Emission Factor Documentation for Section 5.4
Charcoal Manufacturing

Now 10.7

Prepared for Revision Dated July 30, 1982

Prepared by:

Pacific Environmental Services, Inc.
1905 Chapel Hill Road
Durham, North Carolina 27707

Contract No. 68-02-3511
Work Assignment No. 12

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1.0 INTRODUCTION

This report describes the preparation of a completely revised Section 5.4.

Affected charcoal facilities include both cooking (briquet) and industrial charcoal manufacturing processes which produce charcoal from a carbon source in either a continuous or batch process. Industrial charcoal can be made by the same method and at the same time as cooking charcoal; therefore, this segment of the industry is included. It is estimated that activated carbon production comprises 10 to 15 percent of charcoal briquet and activated carbon production.[3]

Determination of actual emissions from both batch and continuous type processes has been a major problem. Most reported emissions have been based upon published emission factors. These emission factors, in turn, have been based upon experimental lab work and/or data obtained from charcoal plants which were operated primarily for the recovery of wood chemicals, with charcoal production being of secondary interest.

Products of charcoal manufacture are divided into five categories: charcoal, noncondensible gases (CO, CO_2, CH_4 and C_2H_6), pyroacids (primarily acetic acid and methanol), tars and heavy oils, and water.[3] Products and product distribution are variable depending on raw materials and carbonization parameters. It is important to note that the extent to which organics and carbon monoxide are naturally combusted before leaving the retort varies from plant to plant. Uncombusted tars may solidify to form particulate emissions, whereas uncombusted pyroacids may form aerosol emissions.[8]

The manufacture of charcoal without emission control can result in the emission of any of the products of pyrolysis of carbonaceous materials. Over 200 products of wood pyrolysis have been identified, and the list is not complete.[3] Literature sources quantified uncontrolled emissions, either by estimate or by sampling, for uncontrolled emissions of: particulate, carbon monoxide, methanol, acetic acid, methane, nitrogen oxides and nonmethane gases. These species are found in the uncontrolled emissions of both batch and continuous charcoal manufacture.

2.0 PROCEDURE FOR REVISION OF CHARCOAL MANUFACTURING EMISSION FACTORS

The procedure for deriving new emission factors is outlined below. Basically, emission factor data were extracted from the existing AP-42 data base (references 1 and 2) and critically examined; test results and material balances were obtained from new references, and histograms were constructed utilizing both the existing data base and the new information available (references 3-9). Examination of reported data used to determine the revised emission factors is contained in Sections 2.2 through 2.6.

2.1 Conversion of Units

Test results and material balances performed were expressed in both metric and English units. Histograms used in this documentation are scaled to units of g/kg (kg/MT). Arithmetic averages determined from these histograms are further converted to units of lb/ton for publication in the revised AP-42 section. The following conversion factors are used:

$$(\text{g/kg}) \left(\frac{10^3\ \text{kg}}{\text{MT}}\right) \left(\frac{\text{kg}}{10^3\ \text{g}}\right) = \text{kg/MT}$$

Ton (short, 2,000 lb-mass) = 907.4 kg
Metric ton (MT) = Ton (short, 2,000 lb-mass) x 1.102

2.2 Particulate Emissions

Information available concerning particulate emissions was extracted from each reference and converted to units of g/kg. Material balance and laboratory studies were performed in some of the literature (references 1, 6, 8, 10) and several test results were available (references 7 and 9).

The kilns tested were Missouri-type kilns, and no control devices were utilized. EPA Method 5 was used to test for particulates. Sampling uncontrolled batch kilns with multiple stacks proved difficult due to the low intermittent flow through these exhaust stacks. Sampling must be done over the entire burn cycle to arrive at an overall average emission per unit of production for a batch process. Also, instead of sampling each emitting stack each day, the test procedure cited in references 6 and 8 required compositing samples from all eight emitting stacks into one daily sample. In other words, by sampling each emitting stack in turn with the same sampling apparatus and without sample cleanup between stacks, samples from the individual stacks would be automatically combined for a daily average.

A significant portion of particulate emissions from wood charcoal production is wood tars and oils. These materials will pass through the EPA Method 5 filter and condense in the first water impinger of the Method 5 train. EPA Method 5 currently does not include procedures for recovery and quantification of these materials.

A histogram was plotted, and an arithmetic average of 133 g/kg (kg/MT) was obtained (Figure 1) based on data points determined as follows:

Reference 1, page 4-31

Particulates (tars, oils) are estimated to be approximately 5 percent by weight of the total raw material feed.

$$\frac{8{,}000\ \text{lb raw mat.}}{\text{ton charcoal}} \times \frac{(0.05\ \text{particulates})}{\text{raw mat.}} = \frac{400\ \text{lb}}{\text{ton}} = 200\ \text{g/kg}$$

Reference 5, page 50

$$\frac{200\ \text{lb tar}}{960\ \text{lb charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 208\ \text{g/kg}$$

Reference 6, page 6

$$\frac{126.4\ \text{lb}}{\text{ton charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000\ \text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 63\ \text{g/kg}$$

$$\frac{144.7\ \text{lb}}{\text{ton charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000\ \text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 72\ \text{g/kg}$$

$$\frac{160.5\ \text{lb}}{\text{ton charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000\ \text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 80\ \text{g/kg}$$

Reference 7, page 306

$$\frac{193 \times 10^{6}\ \text{lb/yr}}{548{,}000\ \text{ton/yr charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000\ \text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 176\ \text{g/kg}$$

Reference 8, page 6

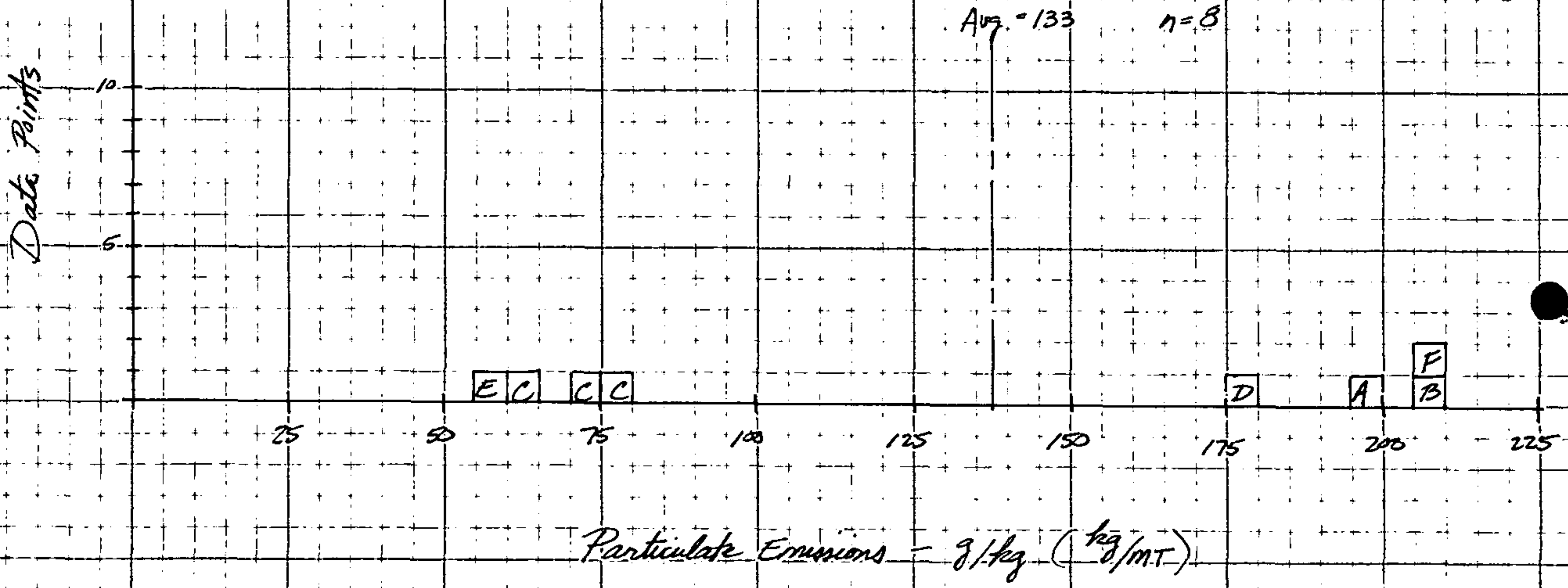
$$\frac{4.23\ \text{lb/hr}(24\ \text{hr/day})(21\ \text{days})}{18\ \text{ton charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000\ \text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 59\ \text{g/kg}$$

Reference 9, page 28

$$\frac{803\ \text{tons tar}}{\text{yr}} \times \left(\frac{2{,}000\ \text{lb}}{\text{ton}}\right) \times \left(\frac{\text{yr}}{3{,}857\ \text{ton}}\right) = 416.4\ \text{lb/ton} = 208.2\ \text{g/kg}$$

HISTOGRAM 1

A. Reference 1
B. " 5
C. " 6
D. " 7
E. " 8
F. " 9



Charcoal Briquetting[3]

Charcoal is crushed, mixed with a binder solution, pressed and dried. This composition results in a briquet of approximately 90 percent charcoal. Briquetting operations can control particulate emissions with centrifugal collection (65 percent control) or fabric filtration (99 percent control).

The industrial survey controlled particulate emission factor of 1.25×10^{-3} lb particulate/lb briquet was converted to an uncontrolled emission factor assuming 95 percent control efficiency and a briquet containing 90 percent charcoal as follows:

$$1.25 \times 10^{-3}\ \frac{\text{lb particulate controlled}}{\text{lb briquet}}\left(\frac{\text{lb briquet}}{\text{0.9 lb charcoal}}\right)\left(\frac{\text{2,000 lb}}{\text{ton}}\right)\left(\frac{\text{20 lb uncontrolled}}{\text{lb controlled}}\right)\left(\frac{\text{454 g}}{\text{lb}}\right)\left(\frac{\text{ton}}{\text{2,000 lb}}\right)\left(\frac{\text{2.2 lb}}{\text{kg}}\right) = \text{28 g/kg}$$

2.3 Nonmethane Volatile Organic Compounds (NMVOCs)

NMVOCs consist of both noncondensibles (ethane, formaldehyde and unsaturated hydrocarbons) and condensibles (methanol, acetic acid and pyroacids).

The acetic acid and methanol emissions reported in the current AP-42 section were based on information contained in reference 1, page 4-34. Emissions data were derived from an engineering analysis performed to determine byproducts of the pyrolysis of hardwood. Emissions estimates of 76 kg/MT (152 lb/ton) and 116 kg/MT (232 lb/ton) were determined for methanol and acetic acid, respectively.

Reference 3, page 59

NMVOC emissions are reported as volume percent ethane and unsaturated hydrocarbons. To convert to a mass emission and emission factor, several assumptions were made: (1) a molecular weight of 35.1 g noncondensibles per mole noncondensibles was calculated based on an "average" noncondensible composition table (page 59), and (2) a noncondensible emission factor of 25 g noncondensibles per 31 g charcoal produced (reference 4).

$$\frac{\text{3.09 moles ethane}}{\text{100 moles noncondensibles}}\left(\frac{\text{30 g ethane}}{\text{mole higher hydrocarbon}}\right)\left(\frac{\text{mole noncondensible}}{\text{35.1 g noncondensible}}\right)\left(\frac{\text{25,000 g noncondensible}}{\text{31 kg charcoal}}\right) = \text{21 g/kg}$$

$$\frac{\text{2.72 moles unsaturated hydrocarbon}}{\text{100 moles noncondensibles}}\left(\frac{\text{28 g unsaturated hydrocarbons}}{\text{mole unsaturated hydrocarbon}}\right)\left(\frac{\text{mole noncondensible}}{\text{35.1 g noncondensible}}\right)\left(\frac{\text{25,000 g noncondensible}}{\text{31 kg charcoal}}\right) = \text{17 g/kg}$$

Reference 5, page 50

$$\frac{\text{190 lb pyroacids}}{\text{960 lb charcoal}} \times \left(\frac{\text{454 g}}{\text{lb}}\right) \times \left(\frac{\text{2.2 lb}}{\text{kg}}\right) = \text{198 g/kg}$$

$$\frac{\text{30 lb ethane}}{\text{960 lb charcoal}} \times \left(\frac{\text{454 g}}{\text{lb}}\right) \times \left(\frac{\text{2.2 lb}}{\text{kg}}\right) = \text{31 g/kg}$$

Reference 7, page 306

$$\frac{73 \times 10^6 \text{ lb methanol/yr}}{548{,}000 \text{ ton/yr charcoal}} \times \left(\frac{454 \text{ g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000 \text{ lb}}\right) \times \left(\frac{2.2 \text{ lb}}{\text{kg}}\right) = 67 \text{ g/kg}$$

$$\frac{112\ 10^6 \text{ lb acetic acid/yr}}{548{,}000 \text{ ton/yr charcoal}} \times \left(\frac{454 \text{ g}}{\text{lb}}\right) \times \left(\frac{\text{ton}}{2{,}000 \text{ lb}}\right) \times \left(\frac{2.2 \text{ lb}}{\text{kg}}\right) = 102 \text{ g/kg}$$

2.4 Methane VOCs

References, 1,5,7 and 9 reported methane emissions in units which required differing conversions to achieve a compatible g/kg format. Reference 1, for example, assumes the volumetric makeup of the noncondensible gas to be 53 percent carbon dioxide, 27 percent carbon monoxide and 15 percent methane. To determine the weight and emission rate of these constituents, the weight of a pound mole of the constituent gas was multiplied by the total weight of the flue gas and by the volumetric percentage of the constituent and divided by the weight of a pound mole of the flue gas. A methane emission factor of 50 g/kg was determined.

Reference 5, page 50

$$\frac{55 \text{ lb methane}}{960 \text{ lb charcoal}} \times \left(\frac{454 \text{ g}}{\text{lb}}\right) \times \left(\frac{2.2 \text{ lb}}{\text{kg}}\right) = 57 \text{ g/kg}$$

Reference 7, page 306

$$\frac{48 \times 10^6 \text{ lb methane/yr}}{548{,}000 \text{ ton charcoal/yr}} \times \left(\frac{454 \text{ g}}{\text{lb}}\right) \left(\frac{\text{ton}}{2{,}000 \text{ lb}}\right) \times \left(\frac{2.2 \text{ lb}}{\text{kg}}\right) = 44 \text{ g/kg}$$

Reference 9, page 28

$$\frac{222 \text{ tons}}{\text{yr}} \times \left(\frac{2{,}000 \text{ lb}}{\text{ton}}\right) \times \left(\frac{\text{yr}}{3{,}857 \text{ ton}}\right) \times \frac{115 \text{ lb}}{\text{ton}} = 58 \text{ g/kg}$$

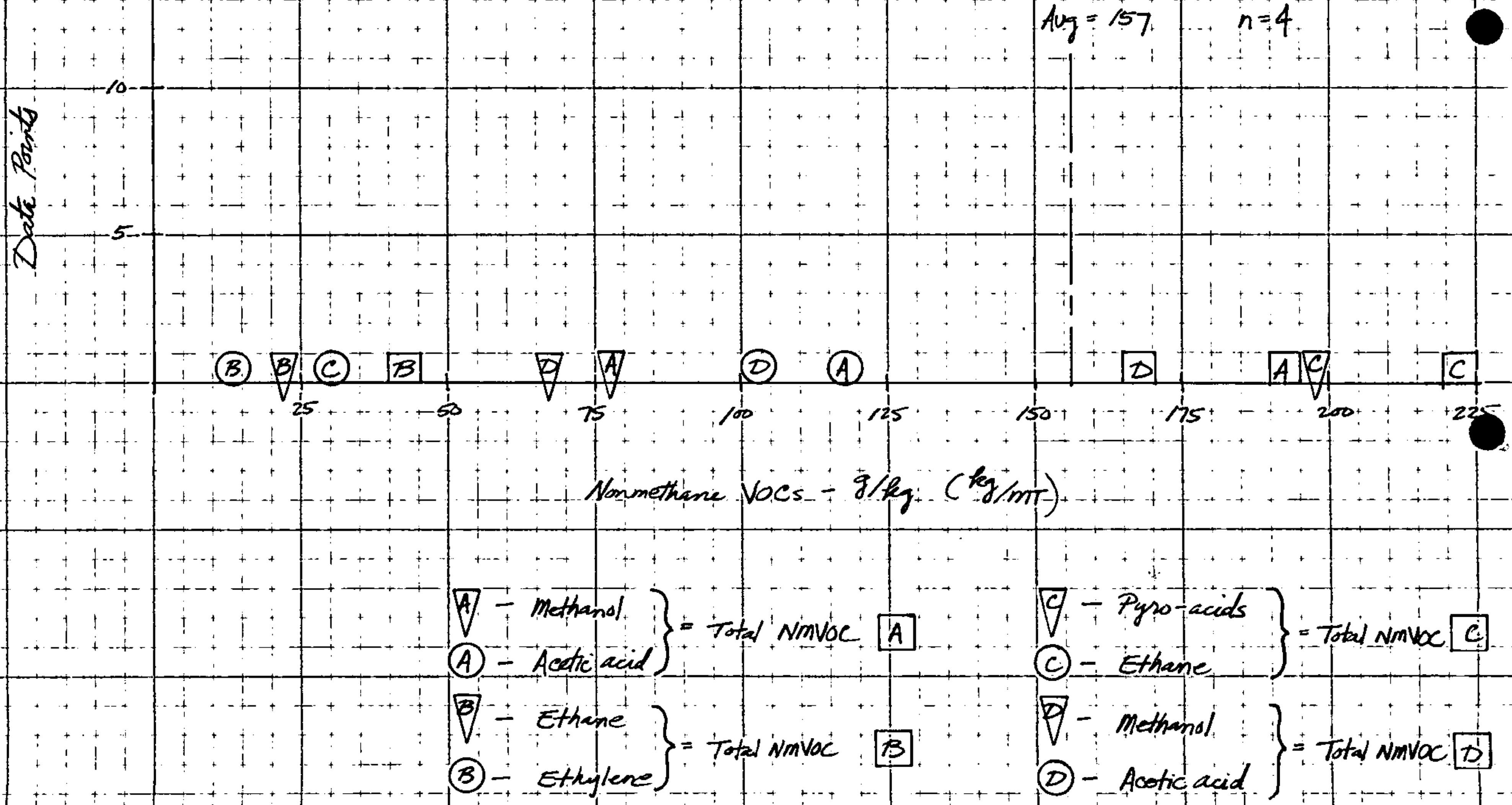
Based on the methane emissions reported for references 1,5,7 and 9, an arithmetic average of 52 g/kg was obtained.

2.5 Carbon Monoxide

Reference 1 assumes the volumetric makeup of the noncondensible gas to be 27 percent carbon monoxide. To determine the weight and corresponding emission rate, the same procedure was followed as is outlined under reference 1, methane VOCs (2.4). Accordingly, a carbon monoxide emission factor of 160 g/kg was obtained from reference 1.

HISTOGRAM 2

A Reference 1
B " 3
C " 5
D " 7



Reference 5, page 50

$$\frac{172\ \text{lb CO}}{960\ \text{lb charcoal}} \times \left(\frac{454\ \text{g}}{\text{lb}}\right) \times \left(\frac{2.2\ \text{lb}}{\text{kg}}\right) = 179\ \text{g/kg}$$

Reference 9, page 28

$$\frac{691\ \text{tons}}{\text{yr}} \times \left(\frac{2{,}000\ \text{lb}}{\text{ton}}\right) \times \left(\frac{\text{yr}}{3{,}857\ \text{tons}}\right) = \frac{358\ \text{lb}}{\text{ton}} = 179\ \text{g/kg}$$

Based on the emissions estimates obtained from references 1, 5 and 9, an arithmetic average of 172 g/kg was determined.

2.6 Nitrogen Oxides (reference 3, page 62)

The uncontrolled emission factor for nitrogen oxides was calculated assuming that no oxides of nitrogen were formed by thermal fixation of air and that all fuel nitrogen was oxidized to NO. Thermal fixation of air is excluded since the normal operating temperatures of charcoal manufacture (approximately 500°C) are not high enough to promote NO formation.

Nitrogen oxides formed from wood nitrogen were calculated assuming all of the 0.14 percent nitrogen in wood was oxidized to NO. With the assumption that 4 kg of wood are needed to produce 1 kg of charcoal, the uncontrolled emission factor is derived as follows:

$$\frac{0.14\ \text{g N}}{100\ \text{g wood}} \times \left(\frac{30\ \text{g NO}}{14\ \text{g N}}\right) \times \left(\frac{4{,}000\ \text{g wood}}{\text{kg charcoal}}\right) = 12\ \text{g/kg}$$

3.0 EMISSION FACTOR RATINGS

Very few data are available to characterize emissions for charcoal manufacture. Most estimates found in the literature were derived from material balance calculations based on laboratory wood pyrolysis studies.

Field sampling data for particulates is available; however, the results are of questionable value because of the improvisational sampling techniques utilized. Sampling uncontrolled batch kilns with multiple stacks proved difficult due to the low intermittent flow through these exhaust stacks. Velometers used were affected by ambient winds and possibly by the flue gas constituents. Sampling must be done over the entire burn cycle to arrive at an overall average emission per unit of production for a batch process. Also, instead of sampling each emitting stack each day, the test procedure cited in references 6 and 8 required compositing samples from all eight stacks into one daily sample. The necessary modifications of the sampling technique cast doubt on the representative nature of the resulting data.

The emission factors were derived from a larger data base than previously existed. However, source tests performed were based on new methodology, and it is not known how representative laboratory and pyrolysis studies are of actual operating conditions within both batch type and continuous type kilns. Therefore, the derived emission factors will retain the C-rating established for the current section.

4.0 REFERENCES

1. Air Pollutant Emission Factors, Final Report, Resources Research, Inc., Reston, VA, Prepared for National Air Pollution Control Administration, Durham, NC, under Contract Number CPA-22-69-119, April 1970.

2. R.N. Shreve, Chemical Process Industries, Third Edition, McGraw-Hill Book Company, New York, 1967, p. 619.

3. C.M. Moscowitz, Source Assessment: Charcoal Manufacturing State of the Art, Contract No. 68-02-1874, Industrial Environmental Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, OH, December 1978.

4. Riegel's Handbook of Industrial Chemistry, Seventh Edition, J.A. Kent, ed., Van Nostrand Reinhold Company, New York, New York, 1974, pp. 475-479.

5. J.R. Hartwig, Control of Emissions from Batch-type Charcoal Kilns, Forest Products Journal, 21(9):49-50, 1971.

6. W.H. Maxwell, Stationary Source Testing of a Missouri-type Charcoal Kiln, Contract No. 68-02-143 (PB258695), Environmental Protection Agency, Kansas City, MO, August 1976. 178 pp.

7. R.W. Rolke, et al. Afterburner Systems Study, EPA-RZ-72-062 (PB 212 560), U.S. Environmental Protection Agency, Research Triangle Park, NC, August 1972, 512 pp.

8. B.F. Keeling, Emission Testing the Missouri-type Charcoal Kiln, Preprint of Paper 76-37.1 presented at the 69th Annual Meeting of the Air Pollution Control Association, Portland, OR, 1976, 6 pp.

9. P.B. Hulman, et al. Screening Study on Feasibility of Standards of Performance for Wood Charcoal Manufacturing, Contract No. 68-02-2608, Radian Corporation, Austin, TX, August 1978.

5.4 CHARCOAL

5.4.1 Process Description[1-3]

Charcoal is the solid carbon residue following the pyrolysis (carbonization or destructive distillation) of carbonaceous raw materials. Principal raw materials are medium to dense hardwoods such as beech, birch, hard maple, hickory and oak. Others are softwoods (primarily long leaf and slash pine), nutshells, fruit pits, coal, vegetable wastes and paper mill residues. Charcoal is used primarily as a fuel for outdoor cooking. In some instances, its manufacture may be considered as a solid waste disposal technique. Many raw materials for charcoal manufacture are wastes, as noted, and charcoal manufacture is also used in forest management for disposal of refuse.

Recovery of acetic acid and methanol byproducts was initially responsible for stimulation of the charcoal industry. As synthetic production of these chemicals became commercialized, recovery of acetic acid and methanol became uneconomical.

Charcoal manufacturing can be generally classified into either batch (45 percent) or continuous operations (55 percent). Batch units such as the Missouri type charcoal kiln (Figure 5.4-1) are small manually loaded and unloaded kilns producing typically 16 megagrams (17.6 tons) of charcoal during a three week cycle. Continuous units (i.e., multiple hearth furnaces) produce an average of 2.5 megagrams (2.75 tons) per hour of charcoal. During the manufacturing process, the wood is heated, driving off water and highly volatile organic compounds (VOC). Wood temperature rises to approximately 275°C (527°F), and VOC distillate yield increases. At this point, external application of heat is no longer required, since the carbonization reactions become exothermic. At 350°C (662°F), exothermic pyrolysis ends, and heat is again applied to remove the less volatile tarry materials from the product charcoal.

Fabrication of briquets from raw material may be either an integral part of a charcoal producing facility, or an independent operation, with charcoal being received as raw material. Charcoal is crushed, mixed with a binder solution, pressed and dried to produce a briquet of approximately 90 percent charcoal.

5.4.2 Emissions and Controls[3-9]

There are five types of charcoal products, charcoal; noncondensible gases (carbon monoxide, carbon dioxide, methane and ethane); pyroacids (primarily acetic acid and methanol); tars and heavy oils; and water. Products and product distribution are varied, depending on raw materials and carbonization parameters. The extent to which organics and carbon monoxide are naturally combusted before leaving the retort varies from plant to plant. If uncombusted, tars may solidify to form particulate emissions, and pyroacids may form aerosol emissions.

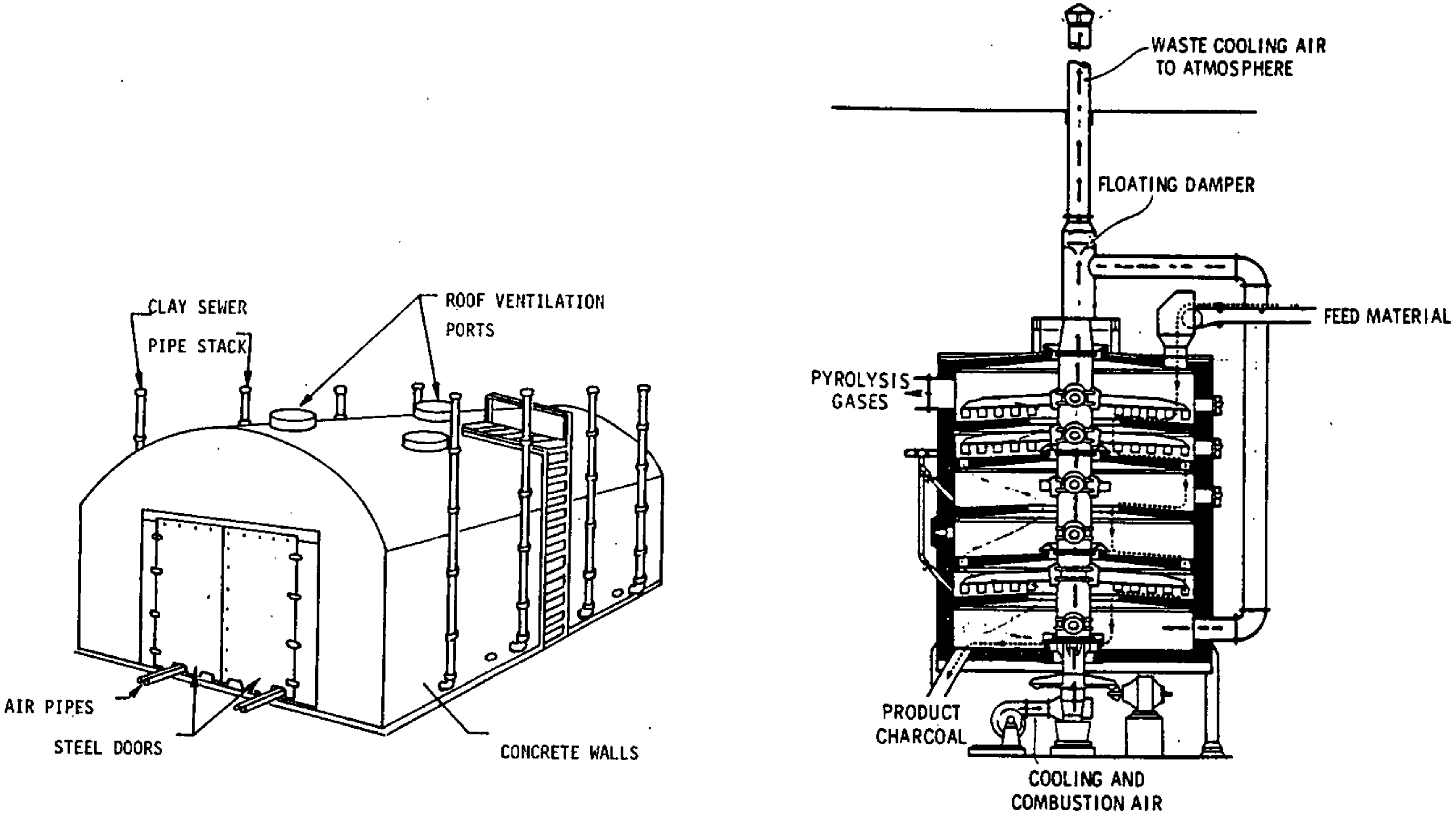


Figure 5.4-1. The Missouri type charcoal kiln (left) and the multiple hearth furnace (right).

Control of emissions from batch type charcoal kilns is difficult because of the cyclic nature of the process and, therefore, its emissions. Throughout a cycle, both the emission composition and flow rate change. Batch kilns do not typically have emission control devices, but some may use afterburners. Continuous production of charcoal is more amenable to emission control than are batch kilns, since emission composition and flow rate are relatively constant. Afterburning is estimated to reduce emissions of particulates, carbon monoxide and VOC by at least 80 percent.

Briquetting operations can control particulate emissions with centrifugal collection (65 percent control) or fabric filtration (99 percent control).

Uncontrolled emission factors for the manufacture of charcoal are shown in Table 5.4-1.

TABLE 5.4-1. UNCONTROLLED EMISSION FACTORS
FOR CHARCOAL MANUFACTURING[a]

EMISSION FACTOR RATING: C

Pollutant	Charcoal Manufacturing		Briquetting	
	kg/Mg	lb/ton	kg/Mg	lb/ton
Particulate[b]	133	266	28	56
Carbon monoxide[c]	172	344	-	-
Nitrogen oxides[d]	12	24	-	-
VOC				
Methane[e]	52	104	-	-
Nonmethane[f]	157	314	-	-

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[a] Expressed as weight per unit charcoal produced. Dash = not applicable. Reference 3. Afterburning is estimated to reduce emissions of particulates, carbon monoxide and VOC > 80%. Briquetting operations can control particulate emissions with centrifugal collection (65% control) or fabric filtration (99% control).

[b] Includes tars and heavy oils (References 1, 5-9). Polycyclic organic matter (POM) carried by suspended particulates was determined to average 4.0 mg/kg (Reference 6).

[c] References 1, 5, 9.

[d] Reference 3 (Based on 0.14% wood nitrogen content).

[e] References 1, 5, 7, 9.

[f] References 1, 3, 5, 7. Consists of both noncondensibles (ethane, formaldehyde, unsaturated hydrocarbons) and condensibles (methanol, acetic acid, pyroacids).

References for Section 5.4

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

2. R. N. Shreve, Chemical Process Industries, Third Edition, McGraw-Hill Book Company, New York, 1967.

3. C. M. Moscowitz, Source Assessment: Charcoal Manufacturing State of the Art, EPA-600/2-78-004z, U. S. Environmental Protection Agency, Cincinnati, OH, December 1978.

4. Riegel's Handbook of Industrial Chemistry, Seventh Edition, J. A. Kent, ed., Van Nostrand Reinhold Company, New York, 1974.

5. J. R. Hartwig, "Control of Emissions from Batch-type Charcoal Kilns", Forest Products Journal, 21(9):49-50, April 1971.

6. W. H. Maxwell, Stationary Source Testing of a Missouri-type Charcoal Kiln, EPA-907/9-76-001, U. S. Environmental Protection Agency, Kansas City, MO, August 1976.

7. R. W. Rolke, et al., Afterburner Systems Study, EPA-RZ-72-062, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 1972.

8. B. F. Keeling, Emission Testing the Missouri-type Charcoal Kiln, Paper 76-37.1, Presented at the 69th Annual Meeting of the Air Pollution Control Association, Portland, OR, June 1976.

9. P. B. Hulman, et al., Screening Study on Feasibility of Standards of Performance for Wood Charcoal Manufacturing, EPA Contract No. 68-02-2608, Radian Corporation, Austin, TX, August 1978.

5.4 CHARCOAL

5.4.1 Process Description[1]

Charcoal is generally manufactured by means of pyrolysis, or destructive distillation, of wood waste from members of the deciduous hardwood species. In this process, the wood is placed in a retort where it is externally heated for about 20 hours at 500 to 700°F (260 to 370°C). Although the retort has air intakes at the bottom, these are only used during start-up and thereafter are closed. The entire distillation cycle takes approximately 24 hours, the last 4 hours being an exothermic reaction. Four units of hardwood are required to produce one unit of charcoal.

5.4.2 Emissions and Controls[1]

In the pyrolysis of wood, all the gases, tars, oils, acids, and water are driven off, leaving virtually pure carbon. All of these except the gas, which contains methane, carbon monoxide, carbon dioxide, nitrogen oxides, and aldehydes, are useful by-products if recovered. Unfortunately, economics has rendered the recovery of the distillate by-products unprofitable, and they are generally permitted to be discharged to the atmosphere. If a recovery plant is utilized, the gas is passed through water-cooled condensers. The condensate is then refined while the remaining cool, noncondensable gas is discharged to the atmosphere. Gaseous emissions can be controlled by means of an afterburner because the unrecovered by-products are combustible. If the afterburner operates efficiently, no organic pollutants should escape into the atmosphere. Emission factors for the manufacture of charcoal are shown in Table 5.4-1.

Table 5.4-1. EMISSION FACTORS FOR CHARCOAL MANUFACTURING[a,d]
EMISSION FACTOR RATING: C

	Type of operation			
	With chemical recovery plant		Without chemical recovery plant	
Pollutant	lb/ton	kg/MT	lb/ton	kg/MT
Particulate (tar, oil)	—	—	400	200
Carbon monoxide	320[b]	160[b]	320[b]	160[b]
Hydrocarbons[c]	100[b]	50[b]	100[b]	50[b]
Crude methanol	—	—	152	76
Acetic acid	—	—	232	116
Other gases (HCHO, N_2 NO)	60	30	60[b]	30[b]

[a] Calculated values based on data in Reference 2.

[b] Emissions are negligible if afterburner is used.

[c] Expressed as methane.

[d] Emission factors expressed in units of tons of charcoal produced.

References for Section 5.4

1. Air Pollutant Emission Factors. Final Report. Resources Research, Inc. Reston, Va. Prepared for National Air Pollution Control Administration, Durham, N.C., under Contract Number CPA-22-69-119. April 1970.

2. Shreve, R.N. Chemical Process Industries, 3rd Ed. New York, McGraw-Hill Book Company. 1967. p. 619.