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January 24, 2006

David Schanbacher
Chief Engineer
Texas Commission on Environmental Quality
Bldg. F, Fourth Floor
12100 Park 35 Circle
Austin, TX 78753

Via Hand Delivery

Re: Initial Comments of the Portland Cement Association on Draft Final Report –
“Assessment of NOx Emissions Reduction Strategies for Cement Kilns - Ellis
County”

Dear Mr. Schanbacher:

Enclosed please find the initial comments of the Portland Cement Association (“PCA”) on the above-referenced Draft Final Report. Individual member companies of the PCA who are affected by the Draft Final Report may also file comments on the document.

These comments are preliminary because information that is essential to a full understanding of the Draft Report’s conclusions is missing. For example, sources and background data for many conclusory statements are not provided in the Draft Report, the section of the Draft Report on “References” is blank, and virtually all cost assumptions and data are missing. In addition, a number of the tasks set out in the scope of work for the cement kiln study have apparently not been performed by the TCEQ’s contractor since they are not addressed in the Draft Report. As you know, these tasks were developed by the TCEQ with input from the interested parties and are important to a full analysis of the various control technologies discussed in the Draft Report. All of these concerns are discussed in more depth in the attached comments.

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David Schanbacher
Chief Engineer
Texas Commission on Environmental Quality
January 24, 2006
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In light of PCA's concerns with the Draft Report, the PCA requests that the TCEQ include the missing data in a revised report and then provide a formal opportunity for all interested persons to comment on the revised Draft Report. Additionally, we ask TCEQ to treat the Draft Report as a work in progress and not finalize it until interested party comments have been adequately considered.

Thank you for your consideration of these comments.

Sincerely,



Albert R. Axe, Jr.

ARA:ltm

Enclosure

cc (w/encl): Brent Wade (*Via hand delivery*)
Ashley Wadick (*Via hand delivery*)
Jason Skaggs (*Via hand delivery*)
Karen Hill (*Via hand delivery*)
Stephanie Bergeron Perdue (*Via hand delivery*)
Booker Harrison (*Via hand delivery*)

**Initial Comments on the Draft Final Report
“Assessment of NOx Emissions Reduction Strategies for Cement Kilns-
Ellis County”**

INTRODUCTION

These comments are filed by the Portland Cement Association (“PCA”) relative to the Draft Final Report prepared by ERG, Inc. for the Texas Commission on Environmental Quality (“TCEQ”), on cement kilns in Ellis County (the “Draft Report”). The PCA is a trade association representing cement companies in the United States and Canada. PCA members represent more than 95 percent of cement-making capacity in the United States and 100 percent in Canada. The owners of the Ellis County cement kilns are all members of PCA.

COMPARISON OF THE DRAFT FINAL REPORT TO THE SPECIFIED SCOPE OF WORK

The Scope of Work for Work Order No. 582-4-65589-05-06, identified nine primary tasks and one secondary task for the Draft Report. A description of these tasks and an assessment of whether the task requirements are adequately addressed by the Draft Report is presented below:

Task 1 – Work Plan

The Work Plan was completed in August 2005.

Task 2 – Compositions of Ellis County Raw Materials

Section 5 of the Draft Report contains only a very general discussion of the chemistry of the raw materials used for cement production in Ellis County. The Draft Report fails to include the ranges of composition for the constituents in the Ellis County kilns, and the required comparison of the Ellis County materials to those in other states and countries. Without these data, it is simply not possible to evaluate the accuracy of the comparisons and conclusions in the Draft Report about operations at the Ellis County kilns with respect to other kilns throughout the world.

Task 3 – Literature Research

Although the ERG Team may have conducted the required literature search, and indeed the Draft Report contains a few references to specific documents, there is no listing of the references reviewed or even of those cited by the Draft Report. In fact, Section 6, titled “References” is blank. Both a list of the references cited by the ERG Team and copies of those documents are essential components of the Draft Report.

Task 3 also requires that the Draft Report contain a review of the emissions limits for other cement kilns outside of Ellis County, in other states and internationally, as well as a

review of relevant regulations and permit conditions that may impact the feasibility of kilns in different countries and states to utilize various NO_x control technologies. While there is some limited discussion of European and Japanese regulatory requirements in Section 4.5.2, and there is one statement (See page 102) that recent US BACT analysis considered SNCR as BACT at an emission rate of 1.95 lb. NO_x /ton clinker, no other information for cement kilns outside of Ellis County is provided. The RACT, BACT, LAER Clearinghouse (RBLC) database, which contains a summary of all RACT, BACT, and LAER permits that have been issued to cement kilns or so-called similar facilities in the US, is readily available. However, even this information is absent from the Draft Report.

Task 4 – Kiln Conversion

Section 4.4.5 contains a discussion of kiln modifications and conversions. The section focuses on the energy efficiency benefits of newer kiln types. This section admits that the cost analysis in the Draft Report does not account for the current use of waste fuels by certain Ellis County kilns. The section also alludes to additional benefits from the sale of credits from the simultaneous reduction of other pollutants that might result from kiln modification/conversion. Because Ellis County is currently in attainment for these other pollutants, no market exists for these “credits”, and no program is in place to manage the marketing of such credits. Any suggestion of benefit from the sale of other pollutants is speculative. Furthermore, these statements are outside the scope of this task and study.

Furthermore, the Draft Report identifies a candidate preheater/precalciner kiln upgrade (Holcim #1). However, as justification the Draft Report uses the NO_x emission rate at a different plant (TXI #5), ignoring the more appropriate comparison, which is with the other more advanced preheater/precalciner kiln at the same plant (Holcim #2). Therefore, the suggestion as to a candidate preheater/precalciner kiln upgrade is not warranted.

Task 5 – Low Temperature Oxidation

Section 4.3.2 of the Draft Final Report discusses LoTO_x technology. While the Draft Report states that LoTO_x has been installed on similar sources, the examples referenced in this section reveal that these sources are in fact not similar to cement kilns. Furthermore, this section concedes that operational information for an actual full-scale application of LoTO_x is sketchy (section 4.3.1 page 76), and that available cost information is “not very helpful for determining costs for the cement industry.” Then the report states: “...cost effectiveness is heavily dependent on each individual facility’s control equipment, the extent of modifications necessary to install new control equipment, and the degree of DRE [destruction removal efficiency of NO_x] required to achieve the desired results.” The Draft Report states estimated costs and includes cost analysis tables, but fails to provide references to the specific sources of the cost analysis inputs or the spreadsheets and calculations used to support the data contained in the tables. Therefore, it is impossible to evaluate the accuracy of these estimates. The Draft Report does not provide adequate documentation of the LoTO_x review or the

applicability of the technology to the cement industry. Additional technical comments are contained in later sections of this document.

Task 6 – Kiln Specific Application

This task requires the Draft Report to include a discussion of all possible reduction technologies and the kiln specific feasibility assessments for those technologies. While the Draft Report contains some discussion of other NOx control technologies beyond SCR, SNCR, and LoTOx, it does not assess the reductions achieved by the use of these technologies or the NOx reductions associated with the use of waste derived fuels.

Task 7 – Chemical Reactivity

The Draft Report did not address this task.

Task 8 – Changes to Raw Materials and Processes

The Draft Report did not address this task.

Task 9 - Summary of Reductions Associated with Technologies

Section 4.5.3, Summary of European Experiences (Page 103), contains at least some of the information, requested in Task 9, for European countries. However, the similar information required for the technologies currently implemented in Ellis County, and other Texas, U.S., and other international cement plants, is not in the Draft Report

Task 10 – Kilns Located in Counties other than Ellis County

This secondary task was not included in the Draft Report.

GENERAL REPORT DEFICIENCIES

References

The Draft Report as posted on the TCEQ website does not contain Section 6.0 titled “References.” The inclusion of both a listing of the references cited and the attachment of these cited references are essential in order to clarify and verify the facts, statements and assumptions, which constitute the Draft Report. Without the inclusion of the references, the statements, assumptions, and conclusions are no more than conjecture.

Documentation

In addition to the failure to provide copies of the documents referenced within the Draft Report, the Draft Report contains numerous statements with no reference whatsoever. If a statement is attributed to a person or entity such as EPRI, as noted on page 33, then the source of that statement needs to be identified.

Cost Basis

There are no spreadsheets, data, assumptions, or calculations regarding the cost calculations in the Draft Report. All information, excluding the data determined to be confidential, must be included with the Draft Report. Also, spreadsheets containing the individual company data should have been provided to the respective companies for review.

CLASSIFICATION OF CONTROL TECHNOLOGIES

A brief explanation /definition of the terms “Available,” “Transferable,” and “Innovative” is contained on page 3 of the Executive Summary. The Executive Summary first concludes that no control technology is available for wet kilns, then obfuscates that important conclusion by declaring that the technology is “available” for the long wet kilns through kiln conversion; i.e., replacement with modern preheater/precalciner kiln technology. In no place within the body of the Draft Report is there a discussion of the definition of these terms. However, in the discussion of the technical aspects of the technologies in Section 4, statements are made as to whether each technology is available or transferable. The discussion of these terms in the Executive Summary and their use in the Draft Report suggest that the usage of these terms is consistent with the definitions of these terms in both federal and state New Source Review (NSR) regulations. Based upon a comparison of the terms used in the Draft Report to the terms defined in the New Source Review Workshop Manual; Draft dated October 1990, beginning on page B-11, the terms used in the Draft Report are not consistent with the NSR definitions.

LoTOx

The LoTOx discussion in Section 4.3.2 on page 75 states: “This technology should be considered transferable in nature. It has not been used on a cement kiln but it has been used on similar large sources...” The Draft Report does not identify the similarities that support this assertion. Moreover, the Draft Report even admits that the details are “sketchy” (page 76) for at least one of these supposed comparable applications. The limited supporting information in the Draft Report is “vendor” data that does not support a classification of “transferable” for LoTOx. In fact, based upon information available to PCA, the technology has not been used on any source, which can be reasonably described as “similar” to any of the Ellis County kilns. In response to inquires made by or on behalf of individual cement companies, BOC (the LoTOx vendor) has consistently indicated that a pilot study must be conducted, at a potentially significant cost, before a design or final cost quote can be provided for a full scale, permanent application. Clearly, LoTOx is not “available” for a cement plant and it is also not yet “transferable.” The mere fact that a pilot study is essential before a system design, pricing or guarantees can be finalized confirms that use of LoTOx in the cement industry currently should be classified as “innovative.”

SCR

The Executive Summary and the Draft Report state that SCR is “available” for application to the Ellis County cement kilns. This assertion is apparently based upon the existence of a single SCR system operating at the Solnhofen cement plant in Germany. The Draft Report leaps to the unsubstantiated conclusion that the Solnhofen kiln is similar to the Ellis County kilns. It is not. The Solnhofen kiln is a relatively small dry preheater kiln. The Ellis County kilns, on the other hand, consist of three preheater/precalciner (PH/PC) kilns and seven long wet kilns. As discussed in some detail in Sections 2 and 3 of the Draft Report, the different kiln types have varying thermal efficiencies. The thermal efficiencies are impacted by the burnability and chemical composition of the raw materials. These variations in both thermal efficiency (design) and raw materials result in variations in the magnitude of the NO_x emissions and the composition of the SCR inlet gases. Another clear example of the difference in the kilns is the fact that TXI’s Kiln No. 5 is four times the size of the Solnhofen kiln. The fact that one SCR unit is in operation on one significantly different kiln type does not equate to a technology that is “available” to other kiln types.

Additionally, according to generally available information, the German government at least partially funded the SCR system installed on this plant. Solnhofen conducted a lengthy pilot test program including testing of multiple (perhaps as many as 20) catalyst types and designs. (*See* Attachment 1) In fact, in 2004, the Solnhofen facility replaced the first stage honeycomb catalyst with a plate catalyst. Whether this was done for control efficiency or for operations and maintenance reasons is unknown. Based on discussions with an experienced catalyst supplier and operator in the power industry, PCA believes that an SCR system is not commercially available for a cement plant. A pilot test would be required in order to determine the technical feasibility and to develop the chemistry and flow data necessary to design an SCR system retrofit to other kiln types and different raw materials. Therefore, classification of SCR as “available” is not supportable. As the Solnhofen example illustrates, even the transfer of SCR from use in coal fired boilers to the relatively simple Solnhofen cement kiln system required extensive pilot testing and significant design adjustments. Moreover, as discussed later in the comments, even after extensive pilot testing and design adjustments, emission consistency at the Solnhofen kiln is well below what would be considered acceptable in Texas.

SNCR

The classification of SNCR as “available” for the three PH/PC kilns in Ellis County is supportable. Most European kilns have been utilizing SNCR for several years. Currently, there are only four SNCR systems in operation at US cement plants. Two of these are being utilized on two new modern PH/PC kilns in Florida. These kilns are achieving their permitted NO_x emissions rates of 1.95 lb NO_x/ton clinker. SNCR systems have also been proposed on other kilns around the country.

PCA agrees with the ERG Team that SNCR is not currently available for long wet kilns. The required ammonia injection zone is located in the middle of the long rotating kiln, and the logistics of ammonia injection into this zone have not been developed.

DETERMINATION/ASSIGNMENT OF CONTROL EFFICIENCIES TO THE NO_x CONTROL TECHNOLOGIES

The control efficiencies reported for SCR, LoTO_x and SNCR are inconsistent between the Executive Summary and the text of the Draft Report. Furthermore, although the Executive Summary and the Draft Report both claim that the control efficiencies are “conservative,” as explained in more detail below, the facts do not support this assertion.

SCR - Power Plants

The use of SCR on coal-fired power plants is not particularly relevant to the use of this technology on cement kilns. The raw physical and chemical characteristics of the dust loading to an SCR in a cement kiln are significantly different than those seen in coal-fired boilers. This being the case, the following comments are related to the assumptions for control efficiencies made by the ERG team.

Page 15 of the Executive Summary states that SCR applications in coal-fired boilers achieve 90% control efficiency or better. However, the Draft Report in Section 4.1.1, page 33, references SCR efficiencies of 80 to 90% or higher. No specific reference for the basis of either of these statements is provided for verification. The Draft Report also states in Section 4.1.1, page 33, that vendor guarantees to the power industry for SCR systems range from 90-94%. However, copies or references to specific vendor guarantees were not provided in the document. (And, of course, there can be no assurance that the vendors would provide similar guarantees for use of their systems in dissimilar operations.) Information gathered from conversations with Kansas City Power & Light Co. and Texas Genco suggests that their respective experiences with the use of SCR on coal-fired boilers have shown that control efficiencies of 70-80% are sustainable on a regular basis, NOT the 80-90% or 90-94% range specified in the Draft Report. Based on a review of the RBLC database, since the beginning of 2000, there have been 9 coal-fired power plants that have been permitted as BACT or LAER with SCR control technology. According to the data in the RBLC database, the control efficiency for those facilities range from 60-90%.

SCR - Solnhofen

Section 4.1.1, page 34 of the Draft Report discusses the sole cement plant application of SCR, the Solnhofen plant in Germany. The report states:

“With SCR, the plant has been achieving approximately 200 mg/Nm³ (0.8 lb/ton of clinker). Based on an uncontrolled NO_x emission rate of 1050 mg/Nm³ (4.2 lb/ton of clinker), the emissions rate corresponds to a NO_x control efficiency of

80%. It has been indicated, however, that the SCR system was capable of achieving a lower NOx emission rate (they are not using all of their beds), but that they were operating at 200 mg/Nm³ since German law only required a NOx emissions limit of 500 mg/Nm³.”

Information from available literature and from direct communications with a cement industry expert, conflict with the claims made in the Draft Report regarding overall average control efficiencies achieved at Solnhofen. The communication regarding this topic was to PCA representatives by Mr. Mark Terry, President of Polysius/USA, a cement plant design company and equipment manufacturer. Mr. Terry has spent time at the Solnhofen facility and studied the application of SCR at that location (*See* e-mail from Mr. Mark Terry attached as Attachment 2).

A review of permitting documents for the Solnhofen facility also does not support all of the statements and conclusions in the Draft Report regarding Solnhofen. According to the permit records, in 1990 the facility was permitted to emit 950 mg/Nm³ NOx. No SNCR or SCR systems were installed at that time. Thus, the baseline (or “uncontrolled NOx emission rate”) for Solnhofen is 950 mg/Nm³, not 1050 mg/Nm³, as stated in the Draft Report. (The overstatement of the baseline in the Draft Report results in an overstatement of the control efficiencies.) An SNCR system was permitted and installed at Solnhofen in 1995, and the authorized emission rate was reduced to 850 mg/Nm³. (This reflects a control efficiency associated with the SNCR unit of 10.5%.) The permit for the installation of the SCR unit, issued in 2000, states that the SCR system would be installed with a goal of achieving an emission rate of 200 mg/Nm³. Significantly, the Texas Clean Air Act and the NSR permit scheme adopted in Texas does not adopt an “emission goal” concept. Furthermore, this goal obviously was too optimistic, as the operating permit issued in 2002 after the SCR system was built and operating, sets a NOx limit of 500 mg/Nm³.

Little, if any, written documentation via CEMS or stack testing data is available for Solnhofen that could be used to verify the SCR inlet concentration to calculate control efficiency. However, Mr. Terry has indicated (*See* Attachment 2) that the plant’s baseline emission rate ranges from 700 to 1,400 mg/Nm³.

The conclusion in the Draft Report that SCR has achieved an emission limit of 200 mg/Nm³ (and thus the suggestion that such a limit can be attained at Ellis County cement kilns) is NOT supported by the facts. Although the Solnhofen plant had a goal of operating at 200 mg/Nm³ and that rate was achieved in a short-term pilot test (*See* Table 4-5.5 of the Draft Report), this rate has not been sustainable during long-term operations. In fact, according to the 2004 annual emissions report for Solnhofen (copy attached as Attachment 3), the plant only met the permitted 500 mg/Nm³ NOx emissions rate 72.3% of the time in 2004. In other words, Solnhofen exceeded its permitted limit of 500 mg/Nm³ nearly 28% of the year. An emission rate of 500 mg/Nm³ equates to a NOx emissions rate of approximately 2 lb/ton of clinker, a rate that is already being achieved by TXI’s Kiln No. 5 and other preheater/precalciner kilns in the United States. The Solnhofen report indicates that the measures to be taken to correct future NOx excursions

are to “Improve operations of the unit.” One must assume that if the plant could have routinely operated at 200 mg/Nm³, the excursions of the 500 mg/Nm³ limit could easily have been avoided.

Discussions with Mr. Terry cast even greater doubt on the control efficiency for SCR at Solnhofen contained in the Draft Report. While Mr. Terry was at Solnhofen, the facility operated both SNCR and SCR systems. Although the SCR system served as the primary NO_x control technology, its inherent process constraints limited its reliability and required the plant to utilize SNCR as a backup system. Apparently when the preheater exhaust temperatures fall outside the allowable SCR temperature operating range, or the catalyst beds become plugged, the SCR is bypassed and SNCR is initiated to control the NO_x emissions. Mr. Terry confirms that the SCR system exhibited serious plugging problems early on and that extensive catalyst cleaning requirements were developed over time to improve this issue. It is our understanding that routine catalyst cleaning takes two shifts to complete along with further acoustic cleaning overnight. The cleaned SCR has a pressure drop of about 4 mbar, but over a period of one to two weeks, the top two layers of the catalyst bed gradually foul with preheater dust. Once the pressure drop reaches 14 mbar, the SCR is bypassed and SNCR is initiated. The SCR system is also bypassed for both high (greater than 400° C) and low temperatures (less than 320°C) outside the catalyst design range in order to protect the catalyst from either thermal destruction, plugging, or to avoid excessive ammonia slip. Operation in bypass mode likely accounts for some of the 28% excursions, and the catalyst plugging and the resulting cleanout may account for the balance of the excursions. Given the frequency and routine nature of the maintenance, it may not be possible to operate the systems during the ozone season to avoid a bypass. The Draft Report ignores these important considerations.

Mr. Terry also indicated that the data collected at Solnhofen show that a maximum control efficiency of 70% occurs and levels off at a molar ratio of 1 mole NH₃ to 1 mole of NO_x and the removal efficiency does not increase even if ammonia injection is increased. Conversely, SNCR testing conducted by Polysius has demonstrated that an increase in molar ratio beyond 1 further increases the control efficiency and that it does not level off.

Clearly, the 2004 operational data indicate that the 200 mg/Nm³ emission rate was demonstrated only during short-term testing. This fact, along with the information indicating that the plant alternately utilizes both SCR and SNCR, brings into question what exact control efficiency and NO_x emissions rate are routinely achievable with the application of SCR for the Solnhofen kiln. Given that the Solnhofen kiln type is not represented by the Ellis County kilns, and that there have been and continue to be operations and maintenance issues with the Solnhofen SCR system, the conclusion of the Draft Report to apply an 80–85% control efficiency for the cost estimates for SCR systems on the Ellis County kilns is not appropriate. The Solnhofen SCR experience, the only SCR usage in a cement plant cited in the Draft Report, was at best 80% efficient during a short-term test, but was less than 55% efficient about 28% of the time in 2004. The Draft Report application of 80-85% control efficiency further fails to acknowledge that the underlying Solnhofen data represent alternating SNCR/SCR operations. In

consideration of the above, SCR is not an “available” technology. Even if it were “available”, significantly lower control efficiency must be assumed for SCR use in the cement industry. If used in Ellis County, the SCR system would have to be bypassed during both high and low temperature events and cleaning cycles. Therefore, the assigned control efficiency and resulting emissions reductions must be lowered to account for plant operations during these required bypass periods inherent in the use of the SCR technology.

SNCR

Test results for two kilns in Florida that recently installed SNCR systems show a broad range of resulting NO_x reduction efficiencies. The testing at Suwannee American Cement indicated a range of control efficiencies between 13% with a very low molar ratio, to 65% at a molar ratio of 0.9. These data are in Table 4.1.3 (Page 48) of the Draft Report. Testing at the Florida Rock facility was conducted at two different operating scenarios—with and without tire burning. The testing with tires as a portion of the fuel resulted in control efficiencies that ranged from 34 to 68%. Without the use of tires, the range of control efficiencies was 65 to 82%. Copies of these test reports are attached as Attachments 4 and 5.

In addition to these two operations, two plants in Sweden have been complying with the Swedish emission limit of 200 mg/Nm³ using SNCR and not SCR. These represent control efficiencies of 80 to 85% reduction, although the molar ratios are high. These data are in the Draft Report on page 50, along with references to testing conducted by the Research Institute of the Cement Industry in Dusseldorf, Germany. These tests confirm a broad range of control efficiencies from 15 to 75% for SNCR. Page 51 of the Draft Report reports the results of testing by F.L. Smidth & Co. on PH/PC kilns with results of over 90% control efficiency with SNCR operating at stoichiometric molar ratios greater than one. Various other SNCR test data in the Draft Report include data from other tests conducted in the 1990’s of SNCR and NO_xOUT pilot or full-scale systems. These earlier tests range from very poor to 50% control efficiencies.

In some instances, SNCR reductions have been observed to be half of the theoretically expected values based on the molar ratio of ammonia to NO_x. The results possible for the Ellis County kilns may vary from experiences at other kilns due to the significant differences in raw materials used in the individual Ellis County kilns and the other kilns. Recent testing performed at the Midlothian Holcim plant with oversight by TCEQ resulted in optimum control efficiencies between 35 and 45%. It is important to note that the tests conducted in Europe do not indicate whether high opacity or detached plume problems occurred at these facilities while operating SNCR systems at the stated control efficiencies and higher molar efficiencies. In general, European opacity requirements, where they exist, are less stringent than either U.S. or Texas opacity standards. The efficiencies achievable by the Ellis County kilns will likely be constrained by these federal and Texas opacity standards.

COST ANALYSIS

The cost analyses provided in the Executive Summary and throughout the Draft Report are not currently supported by the contents of the Draft Report. As previously noted, the basis for the emissions rates and control efficiencies are questionable, but the backup for the capital and operating costs are simply non-existent. In combination, it is impossible to evaluate the accuracy of any cost figures set forth in the Draft Report.

For example, Tables 1-1 through 1-8 in the Executive Summary list emission rates before control in units of lb NO_x/tonne. For each table the numbers in this column should be consistent for all rows in the table. This is not true for Tables 1-4, 1-6, 1-7, or 1-8. There also appear to be either arithmetic errors or assumptions that have not been documented, as it is not possible to reproduce the numbers in the tables from the data and footnotes provided.

Due to the failure to include the details of the cost analysis within the Draft Report, it is impossible to determine whether the cost estimates account for the full costs associated with installation and operation of each identified technology. For example, both LoTO_x and SCR technologies will require the installation of pilot plants to determine the technical feasibility of these technologies to a cement kiln prior to the design and construction of full-scale control systems. These pilot plants will need to be operated for extended lengths of time to get good operational data for physical design and component selection to ensure full-scale successful operations and efficiencies. Are the costs associated with pilot plant design, installation and operation included in the costs analyses? They certainly should be.

The cost analyses for LoTO_x systems are artificially low. The text of the Draft Report and Executive Summary indicate that the cost provides for the installation of simple spray towers after the LoTO_x system. The SO₂ conversion to SO₃, which will occur in the LoTO_x system, will result in the formation of sulfuric acid mist in the spray tower and result in corrosion/deterioration of the spray tower and subsequent equipment. A wet scrubber system must be installed to effectively control the SO₃ and subsequent sulfuric acid mist formation. The increased cost of the scrubber system should be included in the control cost. Given the lack of supporting data for the cost analysis, there is no way to determine whether these additional costs are reflected in the summary tables. Based on a general familiarity with the costs associated with wet scrubber systems, it appears that their installation is not included in the cost analysis.

Finally, as discussed in the previous section on the assignment of control efficiencies, the use of overly optimistic control efficiencies for SCR and LoTO_x greatly skew the results of the cost analysis. High efficiencies for SCR and LoTO_x result in unrealistic operating costs and costs per ton of NO_x removed.

COMPARISON OF SCR IMPLEMENTATION IN CEMENT PLANT APPLICATIONS VERSUS COAL-FIRED BOILERS

The Draft Report, Section 4.1.1, page 33, states that: “The high dust, high temperature characteristics of coal plant emissions thus are similar to those of cement kiln exhaust gases. The experience of the power industry with SCR on coal-fired power plants suggests that the catalyst poisoning and fouling concerns may be manageable.” While conceptually this statement may have merit, in reality significant differences in dust loading and the chemical and physical characteristics of the dust in a power plant vs. a cement kiln result in significantly different potential impacts to the SCR catalyst system. For example, lignite-fired power plants in Texas have tried SCR for NO_x control. The results of those efforts were significantly different than those experienced by boilers burning bituminous coals. A lower control efficiency and increased operational issues such as plugging occurred in lignite-fired boilers using SCR.

Chemical and Physical Characteristics of Cement Kiln Emissions

Variations in the raw materials utilized by each cement kiln will generate variations in the chemical and physical characteristics of the cement dust particles by each kiln type at each location and for the same kiln type at different locations. Different kiln types partition different elements at different locations within the kiln system. This impacts critical components such as alkalis (sodium and potassium) and calcium oxides (CaO), which can poison or plug catalyst pores and result in fewer active catalyst sites for NO_x reduction.

An evaluation of the physical characteristics of cement dust particles to that of typical fly ash from coal-fired boilers shows that, while fly ash is typically spherical in nature and of relatively consistent size, cement ash particles are larger and very jagged and irregular in shape and size. The plugging potential for the type of particle from a cement kiln would be higher. It is also likely that a larger, jagged particle will erode the catalyst bed more rapidly. The Draft Report completely ignores this critical difference between the two operations.

Dust Loading

The dust loading from cement kilns, regardless of kiln type, also is higher than that found for even relatively high ash coal systems. This increase appears to be an order of magnitude or more (*See* memo comparing a cement plant dust loading to that of a coal-fired boiler burning Powder River Basin coal attached as Attachment 6). In addition, during kiln upset conditions, periods of unusually high dust loading can occur. These upset conditions may result in dust buildup on the catalyst beds, blanking off portions of the catalysts and substantially reducing the amount of catalyst available for NO_x reactions, or completely blocking gas flow and negating the operations of the SCR system and/or the kiln.

Pilot Testing Required

For the reasons stated above, it is anticipated that the cement dust particles would have a much more significant negative impact on catalysts than that experienced by coal-fired power plants. Installation of pilot systems would clearly be required to determine the technical feasibility of SCR technology at each cement plant. No particular NOx control efficiency could be guaranteed. Where two coal-fired boilers both burning Powder River Basin coal would be expected to produce very similar ash and dust loading to the SCR, two different kiln types, even if they are located at the same cement plant, are not expected to generate similar exhaust gas constituents. Therefore, not only is experience from coal-fired boiler systems not adequate to address critical design parameters at a cement plant, but experience from one kiln type to another or one plant to another is not adequate to address this issue.

MULTI-KILN SCR SYSTEMS

The Draft Report discusses the possibility that multiple wet kilns might be controlled with one large SCR system. This approach is unlikely to succeed for a number of reasons. First, SCR systems in the power industry typically operate at a relatively constant boiler capacity, with a relatively small turndown ratio required. In contrast, if several kilns were ducted to one SCR unit, the unit would need to be able to control emissions no matter how many kilns were in operation. This would result in the need to adjust to significantly different airflow volumes and velocities. Given that flow distribution issues are common for even steady state installations, the reduction or increase in airflow and velocity associated with the startup or shutdown of a kiln will significantly impact gas distribution through the SCR catalyst. This could result in either excessive erosion of the catalyst, or deleterious settling of dust particles that would blank off catalyst pores and reduce catalyst control capacity. Secondly, and perhaps more importantly, if a problem occurs with an SCR unit that controls emissions from multiple process units, bypassing all the kilns would significantly increase NOx emissions in the air shed.

DELAYED IMPLEMENTATION ASSOCIATED WITH LoTOx and SCR RESULTING FROM THE NEED FOR PILOT TESTING

The Draft Report ignores critical details associated with the use of the proposed technologies. LoTOx has not been installed or even pilot tested on any type of cement kiln. A pilot test would need to be conducted before design and installation of a full-scale system can begin. The duration of a necessary pilot test is unknown, and will differ from site to site. Although one SCR installation in the cement industry has been in operation, the data available from this installation is limited, and the kiln type (preheater) is significantly different from the long wet or PH/PC kilns and raw materials in Ellis County. In fact, based upon conversations with Mr. Terry and other experts familiar with SCR systems in the power industry and at the Solnhofen plant, an 18-month pilot test would be necessary prior to design and construction of full-scale SCR systems in Ellis County (if such design and construction was shown to be feasible through the pilot test).

This timeframe, combined with a design and construction period for the full-scale SCR system, would result in a considerable delay in the implementation of NO_x controls for the Ellis County kilns. As a consequence, reductions in NO_x emissions from utilizing SCR technology would not be realized for more than three years after the permits for such systems were approved.

CONCLUSIONS

As a summary, the Draft Report prepared by the ERG Team fails in the following respects:

- The Draft Report fails to provide the ranges of composition for the constituents of the Ellis County kilns and does not include the required comparison of raw materials used at the Ellis County kilns to the materials used in kilns in other states and countries.
- The Draft Report fails to provide information about the quality or integrity of emissions data or information regarding raw materials.
- The Draft Report does not provide references used in the report development. These references are essential to support the conclusions presented in the report.
- The Draft Report fails to identify relevant NO_x regulatory and permit limits for cement plants in other states and countries. For example, the Draft Report fails to address whether certain regulatory requirements that apply to kilns in Ellis County also exist in Germany and whether these requirements may affect the use of SCR on the Ellis County kilns. The Draft Report also fails to evaluate the RBLC database used in the U.S. to identify BACT and LAER determinations for new and modified facilities.
- The Draft Report identifies the potential economic benefit derived from the sale of credits from the reduction of other pollutants at Ellis County cement kilns when no program or market currently exists, or is likely to exist in the foreseeable future, for such credits. Further, the discussion on kiln conversions fails to identify the potentially significant implementation delays associated with permitting new or modified kilns, especially those utilizing waste fuels.
- LoTOx is identified as “transferable” based upon its alleged use on similar types of sources. The facts do not support this claim.
- The Draft Report fails to provide the details of the cost analysis, making it impossible to verify the results.
- Both LoTOx and SCR would require pilot testing to determine whether full-scale control units would be technically feasible. The delays and costs associated with the pilot tests have not been addressed by the Draft Report.
- The LoTOx cost fails to include the cost of a wet scrubber to address the sulfuric acid mist that will result from the SO₂ conversion to SO₃ that will result from the LoTOx process.
- The Draft Report’s determination that SCR is “available” based upon its use at a single kiln of a different design, using different raw materials and operating under a different regulatory structure, is inappropriate, and not supportable.
- The assumed control efficiency for SCR based upon experiences at Solnhofen and coal-fired boilers is not supportable. The process differences, and the lack of

long-term SCR-only operational data for Solnhofen conflict with this conclusion. The Draft Report also fails to take into account the impact of cement plant materials and higher dust loading when making the comparison to coal-fired boilers.

- The failure to provide the details used for the cost analysis, and the errors in the assumed control efficiencies, invalidates the cost comparisons contained within the Draft Report.
- The concept of multi-kiln control systems is fatally flawed. The use of one control device on multiple emission units would either result in operation of multiple emission units without control when the control system malfunctions, or would result in the shutdown of multiple production units at once for the failure of one control device. Shutdown of multiple units would have far-reaching economic impact, and would be physically detrimental to the kiln systems themselves.

From: Jennifer Seinfeld [mailto:JSeinfeld@zephyrenv.com]
Sent: Friday, January 20, 2006 7:23 AM
To: Fran Streitman
Cc: Tom Carter; Roger Brower
Subject: Follow-up on SCR information

Hi Fran - as you'd mentioned, Bob Schreiber called yesterday afternoon asking about the statement I'd included in a summary memo to you on the status of SCR, specifically regarding the number of different catalyst formulations that had been tested at Solnhofen. I looked back in my notes and I'd made the following notes during a conversation that Roger Brower and I had on September 26, 2005 with Gernot Mayer-Schwinning who is with Lurgi in Germany:

- Lurgi designed 'recipe' for catalyst for Solnhofen
- They tried many different combinations of catalyst materials
- They tested about 20 different catalyst formulations

Here is Gernot's contact information: gernot_mayer-schwinning@lurgi.de; phone: 011-49-69-4011-262

I called Bob back and left him a voice mail telling him the source of my information, and told him I'd send him an e-mail with the specific contact information. Could you forward this e-mail to him please?

Give me a call if you have any other questions.

Jennifer Sharp Seinfeld, P.E.
Principal
Zephyr Environmental Corp
10420 Little Patuxent Parkway, Suite 320
Columbia, Maryland 21044
410-312-7915 (office - direct)
410-312-7900 (office - main)
410-312-7901 (fax)
410-908-6431 (cell)
www.zephyrenv.com
www.HazMatAcademy.com

ATTACHMENT 1

From: Terry, Mark [TerryM@polysius.com]
Sent: Friday, January 20, 2006 6:10 PM
To: rschrei45@aol.com
Cc: Jette@syaeng.com
Subject: SCR in Cement Plants

Hi Bob,

It was nice talking with you again today. After our discussion, I could tell it would be better if I tried to document my observations from my visits to Solnhofen. As mentioned, the Solnhofen facility in Southern Germany has been using the SCR technology for a number of years and is identified as the prototype facility for use of SCR in cement manufacturing operations. Since there is little published data on the actual operations of the facility, I will try to summarize what I have learned about their operations from my last couple of visits.

The Solnhofen cement manufacturing facility uses a 4-stage preheater kiln (with no precalciner) for cement production, producing around 1500 metric tons per day of clinker. The kiln uses oil and waste fuels as substitute fuels to fire the kiln, and exhibits little alkali or sulfur in the raw materials used for production. Uncontrolled NOx emissions from the kiln system are relatively low at 700-1400 mg/m³. As noted above, the facility uses SCR as their primary NOx control technology, but also employs the use of SNCR as their secondary or back up control technology for NOx, with two injection locations in the preheater tower. The selection of the overall control equipment, in addition to deriving and maintaining satisfactory operating conditions for the equipment at this facility, has been very challenging.

The catalyst selection for the SCR technology was a challenging part of developing the system, with numerous trials taking place before an acceptable design was selected. The SCR includes a multiple stage honeycomb and plate catalyst bed of primary titanium dioxide and about 2% vanadium pentoxide which utilizes the catalyst beds as necessary to control of NOx to achieve the permitted limit of 500 mg/m³. The low sulfur and low alkali content of the exhaust gas and dust from the kiln system has allowed this catalyst to work some of the time with extensive cleaning, but it took 3 years of pilot testing and one year of operations to debug the system in order to maintain more consistent operations of the equipment. Probably the main reasons that their system works as well as it does are the Bavarian raw materials, which are low in alkalis and sulfur (which cause plugging of the catalysts) and easy to burn.

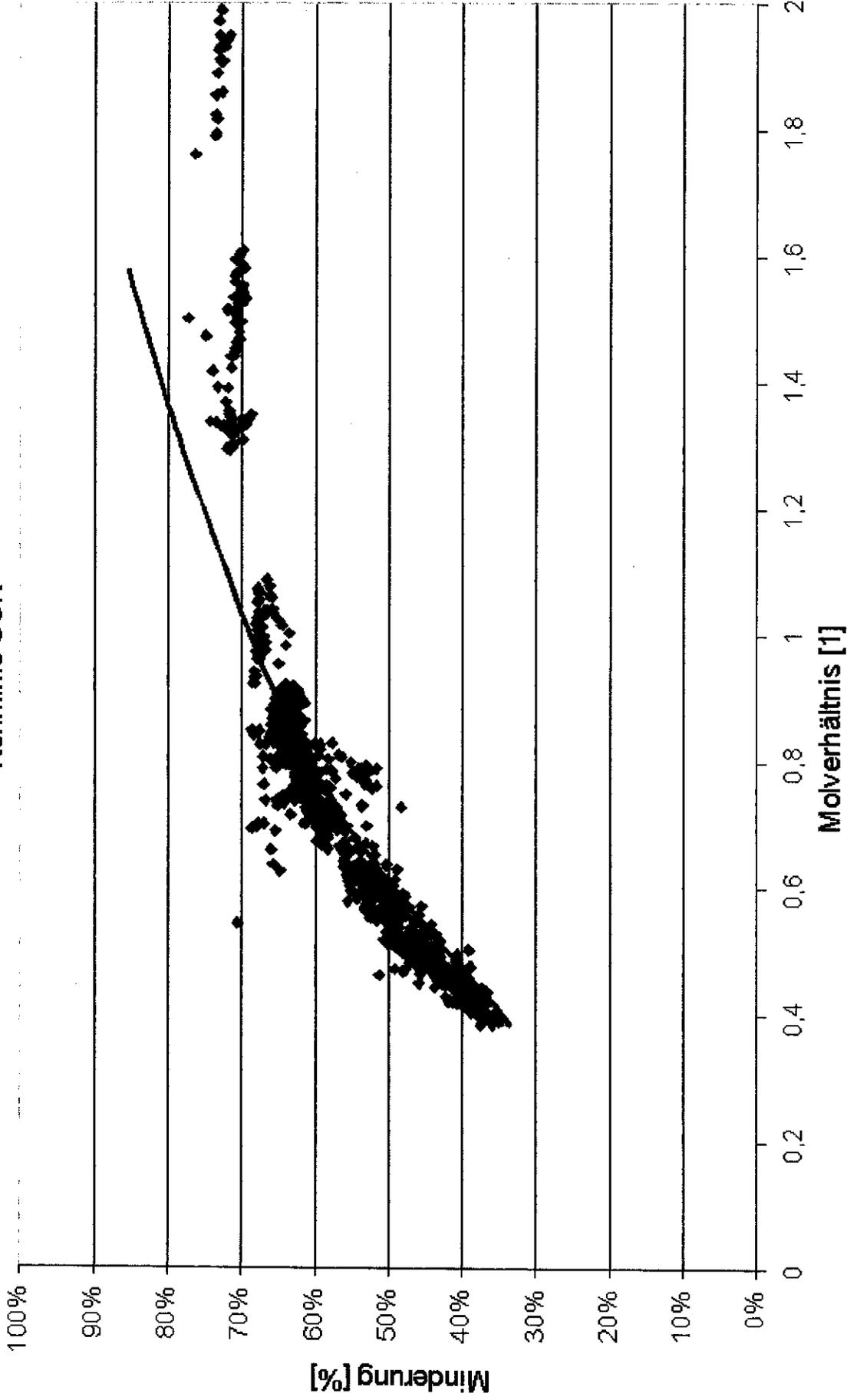
During start-up/debugging of the SCR catalyst operations, the facility developed an extensive and unique system of catalyst dust cleaning. Cleaning activities for this challenging environment include significant use of high pressure air, reverse heated compressed air flow, air cleaning valves and low frequency acoustical horns. In addition to the extensive automated cleaning activities, it is still necessary to perform a substantial amount of regular manual cleaning activities (taking two shifts to accomplish the cleaning in conjunction with overnight cleaning with acoustic horns). Generally, they can run for 7 to 14 days before the upper two layers of the catalyst are plugged requiring 24 hrs of cleaning activities on the catalyst to return the system back into full operation. The actual timing between cleaning is determined by the pressure drop across the catalyst bed, which is evaluated through monitoring. If the pressure drop is too high the system is bypassed for cleaning, and SNCR serves as the back up NOx control

system. This particular problem is a main contributor to the reliability issues associated with such high dust, SCR systems.

The SCR technology is also very temperature dependent, and the Solnhofen facility has to operate in a narrow temperature window due to the specific composition of the catalyst material. Temperatures must be maintained below 400°C to prevent damaging the catalyst, and above 330 °C to stay in the effective working range of the catalyst material. At temperatures outside of the 330 - 400 °C operating window, the catalyst bed is bypassed and SNCR is started as their back up system.

The data I have on the catalytic operations of the SCR system at Solnhofen indicates that the control efficiency peaks and levels off at 70% NO_x reduction at a molar ratio of 1:1 and the removal efficiency does not increase with more ammonia usage. This would indicate a maximum efficiency for their SCR control as less than the 80-90 percent reported in some documents. In contrast, there is also data (graphs attached) that shows SNCR (red line) is capable of meeting and exceeding this control efficiency in some instances, and it is not limited to the 1:1 molar ratio as found at Solnhofen(blue dots). Also many of the SNCR test in both the U.S. and Europe have indicated good results (greater than 60% control). It is important to note that these results are also dependent on kiln specific chemical and physical limitations.

Kennlinie SCR



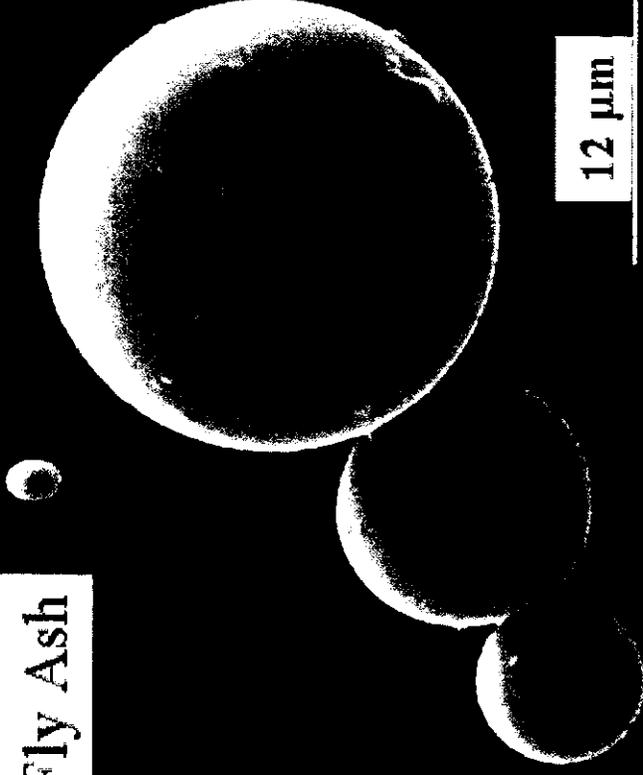
Some of the issues with using SCR technologies developed from transfer of the technology from the power industry to the cement industry. The cement industry exhibits higher dust loading, and different types, shapes and chemistry of the dust. Power plant dust is fine, spherical, and typically lower in calcium oxide and alkalis than cement kiln dust (pictures of dust attached). Cement kiln dust is coarser and larger, which will exasperate plugging, fouling and poisoning of the catalyst. Cement kiln dust loading is also about ten times higher than the typical power plant high dust applications.

Cement



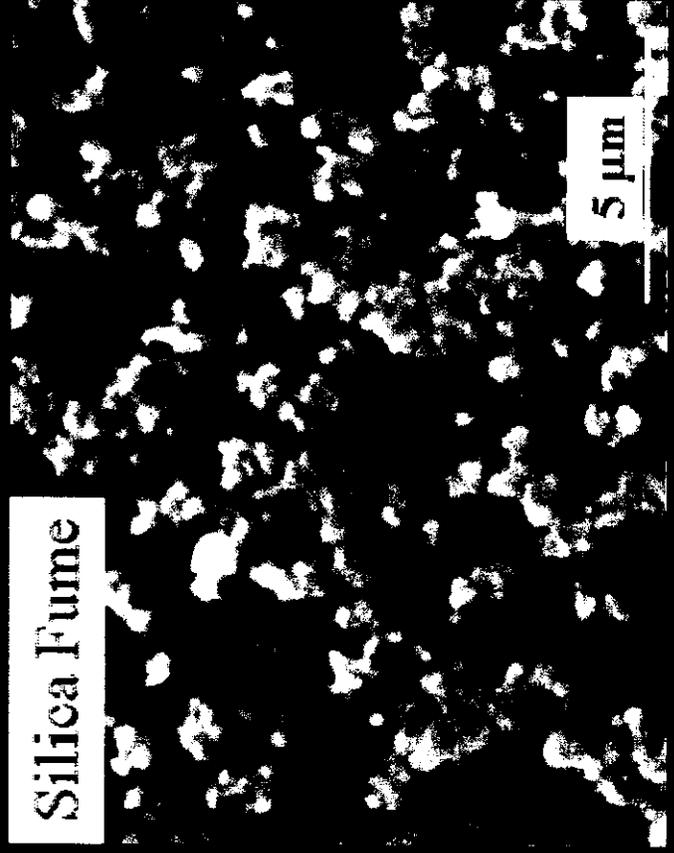
5 μm

Fly Ash



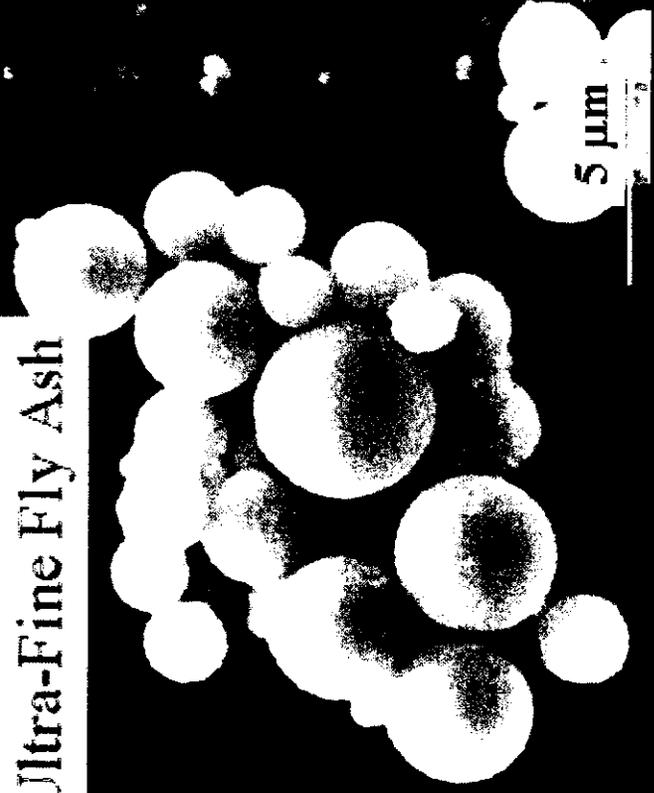
12 μm

Silica Fume



5 μm

Ultra-Fine Fly Ash



5 μm

SCR in Cement Plants

I know this was sort of long winded ; but such a topic is difficult to describe with a few bullet point. I hope it helps. If you need anything else or have any questions, just give me a call.

Best Regards,

Mark

This e-mail message and any attachment contains private and confidential information and is intended for the addressee only. If you are not the intended recipient (or responsible for delivery of the message to such person), please do not read, copy, use or disclose this communication to others. If you have received this message in error, please notify the sender by replying to this message, and then delete it from your system. Thank you.

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Voice: 770-955-3660

Main Fax: 770-955-8789

2004 data translated

Continuously measured emissions combustion conditions and its estimation

All numbers in dry mg/Nm ³ (milligram per cubic meter dry exhaust fumes at standard conditions in reference to 10% oxygen)	Half-hour Averages		Daily Averages	
	Limit	Compliance in %	Limit	Compliance in %
Dust	36	100	16	95.6
HCl	60	100	10	77.7
SO ₂	200	100	50	100
NO _x	1000	99.3	500	72.3
Mercury	0.05	100	0.03	89.8
Measures against future infringements: NOx: Improve operations of the unit				
Optimization of changing operations Mercury and chlorine hydrogen: short-term buildup by				

Unterrichtung der Öffentlichkeit gemäß der 17. BImSchV über den Betrieb des Zementwerkes

1. Eigentümer der Anlage: Solnhofer Holding AG

2. Betreiber: Solnhofer Portland-Zementwerke GmbH & CO.KG

3. Berichtszeitraum: 01.01.2004 - 31.12.2004

4. Rauchgasreinigungen:

- Entstaubung: Gewebefilter
- Entstickung: Katalysator SCR-Verfahren, Reduktionsmittel NH₄OH

5. Abfall-Mitverbrennung:

- genehmigter Einsatzstoff: BPG (produktspezifische Abfallstoffe)

6. Kontinuierlich gemessene Emissionen/Verbrennungsbedingungen und deren Bewertung:

alle Zahlen als mg/m ³ i.N. trocken (=Milligramm pro Kubikmeter trockenes Abgas im Normzustand bei einem Bezugssauerstoff von 10,4 %)	Halbstundenmittelwerte		Tagesmittelwerte	
	Grenzwert	Einhaltung in %	Grenzwert	Einhaltung in %
Staub	36	100	16	95,6
Chlorwasserstoff	60	100	10	77,7
Schwefeloxide	200	100	50	100
Stickoxide	1000	99,3	500	72,3
Quecksilber	0,05	100	0,03	89,8

Maßnahmen gegen zukünftige Überschreitungen:	Staub:	Gasberührende Metallteile in Edelstahl ausführen
	Nox:	Bessere Brennbedingungen durch Einsatz eines neuen Ofenbrenners sowie weitere Optimierung der SCR-Anlage
	Chlorwasserstoffe:	Chloreintrag durch Sekundärbrennstoffe erheblich mindern
	Quecksilber:	Optimierung der kurzfristig ändernden Rohmaterialzustände

7. Einzelmessungen und deren Bewertung

Die Messungen wurden durch eine nach § 26 BImSchG zugelassenen Meßstelle durchgeführt.

Parameter	Einheit	Grenzwert	Mittelwert	Maxwert der Messreihe
gasförmige anorg.	mg/m ³	60	<0,15	0,4
gasförmige anorg. Fluorverbindung	mg/m ³	4	<0,17	0,3

Quecksilber und seine Verbindung	mg/m ³	0,05	0,012	0,0166
Cadmium und seine Verbindungen	mg/m ³	0,015	<0,00007	0,00018
Thallium und seine Verbindungen	mg/m ³	0,015	<0,00001	<0,00001
Nickel und seine Verbindungen	mg/m ³	0,15	0,00008	0,00017
Summe aus Antimon, Arsen, Blei, Chrom, Kobalt, Kupfer, Mangan, Nickel, Vanadium, Zinn und deren Verbindungen	mg/m ³	0,4	0,00156	0,0029
Summe aus Benzo(a)pyren, Arsen, Cadmium, Chrom, Kobalt und deren Verbindungen	mg/m ³	0,05	0,00053	0,00105
Dioxine und Furane: Toxizitätsäquivalente	ng/m ³	0,05	0,00142	0,00168

8. Ansprechpartner bei Rückfragen:

Landratsamt Weißenburg/Gunzenhausen

Herr Löffler

Tel.: 09141/902-319

Herr Schott

Tel.: 09141/902-324

Solnhofer Portland-Zementwerke

Herr Sauter

Tel.: 09145/601-220



P.O. Box 410
Branford, FL 32008

February 10, 2005

Trina Vielhauer
Division of Air Resources
Department of Environmental Protection
2600 Blair Stone Road, MS # 5500
Tallahassee, Florida 32399-2400

SUBJECT: Selective Non-Catalytic Reduction (SNCR) Test Report
DEP File No. 1210465-013-AC
Suwannee American Cement – Branford Plant
Facility ID No. 1210465
PSD-FL-259D

Ms. Vielhauer:

In accordance with the Departments Authorization for SNCR Testing for the Control of Oxides of Nitrogen NOx (DEP Permit 1210465-013-AC) Suwannee American Cement (SAC) tested SNCR from November 8th to November 29th. SAC enlisted the help of the Process Manufacturer and Cement Process Expert Polysius to provide test equipment and assistance in testing. Additionally, SAC reserved the services of local Environmental Consulting Company Koogler & Associates to help during testing and perform emission monitoring during the SNCR testing. The services of cement and process expert Dr. F. Gregory Miller were also retained by SAC to oversee testing and evaluate the overall results of the SNCR test.

Please find the following information included in this package:

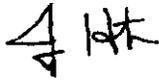
- Written Report from SAC containing information requested in DEP Permit 1210465-013-AC,
- Copy of Report provided to SAC from Polysius summarizing results and findings of SNCR testing,
- A summary report from Dr. John Koogler on the results of the SNCR testing,
- A report from Dr. F. Gregory Miller on the observations and results of the SNCR testing,
- Stack Test report provided by Koogler & Associates, and
- Data CD with all relevant process and emission data recorder during SNCR testing

In general SAC was very pleased with the results of the testing which indicated some favorable results for the use of SNCR to reduce NOx emissions. Several unique conditions were identified at SAC which allowed for substantial reductions in NOx emissions with the existing process equipment beyond expected and typical results.

ATTACHMENT 4

If you have any questions or require any additional information, please feel free to contact me at (386) 935-5039 or by e-mail at jhorton@suwanneecement.com.

Sincerely,

A handwritten signature in black ink, appearing to be 'J Horton'.

Joe Horton
Suwannee American Cement

CC: **Jim Pennington – DEP**
Al Linero – DEP
Chris Kirts – DEP
Celso Martini – SAC
Tom Messer – SAC
Dr. F. Gregory Miller – Cement Etc., Inc.
Dr. John Koogler – Koogler and Associates

SAC SUMMARY OF SNCR TESTING



SNCR RESULTS

BACKGROUND

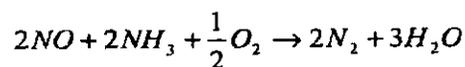
On November 3, 2004 Suwannee American Cement (SAC) received authorization from the Department under Construction Permit 1210465-013-AC to conduct testing of a Selective Non-Catalytic Reduction (SNCR) system for the reduction of NOx emissions. SAC wished to evaluate the effectiveness of the SNCR system on controlling of NOx emission and to determine what affect use of SNCR would have on the process and quality of the product. SAC outlined with the Department a Testing Protocol to be followed during the testing to help both SAC and the Department to evaluate the effectiveness of the SNCR system. Due to operational restraints some portions of the Testing Protocol had to be adjusted, but overall the goals set forth in these principals were accomplished.

NOx FORMATION AND SNCR PROCESS

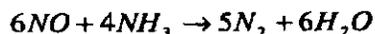
NOx is formed as a result of reactions occurring during combustion of fuels in the main kiln and calciner of the kiln system. NOx is produced through three mechanisms during combustion 1) fuel NOx, 2) "prompt" NOx, and 3) thermal NOx. Typically Fuel NOx and "prompt" NOx are minimal in comparison to thermal NOx. Due to the process nature of Cement Manufacturing a portion of thermal NOx can not be avoided since high temperatures are needed to insure proper chemistry and quality of the clinker.

Certain controls can be put in place to help reduce the formation of thermal NOx however, NOx levels increase with higher flame temperatures that are typical in the kiln burning zone and excess Oxygen. SAC currently utilizes several of the latest Control Technologies to help reduce the formation of NOx and to help reduce the NOx emissions that are generated. These include a modern Preheater/Preclinker design, a Calciner design with Staged Combustion (Staging of Air, and Feed), and Low NOx burners. With the above technologies SAC is able to control NOx emission limits below 2.9 lb NOx/ton of clinker and 304.5 lb NOx/hour on a twenty four average. These are low emission limits and to achieve them over short averaging periods requires sacrificing kiln operations and product quality at times to insure compliance. To achieve greater reductions in NOx emissions and/or to allow for higher flame temperatures and excess oxygen, an additional add-on technology would need to be employed to further reduce NOx emissions.

SNCR is a type of add-on technology that can help to reduce NOx emissions by re-acting the NO (approximately 97% to 99% portion of NOx at SAC) with an ammonia based reagent to form Nitrogen gas (N₂). There two main reactions that occur to reduce NO to N₂ in the presence of excess oxygen are as follow:



The first equation dominates the second in temperature ranges from 1,600 °F to 2,000°F which are the typically temperatures available for injection in the kiln system. Another reaction is possible in the absence of oxygen but is typically associated with a catalyst in the Selective Catalytic Reaction (SCR) Process.





The SNCR system from Polysius also consisted of a control panel to monitor and record process variable such as flow of ammonia solution. The control panel also could be used to control the ammonia flow in relation to NOx emissions at the stack. Polysius also provided a duplicate Continuous Emission Monitoring (CEM) system for monitoring NOx and CO emissions at the stack for automatically controlling the ammonia solution.

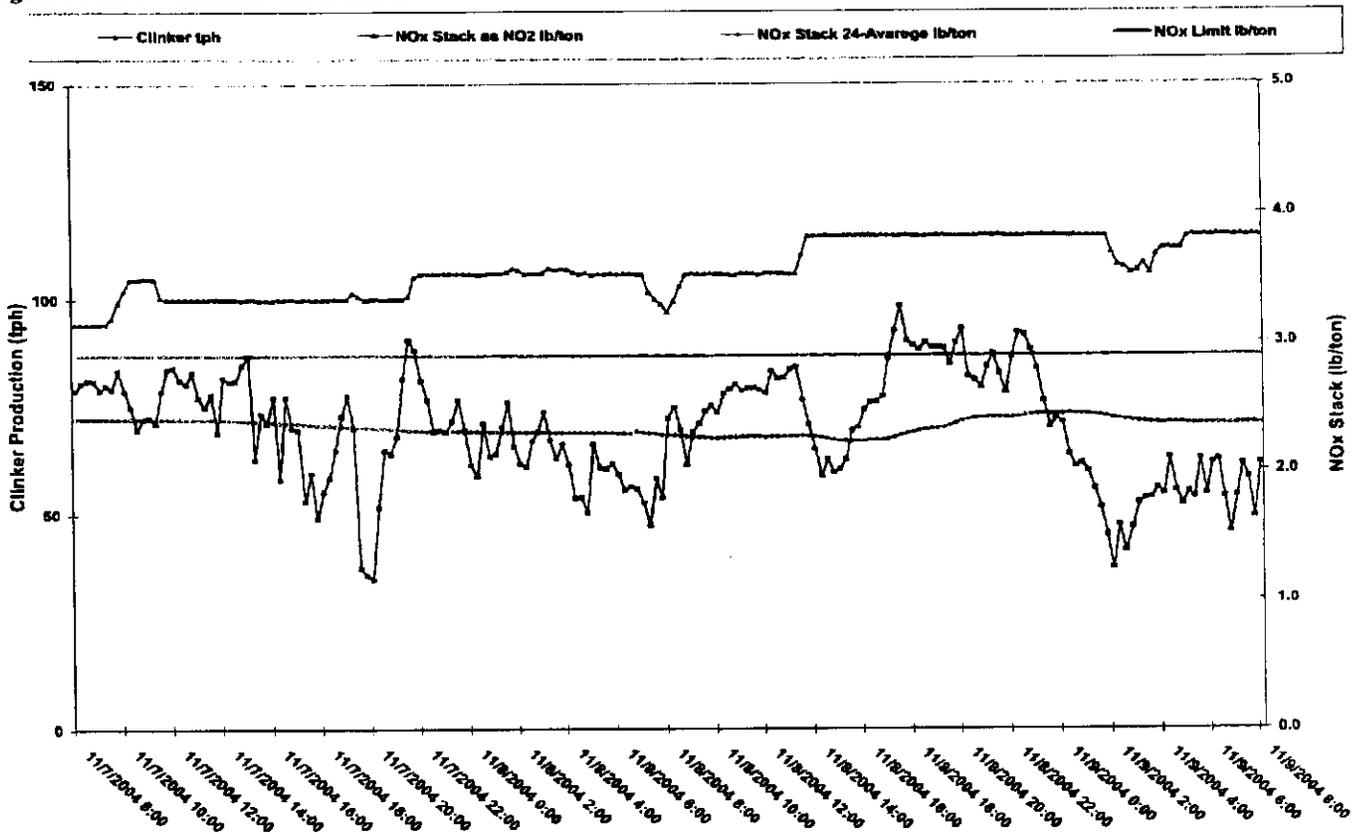
RESULTS OF SNCR TESTING

In accordance with the Testing Protocol provided by the Department in Attachment A of the SNCR Construction Permit (1210465-103-AC), SAC sought to gather data for the different operating conditions. The operating and testing conditions had to be adjusted in accordance to operational limitations but the following two scenarios were established and tested

1. DETERMINATION FOR MSC WITH SNCR

SAC established baseline emissions for NOx utilizing existing operating conditions and MSC to control NOx emissions prior to the arrival of Polysius and the SNCR testing equipment. Figure 2 shows the kiln production and the NOx emissions on a 15-minute average and 24-hour average for the two days prior to injection.

Figure 2: MSC without SNCR Baseline





From Figure 2, it can be seen that normal NOx emissions utilizing MSC in conjunction with low NOx burners resulted in NOx emissions on average of 2.4 to 2.5 lb NOx/ton of clinker. To accomplish this, SAC utilizes the MSC and the Combustion Chamber to create reducing conditions to reduce the NOx generated by the Kiln Main Burner. SAC typically operates in this manner to comply with low NOx limits and short averaging times. SAC also frequently encounters process problems caused by this type of operation; i.e., the need to force strong reducing conditions and high CO at the kiln inlet. Most typically the problems consist of buildup in the riser duct (lowest portion of the calciner prior to the exit of the kiln). During the establishment of the baseline SAC did experience some operational problems that can be noted by the abrupt changes in clinker production. These signify process upsets or problems. However, overall operations were satisfactory and even with the characteristic NOx variation on the 15-minute average the 24-hour average remained relatively low.

The next portion of the testing called for SAC to maintain operations with the use of the MSC and injection progressively larger amounts of ammonia to ascertain the affects of ammonia and MSC in conjunction. On November 10th and 11th SAC began the process of injection of ammonia while utilizing the MSC as shown in Figure 3 and Figure 4.

Figure 3: SNCR Injection with MSC November 10th

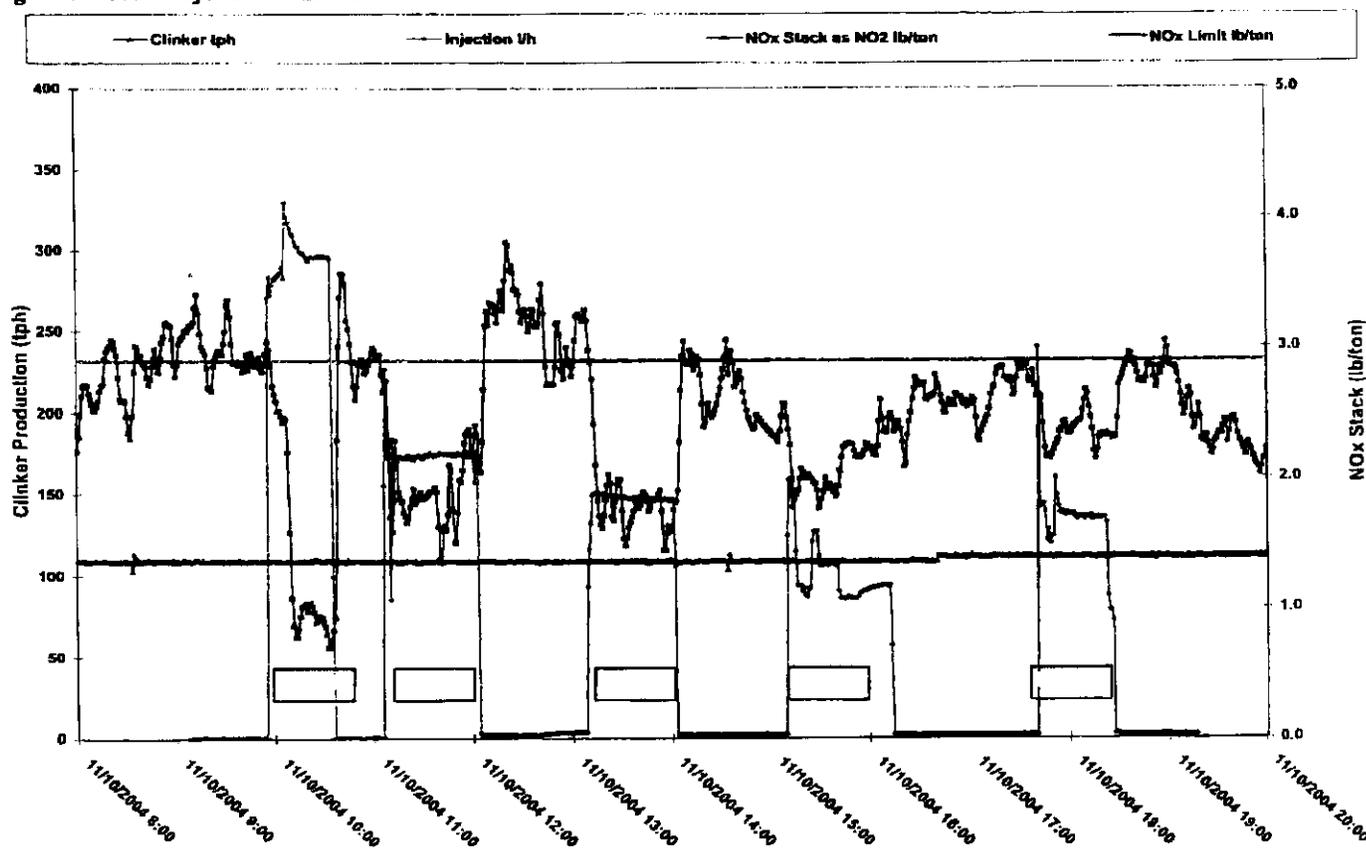
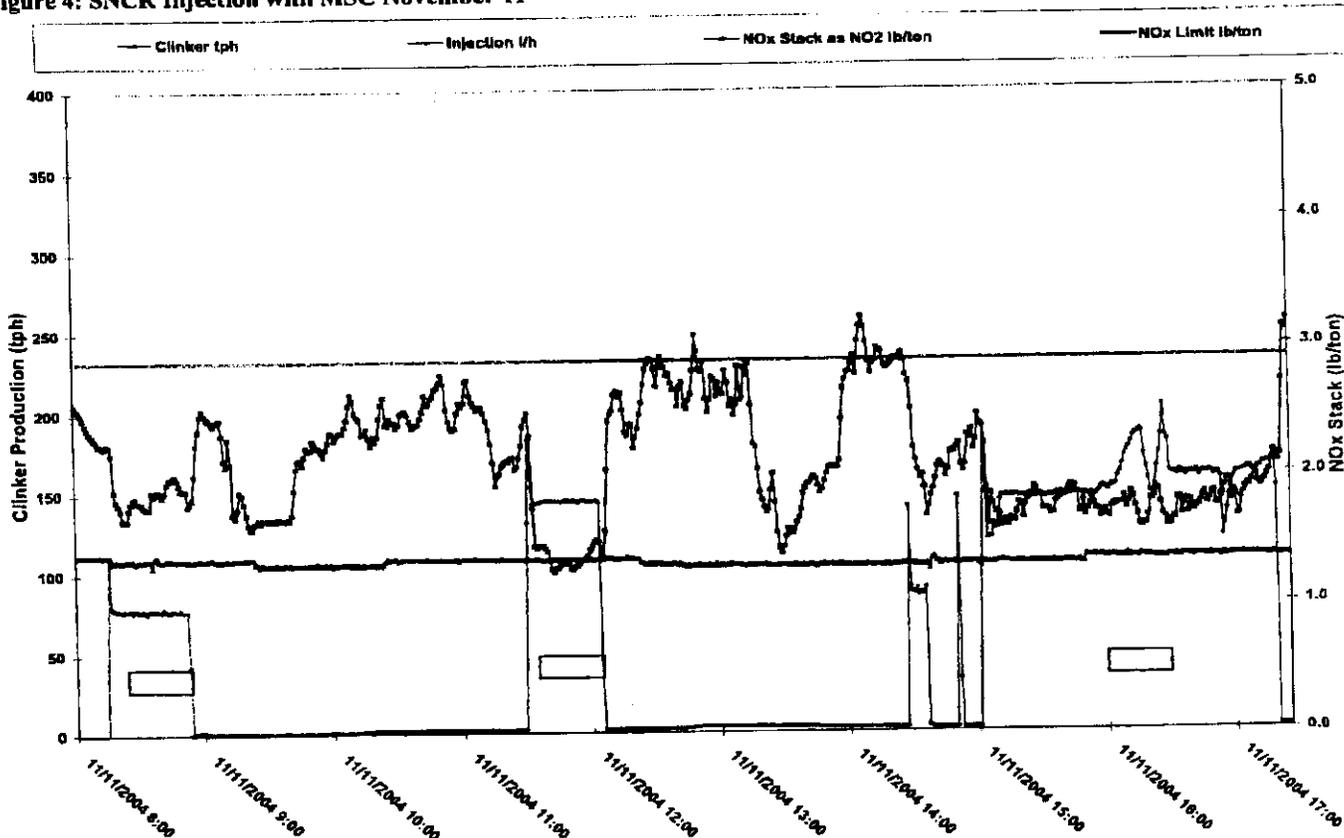




Figure 4: SNCR Injection with MSC November 11th



As can be seen from the graphs, the injection of the ammonia reduced the NOx emission observed at the stack. The increase in ammonia solution injection corresponded to increases in NOx reductions at the stack as expected. However with the use of the SNCR it was difficult to hold the baseline for NOx emissions established prior to injection of ammonia by utilizing only MSC. This results in NOx emissions rising above the original baseline established in Figure 1 when the ammonia solution was stopped after most of the test runs. For each ammonia injection test period, the uncontrolled NOx emissions were calculated as the average of the uncontrolled emissions prior to and after the injection period.

During the combined testing of SNCR with MSC, much more stable kiln conditions were observed as shown by the steady production rate with no the abrupt changes in clinker production noted in Figure 1. This could be in part to the increasing of the excess oxygen in the kiln above the baseline despite the attempt to keep oxygen constant with the baseline as proposed in the Protocol. This could have been due in part to increased NOx emissions at the stack being masked by the SNCR reductions. Regardless the MSC in conjunction with the SNCR yielded excellent results for NOx reduction and for stability of kiln operations.

The other surprising factor was the efficiency with which the ammonia injection reduced the NOx emissions. The typical method for measuring the efficiency is defined by comparing the molar ratio of NOx (NO) to Ammonia (NH₃). As previously discussed the dominating reaction for reduction of NOx



with an ammonia solution is one to one molar ratio. This results in the best theoretical reduction possible of 100% with a one to one molar ratio. However in typical applications, only half of the theoretical reduction is achieved. SAC however was able to achieve much larger reductions than are typically empirically observed. These results are summarized in Table 1 and will be discussed in more detail in the Conclusion section.

Table 1: Ammonia to NOx Reduction

Run #	SAC Molar Ratio	NOx Reduction	Average NOx Before	Average NOx During SNCR
	NH3:NO	%	lb/hr	lb/hr
1	0.918	65.49%	325.47	112.31
2	0.533	36.71%	322.90	204.35
3	0.425	44.93%	345.52	190.27
4	0.331	16.90%	282.70	234.91
5	0.465	15.49%	290.18	245.25
6	0.286	12.95%	269.35	234.47
7	0.534	45.06%	269.35	147.97
8	0.552	31.91%	281.71	191.81

2. DETERMINATION FOR SNCR WITHOUT MSC

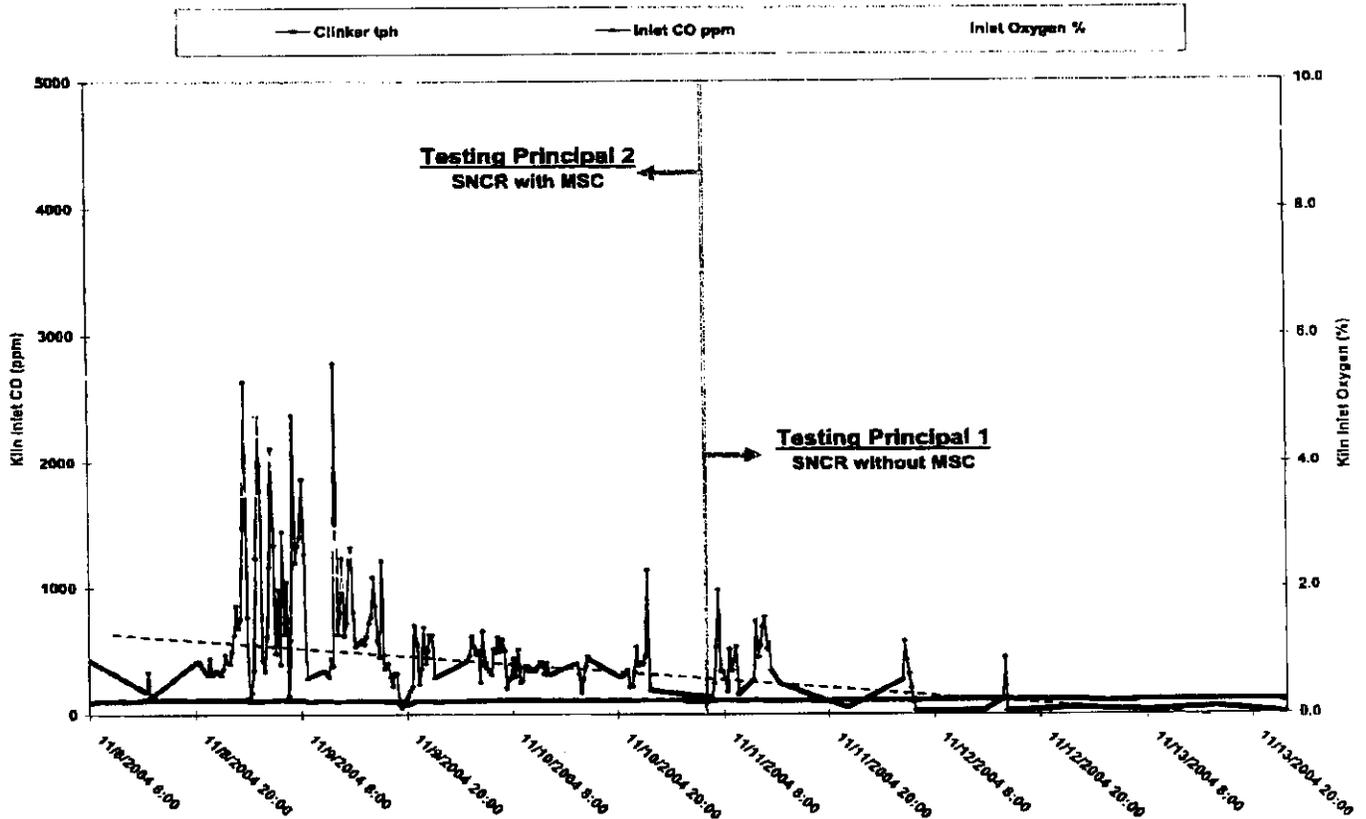
The second portion of the Testing Protocol involved the testing of SNCR without the use of the MSC principals. This phase of testing would help SAC to determine the operational advantages of operating the kiln with excess oxygen, resulting in higher NOx emissions, but relying on the SNCR to reduce the NOx emissions down to permitted limits. This phase of the testing would also allow SAC to evaluate the efficiency of the SNCR reaction in both the reducing MSC atmosphere and an oxidizing atmosphere.

To establish this phase of testing, SAC completed the SNCR testing with the MSC as described above and then proceeded to change the kiln operation by increasing the oxygen through the burning zone and kiln. This subsequently should produce more NOx from the kiln. After the testing on November 11, 2004, SAC and Polysius placed the SNCR system in automatic operations. In automatic operations, the SNCR system controls the injection rate of ammonia to maintain a set point for the NOx emissions at the stack. SAC attempted to keep the NOx emissions at or around 2.0 lb of NOx/ton of clinker in the automatic operations.

With the set point in place, SAC began to operate the kiln with more oxygen and to rely on the ammonia injection to control NOx emissions from the stack. The kiln was primarily run with the kiln inlet analyzer prior to the ammonia injection location. SAC attempted to control CO and oxygen at this location. The goal was to reduce the CO to as low as possible which inversely requires excess oxygen in the kiln for complete and proper combustion of all fuel at the main kiln burner. These conditions in theory should lead to easier kiln operations and better product quality because CO generation is avoided in the kiln and riser duct and the flame temperature can be increased. The overall increase in oxygen can be seen from previous operating conditions prior to November 11 and after November 11, 2004 in Figure 5.



Figure 5: Kiln Oxygen and CO evolution



From Figure 5 it can be seen that SAC achieved the results of increasing the oxygen in the kiln which subsequently eliminated CO in the kiln inlet area. As expected, this did help kiln stability. SAC proceeded to operate the kiln in this manner for the remainder of the test period; until November 29, 2004. Also during this time, SAC operated the SNCR system in automatic mode to determine the NO_x reduction possible in this operating mode and the efficiency of the reduction.

With the increase in oxygen in the kiln, increases in NO_x generation from the kiln were unavoidable. SAC relied on the SNCR to control emissions to around 2.0 lb NO_x/ton of clinker. Overall SNCR operations were able to keep and maintain this level of NO_x reduction with similar efficiency as tested prior with the MSC. With the SNCR system being a temporary installation, several periods of time arose when SNCR operations were stopped for operational problems or to make nozzle adjustments. SAC however, continued to operate without use of the MSC and in an oxidized state to establish baseline NO_x emissions without SNCR. An example of the baseline emissions of NO_x without SNCR and the reduction achieved with the SNCR can be seen in Figures 6 and 7.



Figure 6: SNCR Reduction without MSC #1

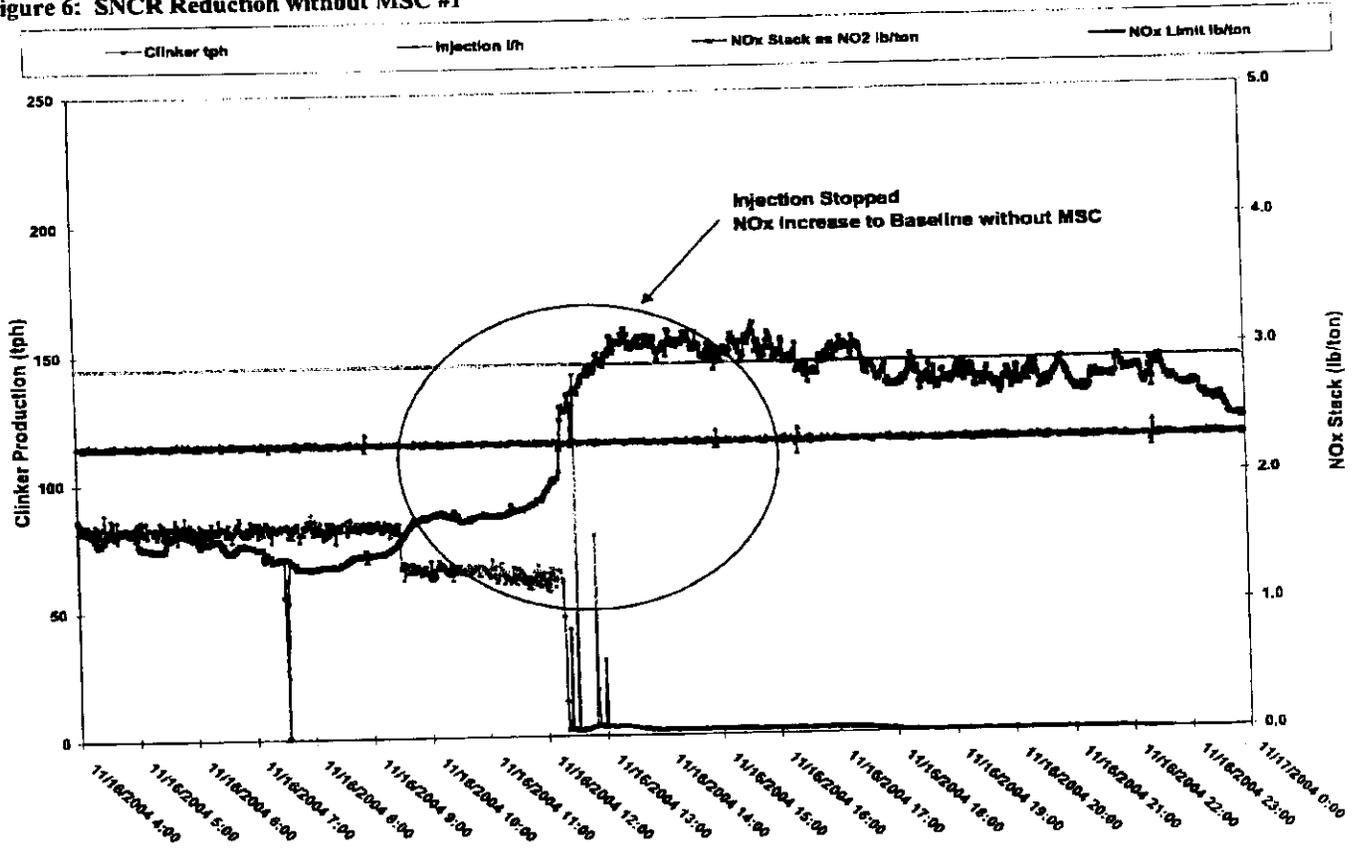
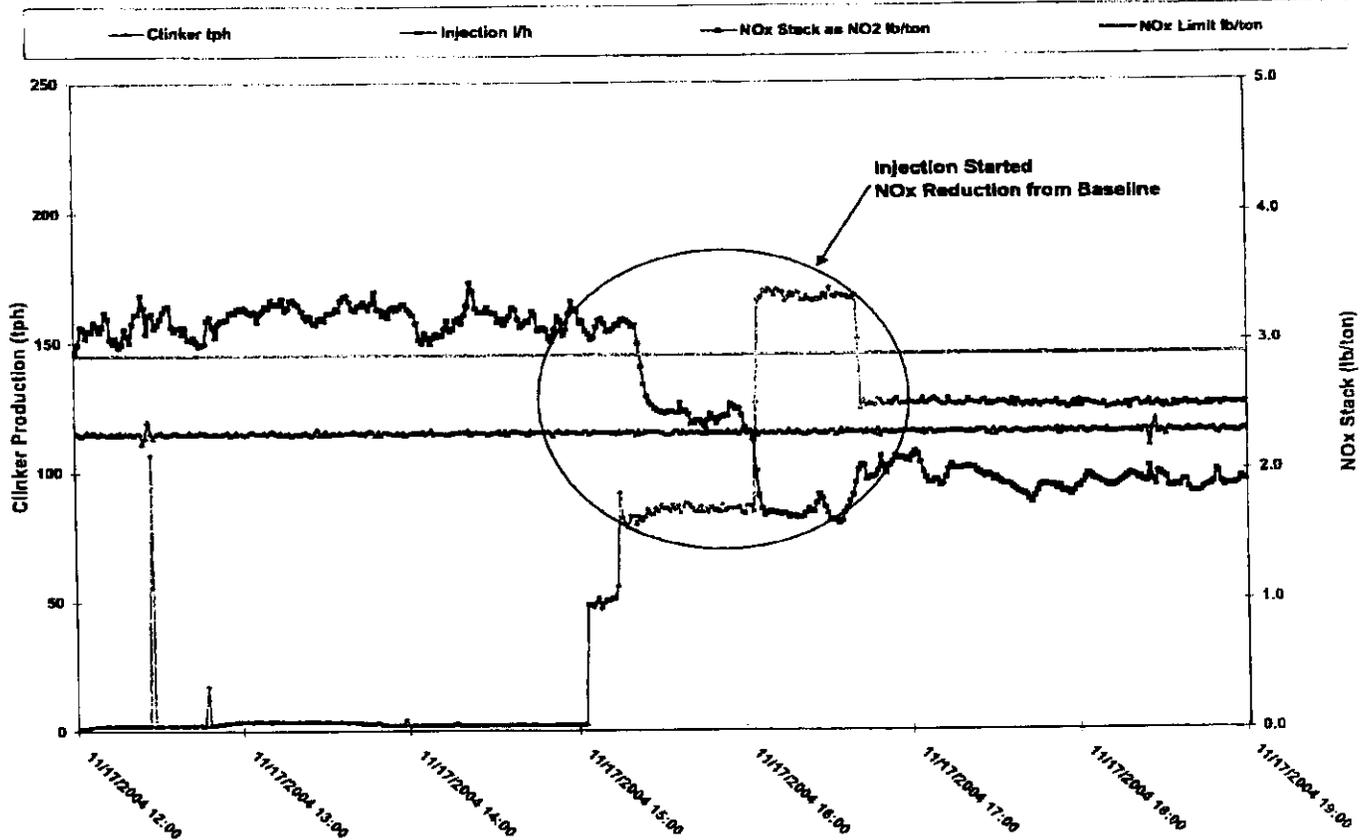




Figure 7: SNCR Reduction without MSC #2



Baseline emissions without utilizing the SNCR ranged from 2.8 lb NO_x/ton of clinker to 3.5 lb NO_x/ton of clinker. Based on the baseline emissions of NO_x during periods like those observed in Figures 6 and 7, SAC predicted similar efficiencies to those established during the first phase of testing. Since SAC was also trying to evaluate long-term operations of the SNCR during the second phase of testing, the SNCR system was not run in short test periods but for prolonged periods. However several periods of downtime for the SNCR still allowed SAC to evaluate the NO_x baseline emissions when operating with excess oxygen in the kiln.

AMMONIA EVOLUTION

One concern of the injection of ammonia based compounds into the kiln system is the possibility that not all of the ammonia will react with the NO_x, and that some of the unreacted will leave the process through the stack. As previously discussed, it has been observed elsewhere that typically only half of the theoretical reductions of NO_x are achieved; i.e., the ammonia utilization is about 50%. The simplest means to increase the NO_x removal efficiency is to increase the amount of ammonia beyond theoretical amounts to increase the reaction of ammonia with NO_x. This of course, will result in un-reacted ammonia in the stack gas. Even when less than theoretical molar ratios of ammonia are used, mixing and limited retention time in the required temperature zones can cause portions of the ammonia to not react and exit through the stack. This un-reacted ammonia is typically referred to as "ammonia slip".



Ammonia slip raises two concerns. First are the emissions of ammonia with the stack gas into the environment. The second and more notable concern is the formation of a detached plume. This is caused by the un-reacted ammonia reacting with SO₂ or HCl which themselves can be formed in the upper portions of the preheater tower from raw materials. The ammonia reacts with these compounds to form ammonium chloride and/or ammonium sulfate salts. These salts form in water droplets in the atmosphere some distance from the stack, depending on the stack temperature and dew point. This detached plume can cause major opacity concerns and visual impairments to the community. SAC was hopefully that detached plumes issues could be avoided since very little sulfur and chlorine are present in the kiln system. SAC wanted to continually monitor for ammonia slip to try and avoid it all together as a means of eliminating the potential of a detached plume.

To check for ammonia slip, SAC contracted Koogler and Associates to conduct continual monitoring of ammonia emissions in the main stack. This requires some extensive equipment and manpower to monitor these emissions continuously and it is not typically done during SNCR testing. Additionally, SAC and Koogler & Associates observed the stack for the detached plume or opacity occurrences.

As expected, detached plumes were not observed during the testing since very little SO₂ and HCl are present in the stack gases. However ammonia emissions were observed by Koogler & Associates. Ammonia slip only appeared in the stack when the kiln was operated without the raw mill. Figures 8 and 9 show the only two occurrences of operating with the raw mill down and the kiln in operations. The figures show the raw mill feed, the injection rate of ammonia and the ammonia concentration at the stack.



Figure 8: Ammonia Emissions in Stack #1

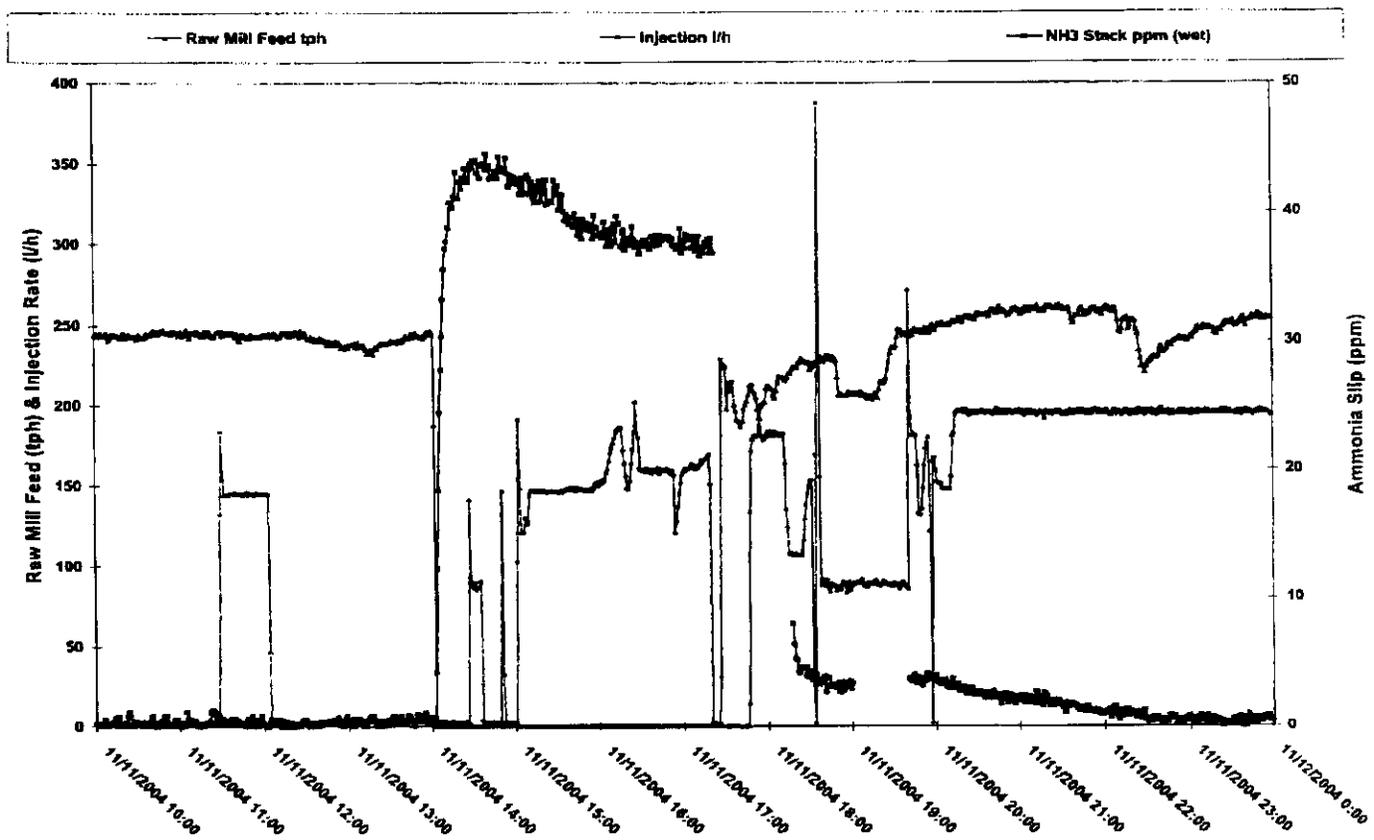
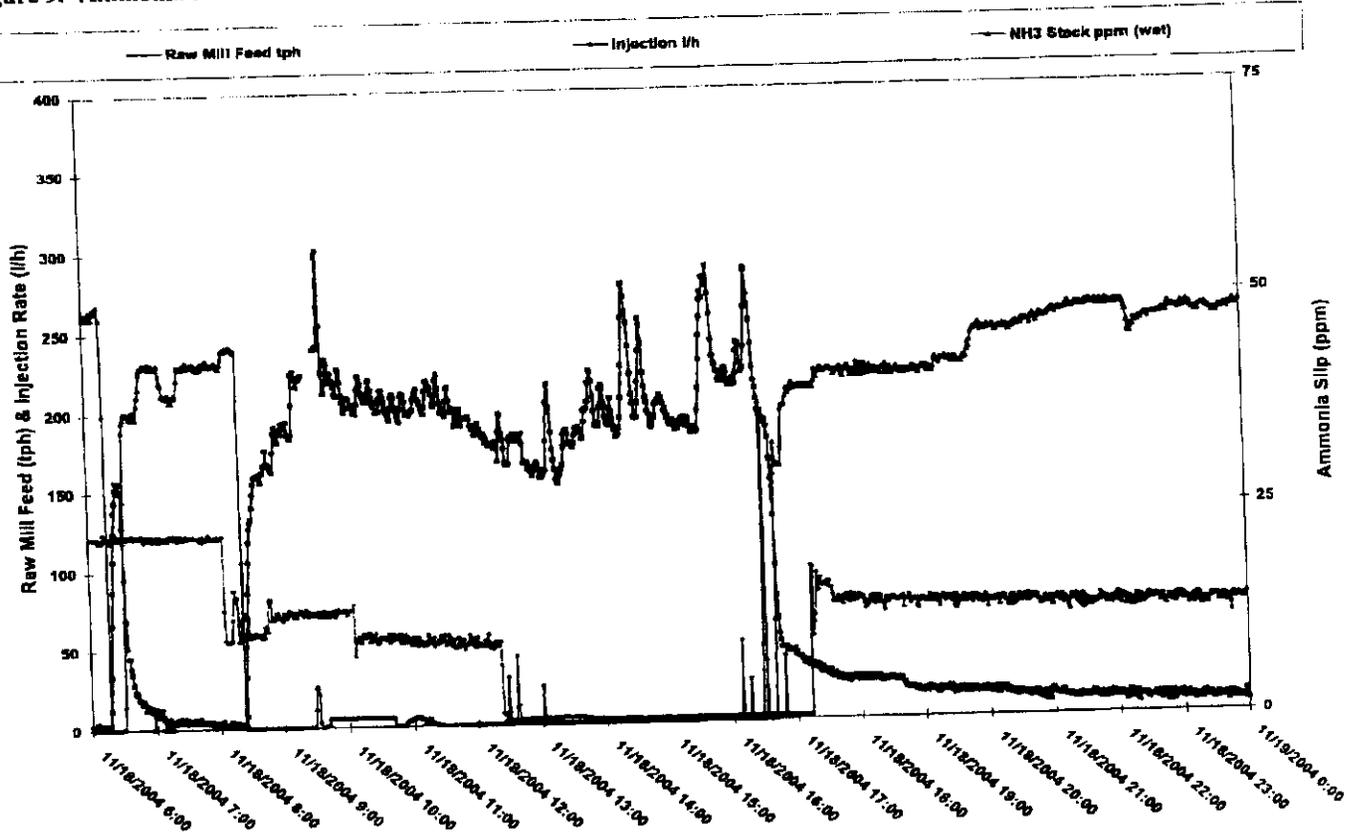




Figure 9: Ammonia Emissions in Stack #2



During the first instance of the raw mill down on November 11, 2004, no ammonia was being injected into the kiln system through the SNCR system. On the second instance with the raw mill down on November 18, 2004, injection was occurring when the raw mill went down but was stopped part way through the mill outage. However the injection rate seemed to have no correlation with the ammonia present in the stack. In both cases the concentration of ammonia in the stack gas peaked at about 50 ppm (v/v).

This led SAC to the conclusion that not all of the ammonia being injected into the system was reacting with the NOx. Additionally, the ammonia seemed to be caught in an internal cycle in the kiln/raw mill system. When the raw mill was removed from the process during raw mill outages, this removed the scrubbing offered by the raw meal and the ammonia escaped through the stack.

SAC sent several kiln feed samples off for evaluation for ammonia concentrations from varying periods during the testing to evaluate the possible enriching of the kiln feed with ammonia. The sample results and time periods are in Table 2.



Table 2: Kiln Feed Ammonia Analysis

Material	Date	Analysis	Results
Kiln Feed – Prior to Injection	11/8 Day Shift Composite	Ammonia (Specific Ion Electrode) Chlorine	<33.9 mg/kg
Kiln Feed – During Ammonia Injection	11/12 Day Shift Composite	Ammonia (Specific Ion Electrode) Chlorine	49.2 mg/kg
Kiln Feed – During Ammonia Injection	11/16 Day Shift Composite	Ammonia (Specific Ion Electrode) Chlorine	34.3 mg/kg
Kiln Feed – During Ammonia Injection	11/17 Night Shift	Ammonia (Specific Ion Electrode) Chlorine	45.4 mg/kg

The analysis on the kiln feed unfortunately yielded higher detection limits than needed for a meaningful comparison. With the detection limit of ammonia in the feed being so high prior to ammonia injection, it is impossible to evaluate whether or not there was an increase in ammonia in the kiln feed. Regardless, the subsequent samples with the exception of the sample on 11/16 seem to show an enriching of the kiln feed with ammonia from un-reacted ammonia. This supports the assumption by SAC that an internal ammonia cycle was present with the raw mill in operations.

SAC attempted to take ammonia gas samples from the downcomer of the preheater tower prior to the kiln exit gases entering the raw mill. The analysis for ammonia at this location in the kiln yielded no detectable amount of ammonia. Based on these data and the short-term nature of the testing SAC, is left to assume that some small portion of ammonia was un-reacted in the SNCR process. As ammonia is highly soluble, the ammonia condenses onto the moist particles in the raw mill. As the volatile ammonia is introduced to the higher temperatures in the raw mill and/or preheater tower, it evaporates back into the gas stream to repeat the process. This would support the results that show the increase in the ammonia present in the kiln feed during the SNCR testing. This process continues until the raw mill is down, removing the scrubbing effect, and the ammonia escapes out the stack.

Unfortunately this ammonia cycling could not be evaluated in more detail during this test and would require long-term studies of SNCR operation to determine the exact nature of the ammonia cycle. SAC is still left with the concerns regarding ammonia slip with the raw mill down and the uncertainty of how long-term operations of SNCR will affect ammonia concentrations in kiln feed and eventually clinker.

Ammonia slip during raw mill down presents the possibility of detached plume problems in the future since raw mill also operates as a scrubbing device for SO₂. The raw mill down portions of normal plant operations could lead to both SO₂ and ammonia emissions, resulting in detached plume issues. SAC has been able to avoid sulfur cycles with the raw mill through careful screening of raw materials but with long-term injection of ammonia, the possibility of a detached plume occurring greatly increase.

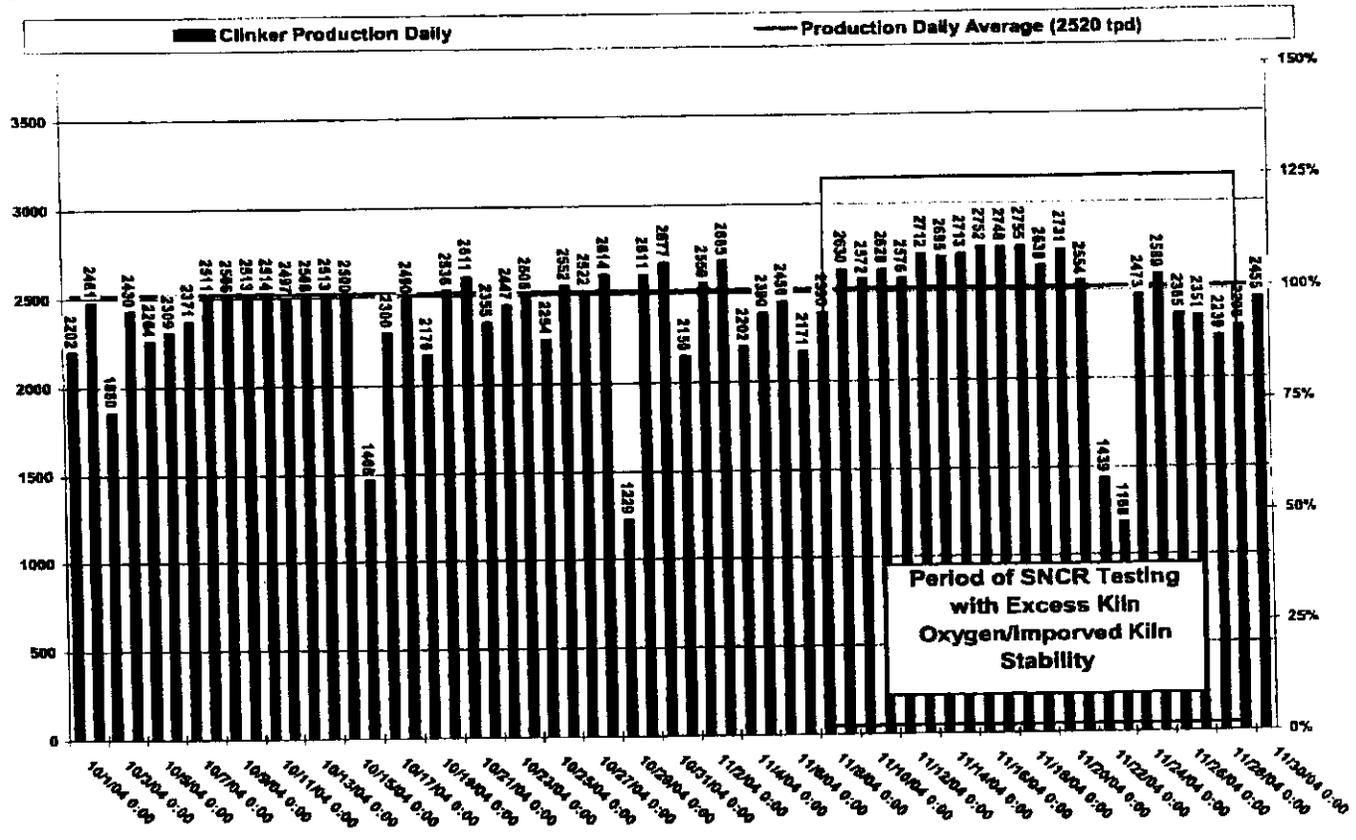
With a permanent SNCR system and more long-term operating experience, better process optimization can occur to try and avoid the ammonia slip all together. Better mixing and longer retention time for the ammonia solution can help to increase the reaction rate of the ammonia with the NO_x. This leads to increased efficiency and reduces ammonia slip. Another means to reduce the slip is reduce the injection amount. However, since the injection rate of ammonia determines the amount of NO_x reduction, to maintain certain emission levels, some ammonia slip may have to occur.

CONCLUSIONS

Considering the goals of the SNCR testing protocol, SAC was pleased with the results of the test. SAC was able to achieve reductions in NO_x emissions to or below 2.0 lb NO_x/ton of clinker utilizing SNCR both with MSC and without MSC. Increased process stability was realized during both testing periods. Figure 10 shows the daily clinker production during the SNCR testing and the dates immediately before and after.



Figure 10: Daily Clinker Production - Month of November, 2004

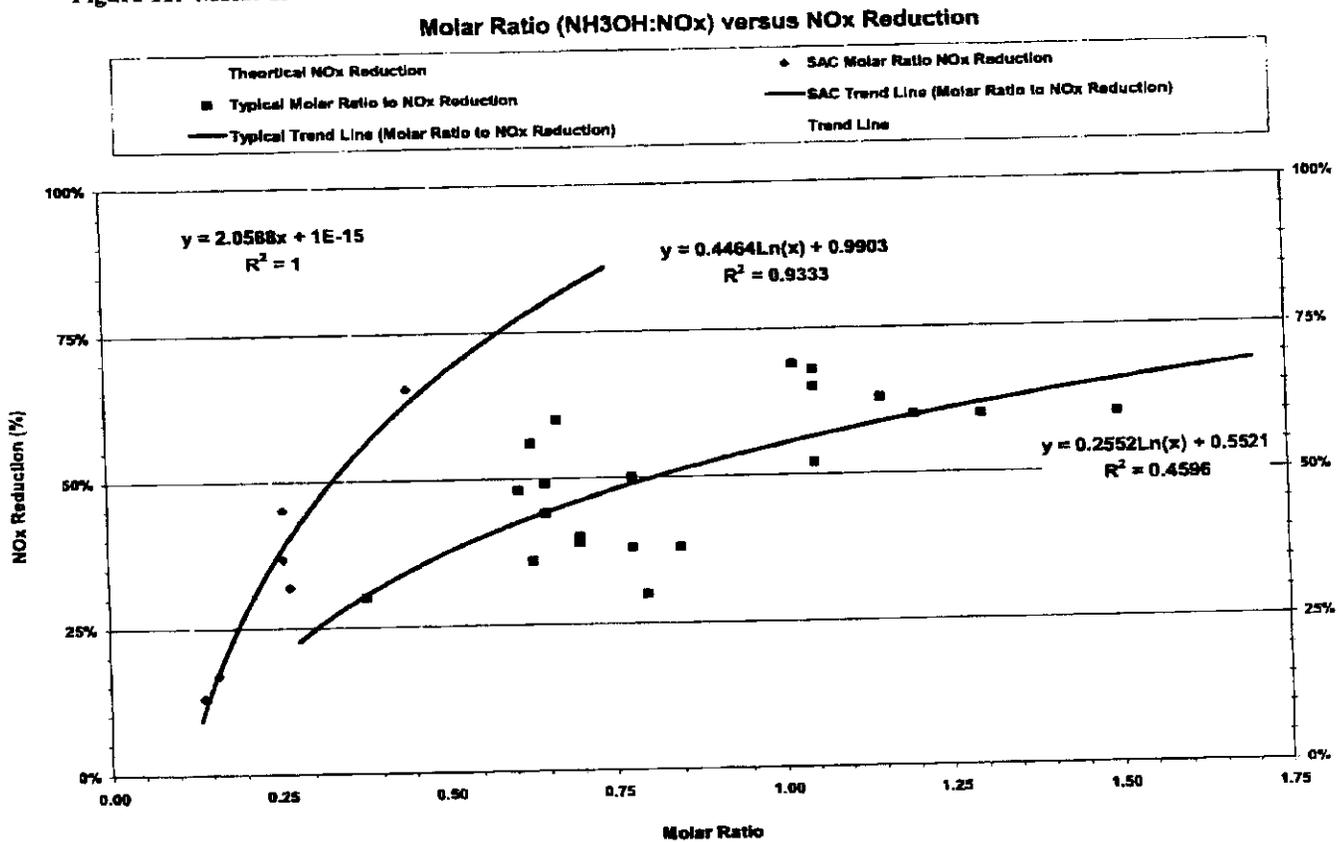


The increased kiln stability during the SNCR testing translated to increase production which can clearly be seen in Figure 10. This kiln stability was realized even in conjunction with the operation of the MSC and SNCR. Again this may have been due to the inability to control baseline emissions, with the SNCR system masking NOx emissions. Operators may have inadvertently drafted more oxygen through the kiln while operating with MSC and SNCR because the NOx emissions were lower than typical with the SNCR.

Another observation made during the testing was the high efficiency with which the SNCR system utilized ammonia to reduce the NOx emission. Based on other tests on cement kilns, and even other industries, the typical results SAC was able to achieve in the efficiency of NOx reductions were substantially greater than those typically seen. Typically, empirically observed SNCR reductions are half of theoretically expected values based on the molar ratio of ammonia to NO. SAC achieved substantially greater NOx reductions, close to stoichiometric reductions in NO, despite the presence of some ammonia slip. SAC compared its results with data from another similar type and size kiln in Europe that conducted SNCR testing. SAC also compared its results with the stoichiometric reduction rates achievable in theoretical or ideal lab situations. The comparisons of molar ratios to NOx reductions for these three scenarios are shown in Figure 11.



Figure 11: Molar Ratio to NOx Reduction



For comparison with Polysius data from a previous test on a similar kiln, SAC had to use the same molar ratio comparison as Polysius. Polysius compares the molar ratio of ammonium hydroxide (NH₄OH) to NO_x, since ammonium hydroxide is the intermediary in the ammonia reduction process that reacts with the NO_x. This essentially multiplies the molar ratio used by SAC by 0.5 (the ratio of the m.w. of ammonia [17] to that of NH₄OH [35]). Also, the empirical data lends itself towards a logarithmic trend. Theoretically the trend should be a linear relationship but understandably limitations apply to mixing and the ability for the ammonia to come in contact with the NO which makes reaction more difficult at higher reduction rates.

However, the data for SAC still show a good correlation with the exception of data from two tests when injection problems occurred. These data points are removed from Figure 11. What is surprising when looking at Figure 11 is the reduction SAC achieved per unit of ammonia when compared with the other plant. The yellow line represents the stoichiometric reduction ratio of one mole of ammonium hydroxide to one mole of NO_x. SAC test results almost achieve this theoretical ratio in a practical SNCR application at a cement plant.

SAC is still actively researching possible causes for such high NO_x removal efficiencies during the testing in order to better understand. SAC is studying the interactions of the SNCR process with CO, oxygen and possible volatile organic compounds (VOC) from incomplete combustion that are present in the area of injection. Additionally the absences of competing reactions for the ammonia from sulfur dioxide and chloride, which are not present at SAC but typically common in cement plants, could help to



explain the favorable results. SAC is also studying the interaction of the ammonia beyond the intended reaction zone with CO which can lower the effective temperature window for the non-catalytic reaction. Lastly SAC is investigating the possible reactions with catalysts that may be present in the raw materials or fly ash to help to determine the means for the positive results.

Regardless of the cause, SAC achieved substantial reductions in NO_x and achieved the desired results set forth in the Test Protocol. Advantages for the use of SNCR in conjunction with MSC and without MSC were observed. With MSC, the amount of NO_x present in the ammonia injection zone is initially reduced, thus minimizing ammonia use. The overall efficiency of the reduction seems to be independent of the operation of the MSC principal. Operation of the SNCR without MSC allowed for excess oxygen to be present in the kiln providing for an oxidizing condition while still maintaining the desired NO_x emission level at the stack. This oxidized condition leads to greater kiln stability and process control.

SAC has currently applied to the Department for permission to install a permanent SNCR system on the existing kiln. Only long-term practical operations will determine the amount of NO_x reduction possible while avoiding such problems as ammonia cycles or ammonia slip. Also, continued operation will be necessary to evaluate the effect of SNCR on carbon monoxide emissions. However from this testing, SAC is confident that SNCR can effectively reduce emissions of NO_x and allow for great process variability.

**SUMMARY REPORT FROM DR. JOHN KOOGLER
OF KOOGLER & ASSOCIATES**

**REPORT OF SNCR RESULTS FROM
DR. F GREGORY MILLER**

**STACK TESTING REPORTS FROM KOOGLER
& ASSOCIATES**

SELECTIVE NON-CATALYTIC REDUCTION TEST REPORT

**FLORIDA ROCK INDUSTRIES, INC.
Thompson S. Baker Cement Plant**

**Facility ID: 0010087
Newberry, Florida**

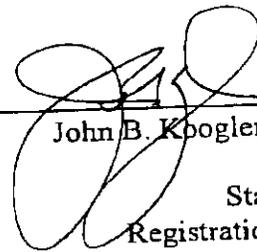
**Test Date: December 6-11, 2004
Report Date: February 2, 2005**

***Koogler & Associates, Inc.
4014 N.W. 13th Street
Gainesville, Florida 32609
(352) 377-5822***

187-04-16



To the best of my knowledge, all test data and plant operating data are true and correct and the conclusions presented herein are representative of the data reported.



John B. Koogler, Ph.D., P.E.

State of Florida
Registration No. 12925

2/2/05

Date



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Appendix

1.0 INTRODUCTION

Florida Rock Industries, Inc. (FRI) operates the Thompson S. Baker Portland cement plant on CR 235, approximately 3.5 miles north of the city center of Newberry, Florida. The plant is a modern preheater/precalciner Portland cement plant designed by the Polysius Corporation. The plant has a permitted clinker production rate of 2650 tons per day and currently operates under FDEP Permit 0010087-009-AV.

On November 8, 2004 the Florida Department of Environmental Protection (FDEP) issued Air Construction Permit 0010087-011-AC to FRI authorizing tests to assess the viability of Selective Non-Catalytic Reduction (SNCR) for the control of NO_x emissions from the cement kiln. These tests were conducted during the period December 6-11, 2004. The Polysius Corporation designed the tests, supplied the equipment for the injection of ammonia and provided personnel to operate the equipment. Additionally, Polysius monitored and reported the ammonia injection rates and the stack gas concentrations of NO and oxygen. FRI personnel were responsible for operating the plant, reporting plant operating data and operating continuous emissions monitors for NO_x, SO₂, total hydrocarbons, and stack gas flow located in the kiln/raw mill stack. Koogler and Associates, Inc. was the engineer of record for the tests and monitored ammonia and carbon monoxide in the kiln/raw mill stack.

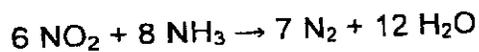
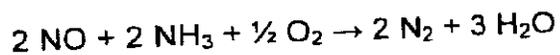
The purpose of the testing was to evaluate the effectiveness of SNCR for NOx reduction. The ammonia used for the tests was a 10 percent (by weight) ammonia/water solution. This solution was injected into the calciner just before the Stage I cyclone (the bottom cyclone) of the preheater. This injection point was selected by Polysius based on experience at other plants. Ammonia was injected at various rates defined by the molar ratio of ammonia to uncontrolled NOx (NO + NO₂) measured in the kiln/raw mill stack. The NOx reductions measured in the kiln/raw mill stack are reported as a function of these molar ratios. The ammonia injection tests were conducted with and without the firing of whole-tire derived fuel at the kiln inlet. The tests demonstrated NOx reduction efficiencies in the range of 6-82 percent with molar ratios in the range of 0.1-1.0.

Additionally, ammonia was injected at varying rates for approximately a 16-hour period to maintain a set stack gas NOx concentration of about 130 ppm (v/v); equivalent to about 1.8 pounds of NOx per ton of clinker. This test demonstrated that a relatively constant NOx stack gas concentration can be maintained with an SNCR system by varying the injection rate of ammonia.

Finally, this report includes a cost estimate for the operation of an SNCR system at the FRI Thompson S. Baker Cement Plant based on the results of this test program.

2.0 THE SNCR PROCESS

The bases of the SNCR process are reactions between ammonia (NH₃) and NO and ammonia and NO₂. In these reactions, the NO and NO₂ are chemically reduced to elemental nitrogen. The governing reactions are as follows:



These reactions take place without the aid of a catalyst and are highly temperature dependent. With the injection of aqua ammonia (an ammonia/water solution), the optimum reaction temperature is approximately 950°C (1750°F). For urea injection, the optimum temperature is in the range of 1000°C (1830°F). For temperatures significantly below these optimum temperatures, some of the ammonia is unreacted and ends up in the raw materials or as ammonia in the stack gas. At temperatures significantly above the temperatures, the ammonia will react with oxygen, increasing the concentrations of NO and NO₂ (referred to as collectively herein as NO_x).

The actual reaction between ammonia and NO_x first involves the reaction of ammonia with OH[•] radicals to produce the NH₂[•] radical and water. The NH₂[•]

then reacts with NO_x to produce the elemental nitrogen and water as shown in the above equations.

Because of this intermediate reaction, another factor to take into consideration is the presence of carbon monoxide (CO) in the gas stream into which the ammonia is injected. The oxidation of CO to CO₂ involves the same OH[•] radicals that react with ammonia to produce the NH₂[•] radical. Thus, if CO is present, there are competing reactions between the CO and NH₃ for the OH[•] radicals and both the oxidation of CO and the creation of NH₂[•] radicals suffer.

For SNCR to be effective, therefore, there must be enough residence time in the precalciner between the injection of tertiary combustion air and the injection of ammonia for the CO to be substantially oxidized. Considering these factors, Polysius has found that the most favorable point of ammonia injection at this Multi-Stage Combustion (MSC) plant is just prior to the Stage I cyclone of the preheater.

Polysius has found that because of the aforementioned competing reactions between CO and NH₃ for OH[•] radicals, the presence of unoxidized carbon monoxide at the point of ammonia injection will result in an increase in carbon monoxide emissions. Polysius has reported (*Latest Developments in NO_x Reduction Technology in the Cement Industry*, R. M. Erpelding, Polysius A.G.-

Germany, Cement Plant Environmental Handbook, 2003) that at a molar ratio of ammonia to NO_x of 0.8, CO emissions will increase in the range of 0.3-1.0 pounds per ton of clinker. At a molar ratio of 1.0, the CO increase will be in the range of 0.5-1.5 pounds per ton of clinker.

3.0 SNCR TEST EQUIPMENT

Polysius supplied the equipment necessary for injecting the aqua ammonia. For the test at FRI, a 10 percent (by weight) ammonia in water solution was delivered by tank truck. The specific gravity of the solution was 0.9582.

The Polysius equipment consisted of three components; a control panel, the pump station and the injectors. The aqua ammonia was delivered from the tank truck through a 20 stage centrifugal pump and a series of controllers to the injectors at a pressure in the range of 150-220 psig (10-15 bars). Four injector nozzles were placed at 90 degrees to one another in the wall of a circular cross section of the precalciner just upstream of the Stage I cyclone of the preheater. Each injector nozzle created a flat fan-shaped distribution with an aperture angle of 60 degrees. The flat, thin spray of aqua ammonia maximized the interface between the reagent and the gas stream, optimizing the reaction between ammonia and NOx. One to four nozzles were used during the test period depending upon the ammonia injection rate.

The entire system was controlled with a control panel designed to maintain a constant ammonia injection rate or to vary the ammonia injection rate in order to maintain a constant stack gas NOx concentration.

The Polysius controller recorded NO in the stack gas (ppm, dry), stack gas oxygen (volume percent, dry), kiln feed (tons per hour provided by FRI), stack gas flow (from the FRI continuous monitoring system), and the ammonia injection rate, and other operating variables.

4.0 MONITORING

Ammonia injection at varying set molar ratios and ammonia injection at a variable rate to maintain a set stack gas NO_x concentration was conducted during the period 0800 hours on December 9, 2004 and 2400 hours on December 10, 2004. During this period of time, there were two periods of disruption in kiln feed (See Figure 1). Ammonia injection tests were not conducted during these periods.

During the periods of testing, the kiln feed rate ranged from 165-175 tons per hour and averaged approximately 170 tons per hour (approximately 102 tph of clinker). During this period of time, the kiln and calciner were both fired with coal. Testing was conducted for about a one hour period between 0800-0900 hours on December 9 while whole-tire derived fuel was fired at the kiln inlet and again between 1400-2400 hours on December 10, 2004 with the firing of tire derived fuel. The tire firing rate typically averages about one ton per hour and provides about seven percent of the total heat input to the pyroprocessing system.

FRI was responsible for monitoring the kiln feed rate, the fuel firing rates, clinker production rate, and stack gas parameters including NO_x, SO₂, total hydrocarbons, flow rate and temperature. The stack gas monitoring was conducted with continuous monitors permanently installed in the FRI kiln/raw mill stack. These monitors have been previously certified in accordance with the

requirements of 40 CFR 60, Appendices B and F. The FRI NO_x data were used for the analyses presented herein.

Polysius was responsible for the ammonia injection and the monitoring of parameters associated with this injection. These parameters included the ammonia injection rate and stack gas concentration of NO, O₂, and CO. The NO, O₂, and CO were measured on a dry basis in a bypass stream from the Koogler and Associates monitors.

Koogler and Associates was responsible as the engineer of record for the testing and monitored ammonia and CO in the stack. The ammonia was monitored continually in accordance with the general procedures of EPA Method 320 (the FTIR method) and CO was measured in accordance with the general procedures of EPA Method 10. Both methods are described in 40 CFR 60, Appendix A. The CO monitored in accordance with Method 10 was used for the analyses reported herein.

The extractive stack gas monitoring (NH₃ and CO) and the continuous in-stack gas monitoring were conducted in the 112-inch diameter, 241-foot high kiln/raw mill stack. The sampling ports are located 15.7 diameters downstream from the point where gases enter the stack and 5.4 diameters below the top of the stack.

5.0 DESCRIPTION OF TESTS

The purpose of the SNCR tests was two fold. First, the NOx (expressed as NO₂) control efficiency was determined as a function of the molar ratio of ammonia to uncontrolled NOx and secondly, a test was conducted with variable ammonia/NOx molar ratios to see if a set stack gas NOx concentration could be maintained.

In both cases, the ammonia was injected into the calciner just prior to the Stage I cyclone of the preheater. At this point, the average temperature during the test period was 862°C (1580°F) and the average pressure was -15 millibars (approximately -6 in. H₂O).

For the NOx reduction tests, ammonia was introduced for discrete periods of time ranging from approximately 30-60 minutes. During each injection period, the ammonia injection rate was held constant at a predetermined NH₃/NOx molar ratio. The molar ratios ranged from approximately 0.1-1.0. Tests were conducted with whole-tire derived fuel fired at the inlet of the kiln and again with no whole-tire derived fuel being used.

Before and after each ammonia injection period, the uncontrolled NOx (expressed as NO₂) concentrations were measured in the stack gas. The

uncontrolled NOx emission rate for each NH₃ injection period (expressed as pound per ton of clinker) was calculated as the average of the uncontrolled NOx emission rates before and after each injection period. From these data, the NOx reduction for each test period was calculated as:

$$\text{NOx Reduction (\%)} = (\text{NOx}_{\text{uncontrolled}} - \text{NOx}_{\text{controlled}}) \times 100 / \text{NOx}_{\text{uncontrolled}}$$

The molar ratio of ammonia to NOx was calculated as the molar injection rate of ammonia (moles per hour) divided by the uncontrolled NOx emission rate (moles per hour). The molar injection rate of ammonia was based on a 10 percent (by weight) solution of ammonia in water. The specific gravity of this solution was 0.9582. The molar injection rate of ammonia is expressed as moles of NH₃ per hour.

6.0 TEST RESULTS

The results derived from the SNCR testing at FRI are divided into three sections; NOx control as a function of ammonia injection rate, factors associated with carbon monoxide and ammonia emissions and the estimated cost of operating an SNCR system at FRI.

6.1 NOx Control Efficiency

The control of NOx from the kiln/raw mill stack is defined as a function of the uncontrolled emissions and the controlled emissions as defined in Section 5.0. The uncontrolled emissions are based on NOx data collected immediately before and immediately following periods of ammonia injection. During the time periods used for determining uncontrolled NOx emissions, no ammonia was being injected. The controlled emissions were measured and calculated based on data collected during each period of ammonia injection.

The controlled and uncontrolled NOx emissions, expressed both as pounds per ton of clinker and pound-moles (of NO₂) per hour for each period of ammonia injection are summarized in Table 1. One set of data was collected while tire derived fuel was fired at the kiln inlet and the second set of data was collected with no tire derived fuel being burned.

The ammonia injection rate was varied from approximately 75-600 liters per hour during the NOx control efficiency test period. Ammonia was injected at six discrete flow rates while tire derived fuel was being used and six discrete flow rates when no tire derived fuel was being used. The time periods of ammonia injection typically ranged from 30-60 minutes.

The injection rates of ammonia were calculated in terms of moles per hour based on the injection rate of the ten percent aqua ammonia solution (liters per hour), a solution specific gravity of 0.9582 and the molecular weight of ammonia (NH_3 ; m.w. = 17).

The molar ratio of ammonia to NOx was calculated for each period based on the ammonia injection rate (moles per hour) and the uncontrolled NOx emission rate (moles per hour). The data summarized in Table 1 show that the molar ratios for the two test periods combined ranged from approximately 0.1-1.0.

The NOx control efficiencies range from about seven percent with a molar ratio of 0.09 (with no tire derived fuel) to about 82 percent with a molar ratio of 1.04 (with no tire derived fuel). The control efficiencies with tire derived fuel ranged from about 34-68 percent with molar ratios ranging from 0.12-0.64. The control efficiency data are also shown in graphical form in Figure 2.

It will be noted from the data presented in Figure 2 that the apparent NO_x control efficiency is greater when tires are used as a supplemental fuel than when tires are not used. This is particularly true at the lower molar ratios; i.e., between 0.1 and 0.6. At molar ratios of 0.6 and above, the control efficiencies tend to converge.

The difference in control efficiencies with and without tire derived fuel is not readily explained. Looking at the data in Table 1, it will be noted that in general, the uncontrolled NO_x emissions during tests without tire derived fuel were greater than the uncontrolled NO_x emissions when tire derived fuel was being burned. This would indicate a higher oxygen level at the kiln exit (resulting in higher uncontrolled NO_x emissions) when no tire derived fuel was used. This higher oxygen level and the fact that oxygen was not consumed by the combustion of tire derived fuel, would have a tendency to lower CO levels in the calciner and result in a more efficient reaction between ammonia and NO_x (See Section 2.0). The control efficiency data are contrary to this.

The data presented in Figures 3 and 4 are the time dependent NO_x emission rates, carbon monoxide emission rates, and ammonia injection rates for the SNCR tests when tire derived fuel was being burned (Figure 3a-3c) and when no tire derived fuel was being burned (Figure 4). These data confirm that when the highest uncontrolled NO_x emissions occurred (the lower molar ratio injections

with no tire derived fuel), the CO emissions were lowest (approximately 10 pound-moles per hour). As the uncontrolled NOx emissions decreased (again with no tire derived) the CO emissions increased to approximately 20 pound-moles per hour. This higher CO emissions rate was typical of most of the ammonia injection periods when tire derived fuel was fired (Figures 3a-3c). Again, the lower levels of CO would indicate the reaction between ammonia and NOx should be more efficient. As stated previously, the data in Figure 2 do not support this.

For purposes of evaluating the effectiveness of SNCR for NOx control under the variable conditions of this cement plant, it is probably best to use the relationship between ammonia injection and NOx control represented by the combined data set shown in Figure 2.

The molar injection of ammonia (pound-moles per hour) is compared with the reduction in NOx in the stack gas (pound-moles per hour) in Figure 5. Again, these data show an apparent greater reduction when tire derived fuel was being burned than when tire derived fuel was not being burned. Again, it is probably best to use the combined data set to represent the functioning of SNCR at this cement plant.

These data show that stack gas NO_x is reduced by approximately 0.8 pound-moles with the injection of 1.0 pound-mole of ammonia. The data further show that this relationship is linear over the injection rates tested (molar ratios between 0.1 and 1.0). This indicates an ammonia utilization efficiency of about 80 percent.

The other part of the NO_x control efficiency tests was to set a stack gas NO_x concentration and to maintain this concentration over an extended period of time by varying the ammonia injection rate. This was done for an approximate 16-hour period between 1800 hours on December 9 and 1000 hours on December 10, 2004. The ammonia injection rate (liters per hour) and the stack gas NO_x concentration (ppm) for this period of time are presented in Figure 6. These data show (for the limited period of this test) that it is possible to maintain a relatively constant NO_x emission rate by varying the ammonia injection rate.

For the period, the stack gas NO_x concentration averaged approximately 130 ppm (equivalent to an NO_x emission rate of 1.80 pounds per ton of clinker). The ammonia injection rate for the period ranged from approximately 200-400 liters per hour (equivalent to molar ratios of NH₃/NO_x of 0.35-0.70).

6.2 Carbon Monoxide and Ammonia Emissions

Carbon monoxide and ammonia concentrations were measured in the kiln/raw mill stack during the SNCR test period in accordance with the general procedures of EPA Methods 10 and 320, respectively.

6.2.1 Carbon Monoxide Emissions

The carbon monoxide emissions (pound-mole per hour) are presented graphically in Figures 3 and 4 for periods when tire derived fuel was fired and periods when no tire derived fuel was fired. During the period when tire derived fuel was fired (Figure 3a-c) the CO emissions were generally quite variable and no trend between ammonia injection and CO emissions is discernible. During the period when no tire derived fuel was fired (Figure 4) the CO emissions were more stable; especially during the first part of the test period. From these data, a trend of increased CO emissions is observed when ammonia was injected. This is consistent with previous Polysius observations and the reactions between ammonia, CO, and NO_x discussed in Section 2.0.

Until more experience is gathered defining the relationship between CO emissions and the injection of ammonia, FRI is comfortable with the CO emission limit proposed in the Air Construction Permit Application for Line No. 2 of 3.6 pounds of CO per ton of clinker.

6.2.2 Ammonia Emissions

The continuous monitoring of ammonia in the kiln/raw mill stack demonstrated that during most periods of time when the raw mill was operating, very little to no ammonia was observed in the stack gas. When the raw mill was not operating, however, the ammonia concentration in the stack gas peaked at approximately 40 ppm (v/v) (See Figure 7a-7b).

This indicates that the unreacted ammonia is absorbed in the raw materials in the raw mill and recirculated until such time that the raw mill shuts down. With the raw mill down, some of the absorbed ammonia is purged from the system.

Due to the limited period of time over which the SNCR tests were conducted at FRI (six days), no definitive conclusion can be reached regarding long-term ammonia emissions during the operation of an SNCR system.

It appears that long term, an ammonia equilibrium would be reached in the plant and that some ammonia slip may occur even with the raw mill running. The majority of the unreacted ammonia would more than likely still be purged during periods when the raw mill is not operating. The long-term effect of ammonia emissions can only be determined with the continuous operation of an SNCR system.

6.3 SNCR Cost Estimate

The SNCR system is relatively easy to install and operate compared with other add-on NOx control systems. Additionally, the operational costs (reagent, variable operating cost, and capital return) are relatively low compared with other systems and the SNCR system offers considerable operating flexibility.

In general, an SNCR system would include:

- an ammonia storage tank,
- a redundant pumping system,
- a control system,
- a set of injectors, and
- the necessary piping.

The system can be installed in a relatively short period of time with minimal plant downtime.

Based on data provided by Polysius and others, the basic fixed costs associated with an SNCR system for the FRI plant are approximately 0.20 dollars per ton of clinker.

The operating cost can vary considerably depending on the source of ammonia and the ammonia injection rate. For purposes of this report, the ammonia

considered was a 10 percent aqua ammonia solution at a delivered cost of \$145 per ton of solution (\$1,450 per ton of ammonia).

The cost data developed from data collected during the SNCR test period at FRI are presented in Figure 8. These data show the costs of an SNCR system (operating cost plus capital recovery) to reduce NOx emissions from a range of uncontrolled emission rates to a range of targeted controlled emission rates. For example, to reduce NOx emissions from 3.5 pounds per ton of clinker (uncontrolled) to 2.0 pounds per ton of clinker (controlled), the cost would be about 0.60 dollars per ton of clinker.

7.0 CONCLUSION

The six-day SNCR test at FRI demonstrated the apparent feasibility of SNCR for controlling NOx emissions from the FRI cement plant. NOx emissions were reduced between 7 and 82 percent with ammonia injected at molar ratios between 0.1 and 1.0. Limited testing also demonstrated that a relatively constant NOx level can be maintained in the kiln/raw mill stack gas by varying the ammonia injection rate.

Factors that could not be totally evaluated because of the short duration of the tests include the long-term ammonia equilibrium in the kiln/raw mill system and the effect of this equilibrium on ammonia emissions both during periods with the raw mill operating and with the raw mill not operating. Other factors that could not be fully evaluated are the long-term effect of ammonia on overall plant operations and the product quality and the effect of operating an SNCR system while using tire derived fuel.

The tests did demonstrate that SNCR is effective for controlling NOx emissions during normal plant operations. Because of the temperature dependency of the reactions associated with SNCR, it is apparent that SNCR will not be effective during plant startups and during periods of plant upset. There will also be periods of downtime for the SNCR system. During periods of startup, plant

malfunction and SNCR system downtime, NOx emissions can be controlled using best operating practices and Multi-Stage Combustion.

Table 1. Summary of NOx Control Efficiency Data

Test Condition	Uncontrolled NOx (as NO2)		Controlled NOx (as NO2)		NH3 as NH3 (lb-mol/hr)	Molar Ratio (NH3/NOx)	NOx Reduction (%)
	(lb/ton Cl)	(lb-mol/hr)	(lb/ton cl)	(lb-mol/hr)			
With Tires	3.10	6.83	2.05	4.63	0.84	0.12	33.9
	2.86	6.03	1.76	3.76	1.14	0.19	38.5
	3.17	7.02	2.07	4.62	1.78	0.25	34.7
	3.20	7.08	1.96	4.34	2.42	0.34	38.8
	3.28	7.34	1.52	3.43	3.73	0.51	53.7
	3.32	7.47	1.06	2.36	4.75	0.64	68.1
Without Tires	4.46	9.54	4.17	9.01	0.88	0.09	6.5
	4.21	9.00	3.46	7.88	1.85	0.21	17.8
	3.74	8.01	2.64	6.09	2.78	0.35	29.4
	3.59	7.68	1.90	4.10	3.64	0.47	47.1
	3.55	7.63	0.87	1.84	6.10	0.80	75.5
	3.17	6.91	0.58	1.26	7.19	1.04	81.7

Figure 1

Kiln Operating Rate During SNCR Tests

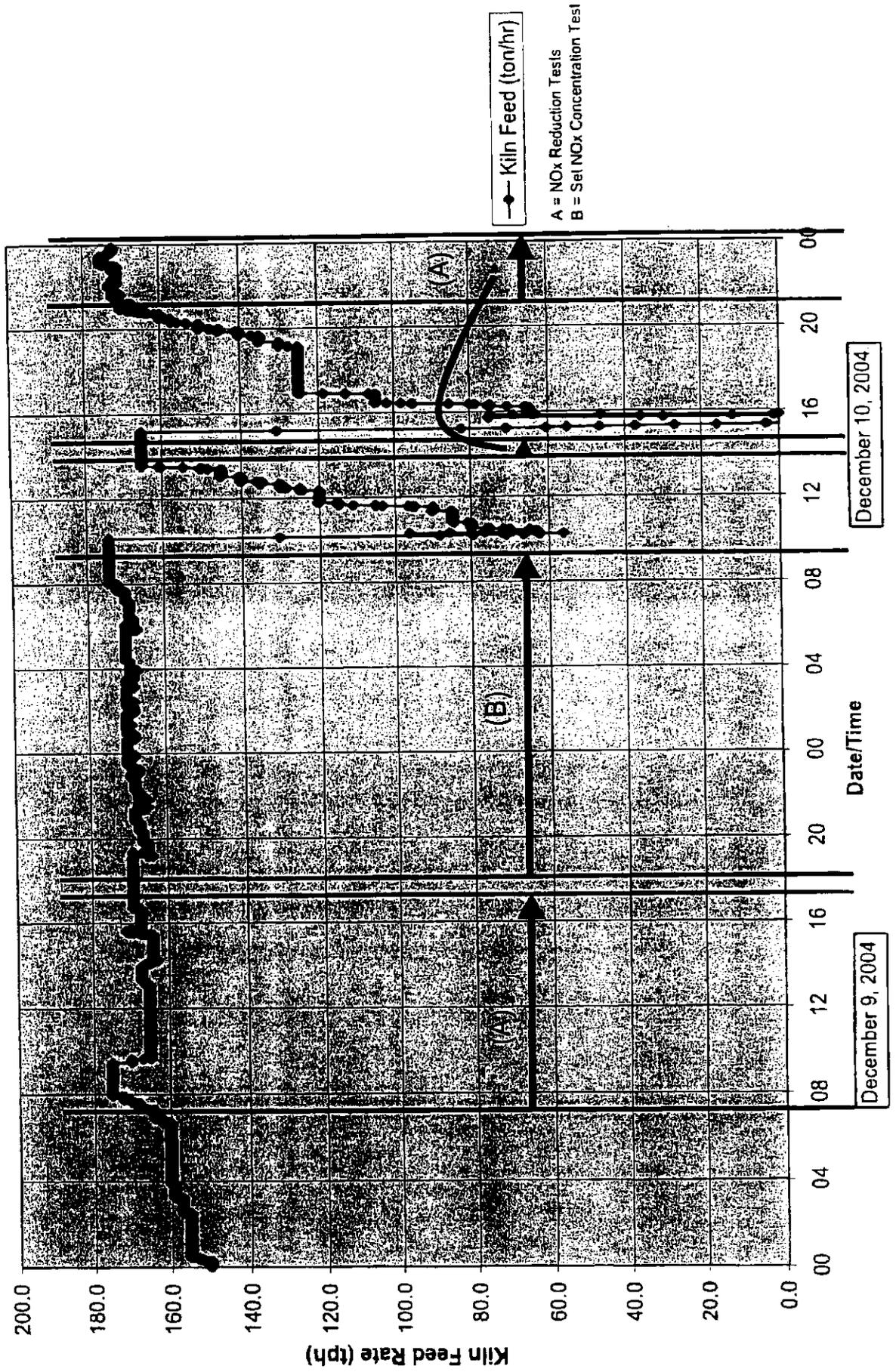


Figure 2
NOx Control Efficiency as a Function of NH3/NOx Molar Ratio

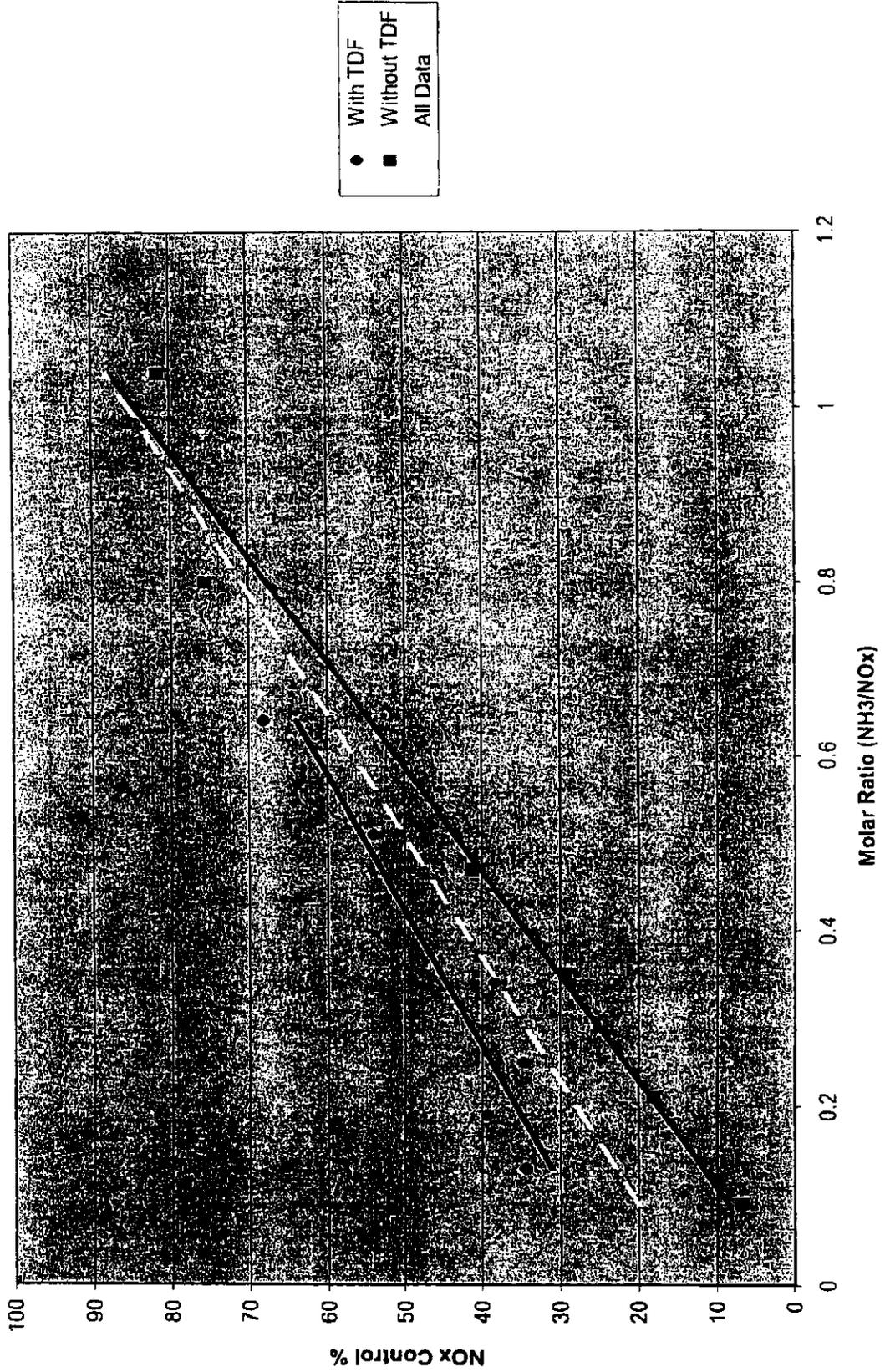


Figure 3a

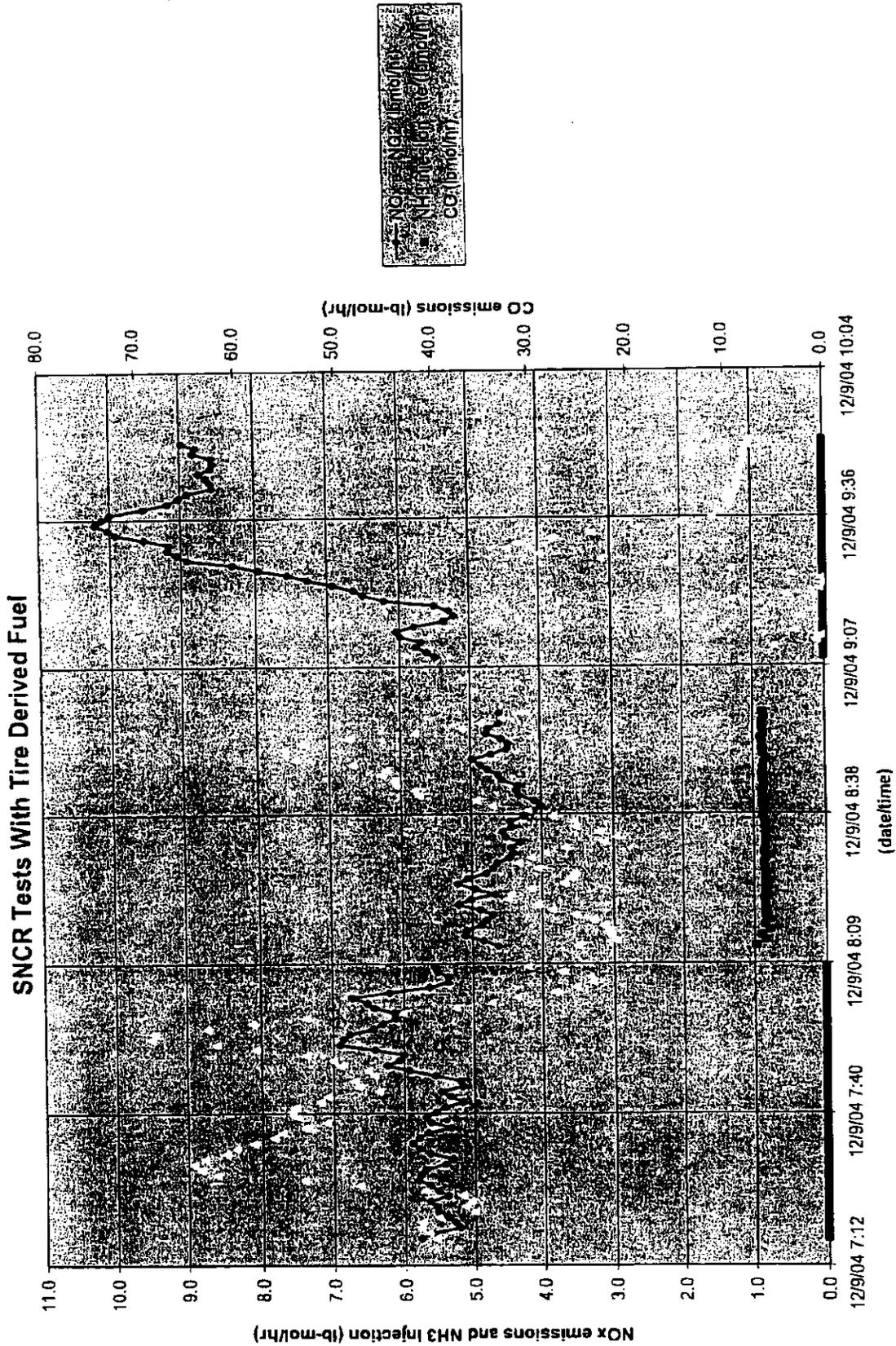


Figure 3b

SNCR Test With Tire Derived Fuel

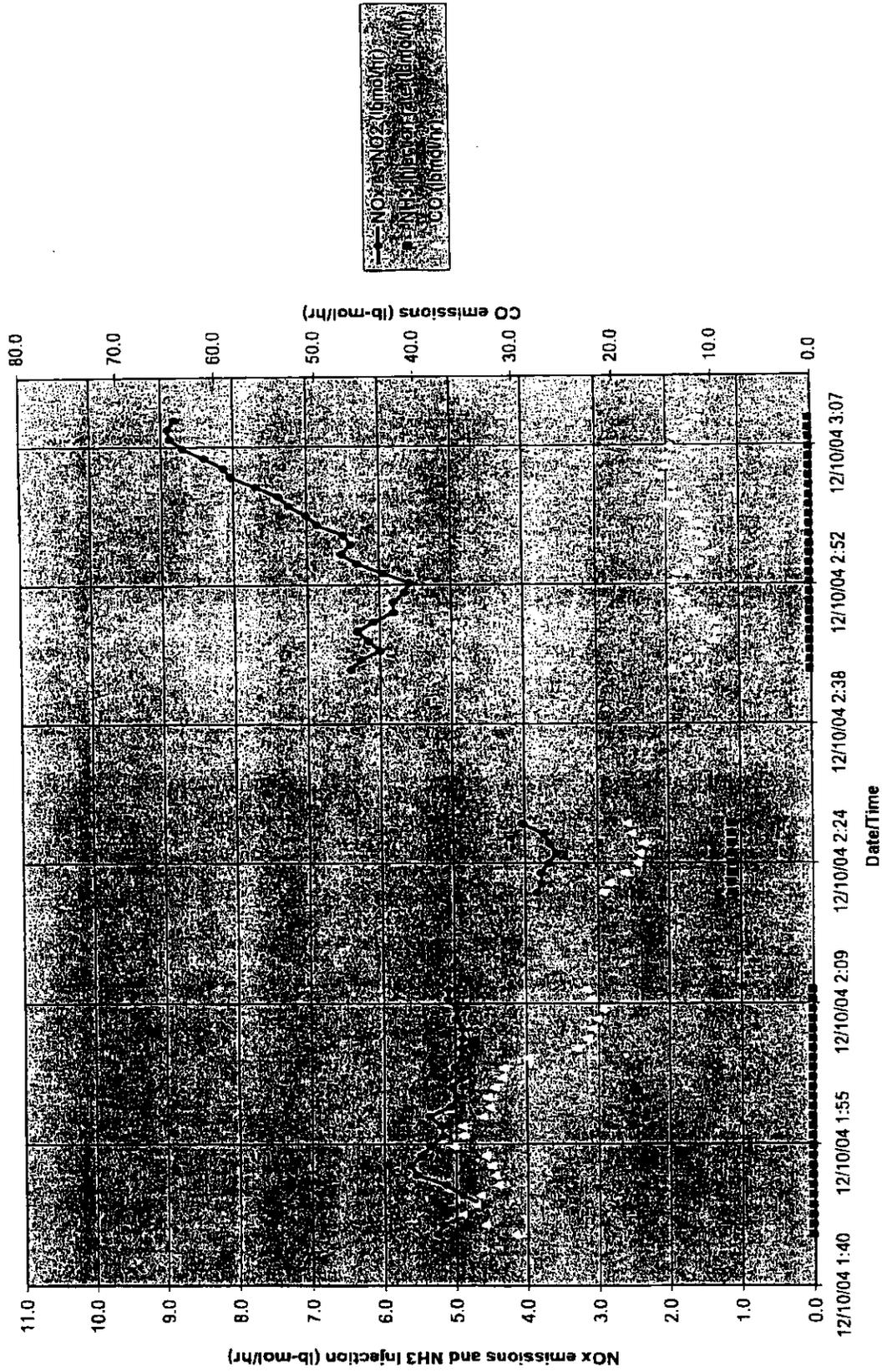


Figure 4

SNCR Tests Without Tire Derived Fuel

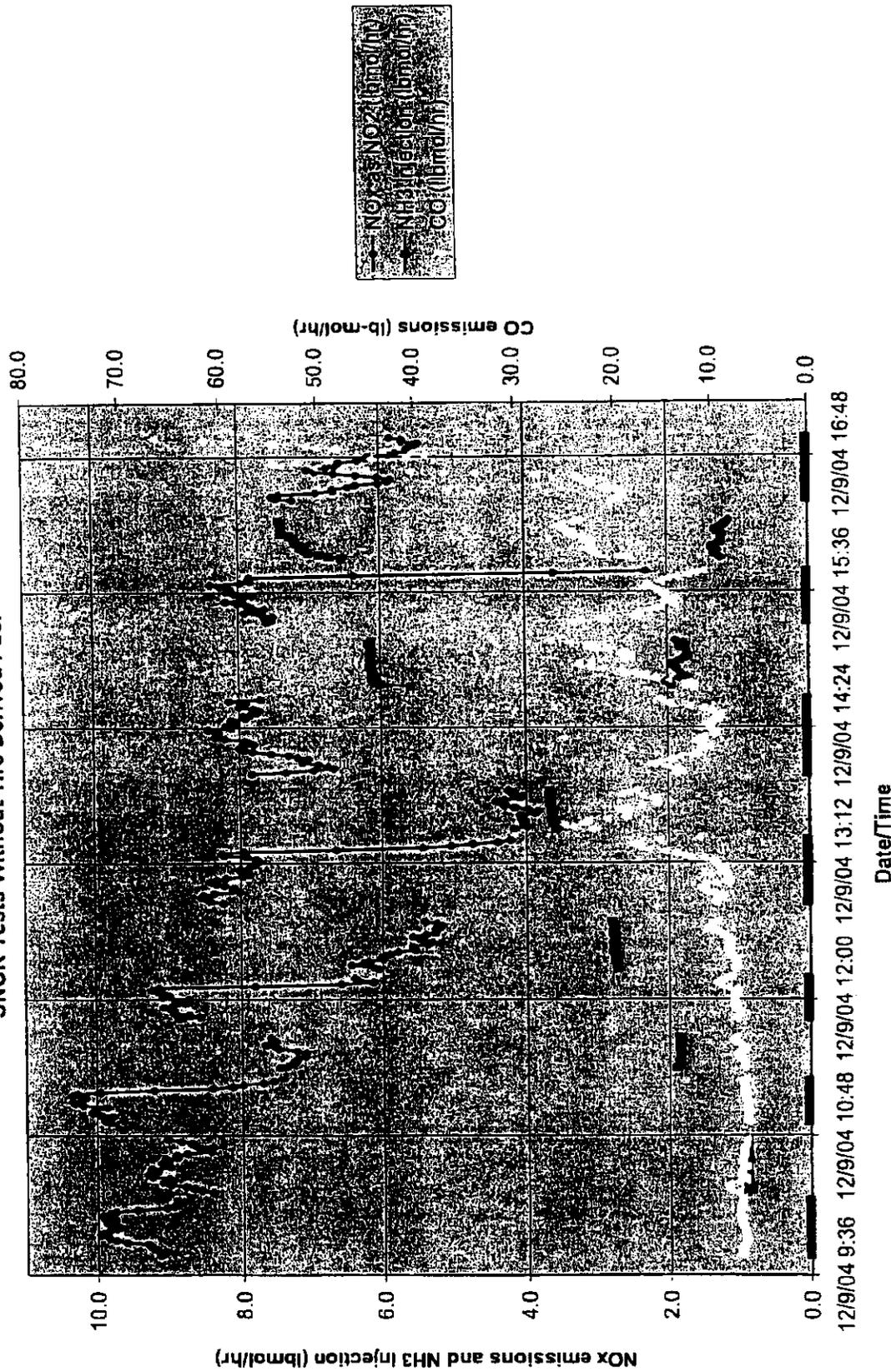


Figure 5
NOx Reduction and Ammonia Injection

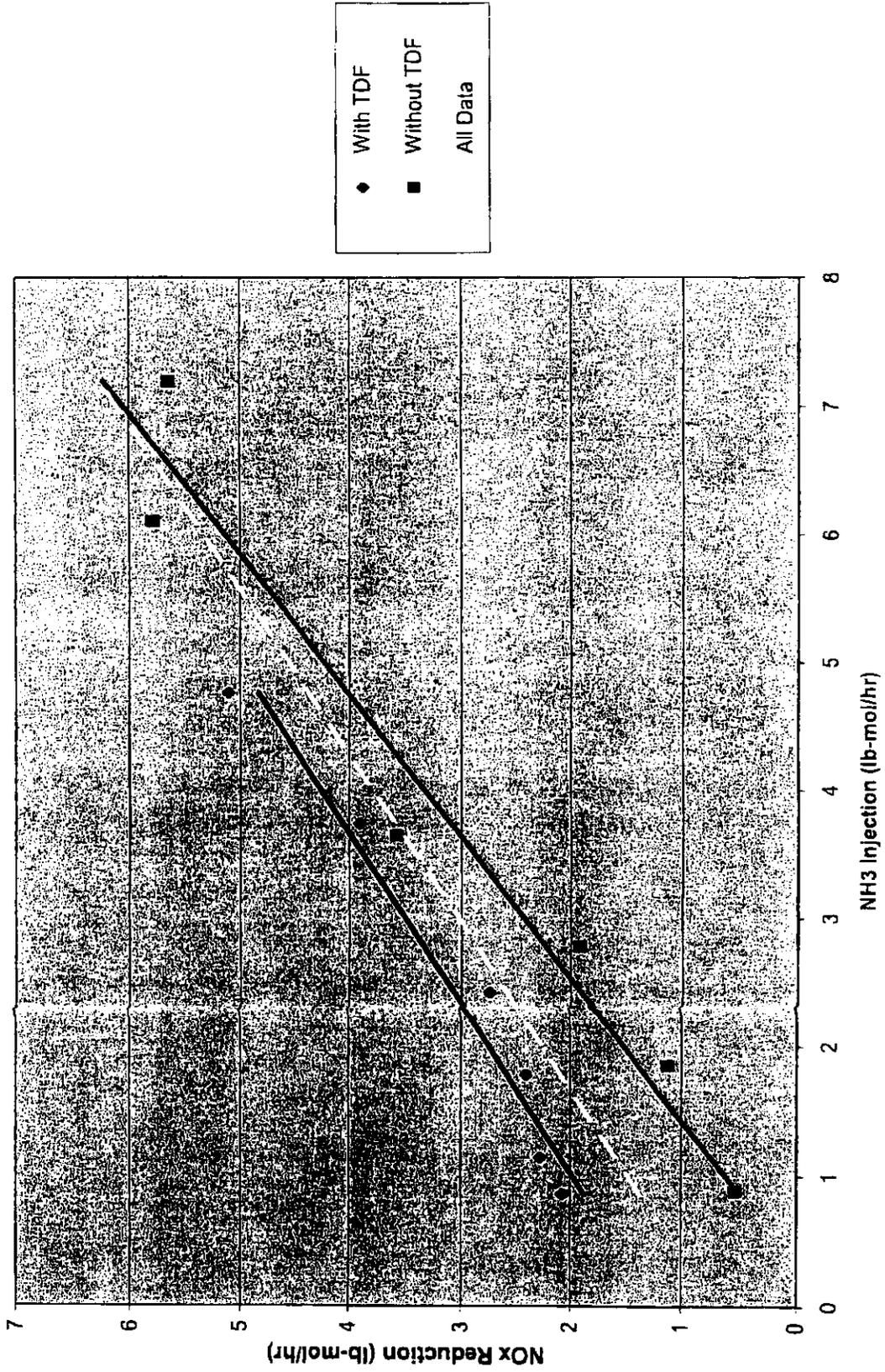


Figure 7a

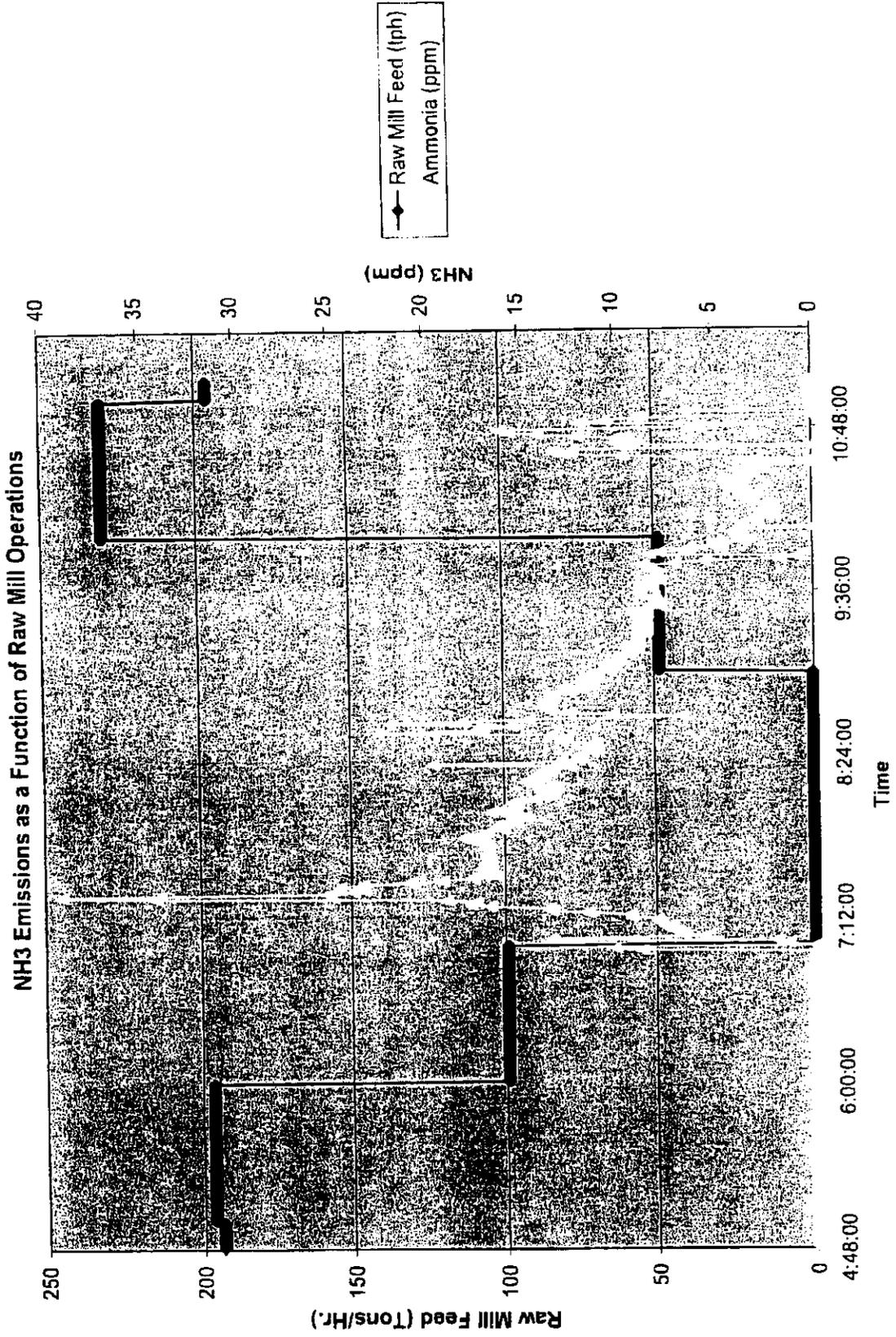
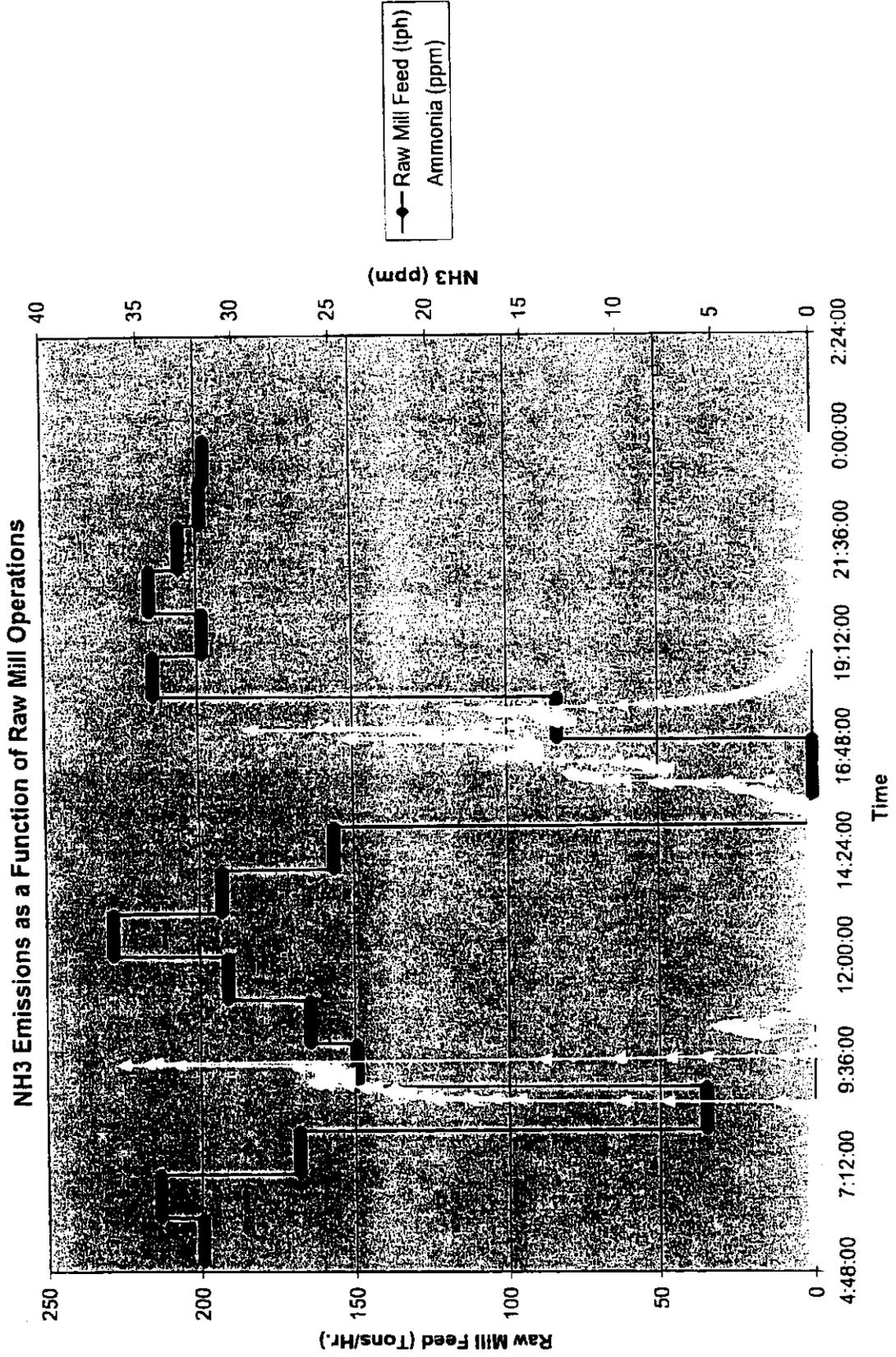


Figure 7b





MEMORANDUM

TO: File

FROM: Jeff Evers

DATE: January 20, 2006

RE: Comparison of dust loading for cement operations and boilers

Based on data from F. L. Smidth (FLS), typical dust loading to the air pollution control device (APCD) for cement operations are as follows:

Long Wet Kilns: 2 – 7.5 gr/acf (units are grains per actual cubic foot)

Preheater/Precalciner (PH/PC): 10 – 20 gr/acf

[F. L. Smidth designs and installs cement kiln systems and plants worldwide, and has been doing this type of work for over 120 years.]

Actual data from a PH/PC cement system and from a Powder River Basin (PRB) fired boiler can be compared to the typical dust loading from FLS.

Type of combustor	Dust Loading (gr/acf)
FLS typical long wet kiln	2 – 7.5
FLS typical PH/PC system	10 -20
Actual PH/PC cement system	28.5
Actual PRB fired boiler	2.5

To make a more direct comparison, the volumetric flow should be converted to dscf (dry standard cubic feet). After converting, the comparison is as shown.

Type of combustor	Dust Loading (gr/dscf)
FLS typical long wet kiln	4.2 - 15.5
FLS typical PH/PC system	20.1 - 40.2

Actual PH/PC cement system	57.8
Actual PRB fired boiler	6.7

-----Original Message-----

From: Miller, Steven [mailto:steven.miller@flsmidth.com]
Sent: Monday, January 16, 2006 4:33 PM
To: christasya@indy.rr.com
Subject: RE: Typical dust rates for main filters

It is grains per actual cubic foot.

-----Original Message-----

From: Christa O. Russell [mailto:christasya@indy.rr.com]
Sent: Monday, January 16, 2006 4:32 PM
To: Miller, Steven
Subject: RE: Typical dust rates for main filters

are these grains or grams? We talked about different units and I wasn't sure...

-----Original Message-----

From: Miller, Steven [mailto:steven.miller@flsmidth.com]
Sent: Monday, January 16, 2006 4:07 PM
To: christasya@indy.rr.com
Subject: Typical dust rates for main filters

Dear Christa,

Based on our phone conversation earlier today, I can provide the follow typical data for the dust loading at the main filter:

Calciner systems

10 – 20 gr/acf

The above value range is based on the raw mill down condition and cooling to 400F with water before the filter for control of dioxin/furan emissions. The range of values depends on the pyro system heat consumption, top stage efficiency, plant elevation, etc.

Wet kilns

2 – 7.5 gr/acf

Note that the above range is an estimate based on old wet kiln guidelines. We have not sold a new wet kiln in the U.S. in over 30 years, so I do not have "up to date" numbers for you. The grain loading has a larger range than the calciner system due to potentially larger variations in the pyro system heat consumption and the kiln dust loss.

I hope you find the above dust loading values useful.

Best regards,

Steven Miller

Manager, Process Design
FLSmidth Inc.