

Date: February 7, 2001

Subject: Draft Emission Factor Documentation for AP-42 Chapter 10, Plywood and Composite Wood Products

I. Introduction

The purpose of this memorandum is to document the development of emission factors for the EPA's *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources* (commonly referred to as AP-42), Chapter 10, Plywood and Composite Wood Products Industry. Four existing AP-42 sections were revised: plywood, waferboard/oriented strandboard, particleboard, and medium density fiberboard. In addition, two new AP-42 sections were created: hardboard and fiberboard, and engineered wood products. Emission factors were not revised for the remaining sections of Chapter 10 (lumber, chemical wood pulping, pulp bleaching, papermaking, charcoal, and wood preserving). Summary tables presenting the average emission factors and the individual data sets used to develop each average emission factor are included as Attachment 1 to this memorandum.

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 emission factors presented in Attachment 1 provide a mechanism for estimating emissions in the absence of plant-specific test data. Attempts were made to select common distinctions in process equipment for purposes of grouping emission data and averaging emission factors. Nevertheless, it is realized that Federal, State, and local air pollution control agencies, plant personnel, and other interested parties responsible for estimating air emissions from plywood and composite wood products facilities 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 detailed data tables presented in Attachment 1 have been provided to assist with customizing emission factors for individual facilities, as necessary.

This background memorandum consists of six sections. Section I is the introduction to the memorandum. 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 pollutants and 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

The emission factors presented in this memorandum are based on data combined from three types of sources: (1) prior versions of AP-42 sections covering the plywood and composite wood products industry; (2) numerous emission test reports (dated 1995 or later) collected from plants during EPA's 1998 maximum achievable control technology (MACT) standard survey; and (3) results from an extensive air emission testing program conducted by the National Council of the Paper Industry for Air and Stream Improvement (NCASI). A total of 111 emission data sources were reviewed in the development of emission factors for the plywood and composite wood products sections of AP-42. These 111 emission data sources are divided into three groups as follows:

(1) Background reports for existing plywood and composite wood products industry sections of AP-42 (including reviews of 124 emission test reports) -- 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. Existing AP-42 Background Reports

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 the type of wood product manufactured. For each section published in AP-42, there is an accompanying background report. The AP-42 background reports provide details from each of the emission data references used to develop the AP-42 emission factors. Emission test data and process information were extracted from the existing 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 existing plywood background 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 existing waferboard/OSB background report includes a review of 105 emission test reports and the OSB portion of NCASI Technical Bulletin No. 694. The existing particleboard background report includes a review of eight emission test reports and the particleboard portion of NCASI Technical Bulletin No. 693.⁸ The existing MDF background report includes a review of six emission test reports and the MDF portion of NCASI Technical Bulletin No. 693.

The four existing AP-42 background reports were the source of approximately 5,600 emission test runs. The background reports include a significant quantity of data for criteria and other non-hazardous air pollutant (HAP) emissions 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 background reports also include measurements for 32 speciated HAP compounds. The background reports include data for uncontrolled emissions sources, as well as data for emissions controlled with 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 the existing AP-42 background reports, 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 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 sections of AP-42. Table 2-1 of Attachment 2 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 test methods or National Institute for Occupational Safety and Health (NIOSH) test methods were discarded if data collected with stack sampling methods were available for the same combination of source, control device, and pollutant. Emission test methods for HAP and non-HAP compounds are discussed in the paragraphs below.

A. Hazardous Air Pollutants (HAP)

"Hazardous air pollutants," as used in this memorandum, refers to the list of pollutants as promulgated in §112(b)(1) of the Clean Air Act (CAA). Emissions data were collected for approximately 30 HAP compounds as part of this revision of AP-42. These HAP are italicized in Table 2-1 of Attachment 2. The available HAP emissions data were collected using a variety of emission test methods.

With one exception, formaldehyde, 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 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 2-2 of Attachment 2. 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). The procedure collects an integrated sample isokinetically at points along perpendicular traverses of the stack. The gaseous and particulate pollutants in the sample gas are collected in an impinger train that contains an aqueous acidic solution of dinitrophenyl-hydrazine. Formaldehyde reacts with the dinitrophenyl-hydrazine to form a formaldehyde dinitrophenylhydrazone derivative. This derivative is extracted, solvent exchanged, concentrated, and analyzed by high performance liquid chromatography.

Although M0011 was developed specifically for formaldehyde emissions, it has not been validated for measuring formaldehyde emissions from 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. However, EPA recommends that M0011 be used only for the determination of formaldehyde, acetophenone, isophorone, acetaldehyde, and propionaldehyde emissions from stationary sources.¹¹⁷ The EPA further concludes that M0011 is not appropriate for the measurement of quinone, acrolein, methyl ethyl ketone, and methyl isobutyl ketone, due either to poor collection efficiency or analytical problems. The poor collection efficiency and analytical problems result in emission estimates for these compounds that are biased low.

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 M0011.¹¹⁸

Other EPA reference methods used to collect HAP emission data include Method 0010 for semi-volatile organic HAP, Method 0030 for volatile organic HAP, Method 308 for methanol, and Method 18 for benzene. In addition, three methods from the EPA Compendium of Methods for the Determination of Toxic Organic Compounds in Ambient Air (TO) 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 NIOSH Physical and Chemical Analytical Method 142 (P&CAM142).

B. Non-HAP Data

Data also were compiled for a number of non-HAP compounds. The majority of the non-HAP emission data collected are measurements taken using EPA reference methods. Emission measurement methods for organic compounds, PM, and other non-HAP compounds are discussed in the paragraphs which follow.

1. Organic Compounds

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 analysis of the volatile organics, 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 CO_2 and collected in an evacuated vessel; then a portion of the CO_2 is reduced to methane (CH_4) 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 , CO_2 , and CH_4 from the remaining nonmethane organic material (NOM). The NOM is then oxidized to CO_2 , reduced to CH_4 , 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 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) provides a negative interference, so the response of the FID to oxygenated compounds (like formaldehyde) is diminished. Consequently, M25A does not include an adequate measure of formaldehyde 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 the existing AP-42 background reports 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 the existing AP-42 background reports 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 organic HAP emission factors (total HAP) for that source. The THC analysis uses the molecular weight (MW) of carbon (12 grams/mole) to convert measured concentrations into mass emission rates. The mass 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 underestimates the concentrations of oxygenated compounds in the exhaust stream.

Guidance from EPA's Emission Factor and Inventory Group (EFIG) indicates that when it is possible, VOC emission factors should be reported in terms of the actual weight of the emitted compound. However, when an actual MW of the emitted stream is not feasible (as is the case with the mixed streams emitted from wood products industry sources), the VOC should be reported using an assumed MW of 44, and reported "as propane." Each VOC-as-propane emission factor is estimated by first converting the THC from a carbon basis to a propane basis. Propane (MW = 44) includes 3 carbon atoms (total MW of 36) and 8 hydrogen atoms (total MW of 8). Every 36 pounds of carbon measured corresponds to 44 pounds of propane. The ratio of the MW of propane to the MW of carbon in propane is 44/36, or 1.22. The conversion from mass on a carbon basis to mass on a propane basis is expressed by the following equation:

$$\text{THC as pounds carbon} \times \frac{44 \text{ pounds propane}}{36 \text{ pounds carbon}} = \text{THC as pounds propane}$$

or

$$\text{THC as pounds carbon} \times 1.22 = \text{THC as pounds propane}$$

After the THC emission factor has been converted from a carbon to a propane basis, the formaldehyde emission factor is added (where available), then the available emission factors for non-VOC compounds, including acetone, methane, and methylene chloride, are subtracted. This procedure is expressed simply by the following equation:

$$\text{VOC as propane} = (1.22 \times \text{THC as carbon}) + \text{formaldehyde} - (\text{acetone} + \text{methane} + \text{methylene chloride})$$

In cases where no emission factor is available (or the emission factor is reported only as below the test method detection limit, or "BDL") for one or more of the compounds used to estimate the VOC-as-propane value, adjustments to the converted THC value are made only for those compounds for which emission factors are available. That is, a value of zero is inserted in the above equation for the specified compounds where no emission factor is available, or where the emission factor is reported only as BDL. For example, if no methane emission factor is available, the THC-as-carbon emission factor is converted to THC-as-propane, formaldehyde is added, and only acetone and methylene chloride are subtracted.

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 equivalent 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.

Test methods for PM (both filterable and condensible) include the standard reference method (EPA Methods 1 through 5 with M5 being the primary PM procedure) and derivatives of M5. Other methods that have been used in the plywood and composite wood products industry are EPA Method 17 (M17) for total PM, M201 and M201A for PM-10, M202 for condensible PM, Oregon Department of Environmental Quality Method 8 (ODEQ-8) for filterable PM, and the Oregon Department of Environmental Quality Method 7 (ODEQ-7) for both filterable PM and condensible PM. The paragraphs below first describe the essential features of M5 and then describe how the other procedures differ from M5. No emissions data based on M17, ODEQ-7, or ODEQ-8 have been used to develop emission factors.

The primary components of the M5 sampling train are the nozzle, the probe, a filter (which is maintained at $120 \pm 14^{\circ}\text{EC}$ [$250 \pm 25^{\circ}\text{EF}$] in a heated filter box), an impinger train that is kept in an ice bath to cool the gas stream to ambient temperature, a meter box, and a pump. The impinger train contains four impingers; the first two contain water, the third is dry, and the fourth contains silica gel to dry the gas stream before it enters the dry gas meter. The M5 train collects an integrated sample over one to several hours at sample points that span a cross-section of the exhaust duct or stack, typically on perpendicular traverses across the diameter of the stack. At each sampling point, a sample of the gas stream is collected isokinetically through the nozzle. The captured gas stream moves through the probe to the filter. Some particles are collected on the walls of the probe, and the remaining material that is in particle phase at 120°EC (250°EF) is collected on the filter. The gases that pass through the filter then go through the impinger train where any organic or inorganic materials that condense between 16°E and 120°EC (60°E and 250°EF) are collected. Typically, the material collected in the probe and filter (front half catch) is considered for regulatory purposes to be PM, and the material captured in the impingers (back half catch) is considered to be condensible PM. The procedures for M5 do not require the back half catch of the sampling train to be quantified. However, as explained below, the M5 train may be coupled with a M202 sampling train for measuring the condensible PM emission rate.

The other two methods that have been used to collect total PM emissions from plywood and composite wood products industry operations, M17 and ODEQ-7, encompass the same principles as M5 but have specific modifications. The primary difference between M5 and M17 is in the collection

temperature for the front half catch. In order to maintain a collection temperature of 120EC (250EF), the M5 train employs a heated probe and filter. In contrast, the M17 train employs an in-stack filter, so the collection temperature is equal to the actual temperature of the stack gas. If the stack gas temperature is less than 120EC (250EF), then any material that condenses at temperatures between the stack gas temperature and 120EC (250EF) will be measured as filterable PM with M17. However, in a M5 train, this material would pass through the front half of the train to the impingers and would not be quantified as filterable PM. The measures are reversed if the stack gas temperature is greater than 120EC (250EF).

The ODEQ-7 method modifies M5 by adding a filter between the third and fourth impingers to collect any condensed material that escapes the impingers. This filter is maintained at approximately ambient temperature, and the material collected in the first three impingers and on the second filter are added to the front-half catch to obtain total PM. This procedure is intended to measure those constituents in the emissions responsible for the formation of PM once the emissions have cooled to ambient temperature.

Oregon Department of Environmental Quality Method 8 is a high volume method of sampling filterable PM emissions, primarily designed for wood product handling cyclone and baghouse exhaust systems whose primary emissions are solid PM. The primary components of the ODEQ-8 train are the nozzle, the probe, a filter (unheated, outside stack), a meter box and a pump. One primary difference between M5 and ODEQ-8 is in the collection temperature for the filter catch. In order to maintain a collection temperature of 120EC (250EF), the M5 train employs a heated probe and filter. In contrast, the ODEQ-8 train uses an unheated probe, and an unheated, out-of-stack filter, so the collection temperature is near the actual temperature of the stack gas. If the stack gas temperature is less than 120EC (250EF), then any material that condenses at temperatures between the stack gas temperature and 120EC (250EF) will be measured as filterable PM with ODEQ-8. However, in a M5 train, this material would pass through the front half of the train to the impingers and would not be quantified as filterable PM. The other major difference between M5 and ODEQ-8 is that the Oregon method does not include a series of impingers, or back half, and, therefore does not quantify condensible PM.

In 40 CFR Part 51, EPA has published a procedure for determining condensible PM emission rates (M202). Method 202, which applies to determination of condensible PM from stationary sources, measures condensible PM as material that passes through the filter and is collected in the impingers of a PM train. The primary method specifies that condensible PM be based on the back-half catch of a M17 train (which uses an in-stack filter), but M5, M201, or M201A procedures are also acceptable. The method specifies that the impinger solution be extracted with methylene chloride, the inorganic and organic fractions be dried separately, the residues weighed, and the condensible PM be determined from the combination of both residues. Note that because the method allows the use of either a heated filter system or an in-stack filter system, some ambiguity in results can occur from test to test.

In 40 CFR Part 51, EPA has published two procedures for determining PM-10 emission rates (M201 and M201A). Methods 201 and 201A are derivatives of M5, both of which include an in-stack cyclone to remove particles with an aerodynamic diameter greater than 10 micrometers (μm) from the gas stream followed by an in-stack filter to collect the remaining particles. The back half of the train is identical to the back half of the M5 train. Both methods require a traverse of the stack, but M201 uses isokinetic sampling with a recirculating system to maintain constant flow through the cyclone, while M201A uses a constant sampling rate. The PM-10 is determined gravimetrically from the material captured in the sample line between the cyclone and filter and on the filter. Neither of the two methods specify procedures for determining condensible PM, but both methods indicate that for applications such as inventories of sources contributing to ambient PM-10 levels, PM-10 should be the sum of condensible PM emissions and PM-10 emissions measured by the M201 or M201A procedures.

It is routine for filterable PM and condensible PM emissions to be summed in order to generate a total, or “primary 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 “primary 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 primary PM-10 emissions.

Separate emission factors are presented for filterable PM and condensible PM; they may be summed to determine an emission factor for total primary PM. Similarly, the separate emission factors presented for filterable PM-10 and condensible PM may be summed to determine an emission factor for total primary PM-10.

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.

Speciated non-HAP aldehyde and ketone data based on M0011 measurements are available, primarily for the MDF and particleboard industry sectors. As mentioned in Section III.A of this memorandum, EPA recommends M0011 be used only for the determination of formaldehyde, acetophenone, isophorone, acetaldehyde, and propionaldehyde emissions.¹¹⁷ Due to poor collection efficiency and analytical problems, emission estimates for other compounds may be biased low. The M0011 data for these compounds have been used to develop emission factors only in cases where no other emission data are available. For compounds where measurements with other methods are available, the M0011 data for these compounds have not been used in the development of average emission factors.

Speciated non-HAP data were also extracted from the NCASI MACT sampling database. The NCASI MACT sampling database includes measurements of nine speciated non-HAP organic compounds. A list of the nine non-HAP compounds and the analytical methods used to measure each compound is provided in Table 2-3 of Attachment 2. The NCASI MACT sampling database also included measurements of CO and methane at selected sources.

C. Emission Testing Issues

Many of the difficulties encountered in developing VOC and PM-10 emission factors for plywood and composite wood products industry dryers and hot presses arise because of the chemical composition of the organic materials found in the emission streams from these processes and the use of different test methods to collect and analyze these organic compounds for the historical data base. Also, the chemical and physical characteristics of these emission streams, particularly the moisture content and temperature variations, complicate sampling and analysis and data reduction. Particular issues of concern are complications associated with high moisture in exhaust streams, differing VOC and PM-10 results from different procedures and associated concerns with the condensible PM-10 as measured by Method 202, and the interrelationship between the estimates of VOC and PM-10 emissions. These issues are a general concern in the wood products industry and should be considered in the planning of emission test programs for the industry. The paragraphs below first discuss the characteristics of the organic material in wood products exhaust streams and then address the general issues outlined above.

1. Organic Emissions From Dryers and Presses

As green wood is subjected to heat in plywood and composite wood product dryers, some of the organic material in the wood is volatilized and carried off with the exhaust stream. These organic materials that emanate from the wood are the primary VOCs and condensible organic PM in the dryer exhaust. Consequently, the organic compounds found in wood products dryer emissions typically include terpenes, terpene-like materials, resins, and fatty acids comparable to those found in wood. The boiling points of many of these materials are in the range of 155E to 370EC (310E to 700EF). These temperatures are greater than typical dryer temperatures for some industry sectors, but the

compounds exhibit significant vapor pressures at dryer temperatures. Consequently, some of these organic compounds are at saturation levels in the gas streams and will condense as the gas stream cools.

2. Moisture Content of Dryer Exhaust

The inherent moisture contents of exhaust streams from plywood and composite wood product dryers complicate measurement of PM-10 emissions in these streams. This problem is most prevalent for facilities that have wet control devices such as wet ESP's or wet scrubbers. Because the exhaust from these systems is saturated, moisture condensation downstream from the control device is common. The EPA reference methods for PM-10 prescribe an in-stack filter that operates at stack temperatures. If the gas stream contains water droplets, sample train filter blinding (blockage of gas flow through the filter) is likely to preclude PM-10 sampling. This problem has been encountered during EPA tests conducted on wet ESP-controlled dryers as a part of the program to develop emission factors for the wood products industry.

One solution to this problem is to use a heated filter rather than an in-stack filter in the Method 201 or 201A train. As a part of the testing, Method 202 could be used to determine condensible PM emissions from the back half of the Method 201 or 201A train. The total PM-10 emissions could be estimated as the sum of the PM-10 emissions obtained from Method 201 or 201A and the condensible PM emissions obtained from Method 202. This solution will eliminate the moisture problem, but it does have two drawbacks. First, since this procedure is different from the procedure used for dry control systems, the results will not be directly comparable. Second, this procedure exacerbates the problems related to the interrelationship of VOC and PM-10 emissions discussed below.

3. VOC and PM-10 Measurements

As suggested by the characteristics of the organic emissions from wood products dryers described above, the dryer exhaust gas contains a substantial amount of organic material that is condensible in the range of 50E to 120E C (120E to 250EF). Because all of the test methods described earlier contain a filter to collect PM, the amount of this material that remains on that filter and the amount that will be measured downstream from the filter depend on the operating temperature of the filter. Consequently, the material classified as PM-10, condensible PM, and VOC differs, depending on filter temperature. The situation related to VOC emissions is further complicated by the presence of aldehydes and ketones in the exhaust streams from dryers and presses. Because these compounds are treated differently by M25 and M25A, results obtained by these two methods are not directly comparable. The paragraphs below first address the PM-10 issues and then the VOC issues.

The applicability sections for M201 and M201A indicate that if PM-10 results are to be used for purposes such as inventories, then the PM-10 results from those methods should be added to condensible PM results from M202 to obtain total PM-10 emissions. Because the primary purpose of

AP-42 is to aid in preparing emission inventories, such a combination appears to be appropriate for developing AP-42 emission factors. However, condensible PM emissions can be determined via M202 in conjunction with a variety of trains. The available data base on condensible PM emissions from the wood products industry has been obtained using a M202 train following M5 and M201A trains. Because these trains operate at different filter temperatures, they can generate different measures of condensible PM emissions for the same facility. Furthermore, because M201A operates with an in-stack filter, the distribution of filterable and condensible fractions will vary from site to site depending on stack gas temperatures. In addition, measurements of filterable PM by M5 and PM-10 by M201 or M201A on the same stack gas can result in a PM-10 emission rate that is higher than the filterable PM emission rate because of the differences in sampling train filter temperatures. Such differences complicate averaging results across facilities to develop emission factors.

As noted in the discussion of M25 above, the protocol concerning the M25 particulate prefilter has changed over time. Data collected during the last several years are based on the organic material that passes through a 120EC (250EF) filter. However, some of the historical VOC data for the wood products industry were based on M25 trains with in-stack filters or with heated filters operating at 88EC (190EF). Because some portion of the organic material in wood products dryers may condense at temperatures between 77EC (170EF) and 120EC (250EF), the results from the historical tests with different filter temperatures cannot be combined consistently.

Development of VOC emission factors is further complicated by the differences between M25 and M25A results. First, M25A allows the use of an in-stack particulate filter in lieu of a heated filter, so the organic material that is subjected to analysis via the two methods is not equivalent. More importantly, the analytical methods are quite different. Method 25 collects an integrated sample over time and essentially counts the number of carbon atoms in the volatile fraction of the organic material collected. Consequently, irrespective of the structure of the organic compounds in the emission stream, the method measures the moles of carbon contained in those compounds. In contrast, M25A provides a continuous measure of the organic material present by measuring the response of an FID to that material relative to the response of the FID to a calibration gas. If the organic compounds in the exhaust gas are primarily aliphatic and aromatic hydrocarbons, the two methods provide reasonably comparable measures, but, if the exhaust contains substantial quantities of oxygenated compounds such as aldehydes and ketones, the results will differ substantially. This difference is a consequence of the diminished response of the FID to aldehydes and ketones. Because the hot press exhaust and some dryer exhaust streams are known to contain quantities of aldehydes and ketones, the two methods are not expected to produce comparable results for those operations.

4. Interrelationship of PM/PM-10 and VOC Emissions

Due to source characteristics, there is an interrelationship between PM/PM-10 and VOC emissions. Because of this interrelationship, the differences in the test methods described above can

result in measuring some fraction of the organic constituents in the exhaust stream as both PM-10 and VOC emissions.

Available test data for wood products dryer emissions indicate that irrespective of filter temperature, essentially all of the condensible PM that passes through the filter and is collected in the back half of a PM or PM-10 train is organic material. Also, any organic material that passes through an in-stack filter used with M25A or that passes through a heated filter at 120EC (250EF) as used with M25 will be measured as VOC. At the same time, organic material that condenses between the stack temperature and 120EC (250EF) will be measured as PM-10 by M201 and M201A. Furthermore, material that condenses in the back half of a M5 train will be classified as condensible PM by M202.

An overlap in the measured PM-10 and VOC emissions in the historical data base may have resulted in two instances. First, if the recommendations of M201 and M201A related to including condensible PM in estimating total PM-10 emissions are followed, condensible PM will be measured as both VOC and PM-10. Second, some fraction of the organic material retained on the M201 or M201A filter and measured as PM-10 may also be counted as VOC via M25 because the filter temperatures in the M25 train can be higher than that of the PM-10 train for these emission sources.

5. Summary of Emission Testing Issues

In summary, plywood and composite wood products industry source characteristics and differences in test methods used for collecting the historical test data make it difficult to combine the available data to obtain average emission factors. Consequently, engineering judgment was used to combine the data and develop average emission factors.

Several general conclusions can be made regarding the measurement of PM-10 and VOC emissions for these sources. First, the source characteristics result in an interrelationship between PM/PM-10 and VOC. The constituent organic pollutants emitted act as both PM and VOC. When an in-stack filter is used during sampling, the measured filterable PM, condensible PM, and VOC will be affected by the stack gas temperature. Consequently, these measurements should be made under normal operating conditions; ideally simultaneous measurements should be taken.

Second, the PM-10 and VOC test methods should be conducted to minimize the amount of overlap in their measurement. Use of M201 or M201A for filterable PM-10 in conjunction with M202 for condensible PM-10 will provide total PM-10 results on the same basis (distribution of emissions between the filterable and condensible fraction will be dependent upon stack gas temperature because the M201 and M201A trains use an in-stack filter). Use of M25A with an in-stack filter will provide VOC data on the same basis as the PM-10 measurements. In this case, the condensible organic PM-10 fraction measured using M202 will also be measured as VOC by M25A. However, the amount of measurement overlap can be estimated.

Finally, M25A has a very low response to formaldehyde, and a reduced response to other aldehydes and ketones; consequently, the VOC emissions measured by M25A will be biased low in cases where these compounds are present. A separate measurement method (e.g., NCASI's impinger method or M0011) should be used to quantify these compounds when they are expected to be present in the emissions; for example, in the exhaust gases from the presses and from drying operations.

IV. Review of Emission Data

As part of the analysis of the emission data, the quantity and quality of the information contained in the reference documents were evaluated. The following data were excluded from consideration:

1. Test series averages reported in units that cannot be converted to the selected reporting units;
2. Test series representing incompatible test methods (i.e., comparison of EPA Method 5 front half with EPA Method 5 front and back half);
3. Test series of controlled emissions for which the control device is not specified;
4. Test series in which the source process is not clearly identified and described; and
5. Test series in which it is not clear whether the emissions were measured before or after the control device.

Test data sets that were not excluded were assigned a quality rating. Data used for AP-42 are assigned A through D letter ratings, where A represents the most reliable data. The rating system used was that specified by EFIG for preparing AP-42 sections. The data were rated 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.

The following criteria were used to evaluate test reports and other primary sources of emission data for sound methodology and adequate detail:

1. Source operation. The manner in which the source was operated is well documented in the report. The source was operating within typical parameters during the test.

2. Sampling procedures. The sampling procedures conformed to a generally acceptable methodology. If actual procedures deviated from accepted methods, the deviations are well documented. When this occurred, an evaluation was made of the extent to which such alternative procedures could influence the test results.

3. Sampling and process data. Adequate sampling and process data are documented in the report, and any variations in the sampling and process operation are noted. If a large spread between test results cannot be explained by information contained in the test report, the data are suspect and are given a lower rating.

4. Analysis and calculations. The test reports contain original raw data sheets. The nomenclature and equations used were compared to those (if any) specified by EPA to establish equivalency. The depth of review of the calculations was dictated by the reviewer's confidence in the ability and conscientiousness of the tester, which in turn was based on factors such as consistency of results and completeness of other areas of the test report.

A. AP-42

In this study, average emission factors were not taken from the four existing AP-42 sections (plywood, OSB, MDF, and particleboard). 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 the existing AP-42 background reports 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*.¹¹⁹

Due to the large quantity of data in the existing AP-42 background reports, 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 data from the existing AP-42 background reports were discarded. The discarded C- and D-rated data do not appear in the emission data spreadsheets in Attachment 1. The discarded data include emission factors in incompatible units, data based on measurements with unspecified 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. It is important to note that this review did not include an in-depth look at field and laboratory procedures to evaluate the degree to which prescribed methods were followed. For purposes of this review, it was assumed that testing contractors and analytical laboratories followed the procedures of the methods that have been indicated in the test reports. However, attention was given to discussions of any problems or unusual circumstances encountered during the testing. The EPA Emission Measurement Center (EMC) was asked to review a list of the emissions sources and emissions test methods cited in these reports to ensure that the proper methods were selected. The approach used to review and extract data from the emission test reports is discussed below, and is also presented in a separate memorandum.¹²⁰

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 significant supporting data to allow recalculation of mass emission rates (summary reports) were generally not reviewed and, consequently, were not used for emission factor development. For test runs with pollutant concentrations below the method detection limit (MDL), a value equal to half of the MDL was entered and clearly noted in the spreadsheets.

Emissions data for all pollutants (HAP and non-HAP) in the test reports were included in the review. Data collected with EPA Method 25A were tabulated as THC on a carbon basis. Where THC concentrations were provided as parts per million by volume (ppmv) as propane, the values were multiplied by a factor of 3 to obtain ppmv as carbon. No adjustments were made to individual data points for non-VOC compounds, such as methane, acetone, and methylene chloride. No adjustments were made to individual data points for compounds with reduced response rates to the flame ionization detector (FID), such as oxygenated compounds, including formaldehyde. The adjusted VOC emission factors were calculated from average emission factors, as described above in section III.B.1. There are no EPA Method 25 runs in the test reports submitted.

Particulate matter (PM) emissions data were tabulated as filterable PM, filterable PM-10, or condensible PM, as appropriate. Recalculation of PM mass emission rates began with raw catch weights in grams.

All other pollutants were reported on an "as pollutant" basis. Recalculation of mass emission rates generally began with dry ppmv. Where wet ppmv were provided, these units were first converted

to dry ppmv (the equation for this conversion is presented in Attachment 4). In the case of CO₂, the calculation began with percent CO₂ in the exhaust stream.

After the data were entered into the spreadsheets, a QA/QC check was performed on the spreadsheets. This check included identifying data entry errors, as well as identifying data that appeared to be out of the typical ranges. During the QA/QC check, individual mills were contacted to clarify information contained in the test reports and/or to obtain additional information (e.g., process rates to allow calculation of emission factors). The spreadsheets subsequently were updated to include any clarifications and new information provided by the mills.

In addition to the stack parameters, process rates, and other data required for the QA/QC review, additional process information was extracted to aid in analyzing the emissions data. These process parameters were entered into a second set of columns to the right of the QA/QC columns in the review spreadsheets. A number of process parameters were tabulated for each source type. Because different parameters were desired for different source types, and to make data entry and analysis easier, separate spreadsheets were created for the eight general source types for which emission test reports were submitted: hot presses; board coolers; rotary dryers; tube dryers; veneer dryers; conveyor dryers; hardboard/fiberboard kilns, ovens, and dryers; and miscellaneous sources.

In some cases, plant-specific data from 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. However, the only survey response data used were for process parameters that are relatively constant, such as press size, dryer type, resin type and 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.

Data ratings were assigned to the individual emission test data based on EFIG guidance. A summary of the rating structure is presented above in section IV. Generally, the data from the test reports were assigned A ratings if they were based on 3 or more emission test runs. If the test included only 2 runs, the data were rated B. If the test included only 1 run, the data were further downrated to C. The emission data were also downrated if the test report noted any conditions that may have adversely impacted the validity of the test data.

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"). These run-by-run data were extracted from the NCASI data base.

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

Generally, the NCASI data were assigned A ratings if they were based on 3 or more emission test runs. If the test included only 2 runs, the data were rated B. If the test included only 1 run, the data were further downrated to C. The emission data were also downrated if any conditions were noted which may have adversely impacted the validity of the test data.

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 emission factors for AP-42 is 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 the existing AP-42 background reports 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.¹²¹

Once the run-by-run data were extracted from the NCASI data base and averaged, the averages (where no non-detect runs were involved) were compared with the values calculated by NCASI, as reported in the technical bulletins. Only those emission factors not including BDL data could be compared in this manner. For sources with multiple vents, emissions from the vents must be summed in order to determine total emissions from the source. The approach to summing emissions for sources with multiple vents was compared with the approach taken by NCASI, using the technical bulletins as a guide. Process data for each unit operation was provided in the technical bulletins.

V. Emission Factor Calculations

A. General Approach

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

B. Grouping of Emission Data

The emission data 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 the data by APCD and how to further group the emission data within source types (e.g., segregate plywood veneer dryer data by firing method).

1. Grouping by Air Pollution Control Device

Primary cyclones installed for product recovery are not considered APCD's. Instead, they are considered to be process equipment because they are a necessary part of the production process; without them, the primary raw material would be lost and the manufacturing process could not continue. Emissions test data collected at the outlet of primary cyclones are considered to be uncontrolled for all pollutants including filterable PM, condensible PM, and PM-10.

Based on a review of the control efficiency data, APCD's installed for PM abatement were considered to have no effect on gaseous emissions, such as THC, CO, CO₂, NO_x, and gaseous HAP. These APCD's include cyclones, multiclones, baghouses, and EFB's. As a result, emission test data for sources with PM controls were averaged with the uncontrolled emission test data 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 data for WESP's and wet scrubbers were averaged with uncontrolled test data 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, RTO's, 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.

2. Grouping within source types

There are several operating and design parameters which may affect emissions from dryers, presses, and other wood products emission sources. 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 memorandum describing the emission test report review process.¹²⁰ 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 simultaneously 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 emission data within emission 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 data. In addition, the grouping schemes used in the previous edition of 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 group the test data.

For particleboard and MDF rotary dryers, a distinction was made between predryers or “green” dryers and “dry” dryers, based on furnish moisture content. Wood moisture content can be expressed on an oven-dry (or dry) basis or on a wet basis. In the plywood and composite wood products industry, percent moisture content is commonly expressed as percent moisture content on a dry basis. The dry-basis moisture content is determined by weighing a sample of wood before and after oven-drying and then calculating the moisture content based on the weight before and after drying. Moisture content on a dry basis is calculated by the following equation:

$$\% \text{ Moisture Content (dry basis)} = \frac{\text{weight of water in wood}}{\text{weight of oven-dry wood}} \times 100$$

Alternately, wood moisture content may be expressed on a wet basis. The procedure for determining wet-basis moisture content involves the same weighing and drying of a wood sample as for the dry-basis determination; however, the calculation of the wet-basis value uses the wet weight of the wood, instead of the dry weight of the wood, as the denominator. Moisture content on a wet basis is calculated by the following equation:

$$\% \text{ Moisture Content (wet basis)} = \frac{\text{weight of water in wood}}{\text{weight of wet wood}} \times 100$$

In general, dryers that dried furnish with a moisture content of greater than 50 percent (dry basis) were considered green dryers. Dryers that dried furnish with a moisture content less than 50 percent (dry basis) were considered dry dryers. There were a few instances in which dryers that were used to dry furnish with a reported 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 processed by a given process unit, 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

Once the emission data were grouped according to pollutant, APCD, and source type, they were then averaged to develop average emission factors. 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 emission data point were considered before they were subsequently averaged into emission factors. If all of the test data 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 using 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 3 is a table with an example calculation to illustrate how the average emission factors were calculated from the individual data points.

D. Emission Factor Ratings

The quality of the emission factors developed from analysis of the test data was rated using the following general criteria:

A—Excellent: Developed from A- and B-rated source 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- or 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 industries. The source category is specific enough so that variability within the source category population may be minimized.

C—Average: Developed only from A-, B- and/or C-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-, B-, and/or C-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 footnoted.

The use of these criteria is somewhat subjective and depends to an extent upon the individual reviewer.

The ratings assigned to the average emission factors are largely a function of the data ratings assigned to the individual data sets and the number of data sets upon which the average emission factors are based. Generally, C- and D-rated data were discarded and were not used in the determination of average emission factors. However, C-rated data were used if the data were downrated only because they were 1-run data. Average emission factors based on a single data set were rated E. For factors based on multiple data sets, the ratings were based primarily on the number of data sets. In general, the average emission factors were rated D, if based on less than 10 data sets, emission factors based on 10 to 19 data sets were rated C, and factors based on 20 or more data sets were rated B. No emission factors were assigned an A rating.

The VOC-as-propane emission factors were assigned ratings one rating below the corresponding THC-as-carbon emission factor rating (unless both were rated E). Emission factors based solely on M0011 data for compounds other than formaldehyde, acetaldehyde, and propionaldehyde were downrated (unless they were already rated E) because M0011 has not been validated for these other compounds and the results are likely to be biased low.

VI. Presentation of the Emission Factors

The emission factors developed for AP-42 Chapter 10 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);
12. the emission factor units; and
13. the average emission factor rating.

Attachment 1 also presents a series of detail tables that show which data sets were used to develop each of the emission factors presented in the summary tables. The organization of the detailed data tables parallels that of the summary tables. The acronyms, codes, and abbreviations used in the emission factor tables are defined in a series of tables in Attachment 2. Attachment 4 provides some useful conversion factors and equations.

VII. References

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Attachment 1

Summary Spreadsheets

The summary spreadsheets of Attachment 1 are provided as separate files. Each file contains the emission factors for one industry sector. The files are named as follows:

AP-42 Section	Industry Sector	Attachment 1 Filename
10.5	Plywood	AP-42PLY_data.xls
10.6.1	Waferboard/Oriented Strandboard	AP-42OSB_data.xls
10.6.2	Particleboard	AP-42PB_data.xls
10.6.3	Medium Density Fiberboard	AP-42MDF_data.xls
10.6.4	Hardboard and Fiberboard	AP-42HB-FB_data.xls
10.9	Engineered Wood Products	AP-42EWP_data.xls

Attachment 2

Acronyms/Codes/Abbreviations

Table 2-1. 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> , bromomethane, carbon disulfide, carbon tetrachloride, <i>chloroform</i> , chloromethane, <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
M201A	EPA Method 201A	PM-10
M202	EPA Method 202	Condensable PM
M25A	EPA Method 25A	Total hydrocarbons (THC)

Table 2-1. (continued)

Code	Test Method	Pollutant(s) Measured ^a
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>
NICM	NCASI impinger/canister method	<i>Acetaldehyde, acetone, acrolein, a-pinene, b-pinene, benzene, bromomethane, camphene, 3-carene, chloroethane, chloroethene, cis-1,2-dichloroethylene, cumene, 1,2-dichloroethane, formaldehyde, limonene, p-mentha-1,5-diene, methanol, methyl ethyl ketone, methyl isobutyl ketone, methylene chloride, p-cymene, phenol, propionaldehyde, styrene, toluene, 1,2,4-trichlorobenzene, o-,m-,p-xylene</i>
P&CAM 142	NIOSH Physical and Chemical Analytical Method 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, o-,m-,p-cresol, naphthalene, phenol, pyridine</i>

Table 2-1. (continued)

Code	Test Method	Pollutant(s) Measured ^a
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 2-2. HAP Analytes and Analysis Techniques for NCASI MACT Sampling Program

HAP Analyte	Analysis Method ^a	
	Impinger	Canister
acetaldehyde	GC/FID	GC/MS
acrolein	GC/FID	GC/MS
benzene	none	GC/MS
bromomethane	none	GC/MS
chloroethane	none	GC/MS
chloroethene	none	GC/MS
cumene	none	GC/FID
1,2-dichloroethane	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	none	GC/MS
m,p-xylene	none	GC/MS
o-xylene	none	GC/MS

^a GC/FID = gas chromatography/flame ionization detector; GC/MS = gas chromatography/mass spectrometer.

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

Non-HAP Analyte	Analysis Method ^a	
	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

^a GC/FID = gas chromatography/flame ionization detector; GC/MS = gas chromatography/mass spectrometer.

Table 2-4. 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 2-5. 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 2-6. Wood Species Codes

Table 2-6. (continued)

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

Table 2-6. (continued)

Code	Wood 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
SYPIKE	Southern Yellow Pine
UFIR	Unspecified Fir
USPINE	Unspecified Southern Pine
WFIR	White Fir
WOAK	White Oak
WSWOOD	Western Softwood
YPOPLAR	Yellow Poplar

Table 2-6. (continued)

Table 2-7. 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 2-8. 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 2-9. 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 2-10. 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 2-11. Veneer Dryer Type Codes

Code	Veneer Dryer Type
LONG	Longitudinal

JET	Jet
PLATEN	Platen
RF	Radio-Frequency Heated
TUNNEL	Tunnel

Table 2-12. 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 3

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 4

Conversion Factors and Equations

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 methane	lb as carbon	0.75
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 methane	ppm as carbon	1
ppm as propane	ppm as carbon	3.0

Useful Equations

Wood moisture content calculations:

$$\% \text{ Moisture Content (dry basis)} = \frac{\text{weight of water in wood}}{\text{weight of oven-dry wood}} \times 100$$

$$\% \text{ Moisture Content (dry basis)} = \frac{\%MC_{WB} \div 100}{1 + (\%MC_{WB} \div 100)} \times 100$$

$$\% \text{ Moisture Content (wet basis)} = \frac{\text{weight of water in wood}}{\text{weight of wet wood}} \times 100$$

$$\% \text{ Moisture Content (wet basis)} = \frac{\%MC_{DB} \div 100}{1 + (\%MC_{DB} \div 100)} \times 100$$

where:

$\%MC_{DB}$ = moisture content (dry basis)

$\%MC_{WB}$ = moisture content (wet basis)

Parts per million by volume, dry:

$$\text{ppmvd} = \frac{\text{ppmvw}}{1 + (\% \text{moisture} \div 100)}$$

where:

ppmvd = concentration, parts per million by volume, dry
ppmvw = concentration, parts per million by volume, wet
%moisture = stack gas moisture content, %

Grains/dscf from grams collected:

$$\text{gr/dscf} = \frac{\text{grams} \times 15.43}{\text{dscf}}$$

where:

gr/dscf = concentration, grains per dry standard cubic foot
grams = grams of pollutant collected
dscf = gas volume sampled, dry standard cubic feet

Stack gas flowrate, dry standard cubic feet per minute:

$$\text{dscfm} = \text{acfm} \times (1 - (\% \text{moisture} \div 100)) \times (68 + 460) \times \frac{\text{barometric pressure}}{(\text{stack temp} + 460) \times 29.92}$$

where:

dscfm = stack gas flow rate, dry standard cubic feet per minute
acfm = stack gas flow rate, actual cubic feet per minute
%moisture = stack gas moisture content, %
barometric pressure = stack pressure, inches of mercury
stack temp = stack gas temperature, degrees Fahrenheit

Lb/hr from grains/dscf:

$$\text{lb/hr} = (\text{dscfm} \times \text{gr/dscf}) \times \frac{60}{7000}$$

where:

lb/hr = emission rate, pounds of pollutant per hour

dscfm = stack gas flowrate, dry standard cubic feet per minute

gr/dscf = pollutant concentration, grains per dry standard cubic foot

Lb/hr from ppmvd:

$$\text{lb/hr} = \text{MW} \times (\text{ppmvd} \times 0.000001) \times \text{dscfm} \times \frac{60}{385.3}$$

where:

lb/hr = emission rate, pounds of pollutant per hour

MW = molecular weight of pollutant

ppmvd = concentration, parts per million by volume, dry

dscfm = stack gas flowrate, dry standard cubic feet per minute

Lb/hr from %:

$$\text{lb/hr} = \text{MW} \times (\text{concentration}\% \div 100) \times 60 \times \frac{\text{dscfm}}{385.3}$$

where:

lb/hr = emission rate, pounds of pollutant per hour

MW = molecular weight of pollutant

concentration% = concentration of pollutant, percent

dscfm = stack gas flowrate, dry standard cubic feet per minute

Emission factor:

$$\text{emission factor} = \text{emission rate, lb/hr} \div \text{process rate, units/hr}$$

Control efficiency:

$$\text{Control efficiency} = \frac{\text{inlet mass emissions} - \text{outlet mass emissions}}{\text{inlet mass emissions}} \times 100$$

Conversion from THC-as-carbon to THC-as-propane:

$$\text{THC as pounds carbon} \times \frac{44 \text{ pounds propane}}{36 \text{ pounds carbon}} = \text{THC as pounds propane}$$

or

$$\text{THC as pounds carbon} \times 1.22 = \text{THC as pounds propane}$$

Calculation of VOC-as-propane from THC-as-carbon:

$$\text{VOC as propane} = (1.22 \times \text{THC as carbon}) + \text{formaldehyde} + (\text{acetone} + \text{methane} + \text{methylene chloride})$$