

**CONTROL TECHNOLOGY ANALYSIS
FOR AIR PERMIT APPLICATION
RAVENA PLANT MODERNIZATION PROJECT**

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SECTION 1

INTRODUCTION

1.1 Project Description

Lafarge Building Materials, Inc. (Lafarge) is proposing the modernization of its cement manufacturing facility in the Town of Coeymans, New York (commonly known as the Ravena Plant). The proposed project includes the construction and operation of a state-of-the-art preheater/precalciner, kiln and clinker cooler operation with future planned replacement and/or upgrade of existing cement grinding mills. Material handling systems and storage will be adjusted to transfer and store the raw and finish materials to and from the modernized production line. There are no physical changes anticipated in the quarry operation. The mode of transportation of raw materials or finished product coming in or out of the plant including the existing barge loading operation will also remain intact. Production is expected to be 8,818 short tons per day (tons/day) and 2.81 million short tons per year (tons/yr) of clinker and 3.22 million short tons/yr of cement and masonry products.

1.2 Cement Manufacturing

Portland cement is used in almost all construction applications including homes, public buildings, roads, industrial plants, dams, bridges, and many other structures. Therefore, the quality of Portland cement must meet very demanding standards. The manufacture of a high quality Portland cement begins with the use of a high quality calcium carbonate material (i.e., marl or limestone) and the production of a high quality cement clinker.

In the Portland cement manufacturing process, raw materials such as limestone, bauxite, iron ore, and other additive materials are heated to their fusion temperature, typically 1,400° to 1,500°C (2,550° to 2,750°F), in a refractory lined kiln by burning various fuels such as coal, coke, and natural gas. Burning an appropriately proportioned mixture of raw materials at a suitable temperature produces hard fused nodules called "clinker," which are cooled and then mixed with calcium sulfate (gypsum) and limestone, and ground to a desired fineness. Different

types of cements are produced by using appropriate kiln feed composition, blending the clinker with the desired additives, and grinding the product mixture to appropriate fineness. Manufacture of cements of all types involves the same basic high temperature fusion, clinkering, and fine grinding process.

There are four primary types of refractory lined kilns used in the Portland cement industry: long wet kilns, long dry kilns, preheater kilns, and preheater/precalciner kilns. The long wet, long dry, and most preheater kilns have only one fuel combustion zone, whereas the newer preheater kilns with a riser duct and the preheater/precalciner kilns have two or more fuel combustion zones. These newer designs of dry pyroprocessing systems increase the overall energy efficiency of the cement plant. The energy efficiency of the cement making process is important as it determines the amount of heat input needed to produce a unit quantity of cement clinker. A high thermal efficiency leads to less consumption of heat and fuel, with correspondingly lower emissions.

1.3 Control Technology Requirements

As discussed in Section 2 of the Regulatory Analysis Report (Tab A), under the Prevention of Significant Deterioration (PSD) rules applicable to this project, Best Available Control Technology (BACT) must be used to control emissions of carbon monoxide (CO).

BACT is defined as “an emission limitation, including a visible emission standard, based on the maximum degree of reduction of each pollutant subject to PSD review that the reviewing authority on a case-by-case basis, taking into account energy, environmental, and economic impacts, and other costs, determines is achievable through application of production processes and available methods, systems, and techniques (including fuel cleaning or treatment or innovative fuel combustion techniques) for control of such pollutant.” If the reviewing authority also determines that technological or economic limitations on the application of measurement methodology to a particular part of a source or facility would make the imposition of an emission standard infeasible, a design, equipment, work practice, operational standard or combination thereof, may be prescribed instead to satisfy the requirement for the application of BACT. Such standard shall, to the degree possible, set forth the emissions reductions achievable by implementation of such design, equipment, work practice, or operation. Each BACT

determination shall include applicable test methods or shall provide for determining compliance with the standard(s) by means that achieve equivalent results.

The EPA has stated their preference for a "top down" analysis to determine BACT. The first step in this approach is to determine, for the emission unit in question, the most stringent control available for a similar or identical source or source category. If it can be shown that this level of control is technically or economically infeasible for the unit in question, then the next most stringent level of control is determined and similarly evaluated. This process continues until the BACT level under consideration cannot be eliminated by any substantial or unique technical, environmental, or economic objections. Presented below are the five basic steps of a top down BACT review procedure according to EPA's *New Source Review Workshop Manual*:

- Step 1. Identify all control technologies
- Step 2. Eliminate technically infeasible options
- Step 3. Rank remaining control technologies by control effectiveness
- Step 4. Evaluate most effective controls and document results
- Step 5. Select BACT.

The EPA has consistently interpreted the statutory and regulatory BACT definitions as containing two core requirements that the agency believes must be met by any BACT determination. First, the BACT analysis must include consideration of the most stringent available technologies, i.e., those which provide the "maximum degree of emissions reduction." Second, any decision to require a lesser degree of emissions reduction must be justified by an objective analysis of "energy, environmental, and economic impacts" contained in the record of the permit decision.

The minimum control efficiency to be considered in a BACT analysis must result in an emission rate less than or equal to any applicable new source performance standards (NSPS) emission rate or National Emission Standards for Hazardous Air Pollutants (NESHAP). The applicable NSPS/NESHAP represents the maximum allowable emission limits from the source.

In this BACT analysis, the most effective technically feasible controls were evaluated based on an analysis of energy, environmental, and economic impacts. As part of the analysis, several control options for potential reductions in criteria pollutant emissions were identified. The control options were identified by:

- (1) Researching the RACT/BACT/LAER Clearinghouse
- (2) Drawing from previous engineering experience

- (3) Surveying available literature
- (4) Review of PSD permits for Portland cement plants.

SECTION 2

BACT ANALYSIS FOR CO

The only significant source of CO associated with the project is the preheater/precalciner kiln system.

2.1 CO Formation Processes

CO [and associated volatile organic compound (VOC)] emissions from cement kiln pyroprocessing systems generally occur from two separate and distinct processes in the system: 1) products of incomplete combustion of fuel and 2) decomposition of organic material in the kiln feed. Each CO formation process occurs under uniquely different conditions and is defined by the process technology and feed materials.

2.1.1 CO from Kiln Feed

For the purpose of this discussion, the pyroprocessing technology is confined to the preheater/precalciner design. In this design, raw meal is introduced to the exhaust gas stream from the preheater and preheated through a series of cyclones (stages) in a countercurrent flow design. In the process of heating, organic materials naturally occurring in the feed (kerogen and bitumin) are progressively heated and they begin to thermally degrade. The heating at relatively low temperature and at a low oxygen atmosphere results in complex organic molecules to be cracked, recombined, and re-ordered until the species are reduced to short-chain VOC's, CO, and/or carbon dioxide (CO₂). During the pyrolytic process, a significant fraction of the organic carbon is fully oxidized to CO₂.

Depending on the nature of the organics present in the feed materials, the location of the thermal decomposition in the preheater varies along with the degree of complete oxidation. The presence of light hydrocarbon species in the meal typically results in VOC and condensable hydrocarbons in the kiln preheater gases, but the CO concentrations are low. Conversely, complex hydrocarbons generally produce CO during decomposition, but low concentrations of VOC.

Depending on the geological deposit of the feed materials, the composition and concentration of organic materials in the kiln feed (meal) may vary significantly. The spatial distribution within the deposit is both lateral and vertical, and cannot be mitigated by selective mining or material substitution. The level of contaminants in the kiln feed is unique to each site and results in site-specific CO emission rates.

The rate of conversion of meal carbon to CO₂ is influenced by the temperature profile of the preheater, the organic content of the kiln feed, and the composition of the organics in the kiln feed. Recent studies do not indicate that the oxygen content of the flue gases influences the CO emission rate. Papers published in Zement-Kalk-Gips also support the same conclusion. The temperature of the preheater stages is defined by the kiln and mix designs (C₃S, silica, etc.) and cannot be modified sufficiently to complete oxidation of CO in the preheater.

2.1.2 CO from Incomplete Combustion

CO (and VOC) may also be produced as a product of incomplete combustion of fuel in the precalciner vessel. Modern precalciners burn fuel in suspension with meal. The precalciner vessel is designed to decarbonize (or calcine) the raw feed simultaneously with the combustion of fuel in suspension. This design allows use of liquid, gaseous, and solid fuels over a range of heat values and qualities (ash, moisture, etc.). Because of the continuous generation of thermal energy (combustion) and consumption of thermal energy due to the decarbonization, the temperatures are stabilized and the thermal variation is minimized. This process results in reduced thermal NO_x and promotes de-NO_x of kiln gases entering the precalciner. With this design, however, it is impossible to eliminate all CO that is normally associated with fuel combustion in a conventional combustion device such as a boiler. Typical CO concentrations after the precalciner and lowest preheater cyclone exit are between 250 and 1500 ppm and VOC is low (i.e., 5 to 10 ppm).

The Multi-Stage Combustion (MSC) design for NO_x control generates a reducing atmosphere zone to enhance NO_x reduction. CO generation will also be increased in this zone. The design functions in a similar manner to Staged Combustion (SC) in boilers. Theoretically, CO is not directly involved in the chemical reactions to reduce NO_x. An oxygen deficiency zone is needed to create more NH_i radicals to reduce NO_x. CO is the result of this reducing atmosphere.

2.2 Identification of CO Control Options

This section reviews the available CO control technologies that were considered for the Ravenna kiln system. VOC's will also be reduced by these technologies.

2.2.1 Thermal Oxidation

Thermal oxidation is performed with devices that use a flame, sometimes combined within an enclosed chamber, to convert CO and VOC to carbon dioxide (CO₂). Thermal oxidizers operate most effectively at temperatures between 1,200° to 2,000°F, with a residence time of 0.2 to 2.0 seconds. By raising the temperature, the residence time for complete combustion can be reduced and vice versa. However, temperature is the more important process variable.

Two types of thermal oxidizers are commonly used in industrial plants. The most common thermal oxidizer is an afterburner. Afterburners can be either direct-fired with no heat recovery, or with recuperative heat recovery. A second type of thermal oxidizer is a regenerative thermal oxidizer (RTO). A regenerative thermal oxidizer operates in an enclosed chamber and recovers up to 85 percent of the heat energy input. For the purposes of this analysis, a regenerative thermal oxidizer was evaluated.

There are no cement plants currently operating using a direct-fired afterburner or a recuperative type afterburner. Afterburners are not desirable for cement kiln applications because of limited residence time resulting in poor CO combustion efficiency, an increase in NO_x emissions, and significant additional fuel burning requirements. There are, however, two plants which have employed an RTO. These are at TXI, Midlothian, Texas and Holcim, Inc., Dundee, Michigan. The TXI operation is a precalciner and the Dundee operation involves two wet process kilns.

TXI, Midlothian, Texas

The system was installed during a plant expansion and was used to reduce CO and VOC emissions below a de minimus increase and therefore avoid PSD review. No BACT analysis was conducted and the Texas Commission on Environmental Quality (TCEQ) does not consider the use of an RTO as BACT under State or Federal requirements. The unit has experienced significant operational difficulties including higher than anticipated heat exchanger fouling and

pressure drop. This has increased afterburner fuel usage and associated costs and decreased kiln capacity. It is also important to note that the plant operates a fabric filter for primary particulate control and a sulfur dioxide (SO₂) scrubber for SO₂ removal prior to the RTO in order to reduce SO₃ formation and resulting corrosion in the RTO and downstream ductwork as well as visible plume formation.

Holcim, Dundee, Michigan

Historically the Dundee kilns have emitted condensable hydrocarbons, which formed visible plumes and an objectionable odor. In an effort to control these problems, the plant installed an RTO. The design was modified from the TXI configuration to include an open type (checker) heat exchanger that was expected to have less potential for fouling. The unit has been effective in control of visible emissions (VE) and odor but has experienced poor heat recovery, higher than expected fuel usage and associated costs, and significant maintenance problems. In some cases under high hydrocarbon loads, the unit has experienced over temperature due to uncontrolled self-fueling. The units were installed to replace existing carbon injection systems for hydrocarbons and did not go through PSD or a BACT analysis. As a result of the failure of the mechanical system, the RTO system was decommissioned.

2.2.2 Catalytic Oxidation

Catalytic oxidation is performed with devices that use a flame within an enclosed chamber to convert CO and VOC to CO₂. Catalytic oxidizers operate effectively at lower temperatures than thermal oxidizers (between 600° to 900°F) because of the use of catalysts to drive the reaction. The catalysts (typically platinum based) are placed on an alumina pellet or honeycomb support and the exhaust gases pass over or through the catalyst within the enclosed chamber. The temperature in the oxidizer is maintained either by the exothermic reaction or with supplemental fuel firing.

The presence of particulate matter in an exhaust gas stream inhibits the operation of the unit and creates problems with catalyst poisoning.

Advantages of a catalytic oxidizer over a thermal oxidizer include:

1. Lower fuel requirements
2. Lower operating temperatures
3. Little or no insulation required
4. Reduced fire hazards
5. Reduced flashback problems.

Disadvantages of this system include:

1. Initial capital cost is higher
2. Catalyst poisoning (fouling) is possible
3. PM₁₀ must be removed first
4. Disposal of spent catalyst, which may be hazardous.

No catalytic oxidation units are currently being used on any cement kilns in the U.S. or abroad.

2.2.3 Excess Air

Excess air introduced into the combustion zones tends to reduce the amount of CO and VOC formed by oxidizing them to CO₂. This reaction is limited to areas in the combustion zone where the CO concentration is greater than 50 ppm. The advantages of the use of excess air are the ease of implementing the technology and the potential for lower SO₂ emissions. The major disadvantage is that increasing excess air in the combustion zone increases NO_x formation and can adversely affect clinker quality.

2.2.4 Good Combustion Practices

Because CO and VOC formation can result from incomplete combustion of fuels and the oxidation of uncombusted carbon in those fuels, the better the combustion practices, the lower the CO and VOC formation. Good combustion practices require the following elements:

1. Proper mixing
2. High temperature.

Good combustion practice is the inherently lowest emitting method of controlling CO and VOC emissions from combustion sources.

2.3 Elimination of Technically Infeasible CO Control Options

The second step in the BACT analysis for CO is to eliminate any technically infeasible or undemonstrated control technologies. Each control technology is considered and those that are infeasible based on physical, chemical, and engineering principles or are undemonstrated in the Portland cement industry were eliminated.

2.3.1 Thermal Oxidation

Because PM present in the uncleaned flue gases would routinely plug and foul thermal oxidation equipment, a thermal oxidation unit would have to be placed downstream of the baghouse and scrubber or other SO₂ emissions reduction technology to be technically feasible. Placing the oxidizer at this location would require supplemental fuel firing to maintain the optimal operating temperature range of 1,200° to 2,000°F. The additional fuel firing would result in an undesirable increase in NO_x and CO₂ emissions, thus negating the NO_x control technology employed upstream and increasing greenhouse gas emissions. Although it appears to be technically feasible to install a regenerative thermal oxidization unit downstream of the preheater/precalciner system dust collector from a theoretical standpoint, in practice these systems have failed to perform successfully. While the use of thermal oxidation (RTO) is considered to be questionable from a practical standpoint, it will be considered further in this BACT analysis.

2.3.2 Catalytic Oxidation

PM present in Portland cement kiln flue gases poisons the catalysts used in catalytic oxidation units and would routinely plug and foul catalytic oxidation equipment. The presence of PM in the catalytic oxidation unit will result in poor CO/CO₂ conversion and an increase in operational interruptions. Therefore, the use of a catalytic oxidation unit is an infeasible option and is not considered further in this BACT analysis.

One environmental issue resulting from the catalytic oxidation control option is that spent catalyst is often classified as a “hazardous waste,” disposal of which represents a significant environmental concern.

2.3.3 Excess Air

Excess air results in an alteration of the flame characteristics in the kiln and precalciner. This change in the flame will have a detrimental affect on the clinker quality. Therefore, the use of excess air is not a technically feasible control alternative and will not be considered further in this BACT analysis.

In addition to the technical argument, the effectiveness of this control method is limited by the carbonation process equilibrium and the CO and VOC concentrations. Adding excess air to either the kiln or precalciner combustion zones would result in an increase in NO_x and PM₁₀

emissions from the system. Creating more NO_x and PM₁₀ to reduce CO emissions does not represent a viable environmental benefit.

2.3.4 Good Combustion Practices

This is a technically feasible option and will be further considered in the BACT analysis.

2.4 Ranking of Technically Feasible CO Control Options

The third step in the BACT analysis for CO is to rank remaining control technologies by control effectiveness. The control technology options that are considered potentially feasible are good combustion practices and an RTO. Two RTO options were evaluated: maximum possible control (95% control) and achieving a practical limit in the exit gases of 100 ppm (74.3% control).

Table 1 shows the ranking and the estimated control efficiency.

TABLE 1. RANKING OF CO CONTROL OPTIONS PREHEATER/PRECALCINER KILN SYSTEMS

| Control Technology | Control Efficiency | Equivalent Emission Rate |
|---------------------------------------|---------------------------|---------------------------------|
| RTO (Maximum control) | 95% | 0.125 lb/ton clinker |
| RTO (100 ppm in exit gases) | 74.3% | 0.64 lb/ton clinker |
| Good combustion practices (base case) | NA | 2.50 lb/ton clinker |

2.5 Evaluation of Technically Feasible CO Control Options

The fourth step in a BACT analysis for CO is to complete the top-down analysis of the feasible control technologies and document the results. The feasible control technologies are evaluated on the basis of economic, environmental, and energy considerations.

Lafarge is proposing to employ good combustion practices in the kiln and calciner. Therefore, the evaluation was limited to the incremental effectiveness of installing an RTO (Table 2). The detailed cost calculations are presented in Appendix A.

TABLE 2. SUMMARY OF IMPACT ANALYSIS FOR CO

| Method | % removal* | CO removed tons/yr | Capital Costs, MM\$ | Annualized Cost MM\$ | Cost Effectiveness \$/ton CO | Impacts | | |
|--------|------------|--------------------|---------------------|----------------------|------------------------------|---------------|-------------------|--------|
| | | | | | | Environmental | Process Operation | Energy |
| RTO | 95 | 3,337 | 51.9 | 29.7 | 8,904 | Yes | Yes | Yes |
| RTO | 74.3 | 2,609 | 51.9 | 29.7 | 11,386 | Yes | Yes | Yes |

A significant portion of the annualized cost (almost \$15 million) is for natural gas, which also results in increased emissions of combustion-related pollutants (e.g., nitrogen oxides and VOC). Also, it is not clear that an uninterruptable supply of natural gas could be provided in the quantity needed. The use of other fuel such as oil would further increase emissions of other combustion-related pollutants.

2.6 Review of Kiln Permit Limits

A review of plants identified in the BACT/LAER Clearinghouse indicated that the documentation is incomplete and that several facilities have been constructed under the Federal PSD program or State-only BACT requirements. Considering the incompleteness of the data, a State-by-State review of recently permitted precalciner facilities was conducted. Table 3 summarizes recent permit determinations for CO.

The range of CO emissions for good combustion practice is site-specific and is between 1.56 and 10.6 lb/ton of clinker. The wide variation in the permit limits is generally due to the wide variability in the organics in the rock used at the different plants.

2.7 Selection of BACT for CO

The addition of an RTO to reduce CO can be rejected on the basis of practical applicability and cost. Lafarge proposes as BACT the use of good combustion practices. The requested CO BACT emission limit is 2.50 lb/ton clinker. Compliance with the CO emission limit will be determined by CEMS on a 30-day rolling average basis.

TABLE 3. SUMMARY OF RECENT CO PERMIT DETERMINATIONS FOR CEMENT KILNS (2000-PRESENT)

| Company | Location | Kiln Type | Permit Date | Technology Applied and \$/Ton | Removal (%) | In Operation (Yes/No) | Limit (lb/ton clinker) | Rejected Technology and \$/Ton |
|---------------------------------------|-----------------|-----------|-------------|-------------------------------|-------------|-----------------------|---------------------------|--------------------------------|
| Lafarge – Kiln 3 | Joppa, IL | PC (new) | 7/6/07 | GC | NA | No | 2.5– annual 5.0 – 8 hr | RTO-not technically feasible |
| Lafarge – Kiln 1 | Harleyville, SC | PC (mod) | 8/18/06 | GC | NA | Yes | 10.5 ¹ | RTO-not practically feasible |
| Lafarge – Kiln 2 | Harleyville, SC | PC (new) | 8/18/06 | GC | NA | No | 6.8 ¹ | RTO-not practically feasible |
| Suwannee American Cement - Kiln 2 | Branford, FL | PC (new) | 2/15/06 | GC | | No | 2.90 ¹ | RTO |
| Sumter Cement | Sumter Co., FL | PC (new) | 2/6/06 | GC | | No | 2.9 ¹ | RTO |
| American Cement | Sumter Co., FL | PC (new) | 2/06 | GC | | No | 2.9 ¹ | RTO |
| Florida Rock Industries – Kiln 2 | Newberry, FL | PC (new) | 7/22/05 | GC | | No | 3.6 – 24 h | RTO |
| Rinker/Florida Crushed Stone – Kiln 2 | Brooksville, FL | PC (new) | 7/6/05 | GC | | No | 3.6 – 24 h | RTO |
| Holcim | Lee Island, MO | PC (new) | 06/08/04 | GC | NA | No | 6.0 ¹ | |
| GCC Rio Grande | Pueblo, CO | PC (new) | 3/5/04 | GC | NA | Yes | 2.11 | |
| Lehigh Portland Cement | Mason City, IA | PC (mod) | 12/11/03 | GC | NA | Yes | 3.7 – 3 h | RTO - \$5900 |
| Roanoke Cement Co. | Troutville, VA | PC (nod) | 6/12/03 | GC | NA | Yes | 3.0 – 24 h | RTO-not practically feasible |
| GCC Dacotah | Rapid City, SD | PC (mod) | 04/10/03 | GC | NA | Yes | 4.88 | |
| Holcim | Theodore, AL | PC (mod) | 02/04/03 | GC | NA | Yes | 10.6 – annual | |
| Holcim (Devil's Slide) | Morgan, UT | PC (mod) | 11/20/02 | GC | NA | Yes | 4.56 | |
| Suwannee American Cement - Kiln 1 | Branford, FL | PC (new) | 06/01/00 | GC | NA | Yes | 3.60 – 3 h | RTO |
| Monarch Cement | Humboldt, KS | 2PC (mod) | 01/27/00 | GC | NA | Yes | 3.7 – annual | RTO - \$2713 |
| Holcim | Holly Hill, SC | PC (new) | 12/22/99 | GC | NA | Yes | 6.8 | |
| Lafarge | Davenport, IA | PC (mod) | 11/09/99 | GC | | Yes | 1.64 | |
| North Texas Cement | Whitewright, TX | PC (new) | 03/04/99 | GC | NA | No | 2.9 ¹ | RTO |
| Continental Cement | Hannibal, MO | PC (new) | 7/24/07 | GC | NA | No | 3.6 | RTO > \$5600 |
| TXI | Midlothian, TX | PC (mod) | 11/98 | RTO | 75 | Yes | 1.56 | |

Notes: GC – Good combustion RTO – Regenerative Thermal Oxidizer ¹30-day rolling average

APPENDIX A