EMISSION FACTOR DOCUMENTATION FOR

AP-42 SECTION 1.2

ANTHRACITE COAL COMBUSTION

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

LIST OF FIGURES- *Figures Missing- 3/25/99*

LIST OF TABLES

DISCLAIMER

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INTRODUCTION

The document "Compilation of Air Pollutant Emission Factors" (AP-42) was first published by the U.S. Environmental Protection Agency (EPA) in 1970. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. The AP-42 is routinely updated by EPA to respond to new emission factor needs of EPA, State, and local air pollution control programs and industry.

An emission factor relates the quantity (mass) of pollutants emitted to a unit of activity of the source. The uses for the emission factors reported in AP-42 include:

1. Estimates of area-wide emissions;
2. Emission estimates for a specific facility; and
3. Evaluation of emissions relative to ambient air quality.

The purpose of this report is to provide background information from over 17 test reports to support revision of emission factors for anthracite coal combustion.

Including the introduction (Chapter 1), this report contains five chapters. Chapter 2 gives a description of the use of anthracite coal for combustion in boilers, furnaces, and space heaters. It includes a characterization of the industry; an overview of the different forms of anthracite fuel (i.e., coal and culm) and boiler types; a discussion of factors affecting emissions; and a description of the technology used to control emissions resulting from anthracite coal combustion. Chapter 3 is a review of emissions data collection and analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. It also describes particle size determination and particle size data analysis methodology. Chapter 4 details pollutant emission factor development. It includes the review of specific data sets, the results of data analysis, and the data base protocol. Chapter 5 presents the new AP-42 Section 1.2 for Anthracite Coal Combustion.

2. INDUSTRY DESCRIPTION

2.1   CHARACTERIZATION OF THE INDUSTRY[1-3]

Nearly all anthracite coal in the U.S. is mined in northeastern Pennsylvania; smaller quantities are produced in Rhode Island and Virginia. Anthracite coal is consumed mostly in Pennsylvania and its surrounding states. The largest use of anthracite is for space heating. Lesser amounts are employed for steam/electric production; coke manufacturing, sintering and pelletizing; and other industrial uses. Anthracite currently represents only a small fraction of the total quantity of coal combusted in the U. S.

2.2   PROCESS DESCRIPTION

2.2.1 Fuel Characteristics[4-6]

Anthracite coal is a high-rank coal with more fixed carbon and less volatile matter than either bituminous coal or lignite; anthracite coal also has higher ignition temperatures and ash fusion temperatures than these other common coal types. As shown in Table 2-1, anthracite coal typically contains approximately 5 percent moisture, 4 percent volatile matter, 10 percent ash, less than 1 percent sulfur, less than 1 percent nitrogen, and 80 percent fixed carbon. Heating values are normally in the range of 6,700 to 7,800 kcal/kg (12,000 to 14,000 Btu/lb).

Another form of anthracite coal burned in boilers is anthracite refuse, commonly known as culm. Culm was produced as breaker reject material from the mining/sizing of anthracite coal and was typically dumped by miners on the ground near operating mines. It is estimated that there are over 15 million Mg (16 millon tons) of culm scattered in piles up to 200 meters (600 feet) high throughout northeastern Pennsylvania.[4] As shown in Table 2-1, culm is characterized by a higher ash content, higher moisture content, and lower heating value; i.e., 1,400 to 2,800 kcal/kg (2,500 to 5,000 Btu/lb) relative to mined anthracite coal.

2.2.2 Combustor Types

Due to its low volatile matter content, and non-clinkering characteristics, anthracite coal is largely used in medium-sized industrial and institutional stoker boilers using stationary and traveling grates. Anthracite coal is not used in spreader stokers because of its low volatile matter content and relatively high ignition temperature. This fuel may also be burned in pulverized coal-fired (PC-fired) units, but due to ignition difficulties, this practice is limited to only a few plants in eastern Pennsylvania. Anthracite coal has also been widely used in hand-fired furnaces. Because of its high

ash content and low heating value, culm has been combusted primarily in fluidized bed combustion (FBC) boilers. The operating principles of each of these combustors are summarized below.

Combustion of anthracite coal on a traveling grate is characterized by a coal bed of 8 to 13 cm (3 to 5 inches) in depth and a high blast of underfire air at the rear or dumping end of the grate. Typical arrangements for traveling grate stokers are shown in Figures 2-1 and 2-2. This high blast of air lifts incandescent fuel particles and combustion gases from the grate and reflects the particles against a long rear arch over the grate towards the front of the fuel bed where fresh or "green" fuel enters. This special furnace arch design is required to assist in the ignition of the green fuel. At the far end of the grate, ash is discharged into an ash pit.

Additional underfire air passes up through the grate through manually-adjusted air boxes. Coal feed rates are controlled by a manually-adjusted leveling gate at the front of the traveling grate which regulates the bed depth. Combustion rates are controlled by the speed of the grate and by the underfire air rates. When automatic controls are used, the grate speed and air rates are regulated by steam pressure. Some of the smaller traveling grate and hand-fired units use only natural draft to supply air.

A second type of stoker boiler used to burn anthracite coal is the underfeed stoker. Various types of underfeed stokers are used in industrial boiler applications but the most common for anthracite coal firing is the single-retort side-dump stoker with stationary grates (see Figure 2-3). In this unit, coal is fed intermittently to the fuel bed by a ram. In very small units, the coal is fed continuously by a screw. Feed coal is pushed through the retort and upwards towards the tuyere blocks. Air is supplied through the tuyere blocks on each side of the retort and through openings in the side grates. Overfire air is commonly used with underfeed stokers to provide combustion air and turbulence in the flame zone directly above the active fuel bed. The air is provided by a separate overfire-air fan and is injected through small nozzles in the furnace walls. Single or double retort boilers are generally less than 73 MW (250 million Btu/hr) in heat input capacity.

In PC-fired boilers, the fuel is pulverized to the consistency of light powder and pneumatically injected through the burners into the furnace. Injected coal particles burn in suspension within the furnace area of the boiler. Hot flue gases rise from the furnace and provide heat exchange with boiler tubes in the walls and upper regions of the boiler. Small particles of ash (i.e., fly ash) are carried overhead with the hot flue gases. Larger ash particles (i.e., bottom ash) drop to the floor of the furnace where they are collected and removed. Pulverized coal-fired boilers may

operate either in a wet-bottom or dry-bottom mode, depending on whether or not the ash is allowed to slag. Because of its high ash fusion temperature, anthracite coal is burned in dry-bottom furnaces.

For anthracite culm, combustion in conventional boiler systems is difficult to achieve due to the fuel's high ash content, high moisture content, and low heating value. However, the burning of culm in a fluidized bed system was demonstrated at a steam generation plant in Pennsylvania. A fluidized bed consists of inert particles (e.g., rock and ash) through which air is blown so that the bed behaves as a fluid. Anthracite coal enters in the space above the bed and burns in the bed. Because of the large thermal mass represented by the hot inert bed particles, fluidized beds can handle fuels with moisture contents up to near 70 percent (total basis). Fluidized beds can also handle fuels with ash contents as high as 75 percent. Heat released by combustion is transferred to in-bed steam-generating tubes.

Fuel is pyrolyzed faster in a fluidized bed than on a grate due to immediate contact with hot bed material. As a result, combustion is rapid and results in nearly complete combustion of the organic matter, thereby minimizing emissions of unburned organic compounds. In addition, limestone may be added to the bed to capture sulfur dioxide (SO_2) formed by combustion of fuel sulfur. Operating bed temperatures for FBC units are typically in the range of 790-900 $^{\circ}$C (1450-1650 $^{\circ}$F).

2.3   EMISSIONS[2,5,7]

Uncontrolled particulate matter (PM) emissions from coal-fired boilers depend primarily on fuel ash content, firing mechanism, and boiler load. Stokers generally have lower PM emissions than do PC-fired units because the coal is burned on a bed, which leads to less entrainment of PM than does suspension firing. Hand-fired and some small natural draft units have lower particulate emissions due to relatively lower underfire air rates. Larger units equipped with forced draft fans may produce high rates of particulate emissions, especially when operating at or near rated capacity. Firing coals with higher ash contents generally results in higher PM emissions. Particulate emissions from stoker units will also be higher if fly ash collected by mechanical collectors is reinjected into the furnace; emissions from all stokers will increase during sootblowing operations.

Coals with higher ash fusion temperatures, such as anthracite, are generally fired in dry-bottom units which emit higher levels of PM than do wet-bottom boilers. The PM emission levels from coal-fired boilers also depend on boiler load. Limited test data indicate that mass emissions of PM on a heat input basis tend to decrease with decreasing load.

Traveling grate stokers emit coarser particles than do underfeed stokers and PC-fired units. Hence, emissions of PM less than 10 microns (PM-10) will also be lower for the former unit relative to the latter units.

Sulfur oxide emissions are directly proportional to the sulfur content of fuel. Some minor differences will occur from unit to unit, however, due to (1) ash partitioning between fly ash and bottom ash and (2) the sodium content of the coal (which tends to react with and bind coal sulfur in the bottom ash as sodium sulfite or sodium sulfate). For FBC boilers, sulfur oxide emissions are inversely proportional, in general, to the molar ratio of calcium (in the limestone) to sulfur (in the fuel) added to the bed.

Nitrogen oxide (NO_x) emissions are lower in traveling grate and underfeed stokers compared to PC-fired boilers. Underfeed and traveling grate stokers have large furnace areas and consequently lower volumetric- and surface area-based heat release rates. Lower heat release rates reduce peak combustion temperatures and, hence, contribute to lower NO_x emissions. In addition, the partially staged combustion that naturally occurs in all stokers due to the use of underfire and overfire air contributes to reduced NO_x emissions relative to PC-fired units. The low operating temperatures which characterize FBC boilers firing culm also favor relatively low NO_x emissions. Reducing boiler load tends to decrease combustion intensity which, in turn, leads to decreased NO_x emissions for all boiler types.

Carbon monoxide (CO) and total organic compound (TOC) emissions are dependent on combustion efficiency. Generally their emission rates, defined as mass of emissions per unit of heat input, decrease with increasing boiler size. The TOC emissions are expected to be lower for PC-units and higher for underfeed and overfeed stokers as a result of relative combustion efficiency levels.

2.4   EMISSION CONTROLS[5,7]

Air pollution control equipment on anthracite coal-fired boilers has been applied primarily for PM emissions control. The most efficient particulate control systems [fabric filters and electrostatic precipitators (ESPs)] have typically been applied to larger pulverized anthracite-fired boilers and FBC units burning culm. Venturi scrubbers and mechanical collectors are normally used for PM control on smaller stoker boilers. Operating principles and factors affecting emissions for each of these control technologies are summarized below.

Mechanical collectors, or cyclones, use centrifugal separation to remove PM from flue gas streams. At the entrance of the cyclone, a spin is imparted to the particle-laden gas. This spin creates a centrifugal force which causes the PM to move away from the axis of rotation and towards the walls of the cyclone. Particles which contact the walls of the cyclone tube are directed to a dust collection hopper where they are deposited.

In a typical single cyclone, the gas enters tangentially to initiate the spinning motion. In a multitube cyclone (or multiclone), the gas approaches the entrance axially and has the spin imparted by a stationary "spin" vane that is in its path. This allows the use of many small, higher efficiency cyclone tubes operating parallel to the gas flow stream, with a common inlet and outlet header.

One variation of the multitube cyclone is to place two similar mechanical collectors in series. This system is often referred to as a dual or double mechanical collector. The first collector removes the bulk of the dust and the second removes smaller particles. Single mechanical collectors have been reported to have PM collection efficiencies up to 80 percent.

Particulate emissions from coal-fired boilers are considered to be abrasive and can cause erosion within the mechanical collector. Such erosion reduces PM collection efficiency over time unless corrective maintenance procedures are employed.

A wet scrubber is a collection device which uses an aqueous stream or slurry to remove particulate and/or gaseous pollutants. There are three basic mechanisms involved with collecting PM in wet scrubbers: interception, inertial impaction, and diffusion of particles on droplets. The interception and inertial impaction effects dominate at large particle diameters; the diffusion effects dominate at small particle diameters.

Wet scrubbers are usually classified by energy consumption (in terms of gas-phase pressure drop). Low-energy scrubbers, represented by spray chambers and towers, have pressure drops of less than 1 kPa (5 inches of water). Medium-energy scrubbers such as impingement scrubbers have pressure drops of 1 to 4 kPa (5 to 15 inches of water). High-energy scrubbers such as high- pressure-drop venturi scrubbers have pressure drops exceeding 4 kPa (15 inches of water). Higher removal levels of PM are usually achieved with higher-energy scrubbers.

The most widely used wet scrubbers for anthracite coal-fired boilers are venturi scrubbers. In a typical venturi scrubber, the particle-laden gas first contacts the liquor stream in the core and throat of the venturi section. The gas and liquid streams then pass through the annular orifice formed by the core and throat, atomizing the liquid into droplets which are impacted by particles in the gas

stream. Impaction results mainly from the high differential velocity between the gas stream and the atomized droplets. The droplets are then removed from the gas stream by centrifugal action in a cyclone separator and (if present) a mist eliminator section.

Wet scrubbers have reported PM collection efficiencies of 90 percent or greater. Operational problems can occur with wet scrubbers due to clogged spray nozzles, sludge deposits, dirty recirculation water, improper water levels, and unusually low pressure drops.

Gaseous emissions such as SO_2, NO_x, CO, and organics may also be absorbed to a significant extent in a wet scrubber. In addition, alkali compounds are sometimes utilized in the scrubber to prevent low pH conditions. If carbon dioxide (CO_2)-generating compounds (such as sodium carbonate or calcium carbonate) are used, CO_2 emissions may increase.

Particulate collection in an ESP occurs in three steps: suspended particles are given an electrical charge; the charged particles migrate to a collecting electrode of opposite polarity while subjected to a diverging electric field; and the collected PM is dislodged from the collecting electrodes.

Charging of the particles to be collected is usually caused by ions produced in a high voltage direct current corona. The electric fields and the corona necessary for particle charging are provided by high voltage transformers and rectifiers. Removal of the collected PM is accomplished mechanically by rapping or vibrating the collecting electrodes. When applied to coal-fired boilers, ESPs are often used downstream of mechanical collector precleaners which remove larger-sized particles. When applied to anthracite coal-fired boilers, ESPs typically are only 90 to 97 percent efficient, because of the characteristic high resistivity of low sulfur anthracite fly ash. It is reported that higher efficiencies can be achieved using larger precipitators and flue gas conditioning.

In fabric filters (also known as baghouses), particulate-laden dust passes through a set of filters mounted inside the collector housing. Dust particles in the inlet air are retained on the filters by inertial impaction, diffusion, direct interception, and sieving. The first three processes prevail only briefly during the first few minutes of filtration with new or recently cleaned filters, while the sieving action of the dust layer accumulating on the fabric surface soon predominates. The sieving mechanism leads to high efficiency PM collection unless defects such as pinhole leaks or cracks appear in the filter cake. The PM collection efficiencies for fabric filters operating on coal-fired boilers can exceed 99 percent.

Cleaning of the bag filters typically occurs in one of three ways. In shaker cleaning, the bags are oscillated by a small electric motor. The oscillation shakes most of the collected dust into a hopper. In reverse air cleaning, backwash air is introduced to the bags to collapse them and fracture the dust cake. Both shaker cleaning and reverse air cleaning require a sectionalized baghouse to permit cleaning of one section while other sections are functioning normally. The third cleaning method, pulse jet cleaning, does not require sectionalizing. A short pulse of compressed air is introduced through venturi nozzles and directed from the top to the bottom of each bag. The primary pulse of air aspirates secondary air as it passes through the nozzles. The resulting air mass expands the bag and fractures the cake.

Figure 2-2. Typical stoker installation for anthracite coal.[6]

Figure 2-3. Cross-section of a single-retort side-dump stoker with stationary grates.[3]

TABLE 2-1. TYPICAL ANALYSES FOR ANTHRACITE COAL AND CULM[3,4]

Parameter	As-fired weight percent	
	Anthracite coal[a]	Anthracite culm
Proximate Analysis		
Moisture	2.1-2.3	-
Volatile Matter	3.1-7.5	-
Fixed Carbon	80.3-87.7	-
Ash	6.9-10.1	67-74
Ultimate Analysis		
Carbon	80.9-86.7	24.2-26.6
Hydrogen	2.2-3.3	0.9-1.0
Oxygen	2.9-4.2	3.1-5.3
Sulfur	0.5	0.3-0.9
Nitrogen	0.8-1.0	0.5-0.6
Heating Value	7,500-7,600 kcal/kg (13,480-13,540 Btu/lb)	1,500-2,350 kcal/kg (2,700-4,160 Btu/lb)

[a] From the Mammoth and Big Lykens seams in Pennsylvania.

REFERENCES FOR CHAPTER 2

1.   Minerals Yearbook, 1978-1979, Bureau of Mines, U.S. Department of the Interior, Washington, DC, 1981.

2.   Air Pollutant Emission Factors, APTD-0923, U. S. Environmental Protection Agency, Research Triangle Park, NC, April 1970.

3.   Chemical Engineers' Handbook, Fourth Edition, J. Perry, Editor, McGraw-Hill Book Company, New York, NY, 1963.

4.   "Operating Experience at the Shamokin Culm Burning Steam Generation Plant", P. Bender, D. Samela, W. Smith, G. Tsoumpas, Stone & Webster Engineering Group, New York, New York, J. Laukaitis, Shamokin Area Industrial Corporation, Shamokin, Pennsylvania, Presented at the 76th Annual Meeting of the Air Pollution Control Association, Atlanta, GA, June 1983.

5.   Background Information Document For Industrial Boilers, EPA 450/3-82-006a, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 1982.

6.   Steam: Its Generation and Use, Thirty-Seventh Edition, The Babcock & Wilcox Company, New York, NY, 1963.

7.   Compilation of Air Pollutant Emission Factors, Volume I, Fourth Edition, AP-42, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1985.

Figure 2-1. Construction details for chain-grate/traveling grate stoker.[6]

3. GENERAL DATA REVIEW AND ANALYSIS PROCEDURES

3.1 LITERATURE SEARCH AND SCREENING

   The first step of this investigation involved a search of available literature relating to criteria
and noncriteria pollutant emissions associated with bagasse combustion in sugar mills. This
search included the following sources:

- AP-42 background files,

- Files and dockets maintained by the Emission Standards Division of OAQPS for relevant NSPSs and NESHAPs,

- "Locating and Estimating" reports available through EPA's Clearinghouse for Inventories and Emission Factors (CHIEF) web site,

- PM-10 "gap filling" documents in the OAQPS library,

- Publications available through EPA's Control Technology Center,

- Reports and project summaries from EPA's Office of Research and Development,

- Control Techniques Guideline documents generated by the Emission Standards Division of OAQPS,

- Information in the Air Facility System (AFS) of EPA's Aerometric Information Retrieval System (AIRS),

- Handbook of Emission Factors, Parts I and II, Ministry of Health and Environmental Protection, The Netherlands,

- EPA's CHIEF and National Air Toxics Information Clearinghouse (NATICH),

- EPA databases, including SPECIATE, XATEF, and TSAR,

- Various EPA contractor reports, and

- In-house files maintained the Contractor.

   To reduce the large amount of literature collected to a final group of references pertinent to
this report, the following general criteria were used:

1. Emissions data must be from a primary reference:

a. Source testing must be from a referenced study that does not reiterate information from previous studies.

b. The document must constitute the original source of test data. For example, a technical paper was not included if the original study was contained in the previous document. If the exact source of the data could not be determined, the document was eliminated.

2. The referenced study must contain test results based on more than one test run.

3. The report must contain sufficient data to evaluate the testing procedures and source operating conditions (e.g., one-page reports were generally rejected).

A final set of reference materials was compiled after a thorough review of the pertinent reports, documents, and information according to these criteria.

3.2 EMISSION DATA QUALITY RATING SYSTEM[1]

As part of the Contractor's analysis of the emission data, the quantity and quality of the information contained in the final set of reference documents were evaluated. The following data were always excluded from consideration.

1. Test series averages reported in units that cannot be converted to the selected reporting units;

2. Test series representing incompatible test methods (i.e., comparison of EPA method 5 front-half with EPA method 5 front- and back- half);

3. Test series of controlled emissions for which the control device is not specified;

4. Test series in which the source process is not clearly identified and described; and

5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Data sets that were not excluded were assigned a quality rating. The rating system used was that specified by the OAQPS for the preparation of AP-42 sections. The data were rated as follows:

A--Multiple tests performed on the same source using sound methodology and reported in enough detail for adequate validation. These tests do not necessarily conform to the methodology specified in either the inhalable particulate (IP) protocol documents or the EPA reference test methods, although these documents and methods were certainly used as a guide for the methodology actually used.

B--Tests that were performed by a generally sound methodology but lack enough detail for adequate validation.

C--Tests that were based on an untested or new methodology or that lacked a significant amount of background data.

D--Tests that were based on a generally unacceptable method but may provide an order-of-magnitude value for the source.

The following criteria were used to evaluate source test reports for sound methodology and adaquate detail:

1. <u>Source operation</u>. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. <u>Sampling procedures</u>. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent such alternative procedures could influence the test results.

3. <u>Sampling and process data</u>. Adequate sampling and process data are documented in this report. Many variations can occur unnoticed and without warning during testing. Such variations can include wide deviations in sampling results. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. <u>Analysis and calculations</u>. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

3.3 PARTICLE SIZE DETERMINATION

There is no one method which is universally accepted for the determination of particle size. A number of different techniques can be used which measure the size of particles according to their basic physical properties. Since there is no "standard" method for particle size analysis, a certain degree of subjective evaluation was used to determine if a test series was performed using a sound methodology for particle sizing.

For pollution studies, the most common types of particle sizing instruments are cyclones and cascade impactors. Traditionally, cyclones have been used as a preseparator ahead of a cascade impactor to remove the larger particles. These cyclones are of the standard reverse-flow design whereby the flue gas enters the cyclone through a tangential inlet and forms a vortex flow pattern. Particles move outward toward the cyclone wall with a velocity that is determined by the geometry and flow rate in the cyclone and by their size. Large particles reach the wall and are collected. A series of cyclones with progressively decreasing cut-points can be used to obtain particle size distributions.

Cascade impactors used for the determination of particle size in process streams consist of a series of plates or stages containing either small holes or slits with the size of the openings decreasing from one plate to the next. In each stage of an impactor, the gas stream passes through the orifice or slit to form a jet that is directed toward an impaction plate. For each stage, there is a characteristic particle diameter that has a 50 percent probability of impaction. This characteristic diameter is called the cut-point (D_{50}) of the stage. Typically, commercial instruments have six to eight impaction stages with a backup filter to collect those particles which are either too small to be collected by the last stage or which are re-entrained off the various impaction surfaces by the moving gas stream.

3.4   EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated utilizing the following criteria:

A--Excellent: Developed only from A-rated test data taken from many randomly chosen facilities in the industry population. The source category is specific enough so that variability within the source category population may be minimized.

B--Above average: Developed only from A-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industries. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

C--Average: Developed only from A- and B-rated test data from a reasonable number of facilities. Although no specific bias is evident, it is not clear if the facilities tested represent a random sample of the industry. As in the A-rating, the source category is specific enough so that variability within the source category population may be minimized.

D--Below average: The emission factor was developed only from A- and B-rated test data from a small number of facilities, and there is reason to suspect that these facilities do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of the emission factor are noted in the emission factor table.

E--Poor: The emission factor was developed from C- and D-rated test data, and there is reason to suspect that the facilities tested do not represent a random sample of the industry. There also may be evidence of variability within the source category population. Limitations on the use of these factors are always noted.

The use of these criteria is somewhat subjective and depends to an extent on the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCES FOR CHAPTER 3

1.   Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1992.

4. POLLUTANT EMISSION FACTOR DEVELOPMENT

This chapter describes the test data and methodology used to develop pollutant emission factors for external combustion processes using anthracite coal as a fuel.

4.1   REVIEW OF SPECIFIC DATA SETS

A total of 17 references reporting emissions data were documented and reviewed during the literature search. Useful data for emission factor development were found in 7 of the 17 references. For the 10 documents not used, the reasons for rejection were:

- Reference 8: Engineering estimates with rating of E;

- Reference 9: Higher quality data available;

- Reference 10: Insufficient data for fuel;

- Reference 11: Higher quality data available;

- Reference 12: Potential for air inleakage, also Reference 5 reports results of concurrent testing on the same sources;

- Reference 13: Better documentation of same test program in Reference 7;

- Reference 14: Better documentation of same test program in Reference 7;

- Reference 15: Engineering estimates with rating of E or sources inadequately described;

- Reference 16: Engineering estimates with rating of E or sources inadequately described;

- Reference 17: Inadequate documentation, not the primary reference.

The seven documents used to develop the revised emission factors included four documents (i.e., References 1 to 4) used for the previous AP-42 supplement (1988).[18] In the subsections to follow, emission measurements qualifying for emission factor development are described for each reference.

4.1.1 Reference 1

Emission tests were conducted at three sites on small boilers described only as stoker fired. Emissions were not controlled.

A Source Assessment Sampling System (SASS) train was used for field sampling. Samples of the flue gas were also collected in gas sampling bags and analyzed onsite for low molecular weight hydrocarbons, using a gas chromatograph with a flame ionization detector.

Samples collected with the SASS train were analyzed for total organic carbon (TOC), metal species (filterable and condensible), and polycyclic organic matter (POM).

Given that the SASS train is designed for screening studies, the data resulting from this test program were of questionable quality. Also, documentation of the test data was sparse. Based on these data quality and documentation limitations, a rating of D was assigned to the data.

4.1.2 Reference 2

The test program described in this document measured total PM and NO_x in the uncontrolled flue gases from each of two small, steam generating boilers. Coal for the two boilers was fed by traveling grate stoker. Orsat analysis was used to determine emission factors for CO_2.

EPA Method 5 was used to determine PM concentrations. Since front-half and back-half catches were measured and reported separately, the determination of emission factors for both filterable and condensible PM was possible.

The manual version of EPA Method 7 was employed to determine NO_x concentrations.

The tests were performed by a sound methodology and their results were well documented. A rating of A was assigned to the data.

4.1.3 Reference 3

The concentrations of total PM and NO_x were measured in the emissions from two small, steam generating boilers. Emissions were not controlled.

Three sampling runs were conducted for each boiler, using EPA Method 5. The filterable and condensible catches from the Method 5 sampling train were reported separately.

Nitrogen oxides were determined, using the manual version of EPA Method 7.

Complete documentation of the test program was not included in the report. Therefore, a rating of B was assigned to the data.

4.1.4 Reference 4

The total PM concentration of the combined emission stream from two small, steam generating boilers was determined. The emissions were uncontrolled. Traveling grate stokers were used in each of the two boilers.

Particulate matter concentrations were determined for both the front-half and back-half material collected with an EPA Method 5 sampling train. Therefore, both filterable and condensible PM emission factors could be developed.

Valid data were obtained from two of the three sampling runs. Data from the first sampling run were not used because the volume of sample collected did not meet Method 5 requirements. Because the test program was not completed as planned, the data were assigned a B rating.

4.1.5 Reference 5

Carbon dioxide emission factors were calculated from data obtained during a test to measure PM emissions. Three small, steam generating boilers were tested. Flue gas was sampled downstream of mechanical collectors. The PM emissions data from this test program were not used because of an inadequate number of points on the sampling traverse.

Two sampling runs were conducted on each boiler. During each run, a gas sample was collected from the exhaust duct of each boiler; CO_2 was determined by Orsat analysis.

The method for measuring coal consumption was not specified. The data for this source category were assigned a rating of B.

4.1.6 Reference 6

The emissions from residential space heaters were sampled and analyzed for methane and polynuclear aromatic hydrocarbons (PAH).

One of the space heaters was designed to burn either anthracite or bituminous coal. The grates were fed from a magazine which was not replenished during the test. The other space heater was designed to burn either coal or wood. The firebox could hold 7-9 kilograms (15-20 pounds) of coal before having to be replenished.

The space heaters were placed on weigh scales and coal consumption rates were determined by weight loss. A flexible connection was installed on the flue gas duct to isolate the weight of the space heater from the rest of the structure.

Particulate matter and PAH concentrations were determined using the modified EPA Method 5 sampling train. The Method 5 sampling train was modified by inserting a XAD-2 resin trap to collect organics. Analyses of combined extracts of filterable material and the resin trap were accomplished with gas chromotography/mass spectrometry (GC/MS).

The data and results were clearly presented but documentation was limited. Modifications of the space heaters to obtain a firing rate introduced some uncertainty about whether the sampling runs typified normal operation. For these reasons, a rating of C was assigned to the data.

4.1.7 <u>Reference 7</u>

Anthracite culm was burned in a FBC boiler. Culm is the breaker refuse discarded during the mining process; it is typically composed of 20 to 30 percent coal. The fluidized bed consisted of culm, inerts, coal ash, and limestone; the latter was used to absorb SO_2.

As part of a series of parametric tests to demonstrate the turndown capability of the FBC unit, continuous sampling and instrumental analyses were employed to determine flue gas concentrations of SO_2, NO_x, and CO. Gas analysis methods were as follows:

- SO_2: pulsed fluorescence,

- NO_x: chemiluminescence, and

- CO: infra-red.

Flue gas samples were collected at the inlet to the air preheater. The air preheater was located downstream of primary and secondary cyclones but upstream of a fabric filter used for removal of PM. Ash from the primary cyclone was reinjected into the fluidized bed to improve carbon utilization. Thirty-six parametric tests, typically four hours in duration, were conducted. Gas analyses data were complete for 11 of these tests; emission factors were calculated for these 11 tests.

Because of the demonstration nature of the test program and of the process variations introduced by the parametric testing, the data quality rating was lowered. Additionally, better sampling protocols than those employed would have insured a more representative sample. Based on these potentials for sub-standard data quality, a rating of D was assigned to the data.

4.2   RESULTS OF DATA ANALYSIS

This section discusses the development of emission factors for tested pollutants based on the data contained in the reference documents described above. In all cases, emission factors were developed using manual and computer spreadsheet manipulation to convert emission data expressed in various units of concentrations or flow rates to mass of the pollutant per ton or kilogram of coal/culm feed.

Using the guidelines described in Chapter 2 for developing the data quality ratings, new test data were utilized if they improved the ratings of an existing factor. Existing criteria pollutant emission factors were dropped in favor of emission factors calculated with new data or with a combination of new data and existing data.

If emission factors from the previous (i.e., 1988) version of AP-42 Section 1.2 were not changed as a result of new data, the previous emission factors and associated factor ratings have been carried forward for the current update. It should be noted that the 1988 version of AP-42 Section 1.2 utilized emission factors from Section 1.1 - Bituminous and Subbituminous Coal Combustion for anthracite coal combusted in PC-fired boilers. Because no recent data were located for combustion of pulverized anthracite coal, the 1988 emission factors are used for this update.

A summary of developed emission factors for tested pollutants is presented in Tables 4-1 to 4-6.

4.2.1 Filterable Particulate Matter

Uncontrolled filterable PM emission factors were determined from the data contained in References 2, 3, and 4. The units tested were all stoker-fired traveling grate units. Data from a total of six boilers were used to calculate the new emission factors. The six boilers ranged in capacity from 11,250 to 11,700 kg steam/hour (25,000 to 26,000 lbs steam/hr).

Filterable PM emission factors from the 1988 version of AP-42 Section 1.2 were retained for hand fired units. A copy of the 1988 version of AP-42 Section 1.2 is contained in Appendix A.

4.2.2 Condensible Particulate Matter

Emission factors for condensible PM were developed from the same sampling run data taken from References 2, 3, and 4, discussed above for filterable PM.

4.2.3 Particulate Matter Less Than 10 Microns (PM-10)

No useful data for PM-10 were found that could provide an update of the previous emission factor. Therefore, 1988 PM-10 emission factors are retained for controlled and uncontrolled PC boilers and for traveling grate stoker-fired boilers. The data were obtained from Reference 19.

4.2.4 Lead

Lead emissions data were found in the Reference 1 document for three stoker-fired boilers using unspecified grate types. The three boilers ranged in design capacity from 2.6 to 3.2 MW (9 to 11 million Btu/hour).

4.2.5 Sulfur Oxides

Uncontrolled sulfur oxides emission factors were retained from the previous AP-42 supplement. Controlled emissions were reported as SO_2 in the Reference 7 document, from which an emission factor was determined. The source category - culm burning in an FBC boiler - is new to the anthracite coal section of AP-42. The tested boiler in this catagory was rated at 9.7 MW (33 million Btu/hour) heat input.

4.2.6 Nitrogen Oxides

Uncontrolled NO_x emission factors for boilers with traveling grate stokers were determined from data found in Reference 2 and 3. Data from a total of four boilers were used to calculate the new emission factors. All four boilers were rated at a steam capacity of 11,250 kg/hr (25,000 lbs/hr). A NO_x emission factor was determined for the culm-burning FBC boiler. The test data were taken from Reference 7. Nitrogen oxide emission factors from the 1988 AP-42 supplement were retained for PC-fired and hand fired units.

4.2.7 Carbon Monoxide

A CO emission factor was determined for the culm-burning fluidized bed boiler (see Section 4.2.5). The test data were taken from Reference 7. The uncontrolled emission factor from the last AP-42 supplement was retained for traveling grate stoker-fired units.

4.2.8 Total Organic Compounds

Data to determine TOCs were reported in the Reference 1 document. Three stoker fired boilers (types of grates unspecified) were tested for organics. The three boilers were rated at 2.6 to 3.2 MW (9 to 11 million Btu/hr) heat input.

4.2.9 Speciated Organic Compounds

Uncontrolled emission factors were determined for a number of organic species in the general classifications of POM and PAH. Useful data were found in Reference 1 and Reference 6 documents. For small stoker-fired boilers, emission data were available to determine emission factors for three speciated organic compounds. The three boilers tested were rated at 2.6 to 3.2 MW (9 to 11 million Btu/hr) heat input capacity. For the residential space heaters tested, useful data were available to determine emission factors for 18 speciated organic compounds.

4.2.10 Trace Elements

Emission factors for nine trace element species were developed from the data reported in Reference 1. The three boilers tested were rated at 2.6 to 3.2 MW (9 to 11 million Btu/hr) heat input capacity.

4.2.11 Carbon Dioxide

Uncontrolled emission factors for CO_2 were calculated using test data from References 2 and 5. The data reported in the Reference 2 document consisted of PM sampling data and Orsat analysis of gases from two boilers with traveling grate stokers, each with 11,250 kg/hr (25,000 lbs/hr) of steam generating capacity. The data reported in the Reference 5 document consisted of PM sampling data and Orsat analysis of gases obtained from two boilers ranging in steam capacity from 10,530 to 17,960 kg/hr (23,400 to 39,900 lbs/hr).

4.2.12 Methane

During the test program reported in Reference 6, residential space heaters were tested to determine emission concentrations of toxic metals and various organics. Actual firing rates varied from 1 to 2 kg/hr (2 to 4 lb/hr) of anthracite coal.

4.3 PROTOCOL FOR DATA BASE

4.3.1 Engineering Methodology

The seven references discussed in Section 4.1 were thoroughly reviewed to establish a data base for the pollutants discussed above. Data rating forms (see Appendix B) were created to facilitate the evaluation of exclusion criteria, methodology/detail criteria, and data rating criteria. These forms were completed for each reference in order to document the rationale for either

excluding the reference from emission factor development consideration or for including the reference and assigning ratings to relevant source test data.

The emissions data from source test reports were averaged as the arithmetic mean of different sampling runs prior to inclusion in the data base. Where two or more combustion devices were reported in the same document, averages were compiled for each combustion device and these averages incorporated into the data base.

Generally, the analysis consisted of one of six methods:

1. Acceptance of reported emission factor.

2. Calculation, using reported time-based rates for pollutant and coal/culm.

3. Calculation, using reported concentrations of pollutant in flue gas as volume percent, ppmv, or weight per volume ratio, or using reported flow rates for flue gas and coal/culm.

4. Calculation, using reported concentrations of pollutant in volume or weight, based on thermal input to the combustion device.

5. Use of an F-factor and a representative heating value for coal to determine stoichiometric volume of flue gas per mass of coal burned. (An F-factor is a typical ratio of flue gas generated to heat input combusted for a given fuel type.) Converted stoichiometric volume to total volume by correcting for reported excess oxygen content of flue gas. Used reported concentrations of pollutants as in method 3.

6. Accept emission factors reported in previous AP-42 version.

One of the six methods described above was chosen (based on the information available in a particular reference) and an emission factor was calculated or chosen for a given sampling run. The procedure was repeated for each sampling run, or for averaged sets of replicate sampling runs, until a data base was assembled for each source category.

In addition to unit conversions, EPA Methods 3, 4 and 5 required some preprocessing to convert data expressed in terms of ppmv or lb pollutant/million Btu to lb pollutant/ton of coal. This was accomplished using the reported heating value of feed coal and an F-Factor of 10,100 dscf/million Btu at 0 percent oxygen (O_2).[20] This factor was adjusted to other O_2 flue gas concentrations using the equation:

$$F = 10,100 \text{ dscf}/10^6 \text{ Btu } [20.9/(20.9\text{-}\%O_{2d})]$$

where $\%O_{2d}$ was the actual flue gas O_2 content measured on a dry basis. Determinations of emission factors were made only when coal or culm feed rates were documented or derivable from plant records. Emission factors for PM and SO_2 were corrected to a feed pollutant concentration basis. The calculated emission factor was divided by the weight percent of pollutant precursor in the feed (such as weight percent ash in the coal for PM factors); the reported emission factor includes the pollutant precursor as a multiplier. For example, if measured emissions were 12 lbs PM/ton coal and ash in the feed coal was 8 weight percent:

$$\text{Reported EF} = (12/8) = 1.5A$$

where A is weight percent ash in coal.

Quality control and quality assurance procedures were used to assure that the data base accurately reflected the reported test data. Each data rating form was checked by a second Contractor staff member to assure accurate documentation of reference exclusion or emission data rating criteria. Example data rating forms are shown in Appendix B. In addition, manual and spreadsheet calculations were spot checked by a second Contractor staff member to assure accurate documentation of reported emission and process data prior to calculation of overall average emission factors. After emission tables were generated, a final comparison was made between randomly selected test reports, their associated data rating forms, and the produced emission table to assure the quality of the data acquisition and associated calculations.

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TABLE 4-1. SUMMARY OF EMISSION FACTORS FOR SPECIATED METALS FROM ANTHRACITE COMBUSTORS

Source category/ reference/rating	Emission factors, kg/Mg							
	Mercury	Arsenic	Beryllium	Cadmium	Chromium	Manganese	Nickel	Selenium
Stoker fired boiler								
1,d	8.5E-05	0.0E+00	2.7E-04	2.9E-05	2.9E-03	4.9E-04	3.9E-03	6.0E-04
1,d	4.4E-05	1.2E-04	1.8E-04	5.5E-05	2.4E-02	2.6E-03	1.7E-02	1.1E-03
1,d	6.5E-05	6.5E-05	1.5E-05	2.3E-05	1.4E-02	2.2E-03	1.8E-02	2.4E-04
	Emission factors, lb/ton							
	Mercury	Arsenic	Beryllium	Cadmium	Chromium	Manganese	Nickel	Selenium
Stoker fired boiler								
1,d	1.7E-04	0.0E+00	5.4E-04	5.8E-05	5.9E-03	9.8E-04	7.8E-03	1.2E-03
1,d	8.7E-05	2.4E-04	3.5E-04	1.1E-04	4.9E-02	5.3E-03	3.4E-02	2.1E-03
1,d	1.3E-04	1.3E-04	3.0E-05	4.5E-05	2.8E-02	4.4E-03	3.5E-02	4.7E-04

TABLE 4-2. SUMMARY OF EMISSION FACTORS FOR TOTAL ORGANIC COMPOUNDS (TOC) AND METHANE (CH$_4$) FROM ANTHRACTIE COMBUSTORS

Source category/ reference/rating	TOC			CH$_4$	
	kg/Mg	lb/ton		kg/Mg	lb/ton
Stoker fired boiler					
1,d	1.7E-01	3.4E-01			
1,d	2.2E-01	4.3E-01			
1,d	7.0E-02	1.4E-01			
Residential Space heaters					
6,c				1	2
6,c				3	6
6,c				8	16

TABLE 4-3. SUMMARY OF EMISSION FACTORS FOR SPECIATED ORGANIC   COMPOUNDS FROM UNCONTROLLED ANTHRACITE COMBUSTORS

| | Source category/reference/rating | | | | | | | |
| | Stoker fired boilers/1/d | | Residential space heaters/6/b | | | | | |
Pollutant	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Biphenyl	1.3E-02	2.5E-02						
Phenanthrene	3.2E-03	6.8E-03	2.1E-01	4.2E-01	4.6E-02	9.1E-02	2.17E-01	4.34E-01
Naphthalene	6.5E-02	1.3E-01	1.0E-01	2.0E-01	4.5E-03	9.0E-03	3.38E-01	6.75E-01
Acenaphthene			1.8E-02	3.6E-02	7.0E-01	1.4E-02	3.38E-01	6.75E-01
Acenaphthylene			1.9E-02	3.8E-02	7.0E-01	1.4E-02	1.98E-02	3.95E-02
Fluorene			1.7E-02	3.4E-02	4.5E-03	9.0E-03	2.89E-02	5.78E-02
Anthracene			2.3E-02	4.5E-02	4.5E-03	9.0E-03	2.17E-02	4.34E-02
Fluoranthrene			1.7E-01	3.3E-01	4.8E-02	9.6E-02	1.14E-01	2.27E-01
Pyrene			1.2E-01	2.4E-01	2.7E-02	5.4E-02	8.90E-02	1.78E-01
Benzo(a)anthracene			1.0E-01	2.0E-01	7.0E-01	1.4E-02	2.65E-02	5.30E-02
Chrysene			1.1E-01	2.2E-01	1.2E-02	2.3E-02	3.62E-02	7.23E-02
Benzo(k)fluoranthrene			1.3E-02	2.6E-02	7.0E-01	1.4E-02	3.14E-02	6.27E-02
Benzo(e)pyrene			3.1E-03	6.1E-03	2.3E-03	4.5E-03	7.25E-03	1.45E-02
Benzo(a)pyrene			1.9E-03	3.8E-03	4.5E-03	9.0E-03	4.10E-03	8.19E-03
Perylene			3.8E-04	7.6E-04	1.2E-03	2.3E-03	9.65E-04	1.93E-03
Indeno(123-cd)perylene			7.0E-01	1.4E-02	2.3E-03	4.5E-03	4.10E-03	8.19E-03
Benzo(g,h,i)perylene			6.0E-01	1.2E-02	2.3E-03	4.5E-03	2.17E-02	4.34E-03
Anthanthrene			9.5E-03	1.9E-04	5.5E-04	1.1E-03	4.82E-04	9.64E-04
Coronene			4.0E-03	8.0E-03	5.5E-04	1.1E-03	3.14E-02	6.27E-03

TABLE 4-4. SUMMARY OF EMISSION FACTORS FOR PARTICULATE MATTER (PM), AND LEAD FROM ANTHRACITE COMBUSTORS

Source category/ reference/rating	Filterable PM		Condensible PM		Lead	
	kg/Mg	lb/ton	kg/Mg	lb/ton	kg/Mg	lb/ton
Stoker fired boilers						
2,a	0.4A[a]	0.8A[a]	0.1A	0.2A		
2,a	0.4A	0.8A	0.015A	0.03A		
3,b	0.6A	1.1A	0.5A	0.1A		
3,b	0.4A	0.8A	0.03A	0.06A		
4,b	0.2A	0.3A	0.005A	0.01A		
1,d					2.0E-03	4.0E-03
1,d					7.0E-03	1.4E-02
1,d					4.4E-03	8.7E-03

[a]A=ash content of fuel, weight percent.

TABLE 4-5. SUMMARY OF EMISSION FACTORS FOR NITROGEN OXIDE COMPOUNDS (NO$_x$) AND SULFUR DIOXIDE (SO$_2$) FROM ANTHRACITE COMBUSTORS

Source category/reference/rating	NO$_x$		SO$_2$	
	kg/Mg	lb/ton	kg/Mg	lb/ton
Stoker fired boilers				
2,a	7	14		
2,a	3	6		
3,b	4.5	9		
3,b	3.5	7		
Fluidized bed[a]				
7,d	0.9[b]	1.8[b]	1.5[b]	2.9[b]

[a]Fluidized bed combustors used culm fuel only. All other sources used anthracite.

[b]Emissions for fluidized bed combustors controlled with mechanical collector/fabric filter. All other emission sources were uncontrolled. Gaseous FBC emissions measured downstream of   mechanical collector and upstream of fabric filter.

TABLE 4-6. SUMMARY OF EMISSION FACTORS FOR CARBON MONOXIDE (CO)
AND CARBON DIOXIDE (CO_2) FROM ANTHRACITE COMBUSTORS

Source category/reference/rating	CO		CO_2	
	kg/Mg	lb/ton	kg/Mg	lb/ton
Stoker fired boilers				
2,a			3200	6400
2,a			2000	4000
5,b			3200	6400
5,b			2450	4900
5,b			3350	6700
Fluidized bed[a]				
7,d	1.5E-02[b]	0.3b[b]		

[a]Fluidized bed combustors used culm fuel only. All other sources used anthracite.

[b]Emissions for fluidized bed combustors controlled with MC/fabric filter. All other emission sources   were uncontrolled. Gaseous FBC emissions measured downstream of MC and upstream of fabric   filter.

5. AP-42 SECTION 1.2: ANTHRACITE COAL COMBUSTION

The revision to Section 1.2 of AP-42 is presented in the following pages as it would appear in the document. A marked-up copy of the 1988 version of this section is included in Appendix A.

APPENDIX A

MARKED-UP 1988 AP-42 SECTION 1.2

APPENDIX B

EMISSION SOURCE DATA RATING FORMS

REPORT ON REVISIONS TO

5TH EDITION AP-42

Section 1.2

Anthracite Coal Combustion

Prepared for:

Prepared by:

Eastern Research Group
Post Office Box 2010
Morrisville, North Carolina 27560

December 1996

Table of Contents

1.0   INTRODUCTION

        This report supplements the Emission Factor (EMF) Documentation for AP-42
Section 1.2, Anthracite Coal Combustion, dated April 1993. The EMF describes the source
and rationale for the material in the most recent updates to the 4th Edition, while this report
provides documentation for the updates written in both Supplements A and B to the
5th Edition.

        Section 1.2 of AP-42 was reviewed by internal peer reviewers to identify technical
inadequacies and areas where state-of-the-art technological advances need to be incorporated.
Based on this review, text has been updated or modified to address any technical
inadequacies or provide clarification, emission factors were checked for accuracy with
information in the EMF Document, new emission factors generated if recent test data was
available, and corrections made to cite the appropriate reference documents.

        If discrepancies were found when checking the factors with the information in the
EMF Document, the appropriate reference materials were then checked. In some cases, the
factors could not be verified with the information in the EMF Document or from the
reference materials, in which case the factors were not changed.

        Four sections follow this introduction. Section 2 of this report documents the
revisions and the basis for the changes. Section 3 presents the references for the changes
documented in this report. Section 4 presents the revised AP-42 Section 1.2, and Section 5
contains the EMF documentation, dated April 1993.

2.0   REVISIONS

2.1   <u>General Text Changes</u>

Information in the EMF Document was used to enhance text concerning anthracite coal characteristics; emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and carbon monoxide (CO); and controls for particulate matter (PM) and SO_2. Also, at the request of EPA, metric units were removed.

2.2   <u>Nitrogen Oxides, NO_x</u>

The NO_x emission factors were checked against information in Table 4-5 of the EMF Document and the 9/88 version of Section 1.2 and no changes were necessary.

2.3   <u>Sulfur Oxides, SO_x</u>

The SO_x emission factors were checked against information in Table 4-5 of the EMF Document and the 9/88 version of Section 1.2 and no changes were required.

2.4   <u>Carbon Monoxide, CO</u>

The CO emission factors were checked against information in Table 4-6 of the EMF Document and the 9/88 version of AP-42. CO for FBC boilers was 1.5E-02 kg/mg (0.3 lb/ton) in Table 4-6 of the EMF Document and 0.15 kg/mg (0.3 lb/ton) in AP-42. Due to this discrepancy in the metric units, it was necessary to consult the reference to determine the correct value.[1] The CO emission data is shown in Table 1:

Table 1. CO Emissions Data from Parametric Tests

Run No.	CO, lb/MMBtu
6	0.02
7	0.08
8	0.02
9	0.03
10	0.01
11	0.03
12	0.05
13	0.04
14	0.02
15	0.03
16	0.06
17	0.08
30	0.08
31	0.05
32	0.09
33	0.28
34	0.28
35	0.28

36	0.17
Avg:	**0.09**

Based on this information, the following emission factor was calculated:

CO, lb/ton =   (0.09 lb/MMBtu)*(3,220 Btu/lb)*
                  (2000 lb/ton)*(MMBtu/1,000,000Btu) = 0.60 lb/ton

Where: 0.09 lb/MMBtu is the average CO emission
          3,220 Btu/lb is the average heating value of culm (page 39, Table 5.2 of the
          reference)

2.5   Carbon Dioxide, CO_2

The CO_2 factors were checked against information in Table 4-6 of the EMF Document and no changes were necessary.

2.6   Filterable and Condensible Particulate Matter, PM

Filterable and condensible PM emission factors were checked against information in Table 4-4 of the EMF Documentation and the 9/88 version of AP-42 and no changes to the factors were necessary. However, the figure was deleted for cumulative size-specific emission factors for dry-bottom boilers burning pulverized anthracite coal. The figure was not as accurate, nor as precise, as the table presenting the same data.

2.7   Lead, Pb

The Pb factors were checked against information in Table 4-4 of the EMF Documentation and no changes were necessary.

2.8   Particle Size Distribution

The particle size factors remain the same as in the 9/88 version of AP-42.

2.9   Speciated Organic Compounds

Factors for speciated organic compounds were checked against Table 4-3 of the EMF Document and a number of the factors appeared to be incorrect. The reference was checked to determine if the information in Table 4-3 was correct. Calculations were performed to

convert the concentration (μg/scm) to lb/ton; however, the factors in Table 4-3 could not be reproduced. The new calculations were then reviewed and confirmed by the original contractor. Table 2 presents the new factors and the procedure used to generate the new factors.

2.10   Speciated Metals from Stoker Fired Boilers

Speciated metals factors were checked against Table 4-1 of the EMF Document and the following mathematical error was corrected:

Metal	Existing Range lb/ton	Revised Range lb/ton
Mercury	8.7E-05 - 1.3E-04	8.7E-05 - 1.7E-04

2.11   Total Organic Compounds (TOC) and Methane (CH_4)

The TOC and CH_4 factors were checked against information in Table 4-2 of the EMF Document. The following mathematical error was corrected:

Source Category	Existing Factors lb/ton	Revised Factors lb/ton
Stoker	0.20	0.30

Table 2. PAH Data

Pollutants	Concentrations			Metric Calculations				English Calculations			
	Stove B High Rate Anthracite (ug/scm)	Stove B Low Rate Anthracite (ug/scm)	Stove C Mod Rate Anthracite (ug/scm)	Stove B High Rate Anthracite (kg/Mg)	Stove B Low Rate Anthracite (kg/Mg)	Stove C Mod Rate Anthracite (kg/Mg)	Average of B,B,C (kg/Mg)	Stove B High Rate Anthracite (lb/ton)	Stove B Low Rate Anthracite (lb/ton)	Stove C Mod Rate Anthracite (lb/ton)	Average of B,B,C (lb/ton)
Napthalene	5.3	0.08	14	8.088E-05	3.520E-06	2.405E-04	1.083E-04	1.618E-04	7.040E-06	4.810E-04	2.166E-04
Acenaphthene	0.94	0.12	0.82	1.434E-05	5.280E-06	1.409E-05	1.124E-05	2.869E-05	1.056E-05	2.818E-05	2.247E-05
Acenaphthylene	0.99	0.12	6.3	1.511E-05	5.280E-06	1.082E-04	4.287E-05	3.021E-05	1.056E-05	2.165E-04	8.575E-05
Fluorene	0.89	0.08	1.2	1.358E-05	3.520E-06	2.062E-05	1.257E-05	2.716E-05	7.040E-06	4.123E-05	2.514E-05
Phenathrene	11	0.81	9	1.679E-04	3.564E-05	1.546E-04	1.194E-04	3.357E-04	7.128E-05	3.092E-04	2.387E-04
Anthracene	1.2	0.08	0.9	1.831E-05	3.520E-06	1.546E-05	1.243E-05	3.662E-05	7.040E-06	3.092E-05	2.486E-05
Fluoranthene	8.7	0.85	4.7	1.328E-04	3.740E-05	8.075E-05	8.364E-05	2.655E-04	7.480E-05	1.615E-04	1.673E-04
Pyrene	6.3	0.48	3.7	9.614E-05	2.112E-05	6.357E-05	6.027E-05	1.923E-04	4.224E-05	1.271E-04	1.205E-04
Benzo(a)anthracene	5.4	0.12	1.1	8.240E-05	5.280E-06	1.890E-05	3.553E-05	1.648E-04	1.056E-05	3.780E-05	7.105E-05
Chrysene	5.9	0.2	1.5	9.003E-05	8.800E-06	2.577E-05	4.153E-05	1.801E-04	1.760E-05	5.154E-05	8.307E-05
Benzo(k)fluoranthene	0.68	0.12	1.3	1.038E-05	5.280E-06	2.233E-05	1.266E-05	2.075E-05	1.056E-05	4.467E-05	2.533E-05
Benzo(e)pyrene	0.16	0.04	0.3	2.442E-06	1.760E-06	5.154E-06	3.119E-06	4.883E-06	3.520E-06	1.031E-05	6.237E-06
Benzo(a)pyrene	0.1	0.08	0.17	1.526E-06	3.520E-06	2.921E-06	2.656E-06	3.052E-06	7.040E-06	5.841E-06	5.311E-06
Perylene	0.02	0.02	0.04	3.052E-07	8.800E-07	6.872E-07	6.241E-07	6.104E-07	1.760E-06	1.374E-06	1.248E-06
Indeno(1,2,3-cd) perylene	0.37	0.04	0.17	5.646E-06	1.760E-06	2.921E-06	3.442E-06	1.129E-05	3.520E-06	5.841E-06	6.885E-06
Benzo(ghi)perylene	0.31	0.04	0.09	4.731E-06	1.760E-06	1.546E-06	2.679E-06	9.461E-06	3.520E-06	3.092E-06	5.358E-06
Anthanthrene	0.005	0.01	0.02	7.630E-08	4.400E-07	3.436E-07	2.866E-07	1.526E-07	8.800E-07	6.872E-07	5.733E-07
Coronene	0.21	0.01	0.13	3.205E-06	4.400E-07	2.233E-06	1.959E-06	6.409E-06	8.800E-07	4.467E-06	3.919E-06

Parameters	Stove B	Stove B	Stove C
Burn rate, kg/hr	1.9	0.7	0.9
Sample time, min.	120	155	155
Discharge, scm	58	80	44
Coefficient	1.526E-05	4.442E-05	1.892E-05

NOTE: Coefficient x ug/scm = kg/Mg.

Calculations used: $\text{kg pollutant/Mg fuel} = \dfrac{\text{(ug/scm) x (Kg/1E09) x (scm discharge)}}{\text{(kg fuel/hr) x (hr/test) x (Mg/1E03 kg)}}$

$\text{lb pollutant/ton fuel} = \dfrac{\text{(ug/scm) x [(lb/453.59 g) x (1E06 ug)] x (scm discharge)}}{\text{(kg fuel/hr) x (hr/test) x (ton/907 kg)}}$

Other calculations: (1 kg/Mg) = (2.205 lb/kg/2204.5 lb/Mg) x (2000 lb/ton) = 2 lb/ton

Example: Acenaphthene, Stove B, Anthracite, low burn rate Reference 14, Tables I and V

Given: 0.12 ug/scm
       Total stack discharge = 80 scm
       Burn rate = 0.7 kg/hr
       155 minute test

$$\frac{(0.12) \text{ x } (1/1{,}000{,}000{,}000) \text{ x } 80}{(0.7) \text{ x } (155 \text{ min.}/60 \text{ min.}) \text{ x } (1/1000)} = 5.3\text{E}^{-}06 \text{ kg/Mg}$$

(Reported as 7.0E01-01 in EMF Table 4.3)

$$\frac{(0.12) \text{ x } (1/453.59 \text{ x } 1.\text{E}6) \text{ x } 80}{(0.7) \text{ x } (155 \text{ min.}/60 \text{ min.}) \text{ x } (1/907)} = 1.06\text{E}^{-}05 \text{ lb/ton}$$

(Reported as 1.4E-02 in EMF Table 4.3)

3.0   REFERENCES

1.   D'Aciermo, J., Richards, H., and F. Spindler. Design, Construction, Operation, and
        Evaluation of a Prototype Culm Combustion Boiler/Heater Unit. Contract
        No. AC21-78ET12307, U.S. Department of Energy, Morgan town Energy Technology
        Center, Morgantown, WV. October 1983. Page 63, Table 7.2.

y-axis: Uncontrolled emission factor (kg/Mg coal, as fired)

x-axis: Particle diameter (m)