OLYMPIC REGION CLEAN AIR AGENCY

2940 Limited Lane NW - Olympia, Washington 98502 - 360-539-7610 – Fax 360-491-6308

FORM 1- NOTICE OF CONSTRUCTION

TO CONSTRUCT - INSTALL - ESTABLISH OR MODIFY AN AIR CONTAMINANT SOURCE

Form 1 Instructions:

1. Please complete all the fields below. **This NOC application is considered incomplete until signed.**
2. If the application contains any confidential business information, please complete a Request of Confidentiality of Records (www.orcaa.org/permit-programs/permit-registration-assistance/permit-registration-forms/)
3. Duty to Correction Application: An applicant has the duty to supplement or correct an application. Any applicant who fails to submit any relevant facts or who has submitted incorrect information in a permit application must, upon becoming aware of such failure or incorrect submittal, promptly submit supplementary factors or corrected information.

Business Name: Sierra Pacific Industries	**For ORCAA use only**
Mailing Address: 301 Hagara Street, Aberdeen, WA 98520	File No: 209 County No: 27 Source No: 28 Application No: 20NOC 1449
Physical Address of Project or New Source: 301 Hagara Street, Aberdeen, WA 98520	Date Received: Received JUL 01 2020 ORCAA
Billing Address: 301 Hagara Street, Aberdeen, WA 98520	
Are you currently registered with ORCAA? Yes ☒ No ☐	
Project/ Equipment to be installed/established: 8 Lumber Dry Kilns	
Previous business name (if any):	

This project must meet the requirements of the State Environmental Policy Act (SEPA) and applicable building and fire codes before ORCAA can issue final approval. Complete one of the following options.

☒ SEPA was satisfied by Grays Harbor County (government agency) on ___/___/___ (date). A copy of the final determination and the environmental checklist is enclosed.

☐ SEPA is pending approval by Grays Harbor County (government agency). A copy of the environmental checklist is enclosed and a copy of the final determination will be forwarded to ORCAA when issued.

☐ ORCAA is the only government agency requiring a permit. A completed environmental checklist or documentation that the project or new source is/will be in compliance with local building and fire codes is enclosed.

☐ This project is exempt from SEPA per _____ (WAC citation).

Name of Owner of Business: Sierra Pacific Industries		Agency Use Only
Title:		
Email:	Phone:	
Application Contact Name (if different than owner): Ron Burch		
Title: Division Manager		
Email: RBurch@spi-ind.com	Phone: (360) 532-2323	
Facility Operations Contact Name (if different than owner): Ron Burch		
Title: Division Manager		
Email: RBurch@spi-ind.com	Phone: (360) 532-2323	
I hereby certify that the information contained in this application is, to the best of my knowledge, complete and correct.		
Signature of Owner: [signature]	**Date** 6/29/2020	

Prepared for:

Sierra Pacific Industries
Redding, California

Prepared by:

Ramboll US Corporation
Lynnwood, Washington

June 2020

Project Number:

1690015834

NOTICE OF CONSTRUCTION APPLICATION

LUMBER DRY KILN REDEVELOPMENT ABERDEEN, WASHINGTON

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1. INTRODUCTION

1.1 Background

Sierra Pacific Industries (SPI) owns and operates a lumber manufacturing facility in located in Aberdeen, Washington, which is in Grays Harbor County (hereafter, "the facility"). SPI proposes to replace the existing lumber dry kilns at the Aberdeen facility with new, more efficient, and slightly larger capacity kilns (hereafter, "the project"). As a result of the project, SPI expects the dried lumber production capacity of the Aberdeen facility to increase and requests that the permit condition that limits the facility's dried lumber production to 315 million board feet per year (MMbf/year) be increased to 415 MMBf/yr, and that the permit condition that limits the facility's total lumber production to 350 MMbf/year be eliminated.

The facility is within the jurisdiction of the Olympic Region Clean Air Agency (ORCAA), so the proposed project must comply with regulations adopted by that agency, as applicable. Because the proposed new kilns will emit regulated air pollutants, a Notice of Construction (NOC) must be filed with ORCAA, and installation of new kilns cannot commence until ORCAA issues an Order of Approval (OA).

Based on the magnitudes of the expected changes in air pollutant emission rates associated with the project, the project will not be subject to the requirements of the federal Prevention of Significant Deterioration (PSD) program. An emissions analysis is presented in this document. SPI has retained Ramboll US Corporation (Ramboll) to prepare this NOC application on its behalf.

1.2 Organization

The key components of this application are:

- A description of the project and expected criteria and toxic air pollutant (TAP) emission rates attributable to the project,
- A discussion of potentially applicable air quality regulations,
- An analysis of compliance with ambient air quality standards,
- An analysis of ambient TAP concentration increases,
- An analysis of the Best Available Control Technology (BACT) for criteria pollutants and TAPs (tBACT), and
- Completed standard ORCAA NOC forms (Appendix A).

1.3 Summary of Findings

The proposed project will comply with all applicable regulations. Air dispersion modeling analyses were required to demonstrate compliance with ambient air quality standards and TAP acceptable source impact levels (ASILs). In summary, these analyses indicated that:

- Model-predicted ambient PM2.5 concentrations attributable to project will not cause or contribute to an exceedance of any ambient air quality standards, and
- Model-predicted ambient acetaldehyde concentrations attributable to the project exceed the applicable ASIL. As a result, a second-tier analysis will be required, a petition will be submitted to the Washington Department of Ecology (Ecology), requesting that Ecology perform a second-tier review of the Project to assess whether the proposed increase in TAP emissions attributable to the project is sufficiently low to protect human health and safety from potential carcinogenic and/or other toxic effects.

2. PROJECT DESCRIPTION

SPI is a family-owned wood products company based in Anderson, California, that currently operates several wood products facilities in California and Washington, including the Aberdeen lumber manufacturing facility, which was originally permitted in 2002, and currently operates under NOC #01NOC192.

2.1 Project Location

The facility, including the existing lumber dry kilns, is located at 301 Hagara Street in Aberdeen, Washington.

2.2 Physical Description

SPI proposes to remove the eight existing double-track, steam-heated lumber dry kilns at the Aberdeen facility and install eight new double-track, steam-heated lumber dry kilns in their place. The new kilns will have slightly greater capacity compared to the existing kilns (312,500 bf for each new kiln versus 300,000 bf for each existing kiln) and will operate more efficiently than the existing kilns. The improved efficiency will allow the new kilns to more accurately maintain target kiln temperatures, which will make it possible to adhere more closely to planned drying schedules. A drawing that provides the dimensions of the proposed kilns is provided in Appendix B.

The existing sawmill, planer mill, and natural gas-fired package boiler will not be physically modified as a result of the project, and hourly and daily operations will continue as they have in the past. The facility currently operates 20 hours per day, 5 days per week, and 50 weeks per year, and will potentially add Saturday shifts to increase production as necessary, depending on market demands.

Lumber dried in the new kilns will continue to be from Douglas fir or hemlock logs, and, like the existing kilns, the new kilns may operate continuously throughout the year. The new kilns will continue to be heated by steam from the existing natural gas boiler or from the adjacent cogeneration unit, and the maximum kiln temperature set point will continue to be 200 °F. A drawing that shows the locations of thermocouples in the proposed kilns is provided in Appendix B.

2.3 Project Air Pollutant Emissions

To determine the applicability of regulations, and to predict potential air quality impacts associated with the proposed project, the types and quantities of air pollutant emission increases were identified. Pollutant emission rates are determined by the physical and operational characteristics of the proposed kilns; the emission increases also considers the past actual emissions from the kilns that will be removed as part of the project.

This section describes how criteria and TAP emission increases were calculated. The proposed new lumber kilns will emit particulate matter (PM), volatile organic compounds (VOCs), and TAPs; maximum potential emission rates were calculated using representative emission factors and maximum potential activity rates. For the existing kilns, which will be removed, past actual emission rates were calculated using representative emission factors and actual past activity rates that reflect normal operations; additional detail is provided in Section 2.3.2 and Appendix C.

The original OA that authorized the facility's construction recognized that maximum potential facility emissions were based on the physical constraints of equipment and enforceable emission limitations. Other than the total and dried lumber production limits discussed above, the current permit allows all equipment to operate at its physical limits throughout the year. As a result, this permit application requests authorization to install new kilns in place of the existing kilns, and to increase dried lumber production to 415 MMbf/year.

Table 2-1 presents the annual criteria pollutant emission increases associated with the project by comparing potential emissions from the new kilns to past actual emissions from the existing kilns that will be removed from the facility. Past actual emissions are based on actual throughputs and operating hours obtained from annual reports submitted to ORCAA.

We understand that, for permit applicability determinations, minor new source review considers only criteria pollutant emission increases associated with new equipment, and not emission decreases associated with equipment to be removed or decommissioned. The net effect of the project on emissions is provided in Table 2-1 to highlight the real reduction in emissions that will result from the removal of the existing kilns, and because the air dispersion modeling analysis for the project accounts for that emission reduction. Additional detail

regarding how the emission rates were calculated is provided in the sections that follow.

Table 2-1. Project Criteria Pollutant Annual Emission Increases

Criteria Pollutant	Potential Emissions from Proposed Lumber Dry Kilns (tpy)	Actual Emissions Reduction from Removing Existing Lumber Dry Kilns (tpy)	Net Emission Increase (tpy)
$PM_{10}/PM_{2.5}$[1]	4.2	-3.1	1.1
VOC	238	-142	96.0

1. All PM emitted by the lumber dry kilns was assumed to be $PM_{2.5}$; therefore PM_{10} and $PM_{2.5}$ are equivalent.

Table 2-2 presents maximum potential TAP emission rates associated with proposed new lumber dry kilns and past actual TAP emission rates associated with existing kilns to be removed from the facility. Table 2-2 also presents the net emissions increase of each TAP (potential emissions from the new kilns minus actual emissions from removing the existing kilns).[1] Emission increases that are less than the applicable Small Quantity Emission Rate (SQER) indicate no additional review is necessary. The emission increases above the applicable SQER require a dispersion modeling analysis. Addition detail regarding how the emission rates were calculated is provided in the sections that follow.

Table 2-2. Project Toxic Air Pollutant Emission Increases

Toxic Air Pollutant	CAS #	HAP?	Avg. Period[1]	Emission Rate (lb/averaging period)				Net Increase >= SQER?
				Proposed Kilns[2]	Existing Kilns[3]	Net Increase[4]	SQER	
Acetaldehyde	75-07-0	Yes	Year	28,100	-15,000	13,100	60	Yes
Acrolein	107-02-8	Yes	24-Hr	1.4	-0.73	0.67	0.026	Yes
Formaldehyde	50-00-0	Yes	Year	1,810	-970	840	27	Yes
Methanol	67-56-1	Yes	24-Hr	223	-116	107	1,500	No
Propionaldehyde	123-38-6	Yes	24-Hr	0.45	-0.30	0.15	0.59	No

1. The averaging period basis and SQER for each TAP are assigned in WAC 173-460-150.
2. Proposed kiln emission rates from Table 2-4.
3. Existing kiln emission rates from Table 2-7.

[1] Using reductions in TAPs from removal of existing kiln to offset TAP emission increases expected as a result of new equipment is allowed by WAC 173-460-080(3) .

4. The values in the "Net Increase" column are the proposed kiln emission rate minus the existing kiln emission rate to reflect removal of the existing kilns.

2.3.1 Proposed New Lumber Dry Kilns

The lumber dry kilns will operate as near to continuously as possible to maximize production. The drying schedule of each individual kiln will vary depending upon the dimensions of the lumber, the wood species, and the season (i.e., lumber tends to be drier in the summer, and wetter in the winter), and duration of non-operational periods (e.g., loading, unloading, maintenance, etc.).

As wood dries it releases VOCs at an increased rate which pass to the atmosphere through vents in the roof of the kilns. Some of these compounds condense to form particulate matter, and some compounds are considered TAPs. Emission factors used to calculate emission rates for proposed new kilns and existing kilns are summarized in Tables 2-3. The emission factors reflect a maximum kiln temperature set point of 200 °F and that hemlock and Douglas fir lumber will be dried exclusively.

Table 2-3. Factors Used to Calculate Lumber Dry Kiln Emissions

Pollutant	CAS #	Emission Factor[1] (lb/Mbf)			Maximum Emission Factor Species
		Western Hemlock	Douglas Fir	Maximum	
$PM_{10}/PM_{2.5}$	N/A	0.020	0.020	0.020	Both
VOC	N/A	0.613	1.15	1.15	Douglas Fir
Acetaldehyde	75-07-0	0.0677	0.0275	0.0677	Hemlock
Acrolein	107-02-8	0.0012	0.00050	0.0012	Hemlock
Formaldehyde	50-00-0	0.0044	0.0018	0.0044	Hemlock
Methanol	67-56-1	0.196	0.0671	0.196	Hemlock
Propionaldehyde	123-38-6	0.00040	0.00030	0.00040	Hemlock

1. Hemlock PM emission factor is from a source test conducted by ETI at Chemco's facility in Ferndale, WA in 2013. Douglas fir PM emission factor is from a source test conducted by Horizon at Oregon State University (OSU) in 1998. VOC and TAP emission factors are from "EPA Region 10 HAP and VOC Emission Factors for Lumber Drying, November 2019" issued by EPA Region 10, which is provided in Appendix D.

Because emission factors for lumber dry kilns are based on the quantity of lumber dried, rather than the time the lumber spends in the kilns, it is impossible to calculate exact emission rates over a 24-hour period. As a result, the quantity of lumber dried, as well as the resulting emissions, are totalled over a longer period of time, typically a year. The consistency and overlapping nature

of kiln operations and emissions means the long-term average is representative of the short-term average, and the short-term average is no different from the short-term worst-case scenario. When a representative quantity of lumber dried, or pollutant emitted, is required for a shorter period of time, an average based on the annual total is used.

The approach described above has been applied to calculate emission rates for every project in Washington involving lumber dry kilns of which we are aware, including SPI lumber manufacturing facility projects in Burlington (Northwest Clean Air Agency (NWCAA)), Centralia (Southwest Clean Air Agency (SWCAA)), Frederickson (Puget Sound Clean Air Agency (PSCAA)), and Shelton (ORCAA), as well as the kiln throughput increase at Vaagen Brothers Lumber, in Colville, Washington (Washington Department of Ecology's Eastern Region Office (ERO)), the Teal-Jones facility in Sumas, Washington (NWCAA), and the Skagit River Reman facility in Sedro Wooley, Washington (NWCAA). Moreover, Health Impact Assessments (HIA) modeling protocols approved by Washington Department of Ecology (Ecology) for SPI's Frederickson facility in 2014, SPI's Shelton facility in 2015, Teal-Jones's facility in 2018, and Skagit River Reman in 2019 used this same approach for modeling short-term emissions from lumber dry kilns.

Maximum potential emission rates for the new kilns were calculated using the emission factors in Table 2-3 and a maximum annual kiln throughput of 415 MMbf/yr. Maximum potential annual criteria pollutant and TAP emissions calculated for the proposed new kilns are summarized in Table 2-4.

Table 2-4. Maximum Potential Emissions for the Proposed New Lumber Dry Kilns

Pollutant	Emission Rate[1]		
	(lb/day)	(lb/yr)	(tpy)
$PM_{10}/PM_{2.5}$	--	--	4.2
VOCs	--	--	238
Acetaldehyde	--	28,100	0.404
Acrolein	1.4	--	0.0072
Formaldehyde	--	1,810	0.905
Methanol	223	--	1.17
Propionaldehyde	0.45	--	0.083

1. The maximum potential annual emission rates are based on 415,000 Mbf/yr throughput of the worst-case wood species for each pollutant. The annual average emission rates are assumed to be representative of worst-case daily emission rates based on the overlapping batch-wise nature of drying lumber in kilns, and uniform, year-round operation, as discussed in Section 2.3.1.

2.3.2 Existing Lumber Dry Kilns to Be Removed

Past actual PM and TAP emission rates for the existing kilns were calculated using the emission factors in Tables 2-3 and actual kiln throughput averaged over two consecutive years in which facility production was representative of normal operating conditions. To identify production rates during these years, annual emission reports from the 2009 through 2019 were examined. The reported quantities of lumber dried in the existing kilns from 2009 through 2019, by species, are presented in Table 2-5.

Table 2-5. Lumber Dried in Existing Kilns by Species, 2009 – 2019

Year	Lumber Species (Mbf/yr)		
	Douglas Fir	**Hemlock**	**Total**
2009	77,400	183,900	261,300
2010	129,900	174,600	304,500
2011	113,700	158,400	272,100
2012	106,800	163,200	270,000
2013	104,400	173,100	277,500
2014	132,900	139,800	272,700
2015	163,500	134,400	297,900
2016	186,322	113,678	300,000
2017	167,669	104,336	272,005
2018	160,200	152,700	312,900
2019	182,400	129,900	312,300

Two-year average emissions of criteria pollutants and TAPs, calculated using the emission factors in Table 2-3 and the lumber throughputs in Table 2-5, are summarized in Table 2-6. The maximum emission rate for each pollutant is shaded.

Table 2-6. Past Actual Emissions from Existing Lumber Dry Kilns

Years	Two-Year Average Emission Rate (tpy)						
	PM_{10}/ $PM_{2.5}$	VOCs	Acetal-dehyde	Acro-lein	Formal-dehyde	Meth-anol	Propion-aldehyde
2009-2010	2.8	114	7.49	0.13	0.48	21.1	0.051
2010-2011	2.9	121	7.31	0.13	0.47	20.4	0.052
2011-2012	2.7	113	6.96	0.12	0.45	19.5	0.049
2012-2013	2.7	112	7.14	0.13	0.46	20.1	0.049
2013-2014	2.8	116	6.93	0.12	0.45	19.3	0.049
2014-2015	2.9	127	6.68	0.12	0.43	18.4	0.050
2015-2016	3.0	138	6.60	0.12	0.43	18.0	0.051
2016-2017	2.9	135	6.12	0.11	0.40	16.6	0.048
2017-2018	2.9	134	6.60	0.12	0.43	18.1	0.050
2018-2019	3.1	142	7.14	0.13	0.46	19.6	0.054

Table 2-7. Maximum Two-Year Average Past Actual Toxic Air Pollutant Emissions from Existing Lumber Dry Kilns

Toxic Air Pollutant	Emission Rate[1]		
	(lb/day)	(lb/yr)	(tpy)
PM_{10}/$PM_{2.5}$	--	--	3.1
VOCs	--	--	142
Acetaldehyde	--	15,000	7.49
Acrolein	0.73	--	0.13
Formaldehyde	--	970	0.48
Methanol	116	--	21.1
Propionaldehyde	0.30	--	0.054

1. The annual average emission rates are assumed to be representative of worst-case daily emission rates based on the overlapping batch-wise nature of drying lumber in kilns, and uniform, year-round operation, as discussed in Section 2.3.1.

3. REGULATORY SETTING

The proposed replacement of the existing kilns with new kilns is potentially subject to federal, state, and local regulations. The following section discusses the applicable regulations and why certain regulations are not applicable.

3.1 Permitting Programs

3.1.1 Preconstruction Permits

Rule 6.1 of ORCAA's Regulations prohibits the construction, installation, or modification of a stationary source unless an NOC application has been filed with ORCAA, and ORCAA has issued an OA. Exceptions to this rule are those sources that are exempted from the requirements under Section 6.1(c) or 6.1(d). The proposed project does not quality for any listed exemptions, and is, therefore, subject to the provisions of the New Source Review (NSR) program and is required to obtain an OA.

These provisions address the review of new or modified sources of air contaminants and require that the applicant demonstrate that the new equipment will:

- Not cause violations of the ambient air quality standards;
- Result in TAP emission increases that are sufficiently low to protect human health and safety;
- Meet applicable emission standards;
- Employ BACT and tBACT; and
- Obtain a State Environmental Protection Act (SEPA) determination from the appropriate lead agency.

This permit application demonstrates the project's compliance with all of ORCAA's NSR provisions:

- Compliance with ambient air quality standards is addressed in Section 5;
- Compliance with ambient TAP impact requirements is addressed in Section 5;
- Section 3.2 discusses applicable emission standards;
- A BACT/tBACT analysis that evaluates the energy, environmental, economic, and other costs associated with each technology, and weighs those costs against the reduced emissions the technology would provide is addressed in Section 4;

- Grays Harbor County has confirmed that, because the new kilns will not significantly expand the footprint or scope of the facility, the project does not require a SEPA checklist; an email documenting receipt of this information from the County is provided in Appendix E.

3.1.2 Prevention of Significant Deterioration

The existing Aberdeen lumber manufacturing facility is not considered a major source under the Prevention of Significant Deterioration (PSD) regulations. Therefore, a PSD permit is required for a project if potential emissions of a criteria pollutant exceed 250 tpy. As shown in Table 2-4 the potential criteria pollutant emissions associated with the proposed new kilns will not equal or exceed this threshold. Consequently, the project does not require a PSD permit.

3.1.3 Air Operating Permits

ORCAA implements the U.S. Environmental Protection Agency's (EPA's) Air Operating Permit (AOP) program, also known as "Title V," through Rule 5.1. This program defines a "major source" of air pollutants as a stationary source that has the potential to emit 10 tons or more per year of any single HAP, 25 tons or more per year of any combination of HAPs, or 100 tons or more per year of any other air pollutant subject to regulation.

A facility that falls under this definition of a major source is required to apply for and obtain an AOP. SPI Aberdeen already operates under AOP 15AOP1084 and will continue to do so after the NOC application. The current AOP expires on October 4, 2021; ORCAA must have a complete renewal application six months prior to expiration. If a revised OA reflecting the requested dried lumber production increase to 415 MMbf/yr is issued prior to expiration of the AOP, SPI requests integrated review, as provided in WAC 173-401-500(10)(a), to modify the AOP concurrent with the NOC process.

3.2 Emission Standards

3.2.1 New Source Performance Standards

New Source Performance Standards (NSPS) are uniform standards that apply nationally to specific categories of stationary sources that are constructed, modified, or reconstructed after the standard was proposed. NSPS are found in Title 40, Part 60 of the Code of Federal Regulations (CFR). NSPS usually represent a minimum level of control that is required on a new source. Lumber dry kilns are not subject to an NSPS.

3.2.2 National Emission Standards for Hazardous Air Pollutants

Under the provisions of Section 112 of the 1990 Clean Air Act Amendments, EPA was required to regulate emissions of a total of 189 hazardous air pollutants (HAPs) from stationary sources. EPA does this by specific industry categories to tailor the controls to the major sources of emissions and the HAPs of concern from that industry. The rules promulgated under Section 112 generally specify the Maximum Achievable Control Technology (MACT) that must be applied for a given industry category. Consequently, these rules are often called MACT standards.

MACT standards can require facility owners/operators to meet emission limits, install emission control technologies, monitor emissions and/or operating parameters, and use specified work practices. In addition, the standards typically include recordkeeping and reporting provisions. MACT standards are codified in 40 CFR Parts 61 and 63.

There are two types of HAP sources, "major" sources of HAP emissions and "area" sources of HAP emissions. Major sources are facilities that have a potential to emit, on an annual basis, more than 10 tons of a single HAP, or 25 tons of all HAPs combined. An area source is a facility that is not a major source. The Aberdeen facility is already a major source of HAPs and will continue to be a major source after the project is complete. Only Subparts A (General Provisions) and DDDD (Plywood at Composite Wood Products) are applicable as a result of the proposed project.

3.2.2.1 Part 63, Subpart A (General Provisions)

Subpart A establishes general requirements for reporting, testing, monitoring, and record-keeping for any facility that is major source of HAPs. The Facility must send notifications to ORCAA and EPA of anticipated and actual start-up dates, as defined in §63.9, and submit reports summarizing operations, emissions, and compliance with regulations and limits as specified in the standard.

3.2.2.2 Part 63, Subpart DDDD (Plywood and Composite Wood Products)

Although the Aberdeen facility does not manufacture plywood or composite wood products, and will continue to not do so following the proposed project, Subpart DDDD applies to lumber dry kilns located at any facility. According to 40 CFR 63.2252, the only MACT requirement that applies to lumber kilns is the

initial notification requirement in 40 CFR 63.9(b). Pursuant to 40 CFR 63.9(b)(iii), this permit application will serve as the initial notification for the lumber dry kilns. If other requirements are published that apply to the kilns, SPI will comply with those requirements in a timely fashion.

3.2.3 General Air Pollution Control Regulations

Regulations addressing general air pollution sources in Washington are contained in WAC 173-400. ORCAA has also established general regulations that apply within its jurisdiction. Note that all of these general conditions will apply to the proposed project, which is not exempt from any general requirements.

General standards for maximum emissions from air pollution sources in Washington are outlined in WAC 173-400-040 and in the ORCAA Regulation. These regulations limit:

- Visible emissions to 20 percent opacity except for 3 minutes per hour (ORCAA Rule 8.2(a));
- Particulate matter emissions from equipment, excluding boilers using hog fuel, to 0.1 grains/standard cubic feet of gas calculated at 7 percent oxygen (ORCAA Rule 8.3(a));
- Fugitive particulate material from process operations and equipment (ORCAA Rule 8.3(c)); and
- Nuisance Odor (ORCAA Rule 8.5).

Following implementation of the proposed project, SPI will continue to strive operate in compliance with these regulations as applicable.

4. BEST AVAILABLE CONTROL TECHNOLOGY ANALYSIS

As discussed in Section 3, among the requirements that must be met for ORCAA to issue an OA, is the requirement that proposed new or modified emission units will employ BACT and tBACT for all pollutants not previously emitted, or whose emissions would increase as a result of the project. New emission units associated with the proposed project are the lumber dry kilns and the planer mill dust collection system.

4.1 BACT Review Process

BACT, as it applies to regulated pollutants not subject to major new source review, is defined in WAC 173-400-030 as:

> "…an emission limitation based on the maximum degree of reduction for each air pollutant subject to regulation under chapter 70.94 RCW emitted from or which results from any new or modified stationary source, which the permitting authority, on a case-by-case basis, taking into account energy, environmental, and economic impacts and other costs, determines is achievable for such source or modification through application of production processes and available methods, systems, and techniques, including fuel cleaning, clean fuels, or treatment or innovative fuel combustion techniques for control of each such pollutant. "

In a December 1, 1987 memorandum from the U.S. Environmental Protection Agency (USEPA) Assistant Administrator for Air and Radiation, the agency provided guidance on the "top-down" methodology for determining BACT. The "top-down" process involves the identification of all applicable control technologies according to control effectiveness. Evaluation begins with the "top," or most stringent, control alternative. If the most stringent option is shown to be technically or economically infeasible, or if environmental impacts are severe enough to preclude its use, then it is eliminated from consideration and then the next most stringent control technology is similarly evaluated. This process continues until the BACT level under consideration cannot be eliminated by technical or economic considerations, energy impacts, or environmental impacts. The top control alternative that is not eliminated in this process becomes the proposed BACT basis.

This top-down BACT analysis process can be considered to contain five basic steps:

- Step 1: Identify all available emission reduction alternatives with practical potential for application to the specific emission unit for the regulated pollutant under evaluation;
- Step 2: Eliminate all technically infeasible alternatives;
- Step 3: Rank remaining alternatives by effectiveness;
- Step 4: Evaluate the economic, energy, and environmental impacts starting with the most effective alternative; and
- Step 5: Select BACT, which will be the most effective practical alternative not rejected in the previous steps.

Formal use of these steps is not always necessary. However, both USEPA and the Ecology have consistently interpreted the statutory and regulatory BACT definitions as containing two core requirements, which USEPA believes must be met by any BACT determination, regardless of whether it is conducted in a "top-down" manner. First, the BACT analysis must include consideration of the most stringent available technologies: i.e., those that provide the "maximum degree of emissions reduction." Second, any decision to require a lesser degree of emissions reduction must be justified by an objective analysis of "energy, environmental, and economic impacts" contained in the record of the permit decisions.

Additionally, the minimum control efficiency to be considered in a BACT analysis must result in an emission rate no less stringent than the applicable New Source Performance Standard (NSPS) emission rate, if any NSPS standard for that pollutant is applicable to the source.

This BACT analysis was conducted in a manner consistent with this stepwise approach. Control options for potential reductions in criteria pollution emissions were identified for each emission unit. These options were identified by researching the EPA database known as the RACT/BACT/LAER Clearinghouse (RBLC), drawing upon previous environmental permitting experience for similar units and surveying available literature. Available controls that are judged to be technically feasible are further evaluated based on an analysis of economic, environmental, and energy impacts.

Assessing the technical feasibility of emission control alternatives is discussed in EPA's draft "New Source Review Workshop Manual." Using terminology from this manual, if a control technology has been "demonstrated" successfully for the type of emission unit under review, then it would normally be considered technically feasible. For an undemonstrated technology, “availability” and “applicability” determine technical feasibility. An available technology is one that is commercially available; meaning that it has advanced through the following steps:

- Concept stage;
- Research and patenting;
- Bench scale or laboratory testing;
- Pilot scale testing;
- Licensing and commercial demonstration; and
- Commercial sales.

Suitability for consideration as a BACT measure involves not only commercial availability (as evidenced by past or expected near-term deployment on the same or similar type of emission unit), but also involves consideration of the physical and chemical characteristics of the gas stream to be controlled. A control method applicable to one emission unit may not be applicable to a similar unit, depending on differences in the gas streams’ physical and chemical characteristics.

4.2 Lumber Dry Kilns

A review of EPA’s RBLC database was conducted for lumber dry kilns. The search included all entries made after January 1, 2007 for “lumber kilns.” The initial search was refined by eliminating sources that operate in a significantly different manner (e.g., direct-fired kilns). In some cases, the permitted emission limits indicated in the RBLC were in units of pounds per hour or tpy, making it impossible to compare facilities on a consistent basis. In those cases, a comparison was made with the control option or technology cited in the RBLC. Table 4-1 provides a summary of the RBLC search results.

None of the permitted kilns in the RBLC require an add-on control system to control either PM or VOCs. BACT is frequently listed in the RBLC as “Proper Operation” (or something similar), “None,” or “No Control,” and there are often notes indicating that no control technology was feasible. The most recent permit

for lumber dry kilns in Washington shown in the RBLC is for the SPI's Burlington facility, where a computerized steam management system was deemed to be BACT by the NWCAA in January 2006.

Other permits not listed in the RBLC that include lumber dry kilns have been issued in Washington:

- In 1998, a permit was issued by the PSCAA for new kilns at a new sawmill proposed by Simpson Timber in Tacoma. For that permit, PSCAA determined that BACT for kilns was no control.
- In 2002, ORCAA permitted new kilns for a new SPI sawmill in Aberdeen, Washington. In that case, ORCAA determined that BACT for kilns was use of a computerized steam management system and that no add-on control technology was feasible for kilns.
- In October 2006, SWCAA issued a permit for new kilns at the Hampton Lumber Mills facility in Randle, Washington and also concluded that no add-on controls were required, and that process temperature limits and vertical dispersion of exhaust gases were BACT.
- In October 2007, three kilns at SPI's Centralia facility were permitted, and the use of a computerized steam management system was deemed BACT by SWCAA, and in July 2008, a permit was issued to install three more kilns at the same facility, and the same control technology was deemed to be BACT.
- In September 2010, NWCAA issued a permit to install new kilns at Socco Forest Products' Sumas facility. BACT was determined to be the use of a computerized steam management system, and limiting the maximum kiln temperature to less than or equal to 200 °F. These kilns were not constructed.
- In December 2014, PSCAA issued a permit for a new lumber manufacturing facility in Pierce County, near Frederickson, Washington that included six new kilns. BACT was determined to be the use of a computerized steam management system, and add on controls were deemed technologically and economically infeasible for reducing emissions from kilns.
- In September 2015, a permit was issued by Ecology's ERO for increased usage of two existing kilns at the Vaagen Brothers Lumber facility in Colville, Washington. BACT was determined to be limiting the maximum kiln temperature to less than or equal to 200 °F.
- In September 2016, ORCAA issued a permit to install new kilns at SPI's existing Shelton facility. BACT was determined to be the use of a computerized steam management system, and limiting the maximum kiln temperature to less than or equal to 200 °F.

- In October 2018, NWCAA issued a permit to install new kilns at Teal-Jones's existing facility in Sumas, Washington. BACT was determined to be the use of a computerized steam management system, and limiting the maximum kiln temperature to less than or equal to 200 °F.

- In November 2019, NWCAA issued a permit to increase throughput usage of existing kilns at the Skagit River Reman facility in Sedro Wooley, Washington. BACT was determined to be the use of a computerized steam management system, and limiting the maximum kiln temperature to less than or equal to 200 °F.

SPI proposes that BACT and tBACT for the new lumber dry kilns is use of a computerized kiln management system and limiting maximum kiln temperatures to less than 200 °F.

Table 4-1. Recent RBLC Entries for Lumber Dry Kilns

Permit or RBLC ID	Permit Issuance Date	Company	Location	System Description	Maximum Throughput (MMbf/yr)	Limit(s) (lb/Mbf)	Control Option	Basis
AL-0311	8-30-16	Weyerhaeuser NR Company – Millport Wood Products Facility	Millport, AL	Lumber Dry Kilns	385	VOC – 4.7 lb/Mbf	Proper Operation	BACT
AL-0305	6-24-15	Resolute FP U.S. Inc., Resolute Forest Products – Alabama Sawmill	Childersburg, AL	Lumber Dry Kilns	108.33	CO – 0.73 lb/Mbf VOC – 3.76 lb/Mbf	Proper Operation	BACT
*SC-0166	11-18-15	New South Lumber Company – Darlington Inc.	Darlington, SC	Lumber Dry Kilns	170	None	Proper operation	None
AR-0120	2-11-15	Deltic Timber Corporation	Yell, AR	Lumber Dry Kilns	Two 105; One 60	VOC – 2.77 lb/Mbf; VOC – 3.43 lb/Mbf	None	BACT
LA-0293	3-18-14	Martco Limited Partnership	Natchitoches, LA	Lumber Dry Kilns	50	VOC – 4.29 lb/Mbf	Good operating practices	BACT

Table 4-1. Recent RBLC Entries for Lumber Dry Kilns

Permit or RBLC ID	Permit Issuance Date	Company	Location	System Description	Maximum Throughput (MMbf/yr)	Limit(s) (lb/Mbf)	Control Option	Basis
LA-0281	1-31-14	Tin Inc. – Inland	Beauregard, LA	Wood-fired Dry Kilns	240	VOC – 4.27 lb/Mbf	Proper kiln design and operation	BACT
SC-0149	01-03-13	Klausner Holding USA, Inc.	Orangeburg County, SC	Lumber Dry Kilns	700	PM – 0.0220 lb/Mbf Filt. PM_{10} – 0.013 lb/Mbf Filt. $PM_{2.5}$ – 0.004 lb/Mbf VOC – 3.50 lb/Mbf	None	None
LA-0252	11-01-12	West Fraser, Inc. – Joyce	Winn Parish, TX	Lumber Kilns	300	VOC – 6.2 lb/Mbf	Proper operation	BACT-PSD
SC-0135	09-24-12	New South Companies, Inc. – Conway Plant	Horry County, SC	Lumber Kilns	381	VOC – 799 tons/yr	None	BACT-PSD
TX-0607	12-15-11	West Fraser, Inc. – New Boston	Bowie County, TX	Continuous Lumber Dry Kilns	275	VOC – 3.50 lb/Mbf	Proper operation	BACT-PSD
AR-0102	09-16-09	Anthony Timberlands, Inc.	Ouachita County, AR	Indirect-Fired Kilns	200	VOC – 3.50 lb/Mbf	None	BACT-PSD

Table 4-1. Recent RBLC Entries for Lumber Dry Kilns

Permit or RBLC ID	Permit Issuance Date	Company	Location	System Description	Maximum Throughput (MMbf/yr)	Limit(s) (lb/Mbf)	Control Option	Basis
FL-0315	08-04-09	North Florida Lumber – Bristol	Liberty County, FL	Wood Lumber Kiln	92	VOC – 0.0015 lb/Mbf	Best operating practices	BACT-PSD
OK-0113	07-21-06	Weyerhaeuser – Wright City	McCurtain County, OK	Lumber Kilns	None	VOC – 4.80 lb/Mbf	None	BACT-PSD
WA-0327	01-25-06	Sierra Pacific Industries – Burlington	Skagit County, WA	Dry Kilns	300	PM/PM_{10} – 4.00 tons/yr VOC – 54 tons/yr	Computerized steam management system	BACT-PSD
LA-0181	07-13-05	Hood Industries, Inc – Coushatta	Red River Parish, LA	Wood Lumber Kilns	140	VOC – 28 lb/hr/kiln VOC – 123 tons/yr/kiln	None	BACT-PSD

5. AIR QUALITY IMPACT ANALYSIS

An OA cannot be issued by ORCAA to a proposed new or modified source without a demonstration that the emission increases attributable to the proposed project will not cause or contribute to a violation of any ambient air quality standard, and that increases in TAP emissions are sufficiently low to protect human health and safety. Dispersion modeling analyses are typically used to predict ambient air concentrations attributable to the proposed project for such demonstrations. This chapter documents the near-field air quality impact analysis developed for the proposed new equipment at the existing lumber manufacturing facility.

5.1 Model Selection

Ramboll reviewed regulatory modeling techniques to select an appropriate air quality model to simulate dispersion of air pollutants emitted by the proposed project for a near-field air quality impact analysis. The selection of regulatory modeling tools is influenced by situations where exhaust plumes have the potential to interact with onsite structures (i.e., "building downwash") or impact complex terrain. There are several onsite structures with the potential to interact with exhaust plumes, and there is complex terrain in the northern portion of the modeling domain. As a result, the dispersion model selected for the analysis will be required to consider both complex terrain and building downwash effects to allow for the possibility of emissions from stacks shorter than dictated by Good Engineering Practice (GEP).

EPA's "Guideline of Air Quality Models" in 40 CFR 51 Appendix W ("the Guideline") recommends the use of AERMOD in this situation. AERMOD was specifically designed to estimate impacts of air pollutants in areas containing both simple and complex terrain. AERMOD also includes the PRIME downwash algorithms to estimate effects of surrounding buildings on the dispersion of plumes. Ramboll used the latest version of AERMOD (Version 19191) for the dispersion modeling analysis.

5.2 Modeling Procedures

Ramboll applied AERMOD to model criteria pollutant and TAP emission rates using the regulatory defaults in addition to the options and data discussed below. The option to adjust the surface friction velocity (U*) for low wind or stable conditions is now considered a regulatory default setting and was used in this analysis.

5.3 Averaging Periods

Ambient pollutant concentrations were calculated using AERMOD for averaging periods as required for comparison to applicable regulatory thresholds. For comparison against the applicable significant impact levels (SILs) and ASILs, a variety of pollutant averaging periods were used to calculate ambient concentrations in AERMOD, as required by the applicable ambient criteria for each modelled pollutant. These averaging periods include 24-hour and annual averaging periods.

5.4 Elevation Data and Receptor Network

Terrain elevations for receptors were prepared using 1/3th arc-second elevation data from the National Elevation Dataset (NED), which is a product of the United States Geological Survey (USGS). The NED is a seamless elevation dataset covering the continental United States, Alaska, and Hawaii, and is available on the internet from the USGS National Map Viewer[2]. These data have a horizontal spatial resolution of approximately 10 meters (m), or 33 feet (ft).

For the dispersion model analyses, receptors spacing was determined based on the Ecology First, Second, and Third Tier Review of Toxic Air Pollution Sources Guidance Document. Nested grids of receptors with 12.5-m, 25-m, 50-m, 100-m, 300-m, and 600-m spacing were within 150 m, 400 m, 900 m, 2 km, 4.5 km, and 5 km areas, respectively. All receptor grids were centered on the location of the proposed project. Receptors were also located at 10-m intervals along ambient air boundary of the facility. The final receptor locations are shown in Figure 5-1. The base elevation and hill height scale for each receptor were determined using the EPA's terrain processor AERMAP (Version 18081), which generates the receptor output files that are read by AERMOD. All receptor locations are in Universal Transverse Mercator (UTM) coordinates using the spatial reference of NAD 83, Zone 10.

[2] http://viewer.nationalmap.gov/viewer/

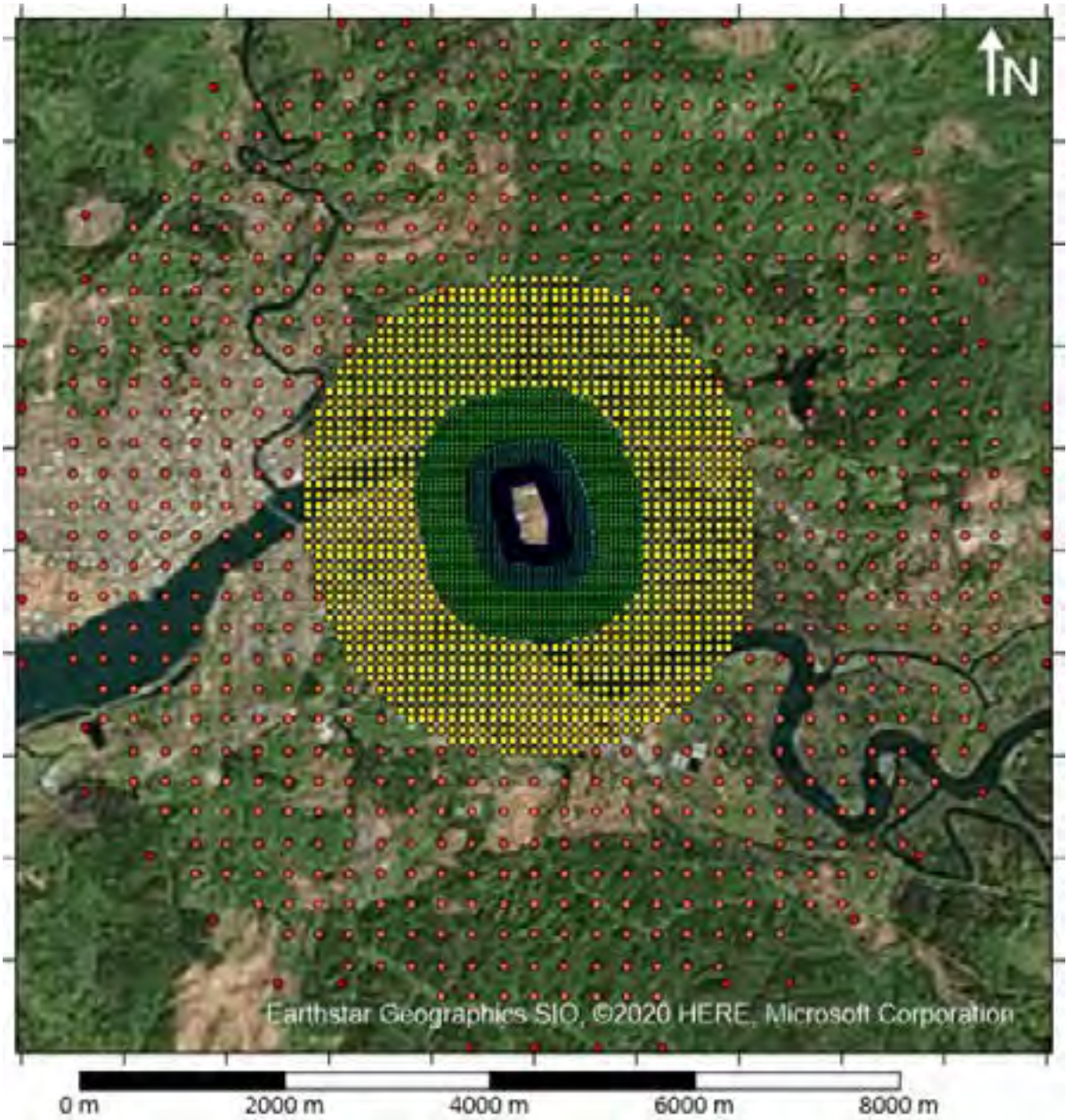

Figure 5-1. Receptor Locations

5.5 Meteorological Data

Ramboll conducted a survey of available meteorological data for use in the modeling simulations. A representative five-year data set was prepared using available surface and upper air data for the period 2015 through 2019. Surface meteorology data from National Weather Service (NWS) observations at Bowerman Airport (KHQM) in Hoquiam, Washington, and upper air data collected at the NWS

station in Quillayute, Washington were used. A windrose summarizing the KHQM wind speed and wind direction data is provided in Figure 5-2.

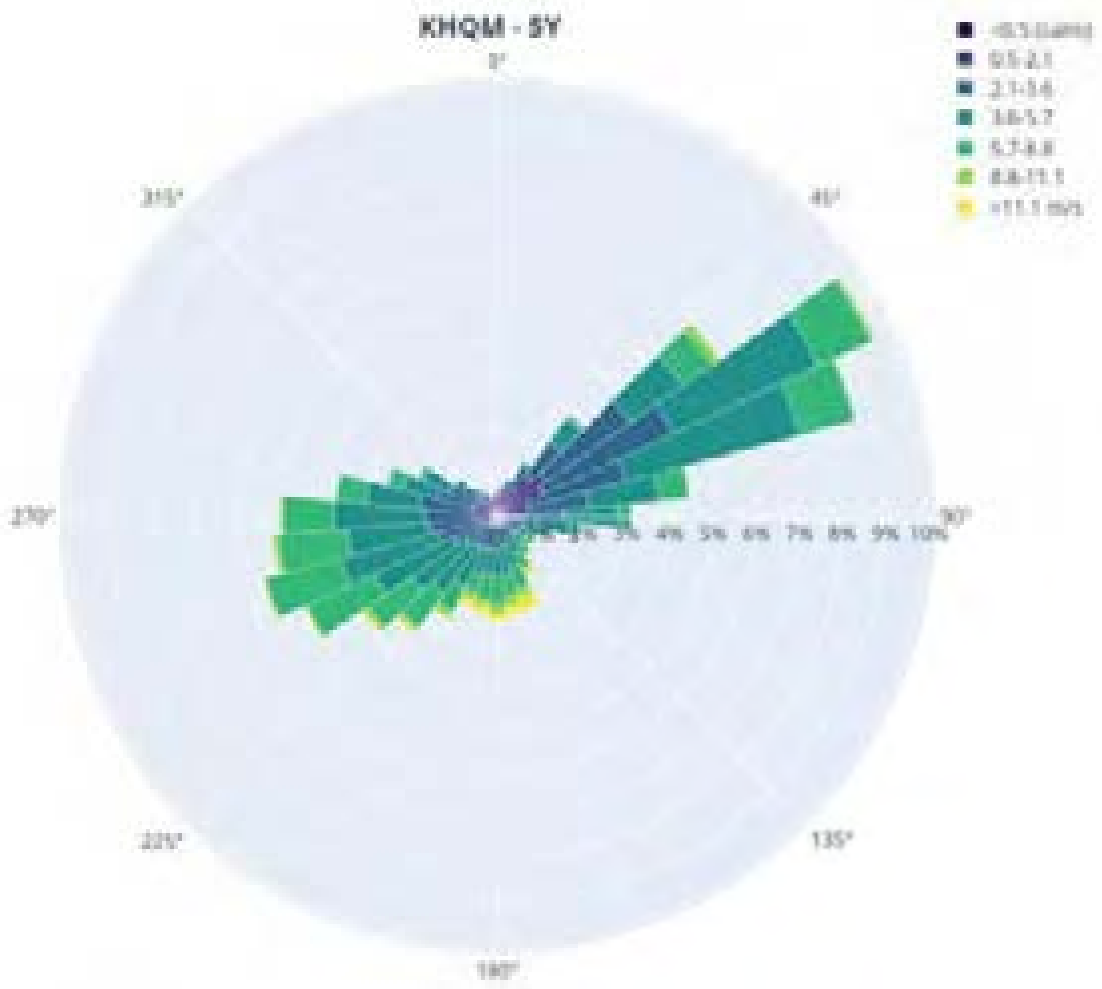

Figure 5-2. KHQM Windrose (2015-2019)

Additional meteorological variables and geophysical parameters are required for use in the AERMOD dispersion modeling analysis to estimate the surface energy fluxes and construct boundary layer profiles. Surface characteristics including albedo, Bowen ratio, and surface roughness length were determined for the area surrounding the KHQM meteorological station using the AERMET surface characteristic pre-processor, AERSURFACE (Version 20060), and the USGS 2016 National Land Cover (NLCD16) land use data set, the USGS 2016 Impervious

surface data set (MPRV2016), and the USGS tree canopy data set (CNPY2016).[3] Seasonal surface parameters were determined using AERSURFACE according to the EPA's guidance.[4]

Seasonal albedo and Bowen ratio values were based on averaging over a 10-km by 10-km region centered on the KHQM meteorological station. An unweighted arithmetic average was used for calculating seasonal albedo; and an unweighted geometric average was used for calculating seasonal Bowen ratio. Seasonal surface roughness values were calculated for twelve 30-degree sectors within 1 km of the Bowerman Airport meteorological station. An inverse-distance weighted geometric average was used to calculate seasonal surface roughness length values for each of the 12 sectors.

The EPA meteorological program AERMET (Version 19191) was used to combine the surface meteorological observations collected by the KHQM meteorological station with the twice-daily upper air soundings from Quillayute, Washington and to calculate the meteorological variables and profiles required by AERMOD. A March 8, 2013 EPA memorandum regarding the use of ASOS meteorological data in AERMOD dispersion modeling recommends using the AERMINUTE program to resolve calm and variable wind conditions in the standard ASOS data. One-minute wind speed and wind direction data from KHQM were used to resolve calm and variable wind conditions using the current version of AERMINUTE (Version 15272) pre-processor, which will accept five-minute data when one-minute data is not available.

5.6 Modeled Criteria Pollutant Emissions

The only criteria pollutants attributable to the project are PM and VOCs, and only PM_{10} and $PM_{2.5}$ have ambient standards; consequently, PM_{10} and $PM_{2.5}$ were the only criteria pollutants for which modeling was developed. The concentrations resulting from this analysis were compared to the SILs provided in WAC 173-400-113(4)(a). Calculated ambient concentrations less than these screening thresholds indicate that the emission increase associated with the project do not have the potential to cause or contribute to a violation of an ambient air quality standard.

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[3] THE USGS landuse data sets are described and can be accessed at: https://www.mrlc.gov/

[4] The AERMOD Implementation Guide (EPA, 2009) and the AERSURFACE User's Guide (EPA-454/B-08-001, January 2008).

The criteria pollutant emissions associated with the proposed new kilns are summarized in Table 5-1. These emissions are incorporated into AERMOD and used to compare modeled concentrations to the SILs.

Table 5-1. Modeled Criteria Pollutant Emissions

Pollutant	Hourly [1]		Annual [1]	
	(lb/hr)	(g/s)	(tpy)	(g/s)
$PM_{10}/PM_{2.5}$	0.947	0.119	4.15	0.119

1. All proposed lumber dry kilns combined. The lumber dry kilns were assumed to operate continuously and uniformly throughout the year, therefore, short-term and annual average emission rates are identical.

5.7 Modeled Toxic Air Pollutant Emissions

Washington regulations, adopted by ORCAA, require a demonstration that TAP emission increases attributable to new or modified emission units will not exceed certain ambient concentration thresholds, called "acceptable source impact levels" (ASILs), which are designed to protect human health and safety. Regulations also provide emission levels, called "small quantity emission rates" (SQERs), below which a modeling demonstration is not required. This process is referred to as a "first tier review." The regulations that describe the first tier review process (WAC 173-460-080) permit the inclusion of reductions in actual TAP emissions from existing emission units at the source, for the purpose of offsetting emissions of the same TAP attributable to a new or modified emission unit.

As shown in Table 2-2, the increase in methanol and propionaldehyde emissions attributable to the project, minus the decrease in actual emissions attributable to existing emission units that will be removed from the facility, is less than the applicable SQER, and, therefore, a modeling demonstration to assess compliance with the ASIL is not required. However, increases in acetaldehyde, acrolein, and formaldehyde emissions exceed the applicable SQERs, and, therefore, a modeling demonstration is required for those TAPs.

Emission increases associated with the new kilns and the actual emission decreases associated with removing the existing kilns are summarized in Table 5-2.

Table 5-2. Modeled Toxic Air Pollutant Emissions

Pollutant	Emission Rate[1]			
	Proposed Lumber Dry Kilns[2]		Existing Lumber Dry Kilns to Be Removed[3]	
	(lb/hr)	(g/s)	(lb/hr)	(g/s)
Acetaldehyde	3.21	0.404	1.71	0.216
Acrolein	0.0568	0.00716	0.0305	0.00384
Formaldehyde	0.207	0.0260	0.111	0.0139

1. The lumber dry kilns were assumed to operate continuously and uniformly throughout the year, therefore, short-term and annual average emission rates are identical.
2. All proposed lumber dry kilns combined.
3. All existing lumber dry kilns combined.

5.8 Emission Unit Release Parameters

Figure 5-3 shows the layout of the facility as it will be following the proposed project, superimposed on a recent aerial photograph of the facility. Locations of proposed new emission units are indicated, as well as significant structures that could potentially influence emissions. It should be noted that the modified facility will include both new buildings and existing buildings that remain.

Table 5-3 provides a summary of the parameters used to represent exhaust from the proposed lumber dry kiln vents, as well as the existing lumber dry kiln vents, which were used only for modeling TAP emission decreases.

Table 5-3. Release Parameters

Emission Unit	Number of Point Sources	Height Above Grade (m)	Exhaust Temperature (K)	Exit Velocity (m/s)	Inside Diameter[1] (m)
Proposed Lumber Dry Kiln Vents	176	7.62	366	1.52	2.26
Existing Lumber Dry Kiln Vents	192	5.49	366	1.52	2.26

1. Vents on both the existing and proposed kilns are 2-ft square (i.e., 24” x 24”), the diameter of a circular stack with the same cross-sectional area was calculated and provided to AERMOD.

In addition to the release parameters discussed above, the building dimensions and facility configuration were provided to AERMOD to assess potential downwash effects. Wind direction-specific building profiles were prepared for the modeling using EPA’s Building Profile Input Program including the PRIME algorithm (BPIP

PRIME). The facility layout and heights of proposed new (green) and retained (yellow) existing structures, as shown in Figure 5-3 and Table 5-4, were used to prepare data for BPIP PRIME, which calculates the necessary input data for AERMOD.

Figure 5-3. Post-Project Facility Layout

Emissions from the existing lumber dry kilns, which were included in the TAPs modeling to account for the decrease in TAP emissions that will result from their removal, are influenced by the current facility configuration rather than the post-

project facility configuration. To account for that difference, wind direction-specific building profiles were also prepared for the existing kilns using BPIP PRIME, the existing facility layout, shown in red in Figure 5-4, and the heights for existing structures in Table 5-4.

Figure 5-4. Current Facility Layout

Table 5-4. Significant Onsite Structure Heights

Structure	New or Existing	Height Above Grade (m)
Proposed Lumber Dry Kilns	New	7.6
Existing Lumber Dry Kilns	Existing, will be removed	5.5
Sawmill	Existing, will be retained	17.3
Fuelhouse	Existing, will be retained	12.2
Boiler	Existing, will be retained	18.3
Turbine	Existing, will be retained	13.7

For the TAPs modeling, positive maximum potential emission rates attributable to the proposed lumber dry kilns, and negative actual emission rates attributable to the existing lumber dry kilns, were provided to AERMOD, along with building profile information unique to each group of kilns. Using those inputs, AERMOD calculates the net concentrations for comparison to the ASILs.

5.9 Results of the Project-Only Criteria Pollutant Analysis

Ambient PM_{10}, $PM_{2.5}$, and TAP concentrations attributable to the project were evaluated using the inputs described in this section. Table 5-6 compares AERMOD-predicted maximum PM_{10} and $PM_{2.5}$ concentrations to applicable SILs. The SILs represent incremental, project-specific impact levels that the State of Washington accepts as insignificant with respect to assessing compliance with the National Ambient Air Quality Standards (NAAQS) or the Washington Ambient Air Quality Standards (WAAQS, which, for PM_{10} and $PM_{2.5}$, are currently identical to the NAAQS). As shown in Table 5-5, the design concentration predicted by AERMOD for 24-hour average PM_{10}, 24-hour average $PM_{2.5}$, and annual average $PM_{2.5}$ exceed the corresponding SILs. As a result, a cumulative analysis is required to assess compliance with the NAAQS, which, for minor source permitting is accomplished by adding representative background values[5] to the modeling results. The NAAQS compliance assessment is described in section 5.11.

[5] Background data were obtained from NW Airquest (https://arcg.is/1jXmHH) for latitude 46.96° and longitude -123.78°.

Table 5-5. Model-Predicted Project-Only Criteria Pollutant Design Concentrations

Pollutant	Averaging Period	Design Concentration[1] (µg/m³)	SIL[2] (µg/m³)	Over SIL?
PM_{10}	24-Hour	8.38	5	Yes
$PM_{2.5}$	24-Hour	7.52	1.2	Yes
	Annual	1.86	0.2	Yes

1. Design concentrations are the maximum 24-hour PM_{10} concentration, the highest 5-year average of the maximum 24-hour average $PM_{2.5}$ concentrations at each receptor, and the highest 5-year average of the maximum annual average $PM_{2.5}$ concentrations at each receptor
2. SIL = Significant Impact Level, from WAC 173-400-113

5.10 Results of the Toxic Air Pollutant Analysis

The results of the TAP dispersion modeling analysis are summarized in Table 5-6, where modeling results are compared with the applicable ASILs. As shown in the table, the maximum annual average acetaldehyde and formaldehyde concentrations predicted by the model attributable to the proposed new lumber dry kilns, including emission offsets resulting from the removal of existing lumber dry kilns, are greater than the applicable ASILs. As provided in WAC 173-460-090, SPI will submit a petition requesting that Ecology perform a second-tier review to determine a means of compliance with the ambient impact requirement.

Table 5-6. Maximum Model-Predicted Toxic Air Pollutant Concentrations

Toxic Air Pollutant	CAS #	Averaging Period	Maximum Concentration (µg/m³)	ASIL (µg/m³)	Over ASIL?
Acetaldehyde	75-07-0	Annual	2.89	0.37	Yes
Acrolein	107-02-8	24-hr	0.214	0.35	No
Formaldehyde	50-00-0	Annual	0.185	0.17	Yes

5.11 Ambient Standard Compliance Assessment

Because the predicted 24-hour average PM_{10} and 24-hour and annual average $PM_{2.5}$ project-only design concentrations exceeded the SILs, a cumulative analysis is required to assess compliance with the ambient standards for those pollutants and averaging periods. Also, to account for other sources, a representative background concentration is added to the design concentration calculated by AERMOD.

Results of the cumulative modeling analysis are summarized in Table 5-7. As shown in the table, the model-predicted design concentration, with a representative background concentration added, is less than the applicable ambient standards in all cases.

Table 5-7. Ambient Standard Compliance Analysis Results

Pollutant	Averaging Period	Concentration (µg/m³)				Over NAAQS/ WAAQS?
		Design[1]	Background[2]	Total[3]	NAAQS/ WAAQS (µg/m³)	
PM_{10}	24-Hour	7.96	42.1	50.1	150	No
$PM_{2.5}$	24-Hour	6.43	15.4	21.8	35	No
	Annual	1.86	5.9	7.76	12	No

1. Design concentrations are the highest 6th-high 24-hour average PM_{10} concentration over five modeled years, the highest 5-year average of the 98th percentile 24-hour average $PM_{2.5}$ concentrations at each receptor, and the highest 5-year average of the annual average $PM_{2.5}$ concentrations at each receptor (based on guidance in the "Modeling Procedures for Demonstrating Compliance with the $PM_{2.5}$ NAAQS" memorandum issued on March 23, 2010 by Stephen Page, Director of OAQPS).
2. Background data obtained from NW Airquest (https://arcg.is/1jXmHH) for latitude 46.96° and longitude -123.78°.
3. Total concentration is the sum of the design concentration and the background concentration.

5.12 Conclusions

The AERMOD modeling methodology described above predicted that emissions attributable to the proposed project will not cause or contribute to an exceedance of any ambient standards. The maximum concentration increases of acetaldehyde and formaldehyde were predicted to exceed the first-tier screening levels in WAC 173-460-150; SPI will submit a second-tier review petition to Ecology to determine a means of compliance for acetaldehyde and formaldehyde emissions.

APPENDIX A: ORCAA NOC FORM 1

OLYMPIC REGION CLEAN AIR AGENCY

2940 Limited Lane NW - Olympia, Washington 98502 - 360-539-7610 – Fax 360-491-6308

FORM 1- NOTICE OF CONSTRUCTION

TO CONSTRUCT - INSTALL - ESTABLISH OR MODIFY AN AIR CONTAMINANT SOURCE

Form 1 Instructions:

1. Please complete all the fields below. **This NOC application is considered incomplete until signed.**
2. If the application contains any confidential business information, please complete a Request of Confidentiality of Records (www.orcaa.org/permit-programs/permit-registration-assistance/permit-registration-forms/)
3. Duty to Correction Application: An applicant has the duty to supplement or correct an application. Any applicant who fails to submit any relevant facts or who has submitted incorrect information in a permit application must, upon becoming aware of such failure or incorrect submittal, promptly submit supplementary factors or corrected information.

Business Name: Sierra Pacific Industries	**For ORCAA use only**
Mailing Address: 301 Hagara Street, Aberdeen, WA 98520	File No: County No: Source No: Application No:
Physical Address of Project or New Source: 301 Hagara Street, Aberdeen, WA 98520	Date Received:
Billing Address: 301 Hagara Street, Aberdeen, WA 98520	

Are you currently registered with ORCAA? Yes ☒ No ☐

Project/ Equipment to be installed/established: 8 Lumber Dry Kilns

Previous business name (if any):

This project must meet the requirements of the State Environmental Policy Act (SEPA) and applicable building and fire codes before ORCAA can issue final approval. Complete one of the following options.

☒ SEPA was satisfied by Grays Harbor County (government agency) on ___/___/___ (date). A copy of the final determination and the environmental checklist is enclosed.

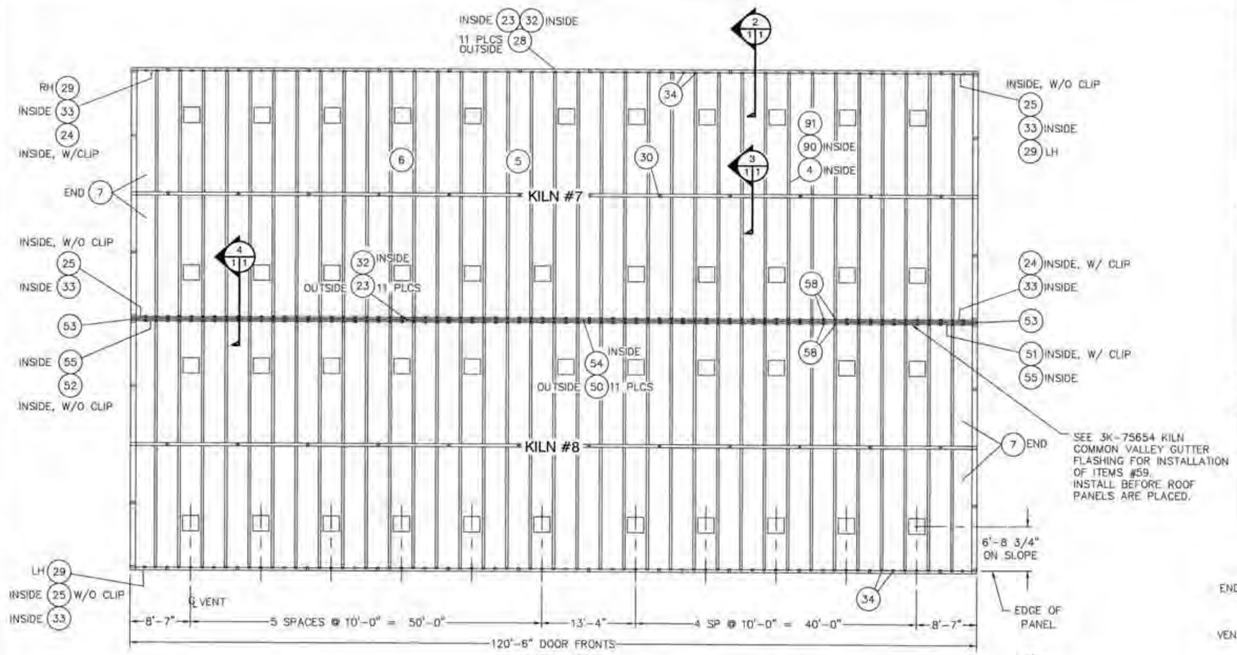
☐ SEPA is pending approval by Grays Harbor County (government agency). A copy of the environmental checklist is enclosed and a copy of the final determination will be forwarded to ORCAA when issued.

☐ ORCAA is the only government agency requiring a permit. A completed environmental checklist or documentation that the project or new source is/will be in compliance with local building and fire codes is enclosed.

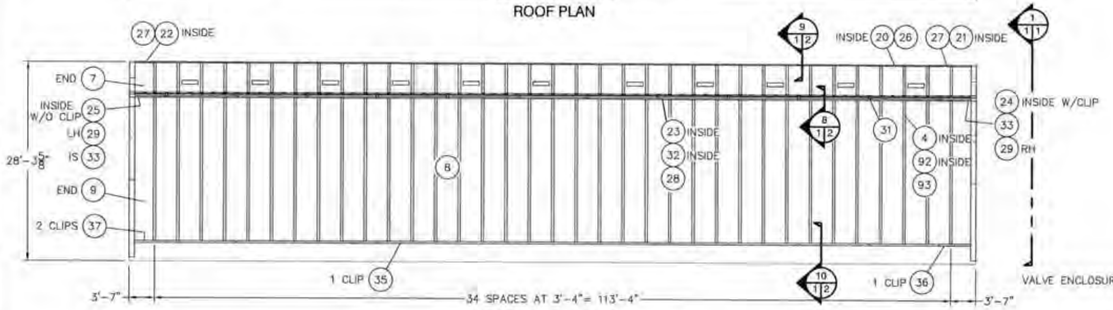
☐ This project is exempt from SEPA per _____ (WAC citation).

Name of Owner of Business: Sierra Pacific Industries		Agency Use Only
Title:		
Email:	Phone:	
Application Contact Name (if different than owner): Ron Burch		
Title: Division Manager		
Email: RBurch@spi-ind.com	Phone: (360) 532-2323	
Facility Operations Contact Name (if different than owner): Ron Burch		
Title: Division Manager		
Email: RBurch@spi-ind.com	Phone: (360) 532-2323	
I hereby certify that the information contained in this application is, to the best of my knowledge, complete and correct.		
Signature of Owner: RBurch	**Date** 6/29/2020	

APPENDIX B: PROPOSED KILN DRAWINGS



ROOF PLAN



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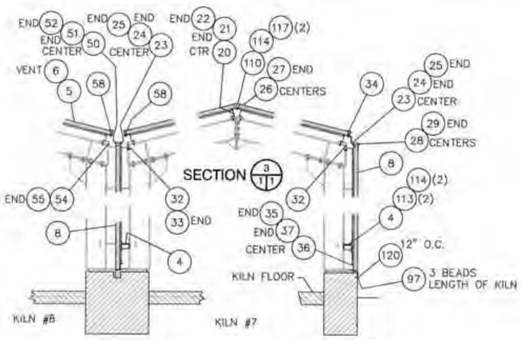

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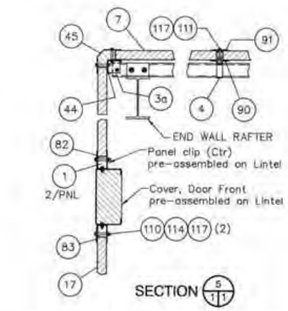
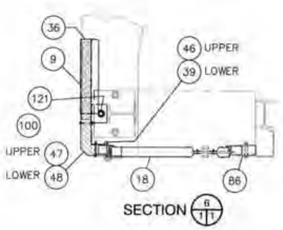
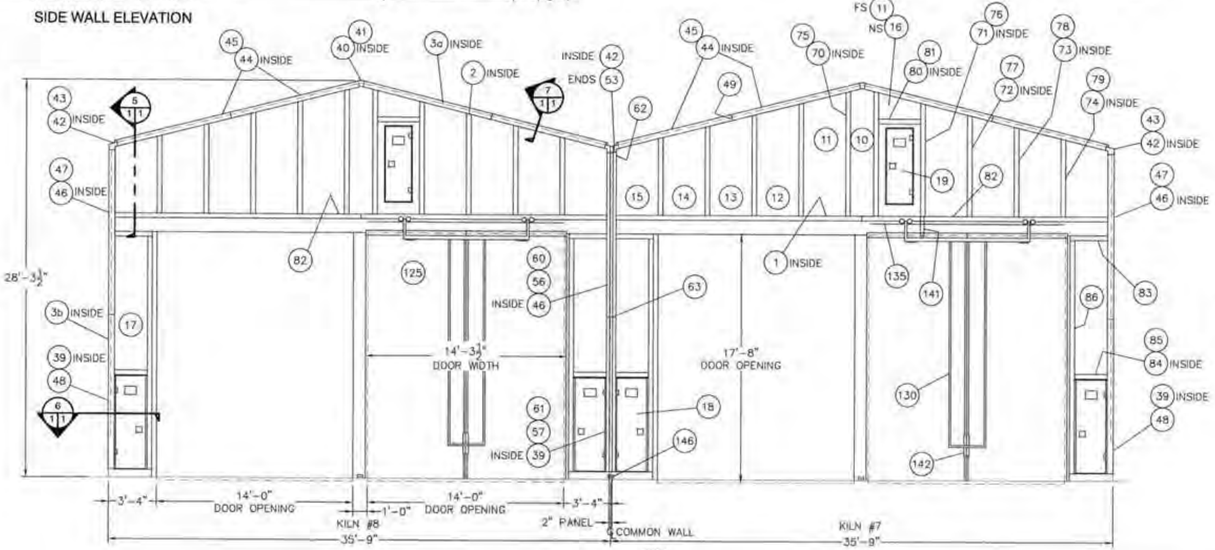


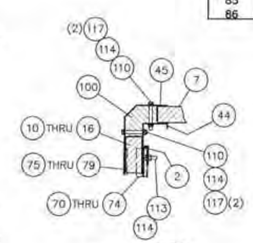
SECTION (5/1/1)



SECTION (6/1/1)



SECTION (1/1/1)



SECTION (7/1/1)

ITEM	QTY	DESCRIPTION	PART NUMBER	REQN	WT
90	140	INSIDE ROOF EXTRUSION	(CUT 17'-8 1/2")	4241	
91	140	OUTSIDE ROOF EXTRUSION	1K-57601		
92	105	INSIDE WALL EXTRUSION	(CUT 20'-1 1/2")		
93	105	OUTSIDE WALL EXTRUSION (15'-8" DO)	1K-50467-8		
95	5	GALLONS FORREST READY MIXED ALUMINUM PAINT		4246	
96	1	GALLONS PAINT THINNER			
97	40	TUBES SEALANT, MODIFIED SILANE			
98	36	ROLLS 3M-4655 HI-TEMP SEALANT TAPE 62.5m x 1/2"			
99	168	CARTRIDGES SILICONE SEALANT (ALUMINUM)			
100	65	PCS. 2" FIBERGLASS INSUL. (38 1/4" X 48")			
101	4	WELLONS LG. BRASS PLAQUE (1 3/4" X 8")			
102	8	WELLONS SM. BRASS PLAQUE (1 1/8" X 4 1/4")			
103	1	WELLONS SERIAL TAB W/SER. NO. K-13909-1			
104	1	WELLONS SERIAL TAB W/SER. NO. K-13909-2			
110	1900	3/8" X 3" SS HEX HEAD BOLT		4249	
111	5250	3/8" X 2 1/4" SS HEX HEAD BOLT			
112	175	3/8" X 1 1/4" SS HEX HEAD BOLT			
113	3700	3/8" X 1 1/4" SS CARRIAGE BOLT			
114	6700	3/8" SS HEX NUT			
115	4300	3/8" SS FLAT WASHER			
116	4300	3/8" SS LOCK WASHER			
117	10000	3/4" OD X 3/8" ID DISHED SS WASHER W/NEOPRENE			
118	2100	3/16" ALUM. POP RIVET; 1/8"-1/4" GRIP			
119	1200	1/8" ALUM. POP RIVET; 0.126"-0.187" GRIP			
120	400	1/4" X 1 5/8" ALUMINUM DRIVE RIVET			
121	50	1/2" X 1 1/2" SS HEX HEAD BOLT, FW & LW			
125	8	KILN DOOR ASSEMBLY, 17'-8"	3K-75728	4251	
130	2	DOOR CARRIER ASSEMBLY, 17'-8" (A=13'-8")	2K-26174	4260	
135	–	DOOR HARDWARE AND RAIL	REF	4261	
140	48	BULB GASKETED DOOR KEEPER	0K-60354	4262	
141	18	DOOR GUARD	1K-39184-8		
142	16	KILN DOOR HANDLE	0K-18660-1		
143	24	DOOR SHIMS (1/8" Thk)	1K-39184-5		
144	24	DOOR SHIMS (.080" Thk)	1K-39184-6		
145	24	DOOR SHIMS (.032" Thk)	1K-39184-7		
146	2	5" DIA. WHEEL GUIDE BRACKET	0K-62901		
147	50	1/2" TRUBOLT 304 SS CONC WEDGE ANCHOR x 5 1/2"			

ITEM	QTY	DESCRIPTION	PART NUMBER	REQN	WT
1	88	PANEL SUPPORT	0K-50257	4226	
2	40	FLASHING CLIP (@ EW EXTRUSION)	0K-75567		
3a	40	FLASHING CLIP (@ 4" PANEL SUP'T CHANNEL)	0K-75564		
3b	40	FLASHING CLIP (@ 3" PANEL SUP'T CHANNEL)	0K-50259		
4	1250	TIE STRAP 4" SS304	0K-75384		
5	92	ROOF PANEL (CENTER)	1K-50276-1	4231	
6	44	ROOF PANEL (VENT)	1K-50277-1		
7	8	ROOF PANEL (END: 4'-6" EB)	1K-75649		
8	102	WALL PANEL (CENTER: 15'-8" DO)	1K-50286-08		
9	6	WALL PANEL (END: 15'-8" DO, 4'-6" EB)	1K-75650		
10	4	END WALL PANEL (UPPER CENTER – 36FT WIDE KILN)	1K-50310-0	4232	
11	6	END WALL PANEL (UPPER)	1K-50310-1		
12	8	END WALL PANEL (UPPER)	1K-50310-2		
13	8	END WALL PANEL (UPPER)	1K-50310-3		
14	8	END WALL PANEL (UPPER)	1K-50310-4		
15	8	END WALL PANEL (UPPER)	1K-50310-5		
16	2	EW PANEL (ABOVE UPPER ACC. DOOR)	1K-50310-6		
17	8	EW PANEL (LWR ACC. DOOR: 17'-8" DO)	1K-50312-12		
18	4R/4L	ACCESS DOOR (LOWER)	3K-50316	4233	
19	2	ACCESS DOOR (UPPER)	3K-75651		
20	22	INSIDE PEAK FLASHING (CENTER)	1K-50335	4235	
21	2	IS PEAK FLASHING W/SPLICE (4'-6" EB)	1K-75627		
22	2	IS PEAK FLASHING W/O SPLICE (4'-6" EB)	1K-75628		
23	33	INSIDE WALL FLASHING (CENTER)	1K-75610		
24	3	IS WALL FLASHING W/SPLICE (4'-6" EB)	1K-75611		
25	3	IS WALL FLASHING W/O SPLICE (4'-6" EB)	1K-75612		
26	22	OUTSIDE PEAK FLASHING (CENTER)	1K-50341		
27	4	OUTSIDE PEAK FLASHING (4'-6" EB)	1K-75626		
28	22	OUTSIDE WALL FLASHING (CENTER)	1K-75613		
29	2R/2L	OUTSIDE WALL FLASHING (4'-6" EB)	1K-75614		
30	28	OUTSIDE PEAK FLASHING JOINT CLIP	0K-50345		
31	28	OUTSIDE WALL FLASHING JOINT CLIP	0K-75615		
32	33	IS WALL FLASHING INSUL. COVER (CENTER)	0K-75616		
33	6	IS WALL FLASHING INSUL. COVER (4'-6" EB)	0K-75617		
34	146	ROOF PANEL CLIP	0K-50349		
35	33	BASE FLASHING (CENTER)	1K-50350		
36	3	BASE FLASHING W/SPLICE (4'-6" EB)	1K-75618		
37	3	BASE FLASHING W/O SPLICE (4'-6" EB)	1K-75619		
39	4R/4L	IS LOWER WALL EW FLASHING (15'-8" DO)	1K-75625		
40	4	INSIDE PEAK EW FLASHING	3K-38618-3	4236	
41	4	OUTSIDE PEAK EW FLASHING	3K-38618-4		
42	4R/4L	INSIDE EAVE EW FLASHING	1K-75620		
43	2R/2L	OUTSIDE EAVE EW FLASHING	1K-75621		
44	8R/8L	INSIDE ROOF EW FLASHING	1K-75652		
45	16	OUTSIDE ROOF EW FLASHING	1K-75653		
46	4R/4L	INSIDE UPPER WALL EW FLASHING	1K-75622		
47	4	OUTSIDE UPPER WALL EW FLASHING	1K-75623		
48	2R/2L	OS LOWER WALL EW FLASHING (17'-8" DO)	1K-75625		
49	32	OUTSIDE EW FLASHING JOINT CLIP	0K-50381		
50	11	VALLEY EAVE TIE-IN FLASHING (CENTER)	1K-75629	4237	
51	1	VALLEY EAVE TIE-IN W/SPLICE (4'-6" EB)	1K-75630		
52	1	VALLEY EAVE TIE-IN W/O SPLICE (4'-6" EB)	1K-75631		
53	2	VALLEY END FLASHING	1K-75632		
54	11	VALLEY FLASH INSUL. COVER (CENTER)	1K-75633		
55	2	VALLEY FLASH INSUL. COVER (4'-6" EB)	1K-75634		
56	2	OUTSIDE UPPER CW FLASHING	1K-50403		
57	2	OS LOWER CW FLASHING (17'-8" DO)	1K-75635		
58	146	ROOF PANEL CLIP	0K-50349		
59	–	COMMON VALLEY GUTTER FLASHING	1K-75654		
60	2	CW DOWNSPOUT (UPPER)	1K-50410	4239	
61	2	CW DOWNSPOUT (LOWER: 17'-8" DO)	1K-75647		
62	2	DOWNSPOUT 'TOP'	1K-50413		
63	2	JOINT SEAL	1K-50414		
70	4R/4L	INSIDE EW EXTRUSION (UPPER)	1K-50426-0	4240	
71	4R/4L	INSIDE EW EXTRUSION (UPPER)	1K-50426-2		
72	4R/4L	INSIDE EW EXTRUSION (UPPER)	1K-50426-3		
73	4R/4L	INSIDE EW EXTRUSION (UPPER)	1K-50426-4		
74	4R/4L	INSIDE EW EXTRUSION (UPPER)	1K-50426-5		
75	4R/4L	OUTSIDE EW EXTRUSION (UPPER)	1K-50427-0		
76	4R/4L	OUTSIDE EW EXTRUSION (UPPER)	1K-50427-2		
77	4R/4L	OUTSIDE EW EXTRUSION (UPPER)	1K-50427-3		
78	4R/4L	OUTSIDE EW EXTRUSION (UPPER)	1K-50427-4		
79	4R/4L	OUTSIDE EW EXTRUSION (UPPER)	1K-50427-5		
80	2	IS EW EXTRUSION (ABOVE UPPER DOOR)	0K-50432		
81	2	OS EW EXTRUSION (ABOVE UPPER DOOR)	0K-50433		
82	8	OS EW EXTRUSION (ABOVE LINTEL)	0K-50434-36		
83	8	OS EW EXTRUSION (BELOW LINTEL)	0K-50435		
84	8	IS EW EXTRUSION (ABOVE LOWER DOOR)	0K-50436		
85	8	OS EW EXTRUSION (ABOVE LOWER DOOR)	0K-50437		
86	8	OS EW EXTRUSION (VERTICAL @ DOOR JAMB 17'-8" DO)	0K-50444-12		

REFERENCE DWGS

3K-75524-2	HOUSING DETAILS
3K-75524-3	COMMON WALL DETAILS
3K-75654	KILN COMMON VALLEY GUTTER FLASHING
3K-38059	KILN DOOR DETAIL
2K-26174	DOOR CARRIER ASSEMBLY
2K-61355	DOOR KEEPER FIELD INSTALLATION
1K-60736	DOOR STIFFENER

AARON M. SHIELDS STATE OF WASHINGTON 34781 REGISTERED PROFESSIONAL ENGINEER

2/25/2020

WELLONS 2525 W. Fairbourne Ln. Vancouver, WA 98660 1-800-WELLONS

DO NOT SCALE THIS DRAWING

SCALE 3/16" = 1'-0"

8400 4225

Kiln Housing Assembly

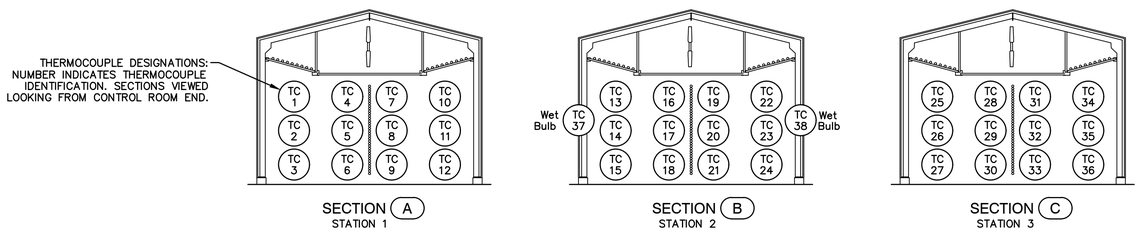
DRAWING TAF DATE 2/21/20

CHECKED CLF 2/21/20 APPROVED AMS 2/22/20

Sierra Pacific Industries Aberdeen, WA K-13909

DRAWING NUMBER 3K-75524-1 1 OF 3 REV 0

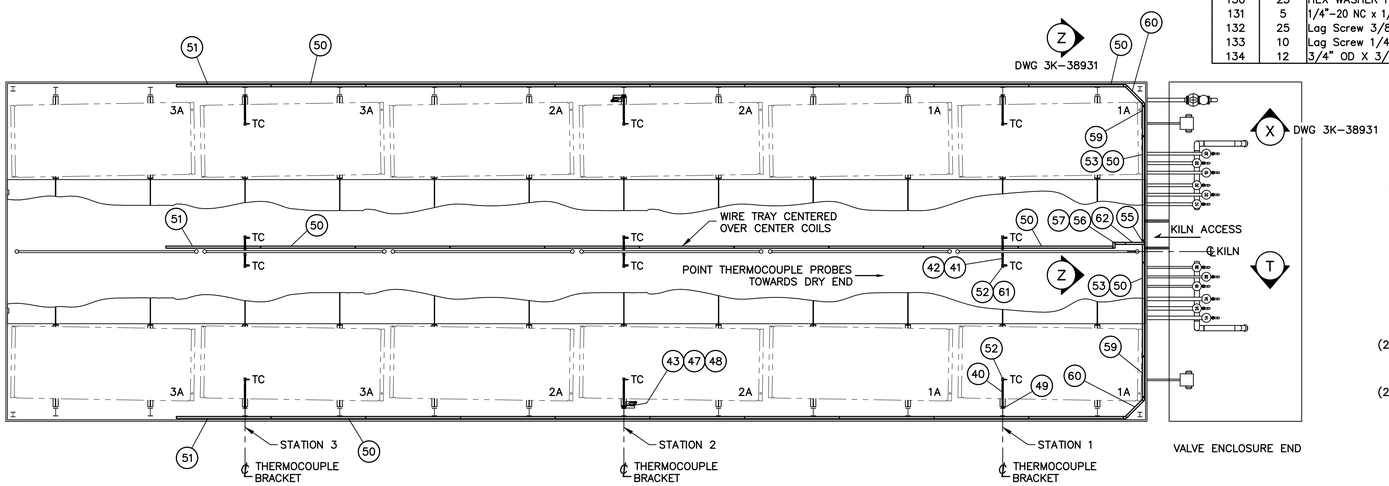
JOB	REV	REVISION	BY	DATE	CHECKED	DATE



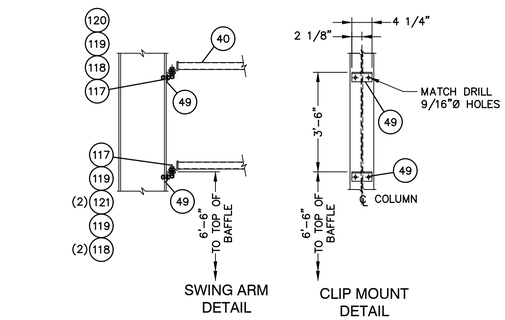
ITEM	QTY	DESCRIPTION	PART NUMBER	REQN	WT
100	2	1/2" Galv Threaded Union (150#)		4360	
101	3	1/2" Galv Threaded Tee (150#)			
102	4	1/2" x 90° Galv Threaded Elbow (150#)			
103	1	1/2" Threaded Bronze Ball Valve	V-1900-B		
104	1	1/2" x 6" Galv Pipe Nipple, Sch 40, TBE, A-120 ERW			
105	6	1/2" x 3" Galv Pipe Nipple, Sch 40, TBE, A-120 ERW			
106	2	1/4" x 4" Galv Pipe Nipple, Sch 40, TBE, A-120 ERW			
107	2	1/2" x 1/4" Galv Threaded Steel Pipe Bushing, A53-A			
108	2	1/2" Galv Threaded Steel Pipe Plug, A53-A			
109	2	1/2" Sch 40 Galv Pipe x 21'-0", T&C, A-53A ERW			
110	8	1/4" x 1/2" Pipe U-bolt, Grinnell Fig. 137			
115	6	HEX BOLT 1/2-13 x 5 1/2, 18-8 SS, PLAIN	1131105	4374	
116	25	HEX BOLT 1/2-13 x 4, 18-8 SS, PLAIN	1131102		
117	50	HEX BOLT 1/2-13 x 2, 18-8 SS, PLAIN	1131094		
118	110	HEX NUT 1/2-13, 18-8 SS, PLAIN	1132103		
119	110	FLAT WASHER 1/2 SAE, 18-8 SS, PLAIN	1132131		
120	25	LOCK WASHER 1/2 REGULAR HELICAL SPRING, 18-8 SS, PLAIN			
121	50	BELLEVILLE DISC SPRING 0.505" ID 1" OD 0.050" THK, SS	1130574		
122	36	HEX BOLT 3/8-16 x 3, 18-8 SS, PLAIN	1130975		
123	12	HEX BOLT 3/8-16 x 2 1/4, 18-8 SS, PLAIN	1130972		
124	5	HEX BOLT 3/8-16 x 1 1/2, 18-8 SS, PLAIN	1130969		
125	36	CARRIAGE BOLT 3/8-16 x 1 1/4, 18-8 SS, PLAIN	1131782		
126	80	HEX NUT 3/8-16, 18-8 SS, PLAIN	1132099		
127	80	FLAT WASHER 3/8 SAE, 18-8 SS, PLAIN	1132129		
128	300	POP RIVET 3/16 X 0.125"-0.25" GRIP, AL 5050/52	1130717		
129	150	POP RIVET 1/8 X 0.126"-0.187" GRIP, AL 5050/52	1130718		
130	25	HEX WASHER HEAD SCREW TAPERED #8 X 3/4	1130719		
131	5	1/4"-20 NC x 1/2" Lg Slotted Round Head Machine Screw			
132	25	Lag Screw 3/8"Ø x 1" (Plated)			
133	10	Lag Screw 1/4"Ø x 1" (Plated)			
134	12	3/4" OD X 3/8" ID DISHED SS WASHER W/NEOPRENE	1130716		

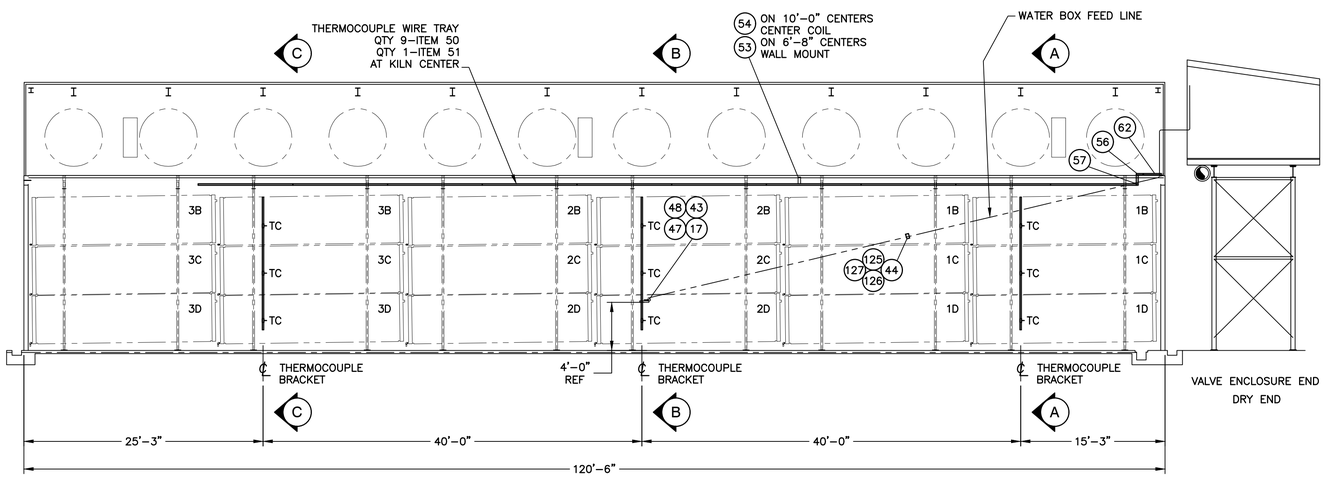
ITEM	QTY	DESCRIPTION	PART NUMBER	REQN	WT
1	1	1/4" C.T. to 1/4" MIP Connector	#68CA-4-4	4351	
3	5	3/8" C.T. to 1/4" MIP Connector	#68CA-6-4		
4	1	3/8" C.T. to 3/8" FIP Connector	#66CA-6-6		
6	2	3/8" C.T. Compression Union	#62CA-6		
8	2	1/4" x 2" Brass Nipple, TBE	#215PNL-4-20		
11	25	3/8" Tube Nylon Loop Clamp, Black	McM Carr #8876T22		
14	50	Ft. 3/8" Copper Tubing			
15	225	Ln. Ft. 3/8" Dia., Tubing, 0.049" Wall, SS, A213-TP316			
16	15	3/8" Dia., SWAGELOK Union, STD, CPF, SS			
17	4	3/8" X 1/4" Dia., SWAGELOK Male Connector, STD, CPF X SCM, SS			
18	20	3/8" Dia., SWAGELOK Union Elbow, STD, CPF, SS			
20	1	1/4" Regulator, 0-125 PSI Output (Vent supply)	#960-069-000	4352	
21	1	1/4" Regulator, 0-60 PSI Output (I/O supply)	#960-068-000		
22	2	1/4" RTI Air Filter w/ RTI #3P-020 Element	#3P-020-P02-Fi		
23	1	2.5" Air Press. Gauge, 0-125 PSI, Back Stem (Vent)	#25-1009AW-02B		
24	1	2.5" Air Press. Gauge, 0-60 PSI, Back Stem (I/O)	#25-1009AW-02B		
25	4	1/4" Threaded Bronze Ball Valve	V-1900B		
26	1	1/2" Threaded Steel Ball Valve	V-1910-S		
27	1	Pressure Transmitter, Ashcroft, 0-200 psi	#K13M0242C1 200		
28	1	3.5" Air Press. Ga. liquid filled, 0-200 PSI, Lwr Stem	#35-1009AW-02L 200		
29	1	Puslation Dampener, Ashcroft, Brass, 1/4" NPT	#1/4-1106B		
30	1	1/2" Siphon, ASTM A-106 Seamless Steel Grade A	#04-1098-S-04		
31	1	3/4" x 90° Socket Weld Elbow, 3000#, FS, A-105			
32	1	3/4" Thd. Steel Pipe Coupling, A-197			
33	1	3/4" x 1/2" Threaded Steel Pipe Bushing			
34	1	1/2" Thd. Tee, (150# BMI), A-197			
35	2	1/2" x 1/4" Threaded Steel Pipe Bushing			
36	1	1/2" x 2" Blk. Pipe Nipple, Sch 80, TBE, A-53A ERW			
37	1	3/4" Sch 40 Black Pipe x 21'-0", PE, A-53A ERW			
38	1	6" x 3/4" Soc-O-Let 3000#, FS, A-105			
40	6	Wall Mount Support (C = 2'-2", D = 2'-4")	3K-75848-2	4357	
41	12	Center Coil Support (A = 8)	3K-75848-3		
42	12	Center Coil Pivot Bracket (G = 6 1/2", H = 4 3/4")	3K-75848-10		
43	2	Water Box Support Bracket	3K-75848-16		
44	36	Aluminum Clip	3K-38930-17		
45	2	Pressure Regulator Support	3K-38930-18		
46	5	Air & Water Main Hanger	0K-24235		
47	2	Water Box Unit W/ Float Valve Assembly	1K-50933		
48	100	TC Wet Bulb Wick			
49	12	Swing Arm Support Bracket	3K-75848-15		
50	30	10' Wire Tray with Sleeve	3K-38356-1	4358	
51	3	10' Wire Tray without Sleeve	3K-38356-2		
52	12	T.C. Wire Tray C = 14'-0"	3K-38356-7		
53	45	Tray Hanger @ Extrusion	3K-38356-8		
54	11	Tray Hanger @ Center Coil	3K-38356-9		
55	1	Wire Tray Tee Section	3K-38356-10		
56	1	Wire Tray Transition @ Kiln Center	3K-38356-11		
57	1	Wire Tray Elbow Section	3K-38356-13		
58	36	Thermocouple Fixture Mount	3K-38356-14		
59	2	Wire Tray Without Sleeve (A = 4'-6")	3K-38356-17		
60	2	Wire Tray Transition @ Corner	1K-47118		
61	18	T.C. Heat Shield	0K-46459		
62	1	Wire Tray Without Sleeve (A = 2'-0")	3K-38356-17		
80	2	3/4" Union (250# BMI), G.J., A-197		4359	
81	3	3/4" Threaded Tee (150# BMI), A-197			
82	2	3/4" Thd Coupling (150# BMI), A-197			
83	2	3/4" x 1/4" Threaded Pipe Bushing (150 BMI), A-197			
84	1	3/4" Threaded Bronze Ball Valve	V-1900-B		
85	1	3/4" x 6" Black Pipe Nipple, Sch 40, T.B.E., A-120 ERW			
86	6	3/4" x 3" Black Pipe Nipple, Sch 40, T.B.E., A-120 ERW			
87	2	1/4" x 3" Black Pipe Nipple, Sch 40, T.B.E., A-120, ERW			
88	2	3/4" Threaded Steel Pipe Plug (150#)			
89	2	3/4" Sch 40 Black Pipe x 21'-0", T&C, A-53A ERW			
90	5	1/4" x 3/4" U-Bolt w/ nuts, Grinnell Fig. 137			
91	4	3/4" x 90° Threaded Elbow (150# BMI), A-197			

*QUANTITIES SHOWN FOR ONE KILN

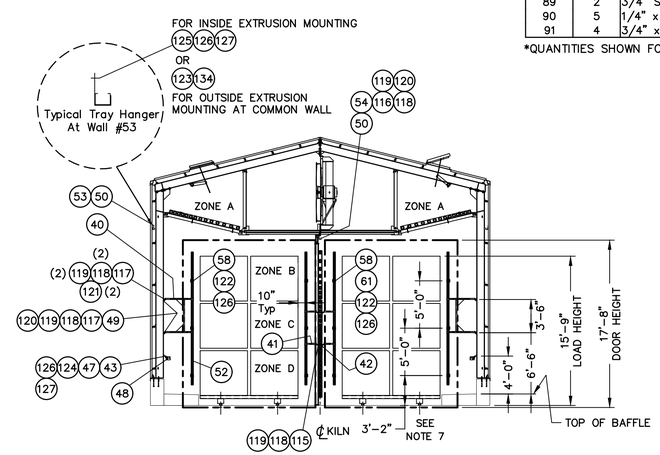


PLAN





ELEVATION



KILN CROSS SECTION

NOTES
1. ALL CONDUITS, FITTINGS, AND JUNCTION BOXES ARE TO BE ALUMINUM.
2. DRILL 1/4" DIA DRAIN HOLE IN BOTTOM OF ALL JUNCTION BOXES.
3. CONDUIT SEALING FITTINGS ARE TO BE USED AT ALL WALL PENETRATIONS. (I.E. KILLARK 2" #ENY-6-T)
4. ALL THERMOCOUPLE WIRING TO BE SINGLE WIRE RUN, NO SPLICES PERMITTED.
5. SEAL CONDUIT ENTRANCES TO ALL PANELS AND KILN WITH RTV SEALANT.
6. REAM ALL CONDUIT AFTER CUTTING AND USE INSULATING BUSHINGS AT THE ENDS OF RUNS TO PREVENT WIRE INSULATION DAMAGE.
7. ADJUSTMENT OF THERMOCOUPLE LOCATIONS SHOWN ON DRAWING MAY BE NECESSARY TO SUIT LUMBER PACKAGES.

REFERENCE DRAWINGS

3K-75528-2	MECHANICAL CONTROL SYSTEM DETAILS
3K-38931	THERMOCOUPLE MOUNT DETAIL
2K-31671	AIR & WATER SUPPLY LAYOUT
0KE-25513-12	THERMOCOUPLE FIELD TERMINATION DETAIL
0KE-25513-3	THERMOCOUPLE FIXTURE DETAIL-WET BULB
0KE-25513-11	THERMOCOUPLE FIXTURE DETAIL DRY BULB
3KE-75440	I/O PANEL CONNECTION DETAIL
3KE-75441	ELECTRICAL INTERCONNECT DIAGRAM
3KE-75442	WIRING DETAILS

NOTE:
1. USE 1/4" BRASS INSERTS (63PT-4-40) AND 3/8" BRASS INSERTS (63PT-6-62) AT ALL PARFLEX NYLON TUBING COMPRESSION FITTING CONNECTIONS. DO NOT USE BRASS INSERTS ON PRESTOLOK FITTING CONNECTIONS.

JOB	REV	REVISION	BY	DATE	CHECKED	DATE

WELLONS 2525 W. Firestone Ln. Vancouver, WA 98660 1-800-WELLONS

DO NOT SCALE THIS DRAWING

SCALE 1/8"=1'-0"

8400 4350

MECHANICAL CONTROL SYSTEM

DRAWING TAF DATE 5/15/20
CHECKED TAF 6/3/20 APPROVED TAF 6/9/20

Sierra Pacific Industries Aberdeen, WA K-13909

DRAWING NUMBER 3K-75528-1 1 of 2 REV 0

REF 3K-70908

APPENDIX C: EMISSION CALCULATIONS

SPI Aberdeen

Lumber Dry Kiln Redevelopment Project

Proposed Lumber Dry Kiln Maximum Potential Emissions Estimates

Material Processed

	Throughput (Mbf/yr)
Maximum Lumber	415,000

Kiln Emission Factors (Maximum Kiln Temperature = 200 °F)

Pollutant	Hem. EF (lb/Mbf)	DF EF (lb/Mbf)	Maximum (lb/Mbf)	Worst-Case Species
PM	0.020	0.020	0.020	both
VOCs	0.613	1.15	1.15	DF
Acetaldehyde	0.0677	0.0275	0.0677	H
Acrolein	0.0012	0.00050	0.0012	H
Formaldehyde	0.0044	0.0018	0.0044	H
Methanol	0.196	0.0671	0.196	H
Propionaldehyde	0.00040	0.00030	0.00040	H

Worst-Case Emissions

		Emission Factors (lb/Mbf)			Emission Rates					
					Short-term	Annual	Short-term	Annual	Ea. Vent	Ea. Kiln
Pollutant	CAS #	Hemlock	Douglas Fir	Maximum	(lb/hr)	(tons/yr)	(g/s)	(g/s)	(g/s)	(g/s)
PM	NA	0.020	0.020	0.020	0.95	4.2	0.119	0.119	1.36E-03	1.49E-02
VOCs	NA	0.613	1.15	1.15	54.4	238	6.86	6.86	7.79E-02	8.57E-01
Acetaldehyde	75-07-0	0.0677	0.0275	0.0677	3.21	14.0	0.404	0.404	4.59E-03	5.05E-02
Acrolein	107-02-8	0.0012	0.00050	0.0012	0.057	0.25	0.00716	0.00716	8.14E-05	8.95E-04
Formaldehyde	50-00-0	0.0044	0.0018	0.0044	0.21	0.90	0.0260	0.0260	2.96E-04	3.25E-03
Methanol	67-56-1	0.196	0.0671	0.196	9.30	40.8	1.17	1.17	1.33E-02	1.47E-01
Propionaldehyde	123-38-6	0.00040	0.00030	0.00040	0.019	0.083	0.00239	0.00239	2.71E-05	2.98E-04

SPI Aberdeen

Lumber Dry Kiln Redevelopment Project

Existing Lumber Dry Kiln Past Actual Emissions Calculations

Material Throughput and Species Mix

Species	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Average
Douglas Fir	77,400	129,900	113,700	106,800	104,400	132,900	163,500	186,322	167,669	160,200	182,400	138,654
Hemlock	183,900	174,600	158,400	163,200	173,100	139,800	134,400	113,678	104,336	152,700	129,900	148,001
Total	261,300	304,500	272,100	270,000	277,500	272,700	297,900	300,000	272,005	312,900	312,300	286,655

Kiln Emission Factors (Maximum Kiln Temperature = 200 °F)

Pollutant	Hem. EF (lb/Mbf)	DF EF (lb/Mbf)	Maximum (lb/Mbf)	Worst-Case Species
PM	0.020	0.020	0.020	both
VOCs	0.613	1.15	1.15	DF
Acetaldehyde	0.0677	0.0275	0.0677	H
Acrolein	0.0012	0.00050	0.0012	H
Formaldehyde	0.0044	0.0018000	0.0044	H
Methanol	0.196	0.0671	0.196	H
Propionaldehyde	0.00040	0.00030	0.00040	H

Annual Emissions (tpy)

Pollutant	CAS #	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
PM	NA	2.61	3.05	2.72	2.70	2.78	2.73	2.98	3.00	2.72	3.13	3.12
VOCs	NA	101	128	114	111	113	119	135	142	128	139	145
Acetaldehyde	75-07-0	7.29	7.70	6.93	6.99	7.29	6.56	6.80	6.41	5.84	7.37	6.91
Acrolein	107-02-8	0.130	0.137	0.123	0.125	0.130	0.117	0.122	0.115	0.105	0.132	0.124
Formaldehyde	50-00-0	0.471	0.498	0.448	0.452	0.471	0.424	0.440	0.416	0.378	0.477	0.447
Methanol	67-56-1	20.7	21.5	19.4	19.6	20.5	18.2	18.7	17.4	15.9	20.4	18.9
Propionaldehyde	123-38-6	0.0484	0.0544	0.0487	0.0487	0.0503	0.0479	0.0514	0.0507	0.0460	0.0546	0.0533

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Lumber Dry Kiln Redevelopment Project

Existing Lumber Dry Kiln Past Actual Emissions Calculations - continued

2-year average annual emissions (tpy)

Pollutant	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019	Max	Max Years
PM	2.83	2.88	2.71	2.74	2.75	2.85	2.99	2.86	2.92	3.13	3.13	2018-2019
VOCs	114	121	113	112	116	127	138	135	134	142	142	2018-2019
Acetaldehyde	7.49	7.31	6.96	7.14	6.93	6.68	6.60	6.12	6.60	7.14	7.49	2009-2010
Acrolein	0.133	0.130	0.124	0.127	0.124	0.119	0.118	0.110	0.118	0.128	0.133	2009-2010
Formaldehyde	0.484	0.473	0.450	0.462	0.448	0.432	0.428	0.397	0.428	0.462	0.484	2009-2010
Methanol	21.1	20.4	19.5	20.1	19.3	18.4	18.0	16.6	18.1	19.6	21.1	2009-2010
Propionaldehyde	0.0514	0.0516	0.0487	0.0495	0.0491	0.0497	0.0510	0.0484	0.0503	0.0540	0.0540	2018-2019

Past Actual Emissions

	Emission Rate				Modeled Emission Rate		Per Vent Emission Rate	
	Hourly	Daily	Annual	Annual	Short-term	Annual	Short-term	Annual
Pollutant	(lb/hr)	(lb/day)	(lb/yr)	(tons/yr)	(g/s)	(g/s)	(g/s)	(g/s)
PM	0.714	17.1	6,252	3.13	0.0899	0.0899	9.37E-04	9.37E-04
VOCs	32.3	776	283,343	142	4.08	4.08	4.25E-02	4.25E-02
Acetaldehyde	1.71	41.1	14,986	7.49	0.216	0.216	2.25E-03	2.25E-03
Acrolein	0.0305	0.731	267	0.133	0.00384	0.00384	4.00E-05	4.00E-05
Formaldehyde	0.111	2.65	968	0.484	0.0139	0.0139	1.45E-04	1.45E-04
Methanol	4.81	116	42,160	21.1	0.606	0.606	6.32E-03	6.32E-03
Propionaldehyde	0.0123	0.296	108	0.0540	0.00155	0.00155	1.62E-05	1.62E-05

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Lumber Dry Kiln Redevelopment Project

Lumber Dry Kiln Emission Factors

Maximum Kiln Temperature 200 °F

Species	Pollutant						
	PM10/PM2.5 (lb/mbf)	VOC (lb/mbf)	Acetaldehyde (lb/mbf)	Acrolein (lb/mbf)	Formaldehyde (lb/mbf)	Methanol (lb/mbf)	Propionaldehyde (lb/mbf)
Hemlock	0.020	0.613	0.0677	0.0012	0.0044	0.196	0.00040
Douglas Fir	0.020	1.15	0.0275	0.00050	0.0018	0.0671	0.00030
MAX	0.020	1.149	0.0677	0.0012	0.0044	0.196	0.00040

Notes:

PM/PM10/PM2.5 Emission Factor Detail:

Hemlock PM emission factor is from a source test conducted by ETI at Chemco's facility in Ferndale, WAfor SPI's Burlington facility in 2013.
Douglas fir PM emission factor is from a source test conducted by Horizon at Oregon State University (OSU) in 1998.

VOC, Acetaldehyde, Acrolein, Formaldehyde, Methanol, and Propionaldehyde Emission Factor Detail:

Emission factors from EPA Region 10 (November 2019):
- HemFir based on maximum of Hemlock and True Firs
- DougFir based on maximum of Douglas Fir and Larch

APPENDIX D: EPA REGION 10 EMISSION FACTORS FOR LUMBER DRYING

EPA Region 10 HAP and VOC Emission Factors for Lumber Drying, November 2019

This spreadsheet calculates and compiles hazardous air pollutant (HAP) and volatile organic compound (VOC) emission factors (EF) in units of pounds of pollutant per thousand board feet of lumber dried (lb/mbf) that are preferred by EPA Region 10 for estimating emissions from indirect steam-heated batch lumber drying kilns. The EFs are based on actual lab-scale emission test data when available. When no suitable HAP or VOC test data is available for a species of wood (e.g western red cedar, engelmann spruce, larch and western white pine), EFs for similar species are substituted. When there are more than one similar species, the highest of the EF for the similar species is substituted. When test data is available for some individual HAP (methanol, formaldehyde, acetaldehyde, propionaldehyde and acrolein) or VOC compounds (ethanol and acetic acid) but not others, data substitution for that species of wood is not performed so as to maintain the integrity of the WPP1 VOC EF calculation. Only douglas fir and ponderosa pine EF are supported by full suite of test data for all seven aforementioned compounds.

A summary of the EFs for each species of wood is included on this sheet. The sheets that follow present the original test data as well as the calculations for creating each EF. There are two sheets per lumber species: one for HAPs and one for VOCs. The methanol, formaldehyde and VOC EF are temperature dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. Because acetaldehyde, propionaldehyde and acrolein emissions across different species are not consistently dependent upon maximum drying temperature, EF are calculated by averaging test results. Whereas HAP EF are derived in the HAP sheets, EF for individual VOC ethanol and acetic acid are derived in the VOC sheets for douglas fir and ponderosa pine (only wood species undergoing testing for these two VOC compounds).

Species	WPP1 VOC[1,2] (lb/mbf)	Methanol[2] (lb/mbf)	Formaldehyde[2] (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
Non-Resinous Softwood Species						
Western True Firs[3]	0.00817x - 1.02133	0.00465x - 0.73360	0.00016x - 0.02764	0.0550	no data	no data
Western Hemlock	0.00369x - 0.39197	0.00249x - 0.39750	0.000046x - 0.007622	0.0677	0.0004	0.0012
Western Red Cedar	0.00817x - 1.02133	0.00465x - 0.73360	0.00016x - 0.02764	0.0677	0.0004	0.0012
Resinous Softwood Species (Non-Pine Family)						
Douglas Fir	0.01460x - 1.77130	0.00114x - 0.16090	0.000028x - 0.003800	0.0275	0.0003	0.0005
Engelmann Spruce	0.1769	0.00088x - 0.13526	0.000042x - 0.006529	0.0201	0.0002	0.0005
Larch	0.01460x - 1.77130	0.00114x - 0.16090	0.000028x - 0.003800	0.0275	0.0003	0.0005
Resinous Softwood Species (Pine Family)						
Lodgepole Pine	1.1352	0.0550	0.0030	no data	no data	no data
Ponderosa Pine	0.02083x - 1.30029	0.00137x - 0.18979	0.000074x - 0.010457	0.0340	0.0010	0.0026
Western White Pine	0.02083x - 1.30029	0.00137x - 0.18979	0.000074x - 0.010457	0.0340	0.0010	0.0026

[1] VOC emissions approximated consistent with EPA's Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC). WPP1 VOC underestimates emissions when the mass-to-carbon ratio of unidentified VOC exceeds that of propane. Ethanol and acetic acid are examples of compounds that contribute to lumber drying VOC emissions (for some species more than others), and both have mass-to-carbon ratios exceeding that of propane. Contribution of ethanol and acetic acid to VOC emissions has been quantified here when emissions testing data is available.

[2] Because WPP1 VOC, methanol and formaldehyde emissions are dependent upon maximum drying temperature, a best-fit linear equation with dependent variable maximum temperature of heated air entering the lumber has been generated to model emissions, with a couple of exceptions. For engelmann spruce and lodgepole pine, a single VOC EF (based upon high-temperature drying) has been generated due to lack of sufficient test data to build a best-fit linear equation.

[3] Western true firs consist of the following seven species classified in the same Abies genus: bristlecone fir, California red fir, grand fir, noble fir, pacific silver fir, subalpine fir and white fir.

Hazardous Air Pollutant Emission Factors for Drying Western True Fir Lumber

This sheet presents lab-scale HAP test data and calculations used to create HAP EF for drying western true fir lumber in an indirect steam-heated batch kiln. Western true fir consists of the following seven species classified in the same Abies genus: bristlecone fir, California red fir, grand fir, noble fir, pacific silver fir, subalpine fir and white fir. The methanol and formaldehyde EF are temperature dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The acetaldehyde EF reflects the results of a single test. No EF are presented for either propionaldehyde or acrolein as EPA Region 10 is not aware of any test data for those HAP.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Western True Fir HAP Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial / Final)	Time to Final Moisture Content (hours)	HAP Sample Collection Technique	Reference
180	0.096	0.0022	no data	no data	no data	2x6	122.0 / 15	42.6	NCASI Method IM/CAN/WP-99.01 without cannisters.	3, 4, 5, 12, 14
180	0.148	0.0034	no data	no data	no data	2x6	133.2 / 15	46.9		
225	no data	no data	0.0550	no data	no data	2x4	170 / 13	54	Dinitrophenylhydrazine coated cartridges.	7
240	0.42	0.0156	no data	no data	no data	2x6	126.3 / 15	24	NCASI chilled impinger method.	5
240	0.419	0.0163	no data	no data	no data	2x6	119.0 / 15	24		

[1] Green highlight denotes data generated by testing conducted on the small-scale kiln at the University of Idaho. All other data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Western True Fir HAP Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
180	0.0875	0.0016	no data	no data	no data
180	0.1348	0.0025	no data	no data	no data
225	no data	no data	0.0550	no data	no data
240	0.3827	0.0115	no data	no data	no data
240	0.3818	0.0120	no data	no data	no data

[1] Green highlighted results from the test conducted at the University of Idaho have not been adjusted because the kiln was not calibrated to a full-scale kiln.

Adjusted OSU emission test data $value_i$ = (OSU reported emission test data $value_i$) X (NCASI TB No. 845 study full-scale kiln $value_i$/NCASI TB No. 845 study OSU small-scale kiln $value_i$)

where: OSU reported emission test data $value_i$ is the emission rate "lb/mbf" for compound "i" documented in Step One (not highlighted in green)

NCASI study full-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

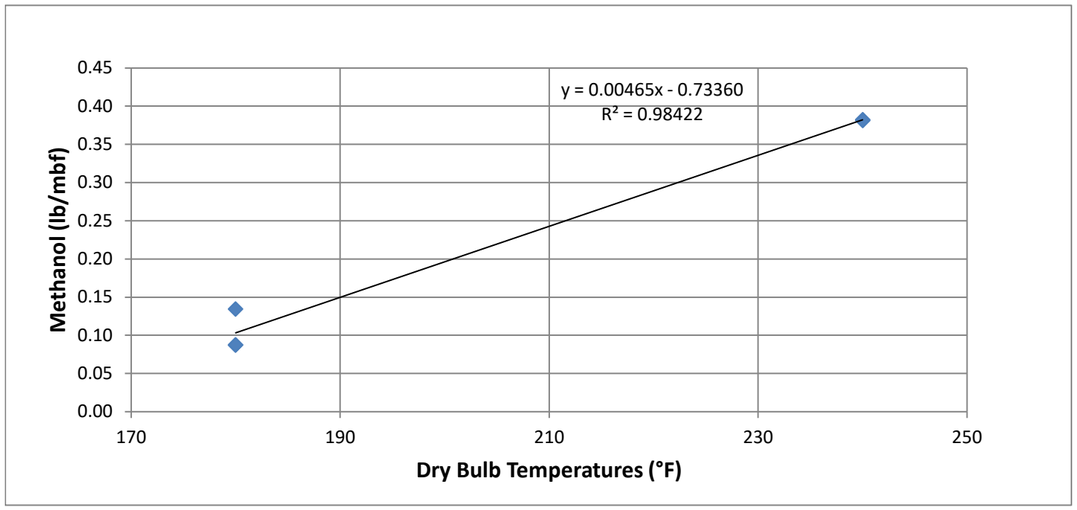
	NCASI TB No. 845 - Emission Rate (lb/mbf)				
	Methanol	Formaldehyde	Acetaldehyde	Propionaldehyde	Acrolein
Full-Scale Kiln	0.205	0.0155	0.039	0.001	0.006
OSU Kiln	0.225	0.0210	0.065	0.003	0.009

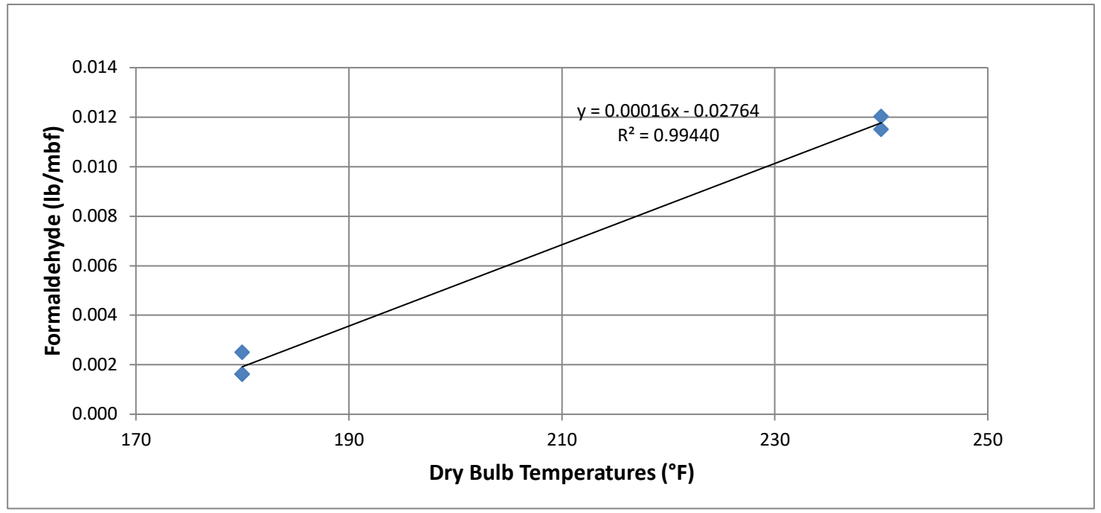
Step Three: Calculate Western True Fir HAP Emission Factors

Methanol[1] (lb/mbf)	Formaldehyde[1] (lb/mbf)	Acetaldehyde[2] (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
0.00465x - 0.73360	0.00016x - 0.02764	0.0550	no data	no data

[1] Because methanol and formaldehyde emissions are dependent upon drying temperature, best-fit linear equations model emissions with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[2] The acetaldehyde EF reflects the results of a single test.


y = 0.00465x - 0.73360
R² = 0.98422
Methanol (lb/mbf)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
170
190
210
230
250
Dry Bulb Temperatures (°F)


y = 0.00016x - 0.02764
R² = 0.99440
Formaldehyde (lb/mbf)
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
170
190
210
230
250
Dry Bulb Temperatures (°F)

Volatile Organic Compound Emission Factors for Drying Western True Fir Lumber

This sheet presents lab-scale EPA Reference Method 25A (RM25A) and speciated VOC test data and calculations used to create VOC EF for drying western true fir lumber in an indirect steam-heated batch kiln. Western true fir consists of the following seven species classified in the same Abies genus: bristlecone fir, California red fir, grand fir, noble fir, pacific silver fir, subalpine fir and white fir. RM25A has some limitations in that it misses some pollutant compounds (or portions thereof) that are VOC and known to exist and reports the results “as carbon” which only accounts for the carbon portion of each compound measured. The missed pollutant compounds (some HAP and some non-HAP) are accounted for through separate testing. RM25A test data is adjusted to fully account for three known pollutant compounds that are VOC using separate speciated test data and is reported “as propane” to better represent all of the unspeciated VOC compounds. This technique is consistent with EPA’s Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC) except that the RM25A results are adjusted to account for not only methanol and formaldehyde but also for acetaldehyde in this case.

More specifically, ten separate drying-temperature-specific VOC emission rates (upon which a best-fit linear equation will be established) are calculated based upon underlying RM25A and speciated VOC test data as indicated above. Temperature-specific methanol and formaldehyde emission rates are calculated for each temperature at which RM25A testing was performed using temperature-dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The temperature-independent acetaldehyde emission rate reflects the result of a single test. EPA Region 10 is not aware of any further speciated VOC test data. That portion of the (speciated) VOC compounds that are measured by the RM25A test method (based on known flame ionization detector response factors) is subtracted from the RM25A measured emission rate. The remaining “unspeciated” RM25A emission rate is adjusted to represent propane rather than carbon and then added to the speciated VOC emission rate to provide the “total” temperature-specific VOC emission rate. The resultant VOC EF is a 10-point best-fit linear equation with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Note that reporting the unspeciated VOC as propane (mass-to-carbon ratio of 1.22 and a response factor of 1) may underestimate the actual mass of VOC for certain wood species because VOC compounds like ethanol and acetic acid with higher mass-to-carbon ratios (1.92 and 2.5, respectively) and lower response factors (0.66 and 0.575, respectively) can be a significant portion of the total VOC. Based upon the mass-to-carbon ratios and response factors noted above, 1 lb/mbf ethanol is reported as 0.4194 lb/mbf propane and 1 lb/mbf acetic acid is reported as 0.2806 lb/mbf propane through the use of EPA Reference Method 25A unless compound-specific sampling and analysis is performed. The contribution of ethanol and acetic acid has been quantified through sampling and analysis for douglas fir and ponderosa pine. For douglas fir, ethanol's contribution over three tests was measured to be 0, 1.4 and 5.4 percent of WPP1 VOC, and acetic acid's contribution over the same three tests was measured to be 37, 20 and 13 percent of WPP1 VOC. For ponderosa pine, ethanol's contribution over one test was measured to be 32 percent of WPP1 VOC, and acetic acid's contribution over the same test was measured to be 6.4 percent. Without western true fir lumber drying test data for ethanol and acetic acid, EPA assumes propane adequately represents the mix of unspeciated VOC.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Western True Fir RM25A VOC Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial/Final)	Time to Final Moisture Content (hours)	Method 25A Analyzer	Reference
180	0.26	2x6	106.3 / 15	36.6	JUM 3-200	3, 4
180	0.27	2x6	113.6 / 15	43.2		
180	0.22	2x6	122.0 / 15	42.6	JUM 3-200	3, 4, 5, 12
180	0.25	2x6	133.2 / 15	46.9		
190	0.63	2x4	138.1 / 15	70	JUM VE-7	2
190	0.50	2x4	138.1 / 15	75		
200	0.53	2x4	96.1 / 15	47		
225	0.39	2x4	170 / 13	54	JUM VE-7	7
240	0.62	2x6	126.3 / 15	25	JUM 3-200	5
240	0.6	2x6	119.0 / 15	25		

[1] Green highlight denotes data generated by testing conducted on the small-scale kiln at the University of Idaho. All other data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Western True Fir VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
180	0.22
180	0.22
180	0.18
180	0.21
190	0.52
190	0.42
200	0.44
225	0.39
240	0.52
240	0.50

[1] Green highlighted results from the test conducted at the University of Idaho have not been adjusted because the kiln was not calibrated to a full-scale kiln.

Adjusted OSU emission test data value = (OSU reported emission test data value) X (NCASI TB No. 845 study full-scale kiln value/NCASI TB No. 845 study OSU small-scale kiln value)

where: OSU reported emission test data value is the RM25A VOC as carbon emission rate "lb/mbf" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf) RM25A VOC as carbon
Full-Scale Kiln	3.53333
OSU Kiln	4.25000

Step Three: Calculate/Compile Western True Fir Speciated HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing[1]

Maximum Dry Bulb Temperature (°F)	Methanol[2] (lb/mbf)	Formaldehyde[3] (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
180	0.1034	0.0012	0.0550	no data	no data
190	0.1499	0.0028			
200	0.1964	0.0044			
225	0.3127	0.0084			
240	0.3824	0.0108			

[1] See western true fir HAP sheet for lab-scale test data and calculations.

[2] Methanol EF = 0.00465x - 0.73360; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.
[3] Formaldehyde EF = 0.00016x - 0.02764; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Step Four: Compile True Fir Speciated Non-HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)
180	no data	no data
190		
200		
225		
240		

Step Five: Convert Western True Fir Speciated HAP and Non-HAP Emission Factors to "as Carbon" and Total

Speciated Compound "X" expressed as carbon = (RF_X) X (SC_X) X $[(MW_C) / (MW_X)]$ X $[(\#C_X) / (\#C_C)]$

where: RF_X represents the flame ionization detector (FID) response factor (RF) for speciated compound "X"
SC_X represents emissions of speciated compound "X" expressed as the entire mass of compound emitted
MW_C equals "12.0110" representing the molecular weight (MW) for carbon as carbon is becoming the "basis" for expressing mass of speciated compound "X"
MW_X represents the molecular weight for speciated compound "X"
$\#C_X$ represents the number of carbon atoms in speciated compound "X"
$\#C_C$ equals "1" as the single carbon atom is becoming the "basis" for expressing mass of speciated compound "X"

Maximum Dry Bulb Temperature (°F)	Methanol as Carbon (lb/mbf)	Formaldehyde as Carbon (lb/mbf)	Acetaldehyde as Carbon (lb/mbf)	Propionaldehyde as Carbon (lb/mbf)	Acrolein as Carbon (lb/mbf)	Ethanol as Carbon (lb/mbf)	Acetic Acid as Carbon (lb/mbf)		Speciated Compounds as Carbon (lb/mbf)
180	0.0279	0	0.0150	no data	no data	no data	no data		0.0429
190	0.0405	0							0.0555
200	0.0530	0							0.0680
225	0.0844	0						SUM ⇨	0.0994
240	0.1032	0							0.1182

Element and Compound Information

Element / Compound	FID RF[1]	Molecular Weight (lb/lb-mol)	Formula	Number of Carbon Atoms	Number of Hydrogen Atoms	Number of Oxygen Atoms	Reference
Methanol	0.72	32.042	CH_40	1	4	1	1
Formaldehyde	0	30.0262	CH_2O	1	2	1	16
Acetaldehyde	0.5	44.053	C_2H_4O	2	4	1	20
Propionaldehyde	0.66	58.0798	C_3H_6O	3	6	1	20
Acrolein	0.66	56.064	C_3H_4O	3	4	1	20
Ethanol	0.66	46.0688	C_2H_6O	2	6	1	1
Acetic Acid	0.575	60.0524	$C_2H_4O_2$	2	4	2	1
Propane	1	44.0962	C_3H_8	3	8	0	16
Carbon	-	12.0110	C	1	-	-	-
Hydrogen	-	1.0079	H	-	1	-	-
Oxygen	-	15.9994	O	-	-	1	-

[1] FID RF = volumetric concentration or "instrument display" / compound's actual known concentration. Numerator and denominator expressed on same basis (ie. carbon, propane, etc) and concentration in units of "ppm."

Step Six: Subtract Speciated HAP and Non-HAP Compounds from Western True Fir RM25A VOC Emission Factors and Convert Result to "as Propane"

Maximum Dry Bulb Temperature (°F)	FROM STEP TWO Method 25A VOC as Carbon (lb/mbf)		FROM STEP FIVE Speciated Compounds as Carbon (lb/mbf)		Method 25A VOC as Carbon without Speciated Compounds (lb/mbf)		Method 25A VOC as Propane without Speciated Compounds (lb/mbf)
180	0.22		0.0429		0.1733		0.2120
180	0.22		0.0429		0.1816		0.2222
180	0.18		0.0429		0.1400		0.1713
180	0.21		0.0429		0.1649		0.2018
190	0.52		0.0555		0.4683	Propane Mass Conversion Factor	0.5731
190	0.42		0.0555		0.3602		0.4408
200	0.44		0.0680		0.3726		0.4560
225	0.39		0.0994		0.2906		0.3557
240	0.52	MINUS ⇨	0.1182	EQUALS ⇨	0.3972		0.4861
240	0.50		0.1182		0.3806	X 1.2238 =	0.4658

Method 25A VOC as propane without speciated compounds = (VOC_C) X $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$

where: VOC_C represents Method 25A VOC as carbon without speciated compounds
RF_{C3H8} equals "1" and represents the FID RF for propane. All alkanes, including propane, have a RF of 1.
MW_{C3H8} equals "44.0962" and represents the molecular weight for propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC
MW_C equals "12.0110" and represents the molecular weight for carbon
$\#C_C$ equals "1" as the single carbon atom was the "basis" for which Method 25A VOC test results were determined as illustrated in Step One of this spreadsheet

$\#C_{C3H8}$ equals "3" as three carbon atoms are present within propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

Note: The following portion from the equation immediately above, $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$, equals 1.2238 and can be referred to as the "propane mass conversion factor."

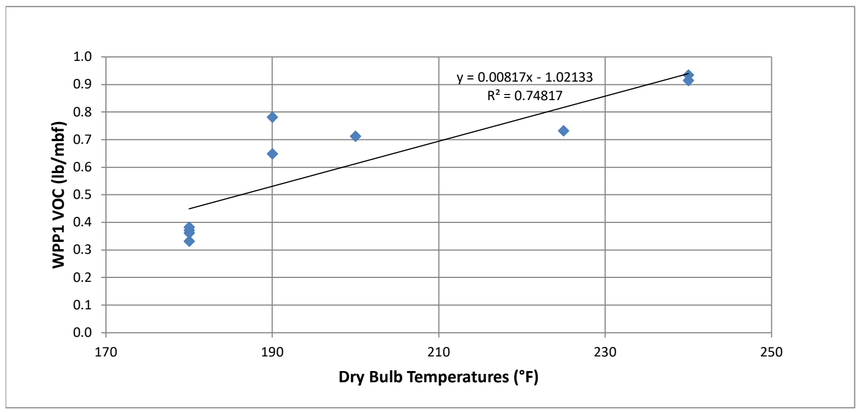
Step Seven: Calculate WPP1 VOC by Adding Speciated HAP and Non-HAP Compounds to Western True Fir RM25A VOC Emission Factors "as Propane"

WPP1 VOC = Method 25A VOC as propane without speciated compounds + ∑ speciated compounds expressed as the entire mass of compound

	FROM STEP SIX		FROM STEP THREE						FROM STEP FOUR			
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)		Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)		Ethanol (lb/mbf)	Acetic Acid (lb/mbf)		WPP1 VOC (lb/mbf)
180	0.2120		0.1034	0.0012	0.0550	no data	no data		no data	no data		0.3716
180	0.2222		0.1034	0.0012								0.3818
180	0.1713		0.1034	0.0012								0.3309
180	0.2018		0.1034	0.0012								0.3614
190	0.5731		0.1499	0.0028								0.7808
190	0.4408		0.1499	0.0028								0.6485
200	0.4560		0.1964	0.0044								0.7118
225	0.3557		0.3127	0.0084								0.7317
240	0.4861	PLUS ⇨	0.3824	0.0108				PLUS ⇨			EQUALS ⇨	0.9343
240	0.4658		0.3824	0.0108								0.9140

Step Eight: Generate Western True Fir Best-Fit Linear Equation with Dependent Variable Maximum Drying Temperature of Heated Air Entering the Lumber to Model WPP1 VOC Emissions

WPP1 VOC (lb/mbf): 0.00817x - 1.02133 ; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber



Hazardous Air Pollutant Emission Factors for Drying Western Hemlock Lumber

This sheet presents lab-scale test data and calculations used to create HAP EF for drying western hemlock lumber in an indirect steam-heated batch kiln. The methanol and formaldehyde EF are temperature dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The acetaldehyde, propionaldehyde and acrolein EF are calculated by averaging test results.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Western Hemlock HAP Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial / Final)	Time to Final Moisture Content (hours)	HAP Sample Collection Technique	Reference
180	0.083	0.0013	no data	no data	no data	2x4	102.3 / 14.7	49.5	NCASI Method 98.01	14, 15
180	0.075	0.0014	0.078	0.002	0.0012	2x4	102.3 / 14.7	49.5	NCASI Method 105	14, 15, 18
180	0.094	0.0015	0.141	0.0008	0.0012	2x4 or 2x6	93.5 / 17.5	no data	NCASI Method 105	18
180	0.052	0.0007	no data	no data	no data	2x4	88.8 / 15	46.2	NCASI Method CI//WP-98.01	13
180	0.0312	0.00082	no data	no data	no data	2x4	56.8 / 15	38.35	NCASI Method CI//WP-98.01	8, 11, 14
180	0.0304	0.00082	no data	no data	no data	2x4	51.1 / 15	35.75		
200	0.098	0.0015	no data	no data	no data	2x6	81.0 / 15	45.2	NCASI Method CI//WP-98.01	11, 14
200	0.175	0.0016	no data	no data	no data	2x6	73.7 / 15	36.5		
200	0.154	0.0018	no data	no data	no data	2x6	100.1 / 15	47.4		
200	0.044	0.0008	0.133	0.0008	0.0024	2x4 or 2x6	83.9 / 15.0	no data	NCASI Method 105	14, 18
200	0.077	0.0014	0.128	0.001	0.0011	2x4 or 2x6	98.6 / 15.0	no data		
200	0.057	0.0014	no data	no data	no data	2x4	76.0 / 15	30.25	NCASI Method CI//WP-98.01	9, 11, 14
215	0.138	0.0043	no data	no data	0.0027	2x4	119.7 / 15	38	no data	6, 11, 14
225	0.189	0.0035	no data	no data	no data	2x6	82 / 15	31.3	NCASI Method CI//WP-98.01	11, 14
225	0.167	0.0034	no data	no data	no data	2x6	77.4 / 15	28.6		
225	0.24	0.004	no data	no data	no data	2x6	101.7 / 15	33.5		
235	0.187	0.0045	0.084	0.0014	0.0019	2x4 or 2x6	76.2 / 15.0	no data	NCASI Method 105	18

[1] All data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Western Hemlcock HAP Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
180	0.0756	0.0010	no data	no data	no data
180	0.0683	0.0010	0.0468	0.0007	0.0008
180	0.0856	0.0011	0.0846	0.0003	0.0008
180	0.0474	0.0005	no data	no data	no data
180	0.0284	0.0006	no data	no data	no data
180	0.0277	0.0006	no data	no data	no data
200	0.0893	0.0011	no data	no data	no data
200	0.1594	0.0012	no data	no data	no data
200	0.1403	0.0013	no data	no data	no data
200	0.0401	0.0006	0.0798	0.0003	0.0016
200	0.0702	0.0010	0.0768	0.0003	0.0007
200	0.0519	0.0010	no data	no data	no data
215	0.1257	0.0032	no data	no data	0.0018
225	0.1722	0.0026	no data	no data	no data
225	0.1522	0.0025	no data	no data	no data
225	0.2187	0.0030	no data	no data	no data
235	0.1704	0.0033	0.0504	0.0005	0.0013

Adjusted OSU emission test data value$_i$ = (OSU reported emission test data value$_i$) X (NCASI TB No. 845 study full-scale kiln value$_i$/NCASI TB No. 845 study OSU small-scale kiln value$_i$)

where: OSU reported emission test data value$_i$ is the emission rate "lb/mbf" for compound "i" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value$_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value$_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

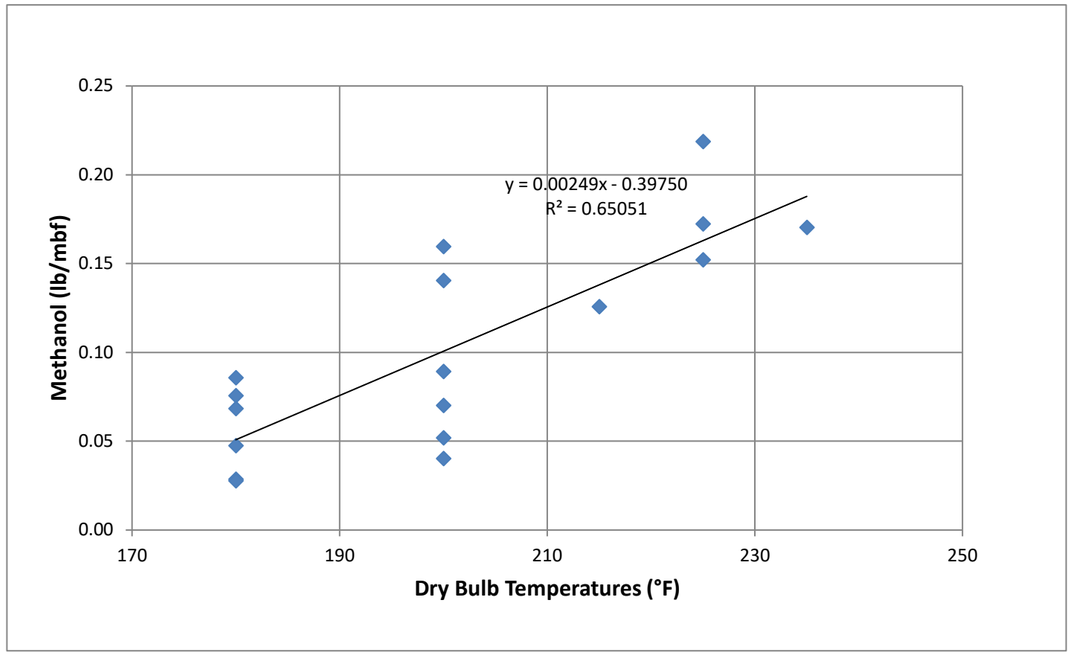
	NCASI TB No. 845 - Emission Rate (lb/mbf)				
	Methanol	Formaldehyde	Acetaldehyde	Propionaldehyde	Acrolein
Full-Scale Kiln	0.205	0.0155	0.039	0.001	0.006
OSU Kiln	0.225	0.0210	0.065	0.003	0.009

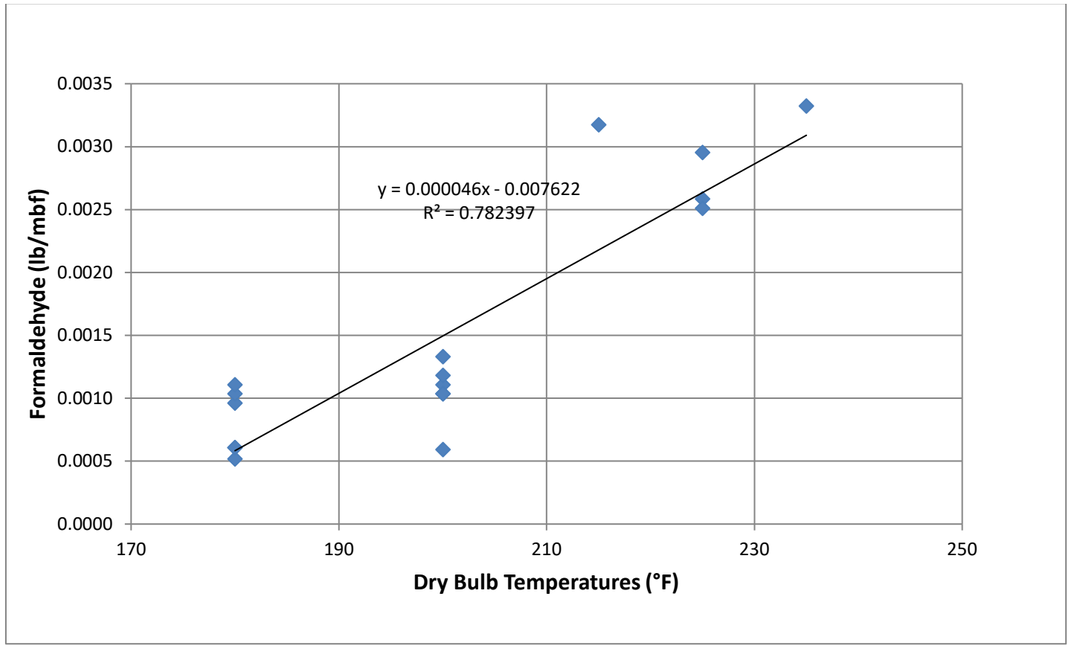
Step Three: Calculate Western Hemlock HAP Emission Factors

Methanol[1] (lb/mbf)	Formaldehyde[1] (lb/mbf)	Acetaldehyde[2] (lb/mbf)	Propionaldehyde[2] (lb/mbf)	Acrolein[2] (lb/mbf)
0.00249x - 0.39750	0.000046x - 0.007622	0.0677	0.0004	0.0012

[1] Because methanol and formaldehyde emissions are dependent upon maximum drying temperature, best-fit linear equations model emissions with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumbe

[2] Because acetaldehyde, propionaldehyde and acrolein emissions across different species are not consistently dependent upon maximum drying temperature, EF are calculated by averaging test results.


0.25
0.20
0.15
0.10
0.05
0.00
Methanol (lb/mbf)
y = 0.00249x - 0.39750
R² = 0.65051
170
190
210
230
250
Dry Bulb Temperatures (°F)


0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
Formaldehyde (lb/mbf)
y = 0.000046x - 0.007622
R² = 0.782397
170
190
210
230
250
Dry Bulb Temperatures (°F)

Volatile Organic Compound Emission Factors for Drying Western Hemlock Lumber

This sheet presents lab-scale EPA Reference Method 25A (RM25A) and speciated VOC test data and calculations used to create VOC EF for drying western hemlock lumber in an indirect steam-heated batch kiln. RM25A has some limitations in that it misses some pollutant compounds (or portions thereof) that are VOC and known to exist and reports the results “as carbon” which only accounts for the carbon portion of each compound measured. The missed pollutant compounds (some HAP and some non-HAP) are accounted for through separate testing. RM25A test data is adjusted to fully account for five known pollutant compounds that are VOC using separate speciated test data and is reported “as propane” to better represent all of the unspeciated VOC compounds. This technique is consistent with EPA’s Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC) except that the RM25A results are adjusted to account for not only methanol and formaldehyde but also for acetaldehyde, propionaldehyde and acrolein in this case.

More specifically, twenty-three separate drying-temperature-specific VOC emission rates (upon which a best-fit linear equation will be established) are calculated based upon underlying RM25A and speciated VOC test data as indicated above. Temperature-specific methanol and formaldehyde emission rates are calculated for each temperature at which RM25A testing was performed using temperature-dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The temperature-independent acetaldehyde, propionaldehyde and acrolein emission rates reflect the average of all test results independent of the temperature of heated air entering the lumber. EPA Region 10 is not aware of any further speciated VOC test data. That portion of the (speciated) VOC compounds that are measured by the RM25A test method (based on known flame ionization detector response factors) is subtracted from the RM25A measured emission rate. The remaining “unspeciated” RM25A emission rate is adjusted to represent propane rather than carbon and then added to the speciated VOC emission rate to provide the “total” temperature-specific VOC emission rate. The resultant VOC EF is a 23-point best-fit linear equation with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Note that reporting the unspeciated VOC as propane (mass-to-carbon ratio of 1.22 and a response factor of 1) may underestimate the actual mass of VOC for certain wood species because VOC compounds like ethanol and acetic acid with higher mass-to-carbon ratios (1.92 and 2.5, respectively) and lower response factors (0.66 and 0.575, respectively) can be a significant portion of the total VOC. Based upon the mass-to-carbon ratios and response factors noted above, 1 lb/mbf ethanol is reported as 0.4194 lb/mbf propane and 1 lb/mbf acetic acid is reported as 0.2806 lb/mbf propane through the use of EPA Reference Method 25A unless compound-specific sampling and analysis is performed. The contribution of ethanol and acetic acid has been quantified through sampling and analysis for douglas fir and ponderosa pine. For douglas fir, ethanol's contribution over three tests was measured to be 0, 1.4 and 5.4 percent of WPP1 VOC, and acetic acid's contribution over the same three tests was measured to be 37, 20 and 13 percent of WPP1 VOC. For ponderosa pine, ethanol's contribution over one test was measured to be 32 percent of WPP1 VOC, and acetic acid's contribution over the same test was measured to be 6.4 percent. Without western hemlock lumber drying test data for ethanol and acetic acid, EPA assumes propane adequately represents the mix of unspeciated VOC.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Western Hemlock RM25A VOC Emission Test Data by Drying Temperature[1,2]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	Lumber Dimensions	Moisture Content[3] (%) (Initial/Final)	Time to Final Moisture Content (hours)	Method 25A Analyzer	Reference
180	~~0.73~~	2x6	126.6 / 15	66.5	no data	11
180	~~0.66~~	2x6	139.3 / 15	67.9		
180	~~0.6~~	2x6	127.8 / 15	65.7		
180	~~0.67~~	2x6	132.7 / 15	67		
180	0.17	2x4	114.8 / 15	45	no data	11
180	0.07	2x4	103.1 / 15	40.7		
180	0.12	2x4	98.0 / 15	37.5		
180	0.4	2x4	115.7 / 15	52.9		
180	0.236	2x4 or 2x6	93.5 / 17.5	no data	JUM VE-7	18
180	0.142	2x4	102.3 / 14.7	49.5	JUM VE-7	15, 18
180	0.18	2x4	88.8 / 15	46.2	JUM VE-7	13
180	0.198	2x4	56.8 / 15	38.35	JUM 3-200	8, 11
180	0.122	2x4	51.1 / 15	35.75		
200	0.24	2x4	112.8 / 15	40	JUM VE-7	2
200	0.2	2x6	81.0 / 15	45.2	no data	11
200	0.15	2x6	73.7 / 15	36.5		
200	0.3	2x6	100.1 / 15	47.4		
200	0.204	2x4	76.0 / 15	30.25	JUM 3-200	9, 11
200	0.214	2x4 or 2x6	83.9 / 15.0	no data	JUM VE-7	18
200	0.239	2x4 or 2x6	98.6 / 15.0	no data		
215	0.34	2x4	112.9 / 15	32.7	no data	11
215	0.34	2x4	119.7 / 15	38	JUM 3-200	6, 11
225	0.28	2x6	82 / 15	31.3	no data	11
225	0.27	2x6	77.4 / 15	28.6		
225	0.31	2x6	101.7 / 15	33.5		
235	0.247	2x4 or 2x6	81.6 / 15.0	no data	JUM VE-7	18
235	0.226	2x4 or 2x6	76.2 / 15.0	no data		

[1] Blue highlight denotes data not considered by EPA Region 10 in 2012. The four test runs not considered here were obtained from a single "sample" and appeared to use a much longer drying cycle than would be in common use in the Pacific Northwest. Therefore, these highlighted values were not used in the EF derivation.

[2] Green highlight denotes data generated by testing conducted on the small-scale kiln at the University of Idaho. All other data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[3] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Western Hemlock VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
180	0.141
180	0.058
180	0.100
180	0.333
180	0.196
180	0.118
180	0.150
180	0.165
180	0.101
200	0.24
200	0.166
200	0.125
200	0.249
200	0.170
200	0.178
200	0.199
215	0.283
215	0.283
225	0.233
225	0.224
225	0.258
235	0.205
235	0.188

[1] Green highlighted results from the test conducted at the University of Idaho have not been adjusted because the kiln was not calibrated to a full-scale kiln.

Adjusted OSU emission test data value = (OSU reported emission test data value) X (NCASI TB No. 845 study full-scale kiln value/NCASI TB No. 845 study OSU small-scale kiln value)

where: OSU reported emission test data value is the RM25A VOC as carbon emission rate "lb/mbf" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf) RM25A VOC as carbon
Full-Scale Kiln	3.53333
OSU Kiln	4.25000

Step Three: Calculate/Compile Western Hemlock Speciated HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing1[1]

Maximum Dry Bulb Temperature (°F)	Methanol[2] (lb/mbf)	Formaldehyde[3] (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
180	0.0507	0.0007	0.0677	0.0004	0.0012
200	0.1005	0.0016			
215	0.1379	0.0023			
225	0.1628	0.0027			
235	0.1877	0.0032			

[1] See western hemlock HAP sheet for lab-scale test data and calculations.

[2] Methanol EF = 0.00249x - 0.39750; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[3] Formaldehyde EF = 0.000046x - 0.007622; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Step Four: Compile Western Hemlock Speciated Non-HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)
180	no data	no data
200		
215		
225		
235		

Step Five: Convert Western Hemlock Speciated HAP and Non-HAP Emission Factors to "as Carbon" and Total

Speciated Compound "X" expressed as carbon = (RF_X) X (SC_X) X $[(MW_C) / (MW_X)]$ X $[(\#C_X) / (\#C_C)]$

where: RF_X represents the flame ionization detector (FID) response factor (RF) for speciated compound "X"

SC_X represents emissions of speciated compound "X" expressed as the entire mass of compound emitted

MW_C equals "12.0110" representing the molecular weight (MW) for carbon as carbon is becoming the "basis" for expressing mass of speciated compound "X"

MW_X represents the molecular weight for speciated compound "X"

$\#C_X$ represents the number of carbon atoms in speciated compound "X"

$\#C_C$ equals "1" as the single carbon atom is becoming the "basis" for expressing mass of speciated compound "X"

Maximum Dry Bulb Temperature (°F)	Methanol as Carbon (lb/mbf)	Formaldehyde as Carbon (lb/mbf)	Acetaldehyde as Carbon (lb/mbf)	Propionaldehyde as Carbon (lb/mbf)	Acrolein as Carbon (lb/mbf)	Ethanol as Carbon (lb/mbf)	Acetic Acid as Carbon (lb/mbf)
180	0.0137	0	0.0185	0.0002	0.0005	no data	no data
200	0.0271	0					
215	0.0372	0					
225	0.0439	0					
235	0.0506	0					

SUM ⇨

Speciated Compounds as Carbon (lb/mbf)
0.0328
0.0462
0.0563
0.0630
0.0698

Element and Compound Information

Element / Compound	FID RF[1]	Molecular Weight (lb/lb-mol)	Formula	Number of Carbon Atoms	Number of Hydrogen Atoms	Number of Oxygen Atoms	Reference
Methanol	0.72	32.042	CH_40	1	4	1	1
Formaldehyde	0	30.0262	CH_2O	1	2	1	16
Acetaldehyde	0.5	44.053	C_2H_4O	2	4	1	20
Propionaldehyde	0.66	58.0798	C_3H_6O	3	6	1	20
Acrolein	0.66	56.064	C_3H_4O	3	4	1	20
Ethanol	0.66	46.0688	C_2H_6O	2	6	1	1
Acetic Acid	0.575	60.0524	$C_2H_4O_2$	2	4	2	1
Propane	1	44.0962	C_3H_8	3	8	0	16
Carbon	-	12.0110	C	1	-	-	-
Hydrogen	-	1.0079	H	-	1	-	-
Oxygen	-	15.9994	O	-	-	1	-

[1] FID RF = volumetric concentration or "instrument display" / compound's actual known concentration. Numerator and denominator expressed on same basis (ie. carbon, propane, etc) and concentration in units of "ppm."

Step Six: Subtract Speciated HAP and Non-HAP Compounds from Western Hemlock RM25A VOC Emission Factors and Convert Result to "as Propane"

Maximum Dry Bulb Temperature (°F)	FROM STEP TWO Method 25A VOC as Carbon (lb/mbf)		FROM STEP FIVE Speciated Compounds as Carbon (lb/mbf)		Method 25A VOC as Carbon without Speciated Compounds (lb/mbf)		Method 25A VOC as Propane without Speciated Compounds (lb/mbf)
180	0.1413		0.0328		0.1085		0.1328
180	0.0582		0.0328		0.0254		0.0311
180	0.0998		0.0328		0.0670		0.0820
180	0.3325		0.0328		0.2998		0.3668
180	0.1962		0.0328		0.1634		0.2000
180	0.118		0.0328		0.0853		0.1043
180	0.150		0.0328		0.1169		0.1430
180	0.165		0.0328		0.1318		0.1613
180	0.101		0.0328		0.0686		0.0840
200	0.240		0.0462		0.1938		0.2371
200	0.166		0.0462		0.1200		0.1469
200	0.125		0.0462		0.0785		0.0960
200	0.249		0.0462		0.2032		0.2486
200	0.170		0.0462		0.1234		0.1510
200	0.178		0.0462		0.1317		0.1611
200	0.199		0.0462		0.1525		0.1866
215	0.283		0.0563		0.2264		0.2770
215	0.283		0.0563		0.2264		0.2770
225	0.233		0.0630		0.1697		0.2077
225	0.224		0.0630		0.1614		0.1976
225	0.258		0.0630		0.1947		0.2383
235	0.205	MINUS ⇨	0.0698	EQUALS ⇨	0.1356		0.1659
235	0.188		0.0698		0.1181	X 1.2238 =	0.1446

Propane Mass Conversion Factor

Method 25A VOC as propane without speciated compounds = (VOC_C) X $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$

where: VOC_C represents Method 25A VOC as carbon without speciated compounds

RF_{C3H8} equals "1" and represents the FID RF for propane. All alkanes, including propane, have a RF of 1.

MW_{C3H8} equals "44.0962" and represents the molecular weight for propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

MW_C equals "12.0110" and represents the molecular weight for carbon

$\#C_C$ equals "1" as the single carbon atom was the "basis" for which Method 25A VOC test results were determined as illustrated in Step One of this spreadsheet

$\#C_{C3H8}$ equals "3" as three carbon atoms are present within propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

Note: The following portion from the equation immediately above, $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$, equals 1.2238 and can be referred to as the "propane mass conversion factor."

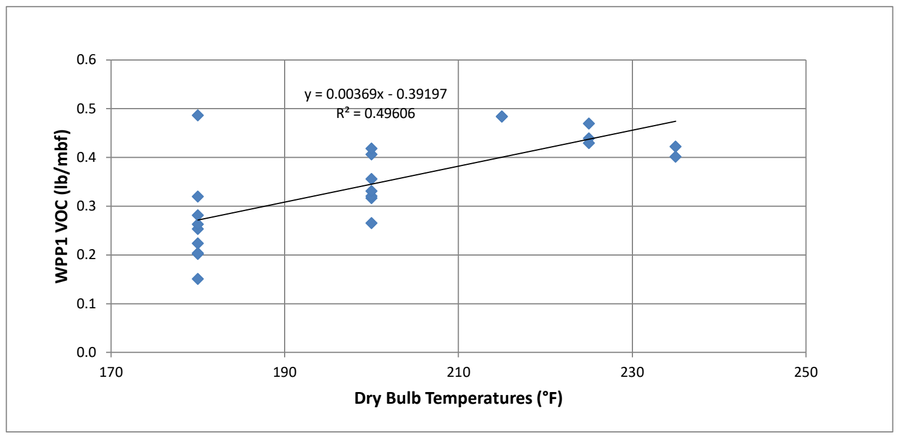
Step Seven: Calculate WPP1 VOC by Adding Speciated HAP and Non-HAP Compounds to Western Hemlock RM25A VOC Emission Factors "as Propane"

WPP1 VOC = Method 25A VOC as propane without speciated compounds + ∑ speciated compounds expressed as the entire mass of compound

	FROM STEP SIX		FROM STEP THREE						FROM STEP FOUR			
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)		Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)		Ethanol (lb/mbf)	Acetic Acid (lb/mbf)		WPP1 VOC (lb/mbf)
180	0.1328		0.0507	0.0007								0.2534
180	0.0311		0.0507	0.0007								0.1505
180	0.0820		0.0507	0.0007								0.2014
180	0.3668		0.0507	0.0007								0.4863
180	0.2000		0.0507	0.0007								0.3194
180	0.1043		0.0507	0.0007								0.2238
180	0.1430		0.0507	0.0007								0.2624
180	0.1613		0.0507	0.0007								0.2808
180	0.0840		0.0507	0.0007								0.2034
200	0.2371		0.1005	0.0016								0.4064
200	0.1469		0.1005	0.0016								0.3161
200	0.0960		0.1005	0.0016	0.0677	0.0004	0.0012		no data	no data		0.2653
200	0.2486		0.1005	0.0016								0.4179
200	0.1510		0.1005	0.0016								0.3202
200	0.1611		0.1005	0.0016								0.3304
200	0.1866		0.1005	0.0016								0.3558
215	0.2770		0.1379	0.0023								0.4836
215	0.2770		0.1379	0.0023								0.4836
225	0.2077		0.1628	0.0027								0.4392
225	0.1976		0.1628	0.0027								0.4290
225	0.2383		0.1628	0.0027								0.4697
235	0.1659	PLUS	0.1877	0.0032				PLUS			EQUALS	0.4223
235	0.1446		0.1877	0.0032								0.4010

Step Seven: Generate Western Hemlock Best-Fit Linear Equation with Dependent Variable Maximum Drying Temperature of Heated Air Entering the Lumber to Model WPP1 VOC Emissions

WPP1 VOC (lb/mbf): 0.00369x - 0.39197 ; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber



Hazardous Air Pollutant Emission Factors for Drying Western Red Cedar Lumber

This sheet presents the HAP EF for drying western red cedar lumber. EPA Region 10 is not aware of any HAP emission testing of western red cedar. When no test data is available for any HAP, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted.

In the absence of western red cedar test data, western true fir test data has been substituted for methanol and formaldehyde and western hemlock test data has been substituted for acetaldehyde, propionaldehyde and acrolein. Western red cedar is similar to western true firs and western hemlock in that all species are non-resinous softwood species in the scientific classification order Pinales. For methanol and formaldehyde, western true fir EF are greater. For acetaldehyde, western hemlock EF is greater. EPA Region 10 is not aware of any western true fir test data for either propionaldehye or acrolein. See the western true fir and western hemlock HAP sheets for lab-scale test data and calculations.

Western Red Cedar (Western True Firs and Western Hemlock Substitution) HAP Emission Factors

Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
0.00465x - 0.73360	0.00016x - 0.02764	0.0677	0.0004	0.0012

Volatile Organic Compound Emission Factors for Drying Western Red Cedar Lumber

This sheet presents the VOC EF for drying western red cedar lumber. EPA Region 10 is aware of two tests being conducted while drying western red cedar lumber, and both were conducted at 160°F. Because VOC emissions increase with maximum drying temperature, employing an EF based upon testing at 160°F would underreport emissions when drying at maximum drying temperatures greater than 160°F. A temperature of 160°F is not a particularly high drying temperature. When little or no test data is available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted.

Given the limited western red cedar test data, western true fir test data has been substituted. Western red cedar is similar to western true firs and western hemlock in that all species are non-resinous softwood species in the scientific classification order Pinales. Western true fir VOC emissions are greater than western hemlock VOC emissions. See the western true fir and western hemlock VOC sheets for lab-scale test data and calculations.

Western Red Cedar (Western True Firs Substitution) WPP1 VOC Emission Factor

WPP1 VOC (lb/mbf): 0.00817x - 1.02133 ; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumb

Hazardous Air Pollutant Emission Factors for Drying Douglas Fir Lumber

This sheet presents lab-scale test data and calculations used to create HAP EF for drying douglas fir lumber in an indirect steam-heated batch kiln. The methanol and formaldehyde EF are temperature dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The acetaldehyde, propionaldehyde and acrolein EF are calculated by averaging test results.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Douglas Fir HAP Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial / Final)	Time to Final Moisture Content (hours)	HAP Sample Collection Technique	Reference
145	0.013	0.001	0.057	0.005	0.000	2x4	49.6 / 15	39.7	NCASI ISS/FP-A105.01	Link to June 8, 2012 Exterior Wood Test Report
160	0.025	0.0008	no data	no data	no data	2x6	37.3 / 15	23.5	NCASI Method IM/CAN/WP-99.01 without cannisters.	3, 4, 12, 14
160	0.023	0.0008	no data	no data	no data	2x6	44.9 / 15	28.5		
160	0.026	0.0017	no data	no data	no data	2x6	40.3 / 15	27.1		
160	0.018	0.0011	no data	no data	no data	2x6	31.9 / 15	25.2		
170	0.015	0.0005	no data	no data	no data	2x4	79.9 / 15	40.5	NCASI Method CI//WP-98.01	13
170	0.026	0.0008	no data	no data	no data	2x4	56.9 / 15	27.5	NCASI Method 98.01	15
170	0.024	0.0008	0.03	0.0004	0.0005	2x4	56.9 / 15	27.5	NCASI Method 105	15, 18
175	0.019	0.001	0.006	0.0001	0.0004	2x4	32.5 / 15	17.8	NCASI ISS/FP-A105.01	Link to May 23, 2013 Sierra Pacific Industries - Centralia Test Report
175	0.084	0.0016	0.042	0.0002	0.0008	4x5	39.5 / 15	150	NCASI ISS/FP-A105.01	Link to March 24, 2015 Columbia Vista Test Report
180	0.050	0.0023	0.050	0.0005	0.0009	2x4	43.7 / 15	48	NCASI Method 105	18, 22
180	0.084	0.0019	0.061	0.0003	0.0007	4x4	44.7 / 15	111	NCASI Method 105	19
200	0.068	0.0018	0.043	0.0005	0.0009	2x4	64.3 / 15	60	NCASI Method 105	14, 18, 22
200	0.069	0.0019	0.071	0.0006	0.0004	2x4	59.5 / 15	56		
200	0.080	0.003	0.037	0.0006	0.0017	2x4	69.3 / 15	20.8	NCASI ISS/FP-A105.01	Link to February 10, 2012 Hampton Lumber - Morton Test Report
220	no data	no data	0.030	no data	no data	2x4	73 / 12	46	Dinitrophenylhydrazine coated cartridges.	7
220	no data	no data	0.022	no data	no data	2x4	73 / 15	46		
235	0.117	0.0043	0.067	0.0008	0.0012	2x4 or 2x6	47.7 / 15	19	NCASI Method 105	18, 21

[1] Green highlight denotes data generated by testing conducted on the small-scale kiln at the University of Idaho. All other data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Douglas Fir HAP Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
145	0.012	0.0007	0.034	0.0017	0.0000
160	0.023	0.0006	no data	no data	no data
160	0.021	0.0006	no data	no data	no data
160	0.024	0.0013	no data	no data	no data
160	0.016	0.0008	no data	no data	no data
170	0.014	0.0004	no data	no data	no data
170	0.024	0.0006	no data	no data	no data
170	0.022	0.0006	0.018	0.0001	0.0003
175	0.017	0.0007	0.004	0.0000	0.0003
175	0.077	0.0012	0.025	0.0001	0.0005
180	0.046	0.0017	0.030	0.0002	0.0006
180	0.077	0.0014	0.037	0.0001	0.0005
200	0.062	0.0013	0.026	0.0002	0.0006
200	0.063	0.0014	0.043	0.0002	0.0003
200	0.073	0.0022	0.022	0.0002	0.0011
220	no data	no data	0.030	no data	no data
220	no data	no data	0.022	no data	no data
235	0.107	0.0032	0.040	0.0003	0.0008

[1] Green highlighted results from the test conducted at the University of Idaho have not been adjusted because the kiln was not calibrated to a full-scale kiln.

Adjusted OSU emission test data value$_i$ = (OSU reported emission test data value$_i$) X (NCASI TB No. 845 study full-scale kiln value$_i$/NCASI TB No. 845 study OSU small-scale kiln value$_i$)

where: OSU reported emission test data value$_i$ is the emission rate "lb/mbf" for compound "i" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value$_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value$_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

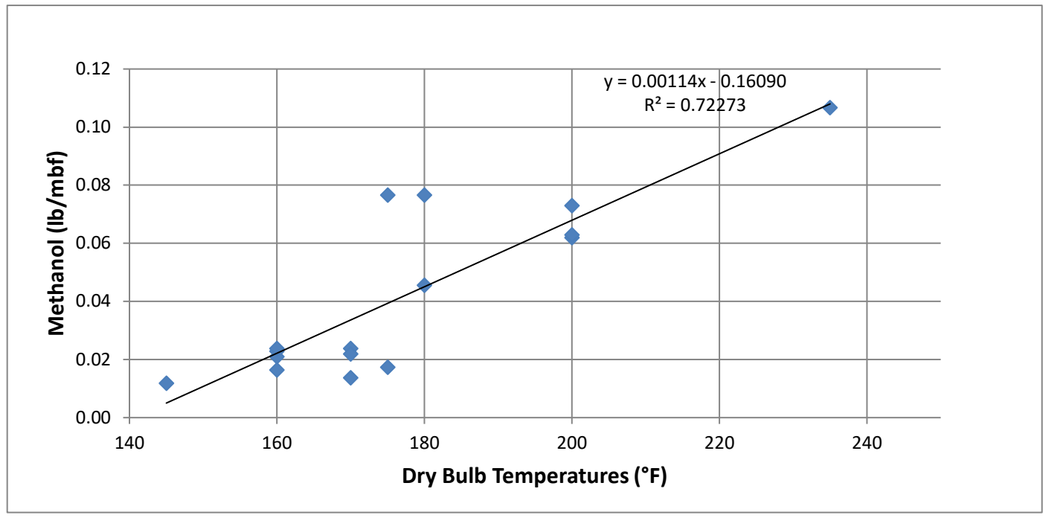
	NCASI TB No. 845 - Emission Rate (lb/mbf)				
	Methanol	Formaldehyde	Acetaldehyde	Propionaldehyde	Acrolein
Full-Scale Kiln	0.205	0.0155	0.039	0.001	0.006
OSU Kiln	0.225	0.0210	0.065	0.003	0.009

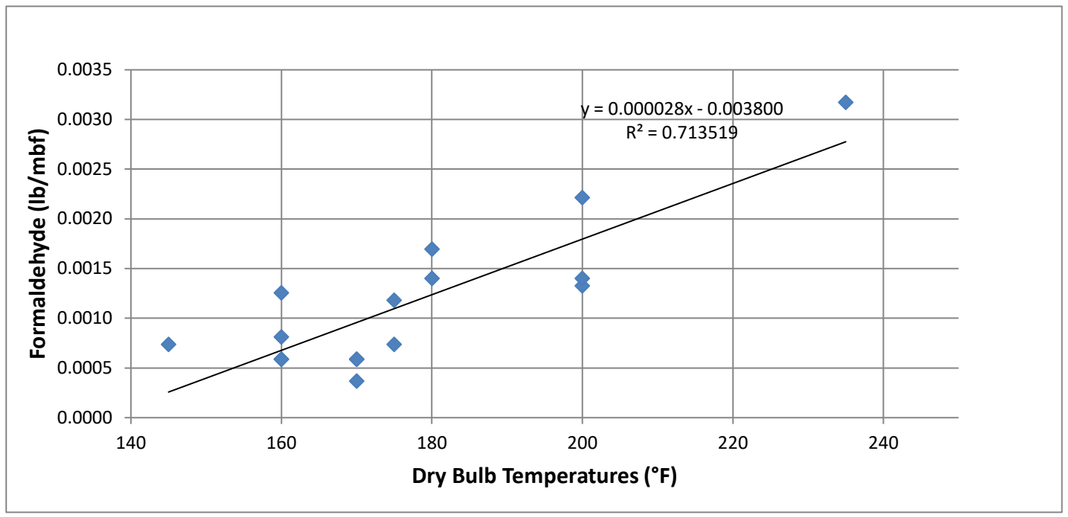
Step Three: Calculate Douglas Fir HAP Emission Factors

Methanol[1] (lb/mbf)	Formaldehyde[1] (lb/mbf)	Acetaldehyde[2] (lb/mbf)	Propionaldehyde[2] (lb/mbf)	Acrolein[2] (lb/mbf)
0.00114x - 0.16090	0.000028x - 0.003800	0.0275	0.0003	0.0005

[1] Because methanol and formaldehyde emissions are dependent upon drying temperature, best-fit linear equations model emissions with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[2] Because acetaldehyde, propionaldehyde and acrolein emissions across different species are not consistently dependent upon maximum drying temperature, EF are calculated by averaging test results.


y = 0.00114x - 0.16090
R² = 0.72273
Methanol (lb/mbf)
0.12
0.10
0.08
0.06
0.04
0.02
0.00
140
160
180
200
220
240
Dry Bulb Temperatures (°F)


y = 0.000028x - 0.003800
R² = 0.713519
Formaldehyde (lb/mbf)
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
140
160
180
200
220
240
Dry Bulb Temperatures (°F)

Volatile Organic Compound Emission Factors for Drying Douglas Fir Lumber

This sheet presents lab-scale EPA Reference Method 25A (RM25A) and speciated VOC test data and calculations used to create VOC EF for drying douglas fir lumber in an indirect steam-heated batch kiln. RM25A has some limitations in that it misses some pollutant compounds (or portions thereof) that are VOC and known to exist and reports the results "as carbon" which only accounts for the carbon portion of each compound measured. The missed pollutant compounds (some HAP and some non-HAP) are accounted for through separate testing. RM25A test data is adjusted to fully account for seven known pollutant compounds that are VOC using separate speciated test data and is reported "as propane" to better represent all of the unspeciated VOC compounds. This technique is consistent with EPA's Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC) except that the RM25A results are adjusted to account for not only methanol and formaldehyde but also for acetaldehyde, propionaldehyde, acrolein, ethanol and acetic acid in this case.

More specifically, twenty-one separate drying-temperature-specific VOC emission rates (upon which a best-fit linear equation will be established) are calculated based upon underlying RM25A and speciated VOC test data as indicated above. Temperature-specific methanol, formaldehyde and ethanol emission rates are calculated for each temperature at which RM25A testing was performed using temperature-dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The temperature-independent acetaldehyde, propionaldehyde, acrolein and acetic acid emission rates reflect the average of all test results independent of the temperature of heated air entering the lumber. EPA Region 10 is not aware of any further speciated VOC test data. That portion of the (speciated) VOC compounds that are measured by the RM25A test method (based on known flame ionization detector response factors) is subtracted from the RM25A measured emission rate. The remaining "unspeciated" RM25A emission rate is adjusted to represent propane rather than carbon and then added to the speciated VOC emission rate to provide the "total" temperature-specific VOC emission rate. The resultant VOC EF is a 21-point best-fit linear equation with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Douglas Fir RM25A VOC Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial/Final)	Time to Final Moisture Content (hours)	Method 25A Analyzer	Reference
145	0.24	2x4	49.6 / 15	39.7	JUM VE-7	Link to June 8, 2012 Exterior Wood Test Report
160	0.51	2x6	37.3 / 15	23.5	JUM 3-200	3, 4, 12
160	0.55	2x6	44.9 / 15	28.5		
160	0.45	2x6	40.3 / 15	27.1		
160	0.46	2x6	31.9 / 15	25.2		
170	0.65	2x4	79.9 / 15	40.5	JUM VE-7	13
170	0.24	2x4	56.9 / 15	27.5	JUM VE-7	15, 18
175	0.185	2x4	32.5 / 15	17.8	JUM VE-7	Link to May 23, 2013 Sierra Pacific Industries - Centralia Test Report
175	0.86	4x5	39.5 / 15	150	JUM VE-7	Link to March 24, 2015 Columbia Vista Test Report
180	0.942	2x4	38.9 / 15	63	JUM VE-7	2
180	0.669	2x4	44.9 / 15	42		
180	0.21	2x4	56.3 / 15	27		
180	0.575	2x4 or 2x6	43.7 / 15	no data	JUM VE-7	18
180	0.39	4x4	29.8 / 19	67.5	JUM 3-200	10
180	0.845	4x4	44.7 / 15	111	JUM VE-7	19
200	0.707	2x4 or 2x6	64.3 / 15	no data	JUM VE-7	18
200	0.879	2x4 or 2x6	59.5 / 15	no data		
200	0.66	2x4	69.3 / 15	20.8	JUM VE-7	Link to February 10, 2012 Hampton Lumber - Morton Test Report
220	1.2	2x4	73 / 12	46	JUM VE-7	7
220	1.3	2x4	73 / 15	46		
235	1.206	2x4 or 2x6	47.7 / 15	19	JUM VE-7	18, 21

[1] Green highlight denotes data generated by testing conducted on the small-scale kiln at the University of Idaho. All other data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100.

Step Two: Adjust Douglas Fir VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
145	0.200
160	0.424
160	0.457
160	0.374
160	0.382
170	0.540
170	0.200
175	0.154
175	0.715
180	0.942
180	0.669
180	0.21
180	0.478
180	0.324
180	0.703
200	0.588
200	0.731
200	0.549
220	1.2
220	1.3
235	1.003

[1] Green highlighted results from the test conducted at the University of Idaho have not been adjusted because the kiln was not calibrated to a full-scale kiln.

Adjusted OSU emission test data value = (OSU reported emission test data value) X (NCASI TB No. 845 study full-scale kiln value/NCASI TB No. 845 study OSU small-scale kiln value)

where: OSU reported emission test data value is the RM25A VOC as carbon emission rate "lb/mbf" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf) RM25A VOC as carbon
Full-Scale Kiln	3.53333
OSU Kiln	4.25000

Step Three: Calculate/Compile Douglas Fir Speciated HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing[1]

Maximum Dry Bulb Temperature (°F)	Methanol[2] (lb/mbf)	Formaldehyde[3] (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
145	0.0044	0.0003	0.0275	0.0003	0.0005
160	0.0215	0.0007			
170	0.0329	0.0010			
175	0.0386	0.0011			
180	0.0443	0.0012			
200	0.0671	0.0018			
220	0.0899	0.0024			
235	0.1070	0.0028			

[1] See douglas fir HAP sheet for lab-scale test data and calculations.

[2] Methanol EF = 0.00114x - 0.16090; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[3] Formaldehyde EF = 0.000028x - 0.003800; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Step Four: Compile Douglas Fir Speciated Non-HAP Emission Test Data by Drying Temperature

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)	Lumber Dimensions	Moisture Content[1] (%) (Initial / Final)	Time to Final Moisture Content (hours)	VOC Sample Collection Technique	Reference
145	0.0000	0.166	2x4	49.6 / 15	39.7	NCASI ISS/FP-A105.01	Link to June 8, 2012 Exterior Wood Test Report
175	0.0010	0.094	2x4	32.5 / 15	17.8	NCASI ISS/FP-A105.01	Link to May 23, 2013 Sierra Pacific Industries - Centralia Test Report
175	0.0230	0.242	4x6	39.5 / 15	150	NCASI ISS/FP-A105.01	Link to March 24, 2015 Columbia Vista Test Report
200	0.0610	0.142	2x4	69.3 / 15	20.8	NCASI ISS/FP-A105.01	Link to February 10, 2012 Hampton Lumber - Morton Test Report

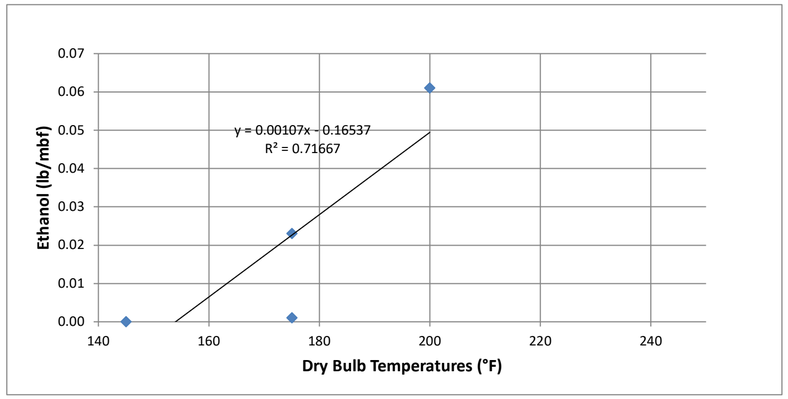
[1] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Five: Calculate Douglas Fir Speciated Non-HAP Emission Factors

Ethanol[1] (lb/mbf)	Acetic Acid[2] (lb/mbf)
0.00107x - 0.16537	0.1610

[1] Because ethanol emissions are dependent upon drying temperature, a best-fit linear equation models emissions with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[2] Because acetic acid emissions are independent of drying temperature, EF is calculated by averaging test results.



Step Six: Calculate/Compile Douglas Fir Speciated Non-HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing

Maximum Dry Bulb Temperature (°F)	Ethanol[1] (lb/mbf)	Acetic Acid (lb/mbf)
145	0	0.1610
160	0.00583	
170	0.01653	
175	0.02188	
180	0.02723	
200	0.04863	
220	0.07003	
235	0.08608	

[1] Ethanol EF = 0.00107x - 0.16537; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Step Seven: Convert Douglas Fir Speciated HAP and Non-HAP Emission Factors to "as Carbon" and Total

Speciated Compound "X" expressed as carbon = (RF_X) X (SC_X) X $[(MW_C) / (MW_X)]$ X $[(\#C_X) / (\#C_C)]$

where: RF_X represents the flame ionization detector (FID) response factor (RF) for speciated compound "X"

SC_X represents emissions of speciated compound "X" expressed as the entire mass of compound emitted

MW_C equals "12.0110" representing the molecular weight (MW) for carbon as carbon is becoming the "basis" for expressing mass of speciated compound "X"

MW_X represents the molecular weight for speciated compound "X"

$\#C_X$ represents the number of carbon atoms in speciated compound "X"

$\#C_C$ equals "1" as the single carbon atom is becoming the "basis" for expressing mass of speciated compound "X"

Maximum Dry Bulb Temperature (°F)	Methanol as Carbon (lb/mbf)	Formaldehyde as Carbon (lb/mbf)	Acetaldehyde as Carbon (lb/mbf)	Propionaldehyde as Carbon (lb/mbf)	Acrolein as Carbon (lb/mbf)	Ethanol as Carbon (lb/mbf)	Acetic Acid as Carbon (lb/mbf)		Speciated Compounds as Carbon (lb/mbf)
145	0.0012	0	0.0075	0.0001	0.0002	0	0.0370		0.0461
160	0.0058	0				0.0020			0.0527
170	0.0089	0				0.0057			0.0594
175	0.0104	0				0.0075			0.0628
180	0.0120	0				0.0094			0.0662
200	0.0181	0				0.0167			0.0797
220	0.0243	0				0.0241		SUM	0.0932
235	0.0289	0				0.0296			0.1034

Element and Compound Information

Element / Compound	FID RF[1]	Molecular Weight (lb/lb-mol)	Formula	Number of Carbon Atoms	Number of Hydrogen Atoms	Number of Oxygen Atoms	Reference
Methanol	0.72	32.042	CH_40	1	4	1	1
Formaldehyde	0	30.0262	CH_2O	1	2	1	16
Acetaldehyde	0.5	44.053	C_2H_4O	2	4	1	20
Propionaldehyde	0.66	58.0798	C_3H_6O	3	6	1	20
Acrolein	0.66	56.064	C_3H_4O	3	4	1	20
Ethanol	0.66	46.0688	C_2H_6O	2	6	1	1
Acetic Acid	0.575	60.0524	$C_2H_4O_2$	2	4	2	1
Propane	1	44.0962	C_3H_8	3	8	0	16
Carbon	-	12.0110	C	1	-	-	-
Hydrogen	-	1.0079	H	-	1	-	-
Oxygen	-	15.9994	O	-	-	1	-

[1] FID RF = volumetric concentration or "instrument display" / compound's actual known concentration. Numerator and denominator expressed on same basis (ie. carbon, propane, etc) and concentration in units of "ppm."

Step Eight: Subtract Speciated HAP and Non-HAP Compounds from Douglas Fir VOC Emission Factors and Convert Result to "as Propane"

	FROM STEP TWO		FROM STEP SIX				
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)		Speciated Compounds as Carbon (lb/mbf)		Method 25A VOC as Carbon without Speciated Compounds (lb/mbf)		Method 25A VOC as Propane without Speciated Compounds (lb/mbf)
145	0.1995		0.0461		0.1535		0.1878
160	0.4240		0.0527		0.3713		0.4544
160	0.4573		0.0527		0.4046		0.4951
160	0.3741		0.0527		0.3214		0.3934
160	0.3824		0.0527		0.3298		0.4035
170	0.5404		0.0594		0.4810		0.5886
170	0.1995		0.0594		0.1401		0.1714
175	0.1538		0.0628		0.0910		0.1114
175	0.7150		0.0628		0.6522		0.7981
180	0.9420		0.0662		0.8758		1.0718
180	0.6690		0.0662		0.6028		0.7377
180	0.2100		0.0662		0.1438		0.1760
180	0.4780		0.0662		0.4118		0.5040
180	0.3242		0.0662		0.2580		0.3158
180	0.7025		0.0662		0.6363		0.7787
200	0.5878		0.0797		0.5081		0.6218
200	0.7308		0.0797		0.6511		0.7968
200	0.5487		0.0797		0.4690		0.5739
220	1.2000		0.0932		1.1068		1.3544
220	1.3000	MINUS	0.0932	EQUALS	1.2068		1.4768
235	1.0026		0.1034		0.8993	X 1.2238 =	1.1005

Propane Mass Conversion Factor

Method 25A VOC as propane without speciated compounds = (VOC_C) X $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$

where: VOC_C represents Method 25A VOC as carbon without speciated compounds

RF_{C3H8} equals "1" and represents the FID RF for propane. All alkanes, including propane, have a RF of 1.

MW_{C3H8} equals "44.0962" and represents the molecular weight for propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

MW_C equals "12.0110" and represents the molecular weight for carbon

$\#C_C$ equals "1" as the single carbon atom was the "basis" for which Method 25A VOC test results were determined as illustrated in Step One of this spreadsheet

$\#C_{C3H8}$ equals "3" as three carbon atoms are present within propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

Note: The following portion from the equation immediately above, $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$, equals 1.2238 and can be referred to as the "propane mass conversion factor."

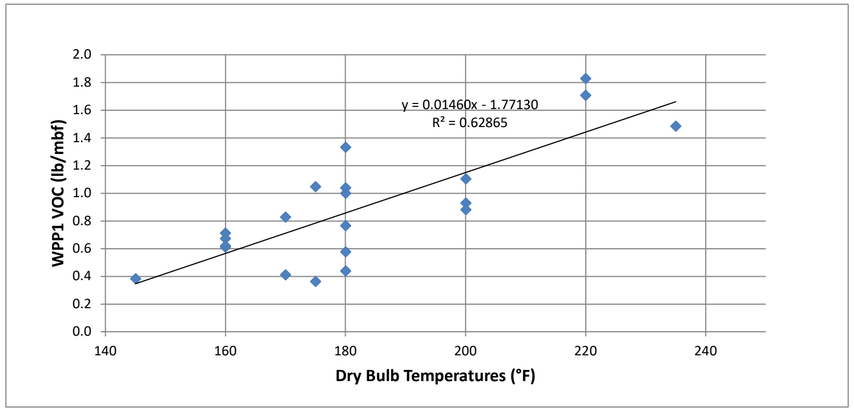
Step Nine: Calculate WPP1 VOC by Adding Speciated HAP and Non-HAP Compounds to Douglas Fir VOC Emission Factors "as Propane"

WPP1 VOC = Method 25A VOC as propane without speciated compounds + ∑ speciated compounds expressed as the entire mass of compound

	FROM STEP EIGHT		FROM STEP THREE						FROM STEP SIX			
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)		Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)		Ethanol (lb/mbf)	Acetic Acid (lb/mbf)		WPP1 VOC (lb/mbf)
145	0.1878		0.0044	0.0003					0			0.3818
160	0.4544		0.0215	0.0007					0.0058			0.6717
160	0.4951		0.0215	0.0007					0.0058			0.7124
160	0.3934		0.0215	0.0007					0.0058			0.6107
160	0.4035		0.0215	0.0007					0.0058			0.6209
170	0.5886		0.0329	0.0010					0.0165			0.8283
170	0.1714		0.0329	0.0010					0.0165			0.4111
175	0.1114		0.0386	0.0011					0.0219			0.3622
175	0.7981		0.0386	0.0011					0.0219			1.0490
180	1.0718		0.0443	0.0012					0.0272			1.3339
180	0.7377		0.0443	0.0012	0.0275	0.0003	0.0005		0.0272	0.1610		0.9998
180	0.1760		0.0443	0.0012					0.0272			0.4381
180	0.5040		0.0443	0.0012					0.0272			0.7661
180	0.3158		0.0443	0.0012					0.0272			0.5779
180	0.7787		0.0443	0.0012					0.0272			1.0408
200	0.6218		0.0671	0.0018					0.0486			0.9286
200	0.7968		0.0671	0.0018					0.0486			1.1036
200	0.5739		0.0671	0.0018					0.0486			0.8808
220	1.3544		0.0899	0.0024					0.0700			1.7060
220	1.4768	PLUS	0.0899	0.0024				PLUS	0.0700		EQUALS	1.8284
235	1.1005		0.1070	0.0028					0.0861			1.4857

Step Ten: Generate Douglas Fir Best-Fit Linear Equation with Dependent Variable Maximum Drying Temperature to Model WPP1 VOC Emissions

WPP1 VOC (lb/mbf): 0.01460x - 1.77130 ; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber



Hazardous Air Pollutant Emission Factors for Drying Engelmann Spruce Lumber

This sheet presents lab-scale test data and calculations used to create HAP EF for engelmann spruce lumber in an indirect steam-heated batch kiln. EPA Region 10 is not aware of any HAP emission testing of englemann spruce. When actual test data is not available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted. In the absence of engelmann spruce test data, white spruce test data has been substituted. The two wood species are similar in that both are resinous softwood species in the scientific classification genus Picea.

The methanol and formaldehyde EF are temperature dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The acetaldehyde, propionaldehyde and acrolein EF are calculated by averaging test results.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Engelmann Spruce (White Spruce Substitution) HAP Emission Test Data by Drying Temperature

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	Lumber Dimensions	Moisture Content[1] (%) (Initial / Final)	Time to Final Moisture Content (hours)	HAP Sample Collection Technique	Reference
180	0.025	0.0013	0.036	0.0003	0.0005	2x4 or 2x6	33.5 / 15	no data	NCASI Method 105	18
235	0.078	0.0044	0.031	0.0007	0.001	2x4 or 2x6	32.7 / 15	no data		

[1] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Engelmann Spruce (White Spruce Substitution) HAP Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
180	0.023	0.0010	0.022	0.0001	0.0003
235	0.071	0.0032	0.019	0.0002	0.0007

Adjusted OSU emission test data $value_i$ = (OSU reported emission test data $value_i$) X (NCASI TB No. 845 study full-scale kiln $value_i$/NCASI TB No. 845 study OSU small-scale kiln $value_i$)

where: OSU reported emission test data $value_i$ is the emission rate "lb/mbf" for compound "i" documented in Step One (not highlighted in green)

NCASI study full-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

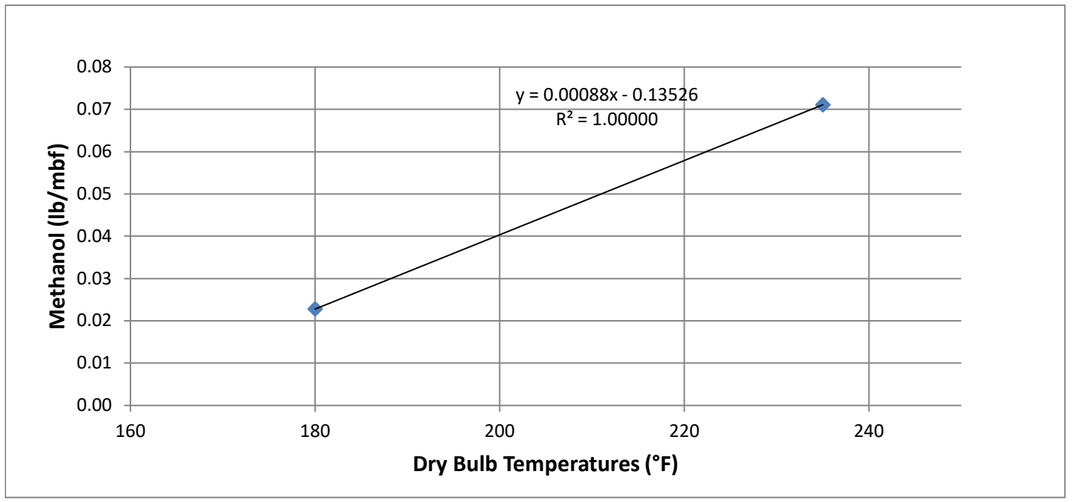
	NCASI TB No. 845 - Emission Rate (lb/mbf)				
	Methanol	Formaldehyde	Acetaldehyde	Propionaldehyde	Acrolein
Full-Scale Kiln	0.205	0.0155	0.039	0.001	0.006
OSU Kiln	0.225	0.0210	0.065	0.003	0.009

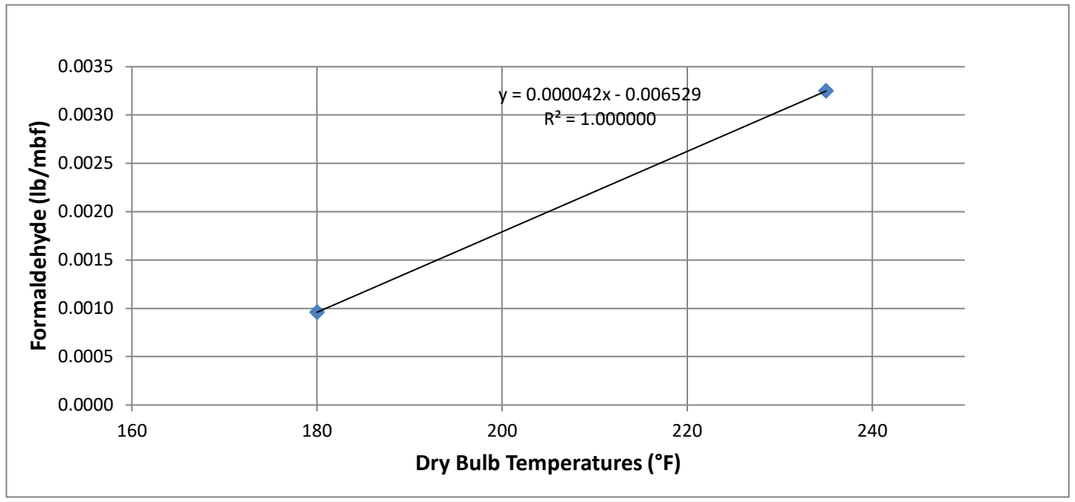
Step Three: Calculate Engelmann Spruce (White Spruce Substitution) HAP Emission Factors

Methanol[1] (lb/mbf)	Formaldehyde[1] (lb/mbf)	Acetaldehyde[2] (lb/mbf)	Propionaldehyde[2] (lb/mbf)	Acrolein[2] (lb/mbf)
0.00088x - 0.13526	0.000042x - 0.006529	0.0201	0.0002	0.0005

[1] Because methanol and formaldehyde emissions are dependent upon drying temperature, best-fit linear equations model emissions with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[2] Because acetaldehyde, propionaldehyde and acrolein emissions across different species are not consistently dependent upon maximum drying temperature, EF are calculated by averaging test results.


y = 0.00088x - 0.13526
R² = 1.00000
Methanol (lb/mbf)
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
160
180
200
220
240
Dry Bulb Temperatures (°F)


y = 0.000042x - 0.006529
R² = 1.000000
Formaldehyde (lb/mbf)
0.0035
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
160
180
200
220
240
Dry Bulb Temperatures (°F)

Volatile Organic Compound Emission Factors for Drying Engelmann Spruce Lumber

This sheet presents lab-scale EPA Reference Method 25A (RM25A) and speciated VOC test data and calculations used to create VOC EF for drying white spruce lumber in an indirect steam-heated batch kiln. EPA Region 10 is not aware of any HAP or VOC emission testing of englemann spruce. When actual test data is not available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted. In the absence of engelmann spruce test data, white spruce test data has been substituted. The two wood species are similar in that both are resinous softwood species in the scientific classification genus Picea. Although only one RM25A VOC test was performed while drying white spruce, it was performed while drying lumber at a relatively high maximum temperature of 235°F. Because emissions increase with maximum drying temperature, employing an EF based upon testing at 235°F would overreport emissions when drying at maximum drying temperatures less than than 235°F.

RM25A has some limitations in that it misses some pollutant compounds (or portions thereof) that are VOC and known to exist and reports the results "as carbon" which only accounts for the carbon portion of each compound measured. The missed pollutant compounds (some HAP and some non-HAP) are accounted for through separate testing. RM25A test data is adjusted to fully account for five known pollutant compounds that are VOC using separate speciated test data and is reported "as propane" to better represent all of the unspeciated VOC compounds. This technique is consistent with EPA's Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC) except that the RM25A results are adjusted to account for not only methanol and formaldehyde but also for acetaldehyde, propionaldehyde and acrolein in this case.

More specifically, one VOC emission rate is calculated based upon underlying RM25A and speciated VOC test data as indicated above. Temperature-specific methanol and formaldehyde emission rates are calculated for each temperature at which RM25A testing was performed using temperature-dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The temperature-independent acetaldehyde, propionaldehyde and acrolein emission rates reflect the average of all test results independent of the temperature of heated air entering the lumber. EPA Region 10 is not aware of any further speciated VOC test data. That portion of the (speciated) VOC compounds that are measured by the RM25A test method (based on known flame ionization detector response factors) is subtracted from the RM25A measured emission rate. The remaining "unspeciated" RM25A emission rate is adjusted to represent propane rather than carbon and then added to the speciated VOC emission rate to provide the "total" temperature-specific VOC emission rate.

Note that reporting the unspeciated VOC as propane (mass-to-carbon ratio of 1.22 and a response factor of 1) may underestimate the actual mass of VOC for certain wood species because VOC compounds like ethanol and acetic acid with higher mass-to-carbon ratios (1.92 and 2.5, respectively) and lower response factors (0.66 and 0.575, respectively) can be a significant portion of the total VOC. Based upon the mass-to-carbon ratios and response factors noted above, 1 lb/mbf ethanol is reported as 0.4194 lb/mbf propane and 1 lb/mbf acetic acid is reported as 0.2806 lb/mbf propane through the use of EPA Reference Method 25A unless compound-specific sampling and analysis is performed. The contribution of ethanol and acetic acid has been quantified through sampling and analysis for douglas fir and ponderosa pine. For douglas fir, ethanol's contribution over three tests was measured to be 0, 1.4 and 5.4 percent of WPP1 VOC, and acetic acid's contribution over the same three tests was measured to be 37, 20 and 13 percent of WPP1 VOC. For ponderosa pine, ethanol's contribution over one test was measured to be 32 percent of WPP1 VOC, and acetic acid's contribution over the same test was measured to be 6.4 percent. Without white spruce lumber drying test data for ethanol and acetic acid, EPA assumes propane adequately represents the mix of unspeciated VOC.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Engelmann Spruce (White Spruce Substitution) RM25A VOC Emission Test Data by Drying Temperature

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	Lumber Dimensions	Moisture Content[1] (%) (Initial/Final)	Time to Final Moisture Content (hours)	Method 25A Analyzer	Reference
235	0.11	2x4 or 2x6	32.7 / 15	no data	JUM VE-7	18

[1] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Engelmann Spruce (White Spruce Substitution) VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
235	0.09

Adjusted OSU emission test data value = (OSU reported emission test data value) X (NCASI TB No. 845 study full-scale kiln value/NCASI TB No. 845 study OSU small-scale kiln value)

where: OSU reported emission test data value is the RM25A VOC as carbon emission rate "lb/mbf" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf) RM25A VOC as carbon
Full-Scale Kiln	3.53333
OSU Kiln	4.25000

Step Three: Calculate/Compile Engelmann Spruce (White Spruce Substitution) Speciated HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
235	0.0715	0.0033	0.0201	0.0002	0.0005

[1] See engelmann spruce HAP sheet for lab-scale test data and calculations.

[2] Methanol EF = 0.00088x - 0.13526; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[3] Formaldehyde EF = 0.000042x - 0.006529; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Step Four: Compile Engelmann Spruce (White Spruce Substitution) Speciated Non-HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)
235	no data	no data

Step Five: Convert Engelmann Spruce (White Spruce Substitution) Speciated HAP Emission Factors to "as Carbon" and Total

Speciated Compound "X" expressed as carbon = (RF_X) X (SC_X) X $[(MW_C) / (MW_X)]$ X $[(\#C_X) / (\#C_C)]$

where: RF_X represents the flame ionization detector (FID) response factor (RF) for speciated compound "X"

SC_X represents emissions of speciated compound "X" expressed as the entire mass of compound emitted

MW_C equals "12.0110" representing the molecular weight (MW) for carbon as carbon is becoming the "basis" for expressing mass of speciated compound "X"

MW_X represents the molecular weight for speciated compound "X"

$\#C_X$ represents the number of carbon atoms in speciated compound "X"

$\#C_C$ equals "1" as the single carbon atom is becoming the "basis" for expressing mass of speciated compound "X"

Maximum Dry Bulb Temperature (°F)	Methanol as Carbon (lb/mbf)	Formaldehyde as Carbon (lb/mbf)	Acetaldehyde as Carbon (lb/mbf)	Propionaldehyde as Carbon (lb/mbf)	Acrolein as Carbon (lb/mbf)	Ethanol as Carbon (lb/mbf)	Acetic Acid as Carbon (lb/mbf)
235	0.0193	0	0.0055	0.0001	0.0002	no data	no data

SUM ⇨

Speciated Compounds as Carbon (lb/mbf)
0.0251

Element and Compound Information

Element / Compound	FID RF[1]	Molecular Weight (lb/lb-mol)	Formula	Number of Carbon Atoms	Number of Hydrogen Atoms	Number of Oxygen Atoms	Reference
Methanol	0.72	32.042	CH_40	1	4	1	1
Formaldehyde	0	30.0262	CH_2O	1	2	1	16
Acetaldehyde	0.5	44.053	C_2H_4O	2	4	1	20
Propionaldehyde	0.66	58.0798	C_3H_6O	3	6	1	20
Acrolein	0.66	56.064	C_3H_4O	3	4	1	20
Ethanol	0.66	46.0688	C_2H_6O	2	6	1	1
Acetic Acid	0.575	60.0524	$C_2H_4O_2$	2	4	2	1
Propane	1	44.0962	C_3H_8	3	8	0	16
Carbon	-	12.0110	C	1	-	-	-
Hydrogen	-	1.0079	H	-	1	-	-
Oxygen	-	15.9994	O	-	-	1	-

[1] FID RF = volumetric concentration or "instrument display" / compound's actual known concentration. Numerator and denominator expressed on same basis (ie. carbon, propane, etc) and concentration in units of "ppm."

Step Six: Subtract Speciated HAP and Non-HAP Compounds from Engelmann Spruce (White Spruce Substitution) VOC Emission Factors and Convert Result to "as Propane"

	FROM STEP TWO		FROM STEP FIVE		Method 25A VOC as Carbon without Speciated Compounds (lb/mbf)	Propane Mass Conversion	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	MINUS ⇨	Speciated Compounds as Carbon (lb/mbf)	EQUALS ⇨			
235	0.0915		0.0251		0.0664	X 1.2238 =	0.0812

Method 25A VOC as propane without speciated compounds = (VOC_C) X $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$

where: VOC_C represents Method 25A VOC as carbon without speciated compounds

RF_{C3H8} equals "1" and represents the FID RF for propane. All alkanes, including propane, have a RF of 1.

MW_{C3H8} equals "44.0962" and represents the molecular weight for propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

MW_C equals "12.0110" and represents the molecular weight for carbon

$\#C_C$ equals "1" as the single carbon atom was the "basis" for which Method 25A VOC test results were determined as illustrated in Step One of this spreadsheet

$\#C_{C3H8}$ equals "3" as three carbon atoms are present within propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

Note: The following portion from the equation immediately above, $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$, equals 1.2238 and can be referred to as the "propane mass conversion factor."

Step Seven: Calculate WPP1 VOC by Adding Speciated HAP and Non-HAP Compounds to Engelmann Spruce (White Spruce Substitution) VOC Emission Factors "as Propane"

WPP1 VOC = Method 25A VOC as propane without speciated compounds + ∑ speciated compounds expressed as the entire mass of compound

	FROM STEP SIX		FROM STEP THREE						FROM STEP FOUR			
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)	PLUS ⇨	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	PLUS ⇨	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)	EQUALS ⇨	WPP1 VOC (lb/mbf)
235	0.0812		0.0715	0.0033	0.0201	0.0002	0.0005		no data	no data		0.1769

Hazardous Air Pollutant Emission Factors for Drying Larch Lumber

This sheet presents the HAP EF for drying larch lumber. EPA Region 10 is not aware of any HAP emission testing of larch. Consistent with other species, when actual test data is not available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted.

In the absence of larch test data, douglas fir test data has been substituted. Larch is similar to douglas fir, engelmann spruce, white spruce, lodgepole pine, ponderosa pine and western white pine in that all seven species are resinous softwood species in the scientific classification order Pinaceae, but larch does not share a common genus with any of these species. It appears to be most similar to douglas fir, engelmann spruce and white spruce in that the four species have small, sparse resin canals as opposed to the large numerous resin canals of the pines. See http://www.faculty.sfasu.edu/mcbroommatth/lectures/wood_science/lab_2_resin_canal_species.pdf. While the white spruce EF for formaldehyde is greater than that of douglas fir at high drying temperatures, the opposite is true at low drying temperatures. The douglas fir EF equation for formaldehyde is based upon seven tests while the white spurce EF equation is based upon two. All other HAP EF are greater for douglas fir at all drying temperatures. Under the circumstances, EPA Region 10 has decided to substitue the douglas fir formaldehyde EF equation. See the white spruce (appearing under engelmann spruce tab) and douglas fir HAP sheets for lab-scale test data and calculations.

Larch (Douglas Fir Substitution) HAP Emission Factors

Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
0.00114x - 0.16090	0.000028x - 0.003800	0.0275	0.0003	0.0005

Volatile Organic Compound Emission Factors for Drying Larch Lumber

This sheet presents the VOC EF for drying larch lumber. EPA Region 10 is not aware of any VOC emission testing of larch. When actual test data is not available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted.

In the absence of larch test data, douglas fir test data has been substituted. Larch is similar to douglas fir, engelmann spruce, white spruce, lodgepole pine, ponderosa pine and western white pine in that all seven species are resinous softwood species in the scientific classification order Pinaceae, but larch does not share a common genus with any of these species. It appears to be most similar to douglas fir, engelmann spruce and white spruce in that the four species have small, sparse resin canals as opposed to the large numerous resin canals of the pines. See http://www.faculty.sfasu.edu/mcbroommatth/lectures/wood_science/lab_2_resin_canal_species.pdf. Because the douglas fir EF is greater than that of white spruce (and EPA Region 10 is not aware of any VOC test data for engelmann spruce), the douglas fir EF has been substituted. See the douglas fir VOC sheet for lab-scale test data and calculations.

Larch (Douglas Fir Substitution) WPP1 VOC Emission Factor

WPP1 VOC (lb/mbf): 0.01460x - 1.77130 ; where x is maximum drying temperature in °F

Hazardous Air Pollutant Emission Factors for Drying Lodgepole Pine Lumber

This sheet presents lab-scale test data and calculations used to create HAP EF for drying lodgepole pine lumber in an indirect steam-heated batch kiln. The EF are calculated by averaging test results. Lodgepole pine testing was performed while drying lumber at a relatively high maximum temperature of around 237°F. Because emissions increase with maximum drying temperature, employing an EF based upon testing at 237°F would overreport emissions when drying at maximum drying temperatures less than than 237°F.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Lodgepole Pine HAP Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial / Final)	Time to Final Moisture Content (hours)	HAP Sample Collection Technique	Reference
195	~~0.073~~	~~no data~~	~~0.012~~	~~no data~~	~~no data~~	no data	no data	no data	no data	14
195	~~0.092~~	~~no data~~	~~no data~~	~~no data~~	~~no data~~	no data	no data	no data	no data	
195	~~0.064~~	~~no data~~	~~no data~~	~~no data~~	~~no data~~	no data	no data	no data	no data	
195	~~0.028~~	~~no data~~	~~no data~~	~~no data~~	~~no data~~	no data	no data	no data	no data	
195	~~0.02~~	~~no data~~	~~no data~~	~~no data~~	~~no data~~	no data	no data	no data	no data	
≤ 200°F	no data									
236	0.063	0.0041	no data	no data	no data	2x4	59.1 / 15	16	NCASI Method IM/CAN/WP-99.01 without cannisters.	3, 4, 12, 14
237	0.062	0.0041	no data	no data	no data	2x4	59.7 / 15	16.6		
238	0.056	0.0039	no data	no data	no data	2x4	56.9 / 15	16		

[1] Blue highlight denotes data not considered by EPA Region 10 in 2012. Five test runs considered by EPA Region 10 in 2007 are not considered here due to lack of documentation. The omitted test values are presented in Oregon Department of Environmental Quality memorandum May 8, 2007 entitled, "Title III Implications of Drying Kiln Source Test Results." The memorandum lists "Forintec #1, #2 and #5" along with "OSU QA # 1 and #2 " as the test data sources.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Lodgepole Pine VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
236	0.057	0.0030	no data	no data	no data
237	0.056	0.0030	no data	no data	no data
238	0.051	0.0029	no data	no data	no data

Adjusted OSU emission test data $value_i$ = (OSU reported emission test data $value_i$) X (NCASI TB No. 845 study full-scale kiln $value_i$/NCASI TB No. 845 study OSU small-scale kiln $value_i$)

where: OSU reported emission test data $value_i$ is the emission rate "lb/mbf" for compound "i" documented in Step One (not highlighted in green)

NCASI study full-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf)				
	Methanol	Formaldehyde	Acetaldehyde	Propionaldehyde	Acrolein
Full-Scale Kiln	0.205	0.0155	0.039	0.001	0.006
OSU Kiln	0.225	0.0210	0.065	0.003	0.009

Step Three: Calculate Lodgepole Pine HAP Emission Factors

Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
0.0550	0.0030	no data	no data	no data

Volatile Organic Compound Emission Factors for Drying Lodgepole Pine Lumber

This sheet presents lab-scale EPA Reference Method 25A (RM25A) and speciated VOC test data and calculations used to create VOC EF for drying lodgepole pine lumber in an indirect steam-heated batch kiln. Although three RM25A VOC tests were performed while drying lodgepole pine, they were performed while drying lumber at a relatively high maximum temperature of around 238°F. Because emissions increase with maximum drying temperature, employing an EF based upon testing at 238°F would overreport emissions when drying at maximum drying temperatures less than than 238°F.

RM25A has some limitations in that it misses some pollutant compounds (or portions thereof) that are VOC and known to exist and reports the results “as carbon” which only accounts for the carbon portion of each compound measured. The missed pollutant compounds (some HAP and some non-HAP) are accounted for through separate testing. RM25A test data is adjusted to fully account for two known pollutant compounds that are VOC using separate speciated test data and is reported “as propane” to better represent all of the unspeciated VOC compounds. This technique is consistent with EPA’s Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC).

More specifically, one VOC emission rate is calculated based upon underlying RM25A and speciated VOC test data as indicated above. Temperature-specific methanol and formaldehyde emission rates are calculated for each temperature at which RM25A testing was performed using temperature-dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. EPA Region 10 is not aware of any further speciated VOC test data. That portion of the (speciated) VOC compounds that are measured by the RM25A test method (based on known flame ionization detector response factors) is subtracted from the RM25A measured emission rate. The remaining “unspeciated” RM25A emission rate is adjusted to represent propane rather than carbon and then added to the speciated VOC emission rate to provide the “total” temperature-specific VOC emission rate.

Note that reporting the unspeciated VOC as propane (mass-to-carbon ratio of 1.22 and a response factor of 1) may underestimate the actual mass of VOC for certain wood species because VOC compounds like ethanol and acetic acid with higher mass-to-carbon ratios (1.92 and 2.5, respectively) and lower response factors (0.66 and 0.575, respectively) can be a significant portion of the total VOC. Based upon the mass-to-carbon ratios and response factors noted above, 1 lb/mbf ethanol is reported as 0.4194 lb/mbf propane and 1 lb/mbf acetic acid is reported as 0.2806 lb/mbf propane through the use of EPA Reference Method 25A unless compound-specific sampling and analysis is performed. The contribution of ethanol and acetic acid has been quantified through sampling and analysis for douglas fir and ponderosa pine. For douglas fir, ethanol's contribution over three tests was measured to be 0, 1.4 and 5.4 percent of WPP1 VOC, and acetic acid's contribution over the same three tests was measured to be 37, 20 and 13 percent of WPP1 VOC. For ponderosa pine, ethanol's contribution over one test was measured to be 32 percent of WPP1 VOC, and acetic acid's contribution over the same test was measured to be 6.4 percent. Without reliable lodgepole pine lumber drying test data for ethanol and acetic acid, EPA assumes propane adequately represents the mix of unspeciated VOC.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Lodgepole Pine RM25A VOC Emission Test Data by Drying Temperature

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	Lumber Dimensions	Moisture Content[1] (%) (Initial/Final)	Time to Final Moisture Content (hours)	Method 25A Analyzer	Reference
236	1.17	2x4	59.1 / 15	16.01	JUM 3-200	3, 4, 12
238	0.87	2x4	56.9 / 15	16.01		
240	1.19	2x4	64.9 / 15	16.81		

[1] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Calculate Lodgepole Pine VOC Emission Factor[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
238	1.0767

[1] Three-run average.

Step Three: Adjust Ponderosa Pine VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
238	0.8951

Adjusted OSU emission test data value = (OSU reported emission test data value) X (NCASI TB No. 845 study full-scale kiln value/NCASI TB No. 845 study OSU small-scale kiln value)

where: OSU reported emission test data value is the RM25A VOC as carbon emission rate "lb/mbf" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf) RM25A VOC as carbon
Full-Scale Kiln	3.53333
OSU Kiln	4.25000

Step Four: Compile Lodgepole Pine Speciated HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing[1]

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
238	0.0550	0.0030	no data	no data	no data

[1] See lodgepole pine HAP sheet for lab-scale test data and calculations.

Step Five: Compile Lodgepole Pine Speciated Non-HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)
238	no data	no data

Step Six: Convert Lodgepole Pine Speciated HAP Emission Factors to "as Carbon" and Total

Speciated Compound "X" expressed as carbon = (RF_X) X (SC_X) X $[(MW_C) / (MW_X)]$ X $[(\#C_X) / (\#C_C)]$

where: RF_X represents the flame ionization detector (FID) response factor (RF) for speciated compound "X"

SC_X represents emissions of speciated compound "X" expressed as the entire mass of compound emitted

MW_C equals "12.0110" representing the molecular weight (MW) for carbon as carbon is becoming the "basis" for expressing mass of speciated compound "X"

MW_X represents the molecular weight for speciated compound "X"

$\#C_X$ represents the number of carbon atoms in speciated compound "X"

$\#C_C$ equals "1" as the single carbon atom is becoming the "basis" for expressing mass of speciated compound "X"

Maximum Dry Bulb Temperature	Methanol as Carbon	Formaldehyde as Carbon	Acetaldehyde as Carbon	Propionaldehyde as Carbon	Acrolein as Carbon	Ethanol as Carbon	Acetic Acid as Carbon	Speciated Compounds as Carbon

(°F)	(lb/mbf)	(lb/mbf)	(lb/mbf)	(lb/mbf)	(lb/mbf)	(lb/mbf)	(lb/mbf)	SUM	(lb/mbf)
238	0.0148	0	no data	no data	no data	no data	no data	⇨	0.0148

Element and Compound Information

Element / Compound	FID RF[1]	Molecular Weight (lb/lb-mol)	Formula	Number of Carbon Atoms	Number of Hydrogen Atoms	Atoms	Reference
Methanol	0.72	32.042	CH_40	1	4	1	1
Formaldehyde	0	30.0262	CH_2O	1	2	1	16
Acetaldehyde	0.5	44.053	C_2H_4O	2	4	1	20
Propionaldehyde	0.66	58.0798	C_3H_6O	3	6	1	20
Acrolein	0.66	56.064	C_3H_4O	3	4	1	20
Ethanol	0.66	46.0688	C_2H_6O	2	6	1	1
Acetic Acid	0.575	60.0524	$C_2H_4O_2$	2	4	2	1
Propane	1	44.0962	C_3H_8	3	8	0	16
Carbon	-	12.0110	C	1	-	-	-
Hydrogen	-	1.0079	H	-	1	-	-
Oxygen	-	15.9994	O	-	-	1	-

[1] FID RF = volumetric concentration or "instrument display" / compound's actual known concentration. Numerator and denominator expressed on same basis (ie. carbon, propane, etc) and concentration in units of "ppm."

Step Seven: Subtract Speciated HAP and Non-HAP Compounds from Lodgepole Pine VOC Emission Factors and Convert Result to "as Propane"

	FROM STEP THREE		FROM STEP SIX			Propane Mass Conversion Factor	
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	MINUS ⇨	Speciated Compounds as Carbon (lb/mbf)	EQUALS ⇨	Method 25A VOC as Carbon without Speciated Compounds (lb/mbf)	X 1.2238 =	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)
238	0.8951		0.0148		0.8803		1.0773

Method 25A VOC as propane without speciated compounds = (VOC_C) X $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$

where: VOC_C represents Method 25A VOC as carbon without speciated compounds

RF_{C3H8} equals "1" and represents the FID RF for propane. All alkanes, including propane, have a RF of 1.

MW_{C3H8} equals "44.0962" and represents the molecular weight for propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

MW_C equals "12.0110" and represents the molecular weight for carbon

$\#C_C$ equals "1" as the single carbon atom was the "basis" for which Method 25A VOC test results were determined as illustrated in Step One of this spreadsheet

$\#C_{C3H8}$ equals "3" as three carbon atoms are present within propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

Note: The following portion from the equation immediately above, $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$, equals 1.2238 and can be referred to as the "propane mass conversion factor."

Step Eight: Calculate WPP1 VOC by Adding Speciated HAP and Non-HAP Compounds to Lodgepole Pine VOC Emission Factors "as Propane"

WPP1 VOC = Method 25A VOC as propane without speciated compounds + ∑ speciated compounds expressed as the entire mass of compound

	FROM STEP SEVEN		FROM STEP FOUR						FROM STEP FIVE			
Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)	PLUS ⇨	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	PLUS ⇨	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)	EQUALS ⇨	WPP1 VOC (lb/mbf)
238	1.0773		0.0550	0.0030	no data	no data	no data		no data	no data		1.1352

Hazardous Air Pollutant Emission Factors for Drying Ponderosa Pine Lumber

This sheet presents lab-scale test data and calculations used to create HAP EF for drying ponderosa pine lumber in an indirect steam-heated batch kiln. The methanol and formaldehyde EF are temperature dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The acetaldehyde, propionaldehyde and acrolein EF are calculated by averaging test results.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Ponderosa Pine HAP Emission Test Data by Drying Temperature

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	Lumber Dimensions	Moisture Content[1] (%) (Initial / Final)	Time to Final Moisture Content (hours)	HAP Sample Collection Technique	Reference
170	0.035	0.0027	0.042	0.0019	0.0017	2x4	82.6 / 15	42	NCASI Method 105	17, 18
176	0.05	0.0022	no data	no data	no data	2x10 & 2x12	107.1 / 12	55	NCASI Method IM/CAN/WP-99.01 without cannisters	3, 4, 12, 14
176	0.08	0.0036	no data	no data	no data	2x10 & 2x12	124.1 / 12	57		
180	0.058	0.005	0.100	0.0035	0.0055	2x4	103.9 / 15	39.4	NCASI Method 105	Link to March 7, 2013 Hampton Affiliates - Randle Test Report
235	0.144	0.0092	0.028	0.0032	0.0045	2x4 or 2x6	89.1 / 15	19	NCASI Method 105	18, 21

[1] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Ponderosa Pine HAP Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions

Maximum Dry Bulb Temperature (°F)	Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
170	0.032	0.0020	0.025	0.0006	0.0011
176	0.046	0.0016	no data	no data	no data
176	0.073	0.0027	no data	no data	no data
180	0.053	0.0037	0.060	0.0012	0.0037
235	0.131	0.0068	0.017	0.0011	0.0030

Adjusted OSU emission test data $value_i$ = (OSU reported emission test data $value_i$) X (NCASI TB No. 845 study full-scale kiln $value_i$/NCASI TB No. 845 study OSU small-scale kiln $value_i$)

where: OSU reported emission test data $value_i$ is the emission rate "lb/mbf" for compound "i" documented in Step One (not highlighted in green)

NCASI study full-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln $value_i$ is the average emission rate "lb/mbf" for compound "i" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

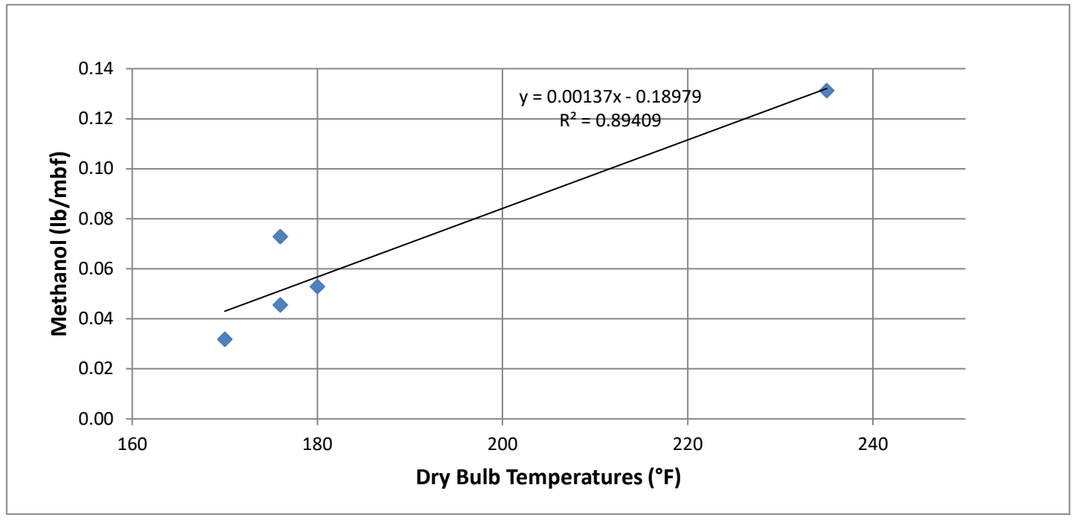
	NCASI TB No. 845 - Emission Rate (lb/mbf)				
	Methanol	Formaldehyde	Acetaldehyde	Propionaldehyde	Acrolein
Full-Scale Kiln	0.205	0.0155	0.039	0.001	0.006
OSU Kiln	0.225	0.0210	0.065	0.003	0.009

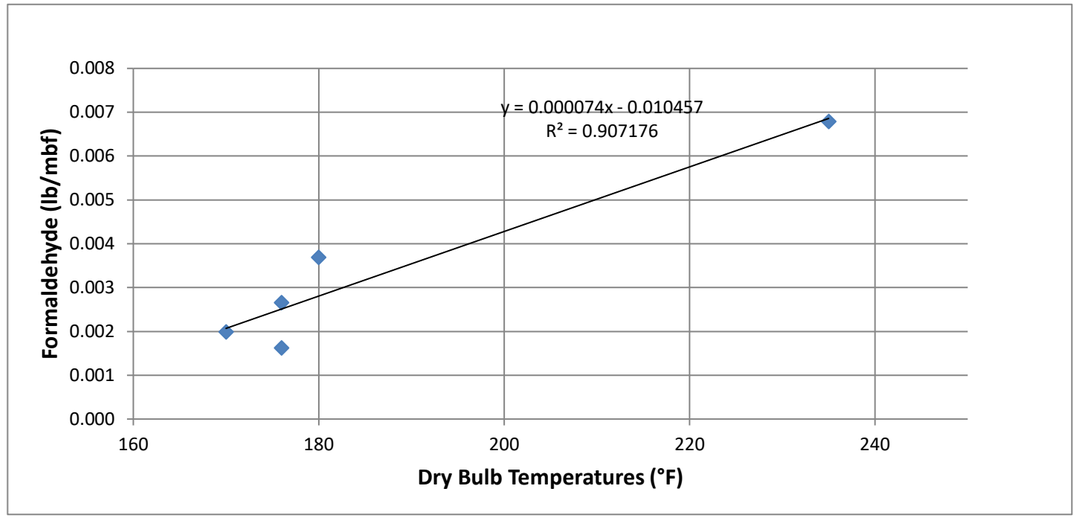
Step Three: Calculate Ponderosa Pine HAP Emission Factors

Methanol[1] (lb/mbf)	Formaldehyde[1] (lb/mbf)	Acetaldehyde[2] (lb/mbf)	Propionaldehyde[2] (lb/mbf)	Acrolein[2] (lb/mbf)
0.00137x - 0.18979	0.000074x - 0.010457	0.0340	0.0010	0.0026

[1] Best-fit linear equations with dependent variable maximum drying temperature entering the lumber

[2] Because acetaldehyde, propionaldehyde and acrolein emissions across different species are not consistently dependent upon maximum drying temperature, EF are calculated by averaging test results.


y = 0.00137x - 0.18979
R² = 0.89409
Methanol (lb/mbf)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
160
180
200
220
240
Dry Bulb Temperatures (°F)


y = 0.000074x - 0.010457
R² = 0.907176
Formaldehyde (lb/mbf)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
160
180
200
220
240
Dry Bulb Temperatures (°F)

Volatile Organic Compound Emission Factors for Drying Ponderosa Pine Lumber

This sheet presents lab-scale EPA Reference Method 25A (RM25A) and speciated VOC test data and calculations used to create VOC EF for drying ponderosa pine lumber in an indirect steam-heated batch kiln. RM25A has some limitations in that it misses some pollutant compounds (or portions thereof) that are VOC and known to exist and reports the results "as carbon" which only accounts for the carbon portion of each compound measured. The missed pollutant compounds (some HAP and some non-HAP) are accounted for through separate testing. RM25A test data is adjusted to fully account for seven known pollutant compounds that are VOC using separate speciated test data and is reported "as propane" to better represent all of the unspeciated VOC compounds. This technique is consistent with EPA's Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 (WPP1 VOC) except that the RM25A results are adjusted to account for not only methanol and formaldehyde but also for acetaldehyde, propionaldehyde, acrolein, ethanol and acetic acid in this case.

More specifically, ten separate drying-temperature-specific VOC emission rates (upon which a best-fit linear equation will be established) are calculated based upon underlying RM25A and speciated VOC test data as indicated above. Temperature-specific methanol and formaldehyde emission rates are calculated for each temperature at which RM25A testing was performed using temperature-dependent best-fit linear equations. The temperature variable reflects the maximum temperature of the heated air entering the lumber. The temperature-independent acetaldehyde, propionaldehyde and acrolein emission rates reflect the average of all test results independent of the temperature of heated air entering the lumber. The ethanol and acetic acid emission rates reflect the results of a single test. EPA Region 10 is not aware of any further speciated VOC test data. That portion of the (speciated) VOC compounds that are measured by the RM25A test method (based on known flame ionization detector response factors) is subtracted from the RM25A measured emission rate. The remaining "unspeciated" RM25A emission rate is adjusted to represent propane rather than carbon and then added to the speciated VOC emission rate to provide the "total" temperature-specific VOC emission rate. The resultant VOC EF is a 10-point best-fit linear equation with dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Test data generated through the use of the smaller of the two small-scale kilns at Oregon State University (OSU) has been adjusted to account for bias documented in NCASI's May 2002 Technical Bulletin No. 845 entitled, "A Comparative Study of VOC Emissions from Small-Scale and Full-Scale Lumber Kilns Drying Southern Pine." See last spreadsheet of this workbook for Stimson Lumber Company's October 18, 2019 letter to EPA Region 10 highlighting the bias.

Step One: Compile Ponderosa Pine RM25A VOC Emission Test Data by Drying Temperature[1]

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)	Lumber Dimensions	Moisture Content[2] (%) (Initial/Final)	Time to Final Moisture Content (hours)	Method 25A Analyzer	Reference
170	1.59	2x4	82.6 / 15	42	JUM VE-7	17, 18
170	1.795	1x4	112.8 / 15	29	JUM VE-7	2
170	1.925	1x4	88.7 / 15	28		
176	1.29	2x10 & 2x12	107.1 / 12	55	JUM 3-200	3, 4, 12
176	1.54	2x10 & 2x12	124.1 / 12	57		
176	1.40	2x10 & 2x12	114.8 / 12	58.5	JUM 3-200	3, 4
176	1.30	2x10 & 2x12	93.0 / 12	57.1		
180	1.48	2x4	103.9 / 15	39.4	JUM VE-7	Link to March 7, 2013 Hampton Affiliates - Randle Test Report
180	1.72	2x4	122.0 / 15	43.6		
235	3.00	2x4 or 2x6	89.1 / 15	19	JUM VE-7	18, 21

[1] Green highlight denotes data generated by testing conducted on the small-scale kiln at the University of Idaho. All other data was generated by testing conducted on the smaller of the two small-scale kilns at OSU.

[2] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Two: Adjust Ponderosa Pine VOC Emission Test Data to Account for Bias in Underlying Small-Scale Kiln to Represent Full-Scale Kiln Emissions

Maximum Dry Bulb Temperature (°F)	Method 25A VOC as Carbon (lb/mbf)
170	1.32
170	1.795
170	1.925
176	1.07
176	1.28
176	1.16
176	1.08
180	1.23
180	1.43
235	2.49

[1] Green highlighted results from the test conducted at the University of Idaho have not been adjusted because the kiln was not calibrated to a full-scale kiln.

Adjusted OSU emission test data value = (OSU reported emission test data value) X (NCASI TB No. 845 study full-scale kiln value/NCASI TB No. 845 study OSU small-scale kiln value)

where: OSU reported emission test data value is the RM25A VOC as carbon emission rate "lb/mbf" documented in Step One (not highlighted in green)

NCASI study full-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in a full-scale indirect steam-heated batch lumber dry kiln

NCASI study OSU small-scale kiln value is the average RM25A VOC as carbon emission rate "lb/mbf" measured while drying southern yellow pine lumber in OSU's small-scale indirect steam-heated batch lumber dry kiln

The lumber dried in the OSU kiln was (a) extracted from the pool of lumber dried in the full-scale kiln and (b) dried according the schedule employed by the full-scale kiln.

	NCASI TB No. 845 - Emission Rate (lb/mbf) RM25A VOC as carbon
Full-Scale Kiln	3.53333
OSU Kiln	4.25000

Step Three: Calculate/Compile Ponderosa Pine Speciated HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A VOC Testing[1]

Maximum Dry Bulb Temperature (°F)	Methanol[2] (lb/mbf)	Formaldehyde[3] (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
170	0.0431	0.0021	0.0340	0.0010	0.0026
176	0.0513	0.0026			
180	0.0568	0.0029			
235	0.1322	0.0069			

[1] See ponderosa pine HAP sheet for lab-scale test data and calculations.

[2] Methanol EF = 0.00137x - 0.18979; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

[3] Formaldehyde EF = 0.000074x - 0.010457; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber.

Step Four: Compile Ponderosa Pine Speciated Non-HAP Emission Test Data by Drying Temperature

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)	Lumber Dimensions	Moisture Content[1] (%) (Initial / Final)	Time to Final Moisture Content (hours)	VOC Sample Collection Technique	Reference
180	0.826	0.162	2x4	103.9 / 15	39.4	NCASI Method 105	Link to March 7, 2013 Hampton Affiliates - Randle Test Report

[1] Dry basis. Moisture content = (weight of water / weight wood) x 100

Step Five: Calculate Ponderosa Pine Speciated Non-HAP Emission Factors

Ethanol (lb/mbf)	Acetic Acid (lb/mbf)
0.826	0.162

Step Six: Calculate/Compile Ponderosa Pine Speciated Non-HAP Emission Factors at Maximum Drying Temperatures Observed during RM25A Testing

Maximum Dry Bulb Temperature (°F)	Ethanol (lb/mbf)	Acetic Acid (lb/mbf)
170	0.826	0.162
176		
180		
235		

Step Seven: Convert Ponderosa Pine Speciated HAP and Non-HAP Emission Factors to "as Carbon" and Total

Speciated Compound "X" expressed as carbon = (RF_X) X (SC_X) X $[(MW_C) / (MW_X)]$ X $[(\#C_X) / (\#C_C)]$

where: RF_X represents the flame ionization detector (FID) response factor (RF) for speciated compound "X"

SC_X represents emissions of speciated compound "X" expressed as the entire mass of compound emitted

MW_C equals "12.0110" representing the molecular weight (MW) for carbon as carbon is becoming the "basis" for expressing mass of speciated compound "X"

MW_X represents the molecular weight for speciated compound "X"

$\#C_X$ represents the number of carbon atoms in speciated compound "X"

$\#C_C$ equals "1" as the single carbon atom is becoming the "basis" for expressing mass of speciated compound "X"

Maximum Dry Bulb Temperature (°F)	Methanol as Carbon (lb/mbf)	Formaldehyde as Carbon (lb/mbf)	Acetaldehyde as Carbon (lb/mbf)	Propionaldehyde as Carbon (lb/mbf)	Acrolein as Carbon (lb/mbf)	Ethanol as Carbon (lb/mbf)	Acetic Acid as Carbon (lb/mbf)		Speciated Compounds as Carbon (lb/mbf)
170	0.0116	0	0.0093	0.0004	0.0011	0.2843	0.0373		0.3461
176	0.0139	0							0.3487
180	0.0153	0						SUM	0.3505
235	0.0357	0						⇨	0.3749

Element and Compound Information

Element / Compound	FID RF[1]	Molecular Weight (lb/lb-mol)	Formula	Number of Carbon Atoms	Number of Hydrogen Atoms	Number of Oxygen Atoms	Reference
Methanol	0.72	32.042	CH_40	1	4	1	1
Formaldehyde	0	30.0262	CH_2O	1	2	1	16
Acetaldehyde	0.5	44.053	C_2H_4O	2	4	1	20
Propionaldehyde	0.66	58.0798	C_3H_6O	3	6	1	20
Acrolein	0.66	56.064	C_3H_4O	3	4	1	20
Ethanol	0.66	46.0688	C_2H_6O	2	6	1	1
Acetic Acid	0.575	60.0524	$C_2H_4O_2$	2	4	2	1
Propane	1	44.0962	C_3H_8	3	8	0	16
Carbon	-	12.0110	C	1	-	-	-
Hydrogen	-	1.0079	H	-	1	-	-
Oxygen	-	15.9994	O	-	-	1	-

[1] FID RF = volumetric concentration or "instrument display" / compound's actual known concentration. Numerator and denominator expressed on same basis (ie. carbon, propane, etc) and concentration in units of "ppm."

Step Eight: Subtract Speciated HAP and Non-HAP Compounds from Ponderosa Pine VOC Emission Factors and Convert Result to "as Propane"

Maximum Dry Bulb Temperature (°F)	FROM STEP TWO: Method 25A VOC as Carbon (lb/mbf)	MINUS	FROM STEP SEVEN: Speciated Compounds as Carbon (lb/mbf)	EQUALS	Method 25A VOC as Carbon without Speciated Compounds (lb/mbf)	Propane Mass Conversion Factor	Method 25A VOC as Propane without Speciated Compounds (lb/mbf)
170	1.3219		0.3461		0.9758		1.1942
170	1.7950		0.3461		1.4489		1.7732
170	1.9250		0.3461		1.5789		1.9323
176	1.0725		0.3487		0.7238		0.8857
176	1.2803		0.3487		0.9316		1.1401
176	1.1639		0.3487		0.8152		0.9976
176	1.0808		0.3487		0.7321		0.8959
180	1.2304		0.3505		0.8799		1.0769
180	1.4300		0.3505		1.0795		1.3210
235	2.4941		0.3749		2.1192	X 1.2238 =	2.5934

Method 25A VOC as propane without speciated compounds = (VOC_C) X $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$

where: VOC_C represents Method 25A VOC as carbon without speciated compounds

RF_{C3H8} equals "1" and represents the FID RF for propane. All alkanes, including propane, have a RF of 1.

MW_{C3H8} equals "44.0962" and represents the molecular weight for propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

MW_C equals "12.0110" and represents the molecular weight for carbon

$\#C_C$ equals "1" as the single carbon atom was the "basis" for which Method 25A VOC test results were determined as illustrated in Step One of this spreadsheet

$\#C_{C3H8}$ equals "3" as three carbon atoms are present within propane; the compound that is the "basis" for expressing mass of VOC per WPP1 VOC

Note: The following portion from the equation immediately above, $(1/RF_{C3H8})$ X $[(MW_{C3H8}) / (MW_C)]$ X $[(\#C_C) / (\#C_{C3H8})]$, equals 1.2238 and can be referred to as the "propane mass conversion factor."

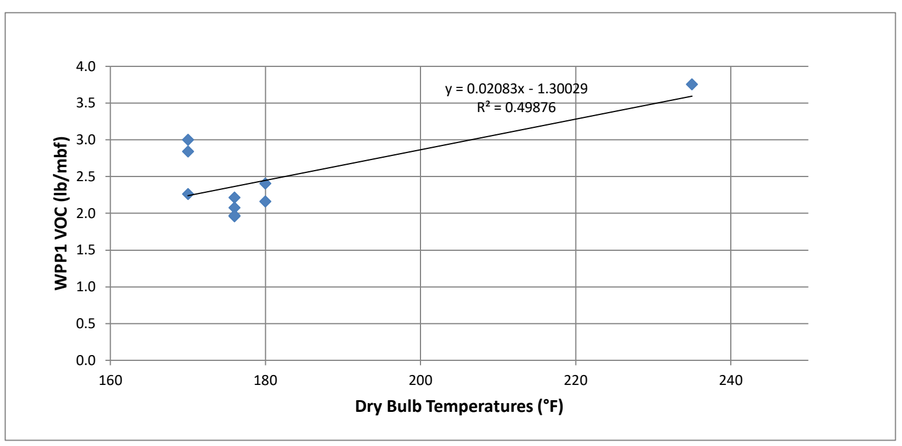
Step Nine: Calculate WPP1 VOC by Adding Speciated HAP and Non-HAP Compounds to Ponderosa Pine VOC Emission Factors "as Propane"

WPP1 VOC = Method 25A VOC as propane without speciated compounds + ∑ speciated compounds expressed as the entire mass of compound

Maximum Dry Bulb Temperature (°F)	FROM STEP EIGHT: Method 25A VOC as Propane without Speciated Compounds (lb/mbf)	PLUS	FROM STEP THREE: Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)	PLUS	FROM STEP SIX: Ethanol (lb/mbf)	Acetic Acid (lb/mbf)	EQUALS	WPP1 VOC (lb/mbf)
170	1.1942		0.0431	0.0021								2.2650
170	1.7732		0.0431	0.0021								2.8440
170	1.9323		0.0431	0.0021								3.0031
176	0.8857		0.0513	0.0026								1.9652
176	1.1401		0.0513	0.0026	0.0340	0.0010	0.0026		0.826	0.162		2.2195
176	0.9976		0.0513	0.0026								2.0771
176	0.8959		0.0513	0.0026								1.9753
180	1.0769		0.0568	0.0029								2.1621
180	1.3210		0.0568	0.0029								2.4063
235	2.5934		0.1322	0.0069								3.7581

Step Ten: Generate Ponderosa Pine Best-Fit Linear Equation with Dependent Variable Maximum Drying Temperature to Model WPP1 VOC Emissions

WPP1 VOC (lb/mbf): 0.02083x - 1.30029 ; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumber



Hazardous Air Pollutant Emission Factors for Drying Western White Pine Lumber

This sheet presents the HAP EF for drying western white pine lumber. EPA Region 10 is not aware of any HAP emission testing of western white pine. When actual test data is not available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted.

Given the limited western white pine test data, ponderosa pine test data has been substituted. Western white pine is similar to ponderosa pine and lodgepole pine in that all three species are resinous softwood species in the scientific classification genus Pinus. EPA Region 10 is aware of three Lodgepole Pine test runs for methanol and formaldehyde and none for acetaldehyde, propionaldehyde and acrolein. Five ponderosa pine test runs were conducted for methanol and formaldehyde and three for acetaldehyde, propionaldehyde and acrolein. While the lodgepole pine runs were conducted at about the same maximum drying temperature, the ponderosa pine runs were distributed across a wide maximum drying temperature range. Based upon the available test data, ponderosa pine is higher-emitting than lodgepole pine for methanol and formaldehyde. See the ponderosa pine and lodgepole pine HAP sheets for lab-scale test data and calculations.

Western White Pine (Ponderosa Pine Substitution) HAP Emission Factors

Methanol (lb/mbf)	Formaldehyde (lb/mbf)	Acetaldehyde (lb/mbf)	Propionaldehyde (lb/mbf)	Acrolein (lb/mbf)
0.00137x - 0.18979	0.000074x - 0.010457	0.0340	0.0010	0.0026

Volatile Organic Compound Emission Factors for Drying Western White Pine Lumber

This sheet presents the VOC EF for drying western white pine lumber. EPA Region 10 is aware of one test being conducted while drying western white pine lumber, and it was conducted at 170°F. Because VOC emissions increase with maximum drying temperature, employing an EF based upon testing at 170°F would underreport emissions when drying at maximum drying temperatures greater than 170°F. A temperature of 170°F is not a particularly high drying temperature. When little or no actual test data is available, data for a similar species is substituted as noted. When there are more than one similar species, the highest of the EF for the similar species is substituted.

Given the limited western white pine test data, ponderosa pine test data has been substituted. Western white pine is similar to ponderosa pine and lodgepole pine in that all three species are resinous softwood species in the scientific classification genus Pinus. EPA Region 10 is aware of three lodgepole pine test runs and eight ponderosa pine test runs. While the lodgepole pine runs were conducted at about the same maximum drying temperature, the ponderosa pine runs were distributed across a wide maximum drying temperature range. Based upon the available test data, ponderosa pine is higher-emitting than lodgepole pine. See the ponderosa pine and lodgepole pine HAP and VOC sheets for lab-scale test data and calculations.

Western White Pine (Ponderosa Pine Substitution) WPP1 VOC Emission Factor

WPP1 VOC (lb/mbf): 0.02083x - 1.30029 ; where dependent variable "x" equal to the maximum drying temperature of heated air entering the lumb

Index to References Appearing in
EPA Region 10 HAP and VOC Emission Factors for Lumber Drying, June 2018

Reference No. 1
(Undated) J.U.M. Flame Ionization Detector Response Factor Technical Information presented at http://www.jum-aerosol.com/images/E-Fakt-02.pdf

Notes
Methanol response factor (RF) of 0.72 equals average of three response factors 0.69, 0.68 and 0.79 for J.U.M. models 3-200 and VE-7. These two models were exclusively employed to determine Method 25A VOC in the testing EPA Region 10 is relying upon to support VOC emission factor derivation.

An alternative RF of 0.65 from Appendix 3 to EPA's Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 at http://www.epa.gov/ttn/emc/prelim/otm26.pdf could have been employed instead.

Employing RF of 0.72 (as opposed to 0.65) generates lower VOC emission factors (EF). A higher RF means that the EPA Method 25A flame ionization detector (FID) measures more of the compound. With the methanol EF having already been determined through speciated sampling and analysis, assuming the FID measures a greater portion of the methanol leaves less of the Method 25A measurement to be accounted for as unspeciated VOC.

Reference No. 2
National Council of the Paper Industry for Air and Stream Improvement, Inc. Technical Bulletin No. 718. July 1, 1996. A Small-Scale Kiln Study on Method 25A Measurements of Volatile Organic Compound Emissions from Lumber Drying.

Notes
To convert Method 25A VOC from "lb C/ODT" to "lb C/mbf," the following calculations were performed:

White Fir – Runs 15 and 16.
(0.85 lb/ODT) X (0.57 lb/mbf) / (0.77 lb/ODT) = 0.63 lb/mbf
(0.68 lb/ODT) X (0.57 lb/mbf) / (0.77 lb/ODT) = 0.50 lb/mbf
See pages 14 and 15 of the reference document.

Western Red Cedar – Runs 10 and 11.
(0.12 lb/ODT) X (0.12 lb/mbf) / (0.15 lb/ODT) = 0.096 lb/mbf
(0.17 lb/ODT) X (0.12 lb/mbf) / (0.15 lb/ODT) = 0.136 lb/mbf
See pages 14 and 15 of the reference document.

Douglas fir – Runs 1 and 3.
(1.00 lb/ODT) X (0.81 lb/mbf) / (0.86 lb/ODT) = 0.942
(0.71 lb/ODT) X (0.81 lb/mbf) / (0.86 lb/ODT) = 0.669
See pages 12 and 15 of the reference document.

Ponderosa Pine – Runs 5 and 6.
(1.92 lb/ODT) X (1.86 lb/mbf) / (1.99 lb/ODT) = 1.795 lb/mbf
(2.06 lb/ODT) X (1.86 lb/mbf) / (1.99 lb/ODT) = 1.925 lb/mbf
See pages 14 and 15 of the reference document.

The moisture content of wood was originally reported on a wet basis. It has been corrected to be on a dry basis using the following equation:
(moisture content on dry basis) = (moisture content on wet basis) / [1 – (moisture content on wet basis)]

Reference No. 3
Small-scale Kiln Study Utilizing Ponderosa Pine, Lodgepole Pine, White Fir, and Douglas-fir. Report by Michael R. Milota to Intermountain Forest Association. September 29, 2000.

Reference No. 4
Milota, Michael. VOC and HAP Emissions from Western Species. Western Dry Kiln Association: May 2001, p. 62-68.

Reference No. 5
Milota, M.R. 2003. HAP and VOC Emissions from White Fir Lumber Dried at High and Conventional Temperatures. Forest Prod. J. 53(3):60-64.

Reference No. 6
VOC and HAP Emissions from the High Temperature Drying of Hemlock Lumber. Report by Michael R. Milota to Hampton Affiliates. June 21, 2004.

Reference No. 7
Fritz, Brad. 2004. Pilot- and Full-Scale Measurements of VOC Emissions from Lumber Drying of Inland Northwest Species. Forest Prod. J. 54(7/8):50-56.

Notes
To convert acetaldehyde from "µg/min-bf" to “lb/mbf,” the following calculations were performed:

White fir.
0.0550 lb/mbf = (7.7 µg/min-bf) X (60 min/hr) X (54 hr) X (kg/1x10^9g) X (2.205 lb/kg) X (1,000 bf/mbf).
See page 54 of the reference document.

Douglas fir.
0.030 lb/mbf = (4.9 µg/min-bf) X (60 min/hr) X (46 hr) X (kg/1x10^9g) X (2.205 lb/kg) X (1,000 bf/mbf).
0.022 lb/mbf = (3.6 µg/min-bf) X (60 min/hr) X (46 hr) X (kg/1x10^9g) X (2.205 lb/kg) X (1,000 bf/mbf).
See page 53 of the reference document.

Reference No. 8
VOC and Methanol Emissions from the Drying of Hemlock Lumber. Report by Michael R. Milota to Hampton Affiliates. August 24, 2004.

Reference No. 9
VOC, Methanol, and Formaldehyde Emissions from the Drying of Hemlock Lumber. Report by Michael R. Milota to Hampton Affiliates. October 15, 2004.

Reference No. 10
VOC Emissions from the Drying of Douglas-fir Lumber. Report by Michael R. Milota to Columbia Vista Corporation. June 14, 2005.

Reference No. 11
Milota, M.R. and P. Mosher. 2006. Emissions from Western Hemlock Lumber During Drying. Forest Prod. J. 56(5):66-70.

Reference No. 12
Milota, M.R. 2006. Hazardous Air Pollutant Emissions from Lumber Drying. Forest Prod. J. 56(7/8):79-84.

Reference No. 13
VOC, Methanol, and Formaldehyde Emissions from the Drying of Hemlock, ESLP, and Douglas Fir Lumber. Report by Michael R. Milota to Hampton Affiliates. March 23, 2007.

Reference No. 14
Oregon Department of Environmental Quality memorandum May 8, 2007 entitled, "Title III Implications of Drying Kiln Source Test Results."

Notes
The reference document presents a compilation of EF.

Reference No. 15
HAP Emissions from the Drying of Hemlock and Douglas-fir Lumber by NCASI 98.01 and 105. Report by Michael R. Milota to Hampton Affiliates. May 22, 2007 report.

Reference No. 16
EPA Interim VOC Measurement Protocol for the Wood Products Industry - July 2007 presented at http://www.epa.gov/ttn/emc/prelim/otm26.pdf

Notes
VOC determined through use of this document is referred to as WPP1 VOC. The document is alternatively known as EPA Other Test Method 26 or "OTM26."

Default formaldehyde RF of 0 and propane (an alkane) RF of 1 appear in Appendix 3 – Procedure for Response Factor Determination for the Interim VOC Measurement Protocol for the Wood Products Industry.

Reference No. 17
HAP Emissions by NCASI 98.01 and 105 from Drying of Ponderosa Pine and White Wood Lumber. Report by Michael R. Milota to Hampton Affiliates. July 25, 2007.

Reference No. 18
Milota, M.R. and P. Mosher. 2008. Emission of Hazardous Air Pollutants from Lumber Drying. Forest Prod. J. 58(7/8):50-55.

Reference No. 19
VOC Emissions From the Drying of Douglas-fir Lumber. Report by Michael R. Milota to Columbia Vista Corp. November 12, 2010.

Reference No. 20
NCASI Technical Bulletin No. 991. September 2011. Characterization, Measurement, and Reporting of Volatile Organic Compounds Emitted from Southern Pine Wood Products Sources.

Notes
Acetaldehyde and propionaldehyde RF appear in Table C-1 of Appendix C. The values are estimates based upon dividing the compound's effective carbon numbers (ECN) by the number of carbon atoms in the compound. See Attachment 2 to Appendix C.

Acrolein RF is also an estimate based upon dividing the compound's ECN by the number of carbon atoms in the compound. In this case, the RF estimate does not appear in Table C-1 of Appendix C. The value is calculated as described above pursuant to Attachment 2 to Appendix C.
RF = (ECN) / (number of carbon atoms in compound)

where ECN = 2 given the aliphatic carbon contribution of CH_2CHCHO (see Table 2.1 to Appendix C) and the number of carbon atoms in acrolein = 3.
RF = 2/3 or 0.66

Reference No. 21
Email of 03/26/12 email from Oregon State University's Michael Milota to EPA Region 10's Dan Meyer.

STIMSON LUMBER COMPANY
Environmental Affairs
520 SW Yamhill, Suite 700
Portland, Oregon 97204-1330
(503) 306-4655

18 October 2019

Mr. Doug Hardesty
U.S. EPA
1435 N Orchard
Boise, Idaho 83706

RE: Proposed Kiln Emissions Factors for Stimson, Plummer Title V Renewal

Dear Mr. Hardesty

Stimson wishes to thank EPA for the time and effort that has gone into the technical analysis needed for renewal of the Plummer facility's Title V permit. We are appreciative of the opportunity to review the proposed emissions factors for the permit analysis.

We have looked over the proposed kiln emission factors, as well as the work done by the Washington Southwest Clean Air Agency (SWCAA) and have the following comments. In general, we agree that the approach is an improvement over previous efforts and, in particularly, the use of a regression equation for the formaldehyde and methanol emissions is superior to having a single cut point.

The issue of concern is the reliance upon small lab-scale kilns to derive the emissions factors. For a number of reasons, these kilns are not representative of operations at full-scale production kilns. Based upon work that we present below, this seems to be particularly true of the OSU kiln used by Dr. Milota, which serves as the primary source of HAP emission factors for western species. The unfortunate fact is that there is very little data comparing the emissions from a small lab kiln to those of a production kiln – in fact, we are only aware of NCASI Technical Bulletin 845 from 2002. However, based upon that study, we find the following differential in measured emissions.

From NCASI Technical Bulletin 845:

Pollutant	FSK	OSU	OSU:FSK
VOC	3.5	4.3	1.23
Formaldehyde	0.016	0.021	1.31
Methanol	0.21	0.23	1.10
Acetaldehyde	0.039	0.065	1.67
Acrolein	0.006	0.009	1.50
Proprionaldehyde	0.001	0.003	3.00

FSK = Full Scale Kiln
OSU = Oregon State University lab scale kiln

We note that the OSU kiln yields a consistently higher bias in the emissions – by an average of 64%. Neither the Mississippi State nor the Horizon Engineering kilns demonstrated this consistent high bias so we do not believe it is simply a matter of the difficulty in fully characterizing the production kiln. In the technical bulletin NCASI staff come to the conclusion that "...VOC emissions measured at a small-scale kiln can reasonably approximate those from a full-scale kiln." However, this conclusion is based upon

the full sample set from multiple small scale kilns. Indeed, if we include the Phase II MSU kiln results in the analysis the average results are much closer. Unfortunately, virtually all of the western species data is from the OSU kiln, so there is a high bias. What significant differences in the operation of the OSU kiln can account for this consistently higher bias?

Unidirectional flow: Unlike full scale production kilns, the OSU kiln features unidirectional airflow. Production kilns have reversible fans that allow bidirectional air flow. The OSU design results in uneven drying that would be unacceptable in a commercial environment.

Hotter wood: The smaller charge size in the OSU kiln results in less volume of wood to absorb the thermal energy of the surrounding air. This is further compounded by the shorter linear distance the air has to travel over in the lab kiln. The result is anticipated to be hotter wood than equivalent kiln temperatures would yield in a full scale production kiln. Thus, we would expect the dry bulb temperature to be less indicative of the actual wood temperature in a full scale kiln than in the lab kilns. This is borne out by the faster drying time in the OSU kiln.

Increased airflow: Table 8.3 of NCASI Technical Bulletin 845 illustrates the dramatically enhanced airflow through the lab kiln relative to a full scale production kiln:

Table 8.3. Phase II Total Volume of Kiln Exhaust Gas per MBF

Test Charge	PSX	MSU	OSU
	$mscf \times 10^3$ per MBF		
	Direct Fired Drying Schedule		
DF1	16.90	8.36	9.19
DF2	16.10	8.72	9.01
DF3	17.30	8.74	9.11
DF4	15.10	7.67	6.61
DF5	[illegible]	[illegible]	[illegible]
DF6	17.00	8.90	8.57
Average	17.30	8.33	8.97
	Steam-Heated Drying Schedule		
SDF1	7.69	9.67	8.96
SDF2	7.48	9.96	[illegible]
SDF3	7.52	9.99	9.20
SDF4	3.44	10.90	7.22
SDF5	3.38	6.68	7.28
SDF7	3.71	7.29	8.68
Average	3.49	8.60	8.05

Note that for steam heated kilns the airflow of the OSU kiln averages over 200% greater on a per unit of lumber basis. This is likely to increase emissions by enhancing pollutant removal.

Of course, the best case scenario would be to have comprehensive production kiln test results, but this would be very expensive and difficult to acquire. And, in any event, it is not currently available. Thus, the straight-forward approach to adapting the lab kiln results is to simply adjust the lab emissions by a correction factor. Absent additional data, the NCASI Technical Bulletin is what we have available to do this. Applying such a correction factor yields the factors attached.

Thus, Stimson proposes revised emission factors for the facility. We note, however, that this accepts that temperature is a valid parameter for correlation with emissions. At this time, Stimson has not looked closely at whether moisture contents might be a useful in this regard. Less data is likely to be available for a moisture approach and it would likely suffer the same issues with scaling of lab kiln results. Further, we have largely accepted EPA's sample selection and analysis due to time constraints. Stimson may look at this in more detail as discussions continue.

We will be providing an analysis of boiler emission factors shortly.

Sincerely,

STEVEN PFTRIN
Environmental Manager

NCASI Technical Bulletin No. 845

Pollutant	Emission Rate (lb/mbf)*		# of Runs	Run ID	Location of Data within Technical Bulletin
	Full Scale Kiln	Oregon State Universtity Kiln			
VOC as carbon	3.533333	4.25	6	1 – 3 & 5 – 7	Table 8.2
Formaldehyde	0.0155	0.021	2	1 & 3	Table 9.5**
Methanol	0.205	0.225	2	1 & 3	Table 9.6**
Acetaldehyde	0.039	0.065	1	3	Appendix BB1
Acrolein	0.006	0.009	1	3	
Propionaldehyde	0.001	0.003	1	3	

* Value reflects arithmetic mean in those instances when more than one run was performed

** Run 3 data also in Appendix BB1

APPENDIX E: SEPA COMMUNICATION FROM GRAYS HARBOR COUNTY

From: Jane Hewitt
To: Ron Burch
Subject: RE: SPI Aberdeen Dry Kiln Rebuild
Date: Monday, April 6, 2020 8:08:55 PM

Ron,
Sorry for the delay in responding. SEPA is not required and Grays Harbor County does not need a copy of previous SEPA determinations with the application. I don't have ready access to this as I am working from home.
I hope you are well.
Best regards,
Jane

Jane W. Hewitt
Jane W. Hewitt, Principal Planner
Grays Harbor County
Planning & Building Division
100 W. Broadway Suite 31
Montesano, WA 98563
360-249-4222 ext. 1684
jhewitt@co.grays-harbor.wa.us

From: Ron Burch <RBurch@spi-ind.com>
Sent: Thursday, March 26, 2020 11:32 AM
To: Jane Hewitt <JHewitt@co.grays-harbor.wa.us>
Subject: SPI Aberdeen Dry Kiln Rebuild
Jane,
Hopefully things are well for you during this unique time. During our February 26 meeting, we discussed the scope of the lumber dry kiln replacement project at SPI's Aberdeen facility and the various associated permits required prior to project commencement. We also discussed SEPA, and there was agreement that, because the project will not significantly expand the scope, footprint, or impact of the facility, a new SEPA checklist would not be needed, and the project would be covered under the existing DNS previously issued by the county. We would like to include a scan of the DNS with our permit applications, and are unable to locate it in our files; could you please send me a scan?
Thank you

Ron Burch
Aberdeen Division Manager
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