

Emissions from the drying of Douglas-fir lumber

Report to
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Summary

One charge of borate-treated 2x4 Douglas-fir lumber was dried in a small kiln at Oregon State University. The kiln dry- and wet-bulb temperatures were based on a schedule provided by Exterior Wood. The maximum temperature was 145°F (63°C). The air velocity was 750 feet per minute (3.7 m/s). The kiln was indirectly heated with steam. The amount of air entering the kiln was regulated to control humidity.

A JUM VE-7 total hydrocarbon analyzer was used to measure organic emissions following EPA Method 25A. The results are shown in Table 1.

Table 1. Summary of total hydrocarbon results to 15% moisture content. VOC units are pounds per thousand board feet.

Charge	Initial MC	Final MC ^A	Time to 15% ^A	VOC ^B
	%	%	hr:min	lb/mbf
Douglas-fir	49.6	14.6	39.70	0.24

^A actual time to 14.6% MC was 41:00 hours

^B as carbon

NCASI Method ISS/FP-A105.01 was used to measure the MACT HAP emissions. The results are shown in Table 2. The sum of the HAPs emitted was 0.072 lb/mbf for Douglas-fir.

Table 2. Summary of HAP results for moisture content and time shown in Table 1. Emissions units are pounds per thousand board feet.

	Methanol	Phenol ^A	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
Douglas-fir	0.013	0.000	0.001	0.057	0.005	0.0000

^A None detected

1. Description of source

The tested source is a lumber dry kiln. Lumber destined for the mill's kiln was sampled and tested in a small-scale kiln at Oregon State University.

Mill personnel reported that sampling was done late in the week of April 30 shortly after the lumber had been through the treating process.

Enough wood for two charges of lumber was delivered to Oregon State by Robert Babb of Exterior wood on May 5, 2012. The wood was sorted into two 33-board units and wrapped in plastic lumber wrap at the mill to prevent predying and loss of organic compounds during transit. The wood appeared to be very fresh. There was no mold on the sapwood.

On May 5, 2012, the wood was placed in a refrigerator (Figure 1) at 35°F. Drying of the charge was started on May 8, 2012.



Figure 1. Wood in refrigerator.

2. Date and time of test

The charge was dried from May 8, 2012 at 8:00 am to May 10, 2012 at 1:00 am. Drying was done under the supervision of Mike Milota at Oregon State University. Students were used to monitor parts of the test.

3. Results

Total hydrocarbon

See Table 1, page 1, for a summary of the hydrocarbon results. Details for each sampling interval are tabulated and the hydrocarbon emissions are summarized graphically here. All emission data is presented in detail in electronic form in Appendix 2.

A summary for each sampling interval is in Table 3. An interval is the period between analyzer calibrations, about six hours of data. The interval time periods shown in the table include the calibration times and mass calculations are adjusted to account for these. Sampling occurred for approximately 95% of the drying time.

Figure 2 shows total hydrocarbon concentration (left scale) and dry gas vent rate (right scale) versus time. Concentration peaks at approximately two hours as the kiln is coming to temperature and venting is low and concentration decreases when venting increases at two hour. The vent rate shows an increase starting at approximately 12 hours when the wet-bulb decreases (schedule is shown on page 8, figure 14). The aberration at 35 hours is because the kiln was opened to check wood moisture content. The aberration at 40 hours is because kiln control ceased for approximately 10 minutes. It was reset for the last hour of drying.

Figure 3 shows the cumulative hydrocarbon emissions (left scale, black line) and the rate of emissions (right scale, jagged line) versus time. The cumulative emissions is the emissions up to any point in time in the schedule. The rate of emissions is how much is coming out per unit time. The maximum emission rate occurs at two hours as the kiln starts to vent and the concentration is high. There is a slight increase at 15 to 20 hours when the kiln temperature rises from 140°F to 145°F. It then steadily decreases as the moisture loss from the wood slows.

Perhaps more useful is Figure 4 which shows the total hydrocarbon emissions as a function of wood moisture content. This graph would be useful for predicting emissions at various final moisture content levels.

Table 3. Summary of results for each sampling interval for total hydrocarbon.

Sample Run	Time hrs	Average Humidity kg/kg	Flow rate		THC mass as C g	THC concentration		THC mass as C lbs/mbf	THC rate as C lb/hr/mbf	Average MC		
			Dry @68 l/min	Wet @68 l/min		wet ppmv	dry ppmv			Wood %	Air %	Analyzer %
1	1.75	0.041	169.4	180.6	0.51	15.9	16.9	0.014	0.0080	49.4	6.2	6.2
2	5.36	0.091	252.5	289.5	2.67	19.8	22.1	0.073	0.0136	43.4	12.8	12.8
3	4.16	0.083	205.6	233.0	1.06	12.5	13.8	0.029	0.0070	35.4	11.8	11.8
4	7.16	0.072	179.0	199.9	1.42	11.3	12.4	0.039	0.0054	28.7	10.4	10.4
5	5.16	0.054	190.9	207.4	0.97	10.2	10.9	0.026	0.0051	23.0	8.0	8.0
6	4.56	0.047	142.8	153.7	0.68	12.8	11.7	0.019	0.0041	20.0	7.1	7.1
7	5.16	0.048	107.6	115.9	0.68	13.6	13.6	0.019	0.0036	17.9	7.2	7.2
8	3.30	0.048	86.9	93.7	0.36	13.2	14.1	0.010	0.0030	16.4	7.2	7.2
9	3.10	0.048	87.5	94.3	0.35	13.4	14.3	0.010	0.0031	15.4	7.1	7.1
Sum	39.70				8.7			0.238				
Average		0.059	158.0	174.2		13.6	14.4		0.0059			

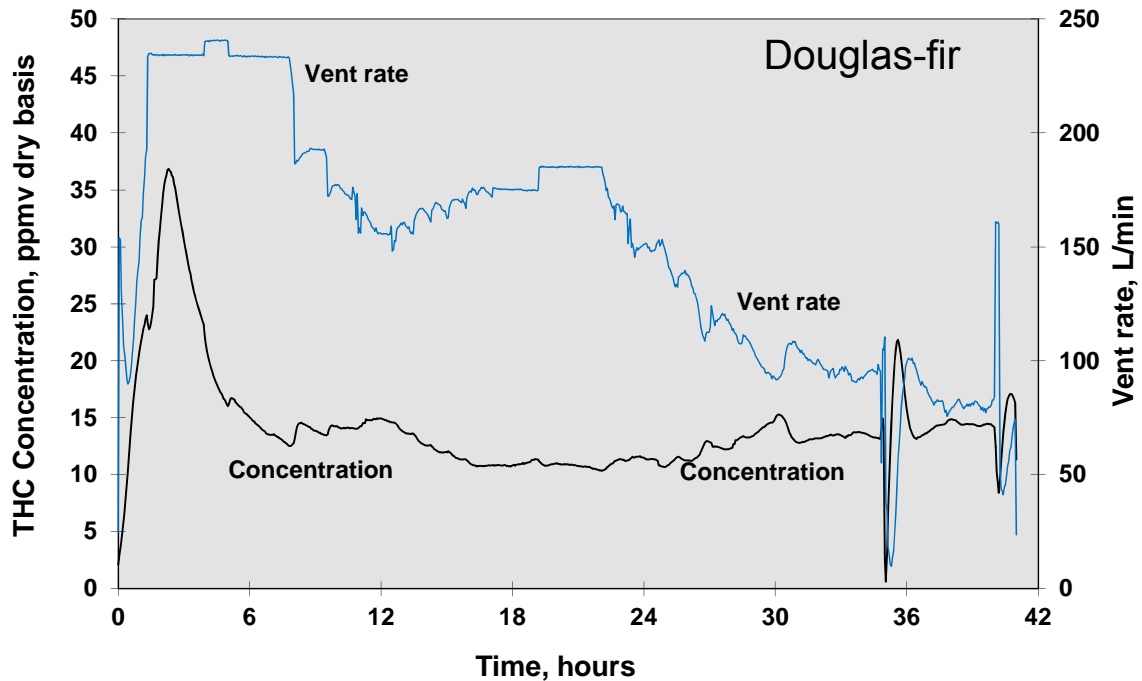


Figure 2. Hydrocarbon concentration and vent rate versus time.

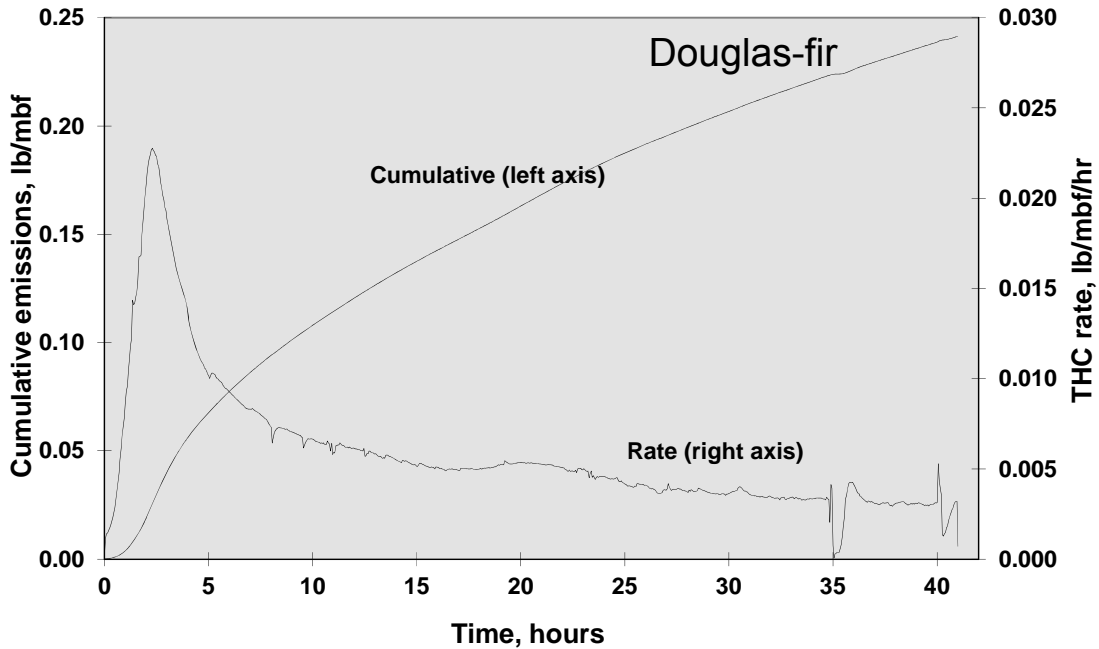


Figure 3. cumulative hydrocarbon emissions (left scale, black line) and the rate of emissions (right scale, jagged line) versus time.

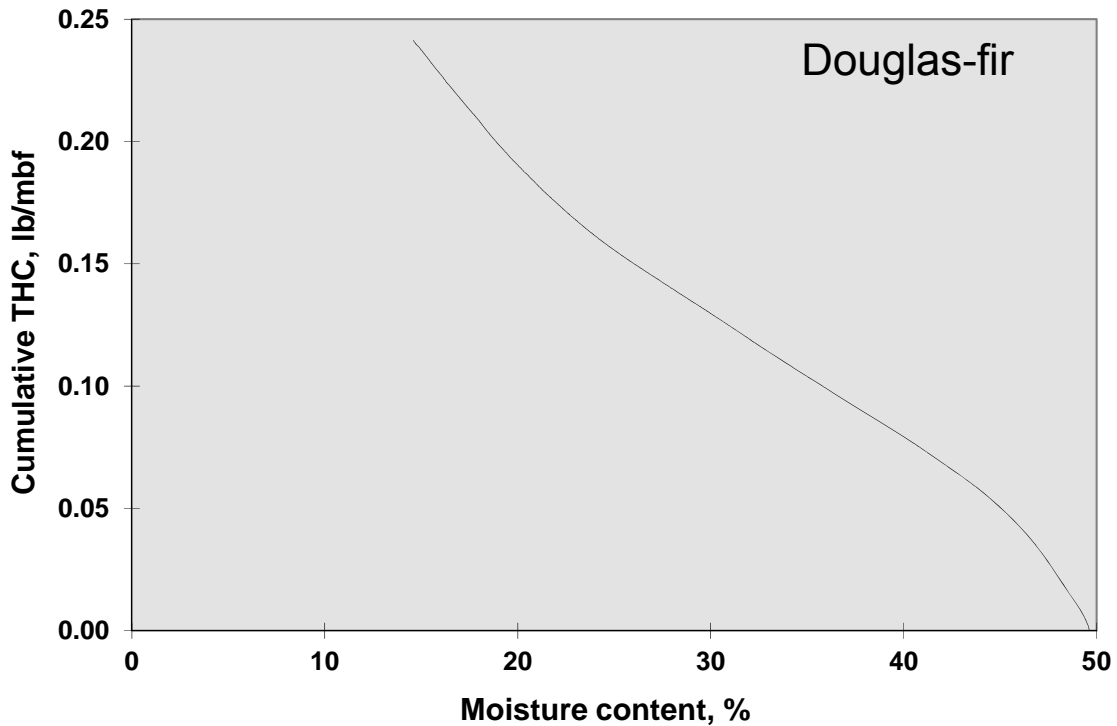


Figure 4. Total hydrocarbon emissions as a function of wood moisture content.

HAPs

See Table 2, page 1, for a summary of the HAP results. Details for each sampling interval are tabulated and the HAP emissions are summarized graphically here. All emission data is presented in detail in electronic form in Appendix 2.

A summary of the kiln conditions for each sampling interval is in Table 4. A collection interval is the time the impingers were on and sampling occurred, approximately 1:15 to 1:30. An adjusted interval is the period spanning the midpoints between collection intervals, about three hours. For example, if the impingers were on from 1:30 to 3:00, 4:30 to 6:00, and 7:30 to 9:00, the 4:30 to 6:30 impinger set represents the interval from 3:45 to 6:45. The mass calculations are adjusted proportionally to represent emissions during the adjusted interval. For example, if a collection interval was one hour and the adjusted interval was three hours, the amount of HAPs in the impinger is multiplied by three. Sampling occurred for approximately 50% of the drying time.

The MACT HAP emissions and the emissions of ethanol and acetic acid are shown in Table 5. The total HAP emissions were 0.072 lb/mbf for Douglas-fir (does not include the non-HAPs, ethanol and acetic acid). Acetaldehyde is the HAP emitted in the greatest quantity followed by methanol. The other HAPs are present, but comprise only 3% of all the HAPs. Phenol was not detected in any sample.

The HAP emissions as a function of time and wood moisture content during the cycle are shown in Figures 5 and 6, respectively. The rate of HAP emissions decrease with time and almost constant or increases slightly with decreasing moisture content.

Table 4. Summary of HAP sampling intervals.

Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass	Average Dry gas flow rate	Molar Humidity	Moisture Content	
						Mid	End
	hours	hours	kg	kg/min	mol/mol	%	%
1	1.43	2.25	30.576	0.226	0.062	49.5	47.8
2	1.45	3.00	55.127	0.306	0.115	44.7	41.7
3	1.55	3.00	53.410	0.296	0.104	39.0	36.6
4	1.47	2.95	41.341	0.233	0.103	34.6	32.7
5	1.50	3.00	37.178	0.206	0.100	30.9	29.3
6	1.50	3.26	43.267	0.222	0.088	27.7	26.0
7	1.50	3.00	41.835	0.232	0.079	24.6	23.4
8	1.50	3.25	44.066	0.226	0.070	22.1	21.1
9	1.52	3.00	32.633	0.181	0.067	20.2	19.5
10	1.50	3.00	25.600	0.142	0.067	18.9	18.3
11	1.47	3.00	23.147	0.128	0.067	17.7	17.1
12	1.45	3.00	18.530	0.103	0.067	16.6	16.2
13	1.47	3.00	20.084	0.111	0.068	15.7	15.3
14	1.50	0.95	5.917	0.104	0.067	15.0	15.0
SUM		39.70					

Table 5. Summary of the HAP and acetic acid and ethanol emissions.

Sample Run ID	Interval Endpoint	Wood Moisture Content	Unit mass leaving kiln							
			Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	hours	%	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	2.25	47.8	0.0015	0.0000	0.0000	0.0193	0.00003	0.0048	0.00003	0.00000
2	5.26	41.7	0.0019	0.0000	0.0000	0.0226	0.00015	0.0075	0.00008	0.00000
3	8.26	36.6	0.0001	0.0000	0.0000	0.0120	0.00010	0.0060	0.00007	0.00000
4	11.21	32.7	0.0001	0.0000	0.0000	0.0124	0.00006	0.0048	0.00004	0.00000
5	14.22	29.3	0.0010	0.0000	0.0000	0.0128	0.00006	0.0052	0.00005	0.00000
6	17.47	26.0	0.0020	0.0000	0.0001	0.0106	0.00005	0.0048	0.00004	0.00000
7	20.48	23.4	0.0003	0.0000	0.0000	0.0223	0.00007	0.0040	0.00006	0.00000
8	23.73	21.1	0.0002	0.0000	0.0001	0.0142	0.00007	0.0040	0.00003	0.00000
9	26.74	19.5	0.0012	0.0000	0.0000	0.0119	0.00003	0.0037	0.00004	0.00000
10	29.74	18.3	0.0012	0.0000	0.0000	0.0103	0.00004	0.0031	0.00004	0.00000
11	32.74	17.1	0.0017	0.0000	0.0000	0.0040	0.00002	0.0034	0.00003	0.00000
12	35.75	16.2	0.0009	0.0000	0.0000	0.0044	0.00001	0.0028	0.00002	0.00000
13	38.75	15.3	0.0009	0.0000	0.0000	0.0066	0.00003	0.0027	0.00003	0.00000
14	39.70	15.0	0.0004	0.0000	0.0000	0.0023	0.00001	0.0007	0.00001	0.00000
		Sums:	0.013	0.000	0.000	0.166	0.001	0.057	0.0005	0.0000

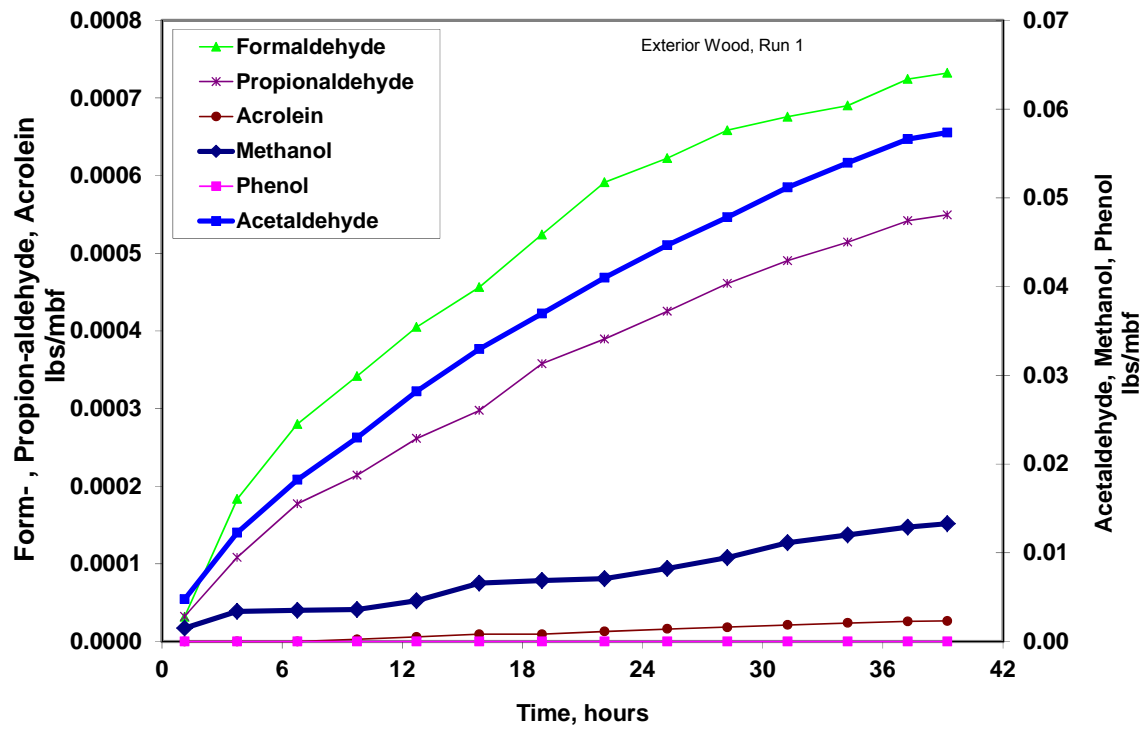


Figure 5. HAP emissions as a function of time.

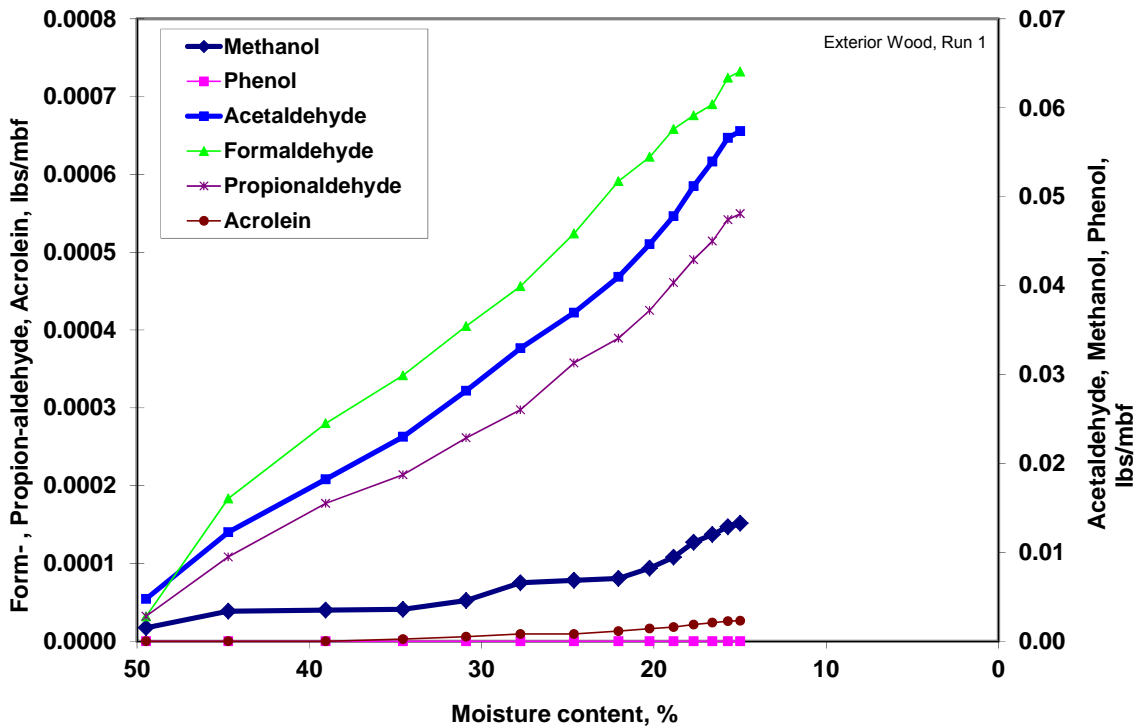


Figure 6. Hap emissions as a function of moisture content.

The detection limits for the GC instrument were

- Methanol – 3.8 µg/mL in the aqueous phase
- Phenol – 0.18 µg/mL in the aqueous phase
- Ethanol – 0.38 µg/mL in the aqueous phase
- Acetic acid – 1.78 µg/mL in the aqueous phase
- Formaldehyde - 0.04 µg/mL in the hexane phase
- Acetaldehyde – 0.08 µg/mL in the hexane phase
- Propionaldehyde – 0.08 µg/mL in the hexane phase
- Acrolein – 0.24 µg/mL in the hexane phase

The method detection limit varies with gas flow through the impingers and the amount of solution in the impingers. Typical (based on the flow conditions and impinger volumes for sample 5) method detection limits in the sampled gas are

- Methanol -4.1 ppm in the kiln exhaust
- Phenol -0.1 ppm in the kiln exhaust
- Ethanol – 0.3 in the kiln exhaust
- Acetic acid – 1.0 in the kiln exhaust
- Formaldehyde -0.01 ppm in the kiln exhaust
- Acetaldehyde - 0.02 ppm in the kiln exhaust
- Propionaldehyde - 0.01 ppm in the kiln exhaust
- Acrolein - mean = 0.04 ppm in the kiln exhaust

All methanol, ethanol, and acrolein samples were below the detection limits. All phenol samples were no detects. Propionaldehyde sample 8 was below detection limits. If one-half the detection limit is substituted for all methanol, ethanol, acrolein samples and sample eight for propionaldehyde, the emissions are shown below. Only the methanol changes significantly and total HAPs change to 0.090 lb/mbf from 0.072 lb/mbf.

Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
0.031	0.000	0.000	0.166	0.001	0.057	0.0005	0.0007

Field spikes were run by operating two impinger trains simultaneously. An aliquot of the compounds was added to one impinger train. Spike recovery percentage is the mass of a compound detected in the lab compared to mass added to the impinger. Table 6 shows the field spikes from sample nine. Recoveries in field spikes in runs four eight, and nine ranged from 71.0% to 106.7%..

The results for a field blank collected during run 11 are shown in Table 7. None of the target compounds were detected in the blank.

Duplicate samples were run by operating two impinger trains simultaneously. The results of duplicates are shown in Table 8. The percentage is the difference between the gas concentrations detected by each impinger. Phenol was not

detected so duplicates could not be compared. Differences ranged from 0.7 to 25.1% with the exception of one methanol sample at 59%. However, both the sample and the duplicate were below the detection limit in this case.

Table 6. Example of spike test results.

Alcohol Spike									
Run	Mass in impinger				Impinger flow mL/min	Mass corrected for flow			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
	µg	µg	µg	µg		µg	µg	µg	µg
9	49.2	0.0	0.0	507.8	323.5	33.2	0.0	0.0	343.0
903	731.5	109.5	789.2	2552.4	218.5	731.5	109.5	789.2	2552.4
Spike mass g	Spike concentrations					Spike recoveries			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
1.07	913.3	117.7	940.5	2264.3		71.5	87.0	78.4	91.2

Aldehyde Spike									
Run	Mass in impinger				Impinger flow mL/min	Mass corrected for flow			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg		µg	µg	µg	µg
9	1.3	156.9	1.5	0.1	323.5	1.8	213.9	2.1	0.2
902	33.5	678.4	12.9	0.1	441.1	33.5	678.4	12.9	0.1
Spike mass g	Spike concentrations					Spike recoveries			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
1.05	27.4	305.1	7.4	26.9		72.5	95.5	91.6	-0.1

Table 7. Results for the field blank.

Field blank							11B
Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 8. Results for duplicate runs.

Duplicate									
Run	Mass in impinger								Impinger flow
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	
2	45.1	0.0	0.0	541.8	3.6	179.6	1.8	0.0	321.6
202	33.3	0.0	0.0	666.2	5.0	242.3	2.5	0.0	437.0
Difference, %	59.0	#DIV/0!	#DIV/0!	10.0	0.5	0.7	0.8	#DIV/0!	
Duplicate									
Run	Mass in impinger								Impinger flow
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	
10	66.7	0.0	0.0	555.0	1.9	168.9	1.9	0.1	323.1
1002	93.1	0.0	0.0	589.5	2.5	234.0	2.2	0.1	441.9
Difference, %	2.1	#DIV/0!	#DIV/0!	25.1	7.0	1.3	16.0	3.0	

4. Control system and operating conditions

A schematic of the kiln is shown in Figure 7(top). The kiln box is approximately 4' by 4' by 4'. It is indirectly heated by steam. Four dry-bulb thermocouples and two wet-bulb thermocouples are located on the entering-air side of the load. The dry-bulb thermocouples are spaced in a grid. The two wet-bulb thermocouples are under a single sock at the center of the entering-air side of the load.

Humidity control

A 200 L/min MKS mass flow meter controlled the amount of air entering the kiln. It was factory calibrated and checked using a bubble meter. The amount of air entering the kiln is based on the wet-bulb temperature - if it is above setpoint, the airflow is increased and if it is below setpoint the airflow is decreased. This is analogous to venting for a commercial kiln. A minimum of 5 L/min entered the kiln at all times, more than removed by the analyzer (1.6 L/min). Putting air into the kiln at a rate of 100 L/min causes the pressure in the kiln to be 60 to 130 Pa above ambient, depending on location in the kiln (high-pressure or low-pressure side). Thus, any fugitive leakage should be out of the kiln. Two additional flow meters can be manually set to provide additional airflow. Flow meter two was used between hours 1.5 and 11.5 of the 41-hour charge. Flow meter three was used from hour 4 to 5

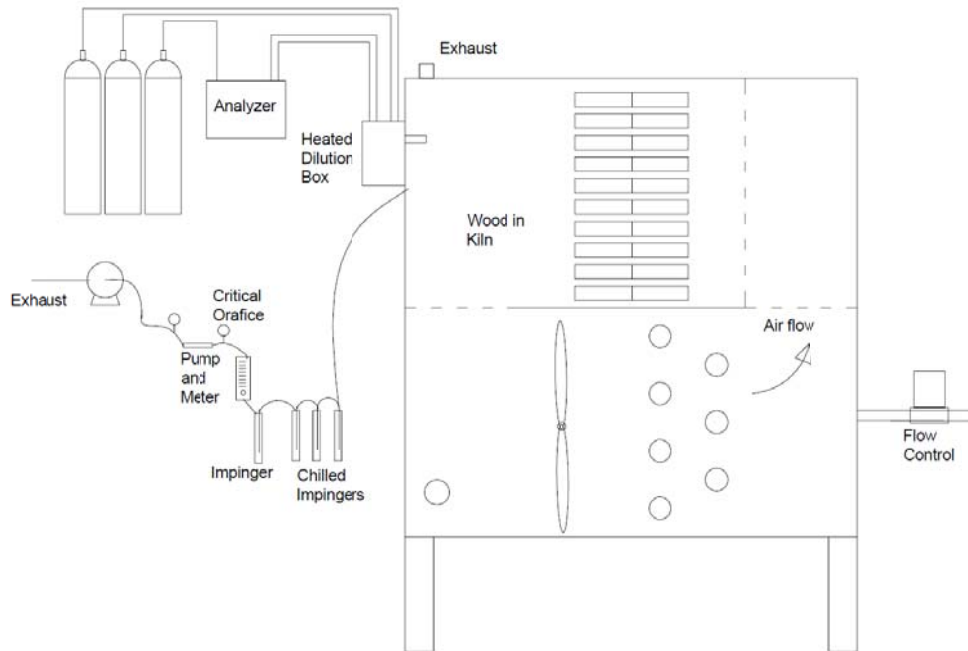


Figure 7. Schematic of kiln and sampling system (top) and photo of kiln charge (bottom).

Temperature control

Temperature in the kiln is controlled by indirect steam heating. When the dry-bulb temperature is below setpoint, the steam pressure in the coil is increased. When it is above setpoint, steam flow to the coil is reduced.

The dry- and wet-bulb temperatures recorded for each charge are shown in Figure 8. The schedule provided by the mill is also shown. The agreement is close. We lacked enough venting capacity between hours 2 and 6 which caused the wet-bulb to rise 4 to 5 degrees above the desired. This is why flow meters 2 and 3 were used as noted above. The kiln was opened at 35 hours to check the moisture content of the wood. At 40 hours kiln control stopped (because we had anticipated no longer than a 36-hour drying time); however, the recording system kept recording. At 40:10 we reset the controller and continued as normal to the end of the charge (41 hours).

Wood quantity

The wood properties were determined using the nominal wood dimensions (2x4 in this case) which provides for 0.66 board feet per lineal foot. There were 33 pieces in the kiln at 44" in length. The board footage was therefore 80.6 board feet. This quantity was used to express the emissions from the drying cycle on a production basis of lb/mbf (pounds per thousand board feet). The actual dimensions of the wood before drying were 1.58" x 3.57 ".

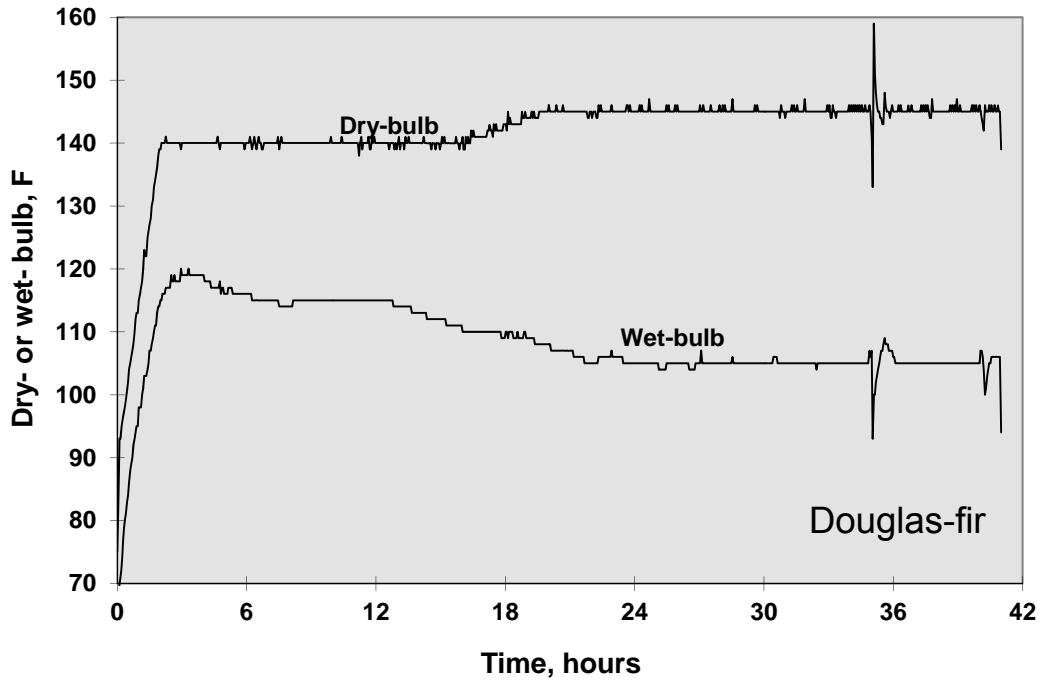
Wood properties

The wood property measurements are shown in Table 9. Individual measurements can be found in the Excel file "Weights, Exterior Wood.XLS" in Appendix 2.

Heartwood percentage was determined by estimating the heartwood percent at each end of the board and averaging all pieces.

The average ring count was determined by counting the rings over a 2" radial distance, dividing by two, and averaging for all boards.

The knots were counted on the top face of each board and averaged. This was a count of all knots. Knot diameter is an average of the knots present. The knots occupied less than 0.5% of the boards' faces.



**Drying Schedule
Exterior Wood**

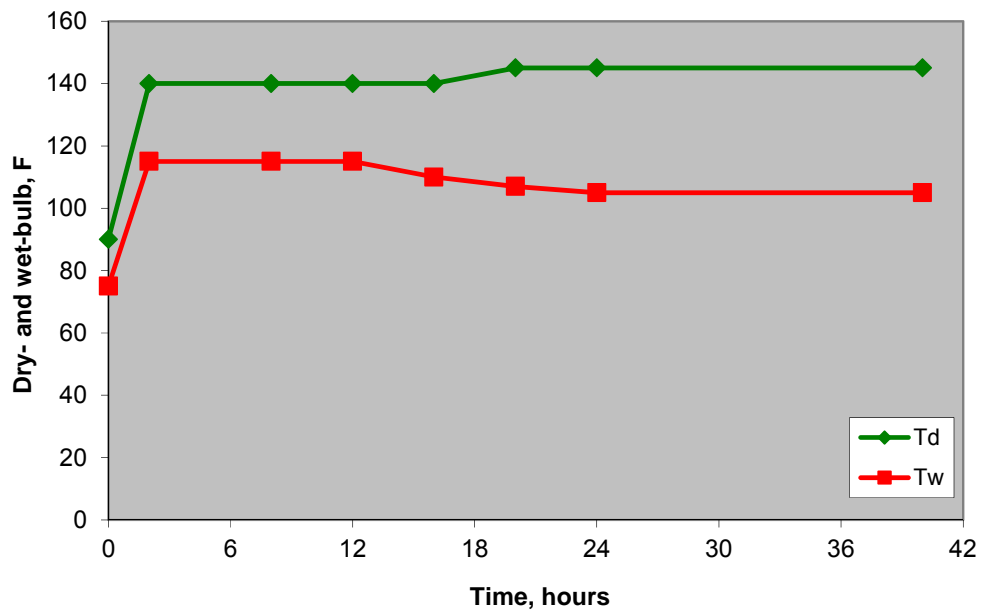


Figure 8. Schedule followed (top) and schedule provided by mill (bottom).

Table 9. Wood properties.

Charge	Knots		Heartwood	Ring count	Pith In
	Number	Size			
	#	In.	%	#/in	# with pith
Douglas-fir	3.9	0.7	38	7.1	4 of 33

6. Test methods

Charge Sequence

The lumber was unwrapped and 2" were trimmed from each end of each board to give 44" samples. These were then weighed, placed in the kiln and dried. At the end of drying the wood was weighed, oven dried, and reweighed so initial and final moisture contents could be determined by ASTM D4442 (oven-dry method).

Sampling Methodologies

Hydrocarbon

Sampling for total hydrocarbon is done directly from the kiln as shown in Figure 7 (top). The concentration obtained from the hydrocarbon analyzer and the amount of air entering the kiln allow the total hydrocarbon emissions to be calculated.

Figure 9 shows the hydrocarbon sampling system. Unlike stack testing, all necessary equipment is permanently mounted on the kiln and flows are controlled with valves. The sample is withdrawn from the kiln under the assumption that the gas in the kiln is well-mixed and that the composition in the kiln near the exhaust is the same as the composition of the exhaust. The THC sample was drawn from the kiln directly into a heated dilution/filter box mounted on the side of the kiln. The box was heated to 250°F. Heated dilution gas can be added to the hydrocarbon sample gas to lower the gas moisture content to the detector. Dilution air would have been used when the gas moisture content in the kiln was greater than 15% so that the air moisture content to the detector remained less than 15%. The sample line from the box to the analyzer was heated to 275°F. The 3-way valve at the back of the analyzer was heated to 295°F.

The fuel gas was hydrogen. The span gas was EPA Protocol 99 ppm propane in air, the mid-gas was EPA Protocol 25 ppm propane. The zero gas was <0.1 ppm air. Detailed sampling procedures are in Appendix 1.

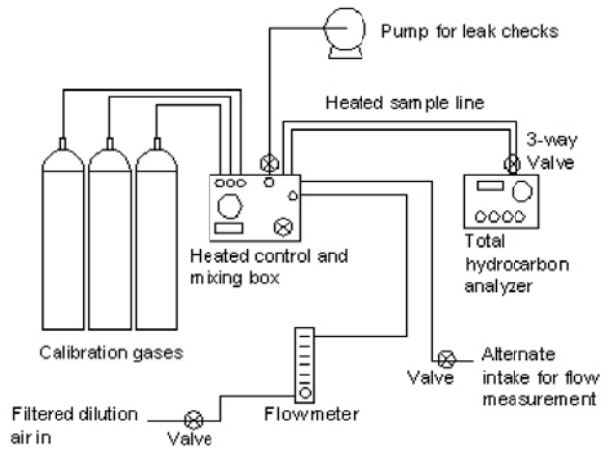


Figure 9. Schematic of heated filter box with air dilution system, heated sample line, and analyzer (left). Sample enters heated box from back of drawing (box is attached to kiln). Photo (right) of heated box (large white box), calibration gases in (valves upper left), dilution air valve (lower left), line to analyzer (green line at left), and valve for alternate air intake (top right).

HAPs

The sampling train for NCASI Method 105 is shown in Figure 10. The impingers were in a glycol solution maintained at -1 C. Prior to each sampling interval, the impingers were laboratory-washed and 10 to 15 mL of BHA solution were added to the first and second impingers. The third impinger was left empty. The fourth impinger was present in the system to prevent any overflow from reaching the critical orifice. The system was then assembled and a vacuum check was performed with the valves at each end closed. Less than 1" Hg of pressure change over 2 minutes was acceptable. This was met for each interval. The flow rate through the system was then measured using a Gilibrator flow meter to take four flow readings at the probe tip. This was approximately 240-500 mL/min, depending on the sampling train. The probe tip was then inserted into the kiln and the sampling interval begun. The collection interval time was approximately 1:30 and an interval was started approximately every three hours.

The sampling line(s) was rinsed at the end of each sampling interval and the flow rate was again measured. The fluid in the three impingers was weighed and placed in a glass bottle. The impingers were then rinsed with 10 mL of water followed by 3 to 5 mL of hexane. The rinses were also placed in the bottle and it

was sealed. Samples were kept refrigerated and in the dark until lab analysis was done. Lab analysis was done within one week of sample collection.

The local airport altimeter setting and the lab temperature were recorded at the beginning and end of each interval so the flow rates could be adjusted to standard conditions.

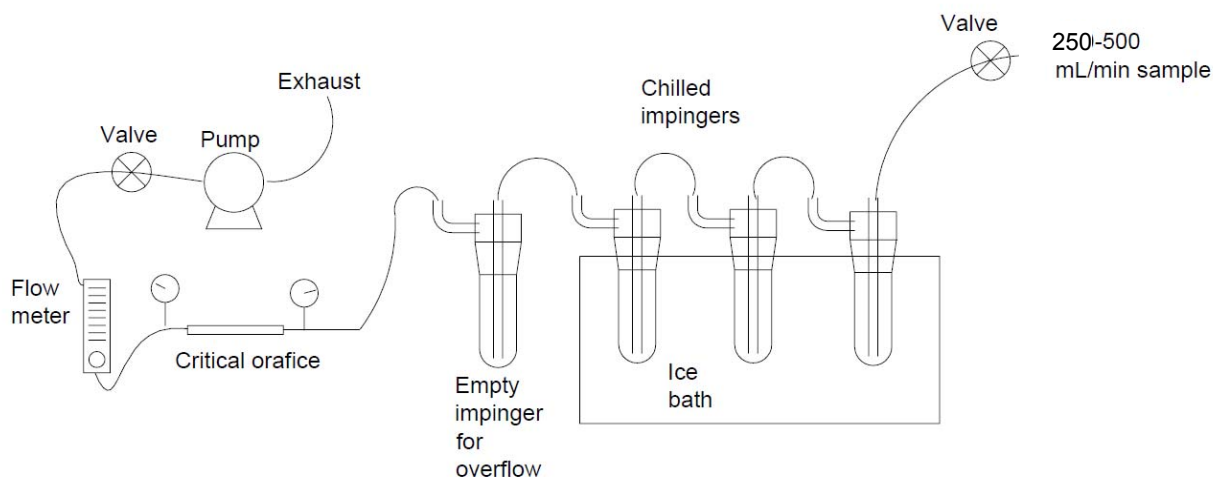


Figure 10. HAPs sampling train.

7. Analytical procedures

Hydrocarbon

Leak checks of the VOC sampling train were conducted before and after the charge was dried. A valve was closed at the probe tip and a 3-way valve was closed at the back of the analyzer. All components from just behind the probe tip to the valve at the back of the analyzer were placed under a 15-20 inHg vacuum. Less than one inHg pressure change during two minutes is acceptable and this was met.

Total flow and sample flow to the analyzer were checked using an NIST-traceable flow meter. Total flow is measured with the dilution gas off and is equal to both the sample flow from the kiln when the dilution is off and the total volume drawn by the analyzer. Sample flow is measured with dilution gas on (if used for that interval) and is the volume of gas sampled from the kiln when the dilution gas is on. This was done at the beginning and end of each sampling interval. The

meter was attached to the system near the probe tip within the heated box. The valves were repositioned so that the sample came from the flow meter (attached to the alternate intake in Figure 9) rather than the kiln. Readings of flow were made with the dilution gas both off and on. The flow readings were verified by observing the analyzer reading for span gas with the dilution gas off and on. The dilution ratio calculated based on the analyzer readings was always within 5% of that determined by the flow meter and usually within 2%. Note that dilution was not actually used for this test because the kiln wet-bulb was low enough that the gas moisture content was less than 15%.

Calibration of the zero and span of the detector was done at the beginning of each run (about every three to six hours). The calibration gas was introduced by setting the valves so the calibration gas entered the system near the probe tip at ambient pressure. The calibration was checked at the end of each run with no adjustments made to the instrument's zero or span during the run. A span drift less than 10% of the span value was acceptable. A zero drift of less than 3% of the span value was acceptable. A total calibration drift less than 10% was acceptable for a sampling run. These criteria were met.

HAPs

Lab analysis for aldehydes

Aldehyde standards were prepared by the volumetric dilution of neat aldehydes in water (to 250 ppm for formaldehyde, propionaldehyde, acrolein and acetaldehyde). This stock solution mixed with a solution of ortho-benzylhydroxylamine hydrochloride (BHA) and water (30g BHA per liter of water). The BHA solution was vigorously agitated and allowed to sit for six hours to allow for derivatization of the aldehydes into aldoximes. The derivatized aldehyde solution was extracted with three aliquots of hexane to create a 400 ppm stock solution in hexane. This was volumetrically (but calculations based on mass) diluted to make standards down to 0.2 ppm. 1.9 mL aliquates were place in GC autosampler vials with 20 μ L of 8800 ppm nitrobenzene added to each as an internal standard.

The samples (from the bottles collected in field) were prepared by extraction in a separatory funnel with two 5-mL aliquots of hexane, the bottle was rinsed with 5 mL of hexane and this was then used for a third extraction, and finally the sepratory funnel was rinsed with 5 mL of hexane. The total hexane volume was approximately 20 mL. The volumes of the two phases were calculated from their weights. A 1.5 mL aliquot of the hexane fraction was transferred to an autosampler vial and spiked with internal standard.

The analytical instrument was a Shimadzu GC model 2010 with a flame thermionic detector (FTD), the Shimadzu equivalent of a nitrogen phosphorous detector (NPD). The column was a 105-meter Restek RTX-5 capillary with a 0.25 mm outside diameter and a stationary phase thickness of 0.25 μ m. The oven

schedule was: 2 minutes at 120°C, 2°C/min ramp to 160°C, 40°C/min ramp to 220°C and 6.5 minutes at 220°C. The column flow was 25 cm/sec, with 3 mL/min septum purge, and a 1:10 split ratio with a glass wool packed split injection liner. The detector make up He was set to 20 mL/min and the H₂ was set to 3 mL/min. The air was set to 140 mL/min, and the source current was set to 2 pA. The He and H₂ gases were grade 5 and the air was grade 0.1. The injector temperature was 200°C and the detector temperature 280°C. An AOC-20i autosampler was used to perform 1 µL injections using a 10 µL syringe with a steel plunger.

Lab analysis for alcohols

Standards for methanol, phenol, ethanol, and acetic acid were prepared by the volumetric dilution of neat reagents in water. The mixed standard was prepared at a concentration of 1000 milligrams per liter (mg/L). Additional standards were prepared by the volumetric dilution of the mixed standard at a range from 1 mg/L to 500 mg/L. Aliquots of these were placed into autosampler vials with 20 mL of 20,000 ppm cyclohexanol internal standard..

Samples were prepared by transferring aliquots of the previously hexane extracted aqueous fractions into autosampler vials and adding internal standard. The analytical instrument was a Shimadzu GC model 2010 with a FID detector. The column was a 60-meter Restek Stabilwax capillary with a 0.53 mm outside diameter and a stationary phase thickness of 1.5 µm. The oven schedule was: 3 minutes at 80°C, 10°C/min ramp to 240°C, and 10 minutes at 240°C. The column flow was 30 cm/sec, with 3 mL/min septum purge, and a 1:10 split ratio with a glass wool packed split injection liner. The detector make up He was set to 25 mL/min and the H₂ was set to 50 mL/min. The air was set to 500 mL/min. The He and H₂ gases were grade 5 and the air was grade 0.1. The injector temperature was 175°C and the detector temperature 250°C. An AOC-20i autosampler was used to perform 1 µL injections using a 10 µL syringe with a PTFE plunger.

8. Field data sheets and sample calculations

Field data sheets

Samples of field data sheets are shown in Figures 11 to 14. All field data sheets are in Appendix 2 this report in electronic format (pdf).

486-570

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - BEFORE

BACKGROUND INFORMATION
 Event (kiln charge): Exterior Wood 1
 Run: 6
 Operator: MRM
 Date: 5-9-12
 Dry-bulb temperature: 145
 Wet-bulb temperature: 105
 Target Dilution Ratio (TDR): 1
 Laboratory temperature: 79 °F

ANALYZER CALIBRATION (change pots to calibrate) [Valves 1, 2 = off; 3=on; 4=vent]

Range	Analyzer, reading	Computer, ppm	Within range	Pot settings
zero	0.0 (0)	-0.0 (0)		
span	9.87 (0.09)	98.6 (09)		
mid	3.53 (0.29)	35.3 (29)	22 to 27	
mid	2			

Reset range to 3. Range: _____

SET DILUTION FLOW BEFORE RUN (do not change pots)

Total flow rate (TFR): 1501 mL/min [Valves 1, 2, 3 = off; 4=meter]
 Target dilution flow rate (TDFR): / mL/min [TFR x (1 - DR)]
 Set and read dilution meter: / scfh [scfh = mL/min * 0.00212]
 Sample flow rate (SFR): 1501 mL/min [1 = on; 2, 3 = off; 4=meter]

CHECK DILUTION FLOW BEFORE RUN (do not change pots) [1, 3=on; 2=off; 4=vent]

Span/Diluted	Analyzer	DR _{Span} [Span/Diluted/Span]	DR _{Flow} [SFR/TFR]	Difference, % 100*(DR _{Span} - DR _{Flow})/DR _{Flow}

START TIME: 7:34 (clock) [1, 2, 5 = on; 3, 4 = off; tank valves off]

ANALYZER RANGE: 2 [0.6 < reading < 7.5]

ANALYZER RANGE ON COMPUTER (set to match analyzer): 2

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - AFTER

Operator: MRM
 Run (sample): 6
 Event (kiln charge): Exterior Wood 1
 Laboratory temperature: 79 °F
 END TIME: 12:04
 Range setting on Analyzer: 2 on Computer: 3
 Reset range to 3. Range: _____

CHECK DILUTION FLOW AFTER RUN (do not change pots) [1, 3=on; 2=off; 4=vent]

Span/Diluted	Analyzer reading	Computer, ppm

Sample flow rate (SFR): 1484 mL/min [1 = on; 2, 3 = off; 4=meter]

Read dilution meter: / scfh

Total flow rate (TFR): / mL/min [1, 2, 3 = off; 4=meter]

Dilution ratio (DR_{Flow}): 1 [SFR/TFR]

CHECK OF ANALYZER CALIBRATION (do not change pots) [1, 2=off; 3=on; 4=vent]

Analyzer reading	Computer, ppm	Within range	Pot settings
span 9.53	95.3	94 to 104	450
mid 3.44	34.3	22 to 27	
zero 0.0	0.0	-5 to +5	479

Dilution ratio (DR_{Span}): / [Span/Diluted / Span]

Dilution ratio difference: / % [100*(Abs(DR_{Span} - DR_{Flow}))/DR_{Flow}]

End time for check: 12:07

Comments: _____

Figure 11. Sample of field data sheet for hydrocarbon analyzer.

249-2.17

FIELD DATA SHEET, 105 HAPS MEASUREMENT
TRAIN #1 - BEFORE SAMPLE

Operator: J.C. Event (kiln charge): Exterior Wood 1
Date: 5-8-12 Run (sample): 5-A

Altimeter setting: 30.09 inHg
Isopropanol rinse or lab wash:

IMPINGER WEIGHTS		(add BHA to impingers)	
	Dry Weight, g	Wet Weight, g	BHA added, g
Impinger #1A	41.54	<u>61.07</u>	(-10 mL)
Impinger #1B	42.22	<u>56.38</u>	(-15.20 mL)
Impinger #1C	42.33	-----	-----
Total BHA added:			

Optional Spike: g Spike type: Alcohol Aldehyde
(date impingers to kiln from scale)

Lab temperature: 82 °F
Leak check: Vacuum 16 inHg Lost after 2 minutes 0
Sample flow rate: 362.9 mL/min (Average of 4, Label printout)
Put sample line in kiln CLOCK TIME: 8:06
ELAPSED TIME: 9:00

Is the sample line in the kiln?
Is gas flowing (look at flow meters)?

FLOW METER READINGS DURING TEST (every 20 minutes)			
Clock time	<u>8:20</u>	<u>8:41</u>	<u>9:00</u>
Vacuum, inHg	<u>18.5</u>	<u>24.8</u>	<u>28.8</u>
Flow rate, mL/min	<u>325</u>	<u>325</u>	<u>325</u>

ON at 8pm
OFF at 9:30

FIELD DATA SHEET, 105 HAPS MEASUREMENT
TRAIN #1 - AFTER SAMPLE

Operator: MJM Event (kiln charge): Exterior Wood 1
Run (sample): 4-A

Altimeter setting: 30.09 inHg
Sample line rinse vial: 10.06 g (with ~5 mL DW)
Lab temperature: 80 °F
Remove sample line from kiln Clock time: 18:28
Elapsed time: 10:28

(rinse sample line then measure flow rate)
Sample flow rate: 370.7 mL/min (Average of 4, Label printout)
(date impingers to scale from kiln)
Sample line rinse vial: 13.62 g (empty)
Empty bottle weight: 126.23 g (with lid)

IMPINGER WEIGHTS			
	Wet Weight, g	Dry Weight, g	Water removed, g
Impinger #1A	<u>66.20</u>		
Impinger #1B	<u>56.33</u>		
Impinger #1C	<u>43.44</u>		

Bottle weight without impinger rinse: 164.76 g (with lid)
(date impingers with 10 mL DW)
Bottle weight with impinger rinse: 174.44 g (with lid)
(rinse impingers with 5 mL DW)
Filled bottle weight: 172.18 g (with lid)
Fluids lost during handling: 0 mL

Comments: _____

Figure 12. Sample of field data sheet for HAPs collection.

Start	Date	Time
End	5/8/2012	

Charge: Exterior Wood 1

Clock time	Elapsed time	Run #	Temperatures			Chiller °C	Valve °F	Flows						Vacuum						
			T dry °F	T wet °F	Box °F			Line °F	Flow 1 L/min	Flow 2 L/min	Flow 3 L/min	Dilution SCFM	Line 1 ml/min	Line 2 ml/min	Line 3 ml/min	Line 1 inHG	Line 2 inHG	Line 3 inHG		
8:20	0:20	1	98	79	249	292	275	-1	57				0	0325				29		
9:21	1:01	1	124	103	260	298	275	-1	195	43			0	033				29		
9:46	1:47	2	135	111	252	289	275	-1	194	43										
10:04	2:04	2	140	116	250	293	275	-1	193	43.5			0							
10:56	2:56	2	139	115	250	298	275	-1	193	43.5			0							
11:53	3:53	2	140	115	250	295	275	-1	193	43			0	350	450			28	275	
12:27	4:27	2	140	117	250	298	275	-1	179	41	50		0	350	450			28	275	
13:55	5:55	2	140	115	250	287	275	-1	193	43			0							
14:55	6:55	2	140	114	250	288	275	-1	173	15	0		0	350	450	375		28	275	29
15:59	7:59	3	140	115	250	289	275	-1	179	16	0		0							
16:59	8:59	3	140	115	250	293	275	-1	179	0	0		0	350	450	33		28	275	29
17:58	9:58	3	140	115	250	299	275	-1	176	0	0		0							
19:07	11:06	3	140	115	250	290	275	-1	158	0	0		0							
20:08	11:59	4	140	115	250	288	275	-1	157	0	0		0	325				28.5		
20:56	12:56		139	114	250	298	275	-1	162	0	0		0	325				28.8		
21:55	13:55		140	113	250	289	275	-1	169	.02	0		0							

Flow 3 to 50 at 11:54
Flow 3 off at 10:1

Figure 13. Sample of kiln log data sheet.

Extension
Wood
5-8-12

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES
 370.7 370.7 01
 371.1 370.9 02
 371.6 371.2 03
 370.5 371.0 04
 371.6 371.1 05

1A
PRE

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES
 1618 1618 01
 1619 1518 02
 1618 1618 03
 1616 1618 04

THE
1A PRE

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES
 362.4 362.4 01
 363.0 362.7 02
 362.8 362.7 03
 362.8 362.8 04

1A
POST

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES
 340.4 340.4 01

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES
 1488 1488 01
 1490 1489 02
 1490 1489 03
 1488 1489 04

THE 1
POST

GILIBRATOR 2 WET V4.4 DATE.....
 PUMP S/N.....ID.....
 FLOW AVERAGE # SAMPLES
 1487 1487 01
 1494 1491 02
 1497 1493 03
 1491 1492 04

STIC
2 PRE

Figure 14. Sample of flow measurement record.

Calculations

The “FlowCalc” worksheet in the Excel files “Kiln,Exterior Wood.XLS in Appendix 2 shows the calculations for each 3-minute interval during the charges. Column A is a reading number. Columns B and C are the clock and charge times, respectively. Columns D/E and F/G are the average dry- and wet-bulb temperatures.

Humidity

Column H is the vapor pressure (P_{vp} , Pa) of water at the wet-bulb temperature. The absolute humidity (AbHum, $\text{kg}_{\text{water}} \cdot \text{kg}_{\text{air}}^{-1}$) is shown in column I and the molal humidity ($\text{mol}_{\text{water}} \cdot \text{mol}_{\text{air}}^{-1}$) in column J. These are calculated based on the dry-bulb temperature (T_d , °C) and wet-bulb temperature (T_w , °C),

$$P_{vp} = P_{\text{ambient}} * 10^{(16.373 - 2818.6/(T_d+273.16) - 1.6908 * \text{LOG}_{10}(T_d + 273.16) - 0.0057546 * (T_d + 273.16) + 0.0000040073 * (T_d + 273.16)**2)}$$

$$\text{AbHum} = (\text{MW}_{\text{water}} / \text{MW}_{\text{air}}) * (1 / (P_{\text{kiln}}/P_{vp}-1)) - ((T_d - T_w) * R_{\text{psy}}) / \lambda$$

$$\text{MolHum} = \text{AbHum} * \text{MW}_{\text{air}} / \text{MW}_{\text{water}}$$

where MW are molecular weights ($\text{kg} \cdot \text{kgmol}^{-1}$), R_{psy} is the psychrometric ratio ($0.95 \text{ kJ} \cdot \text{kg}^{-1} \cdot \text{K}^{-1}$), and λ is the latent heat ($2419 \text{ kJ} \cdot \text{kg}^{-1}$).

Flows

The volumetric dry gas flow rate (DryGasV, $\text{L} \cdot \text{min}^{-1}$) in column K is the flowmeter reading adjusted for the meter calibrations and the molar humidity of the entering gas. This is in standard (at 0°C) liters per minute. In column L this has been converted to a mass flow rate (DryGasM, $\text{kg} \cdot \text{min}^{-1}$) and in column M is the same information is expressed as a molal flow rate (DryGas, $\text{kgmol} \cdot \text{min}^{-1}$). These values are for the dry gas vented from the kiln.

$$\text{DryGasV} = (\text{FlowMeter1} + \text{FlowMeter2} + \text{FlowMeter3}) * (1/(1+\text{MolHum}_{\text{In}}))$$

$$\text{DryGasM} = (\text{DryGasV} \text{ L} \cdot \text{min}^{-1}) * 1/(22.4 \text{ m}^3 \cdot \text{kgmol}^{-1}) * \text{MW}_{\text{air}} / (1000 \text{ L} \cdot \text{m}^{-3})$$

$$\text{DryGas (kgmol/min)} = \text{DryGasM} / \text{MW}_{\text{air}}$$

The water removal rate (WaterVented, $\text{g} \cdot \text{min}^{-1}$) (column N) is calculated from the humidity (column I) and the gas flow (column L). The total water (column O) is an integration of column N over time.

$$\text{WaterVented} = (\text{MolHum} - \text{AbHum}_{\text{In}} * \text{MW}_{\text{Air}}/\text{MW}_{\text{Water}}) * (\text{DryGasM} * 1000 \text{ g} \cdot \text{kg}^{-1})$$

Moisture content

The moisture content of the wood at each three-minute interval (column P) was determined by reducing the moisture content of the wood from the previous value by accounting for the amount of water leaving the kiln during the interval.

$$MC = MC_{\text{Previous}} - 100 * (\text{WaterVented} / (1000 \text{ g}\cdot\text{kg}^{-1}) / \text{ODWoodWt})$$

This amount is then adjusted by adjusting the wet-bulb temperature to make the ending moisture content match that measure by ASTM D4222.

Hydrocarbon

The original total hydrocarbon analyzer reading is shown in column Q. In column R this has been corrected to compensate for the range setting switch on the analyzer. Also in column R, the THA data between sampling runs (rows labeled “test” in column AA) has been adjusted to the average of the data during the 12-minute period before and the 12-minute period after the analyzer testing and calibration time.

The dilution THA (column S) is the corrected THA reading divided by the dilution ratio (from column AA). In column T we have the opportunity to compensate for the effect of moisture on the JUM detector. Column T equals column S because dilution was used and no compensation was made. Finally in column U, the hydrocarbon concentration is converted to a dry gas basis concentration using the molar humidity (column J).

$$\text{THC}_{\text{Dry, ppm}} = \text{THC} * (1 + \text{MolHum})$$

In column V, the hydrocarbon flow rate ($\text{THC}_{\text{Vented, gCarbon}\cdot\text{min}^{-1}}$) is calculated in a manner analogous to the water flow rate using the dry gas flow rate and the hydrocarbon concentration.

$$\text{THC}_{\text{Vented}} = \text{DryGas} * (\text{THC}_{\text{Dry}} / 10^6) * \text{MW}_{\text{Propane}} * (1000 \text{ g}\cdot\text{kg}^{-1}) * (0.81818 \text{ g}_{\text{Carbon}}\cdot\text{g}_{\text{Propane}}^{-1})$$

Column W is the integral of column V over time, the cumulative hydrocarbon released up to that point in the schedule (in grams). Column X is the cumulative unit emissions, that is, column W divided by the oven-dry weight of the wood in the kiln. Column AI is the cumulative emissions in pounds per thousand board feet and column AH is the rate of emissions release ($\text{lb}\cdot\text{mbf}^{-1}\cdot\text{hr}^{-1}$)

Column Z indicates the hydrocarbon sampling run and column AA is the dilution ratio during that run.

The remaining columns are used not used in the hydrocarbon calculations. They are for graphing shown on other worksheets in the workbook.

At the end of the FlowCalc spreadsheet (at the bottom) are summaries by run of the flow data for the total hydrocarbon run intervals (interval summary button will reposition spreadsheet).

Moisture content and board weight data are on the “Define” worksheet and the original data are in the files named “Weights, Exterior Wood.XLS”.

HAPs

Within the file “HAPs, Exterior Wood.xls”, the summary page presents the data by run interval. The data is copied from the other pages to make the spreadsheet more readable.

The “Field Data” page is data transcribed from the field data sheets (copies of the sheets are included in Appendix 2 in PDF format) and includes the ambient pressure, lab temperature, flow rate through the impingers, and run start and stop times.

The “Laboratory Data” page contains results from the lab analysis for HAPs. These values come from the files “AQU, Exterior Wood.xls” and “ALD, Exterior Wood.xls” in the “Lab Data” directory. The GC retention times and peak areas and the GC calibrations are in these files.

On the “Impinger Calculations” page, the field data and laboratory data are used to give a dry gas flow rate through the impingers (columns J and K) and the mass of target compounds in the impingers (columns L to Q). Flow rates were adjusted to standard conditions in columns F and G.

$$\text{ImpgrFlow}_{\text{Std}_m\text{L}} = \text{ImpgrFlow} * (273.16\text{K} / T_{\text{meter}}) / (P_{\text{meter}} / 101.33 \text{ kPa})$$

A dry gas flow rate is calculated in columns H and I

$$\text{ImpgrFlow}_{\text{Dry}_m\text{L}} = \text{ImpgrFlow}_{\text{Std}_m\text{L}} * (1 - \text{MolHum} / (1 + \text{MolHum}))$$

The average of the before and after gas flow measurements through the impingers (column J) is then converted to a mass basis in column K.

$$\text{ImpgrFlow}_{\text{Dry}_g} = \text{MWair} * \text{ImpgrFlw}_{\text{Dry}_m\text{L}} * P / (T * R)$$

Finally, the mass of each compound recovered from the impinger is calculated in columns L to S.

$$\text{Mass}_i = (\text{Concentration}_i) / (\text{DenSolvent}) * (\text{Mass solvent})$$

The “Kiln Calculations” page uses a ratio of the dry gas flow through the kiln (calculated in the spreadsheets named “Kiln, Exterior Wood.xls” and copied to column D) to the dry gas flow rate through the impinger to scale up the quantities and obtain the mass of each compound leaving the kiln (columns I to P).

On the “Emission” page, the amount of a HAP leaving the kiln is divided by the mass (in kg) or volume of wood (in mbf) to express the emissions on a per kg of wood (columns B-I) or per mbf basis (columns J-Q). Concentrations leaving the kiln are given in columns R to AG.

The “Quality Assurance” page presents information on the spikes, duplicates and blanks. For each spike a % recovery is calculated based on the mass of a HAP recovered divided by the amount added. The difference for each duplicate is calculated as a percentage from the difference between the impingers divided by the average mass collected after adjusting for impinger flow.

The remaining pages in “HAPs, Exterior Wood.xls” are for graphing purposes.

9. Chain of custody information

Wood was collected by mill personnel and delivered to Oregon State by Exterior Wood. Wood was retained by Oregon State after delivery as documented in section 1. Field samples remained at Oregon State University.

10. Calibration documentation



Specialty Gases
 11711 S. Alameda Street
 Los Angeles, CA 90059-7100
 (323) 387-8861
 Fax: (323) 507-8869

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Part Number: E02A199E15A1472 Reference Number: 48-124221446-2
 Cylinder Number: SG9133882 Cylinder Volume: 146 Cu.Ft.
 Laboratory: ASG - Los Angeles - CA Cylinder Pressure: 2016 PSIG
 Analysis Date: Jun 04, 2010 Valve Outlet: 590

Expiration Date: Jun 04, 2013

Certificate performed in accordance with EPA Traceability Protocol (Sep. 1997) using the assay procedures listed. Analytical Methodology does not require correction for analytical interferences. This cylinder has a total analytical uncertainty as stated below with a confidence level of 95%. There are no significant impurities which affect the use of this calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
 Do Not Use This Cylinder before 150 psig (4.1 Mega Pascal)

ANALYTICAL RESULTS				
Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty
PROPANE	600.0 PPM	609.6 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS				
Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	000819	SG9107376	493.6PPM PROPANE/	Jul 01, 2013

ANALYTICAL EQUIPMENT		
Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
Nicolet 6700A Propane	FTIR	Jun 02, 2010

Triad Data Available Upon Request

Notes:


 Approved for Release



Specialty Gases
 11711 S. Alameda Street
 Los Angeles, CA 90059-7100
 (323) 387-8861
 Fax: (323) 507-8869

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Part Number: E02A199E15A1472 Reference Number: 48-124221446-2
 Cylinder Number: SG9133882 Cylinder Volume: 146 Cu.Ft.
 Laboratory: ASG - Los Angeles - CA Cylinder Pressure: 2016 PSIG
 Analysis Date: Jun 04, 2010 Valve Outlet: 590

Expiration Date: Jun 04, 2013

Certificate performed in accordance with EPA Traceability Protocol (Sep. 1997) using the assay procedures listed. Analytical Methodology does not require correction for analytical interferences. This cylinder has a total analytical uncertainty as stated below with a confidence level of 95%. There are no significant impurities which affect the use of this calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
 Do Not Use This Cylinder before 150 psig (4.1 Mega Pascal)

ANALYTICAL RESULTS				
Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty
PROPANE	600.0 PPM	609.6 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS				
Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	000819	SG9107376	493.6PPM PROPANE/	Jul 01, 2013

ANALYTICAL EQUIPMENT		
Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
Nicolet 6700A Propane	FTIR	Jun 02, 2010

Triad Data Available Upon Request

Notes:


 Approved for Release

Figure 16. Certificates for calibration gases.

11. Anomalies

The kiln was opened at 35 hours to check moisture content of the wood. We normally do not open the kiln during testing; however, drying was taking a lot longer than expected and we wanted to visually inspect the lumber and wet-bulb. Moisture meter readings indicated the lumber was over 15% moisture content; however, meters do not always work well on treated wood. The wood felt slightly damp. The kiln was closed and the wood was dried for six more hours.

At 40 hours into drying the kiln control system stopped. This occurred because we anticipated no more than 36 hours of drying time and programmed a 40-hour schedule. The control was only down for 10 minutes after which control was reset and normal drying resumed.

The aqueous fractions of samples 3A and 3C were physically mixed in the lab. The hexane extract from 3A was used for the aldehyde analysis and the aqueous portion of 3B was used for the alcohol analysis. Originally, 3A was a sample, 3B was a aldehyde spike, and 3C was an alcohol spike.

An error was made when purchasing standards. An EPA 1000 ppm certified standard of acrolein was purchased instead of neat acrolein. Hence, the acrolein concentration in the original standards was 1000 times lower than planned. A separate set of acrolein standards were mixed. The low concentration also occurred in the spike and there are not spikes for this compound. We did not rerun the charge because all the acrolein samples were below the detection limit.

12. Statement of validity

The statements in this report accurately represent the testing that occurred.



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Appendix 1. Detailed sampling procedures

Checks of kiln to record on log

Purpose: Ensure kiln is operating correctly

Clock time: Record from computer

Run time: Record from computer. Check the box if the computer screen being refreshed and time is advancing.

Box temperature: Read from plastic electrical enclosure on wall or on computer screen. The top and bottom numbers on controller should be similar and greater than the kiln temperature, 230-250°F.

Box temperature: Read from plastic electrical enclosure on wall or on computer screen. The top and bottom numbers on controller should be similar and greater than the box temperature, 255-275°F.

Valve temperature: Read from plastic electrical enclosure on wall or on computer screen. The top and bottom numbers on controller should be similar and greater than the line temperature, 290-300°F.

Dry-bulb temperature: Read from computer screen. Compare to paper graph to be sure it's correct. If it's not within a degree or two of the chart, check again in a few minutes. During startup (the first 3 or so hours), it may not be able to track. If it's too high, the heat valve should be closed, too low and the heat valve should be open. If it does not appear to be working correctly, call Mike.

Wet-bulb temperature: Read from computer screen. Compare to graph to be sure it's correct.

If the wet-bulb is too low, it means that the kiln atmosphere is too dry. Check the flow meters. If Flow1 is about 6 L/min (its lower limit), make sure that Flow2 and Flow3 are turned off. Flow2 records automatically. Enter any Flow3 change into the computer. Otherwise, call Mike.

If it's too high, then either the kiln atmosphere is too humid or the sock is not being wetted. If Flow 1 is near 200 L/min (its upper limit) add venting by opening Flow2 and/or Flow 3. Enter any Flow3 change into the computer. The maximum for Flow2 is 50 L/min, if it reads over this value for several readings, reduce it to about 45 L/min. Don't change Flow3 often, rather set it and leave it for several hours if possible. Keep the Flow 3 reading constant by small adjustments. As Flow1 decreases or Flow2 turned down, there is more pressure behind Flow3 and the flow increased. Check for water in the wet-bulb reservoir (push the float down and make sure it's getting water).

Check both Wet-bulb1 and Wet-bulb2 and make sure they are reading about the same. If they differ by more than 2°F, call Mike

If both wet-bulbs are reading the same as the dry-bulb, check the wet-bulb water.

If these procedures do not correct the wet-bulb temperature within 30 minutes, call Mike.

Chiller temperature: Read the chiller temperature. It should be about -1°C.

Flow 1: Read from computer. The value of Flow1 changes depending on the wet-bulb. If Flow 1 is 6 L/min and the wet-bulb is too low, there's probably nothing we can do. If it's 200 L/min and the wet-bulb is too high, Flow2 and/or Flow3 can be opened. Flow2 and Flow3 should be adjusted so that Flow1 stays below 175 to 200 L/min.

Flow 2: Read from computer. The value of Flow2 is set by you. It will vary a little - as flow 1 goes down, flow 2 will go up. Do not set it to > 40 L/min if you think Flow1 is going to decrease or it will go off scale and not be read by the computer

Flow 3: Read from meter. The value of Flow3 is set by you. It will vary a little - as flow 1 goes down, flow 2 will go up. Be sure to clearly record this value and when you change it. Change it on the computer screen (click on it and type the new value).

Dilution flow: Read dilution flow meter. It should read the same setting as the red flag. Do not adjust. If significantly different, investigate.

Impinger flows: Read from rotometers. This should be about 250 to 500 cc/min.

Line vacuum: Read from the vacuum gauge. This should be about 20"Hg.

Total hydrocarbon analyzer

BACKGROUND INFORMATION

Get the dry- and wet-bulb temperatures from the kiln schedule or off the computer. Use the highest expected values for the next three to six hours.

Read absolute humidity off the psychrometric chart or table.

Calculate or read from tables -

$$\text{Percent moisture} = 100 / [1 + 1 / 1.61 * \text{AbHum}]$$

$$\text{Target Dilution Ratio (TDR)} = 15 / \text{Percent Moisture}$$

Event = the name of the drying cycle.

Run = the number of the 3-hour interval.

Operator, that's you.

Date – use date VOC run will start if close to midnight

AMBIENT DATA

Read the laboratory temperature from the computer or thermometer.

ANALYZER CALIBRATION (BEFORE SIDE OF SHEET)

Set valves so that 1, 2 = OFF; 3=ON; 4=VENT. This allows gas to flow out of the vents from the calibration tanks and shuts off all other sources. Only calibration gas should go through the detector.

Open the zero gas tank valve

set analyzer to range 3

zero valve on, others off

set flow to 3 L/min using regulator on tank

wait for a stable reading (about 30 to 60 seconds)

use the zero dial (pot) on THA to get a zero reading

read the analyzer

read computer

note pot setting

Close valve on zero gas tank

Open span gas tank valve (may be 99 instead of 610)

span valve on, others off

set flow to 3 L/min using regulator on tank

wait for a stable reading (about 30 to 60 seconds)

use the span dial (pot) on THA to get a reading of 610ppm

read the analyzer and record, eg, record 6.10

read computer (should read about 610)

record pot setting
Leave span tank valve open

Open mid gas tank valve
mid valve right on, others off
set flow to 3 L/min using regulator on tank
wait for a stable reading (about 30 to 60 seconds)
read and record analyzer and computer (do not adjust pot settings)
check for within tolerance
switch analyzer to range 2
read analyzer and computer
check for within tolerance
switch analyzer back to range 3
Turn off mid gas tank valve

SET DILUTION FLOW BEFORE RUN (BEFORE SIDE OF SHEET)

Set valves so that 1, 2, 3 = OFF; 4=meter. This allows gas to flow only from the meter to the detector.

Use the Gilibrator to take 4 readings of the total flow rate (TFR). This is the total flow drawn by the analyzer and should be about 1.6 L/min
Make sure the average does not include any "bad" readings
Record the average in mL/min; It should be 1500-1600 mL/min
Write the Run # and "Pre-TFR" on the Gilibrator printout.

Calculate the next two values -
Target dilution flow rate (TDFR) is the $TFR \times (1 - DR)$
Target sample flow rate (TSFR) is the $TFR \times DR$
Check that the sum of these is the Total Flow Rate

Set dilution flow
Set red pointer to desired dilution flow
Slowly open lower valve on dilution flow meter (1=ON)
Use upper valve on dilution flow meter to adjust flow
Do not adjust this meter after this point
Read the meter that you just set and record the value in SCFH
Calculate and record L/min

Use the Gilibrator to take 4 readings of the sample flow rate (SFR). This is the flow through the analyzer after dilution is set. It will vary, depending on the dilution setting.
Make sure the average does not include any "bad" readings
Record the average in mL/min
Write "Pre-SFR" on the Gilibrator printout.

CHECK DILUTION FLOW BEFORE RUN (BEFORE SIDE OF SHEET)

Set valves so that 1, 3 = ON; 2=OFF; 4=VENT. This allows gas to flow out of the vent from the calibration tank and shuts off all other sources. Calibration gas and dilution air will go through the detector.

Open span gas tank valve (should already be open)
span panel valve right (on), others down (off)
set flow to 3 L/min using regulator on tank
set analyzer to range 3
wait for a stable reading (about 30 to 60 seconds), record
turn off all calibration gas tank valves
all calibration gas panel valves off
All tank valves off

Calculate the dilution ratio based on gas flow by dividing the Sample Flow Rate by the Total Flow Rate. $DR = \text{Absolute value of } [100 * (DR \text{ Span} - DR \text{ Flow}) / DR \text{ Flow}]$

Calculate the dilution ratio based on span gas by dividing the diluted span by the undiluted span.

If the Dilution ratios do not agree within 5% - DO NOT PROCEED****. Use to calculate the % difference.

**** check calculations, check that values for ppm and flows make sense, remeasure everything. If it still does not agree, call Mike

START RUN (BOTTOM OF BEFORE SIDE OF SHEET)

Set valve so that 1, 2, 5 = on; 3, 4=off; all calibration tank valves off

Record the start time. Use the computer clock or stopwatch time.

Make sure analyzer is on appropriate range, usually range 3, to keep THC reading on computer between 60 and 600.

Monitor system, as needed. Record system condition at least hourly.

End time should be no more than 3-6 hours from start time.

POST-SAMPLE PROCEDURE - AT END OF RUN (AFTER SIDE OF SHEET)

Record your name as the operator.
Event = the drying cycle.

Run = number of the 3-hour interval.
Operator, that's you. .

AMBIENT DATA

Read the laboratory temperature from the thermometer.

Fill out appropriate information on Pre-sample side of data sheet for next run.
This will save time in between runs.

END TIME

Record computer time.
DO NOT adjust dilution gas or analyzer pots until the instructions tell you to.

CHECK DILUTION FLOW AFTER RUN (AFTER SIDE OF SHEET)

Measure diluted span gas: Set valves so that 1, 3 = on; 2=off; 4=vent. This allows gas to flow out of the vent from the calibration tank and shuts off all other sources. Calibration gas and dilution air will go through the detector.

Open span gas tank valve
span panel valve ON, others OFF
set flow to 3 L/min using regulator on tank
set analyzer to range 3
wait for a stable reading (about 30 -60 seconds)
record

Sample flow rate: Set valves so that 1=on; 2, 3 = off; 4=meter. This allows gas to flow only from the meter and the dilution to the detector.

Use the Gilibrator to take 4 readings of the sample flow rate (SFR). This is the flow through the analyzer with dilution on.

Make sure the average does not include any "bad" readings

Record the average in L/min

Write Run # and "Post-SFR" on the Gilibrator printout.

Read dilution flow meter

To calculate the L/min, divide scfh by 2.12

Turn off dilution flow meter using valve 1 (lower dilution valve)

Total flow rate. Set valves so that 1, 2, 3 = off; 4=meter. This allows gas to flow only from the meter to the detector.

Use the Gilibrator to take 4 readings of the total flow rate (TFR). This is the total flow drawn by the analyzer and should be about 1.6 L/min

Make sure the average does not include any "bad" readings
Record the average
Write Run # and "Post-TFR" on the Gilibrator printout.

Calculate the dilution ratio based on gas flow by dividing the Sample Flow Rate by the Total Flow Rate.

CHECK CALIBRATION OF ANALYZER (AFTER SIDE OF SHEET)

Set valves so that 1, 2 = off; 3=on; 4=vent. This allows gas to flow out of the vents from the calibration tanks and shuts off all other sources. Only calibration gas should go through the detector.

Span gas tank valve should be open
span panel valve ON, others down OFF
set flow to 3 L/min using regulator on tank
set analyzer to range 3
wait for a stable reading (about 30 -60 seconds)
read analyzer (do not adjust pot settings),
record, for example, 6.05 as 605
read computer (should read about the same)
note pot setting
check for within tolerance - between 582 and 619

Open mid gas tank valve
mid panel valve = ON, others OFF
set flow to 3 L/min using regulator on tank
set analyzer to range 3
wait for a stable reading (about 30 -60 seconds)
read analyzer (do not adjust pot settings),
record, for example, 2.97 as 297
read computer (should read same as analyzer)
check for within tolerance

Open the zero gas tank valve
zero panel valve = ON, others OFF
set flow to 3 L/min using regulator on tank
wait for a stable reading (about 30 -60 seconds)
read analyzer (do not adjust pot settings)
read computer
note pot setting

Close all tank valves if charge is ending

Calculate the dilution ratio based on gas concentration by dividing the Diluted span by the Span

Calculate % difference in the two dilution ratios as $100 * \frac{\text{Absolute Value (DRSpan-DRFlow)}}{\text{DRFlow}}$

Record the time now as the end time for check.

Start Pre-Sample procedure for next run.

HAP 105 Collection

BACKGROUND DATA

Begin about 15 minutes before run should start
Operator, that's you.
Date, today or tomorrow if sample will start after midnight
Event = Kiln Charge
Run = sequence of M/F measurement (1-A, or 5-C, etc)

PRE RUN DATA

Call 9-541-754-0081 and get altimeter setting.

IMPINGER WEIGHTS

Dry and weigh the impingers (weight may already be on data sheet).

Put 15 mL of BHA solution in impinger #1.
Put 10 mL of BHA solution in impinger #2.
Impinger #3 is not filled. It is for overflow.

Reweigh the impingers with the BHA solution.
Place BHA stock back into cooler
Install impingers and lower into chiller

LEAK CHECK

Read the laboratory temperature.
Close valve to sample probe.
Turn on pump (it may already be on)
Evacuate to 15 to 18 " Hg, record
Close valve that is near pump
Note pressure and start timer
Allowable pressure change is 1" Hg in 2 minutes, if it is much more than this, find the source of the leak. Record change.
Slowly open valve near probe tip so that pressure is slowly relieved.
Completely open valve near probe tip
Open valve near pump

SAMPLE FLOW RATE

Attach probe tip to Gilibrator
Take 4 readings
Make sure all readings in average are "good" readings
Record the average

START TIME

Put probe into kiln and record time.
Check meters to make sure gas is flowing

FLOW READINGS DURING TEST

Note flow meter reading at least 20-30 minutes
Run test for 1:30 or less if impingers fill

POST RUN DATA

Begin about 10 minutes before run should end
Label a sample bottle with the Event and Run numbers and record the weight.
Call 9-541-754-0081 and get altimeter setting.

END TIME

Remove probe from kiln
Record time

SAMPLE FLOW RATE

Rinse probe with 5 mL of DI water
Read the laboratory.
Attach probe tip to Gilibrator
Take 5 readings
Make sure all readings in average are "good" readings
Record the average

IMPINGER WEIGHTS

Lift impingers from chiller, take to scale, and place onto rack
Dry the outside of the impingers
Remove U tubes connecting the impingers together
Weigh sample bottle
Weigh the impingers (without stoppers) with the catch and record
Transfer the impinger contents to the sample bottle
Weigh the sample bottle and record
Rinse impingers (last to first) with 10 mL DIW (save in the sample bottle)
Weigh the sample bottle and record
Rinse impingers (last to first) with 5 mL hexane (save in the sample bottle)
Weigh the sample bottle and record
Place the sample bottle into cold storage
Record the volume of any liquids lost during this procedure.
Wash glassware with phosphate-free detergent and set out to dry.

Appendix 2. Electronic copy of data and calculations