

Documentation of Emission Factor Development for the Plywood and Composite Wood Products
Manufacturing NESHAP (EPA Contract No. 68-D6-0012; ESD Project No. 95/11;
MRI Project No. 4803-48)
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I. Introduction

This memorandum documents the development of emission factors for the plywood and composite wood products manufacturing national emission standard for hazardous air pollutants (NESHAP), and presents the resulting emission factors. As of this writing, this memorandum is the most comprehensive source of plywood and composite wood products emission factors available. Summary tables presenting the average emission factors are included as Attachment 1 to this memorandum. The individual data sets used to develop each average emission factor are presented in Attachment 2 of this memorandum.

The emission factors presented in this memorandum are based on data combined from three sources: (1) EPA's *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources* (commonly referred to as AP-42); (2) numerous emission test reports (dated 1995 or later) collected from plants during EPA's 1998 maximum achievable control technology (MACT) survey; and (3) results from an extensive emission testing program conducted by the National Council of the Paper Industry for Air and Stream Improvement (NCASI). This memorandum may be useful for regulatory and plant personnel responsible for estimating air emissions from plywood and composite wood products plants. Section II of this memorandum discusses the sources of the emission data used to develop the emission factors. Section III of this memorandum discusses the emission measurement methods used to collect the data. Section IV discusses the review of the emission data. Section V discusses the calculation of the emission factors. Section VI discusses the presentation of the emission factors.

II. Sources of Emission Data

A total of 111 emission data sources were reviewed in the development of the emission factors for the Plywood and Composite Wood Products Manufacturing NESHAP. These emission data sources may be divided into three groups:

- (1) Background reports for wood products industry sections of AP-42 -- four reports;
- (2) Emission test reports submitted with responses to EPA's 1998 MACT survey -- 99 reports; and,
- (3) NCASI technical bulletins (numbers 768 through 774, dated January 1999) and an associated database -- seven bulletins and the database.

When combined, the data from these three emission data sources yielded a total of approximately 30,000 individual emission test runs. Sections A through C below provide brief descriptions of the three data sources.

A. AP-42

Emission factors for the wood products industry are presented in Chapter 10 of AP-42.¹ Chapter 10 is divided into multiple sections according to wood product. For each section, there is a summary (which is presented in Chapter 10) and a background report. The AP-42 background reports provide details about each of the emission test reports used to develop AP-42 emission factors. Emission test data and process information were extracted from the background reports for the following AP-42 sections:²⁻⁵

Plywood Manufacturing (September 1997),
Waferboard/Oriented Strandboard (OSB) Manufacturing (December 1998),
Particleboard Manufacturing (September 1998), and
Medium Density Fiberboard (MDF) Manufacturing (September 1998).

The plywood report includes a review of emission data from five emission test reports, NCASI Technical Bulletin No. 405, and the plywood portion of NCASI Technical Bulletin No. 694.^{6,7} The waferboard/OSB report includes a review of 105 emission test reports and the OSB portion of NCASI Technical Bulletin No. 694. The particleboard report includes a review of eight emission test reports and the particleboard portion of NCASI Technical Bulletin No. 693.⁸ The MDF report includes a review of six emission test reports and the MDF portion of NCASI Technical Bulletin No. 693.

The four AP-42 background reports were the source of approximately 5,600 emission test runs. The AP-42 sections include a significant quantity of data for criteria and other non-HAP pollutants including various particulate matter (PM) fractions, carbon monoxide (CO), nitrogen oxides (NO_x), carbon dioxide (CO₂), total hydrocarbon (THC), and 33 other non-HAP compounds. The emission test data extracted from the AP-42 sections also include measurements for 32 speciated HAP compounds. The AP-42 sections include data for uncontrolled emissions sources as well as data for emissions from a number of air pollution control devices (APCD's), including regenerative thermal oxidizers (RTO's), wet electrostatic precipitators (WESP's), electrified filter beds (EFB's), wet scrubbers, multicyclones (multiclones), and baghouses (fabric filters).

B. Emission Test Reports from EPA MACT Survey

In addition to the data from AP-42, 45 plants (representing 14 companies) submitted 99 emission test reports with their responses to a 1998 EPA MACT survey of the plywood and composite wood products industry.⁹⁻¹⁰⁷ These 99 reports represent approximately 3,400 emission test runs and include measurements of 21 speciated HAP compounds. These reports also include measurements of

THC, CO, CO₂, NO_x, and 25 other non-HAP compounds. The reports include measurements of uncontrolled emissions, as well as controlled emissions from a number of APCD's including RTO's, regenerative catalytic oxidizers (RCO's), thermal oxidizers, exhaust gas recirculation systems, biofilters, wet scrubbers, EFB's, WESP's, baghouses, and multicyclones.

C. NCASI Data

Data from the NCASI MACT sampling program is published in a series of seven technical bulletins and was also provided to EPA electronically in a consolidated emissions database.¹⁰⁸⁻¹¹⁵ The consolidated emissions database includes approximately 21,000 emission test runs and is the largest single source of HAP emission data for the wood products industry. Emission tests were conducted at 29 mills, representing a cross section of product types, source types, and emission control techniques.

The data collected from the NCASI program characterize emissions of 20 speciated HAP compounds, 9 additional non-HAP compounds, THC, and CO. In some cases, methane emissions were measured at RTO outlets so that non-methane THC emissions could be calculated. In addition to uncontrolled emissions, emissions were measured at the outlets of a number of different APCD's, including RTO's, RCO's, biofilters, wet scrubbers, WESP's, EFB's, and baghouses.

III. Pollutants and Emission Measurement Methods

A number of different emission test methods were used to collect the emission data used in the development of emission factors for the plywood and composite wood products project. Table 3-1 of Attachment 3 lists each emission test method used, an abbreviated name for each method, and the pollutants measured with each method. Most of the data were collected using EPA reference test methods or the NCASI impinger/canister method (NICM). In general, all emissions data for a given pollutant were treated equally regardless of the test methods used to collect those data. However, data collected using ambient methods, National Institute for Occupational Safety and Health (NIOSH) methods, or other unusual (non-standard) test methods were discarded if data collected with stack sampling methods were available. Emission test methods for HAP and non-HAP compounds are discussed in the paragraphs below.

A. Hazardous Air Pollutants (HAP)

Emissions data were collected for approximately 30 HAP compounds as part of this project. These HAP are italicized in Table 3-1 of Attachment 3. Because no EPA reference test methods have been developed specifically for measuring HAP emissions from the plywood and composite wood products industry, the available HAP emissions data were collected using a variety of emission test methods.

With one exception, no attempt was made to assess the potential effect of stack sampling methods on measured HAP emissions, primarily because the data sets were too small. However, a significant amount of formaldehyde data was obtained using two distinct test methods (described below), and therefore, the formaldehyde data collected with these two methods were compared to determine if there were any biases associated with the test methods. The results of the data analysis showed no discernible differences in the results obtained using the two methods (in fact, the two data sets completely overlapped), and therefore, all of the available formaldehyde data were treated as one data set.¹¹⁶

The bulk of the speciated organic HAP data (including formaldehyde) was collected as part of the NCASI emissions test program using the NCASI impinger/canister method (NICM). The NCASI test program included the sampling and analysis of 20 different HAP compounds. A list of these compounds and the analysis methods used to measure each HAP is provided in Table 3-2 of Attachment 3. The NICM testing was done using a self-validating quality assurance program and is described in detail in NCASI Technical Bulletin 774.¹¹⁴

A significant amount of formaldehyde and other aldehyde and ketone emissions data from wood products operations also was obtained using EPA Method 0011 (M0011). Although M0011 was developed specifically for formaldehyde emissions, it has not been validated for wood products industry emission sources. EPA Method 0011 also has been applied to other aldehyde and ketone compounds including acetaldehyde, acrolein, propionaldehyde, and methyl ethyl ketone. Some formaldehyde data were collected using California Air Resources Board (CARB) Method 430. The EPA's Emission Measurement Center (EMC) has indicated that this method is similar to M0011.

Other EPA reference methods used to collect HAP emission data include Method 0010 for volatile organic HAP, Method 0030 for semi-volatile organic HAP, Method 308 for methanol, modified Method 5 for phenol, and Method 18 for benzene. In addition, three ambient EPA methods were used to collect HAP data: TO-5, TO-8, and TO-14. The limited data available for methylene diphenyl diisocyanate (MDI) were collected using one of two methods: the 1-(2-pyridyl) piperazine method (1,2-PP) or P&CAM 142.

B. Non-HAP Data

Data also were compiled for a number of non-HAP compounds because these data may be needed in order to more fully evaluate emission control options. The majority of the non-HAP emission data collected are measurements taken using EPA reference methods. Emission measurement methods for THC, PM, and other non-HAP compounds are discussed in the paragraphs which follow.

1. Total Hydrocarbons

Organic compound emissions data for the wood products industry have been obtained primarily via one of two EPA methods: Method 25 (M25) and Method 25A (M25A). It is important to understand that these two methods measure different portions of the total organic compounds in the exhaust stream and that results from the two methods are not directly comparable.

Method 25 measures volatile organic compounds (VOC) emissions as total gaseous nonmethane organics (TGNMO). Results of M25 measurements are typically reported as carbon concentrations or mass rates. Because organic PM interferes with the organic analysis, the sample is drawn through a heated filter for PM removal. The sample is drawn from the filter through a condensate trap into an evacuated sample tank. The material in the trap and sample tank are recovered and analyzed separately, and the results are combined to determine total VOC. The organic material in the condensate trap is oxidized to CO₂ and collected in an evacuated vessel; then a portion of the CO₂ is reduced to methane (CH₄) and measured by flame ionization detector (FID). A portion of the gas collected in the sample tank is first passed through a gas chromatograph to separate CO, CO₂, and CH₄ from the remaining nonmethane organic material (NOM). The NOM is then oxidized to CO₂, reduced to CH₄, and measured by FID. This procedure essentially counts the number of carbon atoms present in the nonmethane volatile organic material and eliminates inconsistencies associated with the variable response of the FID to different organic compounds.

Method 25A is used to provide a continuous measure of the concentration of organic vapors consisting primarily of alkanes, alkenes, and aromatic hydrocarbons, collectively referred to as total hydrocarbons (THC). The stack gas sample is collected through a heated sample line with either an in-stack or heated filter to remove PM. From the filter, the sample is directed to an FID, and the concentration of organic material in the gas stream is measured as calibration gas equivalents or as carbon equivalents. The results depend strongly on the particular constituents that make up the organic content of the gas stream because the FID has different response factors for different organic bond structures. In particular, the carbon/oxygen bond (as in formaldehyde and methanol) provides a negative interference, so the response of the FID to oxygenated compounds (like formaldehyde and methanol) is diminished. Consequently, M25A does not include an adequate measure of formaldehyde and methanol emissions and does not accurately quantify emissions of other oxygenated compounds in the THC estimate. Also, M25A measures methane, which is not regulated as a VOC. This may result in the overestimation of VOC emissions from gas-fired emission sources which may have significant methane emissions.

The limited amount of M25 VOC emission data from AP-42 was discarded. As mentioned above, measurements of VOC obtained using M25 are not directly comparable with measurements of THC obtained using M25A. All of the non-speciated organic compound data from the 99 emission test reports and from the NCASI MACT sampling program were collected using M25A. In addition, most of the non-speciated organic compound data from AP-42 were obtained using M25A. All THC emission factors presented in this memorandum are based on M25A and are reported on a carbon basis. The THC emission factors have not been adjusted to exclude methane.

It is important to note that the THC emission factor for a given source is not directly comparable to the sum of HAP emission factors (total HAP) for that source. The THC analysis uses the molecular weight of carbon (12 grams/mole) to convert measured concentrations into mass emission rates. The emission rates for the individual HAP are calculated using the molecular weights of the individual compounds. Thus, different mass emission rates would be calculated by the two methods even if the measured concentrations were the same. In addition, as mentioned above, M25A underpredicts the concentrations of oxygenated compounds in the exhaust stream.

2. Particulate Matter

There are three distinct PM fractions for which EPA has developed emission test methods: (1) filterable PM, (2) condensible PM, and (3) particulate matter equal to or less than an aerodynamic diameter of nominally 10 micrometers (PM-10). The material collected in the probe and filter (front-half catch) of an EPA Method 5 (M5) sampling train is considered by EPA to be filterable PM. The material collected in the impingers (back-half catch) of an EPA M5 or Method 202 (M202) sampling train is considered by EPA to be condensible PM. The material collected on the filter and in the sample line between the cyclone and filter of an EPA Method 201 or 201A (M201 or M201A) sampling train is considered by EPA to be PM-10.

It is routine for filterable PM and condensible PM emissions to be summed in order to generate a "total PM" value. With regard to PM-10 emissions, the applicability sections of EPA M201 and M201A state that:

EPA recognizes that condensible emissions not collected by an in-stack method are also PM-10, and that emissions that contribute to ambient PM-10 levels are the sum of condensible emissions and emissions measured by an in-stack PM-10 method, such as [Method 201] or Method 201A. Therefore, for establishing source contributions to ambient levels of PM-10, such as for emission inventory purposes, EPA suggests that source PM-10 measurement include both in-stack PM-10 and condensible emissions.

In effect, this means that condensible PM emissions are also PM-10 emissions, and in order to determine "total PM-10" emissions, PM-10 emissions measured with M201 or M201A should be summed with condensible PM emissions. In this memorandum, PM-10 emissions measured with M201 or M201A are referred to as "filterable PM-10" as an indication of EPA's view that these measurements represent only the "front-half" or "dry" portion of total PM-10 emissions.

The data from the AP-42 background reports includes measurements of total PM and total PM-10 emissions. Because of the potential for double-counting the condensible PM portion of the emissions, these data were not used to develop emission factors for total PM or total PM-10. However, the separate emission factors presented in this memorandum for filterable PM and condensible PM may be summed as appropriate to determine an emission factor for total PM.

Similarly, the separate emission factors presented in this memorandum for filterable PM-10 and condensible PM may be summed where required to determine an emission factor for total PM-10. Care should be taken not to double-count the condensible PM emissions when preparing estimates of facility emissions.

3. Other Non-HAP Compounds

Data are available for CO, CO₂, NO_x, SO₂, and a number of volatile and semi-volatile organic compounds. As noted above, most of the non-HAP data have been collected using EPA reference methods. Data for these non-HAP compounds are incorporated from the existing AP-42 data and from the 99 emission test reports submitted with the MACT survey responses. The NCASI MACT sampling database includes measurements of nine speciated non-HAP organic compounds. A list of the nine non-HAP compounds and the analysis methods used to measure each compound is provided in Table 3-3 of Attachment 3. However, because the focus of this project is HAP compounds, the speciated non-HAP data were not extracted from the NCASI MACT sampling database.

IV. Review of Emission Data

A. AP-42

As mentioned in Section II.A of this memorandum, data to be included in AP-42 are presented in two different formats. First, a background report including the individual test data points and a discussion of how they are combined is developed. Then, an AP-42 section which includes only the combined, or average, emission factors is developed. The average emission factors in the final section then are published in the compilation commonly referred to as AP-42. Average emission factors were not taken from the final AP-42 sections. Rather, the emission and process data from the individual tests were retrieved from the background reports to allow averaging with the new data (from the 99 new emission test reports and NCASI). The data from AP-42 had already undergone a thorough EPA review and rating process and were ready to be incorporated with the new data. The review and rating process for AP-42 is described in detail in the EPA manual, *Procedures for Preparing Emission Factor Documents*.¹¹⁷

Data used for AP-42 are assigned A through D letter ratings, where A represents the most reliable data. The AP-42 rating criteria are summarized as follows:

- A -- Multiple test runs that were performed 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 unproven or new methodology, or that lacked a significant amount of background information.
- D -- Tests that were based on a generally unacceptable method, but may provide an order-of-magnitude value for the source.

Due to the large quantity of data in AP-42, the additional emission test reports, and the NCASI database, and the understanding that the additional data would generally be higher A- and B-rated data, all C- and D-rated AP-42 data were discarded. The discarded data included emission factors in incompatible units, data based on measurements with unspecified or unusual test methods, and data where process operations were not clearly defined.

B. Emission Test Reports

The review of the 99 new emission test reports consisted primarily of quality assurance and quality control (QA/QC) review of the emissions calculations, extraction of process information, and assigning of a quality rating like that done for AP-42. The QA/QC review of the additional emission test reports involved retrieving run-specific stack parameters, pollutant concentrations, and production rates from the emission test reports and entering the raw data into a series of spreadsheets to recalculate stack gas standard flow rates, mass emission rates of pollutants in units of pounds per hour (lb/hr), and emission factors in units of pounds of pollutant per process rate unit (for example, pounds of pollutant per oven-dried ton of wood).

Reports that lacked raw data sheets or other supporting data to allow recalculation of mass emission rates (summary reports) were generally not reviewed and, consequently, were not used for emission factor development. Reports that lacked sufficient documentation to calculate emission factors (e.g., reports with no process rates), but which included enough information to recalculate lb/hr mass emission rates were reviewed if they allowed calculation of APCD control efficiency.

In some cases, responses to the EPA's 1998 MACT survey of the plywood and composite wood products industry were used to fill gaps in the process data. Only relatively constant process data were pulled from the survey responses (e.g., resin type, dryer firing method). Process data that vary greatly over time (e.g., equipment throughput) were not pulled from the survey responses, nor was confidential business information (CBI) used to fill data gaps.

A more detailed description of the approach used to review and extract data from the emission test reports is presented in a separate memorandum.¹¹⁸

C. NCASI Data

The NCASI provided EPA with an electronic data base of the run-by-run emission test data summarized in technical bulletins 768 through 774. The run-by-run data in the data base were in units of concentration (ppm) and mass rate (lb/hr and lb/unit operation throughput). The method detection limit (MDL) was included in the data base for test runs that were non-detect (i.e., below the MDL, or “BDL”). Most of these run-by-run data were extracted from the NCASI data base.

During the review of the NCASI data, it was discovered that five HAP compounds (bromomethane, chloroethane, chloroethene, 1,2-dichloroethane, and 1,2,4-trichlorobenzene) were BDL for all test runs on all sources. Data for these HAP were not extracted from the NCASI data base for two reasons: (1) because there were no detectable runs for these compounds, and (2) because there were no test data for these compounds other than that in the NCASI data base. Likewise, there were some compounds that were non-detect for all unit operations within an industry sector (e.g., methylene chloride from OSB emission sources). In such situations, if there were no other data for the source and pollutant, the data for the non-detect HAP were not extracted from the NCASI data base. This approach reduced the number of calculations to be performed and prevented cluttering of the emission factor spreadsheets with compounds that may not be present at certain wood products facilities.

Due to the extensive data review process within NCASI, review of the NCASI data was less stringent than that for the emission test reports submitted with survey responses. Pollutant concentrations and mass emission rates were not recalculated as for the 99 emission test reports. Review of the NCASI data essentially consisted of recalculating average emission factors from the individual run data for each emission source and assigning a data rating.

The most significant adjustment made to the NCASI data was the recalculation of emission factors incorporating “non-detect” test runs. In general, when calculating emission factors NCASI treated non-detects as “zero.” While there are no set rules for handling non-detect data, the methodology used by EPA when developing the AP-42 emission factors was to assign a value of one-half of the MDL for non-detect runs. This same methodology was applied for the data from the emission test reports. Thus, for consistency with the data extracted from AP-42 and the emission test reports, non-detect runs were reassigned a value of one-half the MDL when recalculating the average NCASI emission factors. A detailed discussion of the treatment of non-detect data by NCASI and by EPA is presented in a separate memorandum.¹¹⁹

Once the run-by-run data were extracted from the NCASI data base and re-averaged, the averages (where no non-detect runs were involved) were checked using the technical bulletins. Next, using the technical bulletins as a guide, test results for individual process vents on multi-vent unit operations were combined for total source emissions. Process data for each unit operation was pulled

from the technical bulletins. Attention was also given to the discussions in the technical bulletins of any difficulties or unusual circumstances encountered during the test program.

V. Emission Factor Calculations

A. General Approach

First, emission test averages (typically averages of three-run tests) from AP-42, the MACT survey test reports, and NCASI were combined in a spreadsheet. Next, the combined test averages were grouped by product, pollutant, source type, and APCD. Other parameters that could significantly impact emissions also were used to group the data when appropriate. Once grouped, the test averages were used to calculate average emission factors.

B. Grouping of Test Averages

The test averages were sorted into several groups. Grouping by pollutant, wood product, and general source type (e.g., tube dryer, veneer dryer) was straightforward. However, some interpretation of the data was necessary for deciding how to group test averages by APCD and how to further group test averages within source types (e.g., segregate plywood veneer dryer data by firing method).

1. Grouping by APCD

Based on a review of the control efficiency data, APCD's installed for PM abatement were considered to have no effect on gaseous emissions, including THC, CO, CO₂, NO_x, and gaseous HAP. These APCD's include cyclones, multiclones (or multicyclones), baghouses (or fabric filters), and EFB's. As a result, emission test averages for sources with PM controls were averaged with the uncontrolled emission test averages for all pollutants except filterable PM, condensible PM, and PM-10.

Wet electrostatic precipitators and wet scrubbers installed for PM control also were considered to have no effect on gaseous emissions. These wet systems may achieve short-term reductions in THC or gaseous HAP emissions, however, the HAP and THC control efficiency data, which range from slightly positive to negative values, indicate that the ability of these wet systems to absorb water-soluble compounds (such as formaldehyde) diminishes as the recirculating scrubbing liquid becomes saturated with these compounds. Thus, as for the other PM controls, test averages for WESP's and wet scrubbers were averaged with uncontrolled test averages for all pollutants except filterable PM, condensible PM, and PM-10.

One wet scrubbing system, a combination water tray tower/high energy venturi scrubber that uses treated water and is designed to minimize emissions of both PM and odorous compounds from a hardboard press, did achieve notable HAP and THC emissions reductions. This system reduced

formaldehyde and methanol emissions by 65 percent and 50 percent, respectively, and reduced THC emissions by 86 percent.¹¹³ Separate emission factors were developed for the outlet of this scrubber.

Data were available for several control technologies that achieve significant THC and HAP removal. Most of these technologies are incineration-based, including thermal oxidizers, regenerative thermal oxidizers (RTO's), regenerative catalytic oxidizers (RCO's), and exhaust gas recirculation systems. Data were also available for biofiltration systems. Separate emission factors were developed for sources with outlet data for each of these control devices.

A separate memorandum presents a detailed discussion of the control efficiencies for the various control devices.¹²⁰

2. Grouping within source types

There are several operating and design parameters which may affect emissions from dryers, presses, and other wood products equipment. For example, dryer emissions may be affected by wood furnish characteristics (e.g., wood species, age, season), heat source, fuel, temperature, percent fines, resin addition, etc. Press emissions may be affected by type and amount of resin applied, wood species, moisture content, cycle time, temperature, addition of catalysts and scavengers, etc. Lists of the parameters EPA attempted to collect for each emission source type are included in the memo describing the emission test report review process.¹¹⁸ It is not practical to consider all of these parameters for emission factor development because the data set becomes smaller each time a distinction is made. Also, in many cases, the source-to-source variability was greater than the variability associated with operating parameters.

Some parameters affect emissions more than others. Furthermore, a parameter that increases emissions of one pollutant may also decrease emissions of another pollutant. Therefore, care was taken to select the parameters that may have the most significant effect on HAP emissions when deciding how to further group test averages among source types. Discussions of grouping according to source parameters in the NCASI technical bulletins were reviewed in making decisions on how to group the emission factors. In addition, the grouping schemes used in AP-42 were also considered because these schemes were reviewed by industry representatives when the AP-42 sections were developed.

Dryers within each industry sector were generally differentiated by firing type, fuel type, and wood species. For MDF and hardboard tube dryers, further distinctions were made for blowline versus non-blowline blending, resin type, and for secondary (relay) dryers. For hardboard and fiberboard board dryers, distinctions were made for differing binder systems. Hot presses within each industry sector were differentiated by resin type only. For the remaining sources, distinctions were made as warranted by the data. The labels in the summary tables found in Attachment 1 indicate which of the parameters were used to differentiate the test averages among sources.

For particleboard and MDF rotary dryers, a distinction was made between predryers or “green” dryers and “dry” dryers. In general, dryers with an inlet moisture content of greater than 50 percent (dry basis) were considered green dryers. Dryers with an inlet moisture content less than 50 percent (dry basis) were considered dry dryers. There were a few instances in which dryers with a reported inlet moisture content just below the 50 percent threshold were included with the green dryers because the plant considered them to be green dryers or predryers.

In cases where one species (or group of species, e.g., softwoods) accounted for 70 percent or more of the wood mix, the process unit was categorized by that species. For example, if a dryer processed 70 percent pines and 30 percent mixed hardwoods, the dryer was grouped with softwood dryers. If the dryer processed 40 percent softwood and 60 percent hardwood, the dryer was grouped with mixed wood species dryers.

Where emission factors for mixed hardwood and softwood species have been calculated, the wood species mix has been specified. Emission factors for other mixes of hardwood and softwood species may be calculated by combining the emission factors for hardwoods and softwoods in the ratio specific to a given application. For example, an uncontrolled THC emission factor for a direct wood-fired OSB rotary dryer processing 70 percent softwood and 30 percent hardwood may be calculated using the uncontrolled THC emission factor for softwood (6.7 lb/ODT) and hardwood (1.7 lb/ODT), and the ratio of 70 percent to 30 percent. The resultant emission factor, rounded to two significant figures, would be 5.2 lb/ODT.

C. Calculating Emission Factors from Grouped Test Averages

Once emission test averages were grouped according to pollutant, APCD, and source type, the test averages were then averaged to develop each emission factor. The data available for some of the emission factors developed included the results of multiple tests on the same piece of equipment. In such cases, the test-specific emission factors for the same piece of equipment were averaged first, and that average emission factor then was averaged with the factors for the other pieces of equipment to yield the overall average emission factor. The averaging of multiple tests on the same piece of equipment was more often an issue for criteria pollutants; it occurred much less frequently for HAP compounds.

The number of non-detect test runs for each test average was considered before test averages were subsequently averaged into emission factors. If all of the test averages for a source were based on non-detect test runs, then no emission factor was developed and a “BDL” code was substituted for the numeric emission factor. If some of the data were non-detect and some were above the MDL, then values of one-half of the MDL were averaged into the emission factors for the non-detect test runs.

Some tests have higher MDL’s than others in the same data set. This can lead to situations where averaging in half of a high MDL will bias the average high. If the half-MDL value for a non-

detect test is higher than all detect values for the other tests in the data set, the non-detect test is discarded. If the half-MDL values are less than detect values, they are included in the average.

Attachment 4 is a table with an example calculation to illustrate how the average emission factors were calculated from the individual data points.

VI. Presentation of the Emission Factors

The emission factors developed for the Plywood and Composite Wood Products NESHAP project are summarized in a series of tables in Attachment 1. These tables present emission factors for hot presses; board coolers; rotary dryers; tube dryers; veneer dryers; conveyer dryers; hardboard/fiberboard kilns, ovens, and dryers; and miscellaneous sources. The miscellaneous table includes a wide variety of emission sources from the green end (including chippers and refiners) to the finishing end (such as sanders and saws) of wood products plants. Each of these tables includes:

1. a description of the unit operation;
2. an identifier for HAP compounds;
3. the number of tests on which each emission factor is based;
4. the number of process units tested;
5. the number of test runs;
6. the number of non-detect (BDL) test runs;
7. the APCD;
8. process-related information such as resin type or wood species (as necessary);
9. the range of the data (minimum and maximum values);
10. the average emission factor;
11. the standard deviation for emission factors based on five or more emission tests; and
12. the emission factor units.

Attachment 2 presents a series of tables that show which data sets were used to develop each of the emission factors presented in the summary tables of Attachment 1. The organization of the tables parallels those of Attachment 1. The acronyms, codes, and abbreviations used in the emission factor tables are defined in a series of tables in Attachment 3. Attachment 5 provides some useful conversion factors.

The purpose of this document is to provide a mechanism for estimating emissions in the absence of plant-specific test data. These emission factors will be used by EPA to estimate nationwide emissions from the wood products industry. Attempts were made to select common distinctions in process equipment for purposes of grouping and averaging emission factors. Nevertheless, it is realized that State or plant personnel may be more interested in emission factors more specific to a particular facility than the ones presented in the summary tables in Attachment 1. The detail tables have been

presented in Attachment 2 to assist State and plant personnel with customizing emission factors for individual facilities, as necessary.

VII. References

1. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, U.S. Environmental Protection Agency, Research Triangle Park, NC, 1995.
2. *Emission Factor Documentation for AP-42 Section 10.5, Plywood Manufacturing*, U. S. Environmental Protection Agency, Research Triangle Park, NC, September 1997.
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Attachment 1

Summary Spreadsheets

Attachment 2

Detail Spreadsheets

Attachment 3

Acronymns/Codes/Abbreviations

Table 3-1. Emission Test Method Codes

Code	Test Method	Pollutant(s) Measured ^a
1,2-PP	1-(2-pyridyl) piperazine method	<i>Methylene diphenyl diisocyanate (MDI)</i>
BCA	Bacharach combustion analyzer	Carbon monoxide
CARB430	California Air Resources Board Method 430	<i>Formaldehyde</i>
DNPH	Unspecified DNPH method	<i>Formaldehyde</i>
GC	Unspecified gas chromatography	Methane
GC/FID	Unspecified gas chromatography/flame ionization detector method	Ethane, methane
M0010	SW-846 Method 0010, Semi-VOST (Semivolatile Organic Sampling Train)	1,2,4-trimethylbenzene, <i>acetophenone</i> , a-pinene, a-terpene, <i>biphenyl</i> , <i>bis-(2-ethylhexyl phthalate)</i> , b-pinene, butylbenzyl phthalate, <i>cumene</i> , p-cymene, <i>di-N-butyl phthalate</i> , <i>hydroquinone</i>
M0011	BIF Method 0011, for Aldehydes and Ketones	2,5-dimethyl benzaldehyde, <i>acetaldehyde</i> , acetone, <i>acrolein</i> , benzaldehyde, butylaldehyde, butyraldehyde, crotonaldehyde, <i>formaldehyde</i> , hexaldehyde, isovaleraldehyde, <i>methyl ethyl ketone</i> , o-,m-,p-tolualdehyde, <i>propionaldehyde</i> , valeraldehyde
M0030	SW-846 Method 0030, VOST (Volatile Organic Sampling Train)	<i>1,1,1-trichloroethane</i> , <i>4-methyl-2-pentanone</i> , a-pinene, acetone, b-pinene, <i>benzene</i> , <i>bromomethane</i> , <i>carbon disulfide</i> , <i>carbon tetrachloride</i> , <i>chloroform</i> , <i>chloromethane</i> , <i>cumene</i> , dimethyl sulfide, <i>ethyl benzene</i> , <i>n-hexane</i> , <i>methyl ethyl ketone</i> , <i>methylene chloride</i> , p-cymene, <i>styrene</i> , <i>toluene</i> , o-,m-,p-xylene
M10	EPA Method 10	Carbon monoxide
M10B	EPA Method 10B	Carbon monoxide
M18	EPA Method 18	<i>Benzene</i> , methane

Table 3-1. (continued)

Code	Test Method	Pollutant(s) Measured ^a
M201A	EPA Method 201A	PM-10
M202	EPA Method 202	Condensable PM
M25A	EPA Method 25A	Total hydrocarbons (THC)
M3	EPA Method 3	Carbon dioxide
M3A	EPA Method 3A	Carbon dioxide
M308	EPA Method 308	<i>Methanol</i>
M5	EPA Method 5	Filterable PM
M6	EPA Method 6	Sulfur dioxide
M6C	EPA Method 6C	Sulfur dioxide
M7	EPA Method 7	Nitrogen oxides
M7C	EPA Method 7C	Nitrogen oxides
M7E	EPA Method 7E	Nitrogen oxides
MM5	Modified EPA Method 5	<i>Phenol</i>
MM0011	Modified BIF Method 0011, for Aldehydes and Ketones	<i>Formaldehyde</i>
NCASI	NCASI impinger method	<i>Formaldehyde, methanol</i>

Table 3-1. (continued)

Code	Test Method	Pollutant(s) Measured ^a
NICM	NCASI impinger/canister method	<i>Acetaldehyde</i> , acetone, <i>acrolein</i> , a-pinene, b-pinene, <i>benzene</i> , <i>bromomethane</i> , camphene, 3-carene, <i>chloroethane</i> , <i>chloroethene</i> , cis-1,2-dichloroethylene, <i>cumene</i> , <i>1,2-dichloroethane</i> , <i>formaldehyde</i> , limonene, p-mentha-1,5-diene, <i>methanol</i> , <i>methyl ethyl ketone</i> , <i>methyl isobutyl ketone</i> , <i>methylene chloride</i> , p-cymene, <i>phenol</i> , <i>propionaldehyde</i> , <i>styrene</i> , <i>toluene</i> , <i>1,2,4-trichlorobenzene</i> , <i>o-,m-,p-xylene</i>
P&CAM142	NIOSH Method P&CAM 142	<i>Methylene diphenyl diisocyanate (MDI)</i>
TO-5	TO-5 (Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air)	2,4-dimethylbenzaldehyde, acetone, benzaldehyde, butyraldehyde, crotonaldehyde, <i>formaldehyde</i> , hexaldehyde, isovaleraldehyde, o-,m-,p-tolualdehyde, valeraldehyde
TO-8	TO-8 (Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air)	<i>Benzo-a-pyrene</i> , <i>o-,m-,p-cresol</i> , <i>naphthalene</i> , <i>phenol</i> , pyridine
TO-14	TO-14 (Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air)	Acetone, <i>benzene</i> , <i>bromomethane</i> , <i>chloroethane</i> , <i>chloromethane</i> , ethanol, <i>ethylbenzene</i> , isobutanol, <i>methyl ethyl ketone</i> , methyl propyl ketone, <i>methylene chloride</i> , propanol, <i>styrene</i> , <i>toluene</i> , trichlorofluoromethane, <i>xylene</i> s
TO-14 (mod)	Modification of TO-14	<i>Methanol</i>

^aHAP compounds in italic.

Table 3-2. HAP Analytes and Analysis Techniques for NCASI MACT Sampling Program

HAP Analyte	Analysis Method	
	Impinger	Canister
acetaldehyde	GC/FID	GC/MS
acrolein	GC/FID	GC/MS
benzene	none	GC/MS
bromomethane ¹	none	GC/MS
chloroethane ¹	none	GC/MS
chloroethene ¹	none	GC/MS
cumene	none	GC/FID
1,2-dichloroethane ¹	none	GC/MS
formaldehyde	Colorimetric	none
methanol	GC/FID	GC/MS
methyl ethyl ketone	GC/FID	GC/MS
methyl isobutyl ketone	GC/FID	GC/MS
methylene chloride	none	GC/MS
phenol	GC/FID	GC/MS
propionaldehyde	GC/FID	GC/MS
styrene	none	GC/MS
toluene	none	GC/MS
1,2,4-trichlorobenzene ¹	none	GC/MS
m,p-xylene	none	GC/MS
o-xylene	none	GC/MS

¹The data for these compounds were not extracted from the NCASI data base because emissions of these HAP were below the method detection limit for all test runs on all sources tested.

Table 3-3. Non-HAP Analytes and Analysis Techniques for NCASI MACT Sampling Program¹

Non-HAP Analyte	Analysis Method	
	Impinger	Canister
acetone	GC/FID	GC/MS
camphene	none	GC/FID
3-carene	none	GC/FID
p-cymene	none	GC/FID
cis-1,2-dichloroethylene	none	GC/MS
limonene	none	GC/FID
p-mentha-1,5-diene	none	GC/FID
alpha-pinene	none	GC/FID
beta-pinene	none	GC/FID

¹The data for these compounds were not extracted from the NCASI database.

Table 3-4. Product Codes

Code	Product
FB	Fiberboard
HB	Hardboard
HPW	Hardwood Plywood
I-joist	I-joist
LSL	Laminated Strand Lumber
Lumber	Lumber
LVL	Laminated Veneer Lumber
MDF	Medium Density Fiberboard
OSB	Oriented Strandboard
PB	Particleboard
SPW	Softwood Plywood

Table 3-5. Air Pollution Control Device (APCD) Codes

Code	Air Pollution Control Device
BH	Baghouse (Fabric Filter)
BIO	Biofilter
CU	Combustion Unit; Exhaust Gas Recirculation
CYC	Cyclone
DESP	Dry Electrostatic Precipitator
EFB	Electrified Filter Bed
MC	Multicyclone (Multiclone)
NONE	None; no air pollution control device
RCO	Regenerative Catalytic Oxidizer
RTO	Regenerative Thermal Oxidizer
SCBR	Wet Scrubber
SF	Sand Filter
TO	Thermal Oxidizer
WESP	Wet Electrostatic Precipitator

Table 3-6. Wood Species Codes

Code	Wood Species
ALDER	Alder
ASPEN	Aspen
BIRCH	Birch
CBI	Wood species is Confidential Business Information
CHERRY	Cherry
DFIR	Douglas Fir

Table 3-6. (continued)

Code	Wood Species
DFIR-fresh	Douglas Fir - fresh cut
DFIR-7day old	Douglas Fir - cut 7 days before testing
DFIR HEART	Douglas Fir Heartwood
DFIR SAP	Douglas Fir Sapwood
GUM	Unspecified Gum
HICKORY	Hickory
HWOOD	Unspecified Hardwood
LARCH	Larch
MAPLE	Maple
MIXED	Mixed hardwood and softwood species
NPINE	Northern Pine
NS	Not Specified
OAK	Oak
PINE	Unspecified Pine
POPLAR	Poplar
PPINE	Ponderosa Pine
ROAK	Red Oak
SPRUCE	Spruce
SWOOD	Unspecified Softwood
SYPINE	Southern Yellow Pine
UFIR	Unspecified Fir
USPINE	Unspecified Southern Pine
WFIR	White Fir
WOAK	White Oak

Table 3-6. (continued)

Code	Wood Species
WSWOOD	Western Softwood
YPOPLAR	Yellow Poplar

Table 3-7. Resin Codes

Code	Resin Type
LINSEED	Linseed Oil Binder System
MDI	Methylene diphenyl diisocyanate
PF	Phenol-Formaldehyde
PF-dry	Dry Phenol-Formaldehyde
UF	Urea-Formaldehyde

Table 3-8. Dryer Firing Type Codes

Code	Dryer Firing Type
DF	Direct-Fired
IF	Indirect Heated
IF/DF	Indirect and Direct Heat
RF	Radio-Frequency Heated

Table 3-9. Dryer Fuel Type Codes

Code	Dryer Fuel Type
DFINE	Dry Wood Fines (unspecified)
FINES	Wood Fines (unspecified)
NGAS	Natural Gas
PROP	Propane
SDUST	Sanderdust
STEAM	Steam Heated (indirect heated)
TRIM	Wood Trim
WDUST	Wood Dust (unspecified)
WREF	Wood Refuse (unspecified)

Table 3-10. Dryer Hot Air Source Codes

Code	Dryer Hot Air Source
BOILER FLUE GAS	Boiler Flue Gas
BOTH	Indirect and Direct Heat
DFIRE	Direct-Fired (unspecified)
FLUE GAS	Flue Gas
FUEL CELL	Fuel Cell
GAS BU	Gas Burner
IHEAT	Indirect heated
RFREQ	Radio-Frequency Heated
STEAM	Steam (indirect heat)
STM COIL	Steam Coil (indirect heat)
SUSP BU	Suspension Burner
TOH	Thermal Oil Heater
WET CELL	Wet Cell

Table 3-11. Veneer Dryer Type Codes

Code	Veneer Dryer Type
LONG	Longitudinal
JET	Jet
PLATEN	Platen
RF	Radio-Frequency Heated
TUNNEL	Tunnel

Table 3-12. Emission Factor Unit Abbreviations

Emission Factor Unit Abbreviation	Definition
lb/1000 ft ³	pounds per thousand cubic feet
lb/MLF	pounds per thousand linear feet
lb/MSF	pounds per thousand square feet of surface area
lb/MSF reclaim	pounds per thousand square feet of reclaimed material surface area
lb/MSF 1/2	pounds per thousand square feet of 1/2-inch thick board
lb/MSF 1/8	pounds per thousand square feet of 1/8-inch thick board
lb/MSF 3/4	pounds per thousand square feet of 3/4-inch thick board
lb/MSF 3/8	pounds per thousand square feet of 3/8-inch thick board
lb/ODT	pounds per oven-dried ton

Attachment 4

Example Calculation

Example Calculation

Unit Operation	Test date	No. of runs	No. of runs BDL	Test emission factor value (average of test runs), lb/ODT	Unit emission factor value, lb/ODT
Plant 30, dryer A	1/19/93	3	0	0.000413	0.000413
Plant 10, dryer A	10/22/97	3	3	0.008121	0.008121 ^a
Plant 10, dryer B	10/22/97	3	3	0.003042	0.003042
Plant 156, dryer A	9/22/97	6	0	0.006574	0.007113
Plant 156, dryer A	9/22/97	3	0	0.007652	
Plant 183, dryer A	5/2/97	3	2	0.003555	0.004664
Plant 183, dryer A	5/2/97	3	0	0.005773	
Plant 30, dryer B	1/20/93	3	0	0.002676	0.002676
Overall emission factor for unit operation (average of unit emission factor values), lb/ODT					0.0036

^aThis unit average emission factor was disregarded when calculating the overall emission factor for the unit operation. This value is one-half of the MDL for a test where all runs were non-detect, and is higher than all of the other detect runs. Using this value would bias the overall average emission factor high.

Attachment 5

Conversion Factors

Useful Conversion Factors

To convert from . . .	to . . .	multiply by . . .
board feet	cubic feet	0.0833
lb as carbon	lb as propane	1.22
lb as propane	lb as carbon	0.82
MSF "X" basis	MSF "Y" basis	X/Y
ppm as carbon	ppm as propane	0.33
ppm as propane	ppm as carbon	3.0