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MRI REPORT

Emission Factor Documentation for AP-42 Section 10.1

Lumber and Wood Products Manufacturing and Woodworking Operations

Revised Draft Report

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

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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 Contract No. 68-D2-0159, Work Assignment No. I-10. Mr. Dallas Safriet was the requester of the work. The report was prepared by David Bullock, Brian Shrager, and Richard Marinshaw.

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EMISSION FACTOR DOCUMENTATION FOR AP-42 SECTION 10.1
Lumber and Wood Products Manufacturing and Woodworking Operations

1. INTRODUCTION

The document Compilation of Air Pollutant Emissions 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 situations, such as making source-specific emission estimates for areawide inventories for dispersion modeling, developing control strategies, screening sources for compliance purposes, 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 10.1, Lumber and Wood Products Manufacturing and Woodworking Operations.

This background report consists of five sections. Section 1 includes the introduction to the report. Section 2 gives a description of the lumber and wood products industry. It includes a characterization of the industry, an overview of the different process types, a description of emissions, and a description of the technology used to control emissions resulting from lumber and wood product manufacturing. Section 3 is a review of process/emission data collection and laboratory analysis procedures. It describes the literature search, the screening of emission data reports, and the quality rating system for both emission data and emission factors. Section 4 details revisions to the existing AP-42 section narrative and pollutant emission factor development. It includes the review of specific data sets and the results of data analysis. Section 5 presents the AP-42 Section 10.1, Lumber and Wood Products Manufacturing and Woodworking Operations.

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2. INDUSTRY DESCRIPTION

Wood products from sawmills and planing mills include lumber; round timbers, mine timbers, and railroad ties; shingles and shakes; cooperage; wood chips; and wood flour. Sawdust and shavings are not wood products in themselves, but are useful by-products of lumber production.

Sawmill and planing mill products are classified under three Standard Industrial Classification (SIC) codes: sawmills and planing mills, general (2421); hardwood dimension and flooring mills (2426); and special product sawmills, not elsewhere classified (n.e.c.) (2429). Special product sawmills included in SIC 2429 primarily manufacture cooperage stock, wood shingles and shakes, and excelsior. The six-digit Source Classification Code (SCC) for the industry is 3-07-008.

2.1 CHARACTERIZATION OF THE INDUSTRY[1]

There are approximately 5,700 general sawmills and planing mills operating in the United States. There are approximately 740 hardwood dimension and flooring mills, and approximately 230 special product sawmills, n.e.c. Table 2-1 lists by SIC code the States in which the largest numbers of these mills are located. Total production from all sawmills and planing mills in 1987 was valued at $18.7 billion.

2.2 PROCESS DESCRIPTION[2-4]

Although all lumber will not go through all of the processes available in a sawmill, most modern sawmills have equipment to accomplish all the steps described in the subsections below. For example, some lumber will not be remanufactured in any way (resawed or re-edged) but may go directly from the edger to the trimmer. Some sawmills do not dry lumber but sell it green, while others produce only rough, unsurfaced lumber. Figure 2-1 presents a generic lumber manufacturing process flow diagram. The specific processes that are found in lumber manufacturing facilities are described below.

Debarking. Debarking is the process of removing the bark from a log before further manufacture. One reason for debarking is to remove bark from wood that is to be chipped for board or pulp use because any substantial quantity of bark in the chips is detrimental to board or pulp

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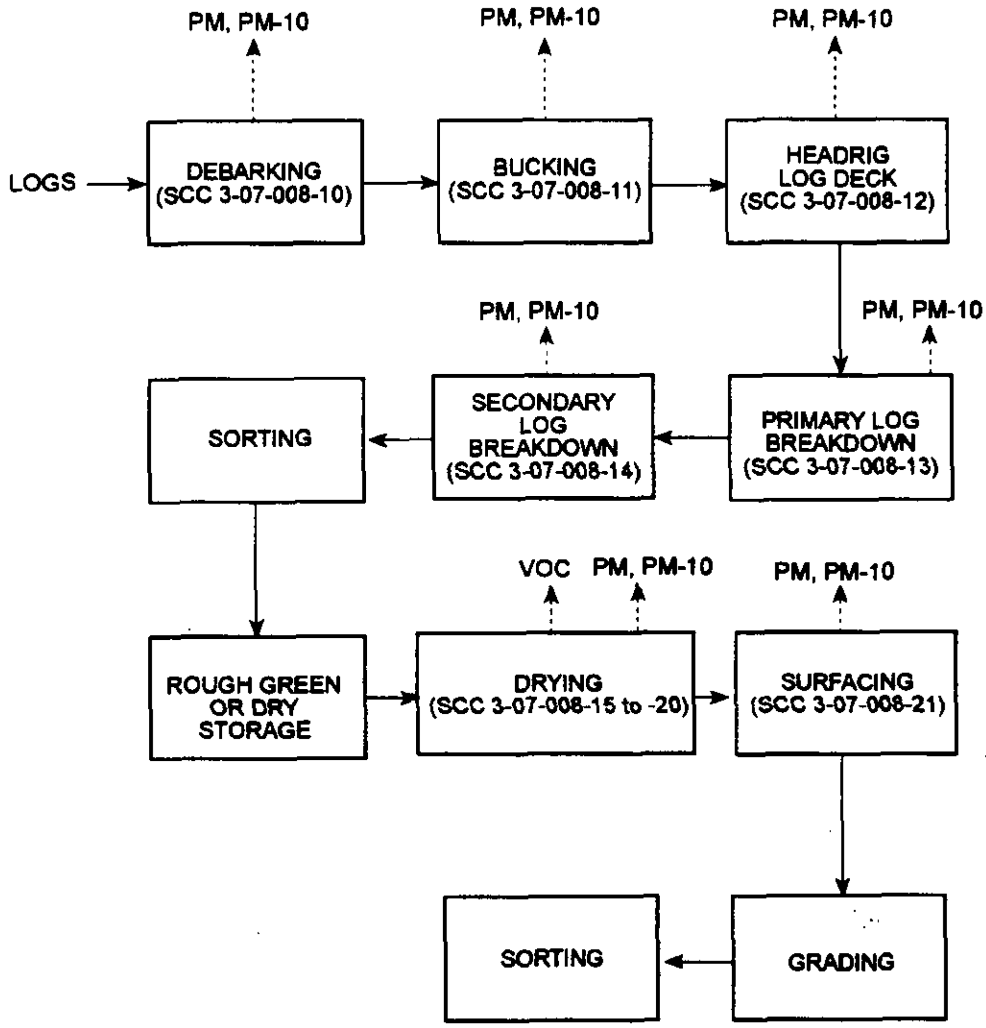
TABLE 2-1. DOMESTIC LUMBER MILLS IN 1987[a]

Industry		Geographic Area	No. of plants		
SIC Code	Product		With < 20 Employees	With ≥ 20 Employees	Total
2421	Sawmills and planing mills, general	Oregon	111	163	274
		California	93	120	213
		Washington	131	110	241
		Georgia	119	85	204
		Total	454	478	932
		United States	4,045	1,697	5,742
2426	Hardwood dimension and flooring mills	Tennessee	17	33	50
		North Carolina	81	80	161
		Mississippi	21	20	41
		Virginia	5	13	18
		Total	124	146	270
		United States	394	343	737
2429	Special product sawmills, n.e.c.		NA	NA	NA
		United States	202	32	234

n.e.c. = not elsewhere classified
NA = data not available.
[a]Reference 1.



WOOD RESIDUE SOURCES	SCC
Sawdust/shavings handling & transfer	3-07-008-22
Sawdust/shavings storage piles	3-07-008-23
Sanderdust handling & transfer	3-07-008-24
Wood residue handling & transfer	3-07-008-25

Figure 2-1. General lumber manufacturing process.
(Source Classification Code in parentheses)

quality. Debarking also provides other benefits. Removal of sand and grit along with the bark during debarking greatly decreases the rate at which saws are dulled, reducing downtime in the mill. Also, bark has become an important source of fuel for energy generation.

Bucking. Bucking refers to the process of crosscutting long logs to shorter segments suitable for breakdown on a sawmill headrig. The objective of this process is to manufacture short logs that will maximize lumber yield and grade recovery on the headrig while separating out material that is suited only for pulpwood or hog fuel.

Headrig Log Deck. The headrig log deck serves as a conveyor between the bucking station and the primary breakdown machine to deliver logs that have been bucked to length for the headrig.

Primary Log Breakdown. In the primary breakdown step, the log is evaluated, oriented, held, transported, and cut into various sizes to be conveyed elsewhere for further manufacture. The primary breakdown of the log is accomplished by one of two methods: by placing the log on a carriage rig, which travels on rails and conveys the log back and forth through the saw, or by passing the log only once through a single-pass headrig.

Secondary Log Breakdown. After primary breakdown on the headrig, the lumber may only require edging or trimming, or cutting to width and length. Most mills do, however, require a greater degree of secondary breakdown, such as sawing or resawing to obtain a board.

Sorting. The various sorting systems available have the common goal of getting pieces of lumber of the same thickness, width, and length into a single stack so they can be easily handled by mechanical means and transported to the next operation. Because sorting of green and dry lumber is usually identical, almost any sorting system can be used for rough green, rough dry, planed green, or dry lumber. In fact, some mills have only one sorter and use it alternately for green, then dry, lumber.

Rough Green and Dry Storage. After lumber is manufactured, sorted, and stacked, it is normally transported to a rough green storage area if it is to be planed in the green, or it is kiln-dried prior to planing. Before lumber is air- or kiln-dried, it is stacked in alternating layers with "stickers," or spacing sticks. In arranging and operating the green storage yard or shed, like widths and lengths

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are stored together so they can be moved in an orderly fashion to the kilns in order to get full kiln charges by widths and lengths.

Drying. Both air-seasoning or forced kiln drying simply evaporate the water from the surface of lumber under controlled conditions until the moisture content reaches a desired level. The desired moisture content varies widely with wood species. Although particular advantages exist for drying a species by one method or another, almost any species can be air dried, given enough time and a location where relative humidity will permit.

Surfacing, Grading, and Sorting. Lumber is typically handled and sorted twice. After being trimmed and edged, lumber is sorted by species, size, and grade. Then, after it is dried and surfaced, it will again be graded, grade-stamped if softwood lumber, sorted, and packaged for shipment. A wide variety of lumber-sorting equipment is available for use at the green, or dry, end of the mill. In the simplest system, the lumber is manually pulled and sorted as it proceeds down a green or dry chain. Manual lumber handling is eliminated in modern mills by mechanical sorters that can be controlled by a single grader-operator. Mechanical sorters exist that can sort lumber automatically by length, width, or thickness.

Wood Residue Handling. Most wood product mills employ pneumatic transfer systems to remove wood residue from each production operation. These systems are a convenient means of transporting wood residue to common collection points where it may be used immediately or stored for future use. Sawdust produced in sawmill operations is often used for fuel at or near the point of production. It is also used for meat smoking, as a soil conditioner and mulch, as stable and kennel bedding, as insulation, and in the manufacture of other products such as particleboard, stucco, and plaster. Shavings produced in planer operations are often used for fuel, either as shavings or in the form of wood briquettes. They are also used as packing material, as stable and kennel bedding, as insulation, and in the production of wood flour and wallboard.

2.3 EMISSIONS[2-7]

Almost any wood product manufacturing step involves the generation of sawdust, planer shavings, or sanderdust, all of which contribute to levels of atmospheric particulate matter (PM) and PM less than 10 micrometers in diameter (PM-10). Log debarking, log sawing, sawdust moving/storage, cutting, and sanding operations are all sources of PM and PM-10 emissions. Sawdust storage piles are usually left uncovered, partially because of the need for frequent material transfer. Particulate matter and PM-10 emissions occur at several points in the storage cycle: during material loading onto the pile, during disturbances by strong wind currents, and during loadout from the pile. The movement of trucks and loading equipment in the storage pile area is also a potentially significant source of dust. The only PM emission data available for lumber and wood products manufacturing are for filterable and condensible PM emissions. No data are available for PM-10 emissions.

Air drying and kiln drying are potential sources of volatile organic compounds (VOC) and condensible organic compound emissions, but emission data are available only for kiln drying. Also, fugitive VOC emissions may be generated from sawdust and shavings piles, but no VOC emission data are available for these sources.

2.4 CONTROLS[4-7]

Large-diameter cyclones historically have been the primary means of separating the wood residue from the airstream in the pneumatic transfer systems, although baghouses have been installed in some plants for this purpose. Hence, the pneumatic systems and cyclones or baghouses act as capture/collection systems for air pollution control and as product recovery systems.

Enclosures are the primary means of controlling fugitive PM and PM-10 emissions generated from sawdust storage piles by either wind erosion or handling operations. Enclosures are an effective way to control fugitive PM and PM-10 emissions from such open sources. Enclosures can either fully or partially enclose the storage pile and transfer operations. Types of passive enclosures traditionally used for open dust control that can be applied to sawdust piles include three-sided bunkers for storing bulk materials, storage silos for various types of material (in lieu of open piles), and open-ended buildings. Partial enclosures used for reducing windblown dust from large exposed areas and storage piles include porous wind screens and similar types of barriers (e.g., trees). The principle of the wind fence/barrier is to provide an area of reduced wind velocity, which allows settling of the large particles and reduces the particle flux from the exposed surface on the leeward side of the fence/barrier.

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REFERENCES FOR SECTION 2

1. Bureau of the Census, U. S. Department of Commerce, *1987 Census of Manufactures*, Industry Series, MC87-I-24A, Logging, Sawmills, and Planing Mills, Industries 2411, 2426, and 2429, Washington, D.C., U. S. Government Printing Office, May 1990.

2. J.G. Haygreen and J. L. Bowyer, *Forest Products and Wood Science: An Introduction,* 2nd edition, Iowa State University Press, Ames, IA, 1989.

3. E.M. Williston, *Lumber Manufacturing: The Design and Operation of Sawmills and Planer Mills*, Miller-Freeman Publications, Inc., San Francisco, CA, Miller-Freeman Publications, Inc. 1976.

4. Written communication (letter No. 1) from David H. Word, National Council of the Paper Industry for Air and Stream Improvement, Gainesville, FL, to Dallas Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 18, 1994.

5. J. W. Walton, *et al.*, "Air Pollution in the Woodworking Industry", presented at the 68th Annual Meeting of the Air Pollution Control Association, Boston, MA, June 1975.

6. C.F. Sexton, "Control of Atmospheric Emissions from the Manufacturing of Furniture", presented at the 2nd Annual Industrial Air Pollution Control Conference, Knoxville, TN, April 20-21, 1994.

7. PEDCo Environmental, Inc., *Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions*. EPA-450/3-77-010. U. S. Environmental Protection Agency. 1977.

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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 Inventory Branch (EIB) 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) 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 *1990 DFPI Directory of the Forest Products Industry, 1987 Census of Manufactures*, and other sources. The Aerometric Information Retrieval System (AIRS) data base also was searched for data on the number of plants, plant location, and estimated annual emissions of criteria pollutants.

Numerous sources of information were investigated specifically for emission test reports and data. A search of the Test Method Storage and Retrieval (TSAR) data base revealed no test reports for sources within this segment of the wood products industry. The EPA library was searched for additional test reports. Using this information and information obtained on plant location from the *1990 DFPI Directory of the Forest Products Industry* and *1987 Census of Manufactures*, 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 wood products industry.

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

1. Emissions data must be from a primary reference:

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

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

2. The referenced study must contain test results based on more than one test run unless no other data are available and there are reasons to believe that the run is representative.

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

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

3.2 EMISSION DATA QUALITY RATING SYSTEM[1]

As part of the 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 fully 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 measured were controlled or uncontrolled.

Test data sets that were not excluded were assigned a quality rating. The rating system used was that specified by EIB 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. <u>Source operation</u>. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

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

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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. Laboratory 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[1]

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 Section 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.

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4. AP-42 SECTION DEVELOPMENT

4.1 REVISION OF SECTION NARRATIVE

The revised AP-42 section narrative expands the narrative included in Section 10.4, Woodworking Waste Collection Operations, in the previous version of AP-42. The revised section narrative includes a description of the industry, a description of the basic steps in processing logs into lumber, a process flow diagram, a description of emissions, and a discussion of emission controls used in the industry.

4.2 POLLUTANT EMISSION FACTOR DEVELOPMENT

A total of 20 references were documented and reviewed in the process of preparing the revised section on lumber and wood products manufacturing and woodworking operations. Table 4-1 presents a list of these references. Fourteen of the 20 references could not be used to develop emission factors. Table 4-2 lists the reasons for rejecting those references. Reviews of the remaining references appear in the following section.

4.2.1 Review of Specific Data Sets

4.2.1.1 Reference 5. This document presents industrial process fugitive particulate matter emission data for 24 industrial categories. Emission factors for log debarking and sawing are estimates based on material balance of the waste produced by the operation and engineering judgement of the amount that becomes airborne. An emission factor for sawdust pile loading, unloading, and storage is based on engineering judgement, which is based on observations from plant visits.

Although these emission factors were presented in a previous version of the AP-42 section on plywood manufacturing, this AP-42 section is the appropriate section for emission factors for such operations. However, because these data are based on engineering judgment with no supporting documentation, these emission factors were not rated and have not been incorporated into the revised AP-42 section.

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TABLE 4-1. REFERENCES FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS

Reference No.	Citation
1	David C. Nicholson, "Characteristics of Particulate Emissions from Particleboard Processes," paper presented at the Fifth Washington State University Symposium on Particleboard, Pullman, Washington, June 1971.
2	F. Glen Odell, "Air Quality Standards for Particleboard Plants," paper presented at the Fifth Washington State University Symposium on Particleboard, Pullman, Washington, June 1971.
3	Nero and Associates, Inc., *Receptor Model Source Emission Composition Library Development*, prepared under contract No. SB08320447/DU-83-CI53, U. S. Environmental Protection Agency, 1984.
4	Research Triangle Institute, *Control Techniques for Organic Emissions from Plywood Veneer Dryers*, prepared for Emission Standards and Engineering Division, U. S. Environmental Protection Agency, 1983.
5	PEDCo Environmental, *Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions*, EPA-450/3-77-010, U. S. Environmental Protection Agency, 1977.
6	Source test data supplied by Robert Harris, Oregon Department of Environmental Quality, Portland, OR, September 1975.
7	J.W. Walton, *et al.*, "Air Pollution in the Woodworking Industry," presented at the 68th Annual Meeting of the Air Pollution Control Association, Boston, MA, June 1975.
8	J.D. Patton and J.W. Walton, "Applying the High Volume Stack Sampler To Measure Emissions from Cotton Gins, Woodworking Operations, and Feed and Grain Mills," presented at the 3rd Annual Industrial Air Pollution Control Conference, Knoxville, TN, March 29-30, 1973.
9	C.F. Sexton, "Control of Atmospheric Emissions from the Manufacturing of Furniture," presented at the 2nd Annual Industrial Air Pollution Control Conference, Knoxville, TN, April 20-21, 1972.
10	A. Mick and D. McCargar, "Air Pollution Problems in Plywood, Particleboard, and Hardboard Mills in the Mid-Willamette Valley," Mid-Willamette Valley Air Pollution Authority, Salem, OR, March 24, 1969.
11	Information supplied by the North Carolina Department of Natural and Economic Resources, Raleigh, NC, December 1975.
12	Guillen, R., and E. Wadington, *Stone Container Corporation, Flagstaff, Arizona, Lumber Kiln #3, Emission Test Report, 1/20-25/92*, Energy and Environmental Measurement Corporation, Tucson, Arizona, 1992.
13	Written communication, from L.M. Lamb, Sirrine Environmental Consultants, to J. Stamps, Weyerhaeuser Company, concerning lumber VOC test results for Weyerhaeuser Lumber facility, Grifton, North Carolina, July 6, 1992.
14	*Source Emissions Survey of International Paper Company Gurdon Wood Products Plant Lumber Kiln Number 1 Vent Stack, Gurdon, Arkansas*, prepared by METCO Environmental, for International Paper Company, Gurdon, Arkansas, April 1992.

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TABLE 4-1. (continued)

Reference No.	Citation
15	*Report on Diagnostic Testing*, prepared by Clean Air Engineering for Weyerhauser Company, Bruce, Mississippi, September 2, 1992.
16	*Emission Test Report, Weyerhauser Company, Mountain Pine, Arkansas, Volume 1-Report*, Radian Corporation, Austin, TX, November 10, 1992.
17	*Emission Test Report, Weyerhauser Company, Mountain Pine Arkansas*, Radian Corporation, Austin, TX, December 28, 1992.
18	*Draft Report on Compliance Testing*, prepared by Clean Air Engineering for Weyerhauser Company, Bruce, Mississippi, June 18, 1993.
19	Written communication from David H. Word, NCASI, Gainesville, FL, to Dallas Safriet, U. S. Environmental Protection Agency, Research Triangle Park, NC, March 18, 1994.
20	Written communication from Gary McAlister, U. S. Environmental Protection Agency, Research Triangle Park, NC, to Ron Myers, U. S. Environmental Protection Agency, Research Triangle Park, NC, May 7, 1993.

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TABLE 4-2. REFERENCES REJECTED FOR EMISSION FACTOR DEVELOPMENT

Reference No.	Reason(s) for rejection
1	Secondary reference. Lacked a significant amount of process detail and background information.
2	Secondary reference. No description of test methods used. No process data or background information.
3	Secondary reference. No process data or background information.
4	Secondary reference. Lacked a significant amount of process detail and background information.
7	Secondary reference. Lacked a significant amount of process detail and background information.
8	Secondary reference. Lacked a significant amount of process detail and background information.
9	No data useful for developing emission factors; cited in support of text subsections presenting general background information and general emission and control information only.
10	No data useful for developing emission factors; cited in support of text subsections presenting general background information and general emission and control information only.
11	No data useful for developing emission factors; cited in support of text subsections presenting general background information and general emission and control information only.
13	No data useful for developing emission factors; laboratory analysis of wood samples using method 25D; not possible to relate measured VOC emissions from wood sample to emissions from a lumber kiln. (Estimated emission factors developed from the data ranged from 2.04 to 3.97 lb VOC/10^3 board feet, with an average of 3.14 lb VOC/10^3 board feet.)
14	No data useful for developing emission factors; no process information provided; only one vent of 12 was tested; no volumetric flow measurements were taken of the 11 untested vents; it is unclear whether emissions were measured from 1 vent or 1 pair of vents over 1 kiln drying cycle or 2 drying cycles; significant amounts of fugitive emissions from the kiln doors were observed.
19	Provides details on References 15-18, but contains no original source test data.
20	Contains no original source test data.

4.2.1.2 Reference 12. This reference documents measurements of condensible PM and total organic compounds (TOC) from an indirect steam-heated lumber kiln. The test was sponsored by the facility to determine if the facility should be subject to prevention of significant deterioration provisions for the State of Arizona.

The emission source tested was one of 13 kilns that are used to dry rough sawed lumber from an initial moisture content of approximately 50 percent (apparently, on a dry basis) to a final moisture content of 12 to 18 percent. The drying process is a batch process, which generally lasts 60 to 100 hours. During the emission test documented in the report, 137,800 board feet (325 cubic meters [m^3]) of Ponderosa Pine were dried over a period of 100 hours. No data are provided on the initial and final moisture contents of the lumber dried during the test. Emissions from the kiln are uncontrolled.

An experimental method was used to quantify emissions from the kiln. The sampling train consisted of a heated stainless steel probe leading to a heated teflon sampling line, which was connected to a set of three impingers and a condensate trap. The first two impingers contained 150 milliliters of water, and the other impinger was empty. The impingers were maintained at a temperature of 7.2°C (45°F) in a Forma bath. The dried gases were then pulled through a glass fiber filter heated to a temperature of 48.9°C (120°F), a heated teflon line, and a sample pump. The gases exiting the pump were routed to a Method 25A flame ionization detector for measuring TOC. Following collection of the sample, the condensible PM catch was extracted with methylene chloride. The extracted and residual solutions were evaporated according to Method 5H procedures. The residual portion of the sample provides an estimate of condensible inorganic PM and the extracted portion corresponds to condensible organic PM.

The concentration of TOC in the exhaust stream was measured at five minute intervals throughout the entire test and average hourly TOC concentrations were calculated. During hours 14 through 17 and hour 33 of the test, the induced draft exhaust fan failed. In addition, during hours 48 through 52 of the test, TOC concentrations exceeded the meter scale and concentrations were estimated. However, because of the duration of the entire test, the impact of these problems on overall results should not be significant. Emission factors were calculated for TOC emissions based on the quantity of wood dried and the cumulative total of TOC (as methane) emitted over the 100 hour-drying cycle.

The report provides little information on the condensible PM results. Apparently, only one cumulative measurement of condensibles was performed, and the results were reported as an average hourly emission rate. The residual and extracted portions of the catch were used to develop emission factors for condensible inorganic and condensible organic PM, respectively.

Emission data for a single run generally are not used for developing emission factors for AP-42, and the emission test documented in this reference consisted of a single run. However, because of the extended duration of the test (100 hours), the data appear to be valid for emission factor development. Because of the nonconventional sampling train configuration used, the results of the TOC test may not be comparable to other Method 25A results. Therefore, the TOC data are rated D. Because of the experimental nature of the methodology used to quantify the condensible PM emission data and the lack of detail in the documentation for the test, the condensible PM data are rated D.

4.1.15 Reference 15

This test report documents the results of emission testing conducted by Clean Air Engineering at the Weyerhauser Company, Bruce, Mississippi, facility on July 16-18, 1992. One test was conducted on two direct-fired kilns, and two tests were conducted on a steam-heated lumber kiln (east and west stacks). The wood species dried during the tests was Southern yellow pine. All of the tests included three 60-minute test runs. A boiler stack was also tested, but the results of the test are not included in this discussion.

Emissions from the direct-fired kilns were sampled through thermocouple holes in the sides of the kilns. The targeted pollutants and corresponding test methods used were CO_2 (EPA Method 3), NO_x (EPA Method 7E), CO (EPA Method 10), and TOC (EPA Method 25A). Volumetric flow rates were calculated for each test run using an F factor for CO_2, and an assumption was made that each grab sample represented a full 17-hour kiln cycle. The TOC results were reported as propane and converted to a methane basis using the ratio of the molecular weight of methane to the molecular weight of propane. Emission factors were calculated by dividing the mass emission rates (lb/hr) by the kiln charge rate (71.4 thousand board feet [MBF]/17 hr) provided in the report appendix.

Emissions of TOC from the steam-heated lumber kiln were measured at east stack #2 and west stack #1 using EPA Method 25A. Volumetric flow rates were measured using EPA Methods 1-4. The kiln has eight identical stacks, four on the east side and four on the west side. At any given time, four of the stacks are drawing air, while the other four are venting the kiln emissions. One stack was sampled from each side. Therefore, the measured emissions and flow rates were multiplied by four to account for four (assumed identical) emission points. Total drying time in the kiln was reported as 19.3 hours, but as specified in Reference 19, the kiln did not vent for the first two hours. Therefore, the measured emissions were assumed to represent a 17.3 hour drying time. The TOC results were reported as propane and converted to a methane basis using the ratio of the molecular weight of methane to the molecular weight of propane. Run-by-run TOC emission factors were calculated by dividing the mass emission rates (lb/hr) by the kiln charge rate (143 MBF/17.3 hr) provided in the report appendix.

The data from the tests on both kilns are assigned a B rating. The testing methodology appeared to be sound, adequate detail was provided in the report, and no problems were reported during the test runs. The data are rated B (rather than A) because the assumption that emissions from all four emitting stacks are identical may not be totally accurate, although it appears to be a reasonable assumption.

4.1.16 Reference 16

This test report documents the results of an emission test conducted by Radian Corporation at the Weyerhauser Company Mountain Pine Mill in Mountain Pine, Arkansas, on August 17-18, 1992. The test was conducted on a steam-heated kiln that was drying Southern yellow pine. Two boilers, an MDF press vent and a new MDF veneer dryer were also tested, but the results of these tests are not included in this discussion.

Emissions from the kiln were measured at two of eight identical stacks (stacks #2 and #6). The targeted pollutants and corresponding test methods used were filterable PM (EPA Method 5), condensible inorganic and organic PM (EPA Method 5 [back half analysis]), formaldehyde (NIOSH Method 3500), CO (EPA Method 10), and TOC (EPA Method 25A). The PM and formaldehyde tests comprised four test runs of at least 60 minutes each during the same kiln cycle, and the CO and TOC tests were continuous tests that spanned the entire kiln cycle. Stack parameters, including volumetric flow rates, were measured using EPA Methods 1-4. At any given time, four of the eight kiln stacks vent the kiln emissions. Therefore, the emission and flow rates measured at a single stack were multiplied by four to account for the four (assumed identical) stacks. Total drying time in the kiln (kiln cycle) was reported as 18.17 hours. The TOC results were reported as carbon and converted to a methane basis. Run-by-run emission factors were calculated by dividing the mass emission rates (lb/hr) by the kiln charge rate (119.25 MBF/18.17 hr) provided in Appendix O of the report.

The data, with the exception of the formaldehyde data, are assigned a B rating. The testing methodology appeared to be sound (except for the formaldehyde test), adequate detail was provided in the report, and no problems were reported during the test runs. The data are rated B (rather than A) because the assumption that emissions from all four emitting stacks are identical may not be totally accurate, although it appears to be a reasonable assumption. The formaldehyde data are assigned a C rating because several potential interferences may bias NIOSH Method 3500, as discussed in Reference 20.

4.1.17 Reference 17

This test report documents the results of an emission test conducted by Radian Corporation at the Weyerhauser Company Mountain Pine Mill in Mountain Pine, Arkansas, on August 12-13, 1992. The source tested was a steam-heated lumber kiln that was drying Southern yellow pine.

Emissions from the kiln were measured at each of eight identical stacks. The targeted pollutants and corresponding test methods used were CO (EPA Method 10) and TOC (EPA Method 25A). The tests were continuous tests and spanned the entire kiln cycle. Stack parameters, including volumetric flow rates, were measured using EPA Methods 1-4. At any given time, four of the eight kiln stacks vent the kiln emissions. Volumetric flow rates were measured one at a time for each of four stacks. Therefore, the flow rates measured at a single stack were multiplied by four to account for the four (assumed identical) stacks. Total drying time in the kiln (kiln cycle) was reported as 17.18 hours. The TOC results were reported as carbon and converted to a methane basis. Emission factors were calculated by dividing the mass emission rates (lb/hr) by the kiln charge rate (119 MBF/ 17.18 hr) provided in Appendix O of Reference 16.

The data are assigned an A rating. The testing methodology appeared to be sound, adequate detail was provided in the report, and no problems were reported during the test runs.

4.1.18 Reference 18

This test report documents the results of an emission test conducted by Clean Air Engineering at the Weyerhauser Company, Bruce, Mississippi, facility on May 4-6, 1993. The test was conducted on a steam-heated lumber kiln (east and west stacks), which is the same as one of the kilns described in Reference 15. The wood species dried during the test was Southern yellow pine. Two boiler stacks were also tested, but the results of these tests are not included in this discussion.

Emissions of TOC from the steam-heated lumber kiln were measured at east stack No. 2 and west stack No. 1 using EPA Method 25A. Volumetric flow rates were measured using EPA Methods 1-4. The kiln has eight identical stacks, four on the east side and four on the west side. At any given time, four of the stacks are drawing air, while the other four are venting the kiln emissions. Therefore, the flow and emission rates measured at one stack were multiplied by four to account for the four (assumed identical) emitting stacks. The measured emissions were assumed to represent the full 17.96 hour drying time. The TOC results were reported as propane and converted to a methane basis. Run-by-run TOC emission factors were calculated by dividing the mass emission rates (lb/hr) by the kiln charge rate (157.5 MBF/17.96 hr) provided in Attachment A of Reference 19.

The data are assigned a C rating. The testing methodology appeared to be sound, adequate detail was provided in the report, and no problems were reported during the test runs. However, Reference 19 reports that a water balance shows that about 59 percent of the water that was lost from the lumber during the drying cycle could be accounted for in the emissions based on the moisture content of the exhaust stream. These data suggest that the sampling measured only about 59 percent of the emissions. This discrepancy may have been due to an imbalance in flows from the eight vents, possibly caused by the stack extensions attached to the two vents that were sampled.

4.1.19 Reference 19

This document is the transmittal letter from NCASI, for References 15 through 18. The letter provides details about the emission tests described in References 15 through 18, and provides several sample calculations, recommendations, and the process data for Reference 18.

4.1.20 Reference 20

This document is a letter (written by Gary McAlister of EPA's Emission Measurement Branch) documenting a number of potential interferences associated with NIOSH Method 3500 (for quantifying formaldehyde emissions). The letter was a response to a request for an evaluation of NIOSH Method 3500 for quantifying formaldehyde emissions from hot mix asphalt (HMA) plants. Although the lumber production process and the associated emissions are dissimilar to the HMA production process and emissions, the potential interferences appear to be applicable to the lumber industry.

4.2.2 Review of XATEF and SPECIATE Data Base Emission Factors

A search of the XATEF data base revealed no emission factors for lumber and wood products manufacturing and woodworking operations.

A search of the SPECIATE data base for speciated particulate revealed emission factors only for sawing cyclone exhaust. A review of the reference cited for these emission factors determined that these factors were ambient levels determined from sites surrounding the mill, rather than source emissions. As such, these factors were not appropriate for inclusion in AP-42.

A search of the SPECIATE data base for speciated VOC's revealed no emission factors for sawmill operations or miscellaneous woodworking operations.

4.2.3 Review of Test Data in AP-42 Background File

The existing AP-42 Chapter 10 includes a Section 10.4, Woodworking Waste Collection Operations, which is the basis for the revised Section 10.1, Lumber and Wood Products

Manufacturing and Woodworking Operations. Six references were cited in support of the data in the original section.

Three references (References 6, 7 and 8) in the previous version of AP-42 Chapter 10, Section 10.4, Woodworking Waste Collection Operations, are cited in support of two PM emission rates, one for sanderdust cyclones, and one for other cyclones. Two of these references (References 7 and 8) are secondary references. Both of these papers present summaries of emission data from various woodworking operations and cyclones. The third reference (Reference 6) is a compendium of PM test results from 10 test reports covering 94 woodworking cyclones. The results are reported as emission concentrations and emission rates rather than emission factors. These results are summarized in Table 4-3.

TABLE 4-3. SUMMARY OF PM EMISSION DATA ON WOOD RESIDUE HANDLING AND TRANSFER[a]

Type of material	Emission concentration, g/SCM (gr/SCF)[b]	
	Range	Average
Sanderdust	0.0114-0.37 (0.005-0.16)	0.126 (0.055)
Wood residue other than sanderdust	0.002-0.37 (0.001-0.16)	0.07 (0.03)

[a]Reference 6. Data rated D. Based on data from emissions of cyclone-controlled wood residue collection systems.
[b]Concentrations in units of grams per standard cubic meter (g/SCM) and grains per standard cubic foot (gr/SCF).

Three additional references (References 9, 10, and 11) are cited in support of the text subsections presenting general background information and general emission and control information. However, these references contained no emission data from which emission factors could be developed.

4.2.4 Results of Data Analysis

Emission factors were identified for PM emissions from log debarking, log sawing, and sawdust handling. These emission factors are presented in Table 4-4. However, because these factors are not rated, they have not been incorporated into the revised AP-42 section. Emission factors have been developed for the following lumber and wood product manufacturing operations and pollutants:

Process	Pollutant
Drying: direct-fired kiln	TOC, CO, CO_2, NO_x
Drying: steam-heated kiln	filterable PM, condensible inorganic PM, condensible organic, PM, TOC, CO, formaldehyde.

These data appear in Table 4-5.

TABLE 4-4. SUMMARY OF EMISSION DATA FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS--MISCELLANEOUS SOURCES[a]

Source	Type of control	Pollutant	No. of test runs	Data rating	Emission factor: Range, kg/Mg (lb/ton)	Emission factor: Average, kg/Mg (lb/ton)	Ref. No.
Log debarking	None	PM	ND	NR	ND	0.012 (0.024)	5
Log sawing	None	PM	ND	NR	ND	0.18 (0.35)	5
Sawdust handling	None	PM	ND	NR	ND	0.50 (1.0)	5

[a]Emission factors in units of kg/Mg (lb/ton) of logs processed. ND = no data available. NR = not rated.

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TABLE 4-5. SUMMARY OF TEST DATA FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS--LUMBER DRYING[a]

Type of kiln	Pollutant	No. of test runs	Data rating	Emission factor range, lb/MBF[b]	Average emission factor, lb/MBF[b]	Ref. No.
Steam-heated[c]	Condensible organic PM	1	D	NA	0.106	12
Steam-heated[c]	Condensible inorganic PM	1	D	NA	0.0485	12
Steam-heated[c]	TOC[d]	1	D	NA	1.67	12
Direct-fired[e]	CO_2	3	B	382	382	15
Direct-fired[e]	NO_x	3	B	0.133-0.242	0.197	15
Direct-fired[e]	CO	3	B	0.486-1.79	1.05	15
Direct-fired[e]	TOC[d]	3	B	1.65-11.7	1.71	15
Steam-heated[f]	TOC[d]	6	B	0.884-1.75	1.01	15
Steam-heated[g]	Filterable PM	4	B	0.0440-0.0989	0.0677	16
Steam-heated[g]	Condensible organic PM	4	B	0.0774-0.179	0.124	16
Steam-heated[g]	Condensible inorganic PM	4	B	0.00385-0.0107	0.00714	16
Steam-heated[g]	Formaldehyde	4	C	0.00483-0.00797	0.00675	16
Steam-heated[g]	CO	[h]	B	NA	0.0280	16
Steam-heated[g]	TOC[d]	[h]	B	NA	2.91	16
Steam-heated[j]	CO	[h]	A	NA	0.109	17
Steam-heated[j]	TOC[d]	[h]	A	NA	16.8	17
Steam-heated[k]	TOC[d]	6	C	1.63-2.97	2.35	18

[a]NA = not applicable. Emission factors represent uncontrolled emissions unless noted.
[b]Emission factors in units of pounds per thousand board feet (lb/MBF) of lumber dried.
[c]For Ponderosa pine dried from about 50 percent moisture on a wet basis to 12 to 18 percent moisture. Data is based on cumulative totals for one 100-hour batch run with TOC emission concentrations measured at 5-minute intervals, and condensibles measured only as a single composite sample.
[d]Total organic compounds on a methane basis as measured using EPA Method 25A.
[e]For Southern yellow pine dried from about 40 percent moisture (assumed wet basis) to about 17 percent moisture.
[f]For Southern yellow pine dried from about 60 percent moisture (assumed wet basis) to about 19.6 percent moisture.
[g]For Southern yellow pine dried from about 94.3 percent moisture (assumed dry basis) to about 9.2 percent moisture.
[h]Emission factors based on a single continuous monitoring run that spanned a full kiln cycle.
[j]For Southern yellow pine dried from about 93.7 percent moisture (assumed dry basis) to about 10.1 percent moisture.
[k]For Southern yellow pine dried from about 104 percent moisture on a dry basis to about 13 percent moisture.

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Based on the data summarized in Table 4-5, emission factors were developed for the revised AP-42 section for lumber and wood products manufacturing. These emission factors are presented in Tables 4-6 through 4-8. The PM and TOC emission factors for lumber and wood products manufacturing and woodworking operations are presented in Table 4-6 in metric units and in Table 4-7 in English units. Table 4-8 presents the CO, CO_2, NO_x, and formaldehyde emission factors for lumber drying. The paragraphs that follow describe how the emission factors in Tables 4-6 and 4-8 were derived and how the ratings were assigned.

Emission factors for uncontrolled filterable PM emissions from log debarking, log sawing, and sawdust handling (from the existing AP-42 section on plywood veneer and layout operations) were not rated because the source for these emission factors is not a primary reference. As such, these emission factors are not included in the revised Section 10.1, Lumber and Wood Products Manufacturing and Woodworking Operations.

Emission factors for uncontrolled CO_2, NO_x, CO, and TOC emissions from direct-fired kilns (drying process) were developed from Reference 15. Because these emission factors are based on B-rated data from a single test, they are rated D.

Emission factors for uncontrolled filterable PM, condensible organic PM, and condensible inorganic PM emissions from steam-heated kilns (drying process) were developed from Reference 16. Because these emission factors are based on B-rated data from single test, they are rated D. Because the Reference 12 data were rated D, the data for condensible PM presented in Reference 12 were not averaged with the Reference 16 data.

An emission factor for uncontrolled formaldehyde emissions from steam-heated kilns (drying process) was developed from Reference 16. Because this emission factor is based on C-rated data, it is rated E.

An emission factor for uncontrolled CO emissions from steam-heated kilns (drying process) was developed from References 16 and 17. Because this emission factor is based on A- and B-rated data from only two tests, it is rated D.

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TABLE 4-6. (Metric Units)
EMISSION FACTORS FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS[a]

EMISSION FACTOR RATING: D

Source	Filterable PM[b]		Condensible PM[c]		TOC[d]
	PM	PM-10	Organic	Inorganic	
Log debarking (SCC 3-07-008-10)					
Bucking (SCC 3-07-008-11)	ND	ND	Neg.	Neg.	Neg.
Headrig log deck (SCC 3-07-008-12)	ND	ND	Neg.	Neg.	Neg.
Primary log breakdown (SCC 3-07-008-13)	ND	ND	Neg.	Neg.	Neg.
Secondary log breakdown (SCC 3-07-008-14)	ND	ND	Neg.	Neg.	Neg.
Surfacing (planing and sanding) (SCC 3-07-008-21)	ND	ND	Neg.	Neg.	Neg.
Sawdust handling (SCC 3-07-008-22)	ND	ND	Neg.	Neg.	Neg.
Lumber drying: direct-fired kiln[e] (SCC 3-07-008-18)	ND	ND	ND	ND	0.34
Lumber drying: steam-heated kiln (SCC 3-07-008-20)	0.020[f]	ND	0.033[f]	0.0019[f]	1.9[g]
Sanderdust handling and transfer[h] (SCC 3-07-008-24)	0.13[i]	ND	Neg.	Neg.	Neg.
Wood residue handling and transfer[h] (SCC 3-07-008-25)	0.07[i]	ND	Neg.	Neg.	Neg.

[a]Factors represent uncontrolled emissions unless otherwise specified. Neg. = emissions of this pollutant from this source are expected to be negligible. ND = no data available; emissions of this pollutant from this source may not be negligible. SCC = Source Classification Code. Emission factors for lumber drying in units of kg/Mg of lumber dried assuming an average density of 721 kg per cubic meter (kg/m^3). Emission factors for other sources in units of kg/Mg of logs processed.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values exclude that PM collected in the PM-10 Sizer Cyclone of an EPA Method 201 or 201A sampling train.
[c]Condensible PM is that PM collected in the impinger portion of a PM sampling train and analyzed using EPA Method 202 (or equivalent).
[d]Total organic compounds on a methane basis as measured using EPA Method 25A.
[e]Reference 15.
[f]Reference 16.
[g]References 15-17.
[h]Reference 6. EMISSION FACTOR RATING E.
[i]Emission concentration in units of g/SCM.

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TABLE 4-7. (English Units)
EMISSION FACTORS FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS[a]

EMISSION FACTOR RATING: D

Source	Filterable PM[b]		Condensible PM[c]		
	PM	PM-10	Organic	Inorganic	TOC[d]
Log debarking (SCC 3-07-008-10)	ND	ND	Neg.	Neg.	Neg.
Bucking (SCC 3-07-008-11)	ND	ND	Neg.	Neg.	Neg.
Headrig log deck (SCC 3-07-008-12)	ND	ND	Neg.	Neg.	Neg.
Primary log breakdown (SCC 3-07-008-13)	ND	ND	Neg.	Neg.	Neg.
Secondary log breakdown (SCC 3-07-008-14)	ND	ND	Neg.	Neg.	Neg.
Surfacing (planing and sanding) (SCC 3-07-008-21)	ND	ND	Neg.	Neg.	Neg.
Sawdust handling (SCC 3-07-008-22)	ND	ND	Neg.	Neg.	Neg.
Lumber drying: direct-fired kiln[e] (SCC 3-07-008-18)	ND	ND	ND	ND	0.68 (1.3)
Lumber drying: steam-heated kiln (SCC 3-07-008-20)	0.040[f] (0.068)	ND	0.066[f] (0.12)	0.0038[f] (0.0071)	3.9[g] (7.2)
Sanderdust handling and transfer[h] (SCC 3-07-008-24)	0.055[i]	ND	Neg.	Neg.	Neg.
Wood residue handling and transfer[h] (SCC 3-07-008-25)	0.03[i]	ND	Neg.	Neg.	Neg.

[a]Factors represent uncontrolled emissions unless otherwise specified. Neg. = emissions of this pollutant from this source are expected to be negligible. ND = no data available; emissions of this pollutant from this source may not be negligible. SCC = Source Classification Code. Emission factors for lumber drying in units of lb/ton of lumber dried assuming an average density of 45 lb per cubic foot (lb/ft^3) (and in units of lb per thousand board feet [lb/MBF] of lumber dried). Emission factors for other sources in units of lb/ton of logs processed.

[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values exclude that PM collected in the PM-10 Sizer Cyclone of an EPA Method 201 or 201A sampling train.

[c]Condensible PM is that PM collected in the impinger portion of a PM sampling train and analyzed using EPA Method 202 (or equivalent).

[d]Total organic compounds on a methane basis as measured using EPA Method 25A.

[e]Reference 15.

[f]Reference 16.

[g]References 15-17.

[h]Reference 6. EMISSION FACTOR RATING E.

[i]Emission concentration in units of gr/SCF.

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TABLE 4-8. (Metric And English Units)
EMISSION FACTORS FOR LUMBER DRYING[a]

EMISSION FACTOR RATING: D

Source	CO		CO_2		NO_x		Formaldehyde	
	kg/Mg	lb/ton (lb/MBF)	kg/Mg	lb/ton (lb/MBF)	kg/Mg	lb/ton (lb/MBF)	kg/Mg	lb/ton (lb/MBF)
Lumber drying: direct-fired kiln[b] (SCC 3-07-008-18)	0.28	0.56 (1.1)	100	200 (380)	0.053	0.11 (0.20)	ND	ND
Lumber drying: steam-heated kiln (SCC 3-07-008-20)	0.018[c]	0.037[c] (0.069)	ND	ND	ND	ND	0.0018[d]	0.0036[d] (0.0068)

[a]Factors represent uncontrolled emissions unless otherwise specified. ND = no data available. SCC = Source Classification Code. Emission factors for lumber drying in units of kg/Mg of lumber dried assuming an average density of 721 kg/m^3 or lb/ton of lumber dried assuming an average density of 45 lb/ft^3 (and in units of lb/MBF of lumber dried).
[b]Reference 15.
[c]Reference 16-17.
[d]Reference 16. EMISSION FACTOR RATING: E.

An emission factor for uncontrolled TOC emissions from steam-heated kilns (drying process) was developed from A- and B-rated data from References 15, 16, and 17. Data from two other tests (References 12 and 18) were not used because they are D- and C-rated, respectively. Because this emission factor is based on A- and B-rated data from only three tests, it is rated D.

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This is preliminary material, in draft form, for purposes of review. This material must not be quoted, cited, or in any other way considered or used as final work.

5. PROPOSED AP-42 SECTION 10.1

A proposed revision to AP-42 Section 10.4, Woodworking Waste Collection Operations, is presented in the following pages as it would appear in the document.

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10.1 Lumber and Wood Products Manufacturing and Woodworking Operations

10.1.1 General

This section covers the processing of logs into lumber, timbers, shingles/shakes, cooperage components, wood chips, and wood flour and generally focuses on the operations of debarking, sawing, planing, sanding, and grinding of wood. These operations are also part of the production of many other products, including wood pulp, plywood, and reconstituted wood panel products. Most wood manufacturing processes begin the same basic way: logs are debarked and sawed to usable lengths, ranging from over 20 feet for lumber to less than 3 feet for shingles. What follows this initial log breakdown are various sawing, planing, splitting, chipping, and grinding operations used to produce such products as round timber, square mine timbers and railroad ties, split-wood shingles and shakes, cooperage (barrel) staves and heads, wood chips (for use in reconstituted wood products or for pulping in paper making), or wood flour (an industrial product with varied uses including toilet seats, furniture parts, cabinets, drawers, and containers). General woodworking operations covered in this section include those of furniture and cabinet manufacturing.

10.1.2 Process Description[1-3]

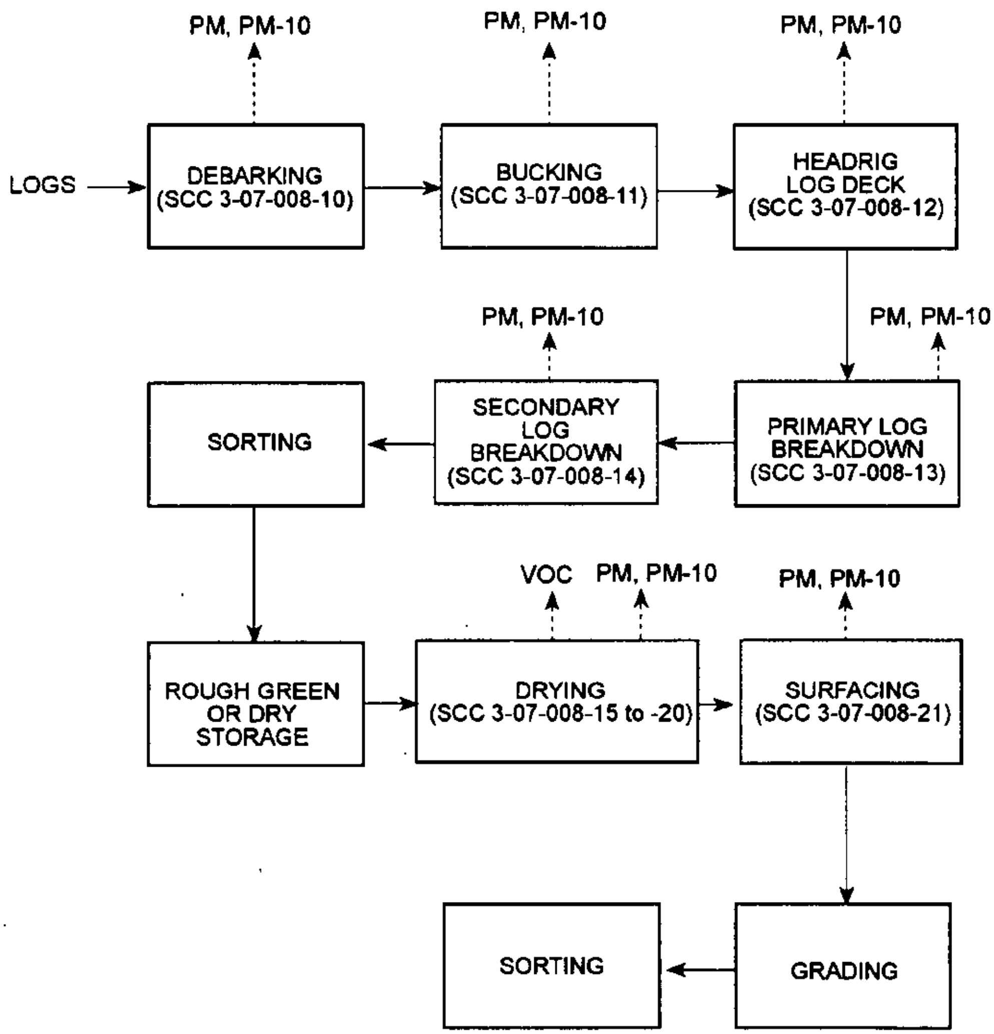
Although all lumber will not go through all of the processes available in a sawmill, most modern sawmills have equipment to accomplish all the steps described in the subsections below. For example, some lumber will not be remanufactured in any way (resawed or re-edged) but may go directly from the edger to the trimmer. Some sawmills do not dry lumber but sell it green, while others produce only rough, unsurfaced lumber. Figure 10.1-1 presents a generic lumber manufacturing process flow diagram. The specific processes that are found in lumber manufacturing facilities are described below.

Debarking. Debarking is the process of removing the bark from a log before further manufacture. One reason for debarking is to remove bark from wood that is to be chipped for board or pulp use because any substantial quantity of bark in the chips is detrimental to board or pulp quality. Debarking also provides other benefits. Removal of sand and grit along with the bark during debarking greatly decreases the rate at which saws are dulled, reducing downtime in the mill. Also, bark has become an important source of fuel for energy generation.

Bucking. Bucking refers to the process of crosscutting long logs to shorter segments suitable for breakdown on a sawmill headrig, which is the main sawing device. The objective of this process is to manufacture short logs that will maximize lumber yield and grade recovery on the headrig, while separating out material that is suited only for pulpwood or hog fuel.

Headrig Log Deck. The headrig log deck serves as a conveyor between the bucking station and the primary breakdown machine to deliver logs that have been bucked to length for the headrig.

Primary Log Breakdown. In the primary breakdown step, the log is evaluated, oriented, held, transported, and cut into various sizes to be conveyed elsewhere for further manufacture. The primary breakdown of the log is accomplished by one of two methods: by placing the log on a carriage rig, which travels on rails and conveys the log back and forth through the saw, or by passing the log only once through the saw on a single-pass headrig.



WOOD RESIDUE SOURCES	SCC
Sawdust/shavings handling & transfer	3-07-008-22
Sawdust/shavings storage piles	3-07-008-23
Sanderdust handling & transfer	3-07-008-24
Wood residue handling & transfer	3-07-008-25

Figure 10.1-1. General lumber manufacturing process.
(Source Classification Code in parentheses)

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Secondary Log Breakdown. After primary breakdown on the headrig, the lumber may only require edging or trimming, or cutting to width and length. Most mills do, however, require a greater degree of secondary breakdown, such as sawing or resawing to obtain a board.

Sorting. The various sorting systems available have the common goal of getting pieces of lumber of the same thickness, width, and length into a single stack so they can be easily handled by mechanical means and transported to the next operation. Because sorting of green and dry lumber is usually identical, almost any sorting system can be used for rough green, rough dry, planed green, or dry lumber. In fact, some mills have only one sorter and use it alternately for green, then dry, lumber.

Rough Green and Dry Storage. After lumber is manufactured, sorted, and stacked, it is normally transported to a rough green storage area if it is to be planed in the green, or it is kiln-dried prior to planing. Before lumber is air- or kiln-dried, it is stacked in alternating layers with "stickers," or spacing sticks. In arranging and operating the green storage yard or shed, like widths and lengths are stored together so they can be moved in an orderly fashion to the kilns in order to get full kiln charges by widths and lengths.

Drying. Both air-seasoning or forced kiln drying simply evaporate the water from the surface of lumber under controlled conditions until the moisture content reaches a desired level. The desired moisture content varies widely with wood species. Although particular advantages exist for drying a species by one method or another, almost any species can be air dried, given enough time and a location where relative humidity will permit.

Surfacing, Grading, and Sorting. Lumber is typically handled and sorted twice. After being trimmed and edged, lumber is sorted by species, size, and grade. Then, after it is dried and surfaced, it will again be graded, grade-stamped if softwood lumber, sorted, and packaged for shipment. A wide variety of lumber-sorting equipment is available for use at the green or dry end of the mill. In the simplest system, the lumber is manually pulled and sorted as it proceeds down a green or dry chain. Manual lumber handling is eliminated in modern mills by mechanical sorters that can be controlled by a single grader-operator. Mechanical sorters exist that can sort lumber automatically by length, width, or thickness.

Wood Residue Handling. Most wood product plants employ pneumatic transfer systems to remove the generated wood residue from the immediate proximity of each production operation. These systems are a convenient means of transporting the wood residue to common collection points where it may be used immediately or stored for future use. Sawdust produced in sawmill operations often is used for fuel at or near the point of production. It is also used for meat smoking, as a soil conditioner and mulch, as stable and kennel bedding, as insulation, and in the manufacture of other products such as particleboard, stucco, and plaster. Shavings produced in planer operations often are used for fuel, either as shavings or in the form of wood briquettes. They are also used as packing material, as stable and kennel bedding, as insulation, and in the production of wood flour and wallboard.

10.1.3 Emissions and Controls[3-10]

Almost any wood product manufacturing step involves the generation of sawdust, planer shavings, or sanderdust, all of which contribute to levels of atmospheric particulate matter (PM) and PM less than 10 micrometers in aerodynamic diameter (PM-10). Log debarking, log sawing, sawdust moving/storage, cutting, and sanding operations are all sources of PM and PM-10 emissions.

Sawdust storage piles are usually left uncovered, partially because of the need for frequent material transfer. Particulate matter and PM-10 emissions occur at several points in the storage cycle: during material loading onto the pile, during disturbances by strong wind currents, and during loadout from the pile. The movement of trucks and loading equipment in the storage pile area is also a potentially significant source of dust. The only PM emission data available for lumber and wood products manufacturing are for filterable and condensible PM emissions. No data are available for PM-10 emissions.

Air drying and kiln drying are potential sources of volatile organic compounds (VOC) and condensible organic compound emissions, but emission data are available only for kiln drying. Also, fugitive VOC emissions may be generated from sawdust and shavings piles, but no VOC emission data are available for these sources.

Large-diameter cyclones historically have been the primary means of separating the wood residue from the airstreams in the pneumatic transfer systems, although baghouses have recently been installed in some plants for this purpose. Hence, the pneumatic systems and cyclones or baghouses act as capture/collection systems for air pollution control and as product recovery systems. These cyclones are the major emission points for PM. The quantity of PM emissions from a given cyclone depend on the dimensions of the cyclone, the velocity of the airstream, and the nature of the operation generating the wood residue. Typical large-diameter cyclones found in the industry only effectively collect particles greater than 40 micrometers in diameter. Baghouses, when employed, collect essentially all of the wood residue in the airstream. The wood residue from numerous pieces of equipment often feed into the same cyclone, and it is common for the material collected in one or several cyclones to be conveyed to another cyclone. It is also possible for portions of the wood residue generated by a single operation to be directed to different cyclones. Because of this complexity, it is useful when evaluating emissions from a given facility to consider the wood residue handling cyclones (instead of the various operations that actually generate the PM) as air pollution sources.

Enclosures are the primary means of controlling fugitive PM and PM-10 emissions generated from sawdust storage piles by either wind erosion or handling operations. Enclosures are an effective way to control fugitive PM and PM-10 emissions from such open sources. Enclosures can either fully or partially enclose the storage pile and transfer operations. Types of passive enclosures traditionally used for open dust control that can be applied to sawdust piles include three-sided bunkers for storing bulk materials, storage silos for various types of material (in lieu of open piles), and open-ended buildings. Partial enclosures used for reducing windblown dust from large exposed areas and storage piles include porous wind screens and similar types of barriers (e.g., trees). The principle of the wind fence/barrier is to provide an area of reduced wind velocity, which allows settling of the large particles and reduces the particle flux from the exposed surface on the leeward side of the fence/barrier.

Tables 10.1-1 (metric units) and -2 (English units) present emission factors for PM and VOC emissions from lumber manufacturing. The VOC emission factors are presented in terms of total organic compounds (TOC) as measured using EPA Method 25A. Tables 10.1-3 (metric units) and -4 (English units) present emission factors for emissions of carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), and formaldehyde from lumber drying kilns.

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Table 10.1-1 (Metric Units).
EMISSION FACTORS FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS[a]

EMISSION FACTOR RATING: D

Source	Filterable PM[b]		Condensible PM[c]		TOC[d]
	PM	PM-10	Organic	Inorganic	
Log debarking (SCC 3-07-008-10)	ND	ND	Neg.	Neg.	Neg.
Bucking (SCC 3-07-008-11)	ND	ND	Neg.	Neg.	Neg.
Headrig log deck (SCC 3-07-008-12)	ND	ND	Neg.	Neg.	Neg.
Primary log breakdown (SCC 3-07-008-13)	ND	ND	Neg.	Neg.	Neg.
Secondary log breakdown (SCC 3-07-008-14)	ND	ND	Neg.	Neg.	Neg.
Lumber drying: air drying, hardwoods (SCC 3-07-008-15)	ND	ND	ND	ND	ND
Lumber drying: air drying, softwoods (SCC 3-07-008-016)	ND	ND	ND	ND	ND
Lumber drying: direct-fired kiln, hardwoods (SCC 3-07-008-017)	ND	ND	ND	ND	ND
Lumber drying: direct-fired kiln, softwoods (SCC 3-07-008-18)	ND	ND	ND	ND	0.34[e]
Lumber drying: steam-heated kiln, hardwoods (SCC 3-07-008-019)	ND	ND	ND	ND	ND
Lumber drying: steam-heated kiln, softwoods (SCC 3-07-008-20)	0.020[f]	ND	0.033[f]	0.0019[f]	1.9[g]
Surfacing (planing and sanding) (SCC 3-07-008-21)	ND	ND	Neg.	Neg.	Neg.
Sawdust/shavings handling and transfer (SCC 3-07-008-22)	ND	ND	Neg.	Neg.	Neg.
Sawdust/shavings storage piles (SCC 3-07-008-23)	ND	ND	Neg.	Neg.	Neg.

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Table 10-1.1 (Metric Units) (continued).

Source	Filterable PM[b]		Condensible PM[c]		TOC[d]
	PM	PM-10	Organic	Inorganic	
Sanderdust handling and transfer with cyclone[h] (SCC 3-07-008-24)	0.13[j]	ND	Neg.	Neg.	Neg.
Wood residue handling and transfer with cyclone[h] (SCC 3-07-008-25)	0.07[j]	ND	Neg.	Neg.	Neg.

[a]Factors represent uncontrolled emissions unless otherwise specified. Neg. = negligible; emissions of this pollutant from this source are expected to be negligible. ND = no data available; emissions of this pollutant from this source may not be negligible. SCC = Source Classification Code. Emission factors for lumber drying are based on process rates reported in thousand board feet per hour (MBF/hr) and are reported in this table in units of kg/Mg of lumber dried assuming an average density of 721 kg per cubic meter (kg/m^3). Emission factors for other sources in units of kg/Mg of logs processed.
[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values exclude that PM collected in the PM-10 Sizer Cyclone of an EPA Method 201 or 201A sampling train.
[c]Condensible PM is that PM collected in the impinger portion of a PM sampling train and analyzed using EPA Method 202 (or equivalent).
[d]Total organic compounds on a methane basis as measured using EPA Method 25A or equivalent.
[e]Reference 8. Based on one emission test of Southern yellow pine dried from about 60 percent moisture (assumed wet basis) to about 17 percent moisture.
[f]Reference 9. Based on one emission test of Southern yellow pine dried from about 94.3 percent moisture (assumed dry basis) to about 9.2 percent moisture.
[g]References 8-10. Based on three emission tests that ranged from 0.20 to 3.3 kg/Mg. The wood species in all tests was Southern yellow pine, which was dried from about 60 percent moisture (assumed wet basis) to about 17 percent moisture in one test, and in the other two tests was dried from about 94 percent (assumed dry basis) to about 10 percent in the other two tests.
[h]Reference 11. EMISSION FACTOR RATING E.
[j]Emission concentration in units of kg per thousand standard cubic meters.

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Table 10.1-2 (English Units).
EMISSION FACTORS FOR LUMBER AND WOOD PRODUCTS MANUFACTURING AND WOODWORKING OPERATIONS[a]

EMISSION FACTOR RATING: D

Source	Filterable PM[b]		Condensible PM[c]		TOC[d]
	PM	PM-10	Organic	Inorganic	
Log debarking (SCC 3-07-008-10)	ND	ND	Neg.	Neg.	Neg.
Bucking (SCC 3-07-008-11)	ND	ND	Neg.	Neg.	Neg.
Headrig log deck (SCC 3-07-008-12)	ND	ND	Neg.	Neg.	Neg.
Primary log breakdown (SCC 3-07-008-13)	ND	ND	Neg.	Neg.	Neg.
Secondary log breakdown (SCC 3-07-008-14)	ND	ND	Neg.	Neg.	Neg.
Lumber drying: air drying, hardwoods (SCC 3-07-008-15)	ND	ND	ND	ND	ND
Lumber drying: air drying, softwoods (SCC 3-07-008-16)	ND	ND	ND	ND	ND
Lumber drying: direct-fired kiln, hardwoods (SCC 3-07-008-17)	ND	ND	ND	ND	ND
Lumber drying: direct-fired kiln, softwoods (SCC 3-07-008-18)	ND	ND	ND	ND	0.68[e] (1.3)
Lumber drying: steam-heated kiln, hardwoods (SCC 3-07-008-19)	ND	ND	ND	ND	ND
Lumber drying: steam-fired kiln, softwoods (SCC 3-07-008-20)	0.040[f] (0.068)	ND	0.066[f] (0.12)	0.0038[f] (0.0071)	3.9[g] (7.2)
Surfacing (planing and sanding) (SCC 3-07-008-20)	ND	ND	Neg.	Neg.	Neg.
Sawdust/shavings handling and transfer (SCC 3-07-008-22)	ND	ND	Neg.	Neg.	Neg.
Sawdust/shavings storage piles (SCC 3-07-008-23)	ND	ND	Neg.	Neg.	Neg.

Table 10-1.2 (English Units) (continued).

Source	Filterable PM[b]		Condensible PM[c]		TOC[d]
	PM	PM-10	Organic	Inorganic	
Sanderdust handling and transfer with cyclone[h] (SCC 3-07-008-24)	0.0079[j]	ND	Neg.	Neg.	Neg.
Wood residue handling and transfer with cyclone[h] (SCC 3-07-008-25)	0.0043[j]	ND	Neg.	Neg.	Neg.

[a]Factors represent uncontrolled emissions unless otherwise specified. Neg. = negligible; emissions of this pollutant from this source are expected to be negligible. ND = no data available; emissions of this pollutant from this source may not be negligible. SCC = Source Classification Code. Emission factors for lumber drying are based on process rates in units of MBF/hr and are reported in this table lumber dried assuming an average density of 45 lb per cubic foot (lb/ft^3) (and in units of lb/MBF of lumber dried). Emission factors for other sources in units of lb/ton of logs processed.

[b]Filterable PM is that PM collected on or prior to the filter of an EPA Method 5 (or equivalent) sampling train. PM-10 values exclude that PM collected in the PM-10 Sizer Cyclone of an EPA Method 201 or 201A sampling train.

[c]Condensible PM is that PM collected in the impinger portion of a PM sampling train and analyzed using EPA Method 202 (or equivalent).

[d]Total organic compounds on a methane basis as measured using EPA Method 25A.

[e]Reference 8. Based on one emission test of Southern yellow pine dried from about 60 percent moisture (assumed wet basis) to about 17 percent moisture.

[f]Reference 9. Based on one emission test of Southern yellow pine dried from about 94.3 percent moisture (assumed dry basis) to about 9.2 percent moisture.

[g]References 8-10. Based on three emission tests that ranged from 0.40 to 6.6 lb/ton (0.76 to 13 lb/MBF). The wood species in all of the tests was Southern yellow pine, which was dried from about 60 percent moisture (assumed wet basis) to about 17 percent moisture in one test, and was dried from about 94 percent (assumed dry basis) to about 10 percent in the other two tests.

[h]Reference 11. EMISSION FACTOR RATING E.

[j]Emission concentration in units of lb per thousand standard cubic feet.

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Table 10.1-3 (Metric Units).
EMISSION FACTORS FOR LUMBER DRYING[a]

EMISSION FACTOR RATING: D

Source	CO	CO_2	NO_x	Formaldehyde
Log debarking (SCC 3-07-008-10)	Neg.	Neg.	Neg.	Neg.
Bucking (SCC 3-07-008-11)	Neg.	Neg.	Neg.	Neg.
Headrig log deck (SCC 3-07-008-12)	Neg.	Neg.	Neg.	Neg.
Primary log breakdown (SCC 3-07-008-13)	Neg.	Neg.	Neg.	Neg.
Secondary log breakdown (SCC 3-07-008-14)	Neg.	Neg.	Neg.	Neg.
Lumber drying: air drying, hardwoods (SCC 3-07-008-15)	ND	ND	ND	ND
Lumber drying: air drying, softwoods (SCC 3-07-008-16)	ND	ND	ND	ND
Lumber drying: direct-fired kiln, hardwoods (SCC 3-07-008-17)	ND	ND	ND	ND
Lumber drying: direct-fired kiln, softwoods[b] (SCC 3-07-008-18)	0.28	100	0.053	ND
Lumber drying: steam-heated kiln, hardwoods (SCC 3-07-008-19)	ND	ND	ND	ND
Lumber drying: steam-heated kiln, softwoods (SCC 3-07-008-20)	0.018[c]	Neg.	Neg.	0.0018[d]
Surfacing (planing and sanding (SCC 3-07-008-21)	Neg.	Neg.	Neg.	Neg.
Sawdust/shavings handling and transfer (SCC 3-07-008-22)	Neg.	Neg.	Neg.	Neg.

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Table 10-1.3 (Metric Units) (continued).

Source	CO	CO_2	NO_x	Formaldehyde
Sawdust/shavings storage piles (SCC 3-07-008-23)	Neg.	Neg.	Neg.	Neg.
Sanderdust handling and transfer (SCC 3-07-008-24)	Neg.	Neg.	Neg.	Neg.
Wood residue handling and transfer (SCC 3-07-008-25)	Neg.	Neg.	Neg.	Neg.

[a]Factors represent uncontrolled emissions unless otherwise specified. ND = no data available; emissions of this pollutant from this source may not be negligible. Neg. = negligible; emissions of this pollutant from this source are expected to be negligible. SCC = Source Classification Code. Emission factors for lumber drying are based on process rates reported in units of MBF/hr and are reported in this table in units of kg/Mg of lumber dried assuming an average density of 721 kg/m^3.
[b]Reference 8. Based on one emission test of Southern yellow pine dried from about 60 percent moisture (assumed wet basis) to about 17 percent moisture.
[c]References 9-10. Based on two emission tests that ranged from 0.0073 to 0.029 kg/Mg. The tests were conducted on kilns drying Southern yellow pine, which was dried from about 94 percent (assumed dry basis) to about 10 percent.
[d]Reference 9. Based on one emission test of Southern yellow pine dried from about 94.3 percent moisture (assumed dry basis) to about 9.2 percent moisture. EMISSION FACTOR RATING: E.

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Table 10.1-4 (English Units).
EMISSION FACTORS FOR LUMBER DRYING[a]

EMISSION FACTOR RATING: D

Source	CO	CO_2	NO_x	Formaldehyde
	lb/ton (lb/MBF)	lb/ton (lb/MBF)	lb/ton (lb/MBF)	lb/ton (lb/MBF)
Log debarking (SCC 3-07-008-10)	Neg.	Neg.	Neg.	Neg.
Bucking (SCC 3-07-008-11)	Neg.	Neg.	Neg.	Neg.
Headrig log deck (SCC 3-07-008-12)	Neg.	Neg.	Neg.	Neg.
Primary log breakdown (SCC 3-07-008-13)	Neg.	Neg.	Neg.	Neg.
Secondary log breakdown (SCC 3-07-008-14)	Neg.	Neg.	Neg.	Neg.
Lumber drying: air drying, hardwoods (SCC 3-07-008-15)	ND	ND	ND	ND
Lumber drying: air drying, softwoods (SCC 3-07-008-16)	ND	ND	ND	ND
Lumber drying: direct-fired kiln, hardwoods (SCC 3-07-008-17)	ND	ND	ND	ND
Lumber drying: direct-fired kiln, softwoods[b] (SCC 3-07-008-18)	0.56 (1.1)	200 (380)	0.11 (0.20)	ND
Lumber drying: steam-heated kiln, hardwoods (SCC 3-07-008-19)	ND	ND	ND	ND
Lumber drying: steam-heated kiln, softwoods (SCC 3-07-008-20)	0.037[c] (0.069)	Neg.	Neg.	0.0036[d] (0.0068)

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Table 10-1.4 (English Units) (continued).

Source	CO	CO_2	NO_x	Formaldehyde
	lb/ton (lb/MBF)	lb/ton (lb/MBF)	lb/ton (lb/MBF)	lb/ton (lb/MBF)
Surfacing (planing and sanding) (SCC 3-07-008-21)	Neg.	Neg.	Neg.	Neg.
Sawdust/shavings handling and transfer (SCC 3-07-008-22)	Neg.	Neg.	Neg.	Neg.
Sawdust/shavings storage piles (SCC 3-07-008-23)	Neg.	Neg.	Neg.	Neg.
Sanderdust handling and transfer (SCC 3-07-008-24)	Neg.	Neg.	Neg.	Neg.
Wood residue handling and transfer (SCC 3-07-008-25)	Neg.	Neg.	Neg.	Neg.

[a]Factors represent uncontrolled emissions unless otherwise specified. ND = no data available; emissions of this pollutant from this source may not be negligible. Neg. = negligible; emissions of this pollutant from this source are expected to be negligible. SCC = Source Classification Code. Emission factors for lumber drying are based on process rates reported in units of MBF/hr and are reported in this table in units of lb/ton of lumber dried assuming an average density of 45 lb/ft^3 (and in units of lb/MBF of lumber dried).

[b]Reference 8. Based on one emission test of Southern yellow pine dried from about 60 percent moisture (assumed wet basis) to about 17 percent moisture.

[c]References 9-10. Based on two emission tests that ranged from 0.015 to 0.057 lb/ton (0.028 to 0.11 lb/MBF). The tests were conducted on kilns drying Southern yellow pine, which was dried from about 94 percent (assumed dry basis) to about 10 percent.

[d]Reference 9. Based on one emission test of Southern yellow pine dried from about 94.3 percent moisture (assumed dry basis) to about 9.2 percent moisture. EMISSION FACTOR RATING: E.

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