Emission Factor Documentation for AP-42
Section 9.5.2

Meat Smokehouses

Final Report

For Emission Factor and Inventory Group
Office of Air Quality Planning and Standards
U. S. Environmental Protection Agency

EPA Contract No. 68-D2-0159
Work Assignment No. II-3

MRI Project No. 4602-03

September 1995

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For Emission Factor and Inventory Group
Office of Air Quality Planning and Standards
U. S. Environmental Protection Agency
Research Triangle Park, NC 27711

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NOTICE

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PREFACE

This report was prepared by Midwest Research Institute (MRI) for the Office of Air Quality Planning and Standards (OAQPS), U. S. Environmental Protection Agency (EPA), under EPA Contract No. 68-D2-0159, Work Assignment Nos. I-08 and II-03. Mr. Dallas W. Safriet was the EPA Work Assignment Manager.

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1. INTRODUCTION

The document Compilation of Air Pollutant Emission Factors (AP-42) has been published by the U. S. Environmental Protection Agency (EPA) since 1972. Supplements to AP-42 have been routinely published to add new emission source categories and to update existing emission factors. 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 is a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. Emission factors usually are expressed as the weight of pollutant divided by the unit weight, volume, distance, or duration of the activity that emits the pollutant. The emission factors presented in AP-42 may be appropriate to use in a number of situation, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance pruposes, establishing operating permit fees, and making permit applicability determinations. The purpose of this report is to provide background information from test reports and other information to support preparation of AP-42 Section 9.5.2, Meat Smokehouses.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the meat smokehouse industry. It includes a characterization of the industry, a description of the different process operations, a characterization of emission sources and pollutants emitted, and a description of the technology used to control emissions resulting from these sources. Section 3 is a review of emission data collection (and emission measurement) procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details how the new AP-42 section was development. It includes the review of specific data sets and a description of how candidate emission factors were developed. Section 5 presents the AP-42 Section 9.5.2, Meat Smokehouses.

2. INDUSTRY DESCRIPTION[1,2]

Meat smokehouses are used to add flavor, color, and aroma to various meats, including pork, beef, poultry, and fish. Smokehouses were at one time used to smoke food for preservation, but refrigeration systems have effectively eliminated this use. No standard industrial classification (SIC) code exists for smokehouses, although SIC code 2013, Sausages and Other Prepared Meats, includes smokehouses under product classes 20136 31, 20136 35, 20136 41, and 20136 52. The single eight-digit source classification code (SCC) for meat smokehouses is 3-02-013-01 (combined operations).

2.1 CHARACTERIZATION OF THE INDUSTRY[2,3]

Meat smokehouses are located primarily in the midwest, California, and New Jersey. In 1987, approximately 250 domestic pork smoking facilities (with annual shipments of $100,000 or more) were operating, with a total annual production of 871,000 megagrams (Mg) (960,000 tons). No data regarding other types of smoked meats are available.

2.2 PROCESS DESCRIPTION[1,6]

Four operations are typically involved in the production of smoked meat: (1) tempering or drying, (2) smoking, (3) cooking, and (4) chilling. However, not all smoked foods are cooked, thus eliminating the cooking and chilling processes from some operations. Important process parameters include cooking/smoking time, smoke generation temperature, humidity, smoke density, type of wood or liquid smoke, and product type.

The two types of smokehouses that are almost exclusively used are batch and continuous smokehouses. Figures 2-1 and 2-2 show typical batch and continuous smokehouses, respectively. Both types of systems circulate air at the desired process conditions (temperature, humidity, and smoke density) over the surface of the meat. In batch smokehouses, the meat is placed on stationary racks for the entire smoking process. In continuous smokehouses, the meat is hung on sticks or hangers and then conveyed through the various zones (smoking, heating, and chilling) within the smokehouse. Following processing in the smokehouse, the product is packaged and stored for shipment.

Several methods are used to produce the smoke used in smokehouses. The most common method is to pyrolyze hardwood chips or sawdust using smoke generators. In a typical smoke generator, hardwood chips or sawdust are fed onto a gas- or electrically-heated metal surface at 350° to 400°C (662° to 752°F). Smoke is then ducted by a smoke tube into the air recirculation system in the smokehouse. Smoke produced by this process is called natural smoke.

Liquid smoke (or artificial smoke), which is a washed and concentrated natural smoke, is also used in smokehouses. This type of smoke (as a fine aerosol) can be introduced into a smokehouse through the air recirculation system, can be mixed or injected into the meat, or can be applied by drenching, spraying, or dipping.

2.3 EMISSIONS[1,7-8]

Particulate matter (PM), carbon monoxide (CO), volatile organic compounds (VOC), polycyclic aromatic hydrocarbons (PAH), organic acids, acrolein, acetaldehyde, formaldehyde, and nitrogen oxides have been identified as pollutants associated with meat smokehouses. The primary source of these pollutants is the smoke used in the smokehouses. Studies cited in Reference 1 show that almost all PM

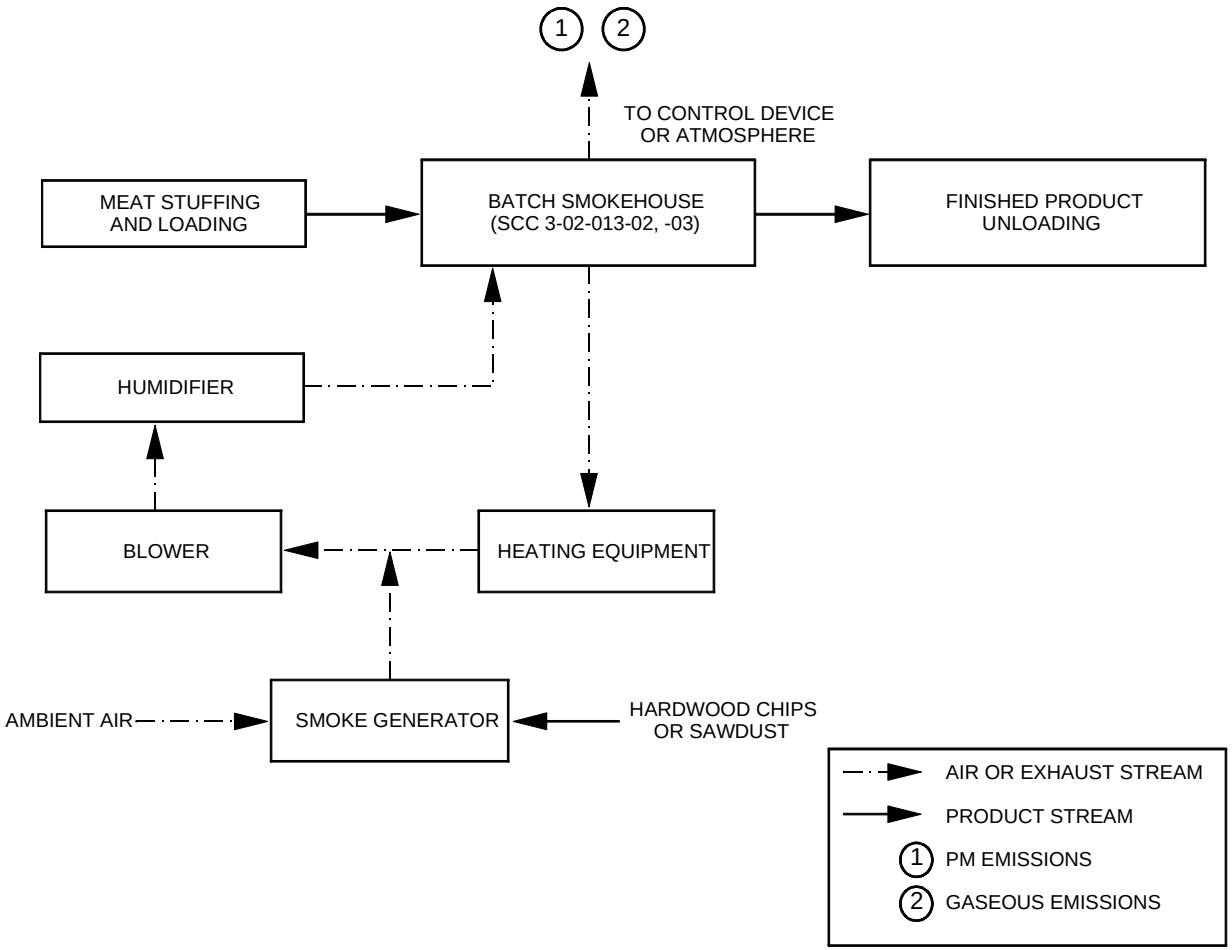

Figure 2-1. Typical batch smokehouse.[1]

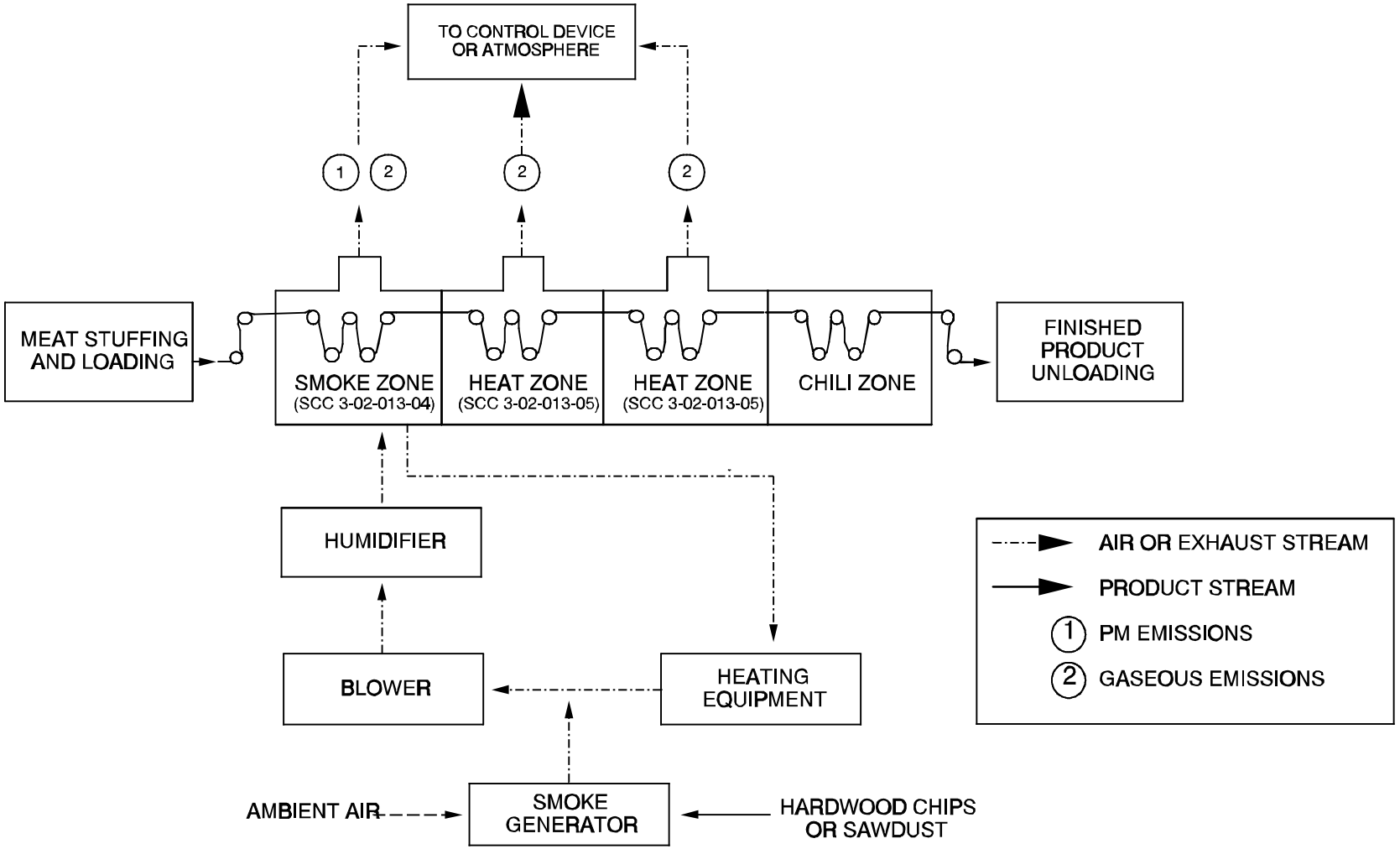

Figure 2-2. Typical continuous smokehouse. [1]

from smoke has an aerodynamic diameter of less than 2.0 micrometers (μm). Acetic acid has been identified as the most prevalent organic acid present in smoke, followed by formic, propionic, butyric, and other acids. Also, acetaldehyde concentrations have been shown to be about five times greater than formaldehyde concentrations in smoke. Heating zones in continuous smokehouses (and the cooking cycle in batch smokehouses) are a source of odor that includes small amounts of VOC. The VOC are a result of the volatilization of organic compounds contained in the meat or the smoke previously applied to the meat. Heating zones are typically heated with ambient air that is passed over electrically-heated or steam-heated coils (steam from boilers used elsewhere at the facility). Therefore, heating zones are not a source of combustion products. Factors that may effect smokehouse emissions include the amount and type of wood or liquid smoke used, the type of meat processed, the processing time, humidity, and the temperature maintained in the smoke generators.

2.4 CONTROL TECHNOLOGY[1,4-6]

Control technologies used at meat smokehouses include afterburners, wet scrubbers, and modular electrostatic precipitators (ESP). Emissions can also be reduced by controlling important process parameters. An example of this type of process control is maintaining a temperature not higher than about 400°C (752°F) in the smoke generator, to minimize the formation of PAH.

Afterburners are an effective control technology for PM, organic gases, and CO from smokehouses, but energy requirements may be costly for continuous smokehouse operations. Also, the additional air pollution resulting from afterburner fuel combustion makes afterburners a less desirable option for controlling smokehouse emissions.

Wet scrubbers are another effective control technology for both PM and gaseous emissions. Different types of scrubbers used include mist scrubbers, packed bed scrubbers, and vortex scrubbers. Mist scrubbers introduce a water fog into a chamber, and exhaust gases are then fed into the chamber and are absorbed. Packed bed scrubbers introduce the exhaust gases into a wetted column containing an inert packing material in which liquid/gas contact occurs. Vortex scrubbers use a whirling flow pattern to shear water into droplets, which then contact the exhaust gases. Limited test data (from Reference 5) show a vortex scrubber (followed by a demister) achieving about 51 percent formaldehyde removal, 85 percent total organic compound removal, 39 percent acetic acid removal, and 69 percent PM removal. Particulate matter removal efficiencies for scrubbers can be increased through the use of surfactants, which may enhance the capture of the smoke particles that do not combine with the scrubber water.

Electrostatic precipitators are effective for controlling PM emissions. Combined control technologies, such as a wet scrubber for gaseous emission control followed by an ESP for PM removal, may also be used to control emissions from smokehouses.

Smokehouse control devices are operated during the smoking cycle and are sometimes bypassed during the cooking and cooling cycles. Continuous smokehouses may include separate vents for exhaust streams from the different zones, thus minimizing the air flow through the control device.

References For Section 2

1. J. R. Blandford, "Meat Smokehouses", in Chapter 13, Food and Agriculture Industry, *Air Pollution Engineering Manual*, Van Nostrand Reinhold Press, 1992.

2. 1987 Census of Manufactures, Industry Series, Meat Products--Industries 2011, 2013, and 2015, U. S. Department of Commerce, Washington, D. C., March 1990.

3. Written communication from D. Theiler, Wisconsin Department of Natural Resources, Madison, WI, to R. Blaszczak, U. S. Environmental Protection Agency, Research Triangle Park, NC, August 26, 1993.

4. Written communication from J. M. Jaeckels, Oscar Mayer Foods Corporation, Madison, WI, to S. Lindem, Wisconsin Department of Natural Resources, Madison, WI, April 1, 1992.

5. *KSI-2 & KSI-3 Continuous Smokehouses Stack Emissions Testing*, Hillshire Farm & Kahn's, New London, WI, September 19-20, 1991.

6. Joseph A. Maga, *Smoke In Food Processing*, CRC Press, Inc., Boca Raton, FL, 1988.

7. Written communication from J. M. Jaeckels, BT^2, Inc., Madison, WI, to D. Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, December 15, 1994.

8. Telephone communication between B. L. Shrager, Midwest Research Institute, Cary, NC, and J.M. Jaeckels, BT^2, Inc., Madison, WI, March 16 and 17, 1995.

3. GENERAL DATA REVIEW AND ANALYSIS

3.1 LITERATURE SEARCH AND SCREENING

Data for this investigation were obtained from a number of sources within the Office of Air Quality Planning and Standards (OAQPS) and from outside organizations. The AP-42 Background Files located in the Emission Factor and Inventory Group (EFIG) were reviewed for information on the industry, processes, and emissions. The Crosswalk/Air Toxic Emission Factor Data Base Management System (XATEF) and VOC/PM Speciation Data Base Management System (SPECIATE) data bases were searched by SCC code for identification of the potential pollutants emitted and emission factors for those pollutants. A general search of the Air CHIEF CD-ROM also was conducted to supplement the information from these two data bases.

Information on the industry, including number of plants, plant location, and annual production capacities, was obtained from the Census of Manufactures and other sources.

A number of sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval (TSAR) data base was conducted to identify test reports for sources within the meat smokehouse industry. However, no reports were contained in the TSAR data base. The EPA library was searched for additional test reports. Using information obtained on plant location, State and Regional offices were contacted about the availability of test reports. However, the information obtained from these offices was limited. Publications lists from the Office of Research and Development (ORD) and Control Technology Center (CTC) were also searched for reports on emissions from the meat smokehouse industry.

To screen out unusable test reports, documents, and information from which emission factors could not be developed, the following general criteria were used:

1. Emission 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

As part of the 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 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.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated as follows:

A--Multiple tests that were 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 EPA reference test methods, although these methods were 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 adequate detail:

1. Source operation. 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. Sampling procedures. 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 to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. 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. Analysis and calculations. 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 EMISSION FACTOR QUALITY RATING SYSTEM

The quality of the emission factors developed from analysis of the test data was rated using the following general 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. 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. In addition, 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 upon the individual reviewer. Details of the rating of each candidate emission factor are provided in Chapter 4 of this report.

REFERENCES FOR SECTION 3

1. *Technical Procedures for Developing AP-42 Emission Factors and Preparing AP-42 Sections*, EPA-454/B-93-050, Office of Air Quality Planning and Standards, U. S. Environmental Protection Agency, Research Triangle Park, NC, October 1993.

4. AP-42 SECTION DEVELOPMENT

4.1 REVISION OF SECTION NARRATIVE

The section narrative currently presented in AP-42 Section 6.5.2 (Fourth Edition) was rewritten to reflect current industry practices. Also, the emission factors from the existing section were replaced with emission factors developed from test data from several recent emission tests.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

Data from emission tests conducted on six different smokehouses at two facilities were used to develop emission factors for smokehouses. All of the tests measured emissions from the smoking process and did not include emissions from the cooking process. Emission factors were developed for filterable PM, condensible organic PM, condensible inorganic PM, volatile organic compounds (VOC), formaldehyde, and acetic acid emissions from smokehouses.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 1. This test report documents a compliance emission test conducted on January 21, 1993, at the Hillshire Farm and Kahn's meat smoking facility in New London, Wisconsin. Formaldehyde and total hydrocarbon emissions from a Knud Simonsen Industries (KSI) continuous smokehouse were measured using EPA Method 0011 and EPA Method 25A, respectively. Uncontrolled emissions were measured at the inlet to the vortex wet scrubber that controls smokehouse emissions, and controlled emissions were measured at the stack, following the scrubber and an in-stack demister. Three valid test runs were completed for each source/pollutant combination. The smokehouse was processing 8,000 pounds of sausage (out) per hour during testing. Data on wood usage and type were not provided in the report, and scrubber operating parameters were not documented.

The data from this test are not rated for use in developing emission factors. The testing methodology was sound and no problems were reported during testing. However, the most important process parameters, the type and amount of fuel used, are not documented in the report. In addition, scrubber parameters are not included in the report. These omissions do not allow for an accurate characterization of the emission source. Hillshire Farm and Kahn's was contacted for these data, but no response was received.

4.2.1.2 Reference 2. This test report documents a compliance emission test conducted on September 19 and 20, 1991, at the Hillshire Farm and Kahn's meat smoking facility in New London, Wisconsin. Filterable PM, condensible organic PM, condensible inorganic PM, formaldehyde, acetic acid, and VOC (as acetaldehyde) emissions from the KSI-2 and KSI-3 continuous smokehouses were measured using EPA Method 5 (including back-half analysis for condensible PM), NIOSH Method 3500, and EPA Method 18 (for both acetic acid and VOC), respectively. Uncontrolled emissions were measured at the inlets to the vortex wet scrubbers that control emissions from the KSI-2 and KSI-3 smokehouses, and controlled emissions were measured at the stacks, following the scrubbers and in-stack demisters. Three valid test runs were completed for each source/pollutant combination. The smokehouses were tested separately and were each processing 8,000 pounds of sausage (out) per hour during testing. Five smoke generators were in operation on each smokehouse; four using wood chips at 20.4 lb/hr and one using sawdust at 22 lb/hr. The total wood usage rate was 103.6 lb/hr. Scrubber operating parameters were not documented in the report. The calculated scrubber control efficiencies

during testing were 69 percent for total PM, 85 percent for VOC, 51 percent for formaldehyde, and 39 percent for acetic acid.

The uncontrolled filterable and condensible PM data from this test are assigned an A rating, and the controlled PM data are assigned a B rating because scrubber parameters are not included in the report. The testing methodology was sound, no problems were reported during testing, and adequate process data were provided. The formaldehyde data are assigned a D rating because NIOSH Method 3500 has been shown to give results that are biased high. The acetic acid and VOC data are assigned a C rating, because several assumptions were necessary to quantify acetic acid and VOC using Method 18. The VOC concentrations were measured on a gas chromatograph calibrated against acetaldehyde and were reported as acetaldehyde. These results were converted to a methane basis. Pertinent test data, process data, and emission factor calculations are provided in Appendix A.

4.2.1.3 Reference 3. This test report documents a compliance emission test conducted on December 6 through 10, 1993, at the Oscar Mayer Foods Corporation's meat smoking facility in Madison, Wisconsin. The sources tested include three continuous smokehouses and one batch smokehouse. Uncontrolled filterable PM, condensible organic PM, condensible inorganic PM, and VOC (as propane) emissions from the four smokehouses were measured using EPA Method 5 (including back-half analysis for condensible PM) and EPA Method 25A. The calculated VOC emission factors were converted to a methane basis. Three valid test runs were completed for each source/pollutant combination. The smokehouses were tested separately, and process rates (including meat throughput and sawdust usage) were documented for each of the tests. Pertinent test data, process data, and emission factor calculations are provided in Appendix B.

The data from this test are assigned an A rating. The testing methodology was sound, no problems were reported during the valid test runs, and the process data were complete.

4.2.1.4 Reference 4. This stack test review presents data from a compliance emission test conducted on February 15 through 18, 1994, at the Oscar Mayer Foods Corporation's meat smoking facility in Madison, Wisconsin. The sources tested were three continuous smokehouses. The products of the three smokehouses were beef franks, pork wieners, and turkey wieners. Uncontrolled filterable PM, condensible organic PM, condensible inorganic PM, and VOC (as propane) emissions from the three smokehouses were measured using EPA Method 5 (including back-half analysis for condensible PM) and EPA Method 25A. The calculated VOC emission factors were converted to a methane basis. Three valid test runs were completed for each source/pollutant combination. The smokehouses were tested separately, and process rates (including meat throughput and sawdust usage) were documented for each of the tests. Pertinent test data, process data, and emission factor calculations are provided in Appendix C.

The data from this test are assigned a B rating. The testing methodology was sound, no problems were reported during the valid test runs, and the process data were complete. The data are not rated A because the document is not the original source of the data.

4.2.1.5 Reference 5. This memorandum contains process data and test summary information for the emission tests documented in References 1 and 2. No original emission data are contained in the report, but the process rates were used for emission factor development, in conjunction with References 1 and 2.

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

No data suitable for use in AP-42 were found in XATEF or SPECIATE.

4.2.3 Review of Test Data in AP-42 Background File

All of the emission factors in the existing AP-42 section are based on summary data from a 1970 publication that does not contain any original test data. Furthermore, this publication does not reference any emission tests, and the emission factors appear to have been calculated from data collected in conversations with State agencies in conjunction with studies conducted in the early 1960's. These emission factors are not included in the revised AP-42 section because they do not meet the minimum criteria described in Section 3 of this report.

4.2.4 Results of Data Analysis

This section discusses the analysis of the data and describes how the data were combined to develop average emission factors for meat smokehouses. The emission factors are in units of pollutant mass per mass of wood (sawdust or wood chips) used. Normally, emission factors are based on either units of raw material or units of product. In this industry, the amount of smoke flavor applied to the meats varies; consequently the emissions are dependent on the quantity of wood (or liquid smoke) used, rather than the quantity of meat processed. Discussions with State agency personnel and the emission data gathered indicate that smokehouse emissions are related to wood use rather than the amount of meat smoked. A summary of the test data obtained from References 2 through 4 are presented in Table 4-1 and the average emission factors are shown in Table 4-2. Because the emission factors presented in Table 4-2 were developed using data from only two facilities, the emission factors may not be representative of the entire industry.

The emission factor ratings assigned to each of the average emission factors developed for meat smokehouses are based on the emission data ratings and the number of data points used to develop the average emission factor. Of the 52 data points from which emission factors were developed, 22 are A-rated, 18 are B-rated, 8 are C-rated, and 4 are D-rated. A- and B-rated data were not averaged with C- and D-rated data, which were only used when A- or B-rated data were not available.

Filterable PM. An emission factor of 12 kg/Mg for uncontrolled filterable PM emissions from batch smokehouses was developed from a single A-rated test. This emission factor is rated D because it is based on a single test.

Emission factors for uncontrolled filterable PM emissions from continuous smokehouses were developed from five A-rated and three B-rated tests. Two of these tests were conducted on the same smokehouse, and the data from these two tests were averaged first, and then combined with the other data. The results of these tests ranged from 12 to 55 kg/Mg, with an average emission factor of 33 kg/Mg. This emission factor is rated D because the seven smokehouses tested were located at only two facilities.

Emission factors for controlled filterable PM emissions from continuous smokehouses were developed from two B-rated tests. Both smokehouses were controlled by vortex wet scrubbers followed by demisters. The calculated control efficiency of the scrubber/demister system is about

TABLE 4-1. SUMMARY OF TEST DATA FOR SMOKEHOUSES

Source/ control	Product	Source of smoke	Pollutant	No. of test runs	Data rating	Emission factor range, kg/Mg (lb/ton) of wood used	Average emission factor, kg/Mg (lb/ton) of wood used	Ref. No.
Continuous smokehouse	ND	Chips and sawdust	Filterable PM	3	A	26.7-30.8 (53.4-61.6)	28.6 (57.2)	2
Continuous smokehouse	ND	Chips and sawdust	Condensible organic PM	3	A	6.14-9.71 (12.3-19.4)	8.09 (16.2)	2
Continuous smokehouse	ND	Chips and sawdust	Condensible inorganic PM	3	A	11.3-21.0 (22.6-42.0)	16.0 (32.0)	2
Continuous smokehouse	ND	Chips and sawdust	Formaldehyde	3	D	0.618-0.685 (1.24-1.37)	0.647 (1.29)	2
Continuous smokehouse	ND	Chips and sawdust	Acetic acid	3	C	2.41-2.58 (4.82-5.16)	2.49 (4.98)	2
Continuous smokehouse	ND	Chips and sawdust	VOC as methane[a]	3	C	12.8-15.5 (25.6-31.0)	14.3 (28.6)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Filterable PM	3	B	5.80-9.32 (11.6-18.6)	7.78 (15.6)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Condensible organic PM	3	B	2.70-4.06 (5.40-8.12)	3.25 (6.50)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Condensible inorganic PM	3	B	4.21-5.54 (8.42-11.1)	5.07 (10.1)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Formaldehyde	3	D	0.280-0.376 (0.56-0.75)	0.315 (0.63)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Acetic acid	3	C	1.15-1.86 (2.30-3.72)	1.52 (3.04)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	VOC as methane[a]	3	C	1.97-2.53 (3.94-5.06)	2.19 (4.38)	2
Continuous smokehouse	ND	Chips and sawdust	Filterable PM	3	A	19.4-26.7 (38.8-53.4)	22.0 (44.0)	2
Continuous smokehouse	ND	Chips and sawdust	Condensible organic PM	3	A	7.06-8.78 (14.1-17.6)	7.80 (15.6)	2
Continuous smokehouse	ND	Chips and sawdust	Condensible inorganic PM	3	A	17.6-25.4 (35.2-50.8)	22.4 (44.8)	2
Continuous smokehouse	ND	Chips and sawdust	Formaldehyde	3	D	0.550-0.685 (1.10-1.37)	0.627 (1.25)	2

TABLE 4-1. (continued)

Source/ control	Product	Source of smoke	Pollutant	No. of test runs	Data rating	Emission factor range, kg/Mg (lb/ton) of wood used	Average emission factor, kg/Mg (lb/ton) of wood used	Ref. No.
Continuous smokehouse	ND	Chips and sawdust	Acetic acid	3	C	1.95-2.14 (3.9-4.28)	2.05 (4.10)	2
Continuous smokehouse	ND	Chips and sawdust	VOC as methane[a]	3	C	8.22-11.6 (16.44-23.2)	9.71 (19.42)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Filterable PM	3	B	5.04-6.42 (10.08-12.84)	5.57 (11.14)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Condensible organic PM	3	B	2.49-3.11 (4.98-6.22)	2.70 (5.40)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Condensible inorganic PM	3	B	3.59-6.16 (7.18-12.32)	4.76 (9.52)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Formaldehyde	3	D	0.251-0.338 (0.502-0.676)	0.306 (0.612)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	Acetic acid	3	C	1.25-1.34 (2.50-2.68)	1.30 (2.60)	2
Continuous smokehouse with vortex wet scrubber and demister	ND	Chips and sawdust	VOC as methane[a]	3	C	2.00-2.32 (4.00-4.64)	2.20 (4.40)	2
Continuous smokehouse	Wieners	Sawdust	Filterable PM	3	A	43.1-72.4 (86.2-144.8)	54.7 (109.4)	3
Continuous smokehouse	Wieners	Sawdust	Condensible organic PM	3	A	15.5-29.1 (31.0-58.2)	22.1 (44.2)	3
Continuous smokehouse	Wieners	Sawdust	Condensible inorganic PM	3	A	13.8-18.3 (27.6-36.6)	16.5 (33.0)	3
Continuous smokehouse	Wieners	Sawdust	VOC as methane[a]	3	A	5.85-13.6 (11.70-27.2)	9.18 (18.36)	3
Continuous smokehouse	Wieners	Sawdust	Filterable PM	3	A	38.2-44.7 (76.4-89.4)	41.3 (82.6)	3[b]
Continuous smokehouse	Wieners	Sawdust	Condensible organic PM	3	A	18.8-22.6 (37.6-45.2)	21.2 (42.4)	3[b]
Continuous smokehouse	Wieners	Sawdust	Condensible inorganic PM	3	A	13.4-30.5 (26.8-61.0)	20.9 (41.8)	3[b]

TABLE 4-1. (continued)

Source/ control	Product	Source of smoke	Pollutant	No. of test runs	Data rating	Emission factor range, kg/Mg (lb/ton) of wood used	Average emission factor, kg/Mg (lb/ton) of wood used	Ref. No.
Continuous smokehouse	Wieners	Sawdust	VOC as methane[a]	3	A	12.1-18.3 (24.2-36.6)	15.7 (31.4)	3[b]
Batch smokehouse	Sausage	Sawdust	Filterable PM	3	A	6.66-19.1 (13.32-38.2)	11.5 (23.0)	3
Batch smokehouse	Sausage	Sawdust	Condensible organic PM	3	A	7.27-10.9 (14.54-21.8)	9.70 (19.4)	3
Batch smokehouse	Sausage	Sawdust	Condensible inorganic PM	3	A	4.24-7.27 (8.48-14.54)	5.51 (11.02)	3
Batch smokehouse	Sausage	Sawdust	VOC as methane[a]	3	A	18.4-28.3 (36.8-56.6)	21.9 (43.8)	3
Continuous smokehouse	Bologna	Sawdust	Filterable PM	3	A	10.7-13.7 (21.4-27.4)	12.0 (24.0)	3
Continuous smokehouse	Bologna	Sawdust	Condensible organic PM	3	A	12.7-14.9 (25.4-29.8)	13.9 (27.8)	3
Continuous smokehouse	Bologna	Sawdust	Condensible inorganic PM	3	A	9.69-15.8 (19.38-31.6)	12.4 (24.8)	3
Continuous smokehouse	Bologna	Sawdust	VOC as methane[a]	3	A	7.16-14.3 (14.32-28.6)	10.2 (20.4)	3
Continuous smokehouse	Beef franks	Sawdust	Filterable PM	3	B	40.0-46.9 (80.0-93.8)	43.9 (87.8)	4[c]
Continuous smokehouse	Beef franks	Sawdust	Condensible organic PM	3	B	16.2-18.8 (32.4-37.6)	17.2 (34.4)	4[c]
Continuous smokehouse	Beef franks	Sawdust	Condensible inorganic PM	3	B	16.3-18.4 (32.6-36.8)	17.7 (35.4)	4[c]
Continuous smokehouse	Beef franks	Sawdust	VOC as methane[a]	3	B	3.12-10.1 (6.24-20.2)	5.78 (11.56)	4[c]
Continuous smokehouse	Pork wieners	Sawdust	Filterable PM	3	B	41.8-50.8 (83.6-101.6)	45.3 (90.6)	4
Continuous smokehouse	Pork wieners	Sawdust	Condensible organic PM	3	B	22.5-39.9 (45.0-79.8)	30.4 (60.8)	4
Continuous smokehouse	Pork wieners	Sawdust	Condensible inorganic PM	3	B	14.1-18.9 (28.2-37.8)	16.3 (32.6)	4
Continuous smokehouse	Pork wieners	Sawdust	VOC as methane[a]	3	B	2.72-9.45 (5.44-18.9)	5.09 (10.18)	4
Continuous smokehouse	Turkey wieners	Sawdust	Filterable PM	3	B	16.8-34.7 (33.6-69.4)	26.9 (53.8)	4
Continuous smokehouse	Turkey wieners	Sawdust	Condensible organic PM	3	B	17.2-55.7 (34.4-111.4)	35.6 (71.2)	4
Continuous smokehouse	Turkey wieners	Sawdust	Condensible inorganic PM	3	B	5.19-38.5 (10.38-77.0)	21.8 (43.6)	4
Continuous smokehouse	Turkey wieners	Sawdust	VOC as methane[a]	3	B	3.71-12.6 (7.42-25.2)	8.04 (16.08)	4

ND = No data available

[a]May include nonreactive compounds.

[b]Smokehouse tested was the same smokehouse as the first Reference 4 smokehouse.

[c]Smokehouse tested was the same smokehouse as the second Reference 3 smokehouse.

TABLE 4-2. SUMMARY OF EMISSION FACTORS FOR SMOKEHOUSES

(Emission factors represent uncontrolled emissions unless noted)

Source/control	Pollutant	No. of tests	Emission factor rating	Emission factor range, kg/Mg (lb/ton) of wood used	Average emission factor, kg/Mg (lb/ton) of wood used	Ref. Nos.
Batch smokehouse	Condensible inorganic PM	1	D	5.51 (11.02)	5.51 (11.02)	3
Batch smokehouse	Condensible organic PM	1	D	9.70 (19.4)	9.70 (19.4)	3
Batch smokehouse	Filterable PM	1	D	11.5 (23.0)	11.5 (23.0)	3
Batch smokehouse	Total PM	1	D	26.7 (53.4)	26.7 (53.4)	3
Batch smokehouse	VOC as methane[a]	1	D	21.9 (43.8)	21.9 (43.8)	3
Continuous smokehouse with vortex wet scrubber and demister	Acetic acid	2	E	1.30-1.52 (2.60-3.04)	1.41 (2.82)	2
Continuous smokehouse	Acetic acid	2	E	2.05-2.49 (4.10-4.98)	2.27 (4.54)	2
Continuous smokehouse	Condensible inorganic PM	8	D	12.4-22.4 (24.8-44.8)	17.8 (35.6)	2, 3, 4
Continuous smokehouse	Condensible organic PM	8	D	7.80-35.6 (15.60-71.2)	19.6 (39.2)	2, 3, 4
Continuous smokehouse	Filterable PM	8	D	12.0-54.7 (24.0-109.4)	33.2 (66.4)	2, 3, 4
Continuous smokehouse with vortex wet scrubber and demister	Condensible inorganic PM	2	D	4.76-5.07 (9.52-10.14)	4.92 (9.84)	2
Continuous smokehouse with vortex wet scrubber and demister	Condensible organic PM	2	D	2.70-3.25 (5.40-6.50)	2.98 (5.96)	2
Continuous smokehouse with vortex wet scrubber and demister	Filterable PM	2	D	5.57-7.78 (11.14-15.56)	6.68 (13.36)	2
Continuous smokehouse with vortex wet scrubber and demister	Formaldehyde	2	E	0.306-0.315 (0.612-0.630)	0.311 (0.622)	2
Continuous smokehouse	Formaldehyde	2	E	0.627-0.647 (1.25-1.29)	0.637 (1.27)	2
Continuous smokehouse with vortex wet scrubber and demister	VOC as methane[a]	2	E	2.19-2.20 (4.38-4.40)	2.20 (4.40)	2
Continuous smokehouse	VOC as methane[a]	6	D	5.09-10.7 (10.18-21.4)	8.65 (17.3)	3, 4
Continuous smokehouse with vortex wet scrubber and demister	Total PM	2	D	13.0-16.1 (26.0-32.2)	14.6 (29.2)	2
Continuous smokehouse	Total PM	8	D	32.2-113 (64.4-226)	70.6 (141.2)	2, 3, 4

[a]May include nonreactive compounds.

80 percent. The results of these tests ranged from 5.6 to 7.8 kg/Mg, with an average emission factor of 6.7 kg/Mg. This emission factor is rated D because it is based on only two tests.

Condensible inorganic PM. An emission factor of 5.5 kg/Mg for uncontrolled condensible inorganic PM emissions from batch smokehouses was developed from a single A-rated test. This emission factor is rated D because it is based on a single test.

Emission factors for uncontrolled condensible inorganic PM emissions from continuous smokehouses were developed from five A-rated and three B-rated tests. Two of these tests were conducted on the same smokehouse, and the data from these two tests were averaged first, and then combined with the other data. The results of these tests ranged from 12 to 22 kg/Mg, with an average emission factor of 18 kg/Mg. This emission factor is rated D because the seven smokehouses tested were located at only two facilities.

Emission factors for controlled condensible inorganic PM emissions from continuous smokehouses were developed from two B-rated tests. Both smokehouses were controlled by vortex wet scrubbers followed by demisters. The calculated control efficiency of the scrubber/demister system is about 73 percent. The results of these tests ranged from 4.8 to 5.1 kg/Mg, with an average emission factor of 4.9 kg/Mg. This emission factor is rated D because it is based on only two tests.

Condensible organic PM. An emission factor of 9.7 kg/Mg for uncontrolled condensible organic PM emissions from batch smokehouses was developed from a single A-rated test. This emission factor is rated D because it is based on a single test.

Emission factors for uncontrolled condensible organic PM emissions from continuous smokehouses were developed from five A-rated and three B-rated tests. Two of these tests were conducted on the same smokehouse, and the data from these two tests were averaged first, and then combined with the other data. The results of these tests ranged from 7.8 to 36 kg/Mg, with an average emission factor of 20 kg/Mg. This emission factor is rated D because the seven smokehouses tested were located at only two facilities.

Emission factors for controlled condensible organic PM emissions from continuous smokehouses were developed from two B-rated tests. Both smokehouses were controlled by vortex wet scrubbers followed by demisters. The calculated control efficiency of the scrubber/demister system is about 85 percent. The results of these tests ranged from 2.7 to 3.3 kg/Mg, with an average emission factor of 3.0 kg/Mg. This emission factor is rated D because it is based on only two tests.

Total PM. An emission factor of 27 kg/Mg for uncontrolled total PM emissions from batch smokehouses was developed from a single A-rated test. This emission factor is the sum of the filterable and condensible PM emission factors and is rated D.

Emission factors for uncontrolled total PM emissions from continuous smokehouses were developed from five A-rated and three B-rated tests. Two of these tests were conducted on the same smokehouse, and the data from these two tests were averaged first, and then combined with the other data. The average total PM emission factor of 71 kg/Mg is the sum of the filterable and condensible PM emission factors. This emission factor is rated D because the seven smokehouses tested were located at only two facilities.

Emission factors for controlled total PM emissions from continuous smokehouses were developed from two B-rated tests. Both smokehouses were controlled by vortex wet scrubbers followed by demisters. The calculated control efficiency of the scrubber/demister systems is about 79 percent. The results of these tests ranged from 13 to 16 kg/Mg, with an average emission factor of 15 kg/Mg. This emission factor is rated D because it is based on only two tests. No emission factor for controlled total PM emissions from batch smokehouses is presented because no test data were available.

Volatile organic compounds. An emission factor of 21.9 kg/Mg for uncontrolled emissions of VOC (as methane) from batch smokehouses was developed from a single A-rated test. This emission factor is rated D because it is based on a single test.

Emission factors for uncontrolled VOC (as methane) emissions from continuous smokehouses were developed from three A-rated, three B-rated tests, and two C-rated tests. Two of these tests were conducted on the same smokehouse, and the data from these two tests were averaged first, and then combined with the other data. The C-rated data were not used in calculating the average emission factor. The results of the A- and B-rated tests ranged from 5.09 to 10.7 kg/Mg, with an average emission factor of 8.65 kg/Mg. This emission factor is rated D because the five smokehouses tested were located at only two facilities.

Emission factors for controlled VOC (as methane) emissions from continuous smokehouses were developed from two C-rated tests. The smokehouses were each controlled by a vortex wet scrubber followed by a demister. The control efficiency of the scrubber/demister systems was about 85 percent. The results of these tests ranged from 2.19 to 2.20 kg/Mg, with an average emission factor of 2.20 kg/Mg. This emission factor is rated E because it is based on C-rated data. No other data were available for controlled VOC emissions.

Acetic acid. Emission factors for uncontrolled acetic acid emissions from continuous smokehouses were developed from two C-rated tests. The results of these tests ranged from 2.1 to 2.5 kg/Mg, with an average emission factor of 2.3 kg/Mg. This emission factor is rated E because it is based on C-rated data.

Emission factors for controlled acetic acid emissions from continuous smokehouses were developed from two C-rated tests. The smokehouses were each controlled by a vortex wet scrubber followed by a demister. The control efficiency of the scrubber/demister systems was about 39 percent. The results of these tests ranged from 1.3 to 1.5 kg/Mg, with an average emission factor of 1.4 kg/Mg. This emission factor is rated E because it is based on C-rated data.

Formaldehyde. Emission factors for uncontrolled formaldehyde emissions from continuous smokehouses were developed from two D-rated tests. The results of these tests ranged from 0.63 to 0.65 kg/Mg, with an average emission factor of 0.64 kg/Mg. This emission factor is rated E because it is based on D-rated data.

Emission factors for controlled formaldehyde emissions from continuous smokehouses were developed from two D-rated tests. The smokehouses were each controlled by a vortex wet scrubber followed by a demister. The control efficiency of the scrubber/demister systems was about 51 percent. The results of these tests ranged from 0.31 to 0.32 kg/Mg, with an average emission factor of 0.31 kg/Mg. This emission factor is rated E because it is based on D-rated data.

References For Section 4

1. *Report on Compliance Testing*, Hillshire Farm & Kahn's, New London, WI, February 9, 1993.

2. *KSI-2 & KSI-3 Continuous Smokehouses Stack Emissions Testing*, Hillshire Farm & Kahn's, New London, WI, September 19-20, 1991.

3. *Report on Diagnostic Testing*, Oscar Mayer Foods Corporation, Madison, WI, January 13, 1994.

4. Written correspondence from D. Sellers, Wisconsin Department of Natural Resources, Madison, WI, to Wisconsin Department of Natural Resources Files, Madison, WI, June 17, 1994.

5. Written correspondence from A. Seeber, Wisconsin Department of Natural Resources, Madison, WI, to Wisconsin Department of Natural Resources Files, Madison, WI, February 22, 1993.

5. AP-42 SECTION 9.5.2

[Not presented here. See instead current AP-42 Section 9.5.2]