

**AIR PERMIT FOR THE CONSTRUCTION AND
OPERATION OF A CALCIUM CARBIDE
MANUFACTURING PLANT**

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by
EMILY WILBUR

Dr. Thomas Marrero, Thesis Supervisor

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The undersigned, appointed by the Dean of the Graduate School, have examined the thesis entitled

**AIR PERMIT FOR THE CONSTRUCTION AND OPERATION OF A
CALCIUM CARBIDE MANUFACTURING PLANT**

presented by Emily Wilbur,

a candidate for the degree of Master's of Science,

and hereby certify that, in their opinion, it is worthy of acceptance.

Professor Thomas Marrero

Associate Professor Patrick Pinhero

Professor Baolin Deng

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ABSTRACT

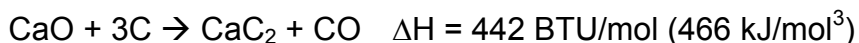
The purpose of this thesis is to determine the regulatory requirements necessary for constructing calcium carbide manufacturing plants. Material and thermal balances were made on the basis of biomass as a substitute for typical carbon raw materials, such as petroleum coke. The calcium carbide plant design was adapted from a novel concept that gasifies biomass in three stages to form the carbon raw material. Emission rates to air were calculated using comparable emission factors to determine the potential environmental impacts of the plant and its compliance to current State of Missouri air pollution regulations. The results show that the emissions associated with the calcium carbide plant allow for 1,657 tons per year of production for a true *de minimis* source, without the need for a construction or operating permit. For higher levels of production, a *de minimis*, minor or major permit is required. A synthetic *de minimis* source can achieve an annual calcium carbide production rate of up to 6,362 tons with the use of particulate filters. A true minor source can produce 30,273 tons per year without control devices. A synthetic minor source can produce 39,876 tons annually with the use of particulate filters. A major source can produce 44,389 tons annually with the installation of low NO_x burners and particulate filters. The results of this thesis are significant for the design and operation of a pilot or permanent calcium carbide manufacturing plant because permitting of air emissions is necessary prior to the start of any construction activities.

Chapter 1: Introduction

1.1 Calcium Carbide and Acetylene

Calcium carbide is an amorphous solid chemical compound. Dark grey in color, pure calcium carbide is difficult to prepare, and once produced quickly oxidizes with air liberating the carbon¹. It is commercially available in a form that is approximately 80% pure. The remaining 20% is composed primarily of calcium oxide and impurities from the raw materials².

The stoichiometric equation for producing calcium carbide from lime is:

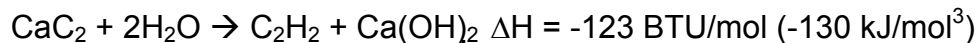


Calcium carbide is produced industrially using a method that has changed very little from its first industrial productions starting in 1896¹. This longstanding method heats calcium oxide and carbon in an electric arc furnace to achieve temperatures up to 3632^oF required by the endothermic reaction. In US plants, the calcium oxide in the form of lime is calcined from limestone in a kiln at the plant. The carbon sources are typically petroleum coke, metallurgical coke and anthracite coal⁴. In the US, the production rate has been decreasing over the years as the production and demand for calcium carbide has grown in China. In 1997, the estimated production of calcium carbide in the US and Mexico combined was 270,000 tons per year, which was 5.7 % of the total global production. China had a production of close to 3 million tons³. More recently,

the production in China has grown rapidly with an increase of 21.4% in total output from 2003 to 2004. That is a production rate of 6.55 million tons per year, of which 600,000 tons are exported⁵. In 2007, China represented 95% of the total global production and consumption of calcium carbide⁶.

Calcium carbide has several uses on its own in the iron and steel industries for desulphurization and the removal of unwanted iron and manganese oxides in slag^{2,1}. It is also used as an intermediate for calcium cyanamide manufacture³. However, the predominant use of calcium carbide is the production of acetylene, and the largest source of acetylene is calcium carbide¹.

The chemical reaction of calcium carbide yields the production of acetylene with the addition of water:



Acetylene is used in industrial applications and chemical manufacture. Industrial applications include using the acetylene for heating, welding and cutting^{1,3}.

1.2 Sustainability of Acetylene from Biomass

Recently, interest in acetylene as an alternative fuel source has increased and new company ventures are pursuing this aspect⁷. As an alternative fuel, acetylene would need to be produced with raw materials available in the US and the raw materials would preferably be renewable for sustainability as a reliable

fuel source. Missouri is a candidate for acetylene production through the manufacture of calcium carbide with renewable materials.

In Missouri, both raw materials for the production of calcium carbide are abundant by using biomass as the carbon source and lime as the calcium component of the formula. Carbon, in the form of trees, is a natural resource already used as a raw material for the production of charcoal in Missouri. In 2000, the primary wood-using industries in Missouri were sawmills, cooperage mills, post mills, charcoal plants, handle mills, and veneer mills processing 127 million cubic feet of industrial roundwood⁸. In 2003, these industries generated 1.8 million green tons of wood and bark residues⁹. According to the Missouri Department of Conservation, in 2007, Missouri was a leader in forest products, including charcoal¹⁰. On a global scale, the potential for biomass availability is substantial with approximately 30% of the Earth's surface covered in forestland¹¹. In 2004, the United States, in combination with other Organisation for Economic Co-operation and Development (OECD) countries, represented 12.6% of the total global shares of available biomass. In contrast, China by itself represented 19.7% of the global total.

Lime is typically produced through the calcination of limestone, although it can be produced from items such as aragonite, chalk, coral, marble and sea shells. Rock that qualifies as limestone must have a calcium carbonate content of at least 50 percent. If the rock contains 30 to 45 percent magnesium carbonate, the limestone is considered dolomite⁴.

Missouri is the highest producer of lime in the nation, according to the Mining Industry Council of Missouri¹². Globally, the United States is the second largest producer of lime with 20,200 metric tons produced in 2007. China led the world with 170,000 metric tons¹³.

Lime production requires quarrying raw limestone, crushing and sizing the limestone, calcining limestone, processing the lime, and storing and handling the lime. The main process of lime production is the calcining process which occurs in a kiln. In the United States, approximately 90 percent of all lime production occurs in a rotary kiln. In this type of kiln, limestone and hot combustion gases pass counter currently through a long, cylindrical, slightly inclined, refractory-lined furnace. Although the details of lime manufacturing are outside the scope of this thesis, a detailed description of the process and the associated emissions can be found in *AP-42 Section 11.17 Lime Manufacturing*⁴.

Once the manufacture of calcium carbide using biomass based raw materials is established, acetylene as a renewable fuel has many benefits. Calcium carbide can be stored in containers and easily transported to locations in need of a power source without the use of extensive piping and storage of combustible fuels. Once on-site, the calcium carbide can be reacted with water to quickly generate acetylene for use in acetylene generators. Existing commercial engines can be modified to operate on acetylene fuel by modifying the fuel injection system¹⁴.

Possible disadvantages of producing calcium carbide from biomass materials stem from the availability of biomass for the production of calcium carbide and the heat requirement of the calcium carbide reaction itself. As the desired production rate of calcium carbide increases, the amount of biomass necessary also increases. Areas with limited access to biomass material would have difficulty producing high quantities of calcium carbide. However, this can be considered similar to the issues raised in the use of non-renewable raw materials such as petroleum coke. Another disadvantage is the high temperatures and large amounts of electricity the calcium carbide manufacturing process itself requires¹⁴.

1.3 Specific Topic of Research

The abundance of both raw materials, lime and biomass, necessary in the gasification process, make Missouri a prime consideration for the location of this process. In order for any entity wishing to construct or modify a source with the potential to emit any regulated air pollutant in the State of Missouri must first obtain proper authority from various permitting agencies. This thesis looks into the regulatory aspect as it pertains to air emissions of establishing a biomass calcium carbide plant in Missouri. This thesis is divided into two evaluations: the process emissions and the permit type based on plant size.

Although biomass encompasses a variety of possible raw materials, wood was chosen for evaluation in this thesis because wood is a common biomass

material. Wood is a general term that includes both hardwoods and softwoods regardless of age. Possible variations in the wood that would affect process emissions were considered and a conservative approach was used during the evaluation of this thesis.

CHAPTER 2

Calcium Carbide Manufacturing through Biomass Gasification

2.1 The Gasification Process

This study is based on an invention that gasifies biomass to produce calcium carbide and ultimately acetylene in a three-stage gasification process. A patent application for the three-stage gasification of biomass was filed in May 2007¹⁵. Biomass is defined as carboneous materials such as biocrops, animal waste, or even used tires and often refers to materials that are renewable.

The first stage of the process is a fixed bed pyrolysis reactor. Similar to charcoal producing techniques, this reactor carbonizes the biomass at temperature specific to this patent of 300-1000^oF. The resulting charcoal is transported to a storage site for use as raw material for the production of calcium carbide. The exhaust for the first stage is vented to the second stage of the process to be partially combusted in a chamber at 1200-1400^oF. This partial combustion produces acetylene, hydrogen, and other carbon gases that are exhausted to a condenser for combustion in the third stage.

The third stage consists of a chamber for the complete combustion of the wood material in addition to the biogases produced in earlier stages to raise the temperature in the chamber to 3000^oF. The heat produced in the third stage chamber supplies the environment necessary for the reaction of the charcoal and

lime to form calcium carbide in molten form. From here the molten calcium carbide is cooled and processed for transport or conversion into acetylene. Electricity is produced by an internal combustion engine fueled by the off-gases and/or acetylene produced by the process¹⁵. A process flow diagram of the process can be found in Figure 1.

2.2 Ancillary Processes

For the purposes of this study, the additional auxiliary processes not mentioned in the patent application are included in order to produce a complete study of the total emissions expected from proposed plant. Haul roads are necessary to truck raw materials onto the property and product to off-site locations. Once the raw materials are delivered, the wood raw material can be stored in storage piles on the property.

From there, the wood is transferred by front-end loader to the dryer where the excess moisture is removed from the wood prior to pyrolysis. The dried wood can either be transferred back to storage or conveyed to the three-stage gasification system for further processing. The lime is trucked in and stored in silos located on the property. From the silos, the lime is conveyed to the gasification system. Once the molten calcium carbide is produced, a condenser is needed to cool and solidify the product. The product is crushed and sized for delivery or sent to the acetylene processing equipment for use in the internal combustion engine. During crushing, the process is ventilated or kept under an

inert gas blanket to prevent explosion hazards from acetylene generated by the reaction of calcium carbide with moisture in the ambient air. The engine provides the electricity necessary to run the gasification process.

Each individual equipment or process is a source of emissions commonly referenced as an emissions unit. For ease of tracking through the process, each emissions unit is labeled with a unique identifier. For this study, the emissions units were divided into three categories: direct process equipment, ancillary processes, and combustion equipment. A summary of these emission units and their labels are presented in Table 1, and Figure 2 is a schematic depiction of the emission units.

2.3 Mass Balance and Energy Balance

Miller¹ evaluates the average mass balance in a carbide furnace using chemical reactions thought to occur in the furnace and typical compositions of the raw materials used in the process. The balance is based on the production of one kilogram of calcium carbide by reaction of lime and coke.

For this study, the same reactions are used as a basis for the material balance in the gasification process. The lime is assumed to have the same general composition as lime in the Miller analysis¹. However, the gasification process uses charcoal as its carbon source which has a different impurity composition from coke thus producing a different mass result from the carbide furnace process.

Charcoal is a carbon residue that is formed through the pyrolysis of carbon containing materials. The most commonly used materials are woods, such as beech, birch, hard maple, hickory, and oak. Other materials can be used, including nutshells, fruit pits, coal, vegetable wastes, and paper mill residues. During the manufacturing process, external heat is applied to the wood to drive off water and highly volatile organic compounds. Once the wood temperature rises to approximately 275°C (527°F), the volatile organic compounds are released at an increasing rate and the carbonization reactions become exothermic⁴. The impurities seen in the charcoal differ considerably from those in coke.

In general, wood has an elemental composition of about 50% carbon and trace amount of several metal ions with the remaining percentage comprised of oxygen and hydrogen¹⁶. Some trace elements reported were calcium, potassium, magnesium, phosphorous, manganese, iron, zinc, sodium and chlorine. For purposes of this study, an average of the metal contents was established over the wood species in the study and used in the material balance. The two elements not mentioned in the study, but of interest in the gasification process, are nitrogen and sulfur in the wood. In general, wood and its associated biomass materials such as bark and greenery have low sulfur content levels. The sulfur content of wood is 0.01 percent with bark, having a slightly higher content of 0.02-0.1 percent based on dry mass¹⁷. The nitrogen content is thought to be 0.1-0.5 percent based on dry mass.

Impurities in the raw materials ultimately end up as an impurity in the resulting product¹. The results of the material balance can be seen in Table 2. The resulting quantities determined in the analysis are used in later sections as the basis for establishing the design rate for the gasification process equipment.

Miller¹ also evaluates the thermal aspects of the carbide furnace process. Based on the mole balance contained in the material balance analysis, a thermal analysis of the gasification process was evaluated following the same reactions used in the carbide furnace process. The results of the thermal balance can be seen in Table 3. The resulting thermal requirements of this analysis are used in later sections for evaluating the fuel combustion requirements of the gasification process. This information is translated into the heating requirements for a boiler design that would be necessary to maintain the process operations. The results of this analysis can be seen in Table 4 and is considered in determining the viability of producing a self-sustaining operation.

CHAPTER 3

REGULATORY REQUIREMENTS

3.1 Regulatory Background

Air permits are regulated under the Clean Air Act of 1963 and its amendments. After incidents of public health safety were threatened by increased pollution in the surrounding air, several federal and state laws were passed, including the original Clean Air Act of 1963. The Act established funding to study air pollution and strategies to clean up the air pollution. In 1970, Congress passed a revised version of the Clean Air Act which created a more comprehensive response for addressing air pollution. It was in that same year that Congress established the Environmental Protection Agency (EPA) with the primary objective to carry out the revised law. Subsequently, several Clean Air Act programs have been established in the effort to reduce nationwide air pollution¹⁸.

The Clean Air Act was further revised and expanded with the passing of the 1990 Amendments which allowed EPA more leeway in implementing and enforcing the regulations that were intended to reduce the emissions of certain air pollutants. It was at this time that the EPA considered cost-effectiveness of a control device in combination with the reduction effectiveness in air pollution.

The EPA is the primary agency for setting limits on regulated air pollutants that ensure that the basic health and environmental condition for the general population is not compromised by excessive air pollution. This is achieved through restrictions on emissions from industrial sources that emit regulated air pollutants. On a local level, the directives of the EPA are executed through state, tribal and local agencies that are approved by the EPA. States and tribes may create stricter air pollution laws that address specific problems the state or tribe wishes to address. However, in no case can those laws be less strict than those set by the EPA. Each state that has an approved State Implementation Plan (SIP) has been designated by the EPA to control air pollution under the Clean Air Act. The SIP is a collection of the regulations, programs and policies that the state will administer for the control of air pollution. In Missouri, the implementation and enforcement of air pollution laws is the responsibility of the Department of Natural Resources Air Pollution Control Program.

It should be noted that although Missouri is a SIP approved state and the results of this study should generally be applicable in other states of the United States, the Missouri air pollution laws do contain slight variations from other states in regards to minor source permitting evaluations. The results of this study are based on Missouri laws effective February 2010.

3.2 Air permitting

There are two major types of permits that can be obtained by a company proposing the emission of any regulated air pollutant: construction permits and operating permits. Construction permits are issued under the New Source Review requirements and are required prior to start of construction. Start of construction is a term that refers to the activities associated with construction of the proposed project, or the Greenfield installation. This includes the establishment of permanent structures for the purposes of the new installation. Pouring concrete is typically cited as an example of starting construction. Activities such as clearing land or leveling the area in which the installation is to be located has historically not been considered start of construction under New Source Review.

Issuance of an operating permit occurs after start up of the installed equipment. Operating permits are intended to consolidate all compliance and monitoring requirements found in construction permits, federal standards, consent decrees, etc. Details on operating permits are outside the scope of this thesis.

3.3 New Source Review

The regulations in the State of Missouri allow for three general (3) types of permitting for Greenfield installations: *De minimis*, Minor, and Major¹⁹. The steps of how a permit type is assessed do not change and a general outline of the

process can be seen in Figure 3. The first step is determining the project scope: is there a modification occurring? The definition of modification as stated in the Missouri State Regulations 10 CSR 10-6.020(M)(8):

Modification – Any physical change, or change in the method of operation of, a source operation or attendant air pollution control equipment which would cause an increase in potential emissions of any air pollutant emitted by the source operation.

For a Greenfield operation, the new plant is considered a modification and the project is defined as the entire installation. For clarification, the term installation is defined in 10 CSR 10-6.020(I)(6) as:

Installation – All source operations including activities that result in fugitive emissions, that belong to the same industrial grouping (that have the same two (2)-digit code as described in the Standard Industrial Classification Manual, 1987), and any marine vessels while docked at the installation, located on one (1) or more contiguous or adjacent properties and under the control of the same person (or persons under common control).

The next step in determining the type of permitting review of the modification is calculation of the potential to emit, which is defined in 10 CSR 10-6.020(P)(19) as:

Potential to emit – The emission rates of any pollutant at maximum design capacity. Annual potential shall be based on the maximum annual-rated capacity of the installation assuming continuous year-round operation. Federally enforceable permit conditions on the type of materials combusted or processed, operating rates, hours of operation and the application of air pollution control equipment shall be used in the determining the annual potential. Secondary

emissions do not count in determining annual potential.

The potential to emit of the installation is established by multiplying the maximum hourly design rate of each equipment by an appropriate emission factor for the process. A comprehensive, but not exhaustive, list of emission factors that are nationally recognized and rated for quality is found in the EPA document AP-42. However, if an emission factor is not listed under the desired process, an approximation can be justified and used in the absence of an appropriate emission factor. In most cases, performance testing conducted on the equipment or similar equipment may be acceptable²⁰.

The *de minimis* levels for each regulated air pollutant are the first tier of regulation found in the Missouri State Regulations. Once an installation reaches *de minimis* levels, they are reviewed for permitting requirements and evaluated under the New Source Review.

The second tier of regulation determines the major source levels as outlined in Table 6 for named and non-named installations. The State maintains a list of sources categories that are called “named installations²¹” that are affected by a different major source level. Currently, there are 27 source categories listed in the Code of State Regulations²¹. For the proposed calcium carbide manufacturing plant, the major source level is 250 tons of air pollutant per year since it is not considered a named installation. Therefore, any fugitive emissions created at this source will be counted towards the potential to emit of

the entire installation. Once the potential emissions of the installation are determined the type of permit that is issued can be determined.

This research is based on a Greenfield installation. Therefore, the permitting levels are also used in defining the source classification. For example, if the potential emissions of this plant are less than *de minimis* levels, the source is called a *de minimis* source.

The timeframe for permit issuance is dependent upon the type of permit being issued. The statutory time limit for all Section (5) and Section (6) permits is 90 days from the receipt of a complete application (10 CSR 10-6.060). However, if additional information is requested by the permitting authority, the application may be placed on hold until the information is received. There is not public comment period for these types of permits.

For major reviews conducted under Section (7), Section (8) or Section (9), the statutory time limit is 184 days from the receipt of a complete application. This also does not include time the application is placed on hold for additional information. However, these permits are subject to a public notice period that is included in the statutory time limit. The notice period lasts for 40 days. At that time, anyone from the public may comment on the proposed permit. A public hearing on the permit is scheduled during the public notice period but may be canceled if a public hearing is not requested. All comments received during the public notice period must be addressed and become a permanent addition to the final permit.

At the time of this writing, carbon dioxide was determined by the Supreme Court to be a greenhouse gas under the jurisdiction of the Clean Air Act. In March 2010, the EPA finalized a rulemaking for the automobile and light-truck industry that increased the efficiency standards for model years 2012 to 2016. Once this rule was final, carbon dioxide became a regulated pollutant by definition under the New Source Review rules and thus became permissible under the same rules. As such, any sources with carbon dioxide emissions will be required to obtain a construction permit prior to construction.

On March 29, 2010, the EPA announced that permitting of these sources will be phased in over the next few years to properly address carbon dioxide emitting sources. Details on the levels at which permitting is necessary are being proposed by EPA through the Greenhouse Gas Tailoring Rule, which proposes to raise the major threshold for carbon dioxide from the current 100 or 250 tons per year to 25,000 tons of carbon dioxide equivalent per year. A carbon dioxide equivalent is methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Permitting requirements will not be triggered until January 2011 and will only first effect large stationary sources as the smaller sources are phased in over the next few years²².

Carbon dioxide emissions are expected from this plant, and emission factors for the release of carbon dioxide were discussed in the emission factors section. No other carbon dioxide equivalents are expected.

3.4 Emissions and Controls

The level of emissions that are generated from the gasification process is dependent upon the size of the equipment involved. The ratio of raw materials necessary to produce a specific amount of product is based on the material balance presented in an earlier section. Figure 4 outlines the conversion ratios used in the potential emission calculations.

Potential emissions are based on information that most accurately characterizes the emissions as they are released into the ambient air. The most reliable source of information is direct testing of the emissions from the emission source. However, this type of information requires that the emission source be built and operating to perform the test. In most cases, this is nearly impossible since a permit is required prior to being built. Test data from similar sources is also acceptable if the sources are identical. Again, this may not be desirable since similar equipment may be owned by competing companies who are not willing to share their private information.

For most sources that lack the resources to provide direct testing data, the EPA has compiled a document called AP-42 that examines various types of industries and their emissions. The EPA document is categorized into 12 general sections. The emission factors are rated by letters that represent the confidence of the emission factor⁴. Other methods of emission quantification are mass balance, and estimation. For this study, the emission factors were taken

from AP-42 for processes addressed in AP-42. Since this is a new process, estimations for emission factors were used.

3.5 Emission factors

The emission factors utilized in this evaluation were all obtained from AP-42. In the cases where there were no emission factors specific to the processes at this plant, a comparable emission factor from AP-42 was used. A summary of the emission factors can be found in Table 7, 8 and 9 for PM₁₀, NO_x and VOC, and CO and CO₂, respectively. Each emission factor is referenced by a Source Classification Code (SCC) that is an 8-digit code the EPA uses to classify different emissions activities.

Prior to processing, the wood may be dried in a wood dryer that is fueled by the combustion of wood or natural gas. The emissions from this part of the process contain particulate matter, NO_x, VOC, CO and CO₂. This type of wood drying is not discussed directly in AP-42. Therefore, drying of similar material was used as a substitution. In particular, particleboard was chosen based on the material used in the manufacturing of particleboard such as wood shavings, flakes, wafers, and chips. These emission factors are found in Section 10.6.2 Particleboard.

The storage and handling of the wood and lime/dolomite raw materials and intermediate products such as charcoal and the combination of charcoal and lime are sources of particulate matter. As the material is conveyed into the silo,

air is displaced through the silo through openings located at the top of the silo. These openings relieve the air pressure in the silo simultaneously carrying entrained particulate matter into the surrounding atmosphere. The quantity of particulate matter that is released is dependent on the material being stored in the silo.

For the raw materials, emissions were based on emission factors taken from Section 11.17-4 Lime Manufacturing⁴, which contains emission factors for both the storage and handling of lime. Wood is hard fibrous substance that is not expected to contribute as much fine particulate emissions as lime and dolomite which are typically shipped as powders. However, emission factors for the storage and handling of wood are not represented in AP-42. Therefore, wood emissions were conservatively estimated using the same emission factors as lime/dolomite.

For the intermediate materials, emissions were based on emission factors taken from Section 11.4 Calcium Carbide Manufacturing⁴. Although the emission factors in this section are based on traditional calcium carbide manufacturing processes, emissions from the intermediate materials are expected to be similar.

The calcium carbide condensing and crushing operations are common in typical calcium carbide manufacturing plants, and the emission factors listed in Section 11.4 Calcium Carbide Manufacturing⁴ are representative of the emissions from this plant. The solidified calcium carbide is crushed in a primary crusher usually a jaw crusher, followed by a secondary crusher and screening for

size. Since crushing is performed in either an air-swept environment, or in an inert atmosphere, the exhaust can be vented to a control device. It should be noted that these emission factors were based on the use of a fabric filter as a control device. To determine the uncontrolled emission factor, a control efficiency of 99% was assumed for the use of a fabric filter as indicated in Appendix B.2 of AP-42⁴ and an emission factor was back-calculated using the controlled emission factor.

The third stage reactor will combust off-gases produced during the process which is expected to create emissions of PM₁₀, NO_x, VOC, CO and CO₂. Since it is difficult to predict the quantities and constituent of the off-gases, it is assumed that natural gas is a comparable fuel type. The off gases are expected to have a high carbon gas content and combustion products from previous stages. Natural gas is comprised mainly of methane. Based on these similarities, the emission factors for natural gas combustion were used to determine emissions of the off-gases. These emission factors were taken from Section 1.4 Natural Gas Combustion and Section 3.2 Natural Gas-fired Reciprocating Engines⁴.

Part of the process relies on the combustion of the product acetylene gas produced by the process as fuel for the equipment of the process. In this way, the process is intended to achieve self-sustaining operations without the need for additional outside resources. The intended combustion products of acetylene are primarily carbon dioxide (CO₂) and water based on the complete combustion

of acetylene in the appropriate amount of oxygen. The emission factor for CO₂ is 157.45 pounds per million BTU²³. However, under real world operating conditions, the possibility of creating an oxygen deficient environment is a possibility and appreciable amounts of carbon monoxide can form¹. Studies have shown that an oxygen content of less than 17% in the air can result in the creation of CO of up to 5.9% of the resulting exhaust gas. Since it is not the intention to run the combustion engine in an oxygen-deficient state, a conservative estimate for CO emissions was based on a conversion of less than 1%. These values are consistent with the values found in AP-42 for natural gas combustion. Therefore, AP-42 values were used as comparable emission factors for CO and CO₂.

The presence of nitrogen in the air allows for the possibility of creating thermal nitrogen oxides (NO_x). At high temperatures, usually above 1600°C (2900°F), the nitrogen (N₂) and oxygen (O₂) molecules in the combustion air decompose into their atomic states allowing for the oxidation of the nitrogen and the formation of NO_x, at a rate that is dependent upon the temperature and residence time at that temperature²⁴. The exact amount of NO_x produced during combustion, although unknown, is comparable to NO_x from the combustion of natural gas due to the low nitrogen content of natural gas.

Two ancillary processes are also considered here: the outside storage of wood in a storage pile and haul roads. These processes are not directly related

to the manufacturing of the product. However, they are necessary for plant operations. Both of these processes will be sources of particulate emissions.

Emissions from wood storage piles can be characterized into three categories: load-in and load-out of wood, wind erosion, and vehicular activity. As wood is loaded onto the wood pile or removed from the wood pile, emissions occur due to the disturbance of the material in the storage pile. The equation for determining these emissions, found in Section 13.2.4 Aggregate Handling and Storage Piles⁴, is included here.

$$E = 0.0032k(U/5)^{1.3}/(M/2)^{1.4} \text{ where}$$

E = emission factor

k = particle size multiplier (dimensionless)

U = mean wind speed (m/s)

M = material moisture content (%)

The wind erosion and vehicular activity emissions were based on equations taken from the Quarry Emission Worksheet²⁵.

Haul roads emissions are addressed in Section 13.2.1 Paved Haul Roads and Section 13.2.2 Unpaved Haul Roads depending on haul road conditions at the plant. Each type yields a different quantity of emissions based on the type of activity occurring at the plant, the kind of material being hauled, and the weight of the truck hauling the material. As the trucks drive over the road, the tires crush the material on the roads and lift it into the air. A set of empirical expressions are included in the AP-42 for the estimation of particulate matter.

(unpaved) $E = k (s/12)^a (W/3)^b$ where

E = size-specific emission factor (lb/VMT)

s = surface material silt content (%)

W = mean vehicle weight (tons)

M = surface material moisture content (%)

S = mean vehicle speed (mph)

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire

wear.

k , a , b , c and d are empirical constants.

(paved) $E = k(sL/2)^{0.65} \times (W/3)^{1.5} - C$

where: E = particulate emission factor (having units matching the units of k),

k = particle size multiplier for particle size range and units of interest (see below),

sL = road surface silt loading (grams per square meter) (g/m^2),

W = average weight (tons) of the vehicles traveling the road, and

C = emission factor for 1980's vehicle fleet exhaust, brake wear and tire wear

CHAPTER 4

EVALUATION AND RESULTS

4.1 True *De minimis* Source

For a plant with a potential to emit (PTE) of less than *de minimis* levels for all criteria air pollutants, no construction permit is required for the construction and operation of the installation. A true *de minimis* source does not require control equipment to maintain the emissions of regulated pollutants below *de minimis* levels. In other words, no control devices are used to reduce emissions released into the ambient air. When considering true *de minimis* sources, if the haul roads that will be used are already paved, the methods for calculating these emissions would differ from haul roads that are unpaved.

In this case study, the two scenarios that are examined are paved haul roads and unpaved haul roads. In order to qualify as a paved haul road, they must be paved with appropriate paving materials such as asphalt or concrete. Table 13 shows the PTE of plant with paved haul roads and with unpaved haul roads. The reductions in emissions from the paving of the haul allows for an increase in production of 104 tons per year. In either case, the rate of production cannot exceed 4.5 tons per day before a construction permit is necessary. This would require a maximum wood feed rate of 0.11 tons per hour.

Because the pollutant with the greatest potential to emit is PM₁₀, it is considered the limiting air pollutant. Therefore, as the production at the plant increases, the emission of PM₁₀ will reach *de minimis* levels before the other pollutants.

4.2 Synthetic *De minimis* Source

A plant with potential emissions greater than *de minimis* levels can consent to emissions limitations and/or control requirements that will lower their potential emissions to *de minimis* levels. Such permitted sources are called synthetic *de minimis* sources and, for these sources, the review and issuance of a construction permit is required prior to start of construction of the installation. If an emissions limitation is imposed, the installation may not operate in a manner that will cause emissions from the installation to exceed the emissions limitation. This typically translates into a limited production rate. If the installation will employ control devices as a means for reducing emissions, the installation will be required to maintain and monitor the pollution control equipment.

Specifically for the carbide production plant, the pollutant being controlled will be PM₁₀. By reducing the PM₁₀ emissions, the limiting pollutant changes from PM₁₀ in a true *de minimis* source to NO_x. Table 13 shows the carbide production level at which NO_x will remain a *de minimis* source. This means that a plant with a maximum production capacity greater than 6,362 tons per year will

require an emissions limit to remain a *de minimis* source based on the NO_x emissions.

Similar to the true *de minimis* source, potential emissions of the installation will vary based on the use of unpaved or paved haul roads. For purposes of simplification, controlled emissions are based on the use of paved haul roads while uncontrolled emissions are based on the use of unpaved haul roads.

The most common means of controlling particulate emissions are fabric filters. Fabric filters can be added to the silos to reduce the particulate matter release at the silo vents. The type of fabric filter can have an effect on how much reduction in particulate matter can be achieved. The range of control efficiencies is 90-99.9% with higher efficiencies possible through bag designs. In this case, a conservative control efficiency of 99% was assumed for the use of a fabric filter on non-combustion equipment. Ancillary processes (i.e. storage piles and haul roads) are not controlled by fabric filters and control options for these units were not explored beyond the paving alternative. A summary of the emissions can be seen in Table 13.

It should be noted that the calculations are based on a capture efficiency of 100%. Enclosures can be utilized to capture emissions from conveyors moving the materials between processes. The captured emissions would be drawn into the silo for control by the fabric filter. Although enclosures only achieve a control efficiency of 3.7% by themselves, the capture efficiency can

increase to 100% depending on how the enclosure is design. If a negative pressure is produced by the induction of air flow into the silo, the capture efficiency is 100%.

Varying degrees of control require varying monitoring and recordkeeping of the control devices. As the control efficiency of the equipment increases, the amount of documentation for the increased control efficiency also increases. Therefore, it is important for a company to take into these factors in the design process to avoid undesirable requirements during the operation of the plant.

4.3 Minor Source

Based on a plant size greater than 30,273 tons per year, the potential emissions will exceed the minor source levels and therefore must be designed at a maximum feed capacity of 2.046 tons per hour to remain a minor source. If the capacity of the plant is higher than this amount, a limit on the emissions that will achieve this capacity can be taken to remain a minor source.

For plants that wish to obtain any minor source permit for PM₁₀ and/or SO_x issued in an increment area, they are required to conduct a modeling analysis. In addition, if the potential to emit of the installation is above 50 tons per year, the minor source will be required to submit modeling showing that their source is in compliance with the PM₁₀ and SO_x National Ambient Air Quality Standards (NAAQS). As the minor source permitting implications are examined with the carbide facility, the modeling aspects are also addressed.

The air quality standards can be found in 10 CSR 10-6.010 and are summarized in Table 11. Since this plant is not expected to have SO_x emissions, a SO_x evaluation is not necessary.

Without a specific location for the installation, an accurate increment or NAAQS modeling analysis cannot be performed. Refined modeling takes into account site specific information to replicate the interactions of the new site with existing emissions in the area. Refined modeling is the preferred method for modeling impacts. However, since site specific information is unavailable for this study, screen modeling is used to determine the impact of pollutants from this process. The most common EPA approved screening model is Screen3. However, when dealing with multiple emission sources and/or area sources like haul roads, Screen3 is not designed to model these types of sources. The Missouri Department of Natural Resources currently maintains a set of modeling nomographs developed by the Air Pollution Control Program that is used for modeling construction industries such as concrete batch plants, asphalt batch plants, and quarry operations. These nomographs are considered very conservative in predicting impacts and were chosen as the modeling method for the carbide plant as a general evaluative tool for determining the impact of emissions from the carbide plant on the ambient air.

For purposes of this research, the impacts from various distances to the property boundary were evaluated. The location of the plant to the property boundary can have a significant effect on a model since the distance the

emissions have to travel before reaching ambient air also affect the impact those emissions have on the ambient air. Although ambient air is defined in the regulations as: “All space outside of buildings, stacks or exterior ducts (10 CSR 10-6.020(2)(A)¹⁹), for modeling and permitting purposes, ambient air is better defined as air outside of a fenced property boundary. This is air that can be reached by a public entity.

The nomograph-based spreadsheet distributed by the Missouri Department of Natural Resources (MDNR) has been utilized as a surrogate for refined modeling. Specifically, the nomograph-based spreadsheets designed to account for emissions of a quarry operation were utilized since the emission points associated with a quarry operation are similar to the emission points associated with this plant study. Quarries operated conveyors, crushers, storage piles and haul roads similar to the operations at the carbide facility. The nomograph-based spreadsheets are considered conservative screening models and, for purposes of this study, these screening models will provide a general overview of how the emissions are impacting the air.

Although two standard averaging times exist for the PM₁₀, only the 24-hour standard is evaluated in this study since the nomograph-based spreadsheets only address the 24-hour standard. Demonstrating compliance first with the 24-hour standard is useful in identifying initial issues that may occur. Without site specific information, further analysis of the annual standard was not conducted.

Figures 5 and 6 show a snapshot of the spreadsheet model taken directly from the MDNR website. Parameters specific to the carbide plant were keyed into the spreadsheet and the results were summarized. Table 12 and 10 provide summaries of the impacts based on the spreadsheet.

For a minor source not wishing to take any conditions on the installation, the potential emissions of PM₁₀ can go up to 249 tons per year without exceeding major levels. For this type of source, the facility is not expected to comply with either the increment or the NAAQS for PM₁₀ unless the facility can be located quite a distance from the property boundary. The nomograph spreadsheet is not equipped for distances greater than 2500 feet. However, if the data is extrapolated as seen in Figure 7, the distance needed to meet the NAAQS is 3140 feet. Moreover, the distance needed to comply with the increment standard is higher at 3525 feet. Unless the installation can be located on a large plot of land, the data suggests that refined modeling will be necessary once specific information on the plant is confirmed if the full installation intends on emitting the 249 tons per year.

As an alternative, the plant may reduce the production rate of the plant to achieve a lower uncontrolled emission rate. Table 12 looks at how a decrease in the production rates affects the installation's impact. A production between 10,000 to 15,000 tons per year at a distance of 2500 feet from the property boundary is able to meet the NAAQS using the spreadsheet model.

For a plant designed for the control of particulate matter, the potential emissions of PM₁₀ decrease drastically allowing production to increase and the limiting pollutant, NO_x, to increase to 249 tons per year. This is a production rate of close to 40,000 tons per year. In addition, the modeled impact decreases such that the plant is able to locate closer to the property boundary without exceeding air quality standards. Table 13 shows a comparison of impacts with respect to the distance of the plant to the property boundary. In contrast to the distance needed for a true minor source to comply with air standards, a synthetic minor source is able to locate as close as 500 feet to the nearest property boundary. This shows how decreasing the emissions increases flexibility for the plant.

4.4 Major Source

Based on a plant size of 44,389 tons per year, the controlled potential emissions of NO_x will exceed the major source levels. The major source evaluated in this thesis will be located in an attainment area for all criteria pollutants. This includes areas outside of the St. Louis metropolitan area (i.e. St. Louis, St. Charles, Jefferson and Franklin Counties and the City of St. Louis). Therefore the review of the plant will be conducted under Section (8) of the construction permit rule. For the review of a major source, a compliant refined modeling analysis and a Best Available Control Technology (BACT) analysis must be conducted for the major pollutant, which is, in this case, NO_x.

For plants that wish to construct in a non-attainment area, a review under Section (7) of the construction permit rule is required. This includes a Lowest Achievable Emission Rate (LAER) review in lieu of a BACT review of the possible control devices. In a LAER review, the most stringent emission limit must be considered regardless of economic, energy or environmental impacts associated with the controls device or limitation. The LAER review is outside the scope of this thesis.

A compliant modeling analysis for a major review for the carbide plant will include a demonstration of compliance with the NO_x NAAQS and increment standard. In addition, any applicable minor source modeling requirements must be completed for all major reviews. In this case, the potential emissions of PM₁₀ exceed the *de minimis* levels but not major levels. Therefore, a PM₁₀ NAAQS and increment analysis is also necessary. Table 14 outlines the PM₁₀ impacts based on the quarry spreadsheet. In order to meet the NAAQS, the plant would need to locate between 400 and 500 feet from the property boundary. For the increment standard, the plant would need to locate more than 1300 feet from the property boundary.

Similar to the discussion found in the previous minor source modeling section, screen modeling is used as a surrogate for refined modeling since site specific information is not available for this study. Again, the nomograph-based spreadsheet model is used as the modeling method for PM₁₀. For NO_x, the conservative model called Screen3 is utilized to evaluate impacts from the site.

As noted previously, Screen3 is not intended for multiple emission sources and is not a good model for haul roads or storage piles. However, there is a procedure allowed by the Screen3 model that merges nearby emission stacks into a single representative stack for evaluation in the Screen3 model²⁶. The carbide facility only consists of three sources of NO_x emissions: the wood dryer, the reactor, and the IC engine. This research uses the representative stack procedure to combine these similar sources and determine the impact of NO_x from the facility.

Screen3 allows the user to input stack parameters, emission rates and other modeling considerations such as building downwash, terrain, and meteorological conditions. Default parameters for the modeling aspects of the program are set up for the Screen3 model and are typically used when running the model for permit screening purposes. However, stack parameters and emission rates must be inputted by the user before the model can run properly. Once the model is finished running, the program supplies an output of information including the impacts at discrete distances from the source. For this research, a user-friendly interface called Screen View Version 3.0, produced by Lakes Environmental, was used. Figure 8 is an example of the output file created by Screen3.

Several factors may affect the impact of emissions including stack height, exit velocity, and exit temperature. These three parameters were investigated using the ranges specified in Table 12. The results seen in Table 13, 14 and 15 show that the lower stack height, temperature, and exit velocity values have the

highest effect on the impact of the plant on the ambient air. These factors should be considered in determining the optimum design for a carbide plant. Finally, by taking the lowest stack parameter values, the distance from the stack to the property boundary can be determined by finding the maximum impact that will not exceed either the NAAQS or the increment standard for NO_x. These results can be seen in Table 16.

For major reviews, a BACT analysis is also required. The top-down approach is outlined in the EPA document Draft New Source Review Manual and is used as the basis for the BACT analysis for this research. The top-down approach consists of five steps that evaluate the technical, economical and environmental aspects of a control technology as it applies to the process. The five steps are:

1. identify all control technologies;
2. eliminate technically infeasible options;
3. rank remaining control technologies by control effectiveness;
4. evaluate most effective controls and document results; and
5. select BACT.

To perform a complete BACT analysis, the costs and specific design parameters are needed for each piece of equipment. However, this type of information is invariably dependent upon the company responsible for the construction of the plant. Therefore, the first three steps of the analysis have

been reviewed and presented. The final two steps were completed based on the typical selection of BACT at other facilities.

To identify control technologies used on throughout the US, the EPA has developed a clearinghouse of permit determinations called the RACT/BACT/LAER Clearinghouse (RBLC). This is used as the tool for permitting authorities to search control technologies currently permitted in other states. Since the three stage reactor is a new technology, previous BACT analyses have not been performed for this process.

The equipment included in this BACT analysis are those equipment that emit the pollutants that exceed the major levels. The only sources of NO_x at the carbide plant are the combustion equipment. This includes the three-stage reactor, the IC engines and the wood dryer.

Although a BACT analysis has not been completed for the three stage reactor, control options for the pollutants found in the exhaust are similar to those found for the control of IC engine emissions. Based on the potential to emit analysis, both processes are expected to emit comparable amounts of NO_x, VOC and CO. Therefore the control technologies discussed in the following sections may be applied to these process emissions.

PM₁₀, VOC and CO will not be emitted in amounts greater than the major threshold levels and are not included in this BACT analysis. However, PM₁₀, VOC and CO control technologies are included in the Appendix as an overview of possible control options for higher production rates.

The control technologies for NO_x from IC engines are:

- Low Excess Air (LEA)
- Low NO_x Burners (LNB)
- Overfire Air (OFA)
- Flue gas recirculation (FGR)
- Selective Non-Catalytic Reduction (SNCR)
- Selective Catalytic Reduction

A description of these control technologies can be found in the Appendix.

Although a BACT analysis can also take into account factors such as cost and environmental impacts, these factors are not examined by this review. Based on the common occurrence of LNBs in BACT determinations, LNBs were chosen as the control of choice for this review. LNBs are designed to limit NO_x formation by controlling the stoichiometric makeup of the combustion flame and the temperature profile in each burner flame. This control is accomplished by regulating the aerodynamic distribution and mixing of the fuel and air, thus reducing oxygen (O₂) in the primary combustion zone, flame temperature and residence time at peak combustion temperatures.

CHAPTER 5

CONCLUSION

A calcium carbide manufacturing plant can be permitted for construction in Missouri at each air regulatory permitting level: *de minimis*, minor and major source levels. The type of permit and level of review necessary will depend on the total amount of production specified in the process. For a true *de minimis* source, or an annual calcium production rate of less than 1,657 tons, no control devices are required. For a synthetic *de minimis* source, or an annual calcium production rate of 6,362 tons, particulate filters with a control efficiency of 99% are required. Similarly, for a true minor source, or an annual calcium production rate of less than 30,273 tons, no control devices are required. For a synthetic minor source, or an annual calcium production rate of 39,876 tons, particulate filters with a control efficiency of 99% are required. A major source, or an annual calcium production rate of 44,389 tons, requires the installation of low NO_x burners in addition to particulate filters.

For each regulated pollutant, emission modeling was performed by the application of screen models. The modeling results indicate compliance with applicable air standards is reasonably achievable depending on the location of the plant to the property boundary.

CHAPTER 6

RECOMMENDATIONS

For future consideration of acetylene production at the calcium carbide plant, air emissions can be considered negligible. Acetylene production requires the addition of water to the calcium carbide. The main source of emissions would be particulate matter from the processing of calcium carbide or the handling of the calcium carbonate produced during the reaction. These emissions would be dependent on the number of equipment used in the plant design and the final production rate. No other regulated air pollutants are expected.

This thesis represents the writer's estimation of emissions from a plant still in the conceptual stages. To the best of the writer's knowledge at the time of writing, these emissions estimations are considered conservative to provide a general idea of the level of permitting required at various production rates. Actual review results are dependent on the final design of the plant, the location of the plant, and any additional regulations that may become effective after publication of this thesis. It is recommended that current regulations are consulted prior to submission of any permit application.

Although Hazardous Air Pollutants are not expected in quantities that would exceed the *de minimis* threshold for HAPs, each individual HAP is

assigned a Screen Modeling Action Level (SMAL) that, for certain HAPs, have considerably lower thresholds than the HAP *de minimis* level. If an individual HAP has a potential to emit greater than its SMAL, modeling will need to be performed to determine if the emissions of that particular HAP will have an impact on the ambient air. The modeled impact must demonstrate compliance with the Risk Assessment Level (RAL) for the modeled HAP. The RAL is a concentration based on a one-in-million cancer risk and is a concentration that is not expected to produce adverse human health effects during a defined period of exposure, which is different for each HAP. Generally, the exposure periods are listed as 8-hour, 24-hour and annual periods. If testing reveals that HAP emissions are a possibility, it is recommended that the emissions are compared to the HAP SMALs for further possible review.

Table 1. Summary of Emission Units for the Gasification Production of Calcium Carbide using Biomass and Lime

Emission Unit Identification	Emission Unit Description	Emission Type	Identifying category
EU-1	Wood dryer	Point	Combustion
EU-2	Dried wood conveyor	Area	Ancillary
EU-3	Charcoal conveyor	Area	Ancillary
EU-4	Lime conveyor	Area	Ancillary
EU-5	Charcoal/lime storage silo	Point	Ancillary
EU-6	Charcoal/lime conveyor	Area	Ancillary
EU-7	Dolomite conveyor	Area	Ancillary
EU-8	Dolomite storage silo	Point	Ancillary
EU-9	3 rd stage reactor combustion	Point	Direct Process
EU-10	Ca C ₂ condenser	Point	Direct Process
EU-11	Ca C ₂ crusher	Area	Ancillary
EU-12	Ca C ₂ conveyor	Area	Ancillary
EU-13	Ca C ₂ loading	Area	Ancillary
EU-14	IC engine – off-gases	Point	Combustion
EU-15	Storage Pile – wood	Area	Ancillary
EU-16	Haul Road	Fugitive - Area	Ancillary

Table 2. Material Balance for Carbide Production from Wood based on 1 ton Carbide¹

Materials Fed (lb)				Carbide Produced (lb)			Gas and dust (excl. CO)			Carbon	CO	
Component	Lime	Wood	Total	Feed	In Product		Feed	Evolved		Consumed	Emitted	
				Component used	as	amount		Component	as			amount
CaO	1846.8		1846.8	1467.4	CaC ₂	1677.0				943.3		
				191.5	CaO	191.5	64.4	CaO	64.4		25.7	
				9.2	Ca	6.6	110.8	Ca	79.1		0.0	
				0.2	CaS	0.2					0.1	
				0.6	Ca ₃ P ₂	0.6					0.6	
				2.7	Ca ₃ N ₂	2.4						
C		1124.9	1124.9	98.8	C	98.8	40.5	C	40.5		139.3	
				0.1	Al ₄ C ₃	0.3					0.1	
				1.9	SiC	6.0					1.9	
H ₂ O	4.1	59.2	63.3				63.3	H ₂	7.2		42.0	
volatiles		112.5	112.5				112.5	H ₂	15.9			
								CH ₄	63.7			
SiO ₂	30.7		30.7	7.8	SiO ₂	7.8	0.8	SiO ₂	0.8			
				9.0	SiC	6.0	13.1	Si			8.9	
Fe ₂ O ₃	14.3		14.3	2.6	Fe ₂ O ₃	2.6	11.7	Fe	3.3		0.0	
Al ₂ O ₃	10.2		10.2	5.1	Al ₂ O ₃	5.1	1.8	Al ₂ O ₃	1.8			
				0.7	Al ₄ C ₃	0.3	2.6	Al	0.7		1.2	
MgO	6.1		6.1	1.0	MgO	1.0	5.1	Mg	3.1		1.5	
Na ₂ O	10.2		10.2				10.2	Na	3.7		2.0	
S	0.0	0.1	0.1	0.1	CaS	0.2	0.0	S	0.0			
SO ₃	2.0		2.0				2.0	SO ₂	1.6		0.0	
CO ₂	20.5		20.5									
P ₂ O ₅	0.6		0.6	0.5	Ca ₃ P ₂	0.6	0.1	P	0.1		0.1	
N	0.0	0.6	0.6	0.5	Ca ₃ N ₂	2.4	0.1	N ₂	0.1			
total (lb)	1944.97	1296.54				2000.0			286.3		1166.9	1009.3

Table 3. Thermal Balance of Carbide Production from Wood based on 1 ton of Carbide¹

Reaction	ΔH BTU/mol	Basis			Heat Consumed BTU
		Reactant	lb	moles	
CaO + 3C = CaC ₂ + CO	441	CaO	1467.4	11885.9	5,241,902
CaO + C = Ca + CO	497	CaO	123	1000.2	496,666
H ₂ O + C = CO + H ₂	167	H ₂ O	63	1435.5	239,108
Ca(OH) ₂ = CaO + H ₂ O	63	H ₂ O	9	205.1	13,013
CaSiO ₃ = CaO + SiO ₂	80	SiO ₂	3	19.3	1,539
SiO ₂ + 2C = Si + 2CO	589	SiO ₂	22	167.3	98,559
Si + C = SiC	-6	SiC	6	68.0	-378
Fe ₂ O ₃ + 3C = 2Fe + 3CO	442	Fe ₂ O ₃	12	53.1	23,480
Ca(AlO ₂) ₂ = CaO + Al ₂ O ₃	0	Al ₂ O ₃	5	23.2	0
Al ₂ O ₃ + 3C = 2Al + 3CO	1230	Al ₂ O ₃	2.5	11.4	14,055
4Al + 3C = Al ₄ C ₃	0	Al ₄ C ₃	0.3	1.1	0
MgO + C = Mg + CO	473	MgO	5	58.0	27,433
Na ₂ O + C = 2Na + CO	288	Na ₂ O	10	77.3	22,290
Ca SO ₄ + C = CaO + SO ₂ + CO	350	SO ₃	2	11.6	4,061
CaCO ₃ + C = CaO + 2CO	331	CO ₂	20	210.8	69,737
Ca ₃ (PO ₄) ₂ + 5C = 3CaO + 2P + 5CO	1566	P ₂ O ₅	0.6	2.5	3,961
3Ca + 2P = Ca ₃ P ₂	-397	P ₂ O ₅	0.6	2.5	-1,003
Ca + Sorganic = CaS	-198	S	0.09	1.3	-253
Ca + Norganic = Ca ₃ N ₂	-198	N	0.5	14.6	-2,892
Total Chemical Reactions					6,251,276
Heat content of carbide at 3578°F, cp 0.522 BTU/lb					2,055,137
Latent heat of fusion					229,942
Heat content of 263.1 lb of dust at 1148°F, cp 0.450 BTU/lb					73,352
Heat content of 1009.3 lb of CO at 1148°F cp 0.468 BTU/lb					292,620
Heat content of 23.1 lb of H ₂ at 1148°F cp 6.299 BTU/lb					28,233
Heat content of 63.7 lb of CH ₄ and 1.8 lb of other gases					18,742
Total chemical and sensible heat					8,949,301
Transformer and electrode cooling water, 8%					715,944
Total (approx)					9,665,246

Table 4. Boiler Design Heating Requirements

heat required for the production based on 1 ton	9,665,246	BTU/ton CaC ₂ produced
boiler efficiency	85%	
heat required to boiler	11,370,877	BTU/ton CaC ₂ produced
Heat Content Comparison among Fuels		
Natural Gas	1,439,277	BTU/ft ³
Methane, CH ₄	1,332,837	BTU/ft ³
Acetylene	1,874,407	BTU/ft ³
Quantity of Fuel Required to Boiler		
Natural Gas	7.9	ft ³ /ton CaC ₂ produced
Methane, CH ₄	8.5	ft ³ /ton CaC ₂ produced
Acetylene	6.1	ft ³ /ton CaC ₂ produced
density of methane	0.0417	lb _m /ft ³
density of natural gas	0.044	lb _m /ft ³
density of acetylene	0.0682	lb _m /ft ³
Natural Gas	0.33	lb _m fuel/ton carbide produced
Methane, CH ₄	0.38	lb _m fuel/ton carbide produced
Acetylene	0.41	lb _m fuel/ton carbide produced

Table 5. *De Minimis* Levels for Regulated Air Pollutants

Regulated Air Pollutants	<i>De minimis</i> Level (tons per year)
Carbon Monoxide	100.0
Nitrogen dioxide	40.0
Particulate Matter less than 10 microns (PM ₁₀)	15.0
Sulfur dioxide	40.0
Ozone (to be measured as VOC)	40.0
Lead	0.6
Hazardous Air Pollutant (each)	10.0
Sum of Hazardous Air Pollutants	25.0

Table 6. New Source Review Major Thresholds

Pollutant	Named Sources (tons per year)	Non-named sources (tons per year)
PM ₁₀	100	250
SO _x	100	250
NO _x	100	250
VOC	100	250
CO	100	250
HAPs	10/25	10/25

Table 7. PM₁₀ Emission Factors for Carbide Production

ID	Emission Unit	location	EF	units	Note
EU-1	Wood dryer	SCC 3-07-006-25, AP-42 Table 10.6.2-1 (uncontrolled)	2.2	lb/dried ton	
EU-2	Dried wood conveyor	SCC 3-05-016-15 AP- 42 Table 11.17-4	2.2	lb PM/ton processed	
EU-3	Charcoal conveyor	SCC 3-05-016-15 AP- 42 Table 11.17-4	2.2	lb PM/ton processed	
EU-4	Lime conveyor	SCC 3-05-016-15 AP- 42 Table 11.17-4	2.2	lb PM/ton processed	
EU-5	Charcoal/lime storage silo	SCC 3-05-004-06 AP- 42 Table 11.4-2 (with fabric filter)	0.22	lb PM/ton processed	Determined uncontrolled EF by assuming 99% control efficiency for the baghouse per AP-42 Appendix B.2
EU-6	Charcoal/lime conveyor (charging conveyor)	SCC 3-05-004-06 AP- 42 Table 11.4-2 (with fabric filter)	0.22	lb PM/ton processed	Determined uncontrolled EF by assuming 99% control efficiency for the baghouse per AP-42 Appendix B.2
EU-7	Dolomite conveyor	SCC 3-05-016-15 AP- 42 Table 11.17-4	2.2	lb PM/ton processed	
EU-8	Dolomite storage silo	SCC 3-05-016-15 AP- 42 Table 11.17-4	2.2	lb PM/ton processed	
EU-9	3 rd stage reactor combustion	SCC 1-02-006-02 AP- 42 Table 1.4-2	0.00745	lb PM/MMBTU	
EU-10	Ca C ₂ condenser (tap fume vents)	SCC 3-05-004-04 AP- 42 Table 11.4-2 (with fabric filter)	0.14	lb PM/ton throughput	Determined uncontrolled EF by assuming 99% control efficiency for the baghouse per AP-42 Appendix B.2

Table 7 ID	(Cont.) Emission Unit	location	EF	units	Note
EU-11	Ca C ₂ crusher	SCC 3-05-004-05 AP-42 Table 11.4-2 (with fabric filter)	0.11	lb PM/ton throughput	Determined uncontrolled EF by assuming 99% control efficiency for the baghouse per AP-42 Appendix B.2
EU-12	Ca C ₂ conveyor	SCC 3-05-020-06 AP-42 Table 11.19.2-2 (uncontrolled)	0.0011	lb/ton throughput	
EU-13	Ca C ₂ loading	SCC 3-05-020-32 AP-42 Table 11.19.2-2 (uncontrolled)	0.0001	lb/ton throughput	
EU-14	IC engine – off-gases	SCC 2-02-002-54 AP-42 Table 3.2-2	7.71E-05	lb/MMBTU	
EU-15	Storage Pile – wood	AP-42 13.2.4 Aggregate Handling and Storage Piles	Equation		
EU-16	Haul Road	AP-42 13.2.1 Paved haul road	Equation	lb/VMT	

Table 8. NO_x and VOC Emission Factors for Carbide Production

		NO _x			VOC		
		location	EF	units	location	EF	units
EU-1	Wood dryer	SCC 3-07-006-25, AP-42 Table 10.6.2-2 (uncontrolled)	2.7	lb/dried ton	SCC 3-07-006-25, AP- 42 Table 10.6.2-3 (uncontrolled)	11.79	lb/dried ton
EU-2	Dried wood conveyor	N/A			N/A		
EU-3	Charcoal conveyor	N/A			N/A		
EU-4	Lime conveyor	N/A			N/A		
EU-5	Charcoal/lime storage silo	N/A			N/A		
EU-6	Charcoal/lime conveyor (charging conveyor)	N/A			N/A		
EU-7	Dolomite conveyor	N/A			N/A		
EU-8	Dolomite storage silo	N/A			N/A		
EU-9	3 rd stage reactor combustion	SCC 1-02-006-02 AP-42 Table 1.4-1	0.098	lb/MMBTU	SCC 1-02-006-02 AP- 42 Table 1.4-2	0.005	lb/MMBTU
EU-10	Ca C ₂ condenser (tap fume vents)	N/A			N/A		
EU-11	Ca C ₂ crusher	N/A			N/A		
EU-12	Ca C ₂ conveyor	N/A			N/A		
EU-13	Ca C ₂ loading	N/A			N/A		
EU-14	IC engine – off-gases	SCC 2-02-002-54 AP-4 Table 3.2-2	0.847	lb/MMBTU	SCC 2-02-002-54 AP- 4 Table 3.2-2	0.118	lb/MMBTU
EU-15	Storage Pile – wood	N/A			N/A		
EU-16	Haul Road	N/A			N/A		

Table 9. CO₂ and CO Emission Factors for Carbide Production

		CO ₂			CO		
		location	EF	units	location	EF	units
EU-1	Wood dryer	SCC 3-07-006-25, AP-42 Table 10.6.2-2 (uncontrolled)	573	lb/dried ton	SCC 3-07-006-25, AP-42 Table 10.6.2-2 (uncontrolled)	3.5	lb/dried ton
EU-2	Dried wood conveyor	N/A			N/A		
EU-3	Charcoal conveyor	N/A			N/A		
EU-4	Lime conveyor	N/A			N/A		
EU-5	Charcoal/lime storage silo	N/A			N/A		
EU-6	Charcoal/lime conveyor (charging conveyor)	N/A			N/A		
EU-7	Dolomite conveyor	N/A			N/A		
EU-8	Dolomite storage silo	N/A			N/A		
EU-9	3 rd stage reactor combustion	SCC 1-02-006-02 AP-42 Table 1.4-1	117.647	lb/MMBT U	SCC 1-02-006-02 AP-42 Table 1.4-1	0.082	lb/MMBT U
EU-10	Ca C ₂ condenser (tap fume vents)	N/A			N/A		
EU-11	Ca C ₂ crusher	N/A			N/A		
EU-12	Ca C ₂ conveyor	N/A			N/A		
EU-13	Ca C ₂ loading	N/A			N/A		
EU-14	IC engine – off-gases	SCC 2-02-002-54 AP-4 Table 3.2-2	110	lb/MMBT U	SCC 2-02-002-54 AP-4 Table 3.2-2	0.557	lb/MMBT U
EU-15	Storage Pile – wood	N/A			N/A		
EU-16	Haul Road	N/A			N/A		

Table 10. Comparison of Wood Feed Rates and Carbide Production Rates to Annual Emission Rates

Permitting Classification	Haul Road Type	MHDR of wood in tons	Control Efficiency	PM ₁₀ tpy	NO _x tpy	VOC tpy	CO tpy	CO ₂ tpy	Carbide Production Rate tpy
True <i>de minimis</i>	unpaved	0.112		14.9	10.4	6.4	7.8	1,436	1,657
	paved	0.119		14.7	11.0	6.8	8.2	1,526	1,761
Synthetic <i>de minimis</i>	paved	0.43	99%	3.8	39.9	24.6	29.8	5,514	6,362
True minor	paved	2.046		249.8	189.7	117.0	141.8	26,236	30,273
Synthetic minor	paved	2.695	99%	20.9	249.9	154.1	186.8	34,558	39,876
Controlled major	paved	3	99%	23.2	278.1	171.6	208.0	38,468	44,389

Table 11.NAAQS and Increment Standards

Pollutant	Concentration ($\mu\text{g} / \text{m}^3$)		Averaging Time
	NAAQS	Increment	
PM ₁₀	50	17	Annual
	150	30	24-hour
CO	10,000	N/A	8-hour
	40,000	N/A	1-hour
NO _x	100	25	Annual

Table 12. Summary of PM₁₀ modeling based on quarry spreadsheet for a true minor installation

	Carbide Production (tpy)	annual emissions (tpy)	distance to boundary (ft)	Installation 24-hour impact * (µg /m ³)
True Minor	30,273	249.8	2000	509.92
	30,273	249.8	2250	419.56
	30,273	249.8	2500	353.85
	25,000	206.2	2500	290.75
	20,000	164.8	2500	232.61
	15,000	124	2500	174.47
	10,000	82.7	2500	116.33

* An installation 24-hour impact of 150 µg /m³ demonstrates compliance with the NAAQS

Table 13. Summary of PM₁₀ modeling based on quarry spreadsheet for a synthetic minor installation

	Carbide Production (tpy)	annual emissions (tpy)	distance to boundary (ft)	Installation 24-hour impact* ($\mu\text{g}/\text{m}^3$)
Synthetic Minor	39,876	20.9	2000	13.49
	39,876	20.9	1500	22.1
	39,876	20.9	1300	28.23
	39,876	20.9	1000	44.2
	39,876	20.9	750	65.5
	39,876	20.9	500	127.6
	39,876	20.9	400	182.5

* An installation 24-hour impact of $150 \mu\text{g}/\text{m}^3$ demonstrates compliance with the NAAQS.

An installation 24-hour impact of $30 \mu\text{g}/\text{m}^3$ demonstrates compliance with the increment standard.

Table 14. Summary of PM₁₀ modeling based on quarry spreadsheet for a major installation

	Carbide Production (tpy)	annual emissions (tpy)	distance to boundary (ft)	Installation 24-hour impact* ($\mu\text{g}/\text{m}^3$)
Major	44389	23.2	2000	14.95
	44389	23.2	1500	24.5
	44389	23.2	1300	31.31
	44389	23.2	1000	49.02
	44389	23.2	750	72.63
	44389	23.2	500	141.5
	44389	23.2	400	202

* An installation 24-hour impact of $150 \mu\text{g}/\text{m}^3$ demonstrates compliance with the NAAQS.

An installation 24-hour impact of $30 \mu\text{g}/\text{m}^3$ demonstrates compliance with the increment standard.

Table 15. Stack parameter ranges for NO_x impact evaluation using Screen3

Stack parameter	Range
Height	5 ft - 30 ft
Exit velocity	19 ft/s - 30 ft/s
Exit temperature	77°F - 185 °F

Table 16. Comparison of increased exiting temperature on NO_x impacts based on Screen 3

Stack height: 5 ft, Diameter: 2 ft, Exit velocity: 10 ft/s

	Carbide Production (tpy)	annual emissions (tpy)	temperature (°F)	maximum 1-hour impact (µg /m ³)	Installation annual impact (µg /m ³)
Major	44,389	23.2	77	1140	483.36
			113	976.2	413.91
			149	755.5	320.33
			185	628.9	266.65

* An installation annual impact of 100 µg /m³ demonstrates compliance with the NAAQS. An installation annual impact of 25 µg /m³ demonstrates compliance with the increment standard.

Table 17. Comparison of increased stack height on NO_x impacts based on Screen3
 Diameter: 2 ft, Exit velocity: 10 ft/s, Exit temperature: 77°F

	Carbide Production (tpy)	annual emissions (tpy)	stack height		maximum 1-hour impact (µg /m ³)	Installation annual impact (µg /m ³)
			(m)	feet		
Major	44,389	23.2	1.524	5	0.7551	0.32
			3.048	10	397	168.33
			4.572	15	175	74.20
			6.096	20	130.9	55.50
			9.144	30	81.72	34.65

* An installation annual impact of 100 µg /m³ demonstrates compliance with the NAAQS.
 An installation annual impact of 25 µg /m³ demonstrates compliance with the increment standard.

Table 18. Comparison of increased exit velocity on NO_x impacts based on Screen3
 Diameter: 2 ft, Exit velocity: 10 ft/s, Exit temperature: 77°F

	Carbide Production (tpy)	annual emissions (tpy)	exit velocity		maximum 1-hour impact (µg/m ³)	Installation annual impact (µg/m ³)
			(m/s)	ft/s		
Major	44,389	23.2	3.048	10	1140	483.36
			4.572	15	758.8	321.73
			6.096	20	570	241.68
			7.62	25	445	188.68
			9.144	30	380	161.12

* An installation annual impact of 100 µg/m³ demonstrates compliance with the NAAQS.
 An installation annual impact of 25 µg/m³ demonstrates compliance with the increment standard.

Table 19. Summary of worst-case NO_x modeling based on Screen3
 Stack Height 5 ft, Diameter: 2 ft, Exit Velocity: 10 ft/s , Temperature: 77°F

	Carbide Production (tpy)	annual emissions (tpy)	distance to boundary		1-hour impact (µg/m ³)	Installation annual impact* (µg/m ³)
			meters	feet		
Major	44,389	23.2	30	98.208	1140	483.36
			100	327.36	370.8	157.22
			200	654.72	211.7	89.76
			300	982.08	136.4	57.83
			500	1636.8	124.8	52.92
			1000	3273.6	63.61	26.97
			1100	3600.96	56.68	24.03
			1500	4910.4	38.11	16.16

* An installation annual impact of 100 µg /m³ demonstrates compliance with the NAAQS.
 An installation annual impact of 25 µg /m³ demonstrates compliance with the increment standard.

Table 20. Pollutants Requiring Modeling Based on Annual Emission Rates

Permitting Classification	Carbide Production Rate tpy	PM ₁₀		NO _x		CO	
		tpy	modeling	tpy	modeling	tpy	modeling
True <i>de minimis</i>	1,657	14.9	n	10.4	n	7.8	n
	1,761	15.0	n	11.0	n	8.2	n
Synthetic <i>de minimis</i>	6,362	4.8	n	39.9	n	29.8	n
True minor	30,273	249.8	y	189.7	n	141.8	n
Synthetic minor	39,876	27.2	y	249.9	n	186.8	n
Major	44,389	30.2	y	278.1	y	208.0	n

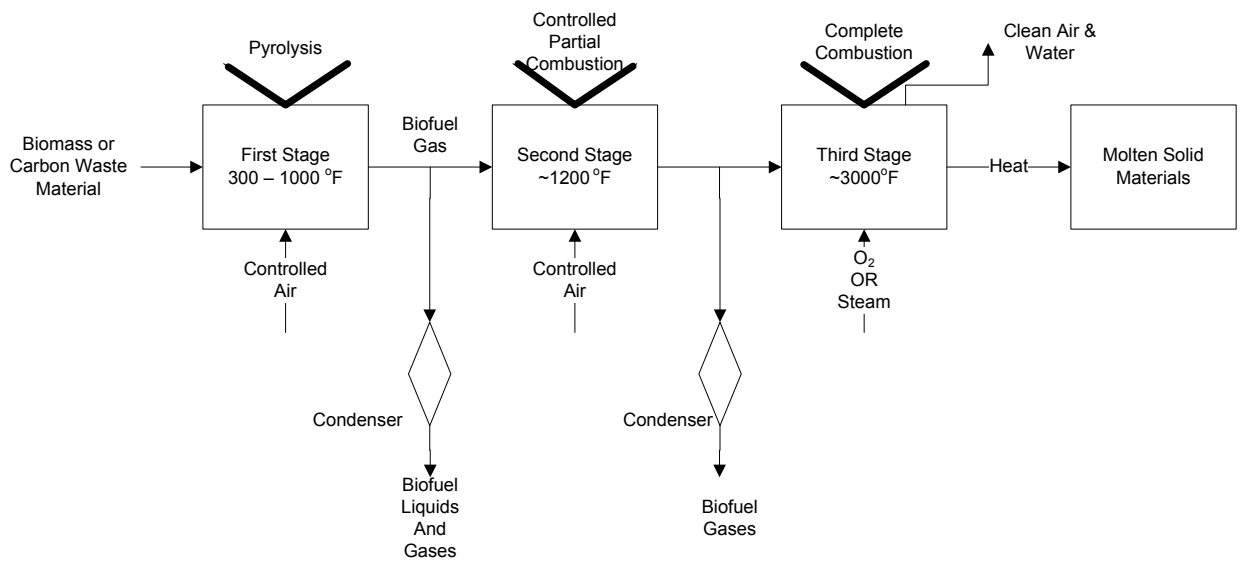


Figure 1. Process Flow Diagram of the Three Stage Gasification Process¹⁵

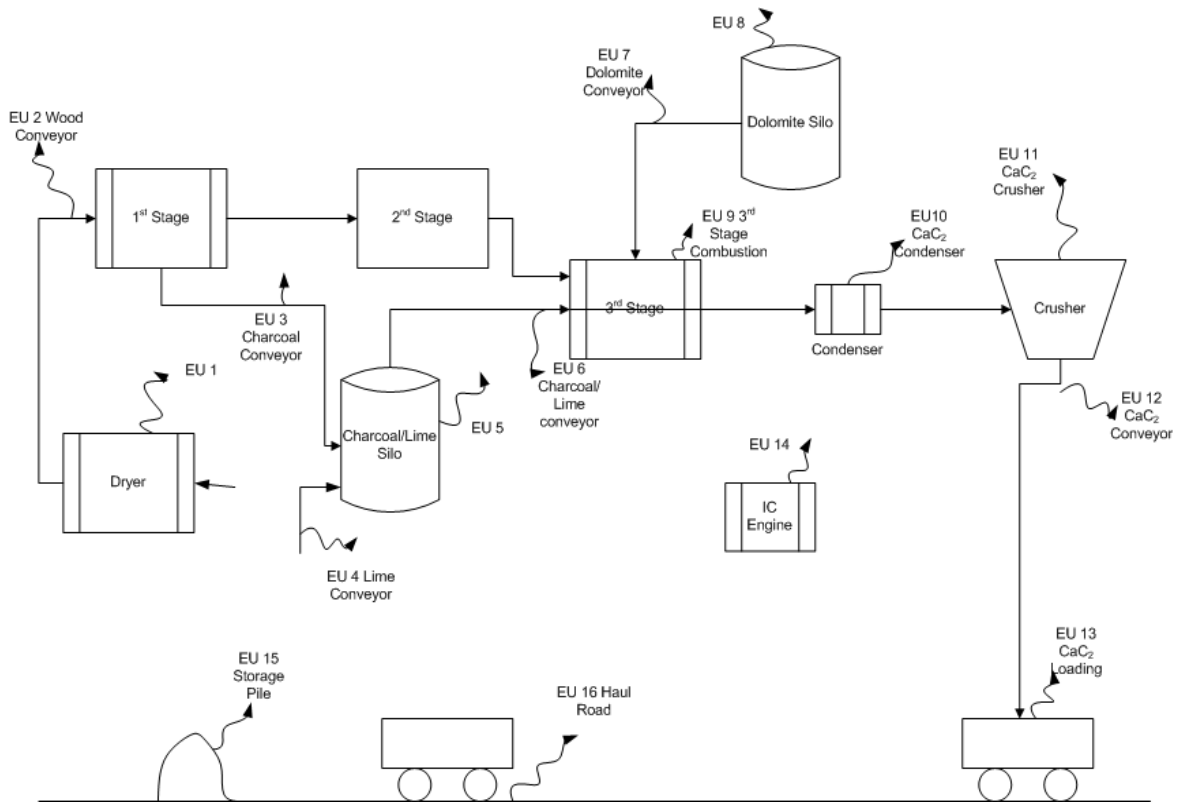


Figure 2. Schematic of Emission Units for a Biomass CaC₂ Plant

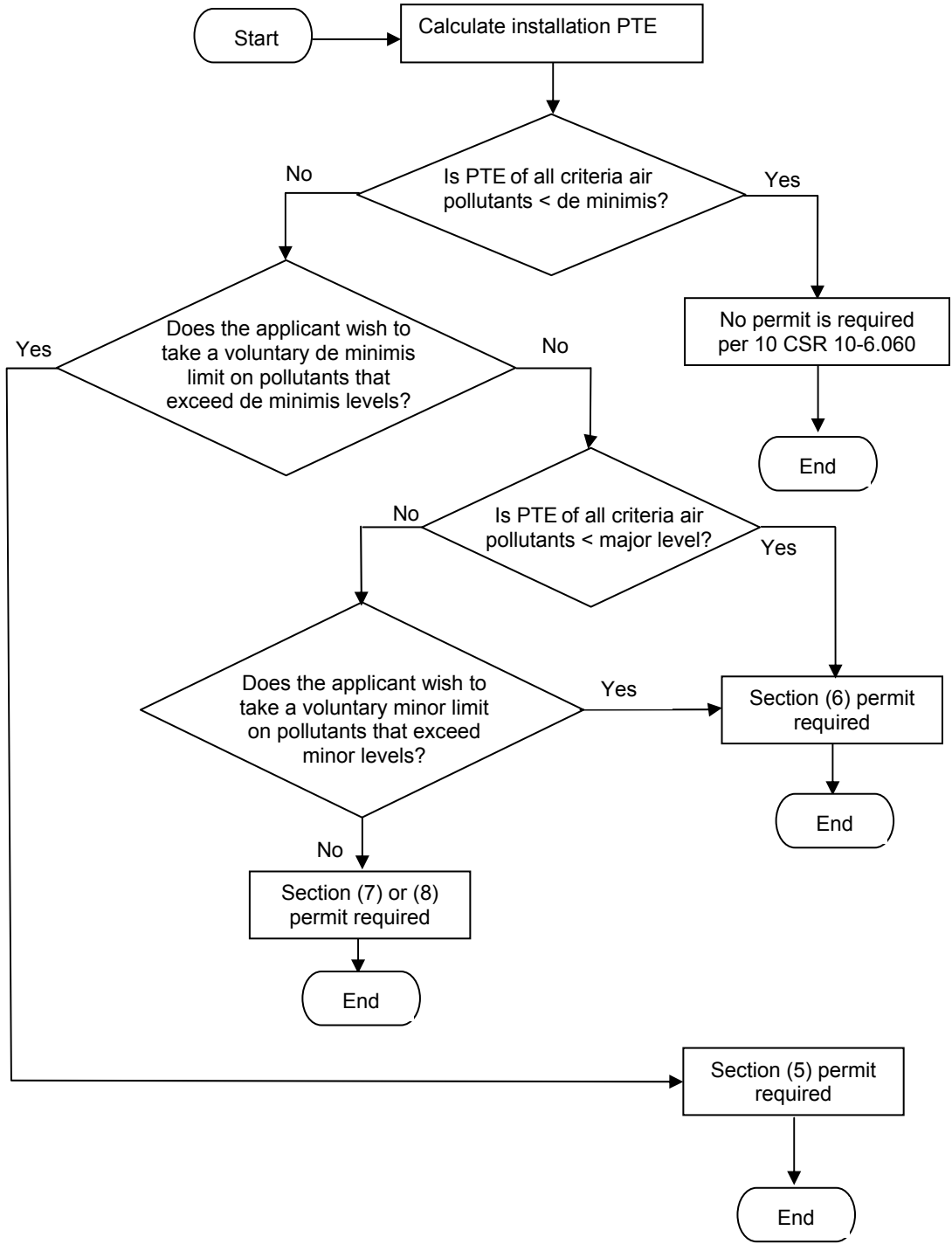


Figure 3. Flow Diagram for Determining Permit Type Required

1124.85 lb wood into process

1846.80lb CaO into process

0.61 ratio of wood to CaO

0.8 conversion factor for wood to charcoal

0.6 ratio of dolomite needed per CaO used

0.56 ratio of wood used to CaC_2 produced

Figure 4. Conversion of Raw Materials through the Carbide Process

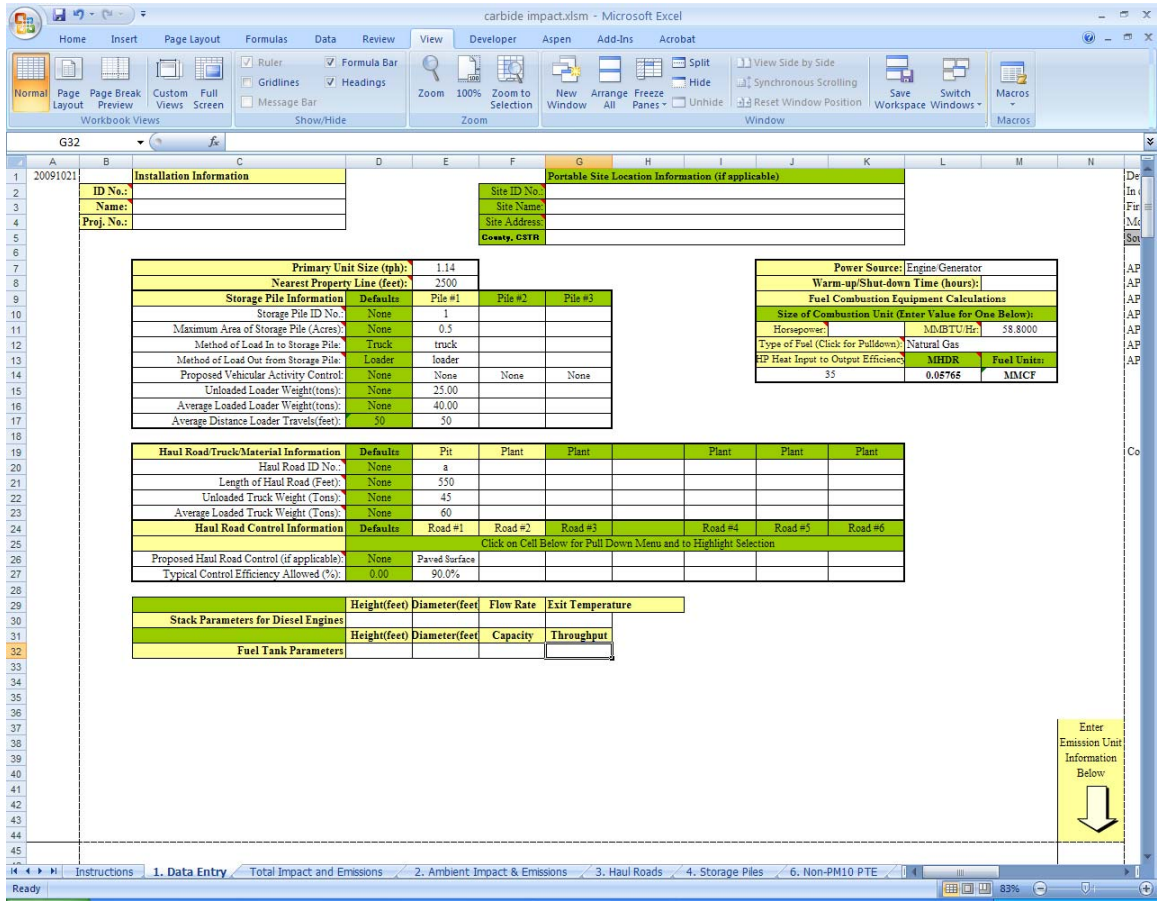


Figure 5. Quarry Spreadsheet - Snapshot of the Data Entry Tab

The screenshot shows a Microsoft Excel spreadsheet with the following data sections:

Installation Information

ID No.		Project No.	
Name			

Portable Site Location Information (if applicable)

Site ID No.	
Site Name	
Site Address	

Hours of Operation - Ambient Impacts (ug/m3)

Generic Equipment	1.8317
Conveyor/Bin/Stacker Drop Points	1.8753
Haul Roads	1.9110
Storage Pile - Loading/Vehicle Activity	1.7555
Storage Pile - Wind Erosion (24 Hours)	1.1676
Combustion	1.8317

Summary Statistics

Hours of Operation per 24 Hour Period	11,7500	
Distance to Nearest Property Line (ft)	2,500.00	
Primary Unit Size (Tons per Hour)	1.14	
Daily PM10 Ambient Impact - (ug/m3)	8.79	Desired
Composite Daily Ambient Impact Factor (ug/m3-ton)	0.6563	Production
Daily Production Limitation - (tons per day)	13.42	
Estimated Annual Production - Daily Limit Basis (tpy)	4.897	
Hourly PM10 Emissions (lb/hr)	4.71	
Composite PM10 Emission Factor (lbs of PM10 per ton)	4.1210	
Conditioned Annual PM10 - Daily Limit Basis (tpy)	10.19	
Production Limitation - 15 Tons of PM10 (tpy)	7.280	
Unconditioned Annual PM10 Emissions (tpy)	20.61	

Unit Emissions Table

Unit ID	Description of Unit	MHDR	PM10-EF	Units	Control Efficiency %	% of Rock through Unit	Controlled PM10 Emissions for Unit (lb/hr)	Controlled PM10 Emissions for Unit (lb/ton)	Nonemograph Value for Unit (ug/m3)	Ambient Impact for Unit (ug/m3)	Modeling PM10 Emissions (lb/hr)
EU-1	Wood dryer	2.6950	2.200000	Tons	99.00	100.00	0.0593	0.051927	1.88	0.111	0.029027396
EU-2	Dried wood conveyor	2.4255	2.200000	Tons	99.00	100.00	0.0534	0.046734	1.88	0.100	0.026124656
EU-3	Charcoal conveyor	1.9404	2.200000	Tons	99.00	100.00	0.0427	0.037387	1.88	0.080	0.020899725
EU-4	Lime conveyor (SCC 3-05-016-15) 2.2 lb PM/ton	4.2000	2.200000	Tons	99.00	100.00	0.0924	0.080923	1.88	0.173	0.0452375
EU-5	Charcoal/lime storage silo	6.1000	0.220000	Tons		100.00	1.3420	1.175337	1.88	2.517	0.657020833
EU-6	Charcoal/lime conveyor	6.1000	0.220000	Tons		100.00	1.3420	1.175337	1.88	2.517	0.657020833
EU-7	Dolomite conveyor	2.5000	2.200000	Tons	99.00	100.00	0.0550	0.048170	1.88	0.103	0.026927083
EU-8	Dolomite storage silo	2.5000	2.200000	Tons	99.00	100.00	0.0550	0.048170	1.88	0.103	0.026927083
EU-9	3rd stage reactor combustion	53.4000	0.007430	MMBTU		100.00	0.3978	0.348424	1.88	0.746	0.194770938
EU-10	C2Ca condenser	4.6000	0.140000	Tons		100.00	0.6440	0.564022	1.88	1.208	0.315291667
EU-11	C2Ca crusher	4.6000	0.110000	Tons		100.00	0.5060	0.443160	1.88	0.949	0.247729167
EU-12	C2Ca conveyor	4.6000	0.001100	Tons		100.00	0.0051	0.004432	1.88	0.009	0.002477292
EU-13	C2Ca loading	4.6000	0.000100	Tons		100.00	0.0005	0.000403	1.88	0.001	0.000225208
EU-14	IC engine - off-gases	53.4000	0.000077	MMBTU		100.00	0.0041	0.003620	1.88	0.008	0.002023526
EU-15	Wood Storage Pile - Load-in/Load-out	1.1418	0.011991	Tons		100.00	0.0137	0.011991	1.76	0.024	0.006703142
EU-15	Wood Storage Pile - Wind Erosion	0.5000	0.089166	Acres		100.00	0.0446	0.039046	1.17	0.052	0.02182716
EU-15	Wood Storage Pile - Vehicle Activity	1.1418	0.003345	Tons		100.00	0.0038	0.003345	1.76	0.007	0.001870006
EU-16	Haul Road	0.0159	2.780008	VMT	0.00	100.00	0.0441	0.038611	1.91	0.084	0.021583914

Figure 6. Quarry Spreadsheet - Snapshot of the Ambient Impact & Emissions Tab

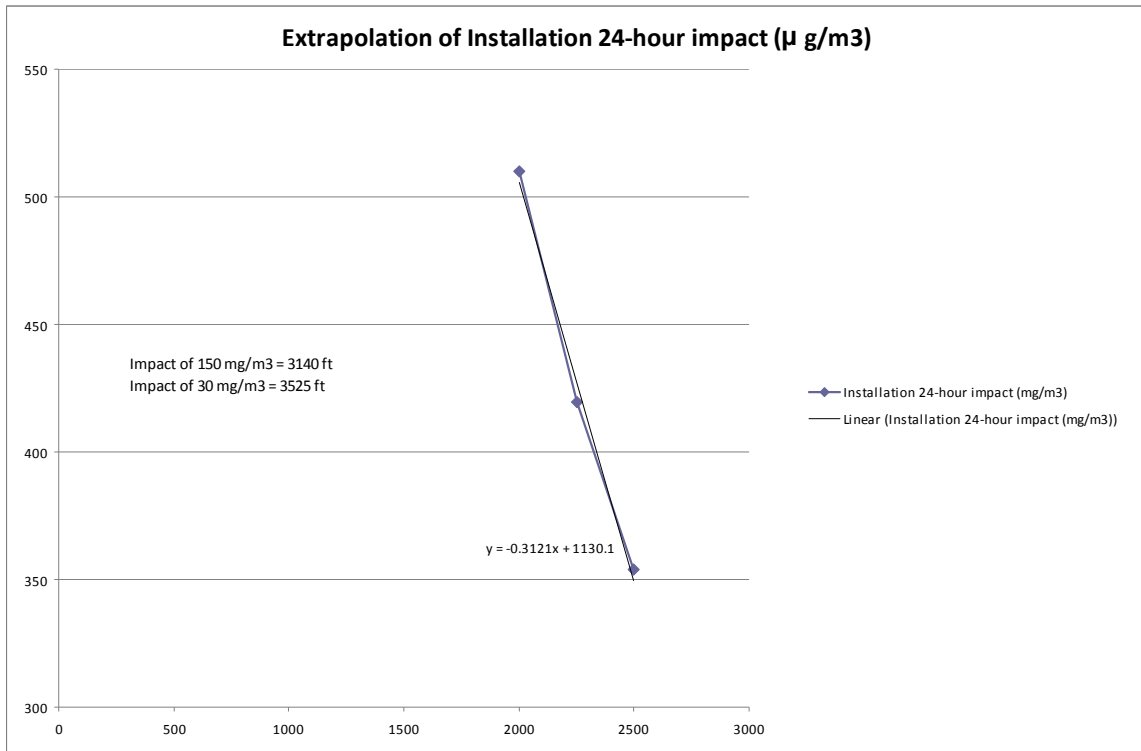


Figure 7. Quarry Spreadsheet Impact Extrapolation for PM₁₀

```

                                03/29/10
                                10:37:30
*** SCREEN3 MODEL RUN ***
*** VERSION DATED 96043 ***

SIMPLE TERRAIN INPUTS:
SOURCE TYPE      = POINT
EMISSION RATE (G/S) = 0.125998
STACK HEIGHT (M)  = 1.5240
STK INSIDE DIAM (M) = 0.6096
STK EXIT VELOCITY (M/S)= 3.0480
STK GAS EXIT TEMP (K) = 298.0000
AMBIENT AIR TEMP (K) = 293.0000
RECEPTOR HEIGHT (M) = 0.0000
URBAN/RURAL OPTION = RURAL
BUILDING HEIGHT (M) = 0.0000
MIN HORIZ BLDG DIM (M) = 0.0000
MAX HORIZ BLDG DIM (M) = 0.0000

THE REGULATORY (DEFAULT) MIXING HEIGHT OPTION WAS SELECTED.
THE REGULATORY (DEFAULT) ANEMOMETER HEIGHT OF 10.0 METERS WAS ENTERED.

BUOY. FLUX = 0.047 M**4/S**3; MOM. FLUX = 0.849 M**4/S**2.

*** FULL METEOROLOGY ***

*****
*** SCREEN AUTOMATED DISTANCES ***
*****

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES ***

DIST  CONC      U10M  USTK  MIX  HT  PLUME  SIGMA  SIGMA
(M) (UG/M**3) STAB (M/S) (M/S) (M) HT (M) Y (M) Z (M) DWASH
-----
30. 1140.  4  5.0  5.0 1600.0  1.55  2.73  1.68  NO
100. 370.8  4  1.5  1.5 480.0  5.24  8.27  4.77  NO
200. 211.7  4  1.0  1.0 320.0  7.10 15.64  8.65  NO
300. 136.4  6  1.0  1.0 10000.0  10.40 11.52  6.17  NO
400. 137.5  6  1.0  1.0 10000.0  10.40 14.85  7.49  NO
500. 124.8  6  1.0  1.0 10000.0  10.40 18.14  8.77  NO
600. 109.2  6  1.0  1.0 10000.0  10.40 21.39 10.01  NO
700.  94.62  6  1.0  1.0 10000.0  10.40 24.59 11.22  NO
800.  82.30  6  1.0  1.0 10000.0  10.40 27.75 12.24  NO
900.  72.09  6  1.0  1.0 10000.0  10.40 30.88 13.23  NO
1000. 63.61  6  1.0  1.0 10000.0  10.40 33.98 14.18  NO
1100. 56.68  6  1.0  1.0 10000.0  10.40 37.05 15.04  NO
1200. 50.87  6  1.0  1.0 10000.0  10.40 40.10 15.86  NO
1300. 45.94  6  1.0  1.0 10000.0  10.40 43.12 16.66  NO
1400. 41.74  6  1.0  1.0 10000.0  10.40 46.12 17.45  NO
1500. 38.11  6  1.0  1.0 10000.0  10.40 49.10 18.21  NO
1600. 34.97  6  1.0  1.0 10000.0  10.40 52.06 18.95  NO
1700. 32.23  6  1.0  1.0 10000.0  10.40 55.00 19.68  NO
1800. 29.82  6  1.0  1.0 10000.0  10.40 57.92 20.39  NO
1900. 27.68  6  1.0  1.0 10000.0  10.40 60.83 21.09  NO
2000. 25.79  6  1.0  1.0 10000.0  10.40 63.73 21.78  NO
2100. 24.17  6  1.0  1.0 10000.0  10.40 66.60 22.35  NO
2200. 22.72  6  1.0  1.0 10000.0  10.40 69.47 22.92  NO
2300. 21.41  6  1.0  1.0 10000.0  10.40 72.32 23.48  NO
2400. 20.23  6  1.0  1.0 10000.0  10.40 75.16 24.02  NO
2500. 19.15  6  1.0  1.0 10000.0  10.40 77.99 24.56  NO
2600. 18.16  6  1.0  1.0 10000.0  10.40 80.80 25.08  NO
2700. 17.26  6  1.0  1.0 10000.0  10.40 83.61 25.60  NO
2800. 16.43  6  1.0  1.0 10000.0  10.40 86.40 26.10  NO
2900. 15.66  6  1.0  1.0 10000.0  10.40 89.19 26.60  NO
3000. 14.95  6  1.0  1.0 10000.0  10.40 91.96 27.10  NO

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 30. M:
30. 1140.  4  5.0  5.0 1600.0  1.55  2.73  1.68  NO

DWASH= MEANS NO CALC MADE (CONC = 0.0)
DWASH=NO MEANS NO BUILDING DOWNWASH USED
DWASH=HS MEANS HUBER-SNYDER DOWNWASH USED
DWASH=SS MEANS SCHULMAN-SCIRE DOWNWASH USED
DWASH=NA MEANS DOWNWASH NOT APPLICABLE, X<3*LB

*****
*** SUMMARY OF SCREEN MODEL RESULTS ***
*****

CALCULATION  MAX CONC  DIST TO  TERRAIN
PROCEDURE   (UG/M**3)  MAX (M)  HT (M)
-----
SIMPLE TERRAIN  1140.    30.    0.

*****
** REMEMBER TO INCLUDE BACKGROUND CONCENTRATIONS **
*****

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Figure 8. Screen3 Model Output File

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GLOSSARY

Ambient Air:

All space outside of buildings, stacks or exterior ducts. 10 CSR 10-6.020(2)(A)

Attainment Area:

All areas that have not been designated as non-attainment. Since attainment designations are pollutant specific, an area may be designated as attainment for one pollutant and non-attainment for another.

BACT:

Best Available Control Technology. An emission limitation (including a visible emission limit) based on the maximum degree of reduction for each pollutant which would be emitted from any proposed installation or major modification which the director on a case-by-case basis, taking into account energy, environmental and economic impacts and other costs, determines is achievable for the installation or major modification through application of production processes or available methods, systems and techniques, including fuel cleaning or treatment or innovative fuel combustion techniques for control of the pollutant. In no event shall application of BACT result in emissions of any pollutant which would exceed the emissions allowed by any applicable emissions control regulation, including New Source Performance Standards established in 10CSR 10-6.070 and 40 CFR part 60 and National Emissions Standards for Hazardous Pollutants established in 10 CSR 6.080 and 40 CFR part 61. If the director determines that technological or economic limitations on the application of measurement methodology to a particular source operation would make the imposition of an emission limitation infeasible, a design, equipment, work practice, operational standard or combination of these may be prescribed instead to require the application of BACT. This standard to the degree possible shall set forth the emission reduction achievable by implementation of the design, equipment, work practice or operation and shall provide for compliance by means which achieve equivalent results. 10 CSR 10-6.020(2)(B)

BTU:

British thermal unit. The amount of energy required to raise the temperature of a pound of water one degree Fahrenheit.

CFR:

Code of Federal Regulations. Codified general and permanent federal rules divided into 50 titles (e.g., Title 40 is Protection of the Environment).

Capture Efficiency:

The capture efficiency is the amount of pollutant that is routed to a control device. This is typically expressed as a percent of the total amount of emissions from a particular emissions unit. Capture efficiency is pollutant dependent.

CO:

Carbon Monoxide. This is a criteria pollutant.

CO₂:

Carbon Dioxide. This is a regulated pollutant.

Construction

Fabricating, erecting, reconstructing, or installing a source operation. Construction shall include installation of building supports and foundations, laying of underground pipe work, building of permanent storage structures, and other construction activities related to the source operation. 10 CSR 10-6.020(2)(C)

Control Device:

The equipment used to reduce the amount of pollutant being emitted from an emissions unit..

Control Efficiency:

Control efficiency refers to the amount of reduction in emissions of a pollutant achieved by the control device. This is typically expressed as a percent of the total amount of emissions from a particular emissions unit.

Criteria Pollutants:

Air pollutants for which air quality standards have been established in 10 CSR 10-6.010. 10 CSR 10-6.020(2)(B)

Specifically they are:

- PM₁₀ - Particulate Matter less than 10 microns in diameter
- NO_x - Nitrogen Oxide Compounds
- SO_x - Sulfur Oxide Compounds
- VOC - Volatile Organic Compounds
- Lead - Lead (Pb)
- CO - Carbon Monoxide

CSR:

Code of State Regulations. Codified general and permanent state rules divided into 22 titles (e.g., Title 10 is Department of Natural Resources).

De minimis Levels:

Any emissions level less than or equal to the rates listed in Table 1, subsection (3)(A) of this rule.

Emission Factor:

An **emissions factor** is intended to be a representative value that relates the amount of emissions associated with a process to the process based on factors such as weight, volume, distance, or duration of the process emitting the pollutant (e.g., pound of pollutant per ton of product produced).

Emission Point:

This is the point at which an emissions unit releases emissions. More than one **Emission Unit** may be associated to one emission point.

Emission Unit:

Any part or activity of an installation that emits or has the potential to emit any regulated air pollutant or any pollutant listed under section 112(b) of the Act. 10 CSR 10-6.020(2)(E)

EPA:

The United States Environmental Protection Agency

Hazardous Air Pollutant (HAP):

Any of the air pollutants listed in 10 CSR 10-6.020(3)(C).

Installation:

All source operations including activities that result in fugitive emissions, that belong to the same industrial grouping (that have the same two (2)-digit code as described in the *Standard Industrial Classification Manual*, 1987), and any marine vessels while docked at the installation, located on one (1) or more contiguous or adjacent properties and under the control of the same person (or persons under common control). 10 CSR 10-6.020(2)(I)

LAER:

Lowest Achievable Emission Rate. That rate of emissions which reflects – 1) the most stringent emission limitation which is contained in any state implementation plan for a class or category of source, unless the owner or operator of the proposed source demonstrated that the limitations are not achievable or 2) the most stringent emission limitation which is achieved in practice by the class or category of source, whichever is more stringent.

LAER shall not be less stringent than the new source performance standard limit. 10 CSR 10-6.020(2)(L)

MHDR (Maximum Hourly Design Rate):

Maximum Hourly Design Rate is the maximum capacity of the equipment during a one hour period of continuous operation. This is typically based on the manufacturer's rated capacity. However, physical bottlenecks may reduce the maximum hourly design rate by limiting the process throughput.

Major Source:

A major source is an installation with the potential to emit of any pollutant greater than the major source levels. The level varies between 100 tons per year and 250 tons per year based on the location of the source in an attainment or non-attainment area or the classification of the source as a named or non-name installation.

Modification

Any physical change, or change in method of operation of, a source operation or attendant air pollution control equipment which would cause an increase in potential emissions of any air pollutant emitted by the source operation. 10 CSR 10-6.020(2)(M)

NAAQS:

National Ambient Air Quality Standards. Air quality standards established by EPA.

NSR

New Source Review

Nonattainment Area:

Those geographic areas in Missouri that have officially been designated by the U.S. Environmental Protection Agency in 40 CFR part 81 as nonattainment areas. 10 CSR 10-6.020(2)(N)

NO_x:

Nitrogen Oxide Compounds. This is a criteria air pollutant.

NSPS:

New Source Performance Standard. These standards are listed in 40 CFR Part 60. Certain emissions limits, testing requirements, monitoring requirements, etc. are required for applicable sources.

PM₁₀ (Particulate Matter less than ten microns):

Particulate Matter with an aerodynamic diameter of less than 10 microns, a criteria air pollutant. This is a criteria pollutant.

Potential to Emit:

The emissions rates of any pollutant at maximum design capacity. Annual potential shall be based on the maximum annual-rated capacity of the installation assuming continuous year-round operation. Federally enforceable permit conditions on the type of materials combusted or processed, operating rates, hours of operation and the application of air pollution control equipment shall be used in determining the annual potential. Secondary emissions do not count in determining annual potential. 10 CSR 10-6.020(2)(N)

Potential Emissions:

Potential emissions are the emissions based on the potential to emit. Potential emissions and potential to emit are commonly interchangeable.

PSD

Prevention of Significant Deterioration. This is commonly used to refer to the type of construction permit issued for a major modification.

RAL

Risk Assessment Level. These levels are concentrations at which adverse human health effects are not expected to be produced during a defined period of exposure.

Regulated Air Pollutant:

All air pollutants or precursors for which any standard has been promulgated. 10 CSR 10-6.020(2)(R)

SMAL

Screen Model Action Levels. These levels are emission rates at which screen modeling is required.

State Implementation Plan (SIP):

A series of plans adopted by the commission, submitted by the director, and approved by the administrator, detailing methods and procedures to be used in attaining and maintaining the ambient air quality standards in Missouri. 10 CSR 10-6.020(2)(S)

SO_x:

Sulfur Oxide Compounds. This is a criteria air pollutant.

TPY

Tons Per Year

VMT:
Vehicle Miles Traveled.

VOC:
Volatile Organic Compounds. This is a criteria air pollutant.

APPENDICES: EMISSION CONTROL TECHNOLOGIES

APPENDIX A: NO_x Control Technologies

- Low Excess Air (LEA)

The LEA control technique reduces the amount of excess air supplied to the combustion chamber through the use of combustion control. This includes LEA firing, adjustments of air registers, fuel injector positions, overfire air dampers and operational controls to reduce the amount of excess air. By limiting the excess air, the combustion temperature is controlled in a manner that may reduce the formation of NO_x during the combustion process. This technique is technically feasible. However, the reduction of excess air could lead to incomplete combustion which would contribute to the increase of VOC and CO emissions.

- Low NO_x Burners (LNB)

LNBs are designed to limit NO_x formation by controlling the stoichiometric makeup of the combustion flame and the temperature profile in each burner flame. This control is accomplished by regulating the aerodynamic distribution and mixing of the fuel and air, thus reducing oxygen (O₂) in the primary combustion zone, flame temperature and residence time at peak combustion temperatures.

- Overfire Air (OFA)

The OFA process reduces the formation of NO_x by the injection of air into the firing chamber staged into two zones. The staging of the combustion air results in a cooler flame, and it also results in less oxygen reacting with fuel molecules.

- Flue gas recirculation (FGR)

The FGR system recycles a portion of the flue gas back into the primary combustion zone to control. The combustion products contained in the recycled air are inert during combustion thereby lowering combustion temperatures and NO_x emissions. In addition, the oxygen content of the recycled air is lower than fresh air thereby lowering the overall oxygen content in the primary flame zone.

- Selective Non-Catalytic Reduction (SNCR)

With the SNCR system ammonia or urea is directly injected at flue gas temperatures of approximately 1600 °F – 1900 °F. The ammonia or urea reacts with NO_x in the flue gas to produce N₂ and water. SNCR systems must be designed properly to ensure that the reagent will be injected at the optimum flue gas temperature, and that there will be adequate mixing and residence time.

- Selective Catalytic Reduction

Like the SNCR system, ammonia is injected into the boiler flue gas, but unlike the SNCR, the SCR system includes the presence of a catalyst to reduce NO_x to

nitrogen and water. The performance of an SCR system is influenced by several factors including flue gas temperature, SCR inlet NO_x level, the catalyst surface area, volume and age of the catalyst, and the amount of ammonia slip that is acceptable.

APPENDIX B: CO and VOC Control Technologies

- Good Combustion Practices

Both CO and VOC emissions occur as a result of incomplete combustion in the combustion chamber of the reactor. The most efficient means of controlling VOC emissions is combustion. The proper operation of the combustion chamber through the use of good combustion practices will promote complete combustion. Although, reducing CO emissions can result in an increase of NO_x emissions, CO and NO_x emissions can be balanced through the use of good combustion practices. Good combustion practices include extended residence time, proper mixing of air and fuel, and steady high temperatures in the combustion zone.

- Catalytic Oxidation

Catalytic oxidation systems are used to oxidize both CO and VOCs to CO₂ and water and are currently used for gas turbines and refinery operations. Catalytic oxidation requires a high exhaust temperature for the oxidation to take place. In this case, the exit temperature of the reactor gas would need to be increased prior to entering the control device. The result would be the combustion of additional fuel and the creation of additional emissions. In evaluating the control device an additional aspect is the catalyst. It does not appear that the exhaust gases will contain materials that will potentially poison the catalyst making it ineffective. Therefore, this control device appears to be technically feasible although it may not be environmentally or cost effective.

- Thermal Oxidation

Thermal oxidizers operate at considerably higher temperatures since there is no catalyst. Thermal oxidizers typically use natural gas to heat the combustion chamber of the control device. This is the same technique that is used in the three-stage reactor and is redundant. Although technically feasible, the addition of this control technique on the three-stage reactor would be redundant. However, such a device on the wood dryer would be technically feasible.

- Good Combustion Practices

Good combustion practices are common BACT determinations. Both CO and VOC emissions occur as a result of incomplete combustion in the combustion chamber of the reactor. The most efficient means of controlling VOC emissions is combustion. The proper operation of the combustion chamber through the use of good combustion practices will promote complete combustion. Although, reducing CO emissions can result in an increase of NO_x emissions, CO and NO_x emissions can be balanced through the use of good combustion practices. Good

combustion practices include extended residence time, proper mixing of air and fuel, and steady high temperatures in the combustion zone.

APPENDIX C: PM₁₀ CONTROL TECHNOLOGIES

- **HAUL ROADS**

Haul road emissions are considered fugitive since the emissions cannot be captured and vented to a control device. Therefore there are two general options for the control of fugitive haul road emissions. The first option is the application of a chemical surfactant or water to an unpaved surface. By applying a chemical surfactant, the particles on the road remain on the road as traffic travels over the surface. The same effect can be achieved by applying water. However, the amount of water applied depends on the size of the road and the type of road material (e.g. crushed rock). This control technique achieves a control efficiency of 90%. The second option is paving the surface and periodically washing the paved surface. By paving the road with asphalt or concrete, the amount of particles on the road is greatly reduced and is dependent on the type of material being hauled on the road. The control efficiency of this technique is greater than 95%. Both techniques are technically feasible.

- **STORAGE PILES**

Similar control techniques apply to the vehicular activity areas of the storage piles as the haul roads. These vehicular activity areas include all areas between and within the active piles and the inactive pile that could be used during material transfer between the piles or individual pile maintenance.

- **MATERIAL HANDLING PROCESSES**

Material handling transfer points include conveyors and silos. There are three general techniques for control these types of emissions: spray dust suppression, enclosures, cyclones, and baghouses. The first option requires the application of a dust suppression material onto the material being handled to reduce the release of the particles into the air. The technical feasibility of this control technique would depend on how the dust suppression agent would react in the process. A typical dust suppression material such as oil would coat the materials. Since the process is dependent on the reaction of the raw materials, coating the materials would reduce the effectiveness of the reaction. Therefore this option is considered technically infeasible.

The second option acts as a capture device for the emissions to be vented to a control device. By fully enclosing the process, the emissions are completely captured. Partial enclosures have lower capture efficiencies than full enclosures, but are also effective in routing emissions to a control device. The third option is the use of a cyclone. A cyclone uses centrifugal force to separate larger particles from the air stream. This technique provides 50% control efficiency. The fourth option is the baghouse. Baghouses use a bag to filter particles out the air stream. The amount that is allowed into the air is dependent on the bag design.

A maximum outlet emission rate of 0.005 grains per dry standard cubic foot (gr/dscf) is considered a high level of control. These control options are all considered technically feasible.