EMISSION FACTOR DOCUMENTATION FOR

AP-42 SECTION 1.9,

RESIDENTIAL FIREPLACES

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1. INTRODUCTION

1.1 BACKGROUND

Emission factors are the basis for emission estimates made by State and local air pollution control agencies, industry and manufacturers of pollution-generating equipment. Beginning in 1972, the U.S. Environmental Protection Agency (EPA) has published "Compilation of Air Pollutant Emission Factors" (AP-42) to make emission factors available to regulators and industry. An emission factor relates the quantity (weight) of a pollutant to a unit of activity from the source. Uses of AP-42 emission factors include:

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

This emission factor document provides background information and the analysis used to review and revise emission factors located in AP-42 Chapter 1, Section 1.9: Residential Fireplaces. The current revision updates section 1.9 to include any new data for criteria and noncriteria pollutants.

This report contains five chapters, including the introduction (Chapter 1). Chapter 2 describes fireplaces, and characterizes fireplace combustion emissions and controls. Chapter 3 describes the procedure used to rank emission data and emission factors. Chapter 4 explains the methodology used to review and revise emission factors and includes an explanation of the data base used to calculate emission factors. Chapter 5 contains the actual, revised AP-42 section for residential fireplaces. Appendix A includes sample calculations and EPA method 5G correlation equations. Appendix B contains the last revised section with hand-written remarks depicting the changes which were made as part of the current revision.

2. SOURCE DESCRIPTION

Residential wood combustion (RWC) is an emission category which primarily consists of emissions from fireplaces and wood stoves. In some airsheds RWC emissions can be the main source of air pollution and cause violations of the National Ambient Air Quality Standard (NAAQS) for particulate matter (PM) with an aerodynamic diameter of 10 μm or less (PM-10). Regulations that control emissions from fireplaces are relatively new, compared to wood stove regulations, and exist only at the state or local level.[1] Fireplace regulation at the state level began in Washington State in 1991, but exists elsewhere at mostly the local level (e.g., Reno, Nevada, Fresno and Mammoth Lakes, California).

2.1 CHARACTERIZATION OF FIREPLACES

Homeowners enjoy the aesthetic effect a fireplace has in a home. Also, wood burning fireplaces can be a source of supplemental heating for residences. Fireplaces are typically operated infrequently and for shorter periods of time compared to wood stoves. There are two basic types of fireplaces: (1) masonry, and (2) prefabricated [i.e., built-in metal type (zero-clearance or free-standing)]. A 1988 survey conducted for the Consumer Product Safety Commission estimates that there are 19.1 million fireplaces in use in the U.S.[2] Of these, over 88 percent are characterized as masonry, and 11 percent as prefabricated.

2.2 PROCESS DESCRIPTIONS

Fireplaces have a large, open firebox (i.e., generally the width is greater than the height) with a damper above the firebox to control the intake of room air and limit heat loss when the fireplace is inactive. Prefabricated fireplaces generally utilize doors and

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[a] These values are based on the 1985 National Acid Precipitation Assessment Program (NAPAP) estimates for RWC emissions, with the following assumptions based on discussions with RWC experts: 66 percent of the total RWC emissions are from wood stoves, 100 percent of the total suspended particulate emissions are PM-10, and a 5 percent increase in all RWC pollutants since 1985 due to growth which exceeds reductions from change-over to new technology stoves.

louvers to close off the firebox from the room and control air flow, thereby increasing heating efficiency. Masonry fireplaces heat a room by radiation and may also utilize doors. Therefore, combustion must release enough heat to transfer through fireplace walls and heat the cool room air. Room air is cool because it is drawn in from the outside to replenish the air which is drawn out through the chimney. 2.3 EMISSIONS

Fireplace emissions, caused mainly by incomplete combustion, include particulate matter (mainly PM-10), carbon monoxide (CO), oxides of sulfur (SO_x), oxides of nitrogen (NO_x), volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), including polycyclic organic material (POM). POM is a class of compounds containing carcinogens [e.g., benzo[a]pyrene (BaP)], which can be emitted as condensable PM or in the vapor phase. An important fuel characteristic which contributes to fireplace PM-10 emissions is moisture content. Other important characteristics which effect emissions are burn rate, flame intensity, and firebox shape and size.

One estimate indicates that the annual emissions from fireplaces in the U.S. are 0.4 million tons of PM-10, 2.3 million tons of CO, and 0.5 million tons of VOCs.[a] The effects of these emissions are worsened two ways. First, by adverse meteorology during the wood burning season (i.e., wintertime temperature inversions). Second, large regional variations in proportions of households actively using fireplaces (e.g., 41.6% of the households in the Pacific region versus 19.4% of the households in the Middle Atlantic region) also affect emissions.

2.4 CONTROL TECHNOLOGY

In order to decrease PM and CO emissions from fireplaces, combustion must be improved. Combustion efficiency improves as burn rate and flame intensity increase. Noncatalytic control techniques can accomplish this improvement.[3] Noncatalytic fireplace inserts reduce emissions by directing unburned hydrocarbons and CO into an insulated secondary chamber, where mixing with fresh, preheated makeup air occurs and combustion is enhanced. (See Emission Factor Documentation for AP-42, Section 1.10, Residential Wood Stoves).

Firebox shape and size also have an effect on emissions. As part of a recent study to determine emissions from fireplaces, researchers performed tests on two fireplaces which were retrofitted with a modified firebox (i.e., Rosin) that decreased the size and altered the shape of the original firebox (i.e., made the firebox narrower at the front, and not as deep).[1] Results of these tests showed that the Rosin fireplaces had PM emissions which were approximately one-half as much as a conventional fireplace.

Although not a traditional control technology, the use of densified wood or artificial "logs" has gained attention as a cleaner-burning fuel compared to cord wood. The results of recent testing conducted in Canada on artificial log combustion in fireplaces shows the potential to reduce particulate emissions by up to 84 percent, with an accompanying reduction in CO emissions of up to 92 percent.[4]

In an attempt to combine a traditional fireplace with noncatalytic (i.e., secondary-burn) technology, a manufactured fireplace has been developed.[5] Early test results, using EPA Method 28A, indicate that this fireplace has a particulate matter emission rate of 5.5 g/hr, less than the EPA allowable limit of 7.5 g/hr for Phase II noncatalytic wood stoves.

REFERENCES FOR CHAPTER 2

1. Barnett, S.G., In-Home Evaluation of Emissions From Masonry Fireplaces and Heaters, OMNI Environmental Services, Inc., Beaverton, OR, September 1991.

2. Zamula, W.W., "Room Heating Equipment Exposure Survey, Final Report," U.S. Consumer Product Safety Commission, Directorate for Economic Analysis, OMB Control No. 3041-0083, Washington, DC, March 1989.

3. Guidance Document for Residential Wood Combustion Emission Control Measures, EPA-4502-89-015, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1989.

4. Hayden, A., C.S. and R.W. Braaten, "Reduction of Fireplace and Woodstove Pollutant Emissions Through the Use of Manufactured Firelogs," Paper 91-129.1, Presented at the 84th Annual Meeting of the Air Waste Management Association, Vancouver, British Columbia, June 1991.

5. Broome, F.H., "The Development of Clean-Burning, Noncatalytic Manufactured Fireplaces," Paper P1.6, Presented at the PM-10 Specialty Conference, Scottsdale, AZ, January 1992.

3. GENERAL EMISSION DATA REVIEW AND ANALYSIS PROCEDURE

3.1 DATA SEARCH AND SCREENING

The first step in updating the fireplace emission factor data base was to contact RWC experts in order to determine if new test data were available since the last AP-42 update.[1,2,3] A recent update of AP-42 emission factors for fireplaces provided a current base on which to add new data.

3.2 EMISSION DATA QUALITY RATING SYSTEM

The quality and quantity of the new test data were ranked pursuant to EPA guidance and assigned a quality ranking based on the following criteria:[4,5]

A - Tests performed using sound methodology and reported in enough detail to provide adequate validation. These tests may not be EPA reference method tests, although such reference methods are preferred and to be used as a guide.

B - Tests performed using sound methodology, but lacking enough detail to provide adequate validation.

C - Tests performed using an unproven or new methodology, or are lacking a significant amount of background data.

D - Tests performed using a generally unacceptable method, but the method may provide an order-of-magnitude value for the source.

Guidelines to evaluate the data for sound methodology and adequate detail were:

- Source operation. The source was operating within typical parameters during the test and the parameters are well documented;
- Sampling procedures. If actual procedures deviated from standard methods during the test, the deviations are well documented and evaluated to determine their influence on the test results;

- ! Sampling and process data. If a large spread between test results cannot be explained by information contained in the test report, then the data are suspect and are given a lower rating; and
- ! Analysis and calculations. The test reports should contain original raw data sheets. Nomenclature and equations used are compared with those specified by EPA to establish equivalency. The depth of calculation review is determined by the reviewers' confidence in the ability and conscientiousness of the tester. Such ability is based on consistency of results and completeness of other areas of the test report.

3.3 EMISSION FACTOR QUALITY RATING SYSTEM

After evaluating emissions data and calculating new emission factors, quality rating of the emission factor was awarded based on the following criteria:

A - Excellent: The emission factor was developed from only A-rated source data, and taken from many randomly chosen facilities. The source category is specific enough to minimize variability within the source population.

B - Above average: The emission factor was developed from only A-rated source data, but it is not clear if the facilities tested represent a random sample of the population. As with the A-rated emission factor, the source category is specific enough to minimize variability within the source population.

C - Average: The emission factor was developed from only A- and B-rated source data, and from a reasonable number of facilities. It is not clear if the facilities tested represent a random sample of the population. As with the A-rated emission factor, the source category is specific enough to minimize variability within the source population.

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

E - Poor: The emission factor was developed from C- and D-rated source data. There may be reason to suspect that the facilities tested do not represent a random sample of the population. Also, there may be evidence of variability with the source population. Any limitations on the use of this emission factor are noted in the emission factor table.

REFERENCES FOR CHAPTER 3

1. Verbal Communication from Robert C. McCrillis, U.S. Environmental Protection Agency, Research Triangle Park, NC, to Paula G. Fields and George E. Weant, E.H. Pechan and Associates, Inc., Rancho Cordova, CA, April-May, 1992.

2. Written Communication from Stockton G. Barnett, OMNI Environmental Services, Inc., Beaverton, OR, to Paula G. Fields, E.H. Pechan and Associates, Inc., Rancho Cordova, CA, May 18, 1992.

3. Written Communication from Paul Tiegs, OMNI Environmental Services, Inc., Beaverton, OR, to George E. Weant, E.H. Pechan and Associates, Inc., Durham, NC, March 26, 1992.

4. 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.

5. "Clarification to AP-42 Procedures Document," Memo from J. Southerland, Emission Factor and Methodologies Section, U.S. Environmental Protection Agency, Research Triangle Park, NC, April 1992.

4. EMISSION FACTOR DEVELOPMENT

This chapter describes the test data and methodology used to review and revise the emission factors for residential fireplaces. Previously existing fireplace test data sets and new test data for fireplaces are discussed and evaluated. The chapter ends with a discussion of the revised emission factor data base.

4.1 REVIEW OF EXISTING DATA SETS

The AP-42 emission factors for residential fireplaces were last reviewed and revised in September 1991, and subsequently published as part of AP-42, Supplement D. As part of the 1991 revision, the data base of fireplace emissions testing results was edited to include only recent test data. During the current revision to AP-42, Chapter 1, Section 1.9, the 1991 data base was reviewed to determine if it contained any noncriteria emissions data and reviewed in order to evaluate the ratings of the existing data since they will be combined with new emissions data.

It is important to note these facts regarding the existing data base: (1) All of these data were collected under laboratory conditions or quasi-laboratory conditions (i.e., testing was conducted in-home, but according to test protocol); (2) The final average emission rate and emission factor are based on the emissions measured during each burn cycle. These facts become relevant when determining how to increase the existing data base by adding data collected in-home, where conditions are "real-life," and emissions are reported as an average for each fireplace (i.e., averages are based on several burn cycles).

In-home data are generally preferred for use in emission factor development. This is evidenced by the conversion from lab data to in-home data for determining residential wood stove emission factors. More in-home fireplace data need to be collected before the quality of all resultant emission data sets and emission factors can be raised to the desired A-to-B range.

It was decided during the review of the existing data base that the data should be re-averaged in order to determine the emission factor for each pollutant by fireplace type instead of by burn cycle. This method of averaging provides a more accurate way to combine the existing laboratory data with the new field data. The ratings assigned to the existing data and/or emission factors are shown in Table 4.1 at the end of this chapter.

4.1.1 References 1 through 10

Reference 1 contained PM, CO, hydrocarbon (HC or VOC), and CO_2 data from fireplace testing conducted in Vail, Colorado during 1977. One of the fireplaces tested had an electrostatic precipitator attached to the stack up-stream of the test ports; the emissions data from this fireplace were dropped from the data base.

Reference 2 contained PM, CO and polycyclic aromatic hydrocarbon (PAH) data from fireplace testing conducted in Colorado during 1986-1987. It was decided to not include these data in the revised data base since the fueling protocol for this series of tests included the use of dimensional wood only (i.e., Douglas fir nominal 4x4s and 3/4 x 3/4 inch strips) which is not representative of real-world fuel loads.

Reference 3 contained PM and total nonmethane organic compound (TNMOC) data from fireplace testing conducted in North Carolina during 1989.

References 4, 5 and 6 contained CO, HC, aldehyde, and NO_x data from fireplace testing conducted by General Motors Research Laboratories.

Reference 7 contained PM, CO, HC and POM data from the testing of a fireplace in Seattle, Washington in 1975. These data were averaged into one set of emission factors for inclusion in the revised data base.

Reference 8 contained CO and NO_x data from the testing of a masonry fireplace in California during 1980.

References 9 and 10 contained average SO_x and TNMOC data from the testing of four fireplaces. The emission factor calculated from the results was reported as an average by fireplace type.

4.2 REVIEW OF NEW DATA SETS

One new data set of in-home fireplace test results were obtained.

4.2.1 Reference 11 - Fireplaces

New in-home fireplace test data included emission rates for PM, CO and CO_2 from five fireplaces located in the Portland, Oregon area. The data from this test series were assigned a rating of "A," since the test report provided documentation of sound methodology in adequate detail.

4.3 EMISSION FACTOR METHODOLOGY

A Lotus123J spreadsheet was used to compile emissions data and calculate \emission factors. Print outs of the spreadsheet files and a disk copy of the spreadsheet were placed in the emission factor background file.

4.3.1 Criteria Pollutant Emission Factor Development

The emission factor for SO_x was the only criteria pollutant emission factor that did not change from the 1991 emission factor. The emission factors for PM-10, NO_x, VOCs, and CO were revised based on the addition of new data and/or the method used to average the emissions by fireplace type instead of by burn cycle. Emission factors were previously reported for methane and nonmethane VOCs, as well as total hydrocarbons.

The methane and nonmethane data (References 3, 7, and 9) did not compare to the total VOC data (References 1, 4, and 9) so it was decided not to use the methane and nonmethane data for emission factor development. The previously reported hydrocarbon emission factors were classified as total VOCs.

4.3.1.1 PM Emission Factor Development. EPA Method 5H (M5H) is the basis for New Source Performance Standards (NSPS) for wood stoves. It is also the reference method used to evaluate fireplace emission test results. The new PM test data were collected using a modified Automated Wood Stove Emissions Sampler (AWES), and related to the EPA Method 5G (M5G) by the following equation:

$$M5G = 0.8635 \ x \ (AWES)^{0.9288}$$

After correcting AWES data to equivalent M5G values, the following equation converts the M5G values to equivalent M5H values:

$$M5H = 1.619 \ x \ (M5G)^{0.905}$$

These equations were developed by performing a linear regression on data taken from simultaneous AWES-M5G and M5G-M5H tests.[12,13,14,15,16] A sample calculation using these conversion equations along with the graphical results of the linear regression of AWES-M5G data are shown in Appendix A. It should be noted that the AWES-M5G tests were conducted on wood stoves having a maximum emission rate of approximately 30 g/hr, while the maximum emission rate from the fireplace tests to which the correlation equation was applied was approximately 83 g/hr. Even though the AWES fireplace data are out of the range of the data used to develop the correlation equation, it is felt that the use of the equation on the fireplace data is appropriate. Emissions from another type of field wood stove emissions sampler developed by Virginia Polytechnic Institute (VPI) have also been correlated with M5G emissions using data collected while attaining emission rates greater than 80 g/hr. In order to evaluate the accuracy of the AWES equation for emission rates greater than 30 g/hr, a comparison was made between the AWES-M5G equation and the VPI-M5G equation for a given emission rate. Assuming an emission rate of 83 g/hr, the adjusted M5H values are 52 and 58 g/hr for the AWES and VPI, respectively. The results compare within about 10 percent, suggesting that use of the AWES-M5H equation for emission rates in the 80 g/hr range may produce a slight understatement of the emission factor.

4.3.2 Noncriteria Pollutant Emission Factor Development

Emission factors for POM were not changed from the 1991 emission factors. The emission factor ratings for POM and aldehydes were revised based on the methodology described in Chapter 3 of this report. A new emission factor for CO_2 was calculated and the emission factor for aldehydes was revised to correct an error found in the existing data base.

4.4 EMISSION FACTOR RESULTS

Table 4-1 shows a summary of the new and revised emission factors for criteria and noncriteria pollutants from residential fireplaces.

TABLE 4-1. SUMMARY OF EMISSIONS DATA FROM RESIDENTIAL FIREPLACES

Pollutant	Previous Emission Factor Rating	Revised Emission Factor Range g/kg	New/Revised Average Emission Factor g/kg	New/Revised Emission Factor Rating	References
PM-10	C	11.0 - 23.4	17.3	B	1,3,7,11
Sulfur Oxides	A	None	0.2[a]	A	9,10
Nitrogen Oxides	C	0.9 - 1.6	1.3	C	4,5,6,8
Carbon Monoxide	C	80.5 - 316.0	126.3	B	1,4,5,6,7,8,11
Carbon Dioxide	None	1459.1 - 2248.1	1699.4	C[b]	1,11
Total VOC	D	2.9 - 184.3	114.5	D	1,4,9
POM	F	None	8.03 E-4[a]	E[c]	7
Aldehydes	D	None	1.20	E[c]	7

a. This emission factor was not revised; the emission factor and rating is carried forward from the 1991 data base.
b. Conversion of ppm_v to kg/hr to g/kg was done using two different methods. Details of analysis are contained in the emission factor background file.
c. The average emission factor was developed from data gathered from a small number of fireplaces.
d. The source data used to develop this emission factor showed a high degree of variability within the source population.

REFERENCES FOR CHAPTER 4

1. "Source Testing For Fireplaces, Stoves, And Restaurant Grills In Vail, Colorado," EPA Contract No. 68-01-1999, Pedco Environmental, Inc., Cincinnati, OH, December 1977.

2. Shelton, J.W., and L. Gay, Colorado Fireplace Report, Colorado Air Pollution Control Division, Denver, CO, March 1987.

3. "Development Of AP-42 Emission Factors For Residential Fireplaces," EPA Contract No. 68-D9-0155, Advanced Systems Technology, Inc., Atlanta, GA, January 11, 1990.

4. Jean M. Dash, "Particulate And Gaseous Emissions From Wood-burning Fireplaces," Environmental Science And Technology, 16(10):643-67, October 1982.

5. Lipari, F., et al., "Aldehyde Emissions From Wood-Burning Fireplaces," Publication GMR-4377R, General Motors Research Laboratories, Warren, MI, March 1984.

6. Written communication from Robert C. McCrillis, U.S. Environmental Protection Agency, Research Triangle Park, NC, to Neil Jacquay, U.S. Environmental Protection Agency, San Francisco, CA, November 19, 1985.

7. Snowden, W.D., et al., "Source Sampling Residential Fireplaces For Emission Factor Development," EPA-450/3-76-010, U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1975.

8. Kosel, P., et al., Emissions From Residential Fireplaces, CARB Report C-80-027, California Air Resources Board, Sacramento, CA, April 1980.

9. DeAngelis, D.G., et al., Source Assessment: Residential Combustion Of Wood, EPA-600/2-80-042b, U.S. Environmental Protection Agency, Cincinnati, OH, March 1980.

10. DeAngelis, D.G., et al., "Preliminary Characterization Of Emissions From Wood Fired Residential Combustion Equipment," EPA-600/7-80-040, U.S. Environmental Protection Agency, Cincinnati, OH, March 1980.

11. Barnett, S.G., "In-Home Evaluation of Emissions From Masonry Fireplaces and Heaters," OMNI Environmental Services, Inc., Beaverton, OR, September 1991.

12. Barnett, S.G., "Relationship of the AWES to EPA Methods 5H and 5G," OMNI Environmental Services, Inc., Beaverton, OR, December 1991.

13. Burnett, P.G., "The Northeast Cooperative Woodstove Study," Volume 1, EPA-600/7-87-026a, U.S. Environmental Protection Agency, Research Triangle Park, NC, November 1987.

14. Cottone, L.E. and E. Messer, "Test Method Evaluations and Emissions Testing for Rating Woodstoves," EPA-600/2-86-100, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1986.

15. McCrillis, R.C., "Long-Term Wood Stove Catalysts Performance Under Simulated Residential Use," EPA-600/0-87-157, U.S. Environmental Protection Agency, Research Triangle Park, NC, June 1987.

16. Memorandum from P.R. Westlin, U.S. Environmental Protection Agency, Research Triangle Park, NC, to J. Kowalczyk, Oregon Department of Environmental Quality, Portland, OR, July 13, 1986.

5. AP-42 SECTION 1.9: RESIDENTIAL FIREPLACES

The revision to Section 1.9 of AP-42 is presented in the following pages as it would appear in the AP-42 document.

1.9 RESIDENTIAL FIREPLACES

1.9.1 General[1,2]

Fireplaces are used primarily for aesthetic effects and secondarily as a supplemental heating source in houses and other dwellings. Wood is the most common fuel for fireplaces, but coal and densified wood "logs" may also be burned. The user intermittently adds fuel to the fire by hand.

Fireplaces can be divided into two broad categories, 1) masonry (generally brick and/or stone, assembled on site, and integral to a structure) and 2) prefabricated (usually metal, installed on site as a package with appropriate duct work).

Masonry fireplaces typically have large fixed openings to the fire bed and have dampers above the combustion area in the chimney to limit room air and heat losses when the fireplace is not being used. Some masonry fireplaces are designed or retrofitted with doors and louvers to reduce the intake of combustion air during use.

Prefabricated fireplaces are commonly equipped with louvers and glass doors to reduce the intake of combustion air, and some are surrounded by ducts through which floor level air is drawn by natural convection, heated and returned to the room. Many varieties of prefabricated fireplaces are now available on the market. One general class is the freestanding fireplace, the most common of which consists of an inverted sheet metal funnel and stovepipe directly above the fire bed. Another class is the "zero clearance" fireplace, an iron or heavy gauge steel firebox lined inside with firebrick and surrounded by multiple steel walls with spaces for air circulation. Some zero clearance fireplaces can be inserted into existing masonry fireplace openings, and thus are sometimes called "inserts." Some of these units are equipped with close fitting doors and have operating and combustion characteristics similar to wood stoves. (See Section 1.10, Residential Wood Stoves.)

Masonry fireplaces usually heat a room by radiation, with a significant fraction of the combustion heat lost in the exhaust gases and through fireplace walls. Moreover, some of the radiant heat entering the room goes toward warming the air that is pulled into the residence to make up for that drawn up the chimney. The net effect is that masonry fireplaces are usually inefficient heating devices. Indeed, in cases where combustion is poor, where the outside air is cold, or where the fire is allowed to smolder (thus drawing air into a residence without producing appreciable radiant heat energy), a net heat loss may occur in a residence using a fireplace. Fireplace heating efficiency may be improved by a number of measures that either reduce the excess air rate or transfer back into the residence some of the heat that would normally be lost in the exhaust gases or through fireplace walls. As noted above, such measures are commonly incorporated into prefabricated units. As a result, the energy efficiencies of prefabricated fireplaces are slightly higher than those of masonry fireplaces.

1.9.2 Emissions[1-13]

The major pollutants of concern from fireplaces are unburnt combustibles, including carbon monoxide, gaseous organics and particulate matter (i.e., smoke). Significant quantities of unburnt combustibles are produced because fireplaces are inefficient combustion devices, with high uncontrolled excess air rates and without any sort of secondary combustion. The latter is especially important in wood burning because of its high volatile matter content, typically 80 percent by dry weight. In addition to unburnt combustibles, lesser amounts of nitrogen oxides and sulfur oxides are emitted.

Hazardous Air Pollutants (HAPs) are a minor, but potentially important component of wood smoke. A group of HAPs known as polycyclic organic matter (POM) includes potential carcinogens such as benzo(a)pyrene (BaP). POM results from the combination of free radical species formed in the flame zone, primarily as a consequence of incomplete combustion. Under reducing conditions, radical chain propagation is enhanced, allowing the buildup of complex organic material such as POM. The POM is generally found in or on smoke particles, although some sublimation into the vapor phase is probable.

Another important constituent of wood smoke is creosote. This tar-like substance will burn if the fire is hot enough, but at insufficient temperatures, it may deposit on surfaces in the exhaust system. Creosote deposits are a fire hazard in the flue, but they can be reduced if the chimney is insulated to prevent creosote condensation or if the chimney is cleaned regularly to remove any buildup.

Fireplace emissions are highly variable and are a function of many wood characteristics and operating practices. In general, conditions which promote a fast burn rate and a higher flame intensity enhance secondary combustion and thereby lower emissions. Conversely, higher emissions will result from a slow burn rate and a lower flame intensity. Such generalizations apply particularly to the earlier stages of the burning cycle, when significant quantities of combustible volatile matter are being driven out of the wood. Later in the burning cycle, when all volatile matter has been driven out of the wood, the charcoal that remains burns with relatively few emissions.

Emission factors and their ratings for wood combustion in residential fireplaces are given in Tables 1.9-1. and 1.9-2.

Table 1.9-1. (ENGLISH UNITS) EMISSION FACTORS FOR WOOD COMBUSTION IN RESIDENTIAL FIREPLACES
(Source Classification Code: 2104008001)

Device	Pollutant	Emission Factor[a] lb/ton	Rating
Fireplace	PM-10[b]	34.6	B
	Carbon Monoxide[c]	252.6	B
	Sulfur Oxides[d]	0.4	A
	Nitrogen oxides[e]	2.6	C
	Carbon Dioxide[f]	3400	C
	Total VOCs[g]	229.0	D
	POM[h]	1.6E-3	E[j]
	Aldehydes[k]	2.4	E[j]

[a]Units are in lbs. of pollutant/ton of dry wood burned.
[b]References 2, 5, 7, 13; contains filterable and condensable particulate matter (PM); PM emissions are considered to be 100% PM-10 (i.e., PM with an aerodynamic diameter of 10μm or less).
[c]References 2, 4, 5, 9, 13.
[d]References 1, 8.
[e]References 4, 9; expressed as NO_2.
[f]References 5, 13
[g]References 4 - 5, 8. Data used to calculate the average emission factor were collected by various methods. While the emission factor may be representative of the source population in general, factors may not be accurate for individual sources.
[h]Reference 2.
[j]Data used to calculate the average emission factor were collected from a single fireplace and are not representative of the general source population.
[k]References 4, 11.

Table 1.9-2. (METRIC UNITS) EMISSION FACTORS FOR WOOD COMBUSTION IN RESIDENTIAL FIREPLACES
(Source Classification Code: 2104008001)

Device	Pollutant	Emission Factor[a] g/kg	Rating
Fireplace	PM-10[b]	17.3	B
	Carbon Monoxide[c]	126.3	B
	Sulfur Oxides[d]	0.2	A
	Nitrogen oxides[e]	1.3	C
	Carbon Dioxide[f]	1700	C
	Total VOCs[g]	114.5	D
	POM[h]	0.8E-3	E[j]
	Aldehydes[k]	1.2	E[j]

[a]Units are in grams of pollutant/kg of dry wood burned.
[b]References 2, 5, 7, 13; contains filterable and condensable particulate matter (PM); PM emissions are considered to be 100% PM-10 (i.e., PM with an aerodynamic diameter of 10μm or less).
[c]References 2, 4, 5, 9, 13.
[d]References 1, 8.
[e]References 4, 9; expressed as NO_2.
[f]References 5, 13
[g]References 4 - 5, 8. Data used to calculate the average emission factor were collected by various methods. While the emission factor may be representative of the source population in general, factors may not be accurate for individual sources.
[h]Reference 2.
[j]Data used to calculate the average emission factor were collected from a single fireplace and are not representative of the general source population.
[k]References 4, 11.

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APPENDIX A

SAMPLE CALCULATIONS AND AWES-M5G CORRELATION EQUATION

SAMPLE CALCULATIONS

GIVEN:

Particulate sampling using AWES unit

$$Emission\ \ Rate\ \ =\ 85.4\ \frac{g}{hr}$$

$$Burn\ \ Rate\ \ =\ 4.17\ \frac{kg}{hr}$$

FIND:

Equivalent M5H Emission Factor (g/kg, lb/ton)

SOLUTION:

Convert AWES g/hr to M5G equivalent

$$M5G\ =\ 0.8635(85.4)^{.9288}\ =\ 53.7\ \ g/hr$$

Convert M5G to M5H equivalent

$$M5H\ =\ 1.619(53.7)^{0.905}\ =\ 59.6\ \ g/hr$$

Calculate g/kg (lb/ton)

$$\frac{59.6\ \ g/hr}{4.17\ \ kg/hr}\ =\ 14.3\ \ g/kg\ =\ 28.6\ \ lb/ton$$

LINEAR REGRESSION FOR DEVELOPMENT OF "AWES" to M5G COORELATION								
September 3, 1992								
AWES ========	= = = = = = =	= = = = =	= = = = = = = =	= = =	= = = = = = = =	= = = = =	= = = = =	= = = = =
Reference:		S.G. Barnett, "Relationship of the AWES to EPA Methods 5H and 5G"						
		OMNI Environmental Services, December 15, 1991						
		Prepared for R.C. McCrillis, U.S. EPA, AEERL, RTP, NC 27711						
5G	LN 5G	AWES	LN AWES					
23.3	3.1484533606	27.1	3.29953372789			Regression Output:		
3.15	1.1474024528	3.5	1.2527629685		Constant			-0.146719
1.5	0.4054651081	4.1	1.41098697371		Std Err of Y Est			0.3029377
2.47	0.9042181506	4.2	1.43508452529		R Squared			0.9277539
0.74	-0.301105093	0.87	-0.1392620673		No. of Observations			14
0.74	-0.301105093	0.8	-0.2231435513		Degrees of Freedom			12
12.9	2.5572273114	22.3	3.10458667847					
17.4	2.8564702062	22.4	3.10906095886		X Coefficient(s)		0.9288379	
6.73	1.9065751437	9.25	2.22462355152		Std Err of Coef.		0.0748238	
11.82	2.469793012	17.13	2.84083131234		R		0.9631998	
3.21	1.1662709371	2.6	0.95551144503		= = = = = = = =	= = = = =	= = = = =	= = = = =
5.95	1.7833912196	9.5	2.25129179861		5G = C * (AWES) ^A			
6.2	1.8245492921	6.61	1.88858365386		C = exp(Constant)=		0.8635	
4.43	1.4883995841	4.35	1.4701758451		A = X Coefficient=		0.9288	
					5G = 0.8635*(AWES)^0.9288			

For Graphing:								
Sorted "X"		Sorted "Y"		5G = 0.8635*(AWES)^0.9288				
0.8		0.74		0.702				
0.87		0.74		0.759				
2.6		3.21		2.098				
3.5		3.15		2.765				
4.1		1.5		3.202				
4.2		2.47		3.275				
4.35		4.43		3.383				
6.61		6.2		4.99				
9.25		6.73		6.818				
9.5		5.95		6.989				
17.13		11.82		12.08				
22.3		12.9		15.44				
22.4		17.4		15.5				
27.1		23.3		18.5				

REPORT ON REVISIONS TO
5TH EDITION AP-42
Section 1.9
Residential Fireplaces

Contract No. 68-D2-0160, Work Assignment 50
EPA Work Assignment Officer: Roy Huntley
Office of Air Quality Planning and Standards
Office of Air and Radiation
U. S. Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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July 29, 1996

Table of Contents

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1.0 INTRODUCTION

This report supplements the Emission Factor (EMF) Documentation for AP-42 Section 1.9, Residential Fireplaces, dated September 1991. 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 1.9 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. Additionally, emission factors were checked for accuracy with information in the EMF Document and new emission factors generated if recent test data were available.

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 1.9, and Section 5 contains the EMF documentation dated April 1993.

2.0 REVISIONS

This section documents revisions made to Section 1.9 of the 5th Edition of AP-42.

2.1 General Text Changes

Minor changes were made to the text concerning emission controls based on information in the EMF Document. Also, at the request of EPA, metric units were removed.

2.2 Criteria Pollutant and Miscellaneous Emission Factors

The criteria pollutant emission factors (PM-10, CO, SO_x, and NO_x) were checked against information in Table 4-1 and no changes were necessary. Also, there were no changes made to other miscellaneous factors (Total VOC, POM, or aldehydes).

2.3 Greenhouse Gases

2.3.1 Carbon Dioxide, CO_2

The CO_2 factors remain the same as in the 1/95 version of AP-42.

2.3.2 Methane, CH_4

No emissions data was found.

2.3.3 Nitrous Oxide, N_2O

Only one reference listed N_2O emissions for residential fireplaces. The source data for this factor was not available for review, so the factor retains and "E" rating.

Table 1. N_2O Emission Factors for Residential Fireplaces[a]
(lb N_2O/ton wood)

Combustion Category	EF Rating	EF	AP-42 EF
Domestic (furnaces and fireplaces	E	0.3	None

[a]Reference 1.

3.0 REFERENCES

1. Ortech Corporation, *Inventory Methods Manual For Estimating Canadian Emissions Of Greenhouse Gases*, Prepared for Environmental Canada, 1994.