Emission Factor Documentation for AP-42
Section 11.4

Calcium Carbide Manufacturing

Final Report

I. INTRODUCTION

This memorandum presents the background information that was used to develop the revised AP-42 Section 11.4 on calcium carbide manufacturing. A description of the industry is presented first. A process description followed by a discussion of emissions and controls is then presented. Following these sections, the references that were used to develop the revised section are described. A review of the information contained in the background file for the section is then presented, followed by a discussion of the results of the data analysis. Finally, a list of references is provided. The revised AP-42 section is provided as the attachment.

II. DESCRIPTION OF THE INDUSTRY[1]

Calcium carbide (CaC_2) is manufactured by heating a lime and carbon mixture to 2000° to 2100°C (3632° to 3812°F) in an electric arc furnace. At those temperatures, the lime is reduced by carbon to calcium carbide and carbon monoxide (CO), according to the following reaction:

$$CaO + 3C \rightarrow CaC_2 + CO$$

Lime for the reaction is usually made by calcining limestone in a kiln at the plant site. The sources of carbon for the reaction are petroleum coke, metallurgical coke, or anthracite coal. Because impurities in the furnace charge remain in the calcium carbide product, the lime should contain no more than 0.5 percent each of magnesium oxide, aluminum oxide, and iron oxide and 0.004 percent phosphorus. Also, the coke or coal charge should be low in ash and sulfur. Analyses indicate that 0.2 to 1.0 percent ash and 5 to 6 percent sulfur are typical in petroleum coke. About 991 kilograms (kg) (2,185 pounds [lb]) of lime, 683 kg (1,506 lb) of coke, and 17 to 20 kg (37 to 44 lb) of electrode paste are required to produce 1 megagram (2,205 lb) of calcium carbide.

Calcium carbide is used primarily in generating acetylene and desulfurizing iron. The Standard Industrial Classification (SIC) code for calcium carbide manufacturing is 2819, industrial inorganic chemicals, not elsewhere classified. The six-digit Source Classification Code (SCC) for calcium carbide manufacturing is 3-05-004.

III. PROCESS DESCRIPTION

The process for manufacturing calcium carbide is illustrated in Figure 1. Moisture is removed from coke in a coke dryer, while limestone is converted to lime in a lime kiln. Fines from coke drying and lime operations are removed and may be recycled. The two charge materials are then conveyed to an electric arc furnace, the primary piece of equipment used to produce calcium carbide. There are three basic types of electric arc furnaces: the open furnace, in which the CO burns to carbon dioxide (CO_2) when it contacts the air above the charge, the closed furnace, in which the gas is collected from the furnace and either used as fuel for other processes or flared, and the semi-covered furnace, in which mix is fed around the openings for the electrodes in the primary furnace cover, resulting in mix seals. Electrode paste composed of coal tar pitch binder and anthracite coal is fed into a steel casing, in which it is baked by heat from the electric arc furnace before being introduced into the furnace. The baked electrode exits the steel casing just inside the furnace cover and is consumed in the calcium carbide production process. Molten calcium carbide is tapped continuously from the furnace into chills and is allowed to cool and solidify. Then, the solidified calcium carbide goes through primary crushing by jaw crushers, followed by secondary crushing and

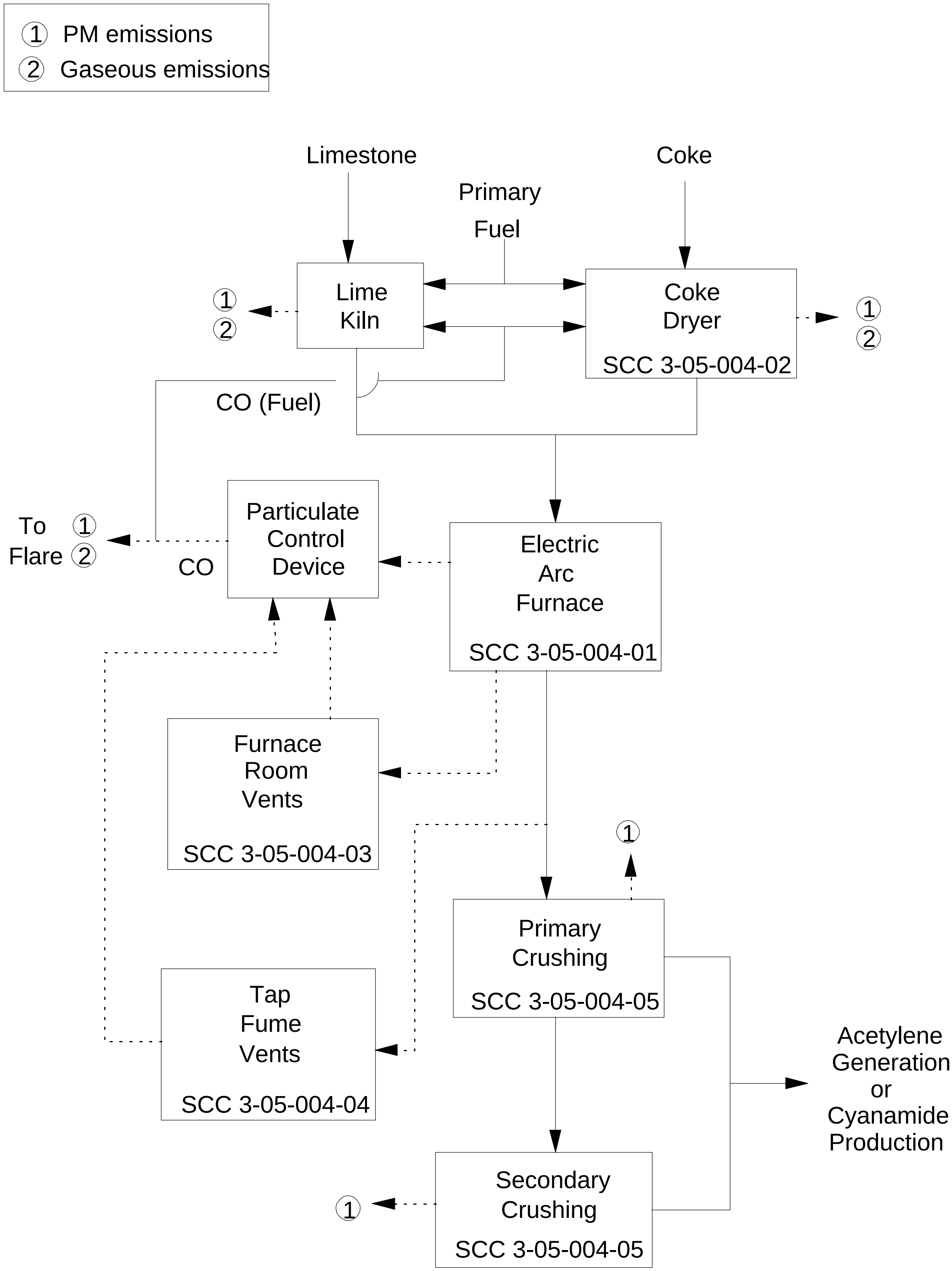

Figure 1. Process flow diagram for calcium carbide manufacturing
(SCC = Source Classification Code).

screening for size. To prevent explosion hazards from acetylene generated by the reaction of calcium carbide with ambient moisture, crushing and screening operations may be performed in an air-swept environment before the calcium carbide has completely cooled or in an inert atmosphere. The calcium carbide product is used primarily in generating acetylene and in desulfurizing iron.

IV. EMISSIONS AND CONTROLS

Emissions from calcium carbide manufacturing include particulate matter (PM), sulfur oxides (SO_x), CO, CO_2, and hydrocarbons. Particulate matter is emitted from a variety of equipment and operations in the production of calcium carbide, including the coke dryer, lime kiln, electric furnace, tap fume vents, furnace room vents, primary and secondary crushers, and conveying equipment. (Lime kiln emission factors are presented in Section 8.15 of the Fourth Edition which will become Section 11.15 of the Fifth Edition in late 1994). Particulate matter emitted from a process source such as an electric furnace is ducted to a PM control device, usually a fabric filter or wet scrubber. Fugitive PM from sources such as tapping operations, the furnace room, and conveyors is captured and sent to a PM control device. The composition of the PM varies according to the specific equipment or operation, but the primary components are calcium and carbon compounds, with significantly smaller amounts of magnesium compounds.

Sulfur oxides may be emitted by the electric furnace from volatilization and oxidation of sulfur in the coke feed and by the coke dryer and lime kiln from fuel combustion. These process sources are not controlled specifically for SO_x emissions. Carbon monoxide is a byproduct of calcium carbide production in the electric furnace. Carbon monoxide emissions to the atmosphere are usually negligible. In open furnaces, CO is oxidized to CO_2, thus eliminating CO emissions. In closed furnaces, a portion of the generated CO is burned in the flames surrounding the furnace charge holes, and the remaining CO is used as fuel for other processes or is flared. In semi-covered furnaces, the CO that is generated is used as fuel for the lime kiln or other processes or is flared.

The only potential source of hydrocarbon emissions from the manufacture of calcium carbide is the coal tar pitch binder in the furnace electrode paste. Because the maximum volatiles content in the electrode paste is about 18 percent, the electrode paste represents only a small potential source of hydrocarbon emissions. In closed furnaces, actual hydrocarbon emissions from the consumption of electrode paste typically are negligible due to high furnace operating temperature and flames surrounding the furnace charge holes. Hydrocarbon emissions from open furnaces are expected to be negligible because of high furnace operating temperatures and the presence of excess oxygen above the furnace. Hydrocarbon emissions from semi-covered furnaces are also expected to be negligible because of high furnace operating temperatures.

V. DESCRIPTION OF REFERENCES

This section describes the additional primary references that contain data on emissions from calcium carbide manufacturing that were used to develop emission factors for inclusion in the revised AP-42 section. Reference numbers for new references begin at No. 12 because there are 11 references (reviewed in Section VI of this memo, REVIEW OF THE BACKGROUND FILE) from the previous AP-42 section. Data from References 1, 4, 8, and 9 were used to develop emission factors and are discussed in Section VI.

A. Reference 12

This test report includes measurements of filterable PM and CO_2 emissions from an electric arc furnace and a carbide cooling conveyor at the Airco Carbide facility in Calvert City, Kentucky. The emissions from both sources are ducted to the furnace fabric filtration system, which consists of a baghouse and four stacks, one of which was not in operation during the test. Filterable PM emissions were measured using an EPA Method 5 sampling train for three test runs conducted at the southwest stack. Total filterable PM emissions were estimated by calculating the total volumetric flow rate through the three operating stacks, dividing this total flow rate by the southwest stack flow rate, and multiplying this ratio by the filterable PM mass flux. Flue gas composition was analyzed using Orsat, and CO_2 concentrations are reported as zero.

A rating of B was assigned to the test data for controlled filterable PM emissions. The report included adequate detail, the test methodology was sound, and no problems were reported during the valid test runs. However, the procedure used for estimating the total emissions from all three stacks may have introduced a small degree of error, so the data could not be rated A. The emission data for this test are summarized in Table 1.

TABLE 1. SUMMARY OF EMISSION DATA FROM CALCIUM CARBIDE MANUFACTURING TEST REPORTS[a]

Source	Type of control	Pollutant	No. of testruns	Data rating	Emission factor range, kg/Mg (lb/ton)	Average emission factor, kg/Mg (lb/ton)	Ref No.
Electric arc furnace and CaC_2 cooler	Fabric filter	Filterable PM	3	B	0.015-0.055[b] (0.03-0.11)	0.035[b] (0.07)	12
Electric arc furnace and CaC_2 cooler	Fabric filter	CO_2	3	NA	Neg.	Neg.	12
Electric arc furnace	Fabric filter	Filterable PM	6	B	0.25-0.64 (0.50-1.27)	0.43 (0.85)	13
Electric arc furnace	Fabric filter	Condensible inorganic PM	3	B	0.50-0.79 (0.99-1.57)	0.60 (1.19)	13
Electric arc furnace	Fabric filter	CO_2	6	NA	Neg.	Neg.	13

NA = not applicable.
Neg. = Negligible.
[a]Emission factors in units of raw material feed (coke and lime) unless noted.
[b]Emission factor in units of calcium carbide produced.

B. Reference 13

This reference, provided by the State of Ohio EPA, includes the results of two emission tests conducted on a calcium carbide electric arc furnace at the Elkem Metals Company in Ashtabula, Ohio. The tests were conducted on September 21, 1992 and March 21, 1989. Controlled emissions of filterable PM and condensible inorganic PM from the No. 13 (semi-covered) furnace were quantified using an EPA Method 5 sampling train (front- and back-half analyses) for three test runs. Emissions were measured at the outlet of the fabric filtration system that controls PM emissions from the furnace. A portion of the furnace emissions are ducted to a set of scrubbers, but these emissions were not quantified during the testing and are not considered significant because an earlier test showed that these emissions were less than 2 percent of the total filterable PM emissions from the furnace. Also, the scrubber off gas is often ducted to the lime kiln for use as fuel. During the 1992 test, the average differential pressure drop across the baghouse was 2.5 inches of water. Carbon dioxide concentrations in the exhaust gas were measured using Orsat and are reported as zero.

A rating of B was assigned to the test data for controlled filterable PM and condensible inorganic PM emissions. The report included adequate detail, the test methodology was sound, and no problems were reported during the valid test runs. However, the process rate (feed) from the 1992 test was used for calculating emission factors for the 1989 test because no process rate was provided for the 1989 test. In addition, the condensible PM data from the 1992 test were not used because there appeared to be an error made either in the reporting of the data or in the calculations, but the error could not be traced. The emission data for this test are summarized in Table 1.

VI. REVIEW OF THE BACKGROUND FILE

The previous version of AP-42 Section 11.4 (which was Section 8.4 of the Fourth Edition) was based on 11 references. Reference 1 is a compilation of operating permits for calcium carbide manufacturing equipment at Airco Carbide Division (Airco), located in Louisville, Kentucky. Undocumented secondary emission data are presented in Reference 1 and are used to develop emission factors for sources and controls for which no other data are available. Reference 2 provides details about the process operations at Airco and contains process rates for various operations that are used in conjunction with emission data from Reference 1 for emission factor development. Reference 3 is a memorandum stating that volatile organic compound (VOC) emissions from the closed-top electric arc furnace at Airco are negligible. No usable emission data are presented in Reference 3. Reference 4 documents an emission test conducted at Airco in 1975. Filterable PM tests and flue gas analyses were performed at the inlet and outlet of a scrubber that controlled furnace emissions. Process rates could not be located in the document, but the filterable PM emission factors already included in the AP-42 section are assumed to be valid and will be presented in the revised section. The results of this test are summarized in Table 2.

TABLE 2. SUMMARY OF EMISSION DATA FROM AP-42 BACKGROUND FILE REFERENCES[a]

Source	Type of control	Pollutant	No. of testruns	Data rating	Emission factor range, kg/Mg (lb/ton)	Average emission factor, kg/Mg (lb/ton)	Ref No.
Coke dryer	None	Filterable PM	NA	D	NA	1.0 (2.0)	b
Coke dryer	None	SO_x	NA	D	NA	1.5 (3.0)	b
Coke dryer	Fabric filter	Filterable PM	NA	D	NA	0.13 (0.26)	1
Tap fume vents	Fabric filter	Filterable PM	NA	D	NA	0.07 (0.14)	1
Furnace room vents	None	Filterable PM	NA	D	NA	13 (26)	b
Furnace room vents	Fabric filter	Filterable PM	NA	D	NA	0.07 (0.14)	1
Primary and secondary crushing	Fabric filter	Filterable PM	NA	D	NA	0.055 (0.11)	1
Circular charging conveyor	Fabric filter	Filterable PM	NA	D	NA	0.11 (0.22)	1
Electric arc furnace main stack[c]	None	Filterable PM	NA	C	NA	13 (26)	4
Electric arc furnace main stack[c]	None	SO_x	NA	D	NA	1.5 (3.0)	b
Electric arc furnace main stack[c]	Scrubber	Filterable PM	NA	C	NA	0.25 (0.50)	4
Electric arc furnace main stack[c]	Fabric filter	Filterable PM	3	B	0.18-0.24 (0.36-0.47)	0.20 (0.40)	8
Electric arc furnace main stack[c]	Fabric filter	Condensible inorganic PM	3	B	0.060-0.21 (0.12-0.41)	0.14 (0.27)	8
Electric arc furnace main stack[c]	Fabric filter	Filterable PM	NA	C	NA	0.36 (0.72)	9

NA = not available.

[a] Emission factors in units of raw material feed unless noted. Furnace feed: coke and lime. Coke dryer feed: coke. Tap fume vent fe lime. Furnace room vent feed: coke and lime. Crusher feed: calcium carbide. Charging conveyor feed: coke and lime.

[b] From previous AP-42 section; reference not identified.

[c] Emission factors applicable to open furnaces using petroleum coke.

Reference 5 is a document describing calcium carbide manufacturing operations at Airco during the early 1970's. No emission data are presented in Reference 5. Reference 6 contains a description of the calcium carbide manufacturing industry and the chemical properties of calcium carbide but does not contain emission data for emission factor development. Reference 7 also provides only a description of the calcium carbide manufacturing industry. Reference 8 is a test report documenting the results of a 1978 compliance test on a calcium carbide electric arc furnace at Midwest Carbide Corporation in Pryor, Oklahoma. Controlled filterable and condensible inorganic PM emissions were quantified using an EPA Method 5-type sampling train (front- and back-half analyses) at the outlets of the three baghouses that controlled furnace emissions. The results of this test are summarized in Table 2. Reference 9 is an emission test report that could not be located for review. The existing emission factors from this document are assumed to represent filterable PM and are included in Table 2, as well as in the revised AP-42 section. Reference 10 is a document that describes the production of acetylene gas from the calcium carbide manufacturing process. No emission data are provided in the document. Reference 11 is an excerpt from the Manual for Process Engineering Calculations that provides two tables documenting chemical properties of different types of coke and combustion properties of coal and coke constituents. No emission data are presented in Reference 11.

Emission data from secondary references, such as Reference 1, generally are not used to develop emission factors for AP-42. However, because other test data are lacking, emission factors developed from Reference 1 have been included in the revised AP-42 section. These emission factors should be useful for order of magnitude estimates and are assigned a rating of E.

VII. RESULTS OF DATA ANALYSIS

Emission factors were developed using data from Reference 1 for sources for which no other data were available. Emission factors for electric arc furnaces were calculated using References 4, 8, and 13. Emission factors developed from Reference 4 data were assigned an E rating because the emission factors were developed from C-rated data from a single source. These emission factors represent uncontrolled filterable PM emissions and filterable PM emissions controlled by two scrubbers (scrubber parameters were not provided). Filterable PM and condensible inorganic PM emission factors for fabric filter-controlled electric furnaces were calculated using data from References 8 and 13 and are assigned a C rating because B-rated data from two sources were used, and an emission factor rating of C is the highest rating that can be assigned to an emission factor developed from B-rated data. The data from Reference 9 representing fabric filter-controlled electric furnaces were not used because C-rated data cannot be combined with B-rated data. Filterable PM emission factors for an electric furnace and calcium carbide cooling conveyor combination were developed from data from Reference 12 and were assigned a D rating because they were developed from data from a single source. Uncontrolled emission factors for filterable PM and SO_x emissions from coke dryers and electric furnaces (from previous AP-42 section--unspecified references section) were assigned an E rating because the references could not be reviewed. Table 3

TABLE 3. SUMMARY OF EMISSION FACTORS FOR CALCIUM CARBIDE MANUFACTURING[a]

Process	Pollutant	No. of tests	Average emission factor, kg/Mg (lb/ton)	Emission factor rating	Ref No.
Coke dryer	Filterable PM	NA	1.0 (2.0)	E	[b]
Coke dryer	SO_x	NA	1.5 (3.0)	E	[b]
Coke dryer with fabric filter	Filterable PM	NA	0.13 (0.26)	E	1
Tap fume vents with fabric filter	Filterable PM	NA	0.07 (0.14)	E	1
Furnace room vents	Filterable PM	NA	13 (26)	E	[b]
Furnace room vents with fabric filter	Filterable PM	NA	0.07 (0.14)	E	1
Primary and secondary crushing with fabric filter	Filterable PM	NA	0.055 (0.11)	E	1
Circular charging conveyor with fabric filter	Filterable PM	NA	0.11 (0.22)	E	1
Electric arc furnace main stack[c]	Filterable PM	1	13 (26)	E	4
Electric arc furnace main stack[c]	SO_x	NA	1.5 (3.0)	E	[b]
Electric arc furnace main stack with scrubber[c]	Filterable PM	1	0.25 (0.50)	E	4
Electric arc furnace main stack with fabric filter[c]	Filterable PM	2	0.32 (0.63)	C	8, 13
Electric arc furnace main stack with fabric filter[c]	Condensible inorganic PM	2	0.37 (0.73)	C	8, 13
Electric arc furnace main stack with fabric filter[c]	CO_2	1	Neg.	NA	13
Electric arc furnace and calcium carbide cooling conveyor with fabric filter[c]	Filterable PM	1	0.035[d] (0.070)	D	12
Electric arc furnace and calcium carbide cooler with fabric filter[c]	CO_2	1	Neg.	NA	12

NA = not available.
neg. = negligible.
[a] Emission factors in units of raw material feed unless noted. Furnace feed: coke and lime. Coke dryer feed: coke. Tap feed: coke and lime. Furnace room vent feed: coke and lime. Crusher feed: calcium carbide. Charging conveyor feed lime.
[b] From previous AP-42 section; reference not specified.
[c] Emission factors applicable to open furnaces using petroleum coke.
[d] Emission factor in units of calcium carbide produced.

summarizes the calcium carbide manufacturing emission factors that have been incorporated in the revised AP-42 Section 11.4.

VIII. REFERENCES

1. "Permits To Operate: Airco Carbide, Louisville, Kentucky", Jefferson County Air Pollution Control District, Louisville, KY, December 16, 1980.

2. "Manufacturing Or Processing Operations: Airco Carbide, Louisville, Kentucky", Jefferson County Air Pollution Control District, Louisville, KY, September 1975.

3. Written communication from A. J. Miles, Radian Corp., Durham, NC, to Douglas Cook, U. S. Environmental Protection Agency, Atlanta, GA, August 20, 1981.

4. "Furnace Offgas Emissions Survey: Airco Carbide, Louisville, Kentucky", Environmental Consultants, Inc., Clarksville, IN, March 17, 1975.

5. J. W. Frye, "Calcium Carbide Furnace Operation", *Electric Furnace Conference Proceedings*, American Institute of Mechanical Engineers, NY, December 9-11, 1970.

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9. L. Thomsen, "Particulate Emissions Test Report: Midwest Carbide, Keokuk, Iowa", Being Consultants, Inc., Moline, IL, July 1, 1980.

10. D. M. Kirkpatrick, "Acetylene From Calcium Carbide Is An Alternate Feedstock Route", *Oil And Gas Journal*, June 7, 1976.

11. L. Clarke and R. L. Davidson, *Manual For Process Engineering Calculations*, Second Edition, McGraw-Hill Company, NY, 1962.

12. "Test Report: Particulate Emissions - Electric Carbide Furnace, Midwest Carbide Corporation, Pryor, Oklahoma", Stuever and Associates, Oklahoma City, OK, April 1978.

13. Letter from C. McPhee, State of Ohio EPA, Twinsburg, OH, to R. Marinshaw, Midwest Research Institute, Cary, NC, March 16, 1993.