used including two bar mill reheat furnaces, a medium section mill reheat furnace, a large section mill reheat furnace and well as other miscellaneous combustion sources.

Chaparral Steel Midlothian – 490 tpy

1. There are not a lot of options available to control NOx from electric arc furnaces. To determine the potential for further control of these sources would require an analysis similar to the analysis conducted for cement plants and power plants.

### **Glass Container**

Saint Gobain Containers is the only major facility in this category. The Saint Gobain plant is a glass container manufacturer. This facility uses three annealing ovens, a distributor mold preheat ovens and a glass-melting furnace all fired on natural gas.

Saint Gobain Containers – 334 tpy

The procedures for manufacturing glass are the same for all products (flat glass, container glass, and pressed and blown glass) except for forming and finishing. Container glass use pressing, blowing or pressing and blowing to form the desired product. The furnace most commonly used in a continuous regenerative furnace capable of producing 50 to 300 tons per day. The melting.

furnace contributes over 99 percent of the total emissions from a glass plant, both particulates and gaseous pollutants. Nitrogen oxides are formed as a product of combustion in the high temperature furnace. To determine the potential for further control of these sources would require an analysis similar to the analysis conducted for cement plants and power plants.

### **Natural Gas Transmission**

The TXU Lone Star Pipeline Company operates a natural gas pipeline compressor station in Ellis County. According to the 2000 Emissions Inventory this was the only natural gas transmission facility in Ellis County that is considered a major source. The facility includes a natural gas fired gas turbine; a standby reciprocating engine fired on either distillate oil or diesel fuel and on compressor.

TXU Lone Star Pipeline Company – 54 tpy

Several technologies are available to control NOx from gas turbines and Internal Combustion engines used at compressor stations. Turbines that are currently uncontrolled can employ Dry Low NOx Combustors (DLNC) Selective Catalytic Control (SCR). There are many applications of SCR for both oil and gas fueled units operating successfully in the U.S. and elsewhere in the world. Reductions of 85 percent to 90 percent are achievable.

**2. CURRENT CONTROL BASELINE****INTRODUCTION**

This section describes the second task of this project to conduct a review of all currently available technologies that could be employed for reducing NOx emissions from existing point sources in Ellis County, Texas. Ellis County had NOx emissions in 1999 of 57 tons per day (tpd), with Point Sources contributing about 53% of those emissions. The remainder are from area sources and mobile sources (on and off-road).

The elements deemed necessary for the project are as follows:

- identify and prioritize the source categories that produce the largest quantities of oxides of Nitrogen (NOx) emissions from stationary point sources
- characterize the baseline of current control levels for prioritized sources
- evaluate the potential of making additional emission reductions beyond current requirements
- within the limits of available data and information, we provide estimates of the quantity and cost-effectiveness of these reductions
- coordinate with and report to the Houston Advanced Research Center (HARC) and the Texas Commission on Environmental Quality (TCEQ) at each stage.

The purpose of this section is to describe the establishment of a baseline of information from which we could determine the potential additional reductions of oxides of nitrogen (NOx) that could be obtained in Ellis County. To perform this task, we reviewed information provided by the TCEQ for each major source in the highest priority categories. The categories identified as the highest priority were based on our preliminary evaluation (reported in our Part 1 memo report of January 15, 2004) of the major sources of NOx emissions in Ellis County. Table 2-1 provides the emissions associated with the major sources for the year 2001.

**Table 2-1. Major Sources of NOx<sup>1,2</sup>**

<b>Company</b>	<b>SIC Code</b>	<b>2001 NOx Emissions TPY</b>	<b>2002 NOx Emissions TPY</b>
Chaparral Steel Midlothian	3312	478.64	489.6
Koral Industries	3312	0	0
Elk Corporation of Texas	2952	25.7	25.7
G.S Roofing Products	2952	3.0	2.8
Ash Grove Cement Company	3241	2,922.9	2571.7
Saint Gobain Containers	3221	303.2	334.3
Owens-Corning, Waxahachie Plant	3296	574.4	580.4
TXI Operations	3241	4,444.4	4221.2
Holcim Texas, LP	3241	3,078.1	4174.8
Owens Corning	2952	10.8	10.2
DARTCO of Texas, LP	3089	21.4	22.2
TXU Lone Star Pipeline Co	4922	29.6	54.2
Waste Management of Texas	4953	3.4	8.0
Midlothian Energy	4911	387.3	721.1

<b>Company</b>	<b>SIC Code</b>	<b>2001 NOx Emissions TPY</b>	<b>2002 NOx Emissions TPY</b>
Total (TPY)		12,282.8	13,216.2

<sup>1</sup> From TNRCC Point Source Emission Inventory. Note that Major Sources are defined as 25 tons per year of either NOx or VOC. Accordingly; major sources of VOC may have emissions less than 25 tons per year of NOx.

<sup>2</sup> The Ennis Tractebel EGU (SIC Code 4911) had 2001 NOx emissions 0 TPY.

This is the other power plant in Ellis County but did not come on until June 2002, and thus is not reflected in the above 2001 emissions. All emissions estimates, and resulting prioritizing of work, will be re-addressed under Tasks 1 and 2.

Based on the information from Table 2-1, the following categories of point sources (in priority order) were identified:

- Cement Kilns
- Power Plants
- Fiberglass Plants
- Steel Industry
- Glass Container Industry
- Natural Gas Transmission

Based on the TCEQ emissions inventory for 2001, five (5) specific facilities (three cement plants and 2 power plants) account for 96% of the point source emissions in Ellis County. Thus, the principal goal under this task was to evaluate the technical feasibility potential of making additional emission reductions beyond current requirements with a priority to address these five facilities.

Specific information was provided by the TCEQ on current emissions (2002), facility operating conditions, fuel use, emission abatement devices and material throughput<sup>1</sup>. In addition, we evaluated current permits as well as written permit conditions on the operation for each facility. To establish the baseline also requires an identification of the control requirements currently in place on the highest priority source categories. This required a review of the current TCEQ regulations and federal requirements that are applicable to these categories as well as recently adopted regulations.

We evaluated the current emissions from each of the three cement plants and the two major power plants. The 2002 emissions inventory of the TCEQ was the primary source for determining emissions from these sources<sup>2</sup>. As indicated earlier, these five largest facilities comprise, by far, most of the NOx emissions in Ellis County. Because of this, and because we want to expand analytical resources in this project with productivity, additional sources were not addressed under this task. As time and resources permit, these additional sources will, however, be reviewed again to determine if further reduction of NOx are appropriate.

<sup>1</sup> Information provided by Russell Nettles of the TCEQ Emissions Inventory group included 2002 Contaminant Summary Reports, and other detailed reports on each of the five facilities.

<sup>2</sup> Information provided by Russell Nettles of the TCEQ Emissions Inventory group included 2002 Contaminant Summary Reports, and other detailed reports on each of the five facilities.

**CEMENT KILNS**

Cement kiln emissions have been a source of considerable debate in the DFW area for several years. Also, there has been considerable debate on the control of emissions from cement plants in New York, Missouri, Iowa and Florida. As such, there is both historical information from previous hearings and regulatory processes, as well as newer information that is a result of recent technology applications in the U.S. and elsewhere. In future portions of this study we intend to gain the very best objective information on current methods for NO<sub>x</sub> reduction as it might be applied to the Ellis County facilities. While this is not a comprehensive engineering study, we do expect to provide a broad understanding that will significantly improve the basis upon which future air pollution related decisions may be made. Of course, in this report we relate the current conditions, upon which we will build our later reports.

Three cement plants operating in Ellis County are considered major sources of NO<sub>x</sub>. The three cement plants emitted nearly 10,968 tons of NO<sub>x</sub> from 10 kilns, based on the year 2002 Emissions Inventory. The specific emissions are as follows:

Ash Grove Cement Company – 2,572 tpy  
 TXI Operations – 4,221 tpy  
 Holcim Texas – 4,175 tpy

Based on information received from TCEQ, we can summarize the existing operations of the three plants.

**Ash Grove Cement Company**

The Ash Grove Cement Company operates three wet process kilns. The wet slurry and dry steel slag are fed into the feed end of each kiln. Upon passing through the final section of the pyro-process, exhaust gasses are controlled and collected. The exhaust gases are collected in electro static precipitators (ESPs) to remove particulate matter from the gas stream before it exits to the atmosphere. Fabric filters are used on other pieces of equipment including clinker coolers, various conveyors and hoppers. The exhaust gases do not have abatement devices for the control of NO<sub>x</sub>, however other NO<sub>x</sub> control techniques are employed. These techniques are discussed later in this section. Fuel for firing the kilns are limited to coal, coke, wood chips, and tire-derived fuel (TDF). Firing of TDF is limited to a maximum of 35 percent of total BTU requirements for Kiln Nos. 1, 2 and 3.<sup>3</sup> Table 2-2 summarizes these operations.

**Table 2-2. Ash Grove Cement Company.**

UNIT	DESCRIPTION	2002 MATERIAL	2002 NOX EMISSIONS
		THROUGHPUT	
		(TONS CLINKER)	(TONS PER YEAR)
KILN 1	WET PROCESS	303,085	823.9
KILN 2	WET PROCESS	306,799	829.2
KILN 3	WET PROCESS	309,192	918.6
	<b>TOTAL</b>	<b>919,076</b>	<b>2571.7</b>

<sup>3</sup> North Texas Cement Company, Special Conditions, Permit No. 4791A.

**TXI Operations, L.P.**

TXI Operations operates four wet process kilns (kilns Nos. 1 through 4) and one dry process kiln (kiln No. 5). The older wet process kilns employ ESPs to remove particulate matter from the gas stream before it exits to the atmosphere. The dry process kiln includes fabric filter particulate removal, sulfur dioxide removal and afterburners. Kiln Nos. 1 through 4 are limited by regulation to firing the kilns with pipeline quality natural gas, fuel oil, coal or coke and waste-derived fuel<sup>4</sup>. Further, the clinker production rate for each of the kilns Nos. 1 through 4 shall not exceed 375,000 tons of clinker per year also by regulation. The average oxygen content measured at the kiln exit of Kilns Nos. 1 through 4 shall be maintained at/or above 0.75 percent by volume on a five-minute average.

Fuels fired in Kiln No. 5 are limited by regulation to pipeline quality natural gas and coal. The clinker production rate of Kiln No. 5 is limited to 2,200,000 tons of clinker per year. In addition, Kilns Nos. 2 and 3 are not authorized to operate when Kiln No. 5 is operating or in start-up mode. The exception to this condition is any two or the four wet kilns may operate in conjunction with Kiln No. 5, provided that the clinker cooler baghouse associated with any wet kiln that operates in conjunction with baghouse No. 5 has been upgraded with high efficiency baghouses. This upgrade has occurred for both Kiln Nos. 2 and 3. Since Kiln Nos. 2 or 3 clinker cooler baghouses have been upgraded, at least three of the four clinker cooler baghouses can be operated with high efficiency bags at any time that all four wet kilns are in operation. Table 2-3 summarizes TXI Operations.

**Table 2-3. TXI Operations, L.P.**

UNIT	DESCRIPTION	2002 MATERIAL THROUGHPUT (TONS CLINKER)	2002 NOX EMISSIONS (TONS PER YEAR)
KILN 1	WET PROCESS	(375000) <sup>1</sup>	1010.2
KILN 2	WET PROCESS	(375000) <sup>1</sup>	24.3
KILN 3	WET PROCESS	(375000) <sup>1</sup>	375.6
KILN 4	WET PROCESS	(375000) <sup>1</sup>	988.4
KILN 5	DRY PROCESS	(2,200,000) <sup>1</sup>	1822.7
<b>TOTAL</b>		<b>1,780,729</b>	<b>4221.2</b>

<sup>1</sup> Maximum allowable clinker production rates represented in parenthesis.

**Holcim Texas, L.P.**

Holcim operates two dry process kilns. The two kilns employ fabric filters for particulate control. Fuels fired in the kiln and precalciners are limited to pipeline quality natural gas, coal, tire-chip fuel (TCF) and wood chips, oil filter fluff, and on-site generated used oil, greases, used sorbents, and rags.<sup>5</sup> The TCF fuel is limited to 45 percent on an hourly average basis of the total fuel fed in the kiln systems on a higher heating value (HHV) basis. In addition, fuel cannot be injected into the precalciner unless the precalciner temperature is greater than 1200 °F.

Table 2-4 summarizes the Holcim Texas operations.

<sup>4</sup> TXI Operations, Special Conditions, Permit No. 1360A.

<sup>5</sup> Holcim Texas, L.P. Special Conditions, Permit No. 8996/PSD-TX-454M2.

**Table 2-4. HOLCIM Texas, L.P.**

Unit	Description	2002 Material Throughput (Tons Clinker)	2002 NOx Emissions (Tons per Year)
Kiln 1	Dry Process	1,168,844	1909.7
Kiln 2	Dry Process	1,073,650	2265.1
	<b>TOTAL</b>	<b>2,242,494</b>	<b>4174.8</b>

### Current Regulations

On April 19, 2000 the TCEQ adopted rules requiring Portland cement kilns in Bexar, Comal, Ellis, Hays, and McLennan Counties to meet specific NOx emission limits. Under the adopted rules, owners and operators of cement kilns were given several options to meet the emission requirements in Chapter 117. Specifically, owners and operators of cement kilns were given options for complying with emission limits in pounds of NOx per ton of clinker produced. The emissions specification contained in Chapter 117.265 are as follows:

- 1) for each long wet kiln:
  - a. in Bexar, Comal, Hays, and McLennan Counties, 6.0 pounds per ton (lbs/ton) of clinker produced and
  - b. in Ellis county, 4.0 lbs/ton of clinker produced
- 2) for each long dry kiln, 5.1 lbs/ton of clinker produced
- 3) for each preheater kiln, 3.8 lbs/ton of clinker produced; and
- 4) for each preheater-precalciner or precalciner kiln, 2.8 lbs/ton of clinker produced.

The adopted rules allow owners and operators of cement kilns several options to meet the above limits. Operators may choose to comply with the above limits on the basis of a weighted average for the cement kilns where there are multiple kilns in the same account. Further, for each wet or long dry kiln, owners and operators are not required to meet the NOx emission limits if the following controls are installed and operated during kiln operation:

- (1) a low-NOx burner and either:
  - (a) mid-kiln firing; or
  - (b) some other form of secondary combustion achieving equivalent levels of NOx reductions; or alternatively
- (2) other additions or changes to the kiln system achieving at least a 30% reduction in NOx emissions

Lastly, each preheater or precalciner kiln for which either a low-NOx burner or low-NOx precalciner is installed and operated during kiln operation is not required to meet the emission limits, and an owner or operator may also use Emission Credits for compliance to meet the NOx emission reductions.

The compliance schedule for meeting these requirements was May 1, 2003 for cement kilns placed into service before December 31, 1999 (Chapter 117, Subchapter E: Administrative Provisions, 117.524). For cement kilns in Ellis County for which an owner or operator has filed an application for modification to meet the requirements of Regulation 117 on or before May 30,

2003, the compliance date was extended until 6 months after issuance of the permit for operation of a low-NOx burner and 12 months after issuance of the permit for operation of a secondary combustion system. We have not reviewed the applications that have been filed for these plants, however we understand that the permit applications do not contain any plans for installing additional control equipment<sup>6</sup>. Rather, the applications are for optimizing the existing NOx control techniques that already exist (see discussion below).

### **Exiting Control Technology**

Kilns in Ellis County have employed or propose to install a variety of controls to reduce NOx emissions. These controls include process modifications, staged combustion, mid-kiln firing and the installation of low-NOx burners. Additional, possible future controls, will be addressed in a future report.

### **Process Modifications**

Process modifications, which reduce NOx emission without the installation of specific control equipment, include the ChemStar process (EC/R, 2000). This process requires the addition of a small amount of steel slag to the raw kiln feed. Steel slag has a low melting temperature and is chemically very similar to clinker. Since many of the chemical reactions required to convert steel slag to clinker have already taken place in the steel furnace, the fuel needed to convert steel slag into clinker is low. The decreased need for limestone calcinations per unit of product and improved thermal efficiency of the process both contribute to reduced thermal NOx. The ChemStar process is employed by the Ash Grove Cement and TXI Operations on its wet process kilns. This process can reduce NOx emissions by 30 percent and increase production by 15 percent.

Changing the kiln fuel also has an impact on NOx emissions. For example, changing the kiln fuel from natural gas to coal can reduce flame temperatures significantly, resulting in lower NOx emissions. Switching to a fuel with a higher heating value (HHV) and lower nitrogen content may also reduce NOx emission from a cement kiln. Petroleum coke has a lower nitrogen content per million btu than coal and is more uniform in terms of heat value, lower in volatile matter content and burns with a lower flame temperature. Coke and coal are both fuels that are allowed in the operating permits of the Ellis County cement kilns.

### **Staged Combustion and Low-NOx Burners**

Staged combustion is another technique currently used in some Ellis County kilns including preheating and calcination of the raw materials at much lower temperatures than the primary zone kiln burning zones. In the secondary combustion zones, part of the fuel is burned at a much lower temperature. In a typical precalciner kiln, almost 40 to 50 percent of the fuel is burned at a lower temperature, which reduces the thermal NOx formation.

<sup>6</sup> Personal Communication with Skip Clark, of the TCEQ's Permits Division on February 12, 2004.

Tire-derived fuel can also be added to the feed end of a preheater or precalciner kiln. Tire-derived fuel (TDF) is employed in Kiln No. 1 at the Holcim facility. Likewise, waste-derived fuel is used for firing at all 4 wet process kilns at TXI Operations.

Another staged combustion technique is referred to as Mid-Kiln Firing (MKF). In this process, solid fuel is fed into the calcining zone of a rotating long kiln using a specially designed feed injection system. MKF allows part of the fuel to be burned at a material calcinating temperature that is much lower than the clinker burning temperature. To maintain continuity in the heat input, solid and slow burning fuels (such as tires) are most amenable for MKF. This technique is employed at Kiln Nos. 1, 2, and 3 at the Ash Grove Cement Company. In addition, this technology was studied at the TXI facility for all four wet kilns from July to November of 2002. The most significant costs associated with this process are those for kiln modifications necessary to facilitate the secondary fuel, and the solid fuel conveying system.

Some cement kiln burners use low-NOx burners. These burners are designed to reduce flame turbulence, delay fuel/air mixing, and establish fuel-rich zones for initial combustion. The longer, less intense flames resulting from the staged combustion lower flame temperatures and reduce NOx formation. Low-NOx burner technology is used on the dry kiln at TXI Operations.

## **UTILITY ELECTRIC GENERATION**

Two energy plants operating in Ellis County are considered major sources of NOx. The two power plant plants emitted nearly 811 tons of NOx, based on the year 2002 Emissions Inventory. The specific emissions are as follows:

Midlothian Energy – 721.1 tpy  
Ennis Tractebel – 89.3

Based on information received from TCEQ, we can summarize the existing operations of the two plants.

### **Midlothian Energy**

Midlothian Energy owns and operates four combined cycle turbine generators rated at a combined nominal capability of 270 MW each. The combustion turbines are ABB Model GT24 with steam injection in combined cycle with Heat Recovery Steam Generators and Steam Turbines. Each are rated at 175 MW electric. Two additional combined cycle generating units are located at the Midlothian facility. The two additional turbines include two ABB Model GT24 gas turbines without steam injection in combined cycle with heat recovery steam generators. Each unit has a single electric generator rated at a nominal capacity of 250 MW each<sup>7</sup>. Fuel for the first combustion turbines are limited to pipeline quality natural gas and No. 2 fuel oil containing no more than 0.05 percent total sulfur, by weight<sup>8</sup>. The use of No. 2 fuel oil is limited to 720 hours per year for each of the first four gas turbine generators. In addition to the 6 generating units, there are 4 natural gas fired heaters at the Midlothian Plant.

<sup>7</sup> Midlothian Energy L.P., Permit Amendment, Source Analysis & Technical Review, Record No. 66908 & 66909.

<sup>8</sup> Midlothian Energy L.P., Special Conditions, Permit Nos. 38191 and PSD-TX-906.

Table 2-5 presents a summary of the Midlothian Energy Facility.

**Table 2-5. Midlothian Energy L.P.**

UNIT	DESCRIPTION	MW RATING	EMISSION LIMIT (ppmvd)	2002 NOX EMISSIONS (TONS/YEAR)
Unit 1	HEATER (12 MMBTU/HR)	N/A	See footnote 9	4.48
Unit 2	HEATER 12 MMBTU/HR)	N/A	"	4.80
Unit 3	HEATER (3.5 MMBTU/HR)	N/A	"	0.70
Unit 4	HEATER (3.5 MMBTU/HR)	N/A	"	0.75
Unit 1	COMBINED CYCLE GAS TURBINE	175	5	140.20
Unit 2	COMBINED CYCLE GAS TURBINE	175	5	124.20
Unit 3	COMBINED CYCLE GAS TURBINE	175	5	95.30
Unit 4	COMBINED CYCLE GAS TURBINE	175	5	106.60
Unit 5	COMBINED CYCLE GAS TURBINE	180	5	115.70
Unit 6	COMBINED CYCLE GAS TURBINE	180	5	128.40
<b>Total</b>				<b>721.13</b>

The total fuel use for each of these operations was not available from the TCEQ at the time of this report. This information will be needed for future cost assessments if additional controls are technically feasible.

**Ennis-Tractebel**

The Ennis Tractebel generating facility consists of one 230 MW Westinghouse Model 501G combustion turbine, equipped with a non-fired heat recovery steam generator (HRSG). Total electric power output from the facility will be 350 MW. The turbine is fired with pipeline quality natural gas only<sup>10</sup>.

Following is a summary of the facility.

UNIT	DESCRIPTION	MW RATING	EMISSION LIMIT (ppmvd)	2002 NOX EMISSIONS (TONS/YEAR)
Unit No. 1	COMBUSTION GAS TURBINE	230	9	89.52
<b>Total</b>				<b>89.52</b>

The total fuel use for this facility in 2002 was 7,912,613 cubic feet.

<sup>9</sup> Heater flue gasses are treated conjointly with the turbine exit gases, and thus emissions limits for Units 1-4 of both the heater and the turbine have a combined limit as shown.

<sup>10</sup> Ennis-Tractebel Power Company, Inc., Preliminary Determination Summary, Permit No. 340363 and PSD-TX-927.

## **Current Regulations**

Current regulations for Combustion at Major Sources for Electric Generation do not apply to Ellis County. Chapter 117-Control of Air Pollution from Nitrogen Compounds, Subchapter B, Combustion at Major Sources, Division I, Utility Electric Generation in Ozone Nonattainment areas apply to the Dallas/Fort Worth ozone nonattainment area. Ellis County is not included in this designation. However, as discussed below, the two energy generation facilities have installed emission control equipment which was required during the permitting process.

## **Existing Control Technology**

NO<sub>x</sub> control methods for gas turbines include methods that reduce NO<sub>x</sub> that is generated in the combustion process itself (primary controls) and methods that reduce NO<sub>x</sub> after it is generated in the combustion process in the exhaust gas (secondary controls).

Dry Low NO<sub>x</sub> Combustors (DLNC) is one of the most widely used primary methods to control NO<sub>x</sub> in turbine combustors. Some suppliers offer combustors on new turbines that are capable of NO<sub>x</sub> emissions under 9 ppm<sub>dv</sub> (parts per million dry volume basis) at 15 % oxygen when firing on natural gas. DLNC technology utilizes a lean, premixed flame as opposed to a turbulent diffusion flame, therefore typically requiring the use of natural gas. In a lean, premixed combustor, the fuel and air are premixed prior to entering the combustion zone. With a lean, premixed flame, the contribution of prompt and thermal NO<sub>x</sub> can be much lower than for a turbulent diffusion flame. The use of low-nitrogen fuels such as natural gas minimizes the contribution of fuel NO<sub>x</sub>.

Selective Catalytic Reduction (SCR) is the exhaust treatment (secondary) technology that is most widely used on gas turbines. It is required on most new gas turbine installations particularly those with Heat Recovery Steam Generators (HRSG). Gas turbines equipped with SCR have been guaranteed to 2 ppm NO<sub>x</sub>.

Simple cycle gas turbines are most commonly controlled with water injection, dry low NO<sub>x</sub> combustors, or selective catalytic reduction. Water injection has a higher energy cost than DLNC or SCR. However, the initial cost of water injection is lower than other controls. Combined Cycle Gas Turbines are typically controlled with SCR.

Those turbines with DLNC can achieve an additional 20% control by the additional application of SCR. SCR control techniques have been widely used in simple cycle gas turbines and almost exclusively in combined cycle gas turbines.

The Midlothian Energy gas turbines met the BACT requirements of the TCEQ by applying SCR in combination with DLNC for the two newest turbines (Unit Nos. 5 and 6. These units were permitted at 5 ppm<sub>dv</sub>. The first four units (Unit Nos. 1 through 4) employ SCR and are limited to 5 ppm<sub>dv</sub> when corrected to 15 % oxygen when fired on natural gas and 9 ppm<sub>dv</sub> corrected to 15 % oxygen when firing on fuel oil<sup>11</sup>.

The Ennis Tractebel gas turbines use SCR with NO<sub>x</sub> emissions levels limited to 9.0 ppm<sub>dv</sub>.<sup>12</sup>

<sup>11</sup> Midlothian Energy L.P., Special Conditions, Permit Nos. 38191 and PSD-TX-906.

<sup>12</sup> Ennis-Tractebel Power Company, Inc., Special Conditions, Permit Nos. 40363 and PSD-TX-927.

**3. EVALUATION OF NO<sub>x</sub> EMISSIONS REDUCTIONS****INTRODUCTION AND PURPOSE**

The previous section evaluated the current NO<sub>x</sub> emission control techniques in place at major sources in Ellis County. The next step is to evaluate the potential for additional NO<sub>x</sub> reductions (that is, beyond current regulatory requirements) from Point Sources in Ellis County. Earlier work established that five sources, three cement plants and two power plants, account for 96% of point source NO<sub>x</sub> emissions in Ellis County. Annual 2002 emissions from these five plants, based on TCEQ data<sup>1</sup>, are as follows:

Facility	2002 NO <sub>x</sub> (tons/yr)
Ash Grove Cement	2,572
TXI Operations	4,221
Holcim Texas	4,175
Midlothian Energy	721
Ennis Tractebel Power	89

The cement plants collectively produced more than 90% of 2002 NO<sub>x</sub> emissions from these five plants. In addition, the two power plants have SCR on all turbines and have limited potential for further reductions. Thus, given the limited resources available to this project, and the importance of this source category in term of total NO<sub>x</sub> emissions and emissions reduction potential in the County, this analysis focuses exclusively on the cement plants.

This section discusses cement plant operations and equipment, available NO<sub>x</sub> control methods and technology, the equipment and controls current in place at Ellis County cement plants, and the technical feasibility of applying additional NO<sub>x</sub> controls. Our analysis and conclusions must be considered preliminary, since they are based on general information about the facilities in Ellis County and do not involve a detailed engineering analysis of plant equipment or operations. Detailed assessment of the actual emissions reductions likely from these facilities would require substantial equipment vendor interaction and plant engineering design. While we have done a preliminary engineering "scoping" assessment, including some very limited vendor discussions, this cannot replace the much more complex and costly process of actual engineering design. Thus the purpose of this study is to guide the reader in making a "first cut" assessment of the potential for emissions reductions through the use of the technologies discussed herein, and provide some insight on next steps that may be considered. Table 3-1 identifies the available control methods and potential emissions reductions that are evaluated in this section.

<sup>1</sup> See Preliminary Task 1 and Task 2 reports for additional background on emissions estimates.

**Table 3-1.** Available control technologies for cement plants.

NOx Control Technology	Applicable Kiln Type		NOx Emission Reduction (%) <sup>1</sup>
	Wet	Precalciner	
Process Controls	X	X	<25
ChemStar	X	X	23-40
Low-NOx Burner	X	X	4-47
Mid-kiln Firing (Wet Kilns)	X		28-59
Mid-kiln Firing (Dry Kilns)		X	11-55
Tire Derived Fuel <sup>2</sup>	X	X	30-40
SNCR		X	10-50
SCR		X	80-95
BioSolids <sup>3</sup>		X	15-30
Oxidation	X	X	80-95
Combination (MSC/SNCR)		X	38-68

<sup>1</sup> Emissions reductions represent tests obtained from review of the literature

<sup>2</sup> Based on TDF in a precalciner with BSI technology

<sup>3</sup> Personal communication from Dr. Anne McQueen, ENVIRON International Corporation, March 2004.

The analysis of cost of installing and operating the equipment described here is addressed in a subsequent section. That subsequent section also provides some comparative "cost effectiveness" figures for other emissions reductions that have been or are being considered for other types of emissions sources, such as trucks, cars, and area/stationary sources.

In conducting this analysis we drew information from a wide variety of sources. In our evaluation we have focused on several technologies that are available to control NOx from cement kilns. These include the application of selective non-catalytic reduction (SNCR) and selective catalytic reduction (SCR) technologies. In addition, we have looked at oxidation technology, which has been successfully demonstrated on other sources of pollution but to date, but not on cement plants. To conduct our evaluation, we reviewed available documents from other states and control agencies with air quality problems as well as work that has been conducted in Europe on similar facilities. Among the numerous sources of information for conducting this evaluation, we have also looked at a pending permit application for St. Lawrence Cement in New York, the permit issued by the Iowa Department of Natural Resources for the Lehigh Cement Company plant in Mason City, Iowa, the permit application to the Missouri Department of Natural Resources for a Holcim Cement plant near St. Louis, tests conducted on cement plants in Germany and Sweden, the use of the oxidation system developed by BOC Process Gas Solutions at a reverberatory furnace used for lead smelting in the City of Industry, California, and an analysis of the costs for installing SNCR by Holcim Texas, L.P. . We have also reviewed articles published by the Air & Waste Management Association and other sources, including articles and papers describing installations of NOx control technologies in Europe, where some of the more advanced control technologies have been applied.

## **CEMENT PLANT PROCESSES AND EQUIPMENT**

### **Overview**

The process of Portland Cement manufacturing consists of quarrying and crushing the raw materials, grinding the carefully proportioned materials to a high degree of fineness and pyroprocessing the raw mix in a rotary kiln. The rotary kiln is a refractory brick-lined cylindrical steel shell [3 to 8 m (10 to 25 ft) wide, 50 to 230 m (150 to 750 ft) long] equipped with an electrical drive to rotate the kiln on its longitudinal axis at 1 to 3 rpm. It is a countercurrent heating device slightly inclined to the horizontal so that material fed into the upper end travels slowly by gravity to be discharged into the clinker cooler at the lower, discharge end. The burners at the firing end, i.e., the lower or discharge end, produce a current of hot gases that heats the clinker, and the calcined and raw materials in succession as it passes upward toward the feed end.

The basic raw materials are oxides of calcium, silicon, aluminum, and iron. The silica and alumina are derived from a clay, shale, or overburden from a limestone quarry. Some plants supplement the iron with mill scale, pyrite cinders or iron ore. Feed material gradually tumbles to the high-temperature end of the kiln, which is sometimes referred to as the "burn zone". The key material produced by the process, which is called "clinker", is produced by heating limestone to temperatures over 2,650 °F, - a process that requires combustion temperatures of about 3,000 °F. The tiled kiln allows gravity to assist the motion of the clinker material while hot exhaust gases move upward and exit at the elevated end of the kiln. After exiting the kiln, the clinker is ground to a fine powder along with appropriate amounts of gypsum to produce cement.

Industrial by-products are becoming more widely used as raw materials for cement, including slags and fly ash from boilers. Coal is often the fuel of choice in cement kilns, primarily because of its low cost, but also because the ash contributes to the product. Additional fuels include natural gas, coke, fuel oil, tire chips (sometimes called "tire derived fuel" or "TDF"), wood chips, and waste derived fuel such as sewage sludge. Because of the high temperatures and long residence times inherent in combustion in kilns, cement plants are sometimes used to treat hazardous wastes.

### **Processes and Equipment**

Cement kilns fall into four general process categories: wet kilns, long dry kilns, preheater kilns and precalciner kilns. Wet process kilns are typically older and are often the choice where the moisture content of the raw materials mined from nearby quarries is high. Wet kilns are normally several hundred feet long, which is much longer than the kilns used in dry processes. In the wet process, the raw materials are ground with about 30 to 40 percent water to producing a well-homogenized mixture called slurry. The slurry is introduced into the feed end of the kiln and undergoes simultaneous heating and drying. As the kiln rotates, the refractory lining is alternately heated by the gases when exposed and cooled by the slurry when immersed. Thus the lining serves to transfer heat, as do the gases themselves. As most of the moisture is evaporated, nodules of material move down the kiln and are gradually heated to about 1650 °F (900 °C) where the calcinations reactions begin (EPA, 1994). As the charge leaves the burning zone and

begins to cool, clinker minerals crystallize from the melt, and the liquid phase solidifies. The granular clinker material drops into the clinker cooler for further cooling.

The dry process utilizes a dry feed rather than a slurry. Other than the need for evaporation of water, its operation is similar to that of a wet kiln. However, in one modification, the kiln has been lengthened to nearly the length of wet-process kilns and chains were added. The chains serve almost exclusively a heat exchange function. Refractory heat-recuperative devices, such as crosses, lifters, and trefoils, have also been installed to give the long dry kiln better energy efficiency than wet kilns.

To further improve the energy efficiency of the dry process, variations such as suspension preheaters and precalciners have been introduced. In preheated kilns, dry pulverized feed passes through a series of cyclones where it is separated and preheated several times. The partially (40 to 50 percent) calcined feed exits the preheater tower into the kiln at about 1500 to 1650 °F (800 to 900 °C). In the precalciner kiln process, a second burner is utilized to carry out calcinations in a separate vessel attached to the preheater. This vessel, called a flash furnace, utilizes preheated combustion air drawn from the clinker cooler and kiln exit gases and burns about 60 per cent of the total kiln fuel. The raw material is calcined almost 95 percent, and the gases continue their upward movement through successive cyclone preheater stages in the same manner as the preheater kilns. The precalciner systems permit the use of smaller dimension kilns since only actual clinkering is carried out in the rotary kiln. The burning process and the clinker cooling operations are the same as the wet kilns.

The two types of processes used in Ellis County are the wet kiln process and the dry, precalciner kiln process.

### **NO<sub>x</sub> Emissions**

In cement manufacturing, conditions favorable for formation of thermal nitrogen oxides (NO<sub>x</sub>) are reached routinely, primarily because of the high process temperatures involved. For example, the thermodynamic equilibrium NO<sub>x</sub> level at 3,000 °F (1600 °C) and 1 percent oxygen is about 1,500 ppm. Due to these high temperatures, fuel combustion in the kiln burning zone is the primary source of NO<sub>x</sub> formation in a cement kiln. The NO<sub>x</sub> formed is referred to as thermal NO<sub>x</sub>, which is basically the homogeneous reaction of oxygen and nitrogen in the gas phase at high temperatures. Due to the presence of nitrogen in the fuels, NO<sub>x</sub> is also formed by the conversion of the nitrogen in the fuels. Although the amount of NO<sub>x</sub> formed from fuel NO<sub>x</sub> is difficult to identify separately from the amount formed from thermal NO<sub>x</sub>, the thermal NO<sub>x</sub> is assumed to be the dominant mechanism in cement kilns. Therefore, most strategies are focused on reducing the formation of NO<sub>x</sub> by reducing combustion temperature, oxygen concentration in the high temperature combustion zone and the gas residence time at the high temperatures. Although heating occurs ahead of the kiln in dry preheating and precalcining processes, heating and drying equipment often utilize recycled kiln exhaust gas.

The NO<sub>x</sub> produced by a plant varies by the characteristics of the raw feed, the type or mix of fuels, and the production process used. The physical characteristics and chemical composition of the raw feed affect NO<sub>x</sub> emissions because of its nitrogen content and the energy required to process it. The nitrogen content of fuels varies significantly. Both oil and natural gas have relatively low fuel bound nitrogen content, whereas coal may contain 1 to 3 percent of nitrogen

by weight depending upon the source of coal. Waste-derived fuels (WDF) such as scrap tires, petroleum wastes and, solvents may contain significant quantities of nitrogen. Among process designs, wet kilns tend to have the highest heat input per ton of clinker (typically around 6 MMBtu/ton) (NESCAUM, 2000) and therefore greater NO<sub>x</sub> emissions per unit of production. Preheater and precalciner kilns use less heat and can run less than 4 MMBtu/ton. Emission factors published by EPA for wet process kilns are 7.4 lb/ton of clinker, 4.8 lb/ton of clinker for kilns with preheaters and 4.2 lb/ton of clinker for kilns with precalciners (EPA, 1995).

The many variables that affect NO<sub>x</sub> formation introduce significant uncertainty into any analysis of NO<sub>x</sub> control effectiveness and cost-effectiveness. This variability must ultimately be considered on a plant-by-plant basis to determine the efficacy and cost-effectiveness of potential future regulatory requirements.

### **AVAILABLE NO<sub>x</sub> CONTROL METHODS**

For an existing facility, available strategies for reducing NO<sub>x</sub> include modernization, altering feed composition, combustion improvements, and post combustion controls. Modern dry kiln processes, with preheating and precalcining, are more energy efficient and produce less NO<sub>x</sub> per unit of production, but are not considered a control method for purposes of this discussion. The practicality and effectiveness of each control method depends on existing conditions.

Retrofit applications are generally more challenging than new installations and often cost more. Among the factors that must be considered are, space available, existing equipment configurations, fuels used, existing emission control systems, and operator capabilities and training. If off-the-shelf system designs and equipment cannot be used, custom design, engineering and construction practices can add significant cost to the obvious technical challenges involved. While this evaluation provides an analysis of the availability of various methods to reduce NO<sub>x</sub> emissions, it does not address specific retrofit considerations for Ellis County facilities. However, issues that would require additional considerations are identified with recommendations where such issues should be further investigated.

### **Changing Feed Composition**

One commercially available approach to reducing NO<sub>x</sub> emissions by altering feed composition is called the ChemStar process. It was discussed in the previous section and is also described as follows in a recent EPA report.

“Another feed modification that can reduce NO<sub>x</sub> emissions is the addition of a small amount of steel slag to the raw kiln feed. This patented technique is known as the ChemStar Process and was developed by TXI Industries. Steel slag has a low melting temperature and is chemically very similar to clinker. Since many of the chemical reactions required to convert steel slag to clinker have already taken place in a steel furnace, the fuel needed to convert steel slag into clinker is low. The decreased need for limestone calcination per unit product and improved thermal efficiency of the process both contribute to reduced thermal NO<sub>x</sub> and CO<sub>2</sub> emissions. ChemStar requires little extra equipment and the addition of steel slag to the feed mix can result in a reduction or elimination of the need for some mineral sources, such as shale or clay. This process can

also increase production by 15 percent. The amount of NO<sub>x</sub> emissions reductions achievable with ChemStar varies by kiln type but ranges from over 20 to 60 percent.” (EC/R, 2000).

### **Fuel Composition**

In the previous section it was noted that different fuels have different heating values and fuel bound nitrogen content and therefore have varying rates of NO<sub>x</sub> formation. Coke produces less NO<sub>x</sub> than coal, and coal less than natural gas, though there are obviously additional environmental impacts from the use of coal (EC/R, 2000). Tire-derived fuel (TDF) can also be added to the feed end of a preheater or precalciner kiln. One report noted that the addition of waste tires reduces NO<sub>x</sub> emissions from the kiln by 30 to 40 percent, and there is no significant change in toxic, hydrocarbon, or metal emissions (EC/R, 2000). Since the cost and availability of fuels varies significantly at the local level, this method of reduction is appropriately considered on a plant-by-plant basis.

### **Improving Combustion Efficiency**

Monitoring and effectively limiting excess air can improve combustion and reduce thermal NO<sub>x</sub> formation in the kiln. According to an EPA report, NO<sub>x</sub> formation can be reduced by 15% (EC/R, 2000). As discussed in Task 2, related methods are staged combustion and the use of more sophisticated burners. By design, modern dry kiln processes heat raw feed and begin calcinations at lower temperatures than in the primary combustion zone of the kiln. This results in lower thermal NO<sub>x</sub> formation than wet kilns. Another staged combustion technique is the addition of mid-kiln firing (MKF) with solid fuels, such as tire chips. Again, the result is that part of the combustion process occurs at lower temperatures, thereby leading to reduced formation of thermal NO<sub>x</sub>. MKF is reported to reduce NO<sub>x</sub> by an average of 33% for dry kilns and 40% for wet kilns (EC/R, 2000).

While mid-kiln firing was discussed in the previous section, it is important to note that this technique has been used successfully at several cement kilns including the Ash Grove wet process kilns. It should be further noted that mid-kiln firing was demonstrated to be successful on the wet process kilns (kilns 1-4) at TXI from July to November 2002.<sup>2</sup> Based on information provided by TXI, CEMS data showed that a reduction of 37 percent in NO<sub>x</sub> was achieved when firing 2 tires per minute and a 64 percent reduction when firing 4 tires per minute. However, because the wet kilns also fire liquid hazardous wastes, a RCRA permit authorization would be required to modify the plant to use mid-kiln firing on a permanent basis. This appears to be an issue of the date for compliance rather than a technical issue with the feasibility of the technology. According to information from Cadence, the developer of the feed fork technology using whole tires that are dropped into the kiln at each revolution. This technology has demonstrated the potential for reducing NO<sub>x</sub> emissions by 38 percent on one kiln with an average of 33 percent reduction on nine dry kilns.

Low NO<sub>x</sub> burners can be installed on any type of kiln. These burners reduce flame turbulence, lower flame temperatures and result in less NO<sub>x</sub> formation. An important consideration on

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<sup>2</sup> Standard Permit, Technical Review, No. 53424, TXI Operations, December 31, 2002.

reducing NO<sub>x</sub> emissions using low-NO<sub>x</sub> burners is the firing system. A majority of the kilns in the US are direct fired. That is, the systems introduce a large proportion of combustion air with the fuel being burned. Indirect firing systems on the other hand use only a small portion of combustion air to convey fuel and thus use less primary air. In general, indirect firing systems produce less NO<sub>x</sub> emissions. Furthermore, some cement kiln burners specifically identified as Low-NO<sub>x</sub> burners typically use 5 to 7 percent primary air and thus can be used only on indirect fired systems. Therefore, converting to indirect firing will allow the use of low-NO<sub>x</sub> burners and thereby reduce emissions. Reductions per ton of clinker of 15% to more than 40% have been reported, depending on the burner used and type of kiln (EC/R, 2000).

### **Selective Non-Catalytic Reduction (SNCR)**

The control technology relies on the reduction of NO<sub>x</sub> in exhaust gases by injecting ammonia or urea without the use of a catalyst (EPA, 1994). This approach avoids problems related to catalyst fouling, but requires injection of reagents in the kiln at a temperature "window" of 1600 to 2000 °F (870 to 1090 °C). At these temperatures, the urea decomposes to produce ammonia, which is responsible for NO<sub>x</sub> reductions. To achieve full effectiveness, SNCR systems must operate in a section of the kiln with the proper temperature and residence time. At lower temperatures, the NO<sub>x</sub> reduction reactions become too slow resulting in too much un-reacted ammonia, which is usually referred to as ammonia slip when discharged to the atmosphere. The effective temperature window range can be lowered to about 1300 °F (700 °C) by the addition of hydrogen along with the reducing agent. Several other reagents can also shift the temperature window.

SNCR has demonstrated significant reductions of NO<sub>x</sub> when applied on dry precalciner kiln configurations. In preheater/precalciner kilns, the temperatures at the cooler end of the rotating kiln, in the riser duct, and in the lower section of the cyclone preheater tower are likely to be in the correct temperature range for this technology. In a demonstration of urea SNCR at the Ash Grove Cement plant in Seattle Washington, over 80 percent NO<sub>x</sub> reduction was achieved. This was a demonstration project on a preheater/precalciner kiln unit (NESCAUM, 2000). Ammonia slip was reported at less than 10 ppm.

Most of the experience with SNCR has been in Europe where the technology has been applied on 18 cement kilns (EC/R, 2000). SNCR was installed in two Swedish dry process cyclone preheater/precalciner kilns in 1996/97. A reduction of 80 to 85 percent was achieved at both kilns (IPPCB, 2000). One of the kilns was 20 years old with a capacity of 5,800 tons of clinker per day and initial levels of NO<sub>x</sub> about 1100 mg/Nm<sup>3</sup>. Small amounts of ammonia slip were estimated, but not specified. In addition, there was reported that there was no increase in CO emissions. Another plant in Sweden (Slite Cement Plant) operates two kilns with SNCR, the largest of which is a 20 year old 5-stage double preheater and precalciner with a capacity of 5,800 tons of clinker per day and a second kiln with a capacity of 1,200 tons per day. It has been shown at this plant that with careful operation of the kilns, the SNCR can obtain a reduction in NO<sub>x</sub> of 85 percent. An additional application of SNCR was tested in two German plants Geseke and Burglengenfeld. The plants, operated by Dyckerhoff Zement GmbH and Heidelberger Zement AG, were tested in 1995/96 (Haug, 2002). These plants were able to achieve levels below the limit of 800 mg/m<sup>3</sup> (Germany emission limits) from uncontrolled levels between 1200 and 1500 mg/m<sup>3</sup> (>33 to 47 percent reduction). However, in the Geseke plant, higher emissions of ammonia were detected. It was therefore concluded by the author of the paper describing this

application that SNCR has limited use in the cement industry due to the need to optimize temperatures and duration periods. Most SNCR installations in Europe today are designed and operated for NOx reduction rates of 10 to 50 percent taking into consideration the ammonia slip (SEPA, 2000).

In addition to the European experience, NOx reduction levels ranging from 25 to 50 percent were achieved at three precalciner units at Taiwan Cement. Ammonia slip was reported at 15 ppm at this facility.

The technology is beginning to gain a foothold in the U.S. market. Iowa recently agreed to SNCR on the Lehigh Portland Cement in Mason City. The PSD permit issued will require the use of SNCR for this plant. This was part of a settlement agreed with the State of Iowa.<sup>3</sup> In addition, the Missouri Department of Natural Resources has placed a draft air pollution permit for the proposed Holcim cement plant on public notice (MDNR, 2004). Based on the draft permit the facility, which is proposed for a location south of St. Louis in Ste. Genevieve County, will likely require the use of SNCR to meet emission limits. In its analysis, the Missouri DNR concluded that SCR was not feasible at this time but concluded that good combustion practices, Low-NOx burners, multi-stage combustion, and SNCR are technologies that should be considered for this facility. Finally, SNCR is being proposed at the St. Lawrence Cement Company manufacturing facility in Hudson/Greenport New York.<sup>4</sup> We understand that the state of New York has now issued a request for additional information that includes information on the use of SCR for this facility.<sup>5</sup>

The technology has a major limitation in that it is very difficult to apply in long dry or wet kilns. Although mid-kiln firing of containerized solid fuels allows injection of a certain amount of reagent into the appropriate temperature zone, this technique can result in the rapid decomposition of solid ammonium or urea salts. A means of continuously injecting ammonia or urea-based reagents into the appropriate temperature zone has not been developed due to the rotating of the kilns.

In designing and operating SNCR systems, it is important to maintain the proper temperatures for the reaction with ammonia to occur. If the temperatures fall below the appropriate temperature window unconverted ammonia is emitted (referred to as ammonia-slip). A temperature above the window, ammonia slip may also occur. The formation of aerosols of ammonia chlorides and ammonia sulfates that pass through the filter can become visible as a white plume above the exhaust stack.

### **Biosolids Injection (BSI)**

This technology was developed by the cement industry for NOx reduction in precalciner and preheater kilns. With this technology, dewatered sewage sludge is added to the mixing chamber of the calciner. The dewatered biosolids provide a source of ammonia, producing an SNCR-like reaction to reduce NOx. At a Mitsubishi Cement Kiln in Lucerne Valley, California, BSI

<sup>3</sup> Personal Conversation with Chris Rowling, Iowa Department of Natural Resources on March 11, 2004.

<sup>4</sup> St. Lawrence Cement Co., LLC (SLC) applied to the New York State Department of Environmental Conservation (Department or DEC) for permits to construct and operate a cement manufacturing facility in the Town of Greenport and City of Hudson, April 2001.

<sup>5</sup> ALJ Recommended Decision for the St. Lawrence Cement Company, State of New York DEC, February 23, 2004.

provided about a 50 percent reduction in NO<sub>x</sub> concentrations, from 250 ppm (at 12 % Oxygen) to 120-125 ppm (at 12 % Oxygen). An additional benefit for this technology is the potential revenue stream it can create for the cement plant. Many communities are willing to pay a tipping fee for accepting biosolids.

### **Selective Catalytic Reduction (SCR)**

Selective catalytic reduction (SCR) is the process of using ammonia in the presence of a catalyst to selectively reduce NO<sub>x</sub> emissions from exhausts gases. The SCR process has been used extensively for gas turbines, internal combustion engines and fossil fuel-fired utility boilers. In this system, anhydrous ammonia, usually diluted with air or steam, is injected through a catalyst bed to carry out NO<sub>x</sub> reduction reactions. A number of catalyst materials have been used, such as titanium dioxide, vanadium pentoxide and zeolite-based materials. The catalyst is typically supported on ceramic materials, e.g., alumina in a honeycomb monolith form. The optimum temperature for the catalyst reactions depends upon the specific catalysts used, but occur in the range from 570 to 840 °F (300 to 450 °C). This can be higher than typical cement kiln flue gas temperatures especially in plants that use heat recovery systems, or use a bag house for particulate collection. Because catalysts can be fouled by particulates, the presence of alkalis, lime and sulfur dioxide in the exhaust gases are of concern.

In an SCR system, ammonia is typically injected to achieve a NO<sub>x</sub> conversion of 80 to 90 percent with an ammonia "slip" of about 10 ppm of the unreacted gases leaving the reactor (EC/R, 2002). The NO<sub>x</sub> removal efficiency depends upon the temperature, the molar ration of the ammonia to NO<sub>x</sub> and the flue gas residence time in the catalyst bed. All of these factors must be considered in designing the desired NO<sub>x</sub> reduction, the appropriate reagent rations, the catalyst bed volume and the operating conditions. Furthermore, ammonia storage and handling, community impact of ammonia emissions are all considerations that must be taken into account to assure safe operations. As with SNCR, the appropriate temperature window must be maintained to assure that ammonia slip does not result in a visible plume.

The installation of an SCR system in a cement plant can occur at two different locations: 1) after the dusting process (particulate collection device) and before the furnace as a "low-dust" set up, or 2) after the last cyclone without dusting as a so-called "high-dust" set-up.

The advantage of a "low-dust" set-up are longer the catalytic converter operation times and lower danger of blockage. The disadvantage is additional energy costs because the cooled exhaust needs to be heated to achieve proper reaction temperatures for the catalyst. This pattern was shown in three early pilot tests conducted by Hitachi Zosen to evaluate SCR on cement kilns in 1976 (EPA, 1994). During these tests, two suspension preheater kilns and a wet process kiln were tested for 5,400 hours each. Electrostatic precipitators were used to remove particulates before the flue gas entered the SCR unit. Also a heat recovery system equipped with supplemental fuel firing was provided to raise the flue gas temperatures to the required reaction temperatures. Initial NO<sub>x</sub> removal efficiencies of 98 percent were achieved in slipstreams of about 3,000 scfm. However, after 5,400 hours of operation, NO<sub>x</sub> removal efficiencies dropped to about 75 percent due to catalyst coating.

The advantage of the high dust set-up is that the temperature of the exhaust after the cyclone stage is more or less equal to the temperature required for the catalyst. Additional heating is not

necessary. However, a "high-dust" SCR installation, which is used for most boilers equipped with SCR, has not been recommended because the high calcium content of the dust in cement kilns form deposits on the catalysts and reduce efficiency below acceptable levels.

A recent application of SCR at the Solnhofen Portland Zementwerke AG (SPZ) has shown that a "high-dust" SCR application can be achieved with proper management. This plant, which has been in full-scale operation for over two years, has shown significant NOx emission reductions as well as hydrocarbon, ammonia, and sulfur dioxide emissions.<sup>6</sup> This facility produces clinker in a rotary furnace with cyclone preheaters and post clinker chillers. This plant has burn zone temperatures above 1,400 °C (2,500 °F) with temperatures reaching 2,000 °C (3,600 °F) during the gas phase. Due to the high temperatures and the long duration, the process produces significant NOx emissions. Prior to designing the SCR system for the main plant, a pilot plant was constructed so that the last cyclone stage was parallel to the exhaust channel. A partial stream of the exhaust from the main operation was directed over the reactor. The reactor was designed with four different catalytic converter types to test different configurations and space velocities. Cleaning intervals for the catalysts were defined that would be realistic for large-scale plants. For successful operation, the cleaning intervals were designed close to the pressure drop of a maximum of 4 to 5 mbar. Results have shown that NOx reductions from 1,200 mg/m<sup>3</sup> to 200 mg/m<sup>3</sup> using the SCR process (>80 percent). The reductions occurred in the range of 250 to 450 °C. To date, this plant has been in operation for 24,000 hours and demonstrates greater than 80 percent NOx reductions.<sup>7</sup> According to Mr. Lugar of KWH Catalysts, Inc., the problem of fouling from the heavy dust loading has proven to be quite manageable with regular cleaning of the catalyst.

According to a recent report, while SCR has only been tested on preheater and semi-dry kiln systems, it might be applicable to other kiln systems as well (IPPCB, 2000).

### **Oxidation Technology**

This technology is a post-combustion control system that uses wet or semi-dry scrubbers to remove NOx by the addition of ozone as a treatment chemical to increase the solubility of relatively insoluble gaseous NOx. This technology has been developed by BOC Gases and is referred to as the LoTOx System. This system, which has been commercialized for about four years, has already been installed and operated in a variety of industries including steel, power production and recycling. According to BOC Gases, the LoTOx system has a small and adaptable footprint and can be applied in retrofit designs. The system has been used in a gas-fired boiler application to achieve levels below 0.15 lb/MMBtu of NOx and even as low as 5 ppm NOx. (85 to 90 percent control) Applications of this technology also include a natural acid pickling process in Pennsylvania, achieving 90 to 95 percent NOx removal, a 25 MW coal-fired boiler in Ohio achieving 85 to 90 percent NOx removal and a lead smelting furnace in California achieving 80 percent NOx removal. Although this technology has not been applied to a cement kiln operation, it may be a logical candidate for an existing NOx scrubber as those used on wet kilns.

<sup>6</sup> Samant, Sauter and G. Fischer, Der Kat fürs Zementwerk, Umwelt Magazine, December 2002.

<sup>7</sup> Personal Conversation with Tom Lugar of KWH Catalysts, Inc. on February 27, 2004.

### Combination of Technologies

Combustion technologies can be combined with post-combustion technologies in some cases. It is also possible to combine multiple combustion technologies in cement kilns. For example, California Portland Cement in Colton California converted its two long dry kilns to indirect firing to permit the use of a low-NOx burner in the kiln.

In Germany, emission limits of 800 mg/m<sup>3</sup> for existing plants and 500 mg/m<sup>3</sup> for new plants has resulted in the development by Krupp Polysius of trials to combine multi-stage combustion (MSC) with the SNCR process (Erpeldin, 2000). The process involved injecting an ammonium based solution at various points of the calciner to find the best place to introduce the solution within a suitable temperature window. The results showed that the best location for the NOx reduction process was obtained by injecting the solution before and after the deflection chamber. The trials were carried out at three plants of different sizes. At emission levels for MSC without ammonia between 400 and 800 mg, 250 mg was achieved corresponding to a reduction rate of between 38 and 68 percent.

### CEMENT PLANT OPERATIONS AND EQUIPMENT IN ELLIS COUNTY

The installed equipment at the three cement plants in Ellis County was described in the previous section.

Table 3-2 summarizes the current situation.

**Table 3-2.** Control technology used in Ellis County cement plants.

Company Name	Unit	Process	Current NOx Control Technology	2002 NOx Emissions (tons/yr)
Ash Grove Cement <sup>1</sup>	Kiln 1	Wet Process	ChemStar, MKF (tires) <sup>3</sup>	823.9
Ash Grove Cement	Kiln 2	Wet Process	ChemStar, MKF (tires) <sup>3</sup>	829.2
Ash Grove Cement	Kiln 3	Wet Process	ChemStar, MKF (tires) <sup>3</sup>	918.6
				<b>Plant Total 2,571.7</b>
TXI Operations, L.P.	Kiln 1	Wet Process	ChemStar	1,010.2
TXI Operations, L.P.	Kiln 2	Wet Process	ChemStar	24.3
TXI Operations, L.P.	Kiln 3	Wet Process	ChemStar	375.6
TXI Operations, L.P.	Kiln 4	Wet Process	ChemStar	988.4
TXI Operations, L.P.	Kiln 5	Dry Process <sup>2</sup>	LNB	1,822.7
				<b>Plant Total 4,221.2</b>
Holcim Texas L.P.	Kiln 1	Dry Process <sup>2</sup>	LNB	1,909.7
Holcim Texas L.P.	Kiln 2	Dry Process <sup>2</sup>	LNB	2,265.1
				<b>Plant Total 4,174.8</b>

<sup>1</sup> Formerly North Texas Cement Company.

<sup>2</sup> Precaleiner Kiln.

<sup>3</sup> TNRCC confirmed that North Texas Cement (Ash Grove) meets the criteria of having mid-kiln firing and low NOx-burners, Letter from Richard L. Hughes, September 20, 2000.

The Ash Grove Cement and TXI plants predominantly use wet process kilns. In 2002 wet process kilns, for which control options are more limited, produced about 45% of all cement plant NO<sub>x</sub> emissions.

## **POTENTIAL ADDITIONAL CONTROLS ON ELLIS COUNTY CEMENT PLANTS**

Our evaluation of potential controls for the cement plants in Ellis County is based on the experience of other plants in the U.S. and Europe as reported in the literature. For the purposes of this report, the term "technically feasible" applies to a control method or technology has been applied to other cement kilns, has been demonstrated to be successful in reducing NO<sub>x</sub> emissions, and appears to be feasible for similar equipment and processes in use in Ellis County. At this level of analysis, where detailed information on plant design, equipment and operations is not available, conclusions on technical feasibility are necessarily preliminary and have significant uncertainty."

### **Wet Kilns**

Seven of the ten kilns in Ellis County are wet process kilns. As discussed earlier, wet process kilns are an older cement production technology with smaller production capacity requiring 30 to 100 percent more thermal energy per unit of production than dry kilns (EC/R, 2000, reported 33% as an average).

Wet kilns also produce a greater volume of exhaust gas than dry kiln processes. Since NO<sub>x</sub> formation is directly related to fuel combustion, wet kilns also produce more NO<sub>x</sub> per unit of production. Conversely, any reduction in the amount of fuel burned in wet kilns will also lower NO<sub>x</sub> emissions per unit of clinker. To address energy efficiency issues and the higher emission rates from wet process kilns in Europe, observers expect most wet process kilns to be converted to dry process kiln systems when the plants are renewed (IPPCB, 2000).

All wet kilns in Ellis County already use ChemStar and some have low-NO<sub>x</sub> burners,<sup>8</sup> but other opportunities for control exist. If applied, strategies such as combustion zone monitoring/regulating excess air, MKF, and supplementing fuels with TDF, will both lower NO<sub>x</sub> and improve fuel efficiency. Low NO<sub>x</sub> burners can also be effective where not currently installed.

Our review indicates that neither SNCR nor SCR is currently available for wet kilns. Oxidation (LoTO<sub>x</sub> System) shows some potential, but has not yet been applied to any type of cement plant. We recommend that this process be investigated for application on the wet process kilns.

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<sup>8</sup> TNRCC confirmed that North Texas Cement (Ash Grove) meets the criteria of having mid-kiln firing and low NO<sub>x</sub>-burners, Letter from Richard L. Hughes, September 20, 2000.

## Dry Kilns

All dry kiln units in Ellis County use low NO<sub>x</sub> burners, however the newer preheater/precalciner kiln designs in Ellis County provide additional opportunities for NO<sub>x</sub> control. In addition to most the control methods available to wet kiln processes, NSCR appears technically feasible pending a more thorough engineering review of the plants. While SCR has not been applied to a U.S. cement plant and poses significant technical challenges, it has had one apparently successful demonstration in Europe. More important, SCR is a proven technology on other types of facilities with a significantly greater emission reduction potential than other technologies available for cement plants. While we consider it only "potentially feasible" at this point, its emission reduction potential is too high to be set aside permanently, especially if significant NO<sub>x</sub> controls are required to attain air quality standards.

## Potential Emission Reductions

The potential emissions reductions that could be achieved by applying the technologies described above to the kiln operations in Ellis County are shown in Table 3-3. For simplicity in presenting the reduction potential of these technologies the emissions reductions shown in Table 3-3 are based on the average emission reduction potential of the technologies from Table 3-1. Actual reductions may be larger or smaller, depending on plant-specific conditions and engineering considerations, including the physical plant layout.

For determining the total emissions reductions feasible, it was assumed that the existing wet kilns at TXI Operations could achieve an additional 30 percent reduction (using either mid-kiln firing or other combustion modification technology), the amount required by Chapter 117, if the emission levels cannot be met. This assumption was not applied to the Ash Grove facility as Mid-Kiln firing is already in use at this facility. Furthermore, emissions of NO<sub>x</sub> per ton of clinker appear to be somewhat less at the TXI operations, however specific production from the TXI operations were not available from the TCEQ. Again, our analysis and conclusions must be considered preliminary, since they are based on general information about the facilities in Ellis County and do not involve a detailed engineering analysis of plant equipment or operations.

For the dry kilns, potential emissions reductions were calculated for both the SNCR process and the SCR process, though only one method would be applied.

Overall, applying the technology described in this report could result in the reduction on NO<sub>x</sub> ranging from 1,200 tons per year to over 5,500 tons per year. The successful application of the technologies will depend on the applicability of the various control techniques to each individual kiln operation. This analysis did not include an engineering feasibility but rather an identification of the potential control technologies that should be further investigated for application in Ellis County.

**Table 3-3. Potential emission reductions from cement plants in Ellis County.**

Company	Unit	2002 NOx Emissions (tons/yr)	Potential NOx Control Technology Reductions					
			Process <sup>3</sup>		SNCR		SCR <sup>4</sup>	
			%	T/Y	%	T/Y	%	T/Y
Ash Grove <sup>1</sup>	Kiln 1 (Wet)	823.9						
Ash Grove <sup>2</sup>	Kiln 2 (Wet)	829.2						
Ash Grove <sup>3</sup>	Kiln 3 (Wet)	918.6						
		<b>2,571.7</b>	<b>0.0</b>					
TXI Operations	Kiln 1 (Wet)	1,010.2	30	303.1				
TXI Operations	Kiln 2 (Wet)	24.3	30	7.3				
TXI Operations	Kiln 3 (Wet)	375.6	30	112.7				
TXI Operations	Kiln 4 (Wet)	988.4	30	296.5				
TXI Operations	Kiln 5 (Dry) <sup>2</sup>	1,822.7	30	546.8	45	820.2	80	1458.2
		<b>4,221.2</b>	<b>1266.4</b>		<b>820.2</b>		<b>1458.2</b>	
Holcim	Kiln 1 (Dry) <sup>2</sup>	1,909.7	30	572.9	45	859.4	80	1527.8
Holcim	Kiln 2 (Dry) <sup>2</sup>	2,265.1	30	679.5	45	1019.3	80	1812.1
		<b>4,174.8</b>	<b>1252.4</b>		<b>1878.7</b>		<b>3339.8</b>	

<sup>1</sup> Formerly North Texas Cement Company.  
<sup>2</sup> Dry Process is Precalciner Kiln.  
<sup>3</sup> Process modifications are assumed to achieve an average reduction of 30 percent.  
<sup>4</sup> SCR is considered "potentially feasible" and is presented here for completeness.

## 4. EVALUATION OF THE COST OF NO<sub>x</sub> EMISSION CONTROLS

### INTRODUCTION

This cost-effectiveness analysis builds on the conclusions of the previous sections. In the previous section we examined the range of possible and probable emissions reduction measures that may be applicable to cement plants in Ellis County. As noted in that section, and repeated here, the emissions reductions, appropriate control measures, and the related costs cannot be defined fully within the context of this study. Such in-depth engineering design assessment would be the next step in furthering emissions reductions from these sources, and would have to be carried out in collaboration with the individual facilities. This overall study is intended to further the necessary constructive dialog between the stakeholders, leading to the possible additional emissions reductions from these facilities.

All information for this study has been derived from public sources such as facility permit files and various TCEQ reports. Shortcomings in those data sets may be reflected in this report. Further detailed information, derived from the facilities described in this and previous reports, would be a wise next step in assuring the accuracy of the data used herein.

The focus is on cement plants because they are the predominant source of NO<sub>x</sub> emissions from stationary sources in Ellis County. Each technically feasible control method/technology discussed in the previous section is analyzed. To the extent possible, given available information, a cost estimate is made for each combination of a technically feasible control method and the specific equipment and process in use at the three cement plants in Ellis County. The steps in the evaluation are:

1. Select a cement plant unit from Table 3-2 in the previous section.
2. Select a technically feasible control method for that equipment from Table 3-3 of the previous section.
3. Estimate the annual cost of applying the feasible control method to that piece of equipment using available information and the methodology described below.
4. Apply the estimated cost of control to the range of emissions reductions estimated in Table 3-3 of the previous section to calculate a range of cost-effectiveness stated as dollars per ton of NO<sub>x</sub> emissions reduced.

This report makes cost estimates at what EPA calls the "study level" of analysis, which produces an accuracy level of, at best, + or - 30% (EPA Air Pollution Control Cost Manual, Sixth Edition, p. 2-3, Figure 2-1). Since cost-effectiveness calculations apply cost estimates to the range of emission reductions estimated in the previous section, all the uncertainties and limitations with emission reduction estimates that were described in the previous section apply equally to the cost-effectiveness numbers in this report.

At these levels of analysis, the capital cost estimates do not address specific retrofit considerations for the Ellis County plants. There is not enough information available to uncover potential hidden costs of a specific installation on a specific unit. EPA guidance notes that a retrofit factor of up to 50% of the capital cost of the control system can be justified on a case-by-case basis, but that it is also important to avoid over-estimates (Control Cost Manual, p. 2-28). Since this study has no means of developing a retrofit factor for each technology-unit

combination, we have chosen to apply an across-the-board contingency factor of 20%. Specific considerations for retrofit requirements are identified in the discussion for each control technology. The contingency factor may or may not be adequate to cover plant and unit specific issues.

In summary, these estimates should be considered rough estimates of the actual cost-effectiveness of emissions reductions measures, should these control methods be applied to Ellis County cement plants.

## **COST CALCULATION METHODOLOGY**

The approach to calculating cost-effectiveness is based on, but not identical to, the cost-calculation methodology used in EPA's 1994 "Alternative Control Techniques Document—NO<sub>x</sub> Emissions From Cement Manufacturing" (ATC) and the 2000 review and update, "NO<sub>x</sub> Control Technologies for the Cement Industry - Final Report" (hereafter "EC/R", the consultant that prepared the report for EPA). The methodologies used in these reports were, in turn, based on the EPA Air Pollution Control Cost Manual, Fifth Edition. EPA is in the process of assembling a Sixth Edition of the cost manual, but at present it contains no information on NO<sub>x</sub> control at cement plants. The approach used here uses the same cost parameters as the EPA documents but, as noted above, applies estimated costs as much as possible to specific Ellis County cement plant units rather than "model plants".

The cost parameters and the sources of the values used in this report are listed in Tables 4-1 and 4-2. The reports mentioned above applied assumptions to some cost parameters and used national data on others. We have applied the same assumptions as the authors of the EPA reports, but updated the information used in some cases to make them more current and specific to Texas. The parameters that use Texas-specific information are identified in Table 4-2. For most control technologies we applied the most recently available purchased equipment costs (PEC) for control equipment from the EPA reports. References are included in the cost calculation tables in Appendix A. Our review showed that in some cases EPA obtained their PEC from early-1990's vintage vendor estimates and then reused these estimates in the 2000 report. It was not possible within the scope of this analysis to comprehensively update EPA estimates with more recent information from vendors. While we relied heavily on published EPA material, we also reviewed European studies, other U.S. reports and articles, and several recent U.S. air permits to verify that the cost estimates in this report are generally within the ranges reported in the literature. Since there was little cost information in the literature on selected catalytic reduction (SCR) in these applications, we also contacted a vendor who recently provided quotes on cement plants.

**Capital Cost Estimation****Table 4-1.** Capital investment components of cost estimates.

<b>Parameter</b>	<b>Value</b>	<b>Source</b>
Purchased equipment cost (control device and auxiliary equipment)	Will vary by equipment	Best available, priority on information from public records
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)	45% of PEC	1994 ATC, also in EC/R report
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)	33% of PEC	1994 ATC, also in EC/R report
Contingencies	20% of PEC	1994 ATC, also in EC/R report
Sales tax	3% PEC	6th Edition cost manual, Chapter 2, Table 2-4
Freight	5% PEC	Same
Production downtime	Two days plus \$77, the market value per ton of clinker in 2003	Downtime from EC/R report, market value from <a href="http://minerals.usgs.gov/minerals/pubs/commodity/cement/170303.pdf">http://minerals.usgs.gov/minerals/pubs/commodity/cement/170303.pdf</a>
<b>Total capital costs (sum of all above)</b>		

Purchased equipment costs for some control methodologies technologies depend on specific characteristics of the units, particularly the production capacity and baseline energy efficiency of the kiln. Since some of this information is not available for this study, assumptions had to be made. These are explained and documented on a case-by-case basis.

If actual direct and indirect installation costs are available, they are used instead of the default values listed in Table 4-1. A contingency factor of 20% is used to account for problems associated with retrofitting technologies on specific units. Actual costs may be larger or smaller. Downtime is assumed for all applications, but it may be an avoidable cost if controls are installed in conjunction with other maintenance shutdowns.

The total capital investment is the sum of the direct cost (which is the purchased equipment costs and direct installation costs), indirect installation costs, contingency costs, sales taxes, freight, and production downtime. Total capital costs are carried forward in the process and used for calculating overhead, capital recovery and other elements of annual cost.

## Annual Operating Costs

Annual operating costs are composed of the direct operating costs of materials and labor for maintenance, operation, utilities, material replacement and disposal and the indirect operating charges, including plant overhead, general administration, and capital recovery charges.

Annual utility costs include both the cost of operating control equipment and post-retrofit changes in fuel consumption. Control strategies can increase or decrease overall fuel consumption, but strategies such as excess air monitoring and control and mid-kiln firing (MKF) reduce NO<sub>x</sub> indirectly by improving overall fuel efficiency. These control approaches offset other costs with fuel savings. Ellis County cement plants are permitted to use a mix of fuels. Since neither the mix nor quantity of typical fuel use is available for this study, baseline and future fuel costs are necessarily based on case-by-case assumptions.

The literature shows that plants in some areas are paid tipping fees to “dispose” of waste tires (tire-derived fuels or TDF), while other plants have to buy tires. The market is fluid and depends heavily on public policy and subsidies. We were unable to identify the “cost” to cement plants of TDF in Texas and therefore have assumed that they can be obtained free by the plants in Ellis County.

Indirect annual costs such as insurance, taxes, and overhead (both labor and materials) are estimated using values from EPA’s Cost Manual.

The capital recovery factor (CRF) used in this analysis assumes a 15-year equipment lifetime and a discount interest rate of 7.7%. These assumptions were taken from Iowa’s recent permit evaluation on the Lehigh facility (see discussion from previous section).

**Table 4-2. Annual cost components.**

Direct Costs		Value	Source
Utilities	Coal	23.47 per short ton	2001 price from <a href="http://www.eia.doe.gov/cneaf/coal/page/acr/tab1e35.html">http://www.eia.doe.gov/cneaf/coal/page/acr/tab1e35.html</a>
	Electricity	\$0.056 per kw-hr	2003 prices in TX for industrial users per <a href="http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls">http://www.eia.doe.gov/cneaf/electricity/page/sales_revenue.xls</a>
	Nat. gas	\$3.40 per 1000 cubic feet	2002 price in TX for industrial users per <a href="http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_stx_a_d.htm">http://tonto.eia.doe.gov/dnav/ng/ng_pri_sum_stx_a_d.htm</a>
	Tires	\$0	Chosen because we were unable to find information on waste tire values in Texas
Labor	Operating labor	12.47 per hour	TX labor rates from 2002 survey for kiln operators, see <a href="http://www.bls.gov/oes/2002/oes_tx.htm#b51-0000">http://www.bls.gov/oes/2002/oes_tx.htm#b51-0000</a>
	Supervising labor	15% of operating labor	EC/R report, p 87
Maintenance	Maintenance labor	19.18 per hour	TX labor rates from 2002 survey for industrial machinery mechanics, <a href="http://www.bls.gov/oes/2002/oes_tx.htm#b51-0000">http://www.bls.gov/oes/2002/oes_tx.htm#b51-0000</a>

Direct Costs	Value	Source
Maintenance materials	100% of maintenance labor	EC/R report, p 87
Total direct cost		
<b>Indirect costs</b>		
Overhead	60% of all labor categories and materials	6th Edition cost manual, Chapter 2, p. 2-34
Property tax	1% of total capital cost	6th Edition cost manual, Chapter 2, p. 2-34
Insurance	1% of total capital cost	6th Edition cost manual, Chapter 2, p. 2-34
Admin. Charges	2% of total capital cost	6th Edition cost manual, Chapter 2, p. 2-34
Total indirect cost		
Capital recovery	Assume 7.7% interest rate and a 15-year equipment life. CRF = 0.1147 per dollar	The capital recovery factor (CRF) is multiplied times total capital cost to calculate annual equipment payments over the equipment life. CRF = $l(1+i)^n / ((1+i)^n - 1)$ , where "l" is annual interest rate in percent and "n" is equipment life in years
<b>Total Annual Costs = Total DC + Total IC+ Capital recovery</b>		

## COST-EFFECTIVENESS CALCULATION METHODOLOGY

Annual costs are used in two ways in this report. First, and specific to the cement plants themselves, the annual cost of control is divided by the estimates of annual emission reductions in order to express cost effectiveness as annual cost per annual emissions reductions (CE = \$/ton). Second, and to put the cement kiln cost-effectiveness results presented above into context, we have also summarized annualized NO<sub>x</sub> control strategy cost effectiveness estimates for a wide variety of control measures considered in the development of ozone attainment strategies in various U.S. cities.

## COSTS OF NO<sub>x</sub> CONTROL APPROACHES

### General Considerations

The capital and operating costs were estimated for each of the control technologies that were deemed technically feasible in the previous section. In addition, we have performed a rough estimate of the cost and cost-effectiveness of Selective Catalytic Reduction (SCR), even though it was classified as "potentially feasible". Because the ChemStar process is used on each of the wet kilns in Ellis County, the cost of this process was not estimated

In order to make the analysis more relevant to the Portland Cement facilities in Ellis County, we applied various technologies to specific kilns and did so with consideration of the equipment and

NO<sub>x</sub> control methods that are already in place at each kiln. Although estimates are not provided for all technologies at each kiln, the general cost and cost-effectiveness ranges would generally apply to all kilns. The exception is where a particular technology is not applicable to a particular kiln, i.e., the application of SNCR to wet kilns. All assumptions and costs identified with this analysis are included in the cost evaluation sheets contained in Appendix A.

Some information on the costs of controls was based on assumptions that were necessary because certain information was not available from the TCEQ for the specific kilns in operation in Ellis County. For example, we were able to obtain material throughput in tons of clinker processed per year for the Ash Grove kilns and the Holcim kilns but not the kilns at TXI Operations. We were also not able to obtain information on the amount and types of fuel used for the kilns at each of the three plants. Assumptions for these parameters as well as assumptions on specific equipment such as the use of direct-fired burners at the wet kilns were also made.

As discussed in the previous section, oxidation (LoTOx System) shows some potential, but has not yet been applied to any type of cement plant. Accordingly, we have not included this technology in our cost estimates. As a result we believe that some of these technologies should be more fully explored with specific attention to the plant configurations and operating conditions at each kiln.

### **Low NO<sub>x</sub> Burners**

Low NO<sub>x</sub> burners are in use at TXI Operations and on the dry kilns at the TXI and Holcim facilities. For reasons discussed in Task 3, low NO<sub>x</sub> burners require an indirect firing configuration. It is our understanding that the wet kilns at TXI Operations are therefore indirect-fired kilns.<sup>1</sup> Because the wet kilns at the Ash Grove plant have mid-kiln firing, a technology that has the potential to provide greater NO<sub>x</sub> emission reductions, we have not estimated the cost of low-NO<sub>x</sub> burners for this analysis.

### **Mid-Kiln Firing**

As discussed in the previous task, strategies such as MKF, and supplementing fuels with TDF, will both lower NO<sub>x</sub> and improve fuel efficiency. The technology can be applied to wet kilns and long dry kilns, but is not considered a candidate control method for the modern dry kilns in use in Ellis County. Mid-kiln firing is currently being used at the Ash Grove Cement facility. In addition, this technology was studied at the TXI facility for all four wet kilns from July to November of 2002. The most significant costs associated with this process are those for kiln modifications necessary to facilitate the secondary fuel, and the solid fuel conveying system. If these modifications were made in 2002 and were still in place at TXI, the cost for implementing this control method at TXI would be significantly lower than shown in Table 4-3 and the range of cost-effectiveness would be more favorable. It is our understanding that the control equipment is no longer installed at these kilns.

The capital and annual operating costs used in this analysis was obtained from the EC/R report on NO<sub>x</sub> Control Technologies for the Cement Industry. The cost includes a fuel credit for the

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<sup>1</sup> Personal conversation with Randy Hamilton, TCEQ, April 9, 2004.

fuel that is replaced with waste tires as well as a tipping fee. Again the assumptions used for these credits are from the EC/R report and do not necessarily reflect actual fees or fuel credits from the specific plants in Ellis County. The negative range of cost-effectiveness shown below reflects the large credits for the fuel and tipping fees as well as the variability in emission reductions that can be achieved by this technology in different installations.

**Table 4-3: Cost of mid-kiln firing.**

Company Name	Unit	Process	NO <sub>x</sub> Reduction (Tons/Yr)	Capital Cost	Operating Cost	Cost-Effectiveness (\$/Ton)
TXI Operations, LP.	Kiln 1	Wet	283 - 596	\$3,227,619	(757,753)	(\$650 - \$1,370)
TXI Operations, LP.	Kiln 2	Wet <sup>1</sup>				
TXI Operations, LP.	Kiln 3	Wet	105 - 222	\$3,227,619	(757,753)	(\$1,749 - \$3,685)
TXI Operations, LP.	Kiln 4	Wet	277 - 583	\$3,227,619	(757,753)	(\$665 - \$1,400)
<b>Total</b>			<b>665 - 1,401</b>	<b>\$9,682,858</b>	<b>(2,273,258)</b>	<b>(\$650 - \$3,685)</b>

Notes

<sup>1</sup> Kiln 2 emissions are very low indicating that the unit was not in full operation during 2002. Therefore, cost estimates were not included for this kiln.

### Multi-stage Combustion (MSC)

Although not discussed as a potential technology in the previous task, MSC is a technology that is available for some preheater/precalciner kilns. Several kilns in the US have recently been retrofitted with these "low NO<sub>x</sub>" precalciners. Preliminary information indicates a noticeable reduction in NO<sub>x</sub> per ton of clinker (up to 46 percent) without causing excessive coating difficulties in the kiln. (EC/R).

It is not possible to use "staged combustion" on preheater kilns that are firing fuel in the riser since in staged combustion it is necessary to add the fuel in an oxygen deficient atmosphere and then supply additional combustion air to fully combust the fuel. Preheater kilns do not have tertiary air ducts to supply the additional combustion air. The air for combustion of the secondary fuel must come through the kiln, which precludes introducing the secondary fuel into an atmosphere with insufficient oxygen for complete combustion. With MSC in a precalciner, emissions reductions in the range of 30 to 40 percent have been reported when burning tire derived fuel (EC/R, 2000).

### Biosolids Injection Process (BSI)

The application of this process to preheater/precalciner kilns has been applied in the U.S. and shows promise for reducing NO<sub>x</sub> emissions. With this technology, dewatered sewage sludge is added to the mixing chamber of the calciner. The dewatered biosolids provide a source of ammonia, producing an SNCR-like reaction to reduce NO<sub>x</sub>. The costs associated with installing this technology include the sludge system and the sludge conveying system. This technology can be very attractive from a cost standpoint if the cement plant is paid a tipping fee to dispose of the sludge. For the purpose of this analysis, a tipping fee of \$5.00 per wet ton was used. This is an average of tipping fees that range from \$0.00 to \$10.00 per wet ton (EC/R, 2000). The capital and annual operating costs used in this analysis was obtained from the EC/R report on NO<sub>x</sub>

Control Technologies for the Cement Industry. Table 4-4 summarizes the cost for this technology.

**Table 4-4. Cost of BSI.**

Company Name	Unit	Type	NO <sub>x</sub> Reduction (Tons/Yr)	Capital Cost	Operating Cost	Cost-Effectiveness (\$/Ton)
TXI Operations, LP.	Kiln 5	Dry <sup>1</sup>	273 - 547	\$1,245,721	(\$482,537)	(\$621) - (\$1,242)
Holcim Texas LP	Kiln 1	Dry <sup>1</sup>	287 - 573	\$987,556	(\$492,863)	(\$663) - (\$1,325)
Holcim Texas LP	Kiln 2	Dry <sup>1</sup>	340 - 680	\$947,392	(\$494,470)	(\$568) - (\$1,136)
<b>Total</b>			<b>900 - 1,800</b>	<b>\$3,180,669</b>	<b>(\$1,469,870)</b>	<b>(\$568) - (\$1,325)</b>

**Notes**

<sup>1</sup> Dry Process is Preclinker Kiln

### Selective Noncatalytic Reduction (SNCR)

As noted in Task 3, our review indicates that neither SNCR nor SCR is currently available for wet kilns. However, SNCR has demonstrated significant reductions of NO<sub>x</sub> when applied on numerous operating dry preclinker kiln configurations in Europe and on tests on several plants in the U.S. The primary information on capital cost for this analysis was from the submittal from Holcim to the TCEQ. The analysis was received by the TCEQ on May 19, 2003 and was submitted as part of an analysis of potential emission reduction techniques to demonstrate that the facility could modify its operations without an increase in emissions<sup>2</sup>. The cost estimates are based on a urea based systems with a removal efficiency of 20 percent. Therefore the costs include of a complete urea delivery and injection system. Because SNCR requires availability of a section of kiln with the proper temperature and residence time as well as a determination of the amount of ammonia injected, (specifically the NH<sub>3</sub>/NO<sub>x</sub> molar ratio), the application of this technology to a specific kiln will determine the level of reduction possible. Therefore, the costs of this technology will vary depending not only on the removal efficiency but also the reagent utilization.

To provide a basis of comparison, we obtained the cost estimates for the SNCR installation at the Lehigh Cement Company plant in Mason City Iowa. The PEC for this plant was \$1,083,666, somewhat less than the \$1,201,496.00 estimate used in this analysis. The Lehigh system is based on baseline NO<sub>x</sub> emissions of 3.8 lb/ton of clinker and 25 percent NO<sub>x</sub> reduction efficiency. Based on this comparison, the capital cost estimates in this report for SNCR appears reasonable.

It should be noted that the application of this technology has resulted in achieving even higher levels than included in this analysis. For example, one demonstration of urea on a preclinker kiln achieved over 80 percent reduction (NESCAUM, 2000). As a result we believe that the associated reductions will be at the upper end, and the cost-effectiveness near the lower end, of the range identified in Table 4-5.

<sup>2</sup> Appendix G, Tier 3 Cost Estimate SNCR for NO<sub>x</sub>, Holcim May 19, 2003.

**Table 4-5. Cost of SNCR.**

Company Name	Unit	Type	NO <sub>x</sub> Reduction (Tons/Yr)	Capital Cost	Operating Cost	Cost-Effectiveness (\$/Ton)
TXI Operations, LP.	Kiln 5	Dry <sup>1</sup>	182 - 911	\$3,948,966	\$1,770,191	\$2,439 - \$12,197
Holcim Texas LP	Kiln 1	Dry <sup>1</sup>	191 - 955	\$3,690,801	\$1,759,864	\$2,266 - \$11,432
Holcim Texas LP	Kiln 2	Dry <sup>1</sup>	227 - 1,133	\$3,650,637	\$1,758,258	\$1,022 - \$9,611
<b>Total</b>			<b>182 - 1,133</b>	<b>\$11,290,404</b>	<b>\$5,288,313</b>	<b>\$1,022 - \$12,197</b>

Notes

<sup>1</sup> Dry Process is Precalciner Kiln

### Combination of Technologies

The combination of multi-stage combustion (MSC) with SNCR can achieve significant reductions at a reduced cost compared to SNCR alone. Trials were conducted on three plants of different sizes in Germany by Krupp Polysius, AG. The trials were carried out on precalciner kilns that were equipped with MSC and that injected ammonia based solution at various points of the calciner. The system used a 25 percent ammonia solution and a film developer wastewater enriched to 5 percent with urea. The best results were achieved by injecting the solution before and after the deflection chamber. The advantage offered by this combination of technologies is that cost effectiveness improves when compared to SNCR alone. According to Dr. R. Erpeldin (2000) of Krupp Polysius AG, the higher investment costs for the ammonia system (above that for just MSC) are compensated by lower costs for the fuel and the ammonia carrier. The best results were achieved when the total emission reduction rates were set above 35 – 45 percent. Using the results for these trials, the cost reduction for this combination of technologies showed approximately a 50 percent reduction in the operating cost over SNCR alone. However, this savings is partially offset by the upfront capital investment for the MSC system. Further investigation of this combination of technologies is suggested for the specific preheater/precalciner kilns at TXI Operations and Holcim Cement.

### Selective Catalytic Reduction (SCR)

As discussed in the previous task, SCR has not been applied on any U.S. cement plants. The track record at cement plants worldwide is also small, since we identified success at only one cement plant in Europe. However, it was our judgment that SCR is worth including in this preliminary analysis because of its promise; namely the excellent track record of SCR technology in other industries and the significant emission reductions that can be achieved.

Capital costs of this control approach are significantly higher than the other technologies primarily due to the cost of an SCR unit, ammonia storage tank, and an ammonia heating/vaporization injection system along with equipment needed for reheating flue gases to an appropriate temperature depending on the placement of the system in the cement production process. We obtained capital cost estimates from the Alternative Control Techniques Document-NO<sub>x</sub> Emissions from Cement Plants published by EPA in March 1994. Because SCR installations require considerable space and are often custom designed, retrofit costs can be very significant, considerably more than the 20% contingency factor we have applied. An estimate of

retrofit costs would be an important issue should there be a more refined level of analysis of the technical feasibility and cost of SCR on these plants.

The NO<sub>x</sub> reduction achieved with SCR technology depends on the amount of ammonia injected, (specifically the NH<sub>3</sub>/NO<sub>x</sub> molar ratio), and the gas phase residence time in the SCR reactor. The SCR equipment costs from the EC/R report were based on application on a dry kiln with exhaust gases at 350 °C (660 °F) and a design NO<sub>x</sub> removal efficiency of 80 percent. The equipment cost estimate included SCR catalysis, SCR reactor, gas/gas heat exchanger, heater, ammonia injection grid, ammonia storage tank, ammonia vaporizer and supply unit, induced draft fan, instrumentation and all piping and ductwork. However, depending on the location of the SCR unit in the kiln process, the additional heating may not be required. This was the case with the experience at the Solenhofen plant in Germany (discussed in the previous section). As a result the costs used for this analysis could be lower. The experience in Germany has also shown that a need for continuous cleaning of the catalyst that would increase the operating cost of this system.

As mentioned earlier, this technology has not been applied in the U.S.; however, the state of New York is evaluating the SCR process for application at the new St. Lawrence Cement facility. A cost estimate from KWH Catalysts was provided for this facility.<sup>3</sup> The capital cost estimate for this plant was \$9,000,000, which is lower than the \$11,900,000 estimate used in this analysis. The estimate for the St. Lawrence facility was based a "high-dust" installation and an exhaust volume of 350,000 m<sup>3</sup>/hour. This tends to confirm that equipment costs for such installations would be lower because reheating the exhaust gases is not necessary.

Despite its high capital cost, the greater NO<sub>x</sub> removal efficiency with this technology results in the cost-effectiveness range, expressed as dollars per ton of NO<sub>x</sub> reduced that is similar to the mid- range of cost-effectiveness for SNCR.

**Table 4-6. Cost of SCR.**

Company Name	Unit	Type	NO <sub>x</sub> Reduction (Tons/Yr)	Capital Cost	Operating Cost	Cost-Effectiveness (\$/Ton)
TXI Operations, L.P.	Kiln 5	Dry <sup>1</sup>	1458 - 1832	\$29,773,249	\$5,191,367	\$4,970 - \$5,902
Holcim Texas L.P.	Kiln 1	Dry <sup>1</sup>	1528 - 1814	\$27,966,093	\$7,023,081	\$5,639 - \$6,696
Holcim Texas L.P.	Kiln 2	Dry <sup>1</sup>	1812 - 2152	\$27,684,944	\$5,107,835	\$3,849 - \$4,571
<b>Total</b>			<b>4798 - 5798</b>	<b>\$85,424,286</b>	<b>\$17,322,282</b>	<b>\$3,849 - \$6,696</b>

Notes

<sup>1</sup> Dry Process is Preclaciner Kiln

## NO<sub>x</sub> CONTROL STRATEGY COST-EFFECTIVENESS COMPARISONS

To put the cement kiln cost-effectiveness results presented above into context, we present here a brief summary of NO<sub>x</sub> control strategy cost effectiveness estimates for a wide variety of control measures considered in the development of ozone attainment strategies in various U.S. cities. We reviewed cost-effectiveness results for measures adopted and/or studied in Texas (including Dallas-Fort Worth Area, Houston-Galveston Area, and San Antonio), Tennessee, West Virginia,

<sup>3</sup> Personal conversation with Tom Luga of KWH Catalysts, Inc, April 7, 2004.

Virginia, as well as those adopted and/or used by the Environmental Protection Agency (EPA) and California Air Resources Board (CARB). Cost-effectiveness values presented here are based on studies listed in Table 4-8. The control measures examined in these studies are used here as examples for comparison purposes only: they are not intended to represent a comprehensive list of all the available control measures that might be applicable to the Dallas – Ft. Worth area.

Cost effectiveness ranges for various types of control measures examined in the studies listed in Table 4-8 are summarized in Table 4-7. For purposes of comparison with the cement kiln NO<sub>x</sub> measures described in the previous sections, only cost-effectiveness estimates specifically for NO<sub>x</sub> are included in Table 4-7: estimates included in the Table 4-8 references that were stated only on a (NO<sub>x</sub> + VOC) \$/ton basis were not included.

**Table 4-7.** Summary of average cost effectiveness estimates for various types of control measures from studies listed in Table 4-8.

Control Measure Category	NO <sub>x</sub> Cost Effectiveness (\$/ton)	
	Minimum	Maximum
Mobile sources: on-road fuel and retrofit programs	\$600	\$65,852
Mobile sources: other on-road measures (vehicle standards, I/M programs, TCMs, etc.)	\$100	\$75,000
Off-Road mobile sources: emission standards, retrofits, etc.	\$200	\$13,000
Industrial and area sources: utility NO <sub>x</sub> limits, other industrial NO <sub>x</sub> controls	\$1,200	\$4,600
Cement kiln controls <sup>4</sup>	\$450	\$1,713

Given the wide range of control measures examined in the studies described above and the unique conditions factored into each study, it is not surprising that the cost-effectiveness values in Table 4-7 span a wide range. Cost-effectiveness estimates for cement kilns (both those listed in Table 4-7 and the more detailed estimates discussed in previous sections) appear to be in line with those of other stationary source control measures and are significantly less expensive than some of the more costly mobile source measures. It should be noted that the \$/ton estimates shown here do not reflect the potential contribution to total NO<sub>x</sub> reductions which might be achieved by the various control measures if they were to be implemented in the Dallas – Ft. Worth area. Some control measures, while not inexpensive on a \$/ton basis, may nevertheless be of interest to planners because they have the potential to result in significant total tonnage reductions.

<sup>4</sup> Two of the studies listed in Table 7, (EPA, 2004; NESCAUM, 2000) included information on the cost effectiveness of cement kiln NO<sub>x</sub> control measures.

Table 4-8. Alternative control measure cost-effectiveness studies.

Study	Source	Reference
NCTCOG	"Evaluation of Attainment Control Strategies for the Dallas-Fort Worth State Implementation Plan", report to the North Central Texas Council of Government (NCTCOG) by ENVIRON	ENVIRON (2000)
H-GAC	"Initial Evaluation of Emission Reduction Potential of Candidate Measures to Obtain NOx Reductions in the Houston-Galveston Area", report for the Houston-Galveston Area Council (HGAC) by ENVIRON, July 25, 2000.	ENVIRON (2000)
San Antonio EAC	"1st Biannual Report: The Early Action Compact for the San Antonio Metropolitan Area," prepared by the Alamo Area Council of Governments, June 2003	(San Antonio EAC, 2003);
Tennessee EAC	"Emission Inventories and Potential Emission Control Strategies for Ozone Early Action Compact Areas in Tennessee," prepared for Tennessee Dept. of Transportation and Dept. of Environment and Conservation, prepared by University of Tennessee, April 13, 2003	Tennessee EAC, 2003
Berkeley Jefferson Counties EAC	"Evaluation of Emissions Control Technologies under Consideration for the Berkeley Jefferson Counties Early Action Compact," report to the Wilbur Smith Associates by ENVIRON, March 2004	ENVIRON (2004)
Winchester Frederick County EAC	Evaluation of Emissions Control Technologies under Consideration for the Winchester Frederick County Early Action Compact," report to the Wilbur Smith Associates by ENVIRON, December 2003	ENVIRON (2003)
CARB Control Measures	"Initial Statement of Reasons for Adopting More Stringent Emission Standards for 2007 and Subsequent Model Year New Heavy-Duty Diesel Engines," staff report prepared by the California Air Resources Board, (CARB), September 2001	CARB, 2001
EPA Mobile Control Measures	"Regulatory Impact Analysis - Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements," EPA420-R-99-023, Environmental Protection Agency, December 1999	EPA, 1999
EPA Point Control Measures	"Identification and Discussion of Sources of Regional Point Source NOx and SO2 Emissions Other Than EGUs," technical support document prepared by EPA, January 2004, and EPA's AirControlNET Database Software on Cost Strategies and Costing Analysis	EPA, 2004
NESCAUM NOx Control Study	"Executive Summary: Status Report on NOx Control for Gas Turbines, Cement Kilns, Industrial Boilers, and Internal Combustion Engines: Technologies & Cost-Effectiveness," prepared by Northeast States for Coordinated Air Use Management, December 2000	NESCAUM, 2000

**ADDITIONAL REFERENCES**

- EC/R. 2000. NOx Control Technologies for the Cement Industry Final Report, EC/R Incorporated, September 19. p 55-67.
- EPA. 1994. Alternative Control Techniques Document—NOx Emissions from Cement Manufacturing, EPA-453/R-94-004, U.S. Environmental Protection Agency, March.
- EPA. 1995. Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, USEPA, AP-42 Fifth Edition, January.
- Erpeldin, R. 2000. NOx reduction with the MSC/SNCR combination: Chances and Risks, June.
- IPPCB. 2000. Integrated Pollution Prevention and Control Bureau (IPPCB), Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries, European Commission, Seville, Spain. March.
- Haug, Sauter and G. Samant, Einsatz der High. 2002. Dust-SCR-Technologies in der Sementindustrie, BAT-und preisorientierte Dioxin/Rauchgasreinigungstechniken 2002 für Verbrennungs-und Feuerungsanlagen. September.
- MDNR. 2004. Missouri Department of Natural Resources, Air Pollution Control Program, Notice of Public Hearing, A PSD Permit Application from Holcim (US) Inc., February 22.
- NESCAUM. 2000. Status Report on NOx Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines, Technologies & Cost Effectiveness, Northeast States for Coordinated Air Use Management, December.
- SEPA. 2000. Per Junker, Reduction of Nitrogen Oxides with SNCR at Slite Cement Plant, Swedish Environmental Protection Agency, March.

**APPENDIX A**  
**COST CALCULATION WORKSHEETS**

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: TXI OPERATIONS, L.P**  
**Kiln: MID-KILN FIRING, KILN 1**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$1,490,000
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 670,500
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 491,700
Contingencies		Default is 20% of PEC	\$ 298,000
Sales tax		3% PEC	\$ 44,700
Freight		5% PEC	\$ 74,500
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 158,219
	<b>Capital cost</b>		<b>\$ 3,227,619</b>
	<b>Annual cost assuming 15 year equipment life</b>		<b>\$ 215,175</b>

Note: PEC Costs based on 1997 Cost Analysis from NOx Control Technologies for Cement Industry, Final Report, EC/R, September 19, 2000

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: TXI OPERATIONS, L.P**  
**Kiln: MID-KILN FIRING, KILN 3**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$1,490,000
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 670,500
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 491,700
Contingencies		Default is 20% of PEC	\$ 298,000
Sales tax		3% PEC	\$ 44,700
Freight		5% PEC	\$ 74,500
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 158,219
	Capital cost		\$ 3,227,619
	Annual cost assuming 15 year equipment life		\$ 215,175

Note: PEC Costs based on 1997 Cost Analysis from NOx Control Technologies for Cement Industry, Final Report, EC/R, September 19, 2000

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: TXI OPERATIONS, L.P**  
**Kiln: MID-KILN FIRING, KILN 4**

Purchased equipment cost, includes the control device, auxiliary equipment and instrumentation.)			\$1,490,000
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 670,500
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 491,700
Contingencies		Default is 20% of PEC	\$ 298,000
Sales tax		3% PEC	\$ 44,700
Freight		5% PEC	\$ 74,500
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 158,219
	Capital cost		\$ 3,227,619
	Annual cost assuming 15 year equipment life		\$ 215,175

Note: PEC Costs based on 1997 Cost Analysis from NOx Control Technologies for Cement Industry, Final Report, EC/R, September 19, 2000

**ANNUAL COST WORKSHEET**

**Plant: TXI OPERATIONS, L.P**  
**Kiln: MID-KILN FIRING, KILN 1**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton		\$ -
	Electricity	\$0.056 per kw-hr		\$ -
	Nat. gas	\$3.40 per 1000 cubic feet		\$ -
	Tires	\$ per ton		\$ -
<b>Utilities subtotal</b>				\$ -
Labor	Operating labor	12.47 per hour		\$ 30,400.00
	Supervising labor	15% of operating labor		\$ 4,560.00
Maintenance Labor	Maintenance labor	19.18 per hour	1095	\$ 21,002.10
	Maintenance materials	100% of maintenance labor		\$ 21,002.10
<b>Labor subtotal</b>				\$ 76,964.20
<b>Disposal Revenue</b>				\$ (510,000.00)
<b>Fuel Credit</b>				\$ (500,000.00)
<b>Total annual direct cost</b>				\$ (933,035.80)
<b>Total from capital cost worksheet</b>				\$ 3,227,619.18
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 46,178.52
	Property tax	1% of total capital cost		\$ 32,276.19
	Insurance	1% of total capital cost		\$ 32,276.19
	Admin. Charges	2% of total capital cost		\$ 64,552.38
<b>Total annual indirect costs</b>				\$ 175,283.29
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF x total capital		\$ 370,207.92
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				\$ (387,544.59)

Cost-Effectiveness (\$ per ton NOx reduced) High \$ (1,370)  
 Low \$ (650)  
 Cost Per Ton of Clinker \$ (1.03)

**ANNUAL COST WORKSHEET**

**Plant: TXI OPERATIONS, L.P**  
**Kiln: MID-KILN FIRING, KILN 3**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton		\$ -
	Electricity	\$0.056 per kw-hr		\$ -
	Nat. gas	\$3.40 per 1000 cubic feet		\$ -
	Tires	\$ per ton		\$ -
<b>Utilities subtotal</b>				\$ -
Labor	Operating labor	12.47 per hour		\$ 30,400.00
	Supervising labor	15% of operating labor		\$ 4,560.00
Maintenance Labor	Maintenance labor	19.18 per hour	1095	\$ 21,002.10
	Maintenance materials	100% of maintenance labor		\$ 21,002.10
<b>Labor subtotal</b>				\$ 76,964.20
<b>Disposal Revenue</b>				\$ (510,000.00)
<b>Fuel Credit</b>				\$ (500,000.00)
<b>Total annual direct cost</b>				\$ (933,035.80)
<b>Total from capital cost worksheet</b>				\$ 3,227,619.18
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 46,178.52
	Property tax	1% of total capital cost		\$ 32,276.19
	Insurance	1% of total capital cost		\$ 32,276.19
	Admin. Charges	2% of total capital cost		\$ 64,552.38
<b>Total annual indirect costs</b>				\$ 175,283.29
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF x total capital		\$ 370,207.92
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				\$ (387,544.59)

Cost-Effectiveness (\$ per ton NOx reduced) High \$ (3,685)  
 Low \$ (1,749)  
 Cost Per Ton of Clinker \$ (1.03)

**ANNUAL COST WORKSHEET**

**Plant: TXI OPERATIONS, L.P**  
**Kiln: MID-KILN FIRING, KILN 4**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton		\$ -
	Electricity	\$0.056 per kw-hr		\$ -
	Nat. gas	\$3.40 per 1000 cubic feet		\$ -
	Tires	\$ per ton		\$ -
<b>Utilities subtotal</b>				\$ -
Labor	Operating labor	12.47 per hour		\$ 30,400.00
	Supervising labor	15% of operating labor		\$ 4,560.00
Maintenance Labor	Maintenance labor	19.18 per hour	1095	\$ 21,002.10
	Maintenance materials	100% of maintenance labor		\$ 21,002.10
<b>Labor subtotal</b>				\$ 76,964.20
<b>Disposal Revenue</b>				\$ (510,000.00)
<b>Fuel Credit</b>				\$ (500,000.00)
<b>Total annual direct cost</b>				\$ (933,035.80)
<b>Total from capital cost worksheet</b>				\$ 3,227,619.18
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 46,178.52
	Property tax	1% of total capital cost		\$ 32,276.19
	Insurance	1% of total capital cost		\$ 32,276.19
	Admin. Charges	2% of total capital cost		\$ 64,552.38
<b>Total annual indirect costs</b>				\$ 175,283.29
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF x total capital		\$ 370,207.92
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				\$ (387,544.59)

Cost-Effectiveness (\$ per ton NOx reduced) High \$ (1,400)  
 Low \$ (665)  
 Cost Per Ton of Clinker \$ (1.03)

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: TXI Operations**  
**Kiln: Biosolids Injection, Kiln 5**

Purchased equipment cost, (Includes the control device, auxiliary equipment and instrumentation.)			\$ 240,000.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 108,000.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 79,200.00
Contingencies		Default is 20% of PEC	\$ 48,000.00
Sales tax		3% PEC	\$ 7,200.00
Freight		5% PEC	\$ 12,000.00
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 751,321.28
	Capital cost		\$ 1,245,721.28
	Annual cost assuming 15 year equipment life		\$ 83,048.09

Note: PEC Costs based on 1997 Cost Analysis from NOx Control Technologies for Cement Industry, Final Report, EC/R, September 19, 2000

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: Holcim Texas, LP**  
**Kiln: Biosolids Injection, Kiln 1**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$ 240,000.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 108,000.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 79,200.00
Contingencies		Default is 20% of PEC	\$ 48,000.00
Sales tax		3% PEC	\$ 7,200.00
Freight		5% PEC	\$ 12,000.00
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 493,156.10
	Capital cost		\$ 987,556.10
	Annual cost assuming 15 year equipment life		\$ 65,837.07

Note: PEC Costs based on 1997 Cost Analysis from NOx Control Technologies for Cement Industry, Final Report, EC/R, September 19, 2000

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: Holcim Texas, LP**  
**Kiln: Biosolids Injection, Kiln 2**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$ 240,000.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 108,000.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 79,200.00
Contingencies		Default is 20% of PEC	\$ 48,000.00
Sales tax		3% PEC	\$ 7,200.00
Freight		5% PEC	\$ 12,000.00
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 452,992.05
	Capital cost		\$ 947,392.05
	Annual cost assuming 15 year equipment life		\$ 63,159.47

Note: PEC Costs based on 1997 Cost Analysis from NOx Control Technologies for Cement Industry, Final Report, EC/R, September 19, 2000

**ANNUAL COST WORKSHEET**

Plant: TXI Operations, L.P  
Kiln: SNCR Kiln 5

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities*	Coal	23.47 per short ton	0	\$ -
	Electricity	\$0.056 per kw-hr	729033	\$ 40,825.87
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$ -
	Tires	\$ per ton	0	\$ -
<b>Utilities subtotal</b>				<b>\$ 40,825.87</b>
Labor	Operating labor	12.47 per hour	10200	\$ 127,194.00
	Supervising labor	15% of operating labor	2040	\$ 19,079.10
Maintenance Labor	Maintenance labor	19.18 per hour	0	\$ -
	Maintenance materials	100% of maintenance labor	Reagents (3483 t/yr)	\$ 835,856.00
<b>Labor subtotal</b>				<b>\$ 982,129.10</b>
<b>Total annual direct cost</b>				<b>\$ 1,022,954.97</b>
<b>Total from capital cost worksheet</b>				<b>\$ 3,948,966.28</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 589,277.46
	Property tax	1% of total capital cost		\$ 39,489.66
	Insurance	1% of total capital cost		\$ 39,489.66
	Admin. Charges	2% of total capital cost		\$ 78,979.33
<b>Total annual indirect costs</b>				<b>\$ 747,236.11</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 452,946.43
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 2,223,137.52</b>
Cost-Effectiveness (\$ per ton NOx reduced)				High \$ 12,196.95
				Low \$ 2,439.39
Cost Per Ton of Clinker				\$ 1.25

**ANNUAL COST WORKSHEET**

**Plant: Holcim Texas, L.P**  
**Kiln: SNCR Kiln 1**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton	0	\$ -
	Electricity	\$0.056 per kw-hr	729033	\$ 40,826
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$ -
	Tires	\$ per ton	0	\$ -
<b>Utilities subtotal</b>				<b>\$ 40,826</b>
Labor	Operating labor	12.47 per hour	10200	\$ 127,194
	Supervising labor	15% of operating labor	2040	\$ 19,079
Maintenance Labor	Maintenance labor	19.18 per hour	0	\$ -
	Maintenance materials	100% of maintenance labor	Reagents (3483 t/yr)	\$ 835,856
<b>Labor subtotal</b>				<b>\$ 982,129</b>
<b>Total annual direct cost</b>				<b>\$ 1,022,955</b>
<b>Total from capital cost worksheet</b>				<b>\$ 3,690,801</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 589,277
	Property tax	1% of total capital cost		\$ 36,908
	Insurance	1% of total capital cost		\$ 36,908
	Admin. Charges	2% of total capital cost		\$ 73,816
<b>Total annual indirect costs</b>				<b>\$ 736,910</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equip-ment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 423,335
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 2,183,199</b>
Cost-Effectiveness (\$ per ton NOx reduced)			High	\$ 11,432
			Low	\$ 2,286
Cost Per Ton of Clinker				\$ 1.87

**ANNUAL COST WORKSHEET**

**Plant: Holcim Texas, L.P**  
**Kiln: SNCR Kiln 2**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton	0	\$ -
	Electricity	\$0.056 per kw-hr	729033	\$ 40,826
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$ -
	Tires	\$ per ton	0	\$ -
<b>Utilities subtotal</b>				<b>\$ 40,826</b>
Labor	Operating labor	12.47 per hour	10200	\$ 127,194
	Supervising labor	15% of operating labor	2040	\$ 19,079
Maintenance Labor	Maintenance labor	19.18 per hour	0	\$ -
	Maintenance materials	100% of maintenance labor	Reagents (3483 t/yr)	\$ 835,856
<b>Labor subtotal</b>				<b>\$ 982,129</b>
<b>Total annual direct cost</b>				<b>\$ 1,022,955</b>
<b>Total from capital cost worksheet</b>				<b>\$ 3,650,637</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 589,277
	Property tax	1% of total capital cost		\$ 36,506
	Insurance	1% of total capital cost		\$ 36,506
	Admin. Charges	2% of total capital cost		\$ 73,013
<b>Total annual indirect costs</b>				<b>\$ 735,303</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 418,728
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 2,176,986</b>
Cost-Effectiveness (\$ per ton NOx reduced)		High	\$	9,611
		Low	\$	1,922
Cost Per Ton of Clinker			\$	2.03

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: Holcim Texas, L.P.**

**Kiln: SNCR Kiln 5**

Purchased equipment cost, (Includes the control device, auxiliary equipment and instrumentation.)			\$ 1,201,496.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 599,558.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 732,794.00
Contingencies		Default is 20% of PEC	\$ 532,941.00
Sales tax		3% PEC	\$ 35,688.00
Freight		5% PEC	\$ 95,168.00
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 751,321.28
	Capital cost		\$ 3,948,966.28
	Annual cost assuming 15 year equipment life		

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: Holcim Texas, L.P**  
**Kiln: SNCR Kiln 1**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$ 1,201,496.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 599,558.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 732,794.00
Contingencies		Default is 20% of PEC	\$ 532,941.00
Sales tax		3% PEC	\$ 35,688.00
Freight		5% PEC	\$ 95,168.00
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 493,156.10
	Capital cost		\$ 3,690,801.10
	Annual cost assuming 15 year equipment life		

Notes: Capital Cost from 2001 Submittal from Holcim to TCEQ

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: Holcim Texas, L.P.**  
**Kiln: SNCR Kiln 2**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$ 1,201,496.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 599,558.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 732,794.00
Contingencies		Default is 20% of PEC	\$ 532,941.00
Sales tax		3% PEC	\$ 35,688.00
Freight		5% PEC	\$ 95,168.00
Production downtime: assume 2 days lost production and a value of \$77 per ton of product		Production per day	\$ 452,992.05
	Capital cost		\$ 3,650,637.05
	Annual cost assuming 15 year equipment life		

**ANNUAL COST WORKSHEET**

Plant: TXI Operations, L.P  
 Kiln: SCR Kiln 5

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton	0	\$
	Electricity	\$0.056 per kw-hr		\$
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$
	Tires	\$ per ton	0	\$
<b>Utilities subtotal<sup>1</sup></b>				<b>\$1,400,000</b>
Labor	Operating labor	12.47 per hour	10200	\$127,194
	Supervising labor	15% of operating labor		\$19,079
Maintenance Labor	Maintenance labor	10 % of PEC		\$0
	Maintenance materials	100% of maintenance labor	Reagents and Catalysts	\$1,479,000
<b>Labor subtotal</b>				<b>\$1,625,273</b>
<b>Total annual direct cost</b>				<b>\$3,025,273</b>
<b>Total from capital cost worksheet</b>				<b>\$ 29,773,249</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 975,164
	Property tax	1% of total capital cost		\$ 297,732
	Insurance	1% of total capital cost		\$ 297,732
	Admin. Charges	2% of total capital cost		\$ 595,465
<b>Total annual indirect costs</b>				<b>\$ 2,166,094</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 3,414,992
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 8,606,359</b>

<sup>1</sup> Energy and fuel cost in 1992 Dollars from Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing, EPA, March 1994.

Cost-Effectiveness (\$ per ton NOx reduced)

High \$ 5,902

Low \$ 4,970

Cost Per Ton of Clinker

\$ 4.83

**ANNUAL COST WORKSHEET**

**Plant: Holcim Texas, L.P**  
**Kiln: SCR Kiln 1**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton	0	\$ -
	Electricity	\$0.056 per kw-hr		\$ -
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$ -
	Tires	\$ per ton	0	\$ -
<b>Utilities subtotal<sup>1</sup></b>				<b>\$ 1,400,000.00</b>
Labor	Operating labor	12.47 per hour	10200	\$ 127,194.00
	Supervising labor	15% of operating labor		\$ 19,079.10
Maintenance Labor	Maintenance labor	10 % of PEC		\$ 1,190,000.00
	Maintenance materials	100% of maintenance labor	Reagents and Catalysts	\$ 1,479,000.00
<b>Labor subtotal</b>				<b>\$ 2,815,273.10</b>
<b>Total annual direct cost</b>				<b>\$ 4,215,273.10</b>
<b>Total from capital cost worksheet</b>				<b>\$ 27,966,092.69</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 1,689,163.86
	Property tax	1% of total capital cost		\$ 279,660.93
	Insurance	1% of total capital cost		\$ 279,660.93
	Admin. Charges	2% of total capital cost		\$ 559,321.85
<b>Total annual indirect costs</b>				<b>\$ 2,807,807.57</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 3,207,710.83
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 10,230,791.50</b>

<sup>1</sup> Energy and fuel cost in 1992 Dollars from Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing, EPA, March 1994.

Cost-Effectiveness (\$ per ton NOx reduced)	High \$	6,696.60
	Low \$	5,639.24
Cost Per Ton of Clinker	\$	8.75

**ANNUAL COST WORKSHEET**

**Plant: Holcim Texas, L.P**  
**Kiln: SCR Kiln 2**

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton	0	\$ -
	Electricity	\$0.056 per kw-hr		
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$ -
	Tires	\$ per ton	0	\$ -
<b>Utilities subtotal<sup>1</sup></b>				<b>\$ 1,400,000</b>
Labor	Operating labor	12.47 per hour	10200	\$ 127,194
	supervising labor	15% of operating labor	2040	\$ 19,079
Maintenance Labor	Maintenance labor	19.18 per hour	0	\$ -
	Maintenance materials	100% of maintenance labor	Reagents and Catalysts	\$ 1,479,000
<b>Labor subtotal</b>				<b>\$ 1,625,273</b>
<b>Total annual direct cost</b>				<b>\$ 3,025,273</b>
<b>Total from capital cost worksheet</b>				<b>\$ 27,684,944</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 975,164
	Property tax	1% of total capital cost		\$ 276,849
	Insurance	1% of total capital cost		\$ 276,849
	Admin. Charges	2% of total capital cost		\$ 553,699
<b>Total annual indirect costs</b>				<b>\$ 2,082,562</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 3,175,463
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 8,283,298</b>

<sup>1</sup> Energy and fuel cost in 1992 Dollars from Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing, EPA, March 1994.

Cost-Effectiveness (\$ per ton NOx reduced)	High \$	4,571
	Low \$	3,849
Cost Per Ton of Clinker	\$	7.72

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: TXI Operations, L.P.  
Kiln: SCR Kiln 5**

Purchased equipment cost, (includes the control device, auxiliary equipment and instrumentation.)			\$ 11,900,000.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 5,355,000.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 3,927,000.00
Contingencies		Default is 20% of PEC	\$ 2,380,000.00
Sales tax		3% PEC	\$ 357,000.00
freight		5% PEC	\$ 595,000.00
Production downtime: assume 14 days lost production and a value of \$77 per ton of product		production per day	\$ 5,259,248.94
	<b>Capital cost</b>		<b>\$ 29,773,248.94</b>
	Annual cost assuming 15 year equipment life		

**CALCULATION SHEET FOR CAPITAL COST**

**Plant: Holcim Texas, L.P.**  
**Kiln: SCR Kiln 1**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$ 11,900,000.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 5,355,000.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 3,927,000.00
Contingencies		Default is 20% of PEC	\$ 2,380,000.00
Sales tax		3% PEC	\$ 357,000.00
Freight		5% PEC	\$ 595,000.00
Production downtime: assume 14 days lost production and a value of \$77 per ton of product		Production per day	\$ 3,452,092.69
	<b>Capital cost</b>		<b>\$ 27,966,092.69</b>
	Annual cost assuming 15 year equipment life		

Notes: REC Cost in 1992 Dollars from Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing, EPA, March 1994.

**CALCULATION SHEET FOR CAPITAL COST****Plant: Holcim Texas, L.P.****Kiln: SCR Kiln 2**

Purchased equipment cost, Includes the control device, auxiliary equipment and instrumentation.)			\$ 11,900,000.00
Direct installation costs (includes physical items needed to install new equipment such as foundations and supports, equipment handling, electrical, piping, ductwork and painting)		Default is 45% of PEC	\$ 5,355,000.00
Indirect installation costs (includes engineering, construction & field expenses, contractor fees, start-up, and performance testing)		Default is 33% of PEC	\$ 3,927,000.00
Contingencies		Default is 20% of PEC	\$ 2,380,000.00
Sales tax		3% PEC	\$ 357,000.00
Freight		5% PEC	\$ 595,000.00
Production downtime: assume 14 days lost production and a value of \$77 per ton of product		Production per day	\$ 3,170,944.38
	Capital cost		\$ 27,684,944.38
	Annual cost assuming 15 year equipment life		

Notes: REC Cost in 1992 Dollars from Alternative Control Techniques Document-NOx Emissions from Cement Manufacturing, EPA, March 1994.

**ANNUAL COST WORKSHEET**

Plant: Holcim Texas, L.P

Kiln: MSC-SNCR Kiln 1

Annual direct cost calculations		Multiplier	Change	Calculation
Utilities	Coal	23.47 per short ton	0	\$ -
	Electricity	\$0.056 per kw-hr	729033	\$ 40,826
	Nat. gas	\$3.40 per 1000 cubic feet	0	\$ -
	Tires	\$ per ton	0	\$ -
<b>Utilities subtotal</b>				<b>\$ 40,826</b>
Labor	Operating labor	12.47 per hour	10200	\$ 127,194
	Supervising labor	15% of operating labor	2040	\$ 19,079
Maintenance Labor	Maintenance labor	19.18 per hour	0	\$ -
	Maintenance materials	100% of maintenance labor	Reagents (3483 t/yr)	\$ 835,856
<b>Labor subtotal</b>				<b>\$ 982,129</b>
<b>Total annual direct cost</b>				<b>\$ 511,477</b>
<b>Total from capital cost worksheet</b>				<b>\$ 3,690,801</b>
<b>Annual indirect cost calculation</b>				
	Overhead	60% of all labor categories and materials		\$ 589,277
	Property tax	1% of total capital cost		\$ 36,908
	Insurance	1% of total capital cost		\$ 36,908
	Admin. Charges	2% of total capital cost		\$ 73,816
<b>Total annual indirect costs</b>				<b>\$ 736,910</b>
<b>Capital recovery calculation</b>				
	Capital recovery factor (CRF)	Assume 7.7% interest rate and a 15-year equipment life.		0.1147
	Annual capital cost	CRF = 0.1147 per dollar		\$ 423,335
<b>Total annual cost, TAC=DC+IC+capital recovery</b>				<b>\$ 1,671,722</b>
Cost-Effectiveness (\$ per ton NOx reduced)		High		\$ 8,754
		Low		\$ 1,751
Cost Per Ton of Clinker				\$ 1.43





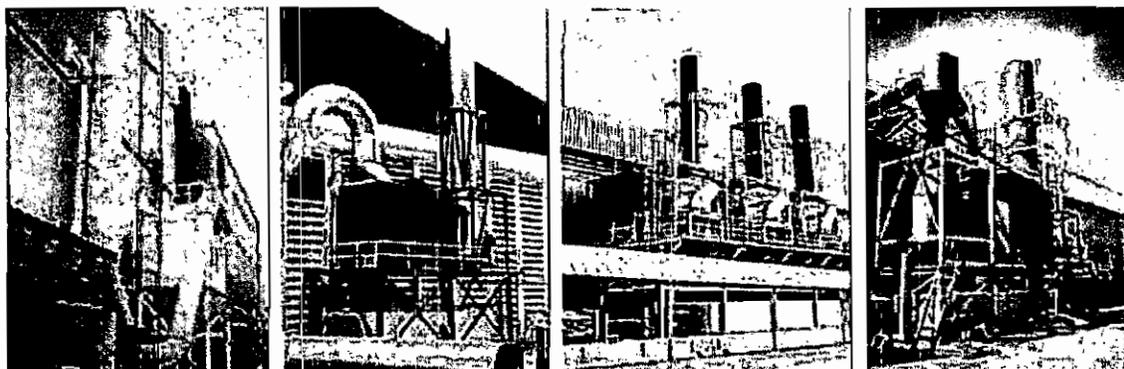
**Appendix G**

**Section 4 of the**  
**Assessment of Control Technology Options for BART-Eligible Sources,**  
**Northeast States for Coordinated Air Use Management In Partnership with**  
**The Mid-Atlantic/Northeast Visibility Union**



# Assessment of Control Technology Options for BART-Eligible Sources

Steam Electric Boilers, Industrial Boilers,  
Cement Plants and Paper and Pulp Facilities



Prepared by  
Northeast States for Coordinated Air Use Management  
In Partnership with  
The Mid-Atlantic/Northeast Visibility Union

March 2005



## 4. PORTLAND CEMENT KILNS

Portland cement is a main ingredient for concrete and other common building materials. Portland cement is mainly composed of clinker, a material formed by heating limestone and other ingredients to temperatures over 2,650°F. High combustion temperatures require significant amounts of fuel and can result in significant emissions of NO<sub>x</sub> and SO<sub>2</sub>. Crushing of ingredients and finished clinker can release dust and particles. Ammonia is sometimes produced during the heating of limestone.

The cement industry has seen significant growth in capacity and technology over the last 30 years. In 2000, the U.S. had 201 cement kilns with the annual capacity to produce 84 million metric tons of concrete, with production projected to grow to 109 million metric tons in 2004 (Portland Cement Association, 2000).

### 4.1. Description of Cement-Making Processes

Concrete is a combination of Portland cement, sand, and gravel. The key component of Portland cement is clinker, a material produced by heating limestone and other raw materials to temperatures over 2,650°F, requiring combustion temperatures of about 3,000°F. These high temperatures are normally achieved in a rotary kiln, as shown in Figure IV-1. Feed material is added at the elevated end of the rotating, refractory-lined, cylindrical kiln and the feed gradually tumbles to the high-temperature end of the kiln and the main combustion zone, sometimes referred to as the "Burn Zone." The tilted design of the cement kiln allows gravity to assist the motion of the clinker material while hot exhaust gases move upward and exit at the elevated end of the kiln.

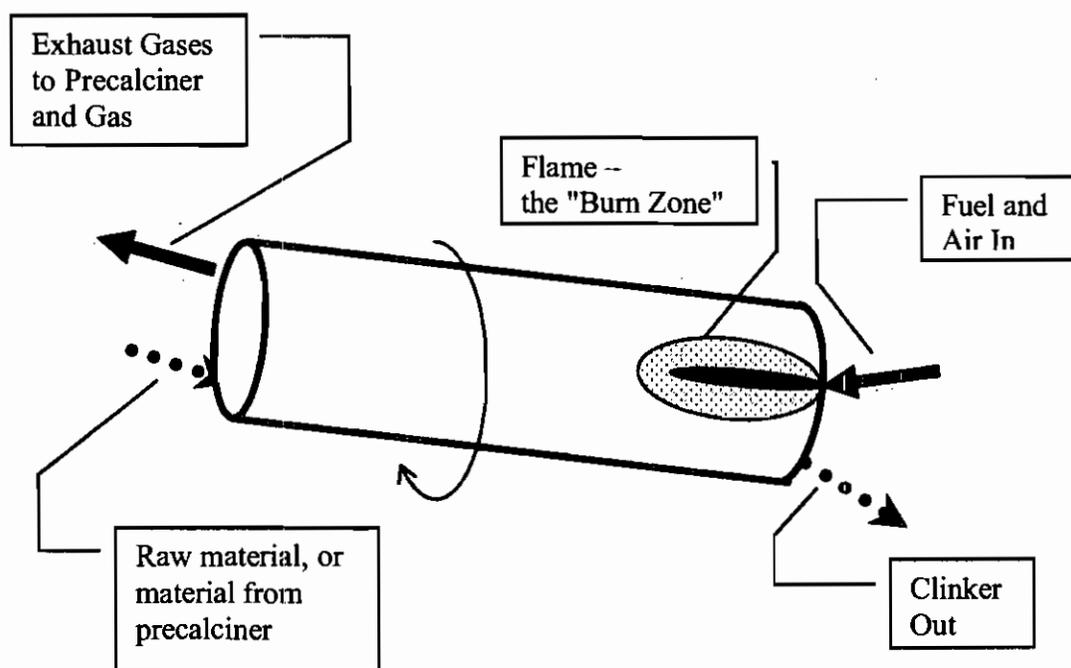


Figure IV-1. Simplified Sketch of a Rotary Kiln.

Cement kilns fall into four general process categories. Preheater kilns preheat and partially calcine feed material in a series of cyclones or grates prior to admitting the feed to the rotary kiln. This additional heat supplements the heat in the exhaust from the kiln. The calcined feed then enters the rotary kiln at about 1,500°F to 1,650°F. Precalciner kilns, on the other hand, utilize a burner in a separate vessel along with a series of cyclones or grates to preheat and calcine the feed. In long kiln systems, the raw feed material is added to the rotary kiln itself as either a powder (“dry”) or a slurry (“wet”). Long wet and long dry kilns do not have preheaters and have much longer rotary kilns, with wet process kilns being the longest - normally several hundred feet long. Preheater and precalciner kilns are more energy efficient than long wet or long dry kilns and typically have greater capacity. A preheater kiln is similar, but fuel is not added and there is no burner on the cyclonic preheater portion. Preheaters could also be replaced with suspension preheaters, but these are less common. If past trends continue, many of the existing long wet kilns and dry kilns are expected to be replaced with precalciner and preheater kilns since precalciner and preheater kilns are more energy efficient and also typically have greater capacity.

Coal is the fuel of choice in cement kilns, primarily because of its low cost, but also because the coal ash contributes somewhat to the product. The current fuel use in cement kilns is about 82% coal; 4% natural gas; and 14% other fuels, mainly combustible waste (industrial waste, tires, sewage sludge, etc.). Fuel nitrogen therefore contributes a small but significant amount to the total NO<sub>x</sub> for nearly all cement applications (see the section on NO<sub>x</sub> controls included later).

Recent years have seen Portland cement plant capacity stretched by high demand, making technologies that can increase capacity without increased capital expenditures very attractive. The industry is therefore developing technologies that improve facility’s outputs or reduce their operating costs. Incidentally, some of these technologies also offer the potential to reduce NO<sub>x</sub> and other emissions.

#### **4.2. Review of BART-Eligible Cement Kilns in the MANE-VU Region**

NESCAUM’s analysis of BART-eligible sources in the MANE-VU Region<sup>6</sup> (NESCAUM, 2004) identified two Portland cement facilities as being eligible for BART. The facilities are shown in Table IV-1. *[Editor’s note: Additional facilities are likely to be added when PA and NY inventories are complete]*

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<sup>6</sup> NESCAUM does not believe that there are any BART-eligible sources in the State of Vermont or any of the member Tribes in MANE-VU and thus we have not developed lists for these jurisdictions. In addition, Pennsylvania and the District of Columbia have developed BART-Eligible source lists following their own methodology and any identified sources are contained here and in the final list in Appendix A.

**Table IV-1 BART-Eligible Portland Cement facilities in MANE-VU Region**

Facility	Kiln type	Capacity, thousands tons/yr	Primary Fuel(s)
St. Lawrence Cement (Hagerstown, MD)	Dry	550	Coal
Dragon Products (Thomaston, ME)	Wet	392	Coal, petcoke

### 4.3. Available Control Technologies

A number of technologies exist for controlling emissions from cement kilns. Secondary (post-combustion) control devices can be helpful in reducing emissions, and a variety of these are available. Many technologies and techniques have been developed in response to a specific environmental need and target a specific pollutant, sometimes achieving reduction in other pollutants at the same time. Both secondary controls and process changes are discussed below, grouped by their targeted pollutant. When additional emissions reductions are possible, they are noted with the targeted pollutant. Controls are examined for SO<sub>2</sub>, NO<sub>x</sub>, PM, and VOCs.

#### 4.3.1. SO<sub>2</sub> Controls

In contrast with electric utility boilers, SO<sub>2</sub> emissions from rotary kilns producing cement clinker under oxidizing conditions are nearly independent of fuel sulfur input, but, rather, are closely related to the amount of sulfide (e.g. pyrite) in kiln feed and to the molar ratio of total sulfur to total alkali input to the system. In cement kilns SO<sub>2</sub> emissions generally depend on:

- Inherent SO<sub>2</sub> removal efficiency of kiln system,
- Form of sulfur (e.g. pyritic) and sulfur concentrations in raw material,
- Molecular ratio between sulfur and alkalis,
- Prevailing conditions (oxidizing or reducing) and their location within kiln, and
- Temperature profile in the kiln system.

Depending upon the level of sulfur in a plant's limestone compared to the sulfur content of its heating fuel, fuel switching may not be sufficient to reduce SO<sub>2</sub> emissions (Tanna and Schipholt, 2004). However, when fuel sulfur levels are high, fuel switching may have a significant benefit of reducing SO<sub>2</sub> levels.

In addition to the control techniques used in the electric utility boilers, cement plants may also resort to other basic reductions techniques involving reduction of sulfur input to the kiln, by switching fuels or changing the limestone, or reduction of SO<sub>2</sub> emissions from reducing both the sulfur in the sources and using a secondary control device. It is common to achieve some level of SO<sub>2</sub> reductions when seeking to reduce another pollutant, usually NO<sub>x</sub> (technologies targeting another pollutant, but also

reducing SO<sub>2</sub>, are described in the NO<sub>x</sub> and PM sections below). In addition to considering a change in the primary fuel for the kiln, staged combustion with mid-kiln injection of a low-sulfur fuel may be considered for reducing SO<sub>2</sub>. Including high-pressure air injection at a mid-kiln firing site can limit oxygen in the kiln and suppress SO<sub>2</sub> formation (Hansen, 2002). Since these techniques are primarily used to reduce NO<sub>x</sub>, more information about mid-kiln fuel injection can be found in the section on NO<sub>x</sub> emissions, but other specific SO<sub>2</sub> control technologies applicable to cement kilns are listed below.

### ***Fuel Switching***

Selecting a fuel with lower sulfur content, a strategy commonly adopted in the utility boilers, is less effective in cement-making systems, where SO<sub>2</sub> emissions are not strongly dependent on fuel sulfur content. Depending upon the level of sulfur in a plant's limestone compared to the sulfur content of its heating fuel, fuel switching may not be sufficient to reduce SO<sub>2</sub> emissions (Tanna and Schipholt, 2004). However, when fuel sulfur levels are high, fuel switching may have a significant benefit in SO<sub>2</sub> levels.

### ***Inherent Removal***

Raw materials, primarily limestone, are preheated in the cement-making process either in the preheater tower or in the rotary kiln. In either case, the limestone comes in contact with hot combustion exhaust gases. The calcium in the lime reacts with SO<sub>2</sub> in the gas, providing in-process removal of sulfur in the kiln system. Removal efficiencies in rotary kiln systems range between 38% and 99% of sulfur input, and 50% to 70% of the remaining SO<sub>2</sub> is removed from exhaust gases when passing through an in-line raw mill system (Miller et al., 2001).

### ***Process Alterations***

The following methods to remove and prevent formation of SO<sub>2</sub> by modifying or controlling conditions in the system are available due to the nature of the Portland cement manufacturing process:

- The oxygen concentration of the exhaust gases can be controlled to ensure sufficient oxygen exists to stabilize alkali and calcium sulfate compounds formed in the process. Concentrations of O<sub>2</sub> and, more importantly CO, have a strong influence on the stability of alkali and calcium sulfates in the burning zone. Control of burning-zone O<sub>2</sub> and CO concentrations is a widely used industrial practice, and a control technique applicable to all rotary kilns producing cement clinker. The downside of this technique is the more favorable conditions created for generation of NO<sub>x</sub> in the rotary kiln.
- Burning-zone flame shape can be modified to minimize localized reducing conditions. It has been observed (Hansen, 1986) that flame impingement in the hot zone had a major effect on SO<sub>2</sub> emissions from the kiln, even if total oxygen is sufficient to fully combust all fuel. Avoiding flame impingement in the burning zone minimizes SO<sub>2</sub> formation. Avoiding flame impingement on the clinker, a technique applicable to all rotary

kilns producing cement clinker, requires proper solid fuel preparation and proper flame shaping and control.

- Raw materials can be altered to affect the alkali/sulfur molar ratio. SO<sub>2</sub> concentrations in kiln exit gases vary with the molar ratio of alkali to sulfur; when alkalis are in excess of sulfur, SO<sub>2</sub> emissions are typically low, due to more sulfur being retained in clinker as alkali sulfates. Also, kiln feed containing carbon seems to directly cause SO<sub>2</sub> emissions. Changing raw materials may reduce SO<sub>2</sub> emissions. Substituting a raw material containing pyritic sulfur or organic sulfur with one containing lesser amounts of these compounds reduces SO<sub>2</sub> emissions. Replacement of raw materials, however, is often constrained by economic considerations, while alkali input increase may also be limited by cement product quality specifications on total alkali in cement.
- Alterations to system can influence SO<sub>2</sub> emissions. It has been found that an improved distribution of kiln feed may equalize temperatures in bottom stage cyclones and reduce SO<sub>2</sub> emission by as much as 20% (Miller, 2001).

## ***Scrubbers***

### ***Dry Reagent Injection***

Steuch and Johansen (1991) found that Ca (OH)<sub>2</sub> (hydrated lime) was the most effective scrubbing agent, particularly when added to the kiln feed and when the exhaust gases were near the dew point. Adding quicklime or hydrated lime into the upper preheater cyclones demonstrated up to 70% removal efficiency (Nielse, 1991).

Several dry reagent systems are available:

- The RMC Pacific process (Sheth, 1991) injects dry Ca(OH)<sub>2</sub>, and with different stoichiometric ratios (40:1 to 50:1), has obtained efficiencies ranging from 55% to 65%. SO<sub>2</sub> removal of 80% was obtained with injection into the roller mill.
- Krupp Polysius Polydesox process uses hydrated lime where SO<sub>2</sub> in the raw feed tends to form from pyrites and obtains removal efficiencies of up to 85% (Miller, 2001).
- De-SoX Cyclone, by Fuller Company (Miller, 2001), reduces SO<sub>2</sub> emissions in a precalciner kiln by removing a portion of the gases from the precalciner outlet to a cyclone, and from there to the Stage II cyclone where pyritic sulfur in kiln feed is decomposed into SO<sub>2</sub>. The feed (or “raw meal”), containing freshly produced lime, is discharged into the outlet duct of the second stage (this process is known as hot meal injection). Removal efficiencies of 5 to 30% are claimed.

### ***Lime/Limestone Spray Dryer Absorber***

Design stoichiometric ratios of calcium to sulfur for spray dryer systems in utility boilers are typically between 0.9 and 1.5, with most below 1.0. These SO<sub>2</sub> scrubbers are designed for removal efficiencies in excess of 80%.

SO<sub>2</sub> reacts with CaCO<sub>3</sub>, to form CaSO<sub>4</sub>, a reaction that becomes more complete as the temperature and the fineness of CaCO<sub>3</sub> increase. The presence of water vapor also increases conversion.

Most of the spray dryer type SO<sub>2</sub> control technologies in the cement industry are applied to preheater or preheater/precalciner kilns. Exhaust gases from long dry kilns are cooled by either spray water introduced into the feed end of the kiln or by dilution air-cooling after the gases leave the kiln. Adding a conditioning tower to replace water sprays or dilution air enables the alkaline slurry system to be used to reduce SO<sub>2</sub> emissions (the equivalent of a spray dryer). The range of temperatures for exit gases from long wet kilns does not allow the use of an alkaline slurry spray dryer type scrubber because the addition of the lime slurry may drop the exhaust gases temperature below the acid dew point, creating significant plugging and corrosion problems in the downstream Particulate Control Device (PCD), duct work, and induced draft (ID) fan.

#### **RMC Pacific's Alkaline Slurry Injection System (Sheth, 1991)**

RMC Pacific uses a hydrated lime, spray dryer absorber to reduce SO<sub>2</sub> emissions. The captured sulfur compounds are returned as a portion of the raw material feedstock to the roller mill, which results in no scrubber effluent or sludge disposal. When SO<sub>2</sub> emissions are high and preheater exit gas temperatures are low, sufficient lime slurry cannot be added to reduce SO<sub>2</sub> to acceptable levels. With different stoichiometric ratios (40:1 to 50:1), the process has obtained efficiencies ranging from 55% to 65%. SO<sub>2</sub> removal of 80% was obtained with injection into the roller mill.

#### **EnviroCare Microfine Lime System (Miller, 2001)**

This system uses the existing gas conditioning tower to introduce the scrubbing reagent (water suspension of finely pulverized calcium hydroxide, Ca(OH)<sub>2</sub>). The small size of the lime particles (3-10 microns) allows the particles to dissolve in water droplets quickly and react with SO<sub>2</sub> as it is absorbed into the water droplet. The dried lime continues to react with any remaining SO<sub>2</sub> in the downstream kiln system and PCD. Lime injection rate can be optimized through a feedback control loop from an SO<sub>2</sub> monitor. EnviroCare claims an SO<sub>2</sub> removal efficiency of greater than 90%.

#### ***Wet SO<sub>2</sub> Scrubbers***

Wet scrubbers have been used successfully in the utility industry. Calcium sulfate scaling and cementitious buildup when a wet scrubber is used for acid gas control applied to the exhaust gas from a cement kiln can be avoided if these systems are installed downstream of a high efficiency PCD (e.g., fabric filter). Failure of the PCD can pose difficult problems for a downstream wet scrubber.

**Fuller Company (FLS Miljø) (Miller, 2001)**

The Monsanto Dyna Wave wet SO<sub>2</sub> scrubber has been installed by the Fuller Company and used on several cement kilns in the U.S. This wet scrubber is designed to remove SO<sub>2</sub>, halide gases, and some particulate matter.

The scrubber, typically located downstream from the kiln PCD and operated under positive pressure, uses limestone as the absorbent. A slurry (approximately 20% limestone and 80% water) produced in the mixing tank is sprayed countercurrent to the gas flow to cool the gases and react with SO<sub>2</sub> forming calcium sulfite (CaSO<sub>3</sub>) and calcium sulfate (CaSO<sub>4</sub>), which precipitates. Air is sparged into the sump at the bottom of the tower to oxidize CaSO<sub>3</sub> to CaSO<sub>4</sub>+2H<sub>2</sub>O (gypsum).

**Monsanto EnviroChem DynaWave (Miller, 2001)**

DynaWave is a "Reverse Jet" scrubber that can simultaneously accomplish several gas cleaning/process needs: hot gas quenching, particulate removal, and acid gas absorption. The reverse jet is an annular orifice scrubber having one to three large-bore nozzles through which a relatively large volume of scrubbing liquid is injected counter to the gas flow to create a froth zone. The gas collides with the liquid, forcing the liquid radially outward toward the wall. A standing wave, created at the point the liquid is reversed by the gas, is an extremely turbulent region where the gas absorption and particulate collection occurs.

The system is a tailpipe system generally installed downstream of the PCD, and operates with a saturated gas stream. Therefore, it would likely be applicable to most if not all the cement kilns. A single-stage DynaWave scrubber in full-scale operation has a reported SO<sub>2</sub> removal efficiency of about 90%. Monsanto EnviroChem claims that multiple units may be installed in series to achieve whatever removal efficiency is required (e.g., 99.9%).

**4.3.2. NO<sub>x</sub> Controls**

The following sections discuss the formation of NO<sub>x</sub> in cement kilns, potential NO<sub>x</sub> control techniques, NO<sub>x</sub> control in the cement industry, and the cost effectiveness of applicable controls.

***NO<sub>x</sub> Formation in Kiln Systems***

Nitrogen oxides (NO<sub>x</sub>) are formed during the combustion of fuels in the cement-making process. In kiln exhaust gases, more than 90% of NO<sub>x</sub> is NO, with NO<sub>2</sub> generally making up the remainder from rotary kilns producing cement clinkers (Gardeik, 1984). There are three different NO<sub>x</sub> formation mechanisms - thermal, fuel, and feed NO<sub>x</sub> - typically contributing to NO<sub>x</sub> emissions.

### *Thermal NO<sub>x</sub>*

Thermal NO<sub>x</sub> is formed by oxidation of atmospheric molecular nitrogen at high temperatures (>1,200 °C). Most NO<sub>x</sub> formed in the high-temperature environment of the main combustion zone (burning zone) of a kiln is "thermal NO<sub>x</sub>". Since the flame temperature in a kiln is significantly above that threshold, a considerable amount of thermal NO is generated in the burning zone.

While conditions in the burning zone of a cement kiln favor formation of thermal NO<sub>x</sub>, those prevalent in secondary combustion zones (e.g. calciners, preheater riser ducts and mid-kiln firing in long wet or dry kilns) with temperatures below 1200°C, are less conducive to significant thermal NO<sub>x</sub> formation. In that zone, formation of fuel NO<sub>x</sub> and feed NO<sub>x</sub> is more prevalent.

The amount of thermal NO<sub>x</sub> produced is related to fuel type, burning zone temperature, and oxygen content. Therefore, raw materials that are hard to burn (i.e., materials that require more heat input per ton of clinker produced) generate more NO<sub>x</sub>.

### *Fuel NO<sub>x</sub>*

Fuel NO<sub>x</sub> is the result of oxidation of nitrogen compounds in fuel. Fuel nitrogen is only partially converted into NO<sub>x</sub> during combustion. The amount formed depends on fuel type, precalciner type and precalciner temperature. NO<sub>x</sub> formed in the secondary combustion zone, primarily fuel NO<sub>x</sub> (Gardeik, 1984), depends on:

- Nitrogen concentration in the fuel,
- Oxygen concentration in the combustion zone,
- Initial NO concentration in the combustion gas,
- Volatile concentration in the (solid) fuel, and
- Temperature in the secondary combustion zone.

As opposed to the burning zone of the kiln, where higher temperatures result in much higher NO<sub>x</sub> formation, higher temperatures (up to 1100°C) in the precalciner may actually reduce NO<sub>x</sub> emissions when a fuel containing nitrogen is used (Nielsen, 1990).

In the design of modern low-NO<sub>x</sub> calciners, high temperatures and reducing conditions are proven methods for suppressing the formation of fuel NO<sub>x</sub> generated in the precalciner, and for destroying thermal NO<sub>x</sub> generated in the burning zone of the rotary kiln (Keefe and Shenk, 2002).

### *Feed NO<sub>x</sub>*

NO<sub>x</sub> emissions can also result from the oxidation of nitrogen compounds in the raw material feed to the kiln (feed NO<sub>x</sub>). The range of nitrogen concentrations in various

kiln feeds is 20-1000 ppm (Gartner, 1983) and the potential contribution of feed  $\text{NO}_x$  to total  $\text{NO}_x$  emissions is 0.2-10 lbs of  $\text{NO}_x$  per ton of clinker.

Up to 50% of feed nitrogen may be converted to  $\text{NO}_x$ , if raw materials are heated slowly: with rapid heating, the conversion rate is much lower.

The following conclusions can be made for rotary kiln systems (Young and von Seebach, 1999):

- Formation of thermal  $\text{NO}_x$  in the burning zone is the major contributor to  $\text{NO}_x$  emissions from the kiln
- Fuel  $\text{NO}_x$  is the major contributor in the secondary combustion zone of precalciner and riser duct fired preheater kilns
- Feed  $\text{NO}_x$  is usually a minor contributor to the total  $\text{NO}_x$  generated in rotary kiln systems.

It should be further noted that, due to the dynamic nature of kiln operations,  $\text{NO}_x$  formation can be highly variable so each kiln will tend to have unique  $\text{NO}_x$  emission characteristics, inherent to the variability in cement manufacturing process. Figure IV-2 illustrates the wide range of  $\text{NO}_x$  emissions from different types of kilns.

$\text{NO}_x$  emissions rates are also site- and kiln-specific, and may be quite dissimilar between two apparently identical kilns, for causes not fully understood, but, probably connected to the raw materials used. Other causes for  $\text{NO}_x$  emissions rate differences may result from different types or classes of cement products being produced; chemical variations between these different products can influence cement kiln operating parameters and thus  $\text{NO}_x$  emissions. Short-term process transients such as kiln feed rates and fuel quality also affect  $\text{NO}_x$  emissions. All of these factors can influence the applicability and costs of incorporating  $\text{NO}_x$  controls.

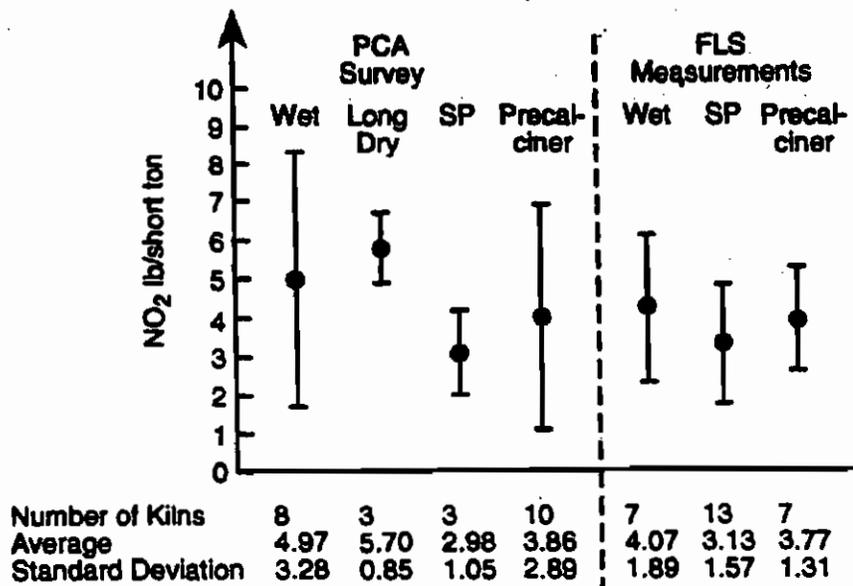


Figure IV-2. NO<sub>x</sub> emissions for various cement kiln types (USEPA, 1994). (SP: Suspension Preheater kilns)

### NO<sub>x</sub> Control Techniques

There are two broad categories of NO<sub>x</sub> reduction techniques for cement kilns: 1) process controls, including combustion modifications, that rely on reducing or inhibiting the formation of NO<sub>x</sub> in the manufacturing process (modifications for cement kilns include low-NO<sub>x</sub> Burners (LNB), secondary combustion, and staged combustion); and 2) post-combustion (secondary) controls, where flue gases are treated to remove NO<sub>x</sub> that has already been formed.

It should be noted that the quality of clinker produced in a kiln varies with characteristics of the combustion, so primary controls need to be selected carefully. Dry low-NO<sub>x</sub> (DLN) operation, for example, has seen varied levels of success. The main firing zone of the kiln requires very high temperatures and is not compatible with the lower flame temperature used by DLN to reduce NO<sub>x</sub>. Low excess air and air-staging are problematic control options for kilns because the kilns need an oxidizing environment not provided by those techniques. Despite these problems, indirect firing in combination with a LNB has been successfully used in some facilities, including California Portland Cement. Low-NO<sub>x</sub> combustion methods can be used in the precalciner because high temperatures are not required in that part of the process.

Indirect firing is a method that permits use of LNBs in the primary kiln burning zone. When indirect firing is used, pulverized coal is fed to and collected in a particulate matter collection system (a cyclone separator that exhausts gas through a fabric filter).

The pulverized coal is then temporarily stored in a bin or hopper, where it is fed to the burner. This method allows less primary air to be used in the burner than with a direct-fired coal mill, resulting in less thermal NO<sub>x</sub>.

LNBs can be used when indirect firing is employed. When implementing indirect firing with LNBs, other process improvements are often implemented, such as better process controls. According to Portland Cement Association (1998), 20%-30% NO<sub>x</sub> reductions can be achieved from the use of indirect firing with LNBs and associated process modifications.

Combustion modifications are less successful at reducing NO<sub>x</sub> emissions in thermal processing applications (like cement kilns) than in boilers for steam and/or power production. Chemical reactions producing cement clinker require high material and gas temperatures, and product quality also requires an oxidizing atmosphere in the combustion zone of a cement kiln. Excessively high temperatures in the burning zone pose equipment damage risk, while temperatures too low will no longer produce a salable product.

NO<sub>x</sub> emissions can also be affected by kiln feed chemical characteristics, feed chemical uniformity, and specific fuel consumption. As stated by EPA's NO<sub>x</sub> Alternative Control Technique Document for the Cement Manufacturing Industry (USEPA, 1994), "For any given type of kiln, the amount of NO<sub>x</sub> formed is directly related to the amount of energy consumed in the cement-making process. Thus, measures that improve the energy efficiency of this process should reduce NO<sub>x</sub> emissions in terms of lb of NO<sub>x</sub> / ton of product."

Following are some of the more common process modifications that have been made to reduce NO<sub>x</sub> emissions from cement kilns (NESCAUM, 2001):

- Changing fuel (e.g. natural gas to coal firing).
- Improving kiln feed chemical uniformity, for more stable kiln operations:
  - Modifications to quarry operations,
  - Raw material blending facilities, and
  - On-line analytical control systems for raw material proportioning (e.g. kiln feed blending systems).
- Modifications to improve thermal efficiency, including:
  - Reducing excess air infiltration,
  - Increasing efficiency of cyclones in preheater kilns,
  - Reducing the amount of moisture in slurry (wet process kilns only),
  - Revising kiln chain systems in long wet or long dry kilns,
  - Modifying or replacing clinker coolers to improve heat recovery and cooler efficiency,
  - Initiating operator training programs, and

- Returning as much cement kiln dust (CKD) as possible to the kiln system (without adversely affecting product quality).
  - Installing or upgrading kiln system sensors and instrumentation.
  - Installing or upgrading computer controls of kiln systems to stabilize kiln operation and avoid burning zone temperature variations.
- According to Young and von Seebach (1999), industry data and experience show that control of burning zone temperature is the primary process control method applicable to lowering thermal NO<sub>x</sub> formation. Process modifications that allow better control of the kiln burning zone temperature will result in reducing thermal NO<sub>x</sub> formation and minimizing NO<sub>x</sub> spikes. Stable kiln operation, through feed chemical uniformity, results in overall NO<sub>x</sub> reductions of 10% - 15%, while poor kiln feed chemical uniformity results in overfiring the kiln, and higher NO<sub>x</sub> emissions.

### *Fuel Switching*

Switching to a lower-nitrogen fuel in a precalciner may reduce NO<sub>x</sub> emissions, but the nitrogen content of the fuel burned in the burning zone has little or no effect on NO<sub>x</sub> generation. Generally, no relationship has been found between fuel nitrogen content and the NO<sub>x</sub> emissions from a cement kiln (Miller and Egelov, 1980).

### *Process Optimization and Automated Control*

Process optimization is a common method for reducing NO<sub>x</sub> emissions from cement kilns. In principle, any effort that reduces the amount of fuel being fired to produce clinker will result in a reduction in NO<sub>x</sub> generation. In practice, process optimization often entails the use of advanced computer controls and instrumentation. Many of the primary NO<sub>x</sub> control technologies described are implemented along with process optimization to take advantage of their combined effects and to improve overall facility operation. NO<sub>x</sub> reductions reported in this Chapter are generally attributed to the changed combustion process (for example, mid-kiln firing). Combined reductions reported in a case study (NESCAUM, 2001) equivalent to 55% reduction in average NO<sub>x</sub> emissions - from 845 lb/hr to 383 lb/hr - were achieved largely by reducing the variability of the process with a computer-automated optimization system. Mid-kiln firing provided additional NO<sub>x</sub> reduction for an overall NO<sub>x</sub> emission reduction of 59% from controls.

### *Flue Gas Recirculation*

Flue gas recirculation (FGR) or water/steam injection into the main flame to reduce flame temperatures and NO<sub>x</sub> formation is not a viable method of reducing NO<sub>x</sub> in a cement kiln burning zone. FGR's effectiveness relies on cooling the flame and generating an oxygen deficient (reducing) atmosphere for combustion to reduce NO<sub>x</sub> formation, conditions that are not compatible with cement kiln operation. High flame

temperature and an oxidizing atmosphere are process requirements to produce a quality clinker product.

### *Indirect Firing*

Conversion from a direct coal firing system to an indirect firing system kiln with a low NO<sub>x</sub> burner may result in NO<sub>x</sub> reductions ranging from 0% to about 20% (Kupper et al., 1990; Schrsemli, 1990). Incorrect use of multi-channel (low NO<sub>x</sub>) burners can increase NO<sub>x</sub> rather than reduce NO<sub>x</sub>, and it has been found (Hansen, 1985) that less excess air in the kiln combustion gases results in less NO formation at the same burning zone temperature. NO<sub>x</sub> reductions of 15% were reported.

### *Low-NO<sub>x</sub> Burners*

LNBS have been successfully used in the primary burn zone and especially in the precalciner kilns.

Secondary combustion zones have proven effective at reducing NO<sub>x</sub> emissions in cement kilns. In long kilns, secondary combustion can be partly accomplished by mid-kiln injection of fuel (less than 20% of kiln fuel). NO<sub>x</sub> emissions are reduced because less fuel is burned in the high temperature environment of the burning zone. Another NO<sub>x</sub> reducing technique is the use of fuel in the riser duct of preheater kilns, although, because of high prevailing temperatures, such reductions do not always occur. With precalciner kilns, which employ a secondary combustion zone at a much lower temperature than the burning zone, typically 60% of the fuel is burned in the precalciner, with the combustion air coming directly from the clinker cooler, and NO<sub>x</sub> emissions for these kilns are less than from long wet, long dry, or preheater kiln systems because 60% of the total fuel requirement is burned under lower temperature conditions where negligible amounts of thermal NO<sub>x</sub> are formed. Furthermore, precalciner kilns have the potential for staged combustion as a NO<sub>x</sub> control technique. All major equipment suppliers offer "low-NO<sub>x</sub>" precalciner designs. Fuel burned in a sub-stoichiometric O<sub>2</sub> environment creates a strongly reducing atmosphere (relatively high concentrations of CO) that inhibits formation of fuel NO<sub>x</sub> and destroys a portion of the NO<sub>x</sub> formed in the kiln burning zone. Additional tertiary combustion air is added later to complete combustion of the fuel.

Staged combustion has become a well-known method for reducing NO<sub>x</sub> emissions from cement plants, but as NO<sub>x</sub> and CO emissions limits become more stringent, control via fuel and air staging are coming under reconsideration. Low- NO<sub>x</sub> calciners combine high temperature combustion and firing under reducing conditions without staging fuel/air.

### *Low-NO<sub>x</sub> Precalciners*

Precalciner kilns can employ LNBS because the temperature in the precalciner can be low enough to reduce thermal NO<sub>x</sub> but still be effective in heating the limestone.

Since roughly 60% of the fuel burned in a precalciner kiln is fired in the precalciner, NO<sub>x</sub> reductions can be substantial. All new precalciner kilns are equipped with low-NO<sub>x</sub> burners in the precalciner. Low-NO<sub>x</sub> precalciners have been shown to reduce NO<sub>x</sub> by 30%-40% compared to conventional precalciners (Young and von Seebach, 1998). This reduction is from the precalciner-generated NO<sub>x</sub>, not for the entire kiln.

Several precalciner kilns in the U.S. have recently been retrofitted with these "two-NO<sub>x</sub>" calciners, and several new kiln lines have been installed using low-NO<sub>x</sub> precalciner technology. Operating experience indicates a noticeable reduction in NO<sub>x</sub> per ton of clinker. Industry reports place the NO<sub>x</sub> reduction potential of staged combustion with a low-NO<sub>x</sub> precalciner at 30% - 40% when compared to a conventional precalciner kiln system.

Low-NO<sub>x</sub> precalciner is a proven way to reduce NO<sub>x</sub> emissions in a cement-making system, and all new cement-making systems are expected to be built with it. They come in two types, "in-line", commonly used with "normal" fuels (e.g. coal, oil, gas), or "separate-line", selected for difficult-to-burn fuels (e.g. petroleum coke and anthracite) because its high oxygen atmosphere ensures improved fuel burnout. In-line calciners have lower specific NO<sub>x</sub> emissions than separate-line ones, but both are capable of meeting current CO/NO<sub>x</sub> emission standards for any combination of fuel and feed, and both are dependent on the presence of strong reduction and oxidation zones.

### *CemStar*

Another approach that has been proven effective in reducing NO<sub>x</sub> is the patented CemStar process, originally developed and sold as a method to increase production of clinker from existing kilns while minimizing capital expenditures (Young, 1995; Young, 1996). In the CemStar process, steel or blast furnace slag is introduced as feed material into the kiln. The slag is generally added at the inlet to the rotary kiln (typically after the precalciner or preheater), regardless of kiln type. Unlike normal cement materials, which require significant processing to achieve adequate grain size, the slag need only be crushed to 3/4 to 1-1/2 inch pieces. Minimal processing is necessary because the slag has a low melting temperature and its chemical nature is very similar to the desired clinker. Minimal slag processing permits the equipment for the CemStar to be inexpensive and also reduces energy consumption per unit of clinker produced. Moreover, the CemStar process can be implemented on a kiln quickly with minimal impact to facility operations. The equipment needed is mostly material handling equipment.

The CemStar approach has many advantages: energy input can be reduced, NO<sub>x</sub> emissions (both lbs/hr and lbs/ton of clinker) can be reduced, and kiln capacity can be increased. Since the steel slag more closely resembles the desired kiln product than do the normal raw materials, kilns with CemStar require less intense firing and allow for a significant reduction of peak burn-zone temperature. The lower burn zone temperature results in less thermal NO<sub>x</sub> generation. NO<sub>x</sub> reduction may be expected to be in the range of 20% or more for most kilns. If initial, uncontrolled NO<sub>x</sub> is high due to thermal NO<sub>x</sub>, CemStar is likely to provide reductions on the order of 40%-50%. Results of controlled testing of CemStar with baseline conditions resulted in 20% reduction in NO<sub>x</sub>.

corresponding with a reduction in average burn-zone temperature of over 200°F. Kiln capacity is increased because each ton of steel slag added to the kiln results in about a ton of additional production, though the precise amount of additional kiln production is dependent on the mineral characteristics of the local raw material. This capacity increase is the reason that many facility owners may initially choose to use CemStar.

TXI, the developer of CemStar, reports that more than 10 plants are currently equipped with the technology. NESCAUM (2001) discusses one application of CemStar on a long-wet process kiln.

### *Mid-Kiln Firing*

Mid-kiln firing entails injecting a fuel, usually tires, mid-way through long dry and long wet kilns. This method has been shown to reduce NO<sub>x</sub> by about 30% with mid-kiln heat input comprising about 20% of the total heat input (Portland Cement Association, 1998). Results of tests of mid-kiln firing on several kilns are summarized in Table 2 (NESCAUM,2001). The average NO<sub>x</sub> reduction for these kilns is about 27%. Mid-kiln firing reduces the heat needed, and therefore the thermal NO<sub>x</sub> produced in the primary burn zone. Fuel NO<sub>x</sub> will also be reduced because tires and other mid-kiln fuels have low nitrogen contents. Nitrogen content in tires is roughly one fifth that of coal on a mass basis, while heating value on a mass basis is similar (Schrama et al., 1995; Stillwater and Wahlquist, 1998). Coal can be used as a mid-kiln firing fuel, but tires are preferable because they provide a revenue source when kiln operators are paid a tipping fee for taking whole tires. Other revenue-generating fuels could potentially be used as well.

**Table IV-2 NO<sub>x</sub> Reduction at Cement Kilns Using Mid-Kiln Technology (NESCAUM,2001)**

Initial NO <sub>x</sub> (ppm)	936	1372	1342	1359	565	513
Final NO <sub>x</sub> (ppm)	790	994	600	883	488	456
% Reduction	16%	28%	55%	35%	14%	11%

High-pressure air injection, mentioned in the previous section as a potential control for SO<sub>2</sub> emissions, was primarily developed as a NO<sub>x</sub> reduction strategy (Hansen, 2002). The technique was designed for use with staged fuel combustion (mid-kiln firing) and mixing air. Mid-kiln firing with mixing air creates stratified thermal layers in the kiln, preventing immediate combustion of the mid-kiln fuel and lowering exit oxygen levels enough that additional CO is produced. Injecting high-pressure air into the kiln provides energy to mix the layers, lowering the main flame temperature and creating a reducing area between the fuel and air injection points, which encourages the destruction of NO<sub>x</sub>. The technique has been shown to reduce NO<sub>x</sub> by about 50%, while also reducing CO by 47% and SO<sub>2</sub> by 97%.

### *Biosolids Injection*

Biosolids Injection (BSI) is a technology that was developed in the 1990's by the cement industry for NO<sub>x</sub> reduction in precalciner and preheater kilns (Biggs, 1995). BSI adds dewatered sewage sludge to the mixing chamber of the precalciner. The dewatered biosolids provide a source of ammonia, producing an SNCR reaction to reduce NO<sub>x</sub>. At a Mitsubishi Cement Kiln in California, BSI provided about 50% reduction in NO<sub>x</sub> from about 250 ppm (at 12% oxygen) to 120-125 ppm (at 12% oxygen). BSI has the additional benefit of offering a potential revenue stream because many communities are willing to pay a tipping fee for accepting biosolids. BSI technology may require significant capital equipment expenditures, however. The material handling equipment needed and the moisture in the dewatered biosolids is sufficient to strain the capacity of the fans of many existing facilities. It appears that biosolids injection may be an effective approach for NO<sub>x</sub> reduction, but it will depend on the specifics of the kiln.

### *Selective Non-catalytic Reduction*

Selective Non-catalytic Reduction (SNCR) of NO<sub>x</sub> is based on the injection of a reagent, typically NH<sub>3</sub> or urea, into the kiln system at a location with an appropriate temperature window 1140 – 2010°F (870 - 1100°C). Some researchers have found that the most effective temperature range is narrower, about 1650 – 2000°F (900 - 1000°C). Temperature is critical because no catalyst is used. At temperatures too high, the reagents will form additional NO<sub>x</sub>, and, at low temperatures, the reactions proceed slowly and promote the escape of substantial amounts of unreacted ammonia. Under optimum conditions about one mole of NH<sub>3</sub> is required to reduce one mole of NO<sub>x</sub>, but the amount of NH<sub>3</sub> is always critically dependent on the reaction temperature. Ammonia slip, which increases rapidly when the molar ratio of NH<sub>3</sub> to NO is above one, causes a detached plume and can increase opacity of the stack gases.

Preheater and precalciner kilns operate with kiln gas exit temperatures in the appropriate temperature range. SNCR systems have been used on some preheater kilns in Europe. For wet and long dry kilns, these temperatures exist midway through the kiln. Access to this area is possible only through ports in the kiln shell as used in mid-kiln firing or with scoops used to return cement kiln dust. Ammonia must be added continuously in a fixed molar ratio to NO<sub>x</sub> in order to be effective and to minimize ammonia slip. Therefore, SNCR is not technically feasible at this time on long wet process or long dry process kilns.

SNCR has been tested in the U.S. on precalciner kilns and is planned for commercial use in other countries (Steuch et al., 1994; Sun et al., 1994). Experience is limited to only a few units worldwide, but some tests have reported significant reductions. Table 3 lists commercial installations of urea SNCR on precalciner kilns and the results of some demonstration programs. Effective operation of SNCR requires availability of a section of kiln with the proper temperature and residence time characteristics for good reduction. The specifics of the installation will determine the level of reduction that is possible. It is unlikely that SNCR can be used effectively on many long kilns (wet or dry) because of the need for access to the proper temperature

region for injecting urea or ammonia reagent. However on some precalciner kilns the access to the proper temperature zone is good.

Although SNCR technology has the potential to offer significant reductions on some precalciner kilns and it is being used in numerous cement kilns in Europe, it has been tested in only one facility in the U.S.

**Table IV-3 NO<sub>x</sub> Reduction Performance of Urea SNCR on Precalciner Cement Kilns (NESCAUM, 2001)**

Company / Location	Unit Type	Size (MMBtu/hr)	NO <sub>x</sub> Baseline	Reduction (%)	NH <sub>3</sub> SLIP, (ppm)
Ash Grove Cement Seattle, WA (Demo)	Cement Kiln/ Precalciner	160 tons solids/hr	350-600 lb/hr	>80	< 10
Korean Cement Dong Yang Cement, Korea (Demo)	New Suspension Precalciner	na	1.27 lb/MMBtu	45	na
Taiwan Cement Units #3, #5, & #6	Cement Kiln/ Precalciner	260 697 658	1.29 lb/MMBtu 1.58 lb/MMBtu 0.92 lb/MMBtu	50 45 25	15 15 15
Wulfrath Cement Germany (Demo)	Cement Kiln	140	1000 mg/Nm <sup>3</sup> 500 ppm	90	na

### *Selective Catalytic Reduction*

Selective Catalytic Reduction (SCR) uses ammonia, in the presence of a catalyst (e.g. titanium dioxide; vanadium pentoxide), to selectively reduce NO<sub>x</sub> emissions from exhaust gases. SCR has been extensively and quite successfully used in a very cost effective manner on coal- and gas-fired utility boilers, industrial boilers, gas turbines and internal combustion diesel engines in the U.S. Typically, anhydrous ammonia, usually diluted with air or steam is injected into hot flue gases, which then pass through a catalyst bed where NO<sub>x</sub> is reduced to N<sub>2</sub> gas and water. The optimum temperature for SCR depends on the catalyst but is usually between 570 and 840°F (300 and 450°C).

Exit gas temperatures from dust collectors on wet kilns, for long dry kilns, and for dust collectors in preheater kilns that use in-line raw mills for grinding and drying raw materials are relatively low and flue gases would have to be reheated before employing SCR. This technology so far has not been applied to the cement kilns but is being

evaluated by some of the state air permitting agencies as Best Available Control Technology (BACT) for some of the new cement kilns being proposed in the U.S.

### *Combination of Technologies*

It is not uncommon to combine combustion technologies with post-combustion technologies for other source types, and this could be done for cement kilns in some cases. It is also possible to combine multiple combustion technologies on cement kilns. For example, one of the case studies in *Status Report on NO<sub>x</sub> Controls for Gas Turbines, Cement Kilns, Industrial Boilers, Internal Combustion Engines; Technologies and Cost Effectiveness* (NESCAUM, 2001) combines indirect firing and mid-kiln firing to reduce NO<sub>x</sub> by a combined amount approaching 50%. It is also reasonable to expect that technologies such as CemStar might be combined with a combustion technology such as mid-kiln firing to provide combined benefits, and it may be feasible to use SNCR or SCR in combination with other controls for cement kilns. The exact amount of reduction will depend upon the regulatory requirements and technical limitations. In some cases the NO<sub>x</sub> reductions may not be additive.

### **4.3.3. PM<sub>2.5</sub> Controls**

The particulate matter exiting the kiln system with the exhaust gases is relatively coarse, with most of the particulate matter having diameters greater than 10 microns, but the concentrations of particles in the exhaust can be several times higher than in a coal-fired power plant. Particulate control devices for cement plants must be able to clean gases with fairly high dust loading.

As is the case for many other industrial sectors, the main control options for fine particles are baghouses (more formally known as Fabric Filters) and electrostatic precipitators (ESPs), described in Section 2.3.2 (EGUs). The following section describes some issues specifically related to cement kilns and the use of these devices, including a new filter system combining a baghouse and an ESP.

Cement kilns primarily utilize baghouses of the reverse-air and pulse-jet types. Both types are usually configured so that the bags can be cleaned during an “off-line” cycle, in which a section of the baghouse is closed off from the main exhaust flow for cleaning. This tends to reduce the need for a high-pressure pulse that causes additional wear on the filtration fabric, allows less time for particles to be collected in the hopper during its brief and frequent use, and requires additional power for operation. The choice between a reverse-air and pulse-jet system is generally made on the basis of the volume of exhaust and production from the kiln. In general, kilns producing less than 1650 stpd (with exhaust volumes below 128,000 acfm) are most efficiently served by a jet-pulse system (D’Lima and Pirwitz, 2000). The decision is more complex for kilns up to 6600 stpd (with exhaust volumes up to 853,000 acfm), for which initial equipment costs are similar but lifetime operation costs are more complicated. D’Lima and Pirwitz (2000) concluded that jet-pulse systems are appropriate for the smallest kilns and reverse-air

systems are preferred for all larger kilns, even though they may have higher installation costs for kilns of more modest size.

Corrosion in baghouses has been an important topic in the cement kiln control literature (Jansen and Mazeika, 2003; Biege and Shenk, 2001). A 2002 EPA rule [40 CFR Part 63 Subpart LLL (2002)] requires gas temperatures entering the control device not to exceed 400°F (205°C) in order to control dioxin emissions. Water sprays are usually utilized to control exhaust temperature, but adding water vapor to the exhaust stream while lowering exhaust temperature brings the gas near the dew point of some corrosive components. Corrosion issues can be addressed in a number of ways, but all add cost to the use of the control system.

The three components of corrosion are corrosive gases, condensation, and a corrodible surface; reducing any component will reduce corrosion. Corrosive gases can be reduced in a roller mill; this may be one of the most effective methods to reduce corrosion. Many of the gases are absorbed by the feed during the milling process and are therefore not available to form acids in the exhaust. Changing the feed may also reduce some of the acidic gases. Condensation is prevented most easily by keeping the exhaust temperature hot; however, when this is not allowed, it is best to maintain the exhaust temperature as high as possible, preventing drops which may allow acidic condensation. Insulating surfaces and carefully sealing unused sections of the control device can prevent exhaust from leaking into cool areas where it can condense and cause corrosion. Finally, corrosive-resistant materials and acid-resistant coatings can help reduce corrosion in control equipment.

Instead of a baghouse or an ESP, a combined system has become available, utilizing components of both systems. Whereas an in-series, hybrid system has the ESP and baghouse systems in independent compartments, this technology is described as “an ESP in which every other row of discharge electrodes is replaced by a single row of filter bags” (Gebert et al., 2003). In this new system, where the filter bags are directly adjacent or parallel to the ESP electrical field, ESP zones alternate with filter zones, allowing primary collection by the ESP and pre-ionization of the remaining dust for collection on the filter bags. A highly efficient expanded polytetrafluoroethylene (ePTFE) membrane is used as the filter fabric, which can remove an order of magnitude more of fine particulate than ordinary bags. During a pilot system test of a 225 m<sup>3</sup>/min (9000 acfm) slipstream from a coal-fired power plant in South Dakota, greater than 99.99% removal efficiency was shown. With the ESP fully engaged, bag cleaning was required only every 300 minutes, compared to every fifteen minutes when the ESP was not used. This system has been utilized in full-scale commercial operation at a cement kiln in Italy since September 2002, capturing dust from the cement kiln, raw mill and clicker cooler. Another similar filter is in operation since October 2002 at the coal-fired power plant in South Dakota mentioned above.

The synergy between the two technologies enables operation of the filter bags at high air-to-cloth (A/C) ratios, and, combined with the new compact size for filters, provides the following benefits for a cement plant:

- Ability to reach high control efficiencies in all operation modes,
- Continuous stable operation, and

- Lower operating costs, due to reduced number of system components.

#### 4.3.4. VOC Controls

No controls which specifically targeted VOCs were identified for cement kilns.

### 4.4. Costs and Availability

#### 4.4.1. Sulfur Dioxide Control

The SO<sub>x</sub> control techniques applicable to the cement industry and the assumed SO<sub>x</sub> reductions that the various control technologies can achieve are summarized in Table IV-4.

The achievable SO<sub>x</sub> reductions vary greatly. Even when the same control technology is applied to kilns of the same type, the removal efficiency will depend on kiln operating parameters, uncontrolled SO<sub>x</sub> emissions rate, and many other site-specific factors.

Wet-limestone scrubbers and spray dryers can be used as secondary control devices to reduce SO<sub>2</sub> emissions from a cement kiln.

Capital and operating costs for spray dryers and wet scrubbers as applied to cement kilns were computed by Young (2002). Both technologies were assumed to be installed *after* the existing APCD, which would allow the CKD to be recycled back to the kiln. If CKD is not recycled, there is a negative impact on the operating cost of the plant. Table IV-5 summarizes the capital and operating costs in terms of \$ per ton of clinker produced for different types of kilns. The capital and operating costs of the spray dryer include a baghouse, new stack and new ID (induced draft) fan. The capital and operating costs for the wet scrubber include new fans and a new stack as well as a new wastewater treatment facility.

Another installation was made in 1998 at Castle Cement's Ribblesdale (UK) facility (Castle Cement, 2004). Scrubber installation cost £5 million and operational costs are about £750,000 annually. Emissions from one unit were reduced by 90%.

**Table IV-4 SO<sub>2</sub> Control Techniques Applicable to Cement Kilns (Miller, 2001)**

SO <sub>2</sub> reduction technique	Applicable to kiln type				Range of removal efficiency
	Long wet	Long dry	Preheater	Precalciner	
Process alterations	x	x	x	x	0-100%
Dry reagent injection			x	x	25-85%
Hot meal injection			x	x	0-30%
Spray dryer absorber		x	x	x	50-90%
Wet SO <sub>2</sub> scrubber	x	x	x	x	80-95%

**Table IV-5 Capital and operating costs of spray dryers and wet scrubbers applied to cement kilns (Young, 2002)**

	Clinker capacity, tpy	Spray Dryer		Wet Scrubber	
		Capital Cost, \$/ton clinker	Annual Operating Cost, \$/ton clinker	Capital Cost, \$/ton clinker	Annual Operating Cost, \$/ton clinker
Small wet kiln	300,000	\$54.67	\$20.02	\$47.00	\$22.59
Medium wet kiln	600,000	\$38.17	\$14.09	\$32.67	\$17.58
Medium dry kiln	600,000	\$39.75	\$14.79	\$31.83	\$17.21
Large dry kiln	1,200,000	\$23.17	\$9.43	\$20.42	\$13.05
Medium preheater kiln	600,000	\$17.92	\$7.51	\$15.83	\$9.85
Medium precalciner kiln w/ bypass	600,000	\$25.17	\$10.20	\$19.33	\$11.42
Large preheater kiln	1,200,000	\$10.96	\$5.41	\$10.83	\$8.14

An alternative secondary control device for SO<sub>2</sub> was designed and applied as part of U.S. Department of Energy's Clean Coal Technology program. A co-project of Passamaquoddy Technology and Dragon Products Company in Thomaston, ME, the Passamaquoddy Technology Recovery Scrubber<sup>TM</sup> (Recovery Scrubber<sup>TM</sup>) utilizes cement-kiln dust as a reagent for removing SO<sub>2</sub> from kiln exhaust gases (USDOE, 2001). Waste heat from the kiln is used to crystallize K<sub>2</sub>SO<sub>4</sub>, a saleable, fertilizer-grade by-product. The remaining cement kiln dust is returned to the kiln, significantly reducing particulate emissions, eliminating the need for removal of the dust to a landfill, and

reducing the requirement for raw materials by about 10 percent. Sulfur dioxide was reduced by 82 to 98.5%, depending on scrubber inlet SO<sub>2</sub> rates. In addition, NO<sub>x</sub> was reduced by about 25% and VOCs by 70%. Capital costs for a Recovery Scrubber™ were estimated at about \$10.5 million in 1996 dollars, with operating and maintenance costs of \$150,000 per year and electricity costs of \$350,000 per year (787 kW at \$0.06/kW).

#### **4.4.2. Nitrogen Oxides Control**

Table 6 presents a summary of NO<sub>x</sub> controls that are feasible for cement kilns, the range of potential NO<sub>x</sub> reductions from applying these controls, the cost effectiveness of the controls, and effects on other emissions when using these controls.

**Table IV-6 Summary of the Feasibility of NO<sub>x</sub> Controls for Cement Kilns**

NO <sub>x</sub> Reduction Technique	Technical Feasibility	NO <sub>x</sub> Reduction Potential (%) <sup>1</sup>	Cost Effectiveness (\$/ton NO <sub>x</sub> removed)	Effect on Other Emissions	Reference
Process Modifications	In full-scale use	0 - 30 [15]	3,100 - 8,800	Unknown	16
Low NO <sub>x</sub> Burners w/ Indirect Firing	In full-scale use	0 - 20 [10]	5,800 - 8,100	Unknown	16
Low NO <sub>x</sub> Burners w/ Indirect Firing and Mid-kiln Tire Injection	In full-scale use	[49]	1 - 1,800	Unknown	17
Mid-Kiln Injection of Fuel, Riser Duct Firing Calciners	In full-scale use	0 - 30 [15]	5,100 - 11,500	May increase CO, SO <sub>2</sub> ; hydrocarbon emission	16
CemStar	Wet kilns	20 - 50 [20]	0-600	Unknown	17
Low NO <sub>x</sub> Precalciner	Have been installed on several full-scale kilns - Offered by several different vendors.	30 - 40 [30]	2,700 - 3,600	May Increase emissions CO, SO <sub>2</sub> , and/ or hydrocarbons	16
SNCR	May be applicable only on preheater or precalciner kilns - limited data	15 - 65 [45]	900 - 1,200	May Increase emissions CO, NH <sub>3</sub> , and NH <sub>4</sub> <sup>+</sup> salts (detached plume)	17
Biosolids Injection	May be applicable only on preheater or precalciner kilns - limited data	[50]	100-1,800	May Increase emissions CO, NH <sub>3</sub> , and NH <sub>4</sub> <sup>+</sup> salts (detached plume)	17

<sup>1</sup>Values in brackets are the assumed NO<sub>x</sub> reductions used to calculate the estimated cost effectiveness of each Technology.

#### 4.4.3. PM<sub>2.5</sub> Control

As discussed above, control of particulate matter in cement kilns is accomplished using baghouses and electrostatic precipitators. These processes are also used in electric utility generating units and industrial boilers. Capital and operating costs for fabric filters and ESPs as applied to cement kilns were computed by Young (2002) and are summarized in Table IV-7. The costs include the addition of a new fan.

**Table IV-7 Capital and operating costs of baghouses and ESPs applied to cement kilns (Young, 2002)**

	Clinker capacity, tpy	New ESP		New baghouse	
		Capital Cost, \$/ton clinker	Annual Operating Cost, \$/ton clinker	Capital Cost, \$/ton clinker	Annual Operating Cost, \$/ton clinker
Small wet kiln	300,000	\$14.00	\$3.35	\$16.67	\$3.81
Medium wet kiln	600,000	\$11.00	\$2.49	\$13.00	\$2.92
Medium dry kiln	600,000	\$10.50	\$2.54	\$12.00	\$2.78
Large dry kiln	1,200,000	\$7.33	\$1.51	\$8.67	\$1.96
Medium preheater kiln	600,000	\$4.33	\$1.03	\$5.17	\$1.17
Medium precalciner kiln w/ bypass	600,000	\$5.33	\$1.42	\$6.33	\$1.53
Large preheater kiln	1,200,000	\$3.33	\$0.74	\$4.00	\$0.90

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## 6.2. Industrial Boilers

For industrial boilers, many of the same control technologies for EGUs are applicable to this source category including: low sulfur coal, wet and dry FGD (or scrubber) technology for SO<sub>2</sub>, combustion modifications and SCR and SNCR technology for NO<sub>x</sub>, and ESP, fabric filter and wet scrubbing techniques for PM. However, industrial boilers have a wider range of sizes than EGUs and often operate over a wider range of capacities. Thus cost estimates for the same technologies will generally range, depending on the capacity of the boiler and typical operating conditions. High end cost estimates for NO<sub>x</sub> removal can be over \$10,000/ton.

## 6.3. Cement Kilns

Designing a system of emission controls for cement kilns are somewhat more complicated given that the quality of clinker produced in a kiln varies with characteristics of the combustion, it is possible to combine combustion technologies with post-combustion technologies for cement kilns in some cases and it is also possible to combine multiple combustion technologies on cement kilns. As a result, primary controls need to be selected carefully taking engineering and cost decisions into account for each specific kiln.

Control options for SO<sub>2</sub> include in-process removal, process changes (e.g. combustion optimization, flame shape adjustment or raw material changes), and the use of wet or dry scrubbers. For NO<sub>x</sub>, both process modifications (e.g. combustion modifications, low-NO<sub>x</sub> burners, secondary combustion or staged combustion) as well as post combustion controls need to be selected carefully. Particulate control devices for cement plants must be able to clean gases with fairly high dust loading given that the concentrations of particles in the exhaust can be several times higher than in a coal-fired power plant. In addition, PM technologies are affected by the presence of corrosive gases which can be reduced most effectively in a roller mill. While fabric filters (baghouses) and electrostatic precipitators are still the most common means of PM control at cement plants, a number of novel techniques and procedures are used to deal with the unique issues face by cement kilns.

Costs for SO<sub>2</sub> controls at cement kilns will vary widely depending on control options selected and process variables (e.g. whether material is recycled in the control process). Capital cost for typical wet/dry scrubbing post-combustion controls have been estimated in the \$10-50/ton of clinker produced with operating costs in the \$5-20/ton of clinker range. PM controls are similarly estimated in the \$3-15/ton of clinker range for capital costs and \$0-30/ton clinker for operating costs on an annual basis. NO<sub>x</sub> has not been estimated on a per ton of clinker basis, but estimates vary between 0 and \$10,000/ton of NO<sub>x</sub> reduced.

## 6.4. Pulp Mills

Paper and pulp facilities have perhaps the widest range of operational configurations and thus possibilities for reducing pollutant emissions. A variety of







## **Appendix H**

### **CALPUFF Modeling Results**

v24.2002.b1559.bowa.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.brig.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.doso.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.grgu.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.grsm.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.hegl.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.isle.dat days	: --- Number of days with Delta-Deciview =>	0.50:	4	365
v24.2002.b1559.jari.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.ligo.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.lybr.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.maca.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.ming.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.sene.dat days	: --- Number of days with Delta-Deciview =>	0.50:	26	365
v24.2002.b1559.shen.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.sips.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365
v24.2002.b1559.voya.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	365

5.257 Max.

DV

v24.2003.b1559.bowa.dat	: --- Number of days with Delta-Deciview =>	0.50:	3	365
days				
v24.2003.b1559.brig.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.doso.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.grgu.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.grsm.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.hegl.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.isle.dat	: --- Number of days with Delta-Deciview =>	0.50:	8	365
days				
v24.2003.b1559.jari.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.ligo.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.lybr.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.maca.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.ming.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.sene.dat	: --- Number of days with Delta-Deciview =>	0.50:	38	365
days				
v24.2003.b1559.shen.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.sips.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				
v24.2003.b1559.voya.dat	: --- Number of days with Delta-Deciview =>	0.50:	0	365
days				

3.644 Max.

DV

v24.2004.b1559.bowa.dat days	: --- Number of days with Delta-Deciview =>	0.50:	7	366
v24.2004.b1559.brig.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.doso.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.grgu.dat days	: --- Number of days with Delta-Deciview =>	0.50:	5	366
v24.2004.b1559.grsm.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.hegl.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.isle.dat days	: --- Number of days with Delta-Deciview =>	0.50:	12	366
v24.2004.b1559.jari.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.ligo.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.lybr.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.maca.dat days	: --- Number of days with Delta-Deciview =>	0.50:	1	366
v24.2004.b1559.ming.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.sene.dat days	: --- Number of days with Delta-Deciview =>	0.50:	37	366
v24.2004.b1559.shen.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.sips.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366
v24.2004.b1559.voya.dat days	: --- Number of days with Delta-Deciview =>	0.50:	0	366

2.481 Max.

DV