

**VOC, Methanol, and Formaldehyde Emissions
From the Drying of
Hemlock, ESLP, and Douglas-fir
Lumber**

Report to

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Report by

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**VOC, Methanol, and Formaldehyde Emissions
From the Drying of Hemlock, ESLP, and Douglas-fir Lumber**

I. Results Summary

Three charges, containing 73.3 board feet of 2x4 hemlock lumber, were dried from green to less than 15% moisture content in a small kiln at Oregon State University. The kiln dry- and wet-bulb temperatures were provided by Hampton Lumber. The maximum temperature was 180°F (82.2°C) for the hemlock and 170°F (76.7°C) for the other species. The wet-bulb temperature was 150 °F (65°C) for the hemlock and 140°F (60.0°C) for the other species. The air velocity was 750 feet per minute (3.8 m/s). The kiln was indirectly heated with steam. There was no humidification. Regulating the amount of air entering the kiln controlled venting and the humidity.

A JUM VE-7 total hydrocarbon analyzer was used to measure organic emissions following EPA Method 25A. A chilled impinger sampling train was used to sample for methanol and formaldehyde following NCASI Method CI/WP-98.01. The results are shown in Table 1.

TABLE 1. Summary of results.

Species	Initial MC	Time ^a	VOC ^b	Methanol ^c	Formaldehyde ^c
	%	hr:min	lb/mbf	lb/mbf	lb/mbf
Hemlock	88.8	46:12	0.18	0.052	0.0007
ESLP ^d	61.8	34:38	0.33	0.029	0.0009
Douglas-fir	79.9	40:33	0.65	0.015	0.0005

^a to a 15% moisture content

^b as carbon from green to 15% moisture content

^c from green to 15% MC

^d Engelmann spruce - lodgepole pine species group

Transposed

II. Lumber Source and Handling

Enough wood for two charges of each species was delivered to Oregon State University on February 12, 2007, one charge of each to be dried and one as a backup. The wood was wrapped in plastic at the mill to prevent predrying and loss of organic compounds during transit. The wood was stored at 4°C until needed. The charges were all dried in February, one per week in the order in Table 1. The second charge of each species was not used.

III. Kiln Description and Operation

A schematic of the kiln is shown in Figure 1. 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 and measured 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 10 L/min entered the kiln at all times, more than removed through the analyzer and impinger train. 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. The steam spray line is disabled, so no water vapor is added to the kiln atmosphere.

Sampling for total hydrocarbon, methanol, and formaldehyde is done directly from the kiln as shown in Figure 1. The concentration obtained from the hydrocarbon analyzer or the impingers and the amount of air entering the kiln allow the emissions to be calculated.

Temperature control

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

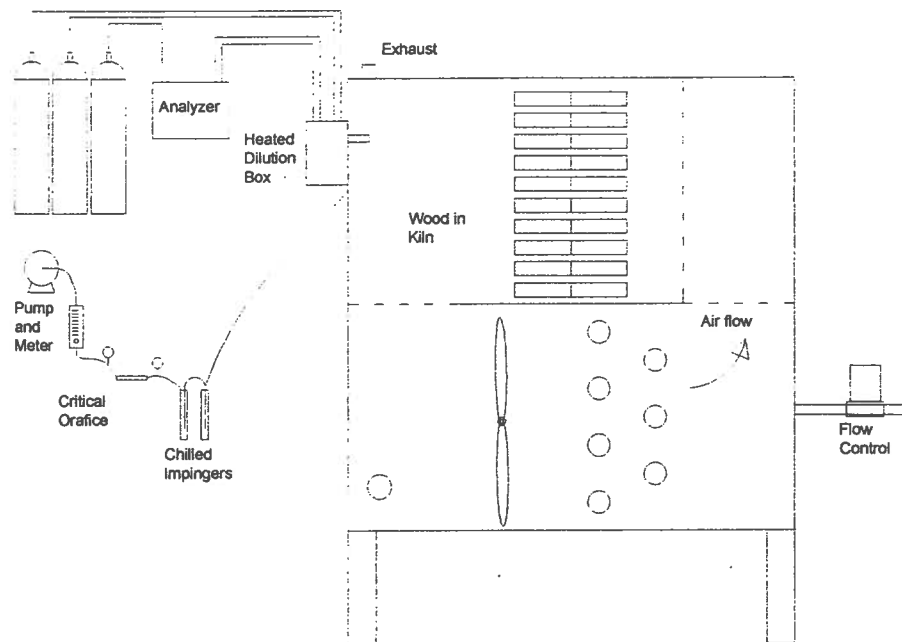


FIGURE 1. Schematic of kiln and sampling system.

Schedules

The drying schedule supplied by the mill is shown in Table 2. The values in Table 2 are based on the entering-air temperature. This represents the highest temperature the wood would experience in a commercial kiln. The actual temperatures in the lab kiln are presented in Figure 2.

Charge Sequence

After removing from the refrigerator and unwrapping, 2" were trimmed from each end of each board to give 44" samples. These were then weighed, placed in the kiln, and dried according to the schedule in Table 2. Sampling for hydrocarbon and HAPs was done as described in section IV. 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.

TABLE 2A. Drying schedule for hemlock. Drying time was 46.2 hours (46:12) to 15% and 53.8 hours to 12.1%.

Step time, hours	Ramp time, hours	Run time, hours	Dry-bulb, °F	Wet-bulb, °F
0	0	0	110	95
9	8	9	180	165
0.5	0.5	9.5	180	150
Until	dry	-	180	150

TABLE 2B. Drying schedule for the ESLP. Drying time was 34.65 hours (34:39) to 15% and 48.30 hours to 10.4%.

Step time, hours	Ramp time, hours	Run time, hours	Dry-bulb, °F	Wet-bulb, °F
0	0	0	90	80
0.5	0.1	0.5	120	110
11	11	11.5	170	140
Until	dry	-	170	140

TABLE 2A. Drying schedule for the Douglas-fir. Drying time was 40.55 hours (40:33) to 15% and 55.05 hours to 10.3%.

Step time, hours	Ramp time, hours	Run time, hours	Dry-bulb, °F	Wet-bulb, °F
0	0	0	90	80
0.5	0.1	0.5	120	110
11	11	11.5	170	140
Until	dry	-	170	140

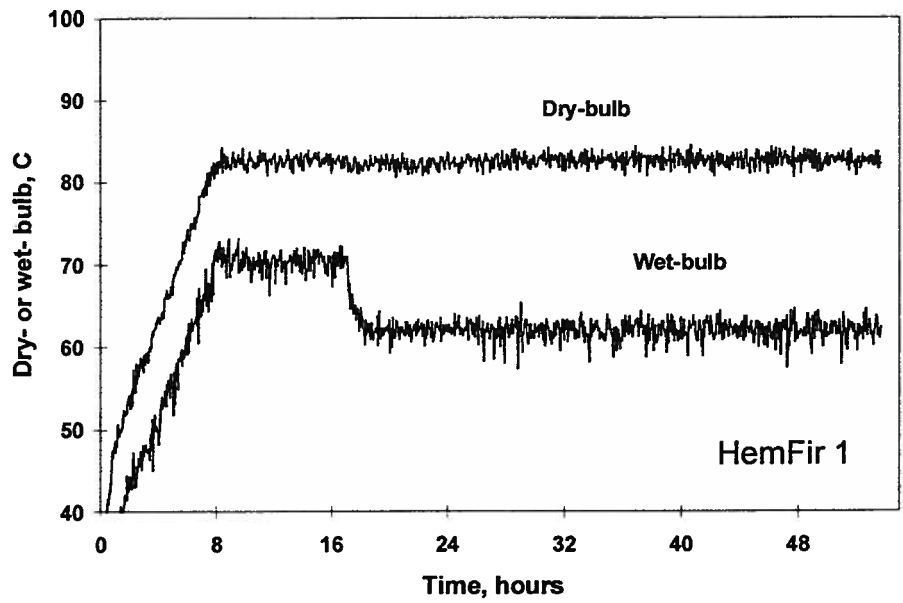


FIGURE 2A. Dry- and wet-bulb temperatures during for hemlock. 15% moisture content was reached at 46.20 hours.

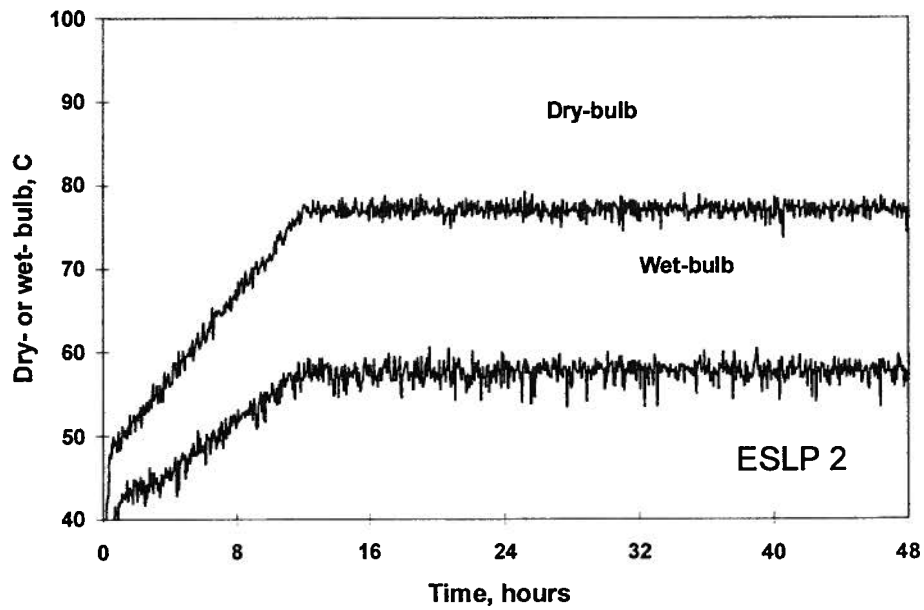


FIGURE 2B. Dry- and wet-bulb temperatures during for ESLP. 15% moisture content was reached at 34.65 hours.

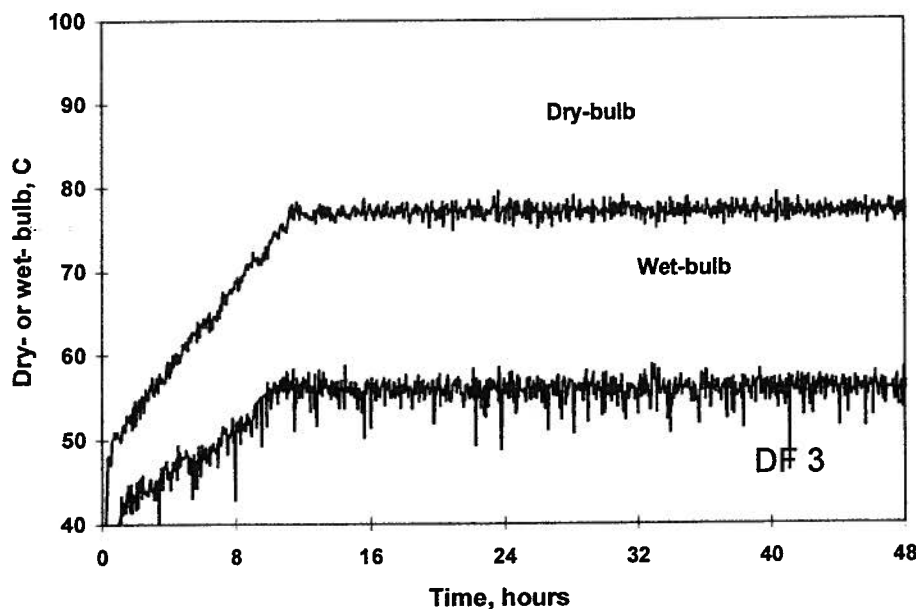


FIGURE 2C. Dry- and wet-bulb temperatures during for Douglas-fir. 15% moisture content was reached at 40.55 hours.

IV. Sampling Systems and Methodologies

Total hydrocarbon

Figures 3a and 3b show the hydrocarbon sampling system. Unlike stack testing, all necessary equipment is permanently mounted on the kiln and flows are controlled with valves and switches. 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 at the composition of the exhaust. The THC sample was drawn from the kiln directly into a dilution/filter box mounted on the side of the kiln. The box was heated to 125°C. Heated dilution gas can be added to the hydrocarbon sample gas to lower the gas moisture content to the detector. The sample line from the box to the analyzer was heated to 133°C. The valve at the back of the analyzer was heated to 145°C.

The fuel gas was hydrogen. The span gas was EPA Protocol 911 ppm propane in air, the mid-gas was certified 412 ppm propane. The zero gas was 0.1 ppm air. Detailed sampling procedures are in Appendix 1 and a summary is presented below.

Leak checks were conducted before and after the charge was dried. Valves are closed and all components from just behind the probe tip to the valve at the back of the

analyzer are placed under a 18-20 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. 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 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 change in the analyzer reading for span gas with the dilution gas off and on. The dilution ratio calculated based on the analyzer readings was within 1 to 2% of that determined by the flow meter. Dilution was used when the gas moisture content in the kiln was greater 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 zero or span during the run. The span drift was always less than two percent of full scale for a run and generally less than one percent. The zero drift was minimal during entire drying cycle.

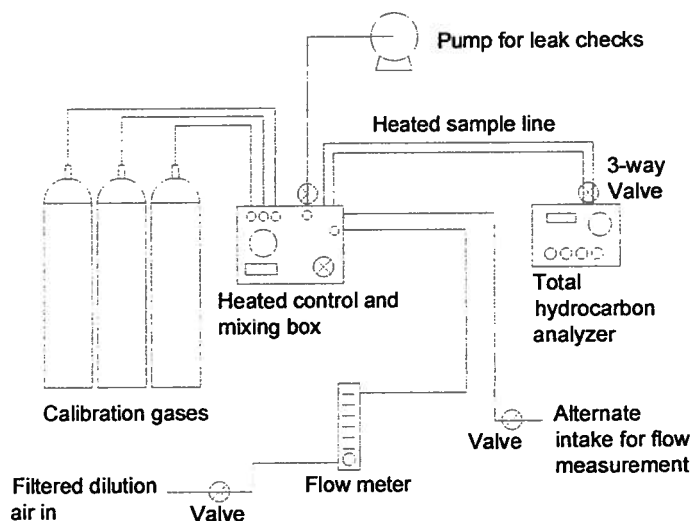


FIGURE 3A. Schematic of heated filter box with air dilution system, heated sample line, and analyzer. Sample enters heated box from back of drawing (box is attached to kiln).



FIGURE 3B. Photo of VOC sampling system showing heated sample box (with white insulation), valves and flow meter for calibration gases (upper left), on/off valve for calibration gas (3 at upper center right), heated sample line to analyzer (green tube), valve for sample (2 at center), toggle valve to vacuum pump (near calibration gas valves), vent/flowmeter valve (4 at upper right), and dilution air meter (bottom).

Methanol/formaldehyde

The sampling train for NCASI Method CI//WP-98.01 is shown in Figure 4. The impingers were in a glycol solution maintained at -1 C. Prior to each sampling interval, the impingers were rinsed and 10 mL and 15 to 20 mL of distilled water were added to the first and second impingers, respectively. The system was then assembled and a vacuum check was performed with the valves at each end closed. More than 1" Hg of pressure change over 2 minutes was unacceptable. The flow rate through the system was then measured by taking four flow readings by attaching the probe tip to a Gilibrator flow meter. This was approximately 500 mL/min. The probe tip was then inserted into the kiln and the sampling interval begun. The collection interval time varied from 3 to 6 hours, depending on the expected concentration. At the end of each interval, the flow rate was again measured. The fluid in the impingers was weighed, placed in a sealed vial, and immediately stored in a dark refrigerator. 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. Samples were kept refrigerated and in the dark until lab analysis was done. Lab analysis was done within two weeks after sample collection.

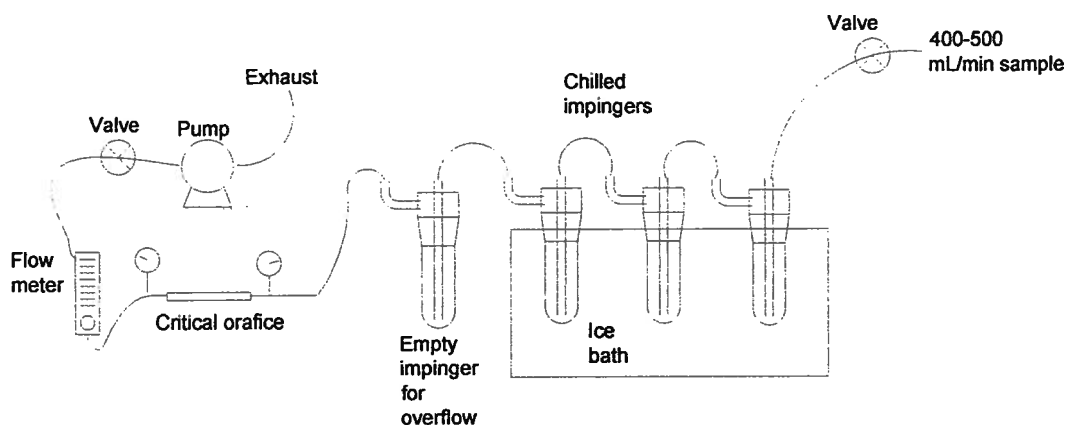


FIGURE 4. Sampling train for the methanol and formaldehyde.

Lab analyses

Methanol solutions in varying concentrations were prepared by dilution, 1 gram of HPLC grade methanol to 1000 grams with distilled water (at 20°C). This stock solution was further diluted to provide methanol solutions in the 1 ppm to 150 ppm range for use as standards.

Autosample vials for GC analysis were prepared by adding 2mL of the impinger sample or standard to a 2mL vial. These were crimp sealed and refrigerated until tested.

The GC was an Shimadzu 2010 with a 60-meter Restek Rtx-624 fused capillary column. A FID was the detection device. The column had a internal diameter of 0.53 mm and a stationary phase thickness of 3 μm . The oven schedule was: 7 minutes at 10°C, 20°C/min ramp to 200°C, and 5.5 minutes at 200°C. The column flow was 6 mL/min of He (48.1 Pa head pressure), 3 mL/min septum purge, and a 1:4 split ratio (24 mL/min through the split vent purge). 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 150°C and the detector temperature 250°C. An AOC-20i autosampler was used to perform 1 μL injections.

Formaldehyde solutions in varying concentrations were prepared by diluting 2.703 grams of formalin to 1000 grams with distilled water at 20°C. This stock solution was further diluted to provide methanol solutions in the 0.25 ppm to 10 ppm range for use as standards.

An acetylacetone reagent was prepared by dissolving 15.4 g of ammonium acetate in 50 mL of water. To this, 0.2 mL of acetylacetone and 0.3 mL of glacial acetic acid were added. This was then diluted to 100 mL and stored in the dark in a refrigerator.

A 2.0 mL aliquot of the impinger catch or standard was placed in a test tube and 2 mL of the acetylacetone reagent was added. Once mixed, the test tube was placed in a 60°C water bath for 10 minutes. The vials were allowed to cool to room temperature, then the solution was transferred to a cuvette and absorbance measured at 412 nm. For each impinger catch, two replications of this procedure were done.

V. Data Reduction and Treatment

The "FlowCalc" worksheet in the Excel file "Kiln.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 and E are the average dry- and wet-bulb temperatures. Column F is the vapor pressure at the wet-bulb temperature. The absolute humidity is shown in column G and the molal humidity in column H.

Flow calculations

The volumetric dry gas flow rate in column I 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 J this has been converted to a mass flow rate in kg/min and in column K is the same information is expressed as a molal flow rate.

Moisture calculations

The water removal rate in g/min (column L) is calculated from the humidity and the gas flow rate and the total water (column M) is an integration of column L over time.

The moisture content of the wood at each interval in the event (column N) was determined by reducing the MC of the wood from the previous value by accounting for the amount of water leaving the kiln during the interval.

Total hydrocarbon calculations

The original total hydrocarbon analyzer reading is shown in column O. In column P this has been corrected to compensate for the range setting switch on the analyzer and scaling between the analyzer reading and the computer reading. Also in column P, the THA data between sampling runs has been adjusted to the average of the data during the 12-minute periods before and/or after the analyzer testing and calibration time. The dilution THA (column Q) is the corrected THA reading divided by the dilution ratio (from column Y). In column R we have the opportunity to compensate for the effect of moisture on the JUM detector. This was not done so column R equals column Q. Finally in column S, the hydrocarbon concentration is converted to a dry gas basis concentration.

In column T the hydrocarbon flow rate in $g_{\text{carbon}}/\text{min}$ is calculated in a manner analogous to the water flow rate using the dry gas flow rate and the hydrocarbon concentration. Column U is the integral of column T over time, the cumulative hydrocarbon release up to that point in the schedule. Column V is the cumulative unit emissions, that is, column U divided by the oven-dry weight of the wood in the kiln.

Column X indicates the hydrocarbon sampling run and column Y is the dilution ratio during that run. The next two columns, Z and AA, are the cumulative dry gas and water during the kiln cycle. These are used to obtain the average gas moisture contents. The corrected wood moisture content is shown in column AC. This is the MC in column N adjusted so that the initial and final values match the values obtained by weighing. The kiln air and analyzer air moisture contents are shown in columns AD and AE.

At the end of the FlowCalc spreadsheet are summaries by run of the flow data for the total hydrocarbon run intervals and by impinger interval.

The other pages in the files "Kiln.XLS" are graphs of the data in the FlowCalc page. Moisture content and board weight data are in the files named "Board.XLS."

HAP calculations

The laboratory data reduction for the HAPs (from the field data sheets and lab analysis) is shown in electronic form in the file named "Methanol and Formaldehyde.XLS" in Appendix 2. Within this file the summary page presents the data by run interval. The "Field Data" page is the data from the field data and includes the ambient pressure, lab temperature, flow rate through the impingers, and run start and stop times. The field data sheets are presented electronically in Appendix 2. The "Concentrations" page includes the results of the lab analyses on the impinger catch. The lab data sheets are included in Appendix 2. On the "Impinger Calculations" page, the field data is manipulated to give a dry gas flow rate through the impingers (columns J and K) and the mass of methanol and formaldehyde in the impingers.

The "Kiln Calculations" page uses a ratio of the dry gas flow through the kiln (calculated in the spreadsheets named "Kiln.XLS") to the dry gas flow rate through the impinger to scale up the quantities and obtain the mass of each compound leaving the kiln (column I-M). The unit emissions in columns K-N are obtained by dividing the total emissions by either the volume or mass of wood in the kiln.

The instrument detection limits were 0.50 µg/mL for methanol and 0.12 µg/mL for formaldehyde. The method detection limit varies with gas flow through the impingers and the amount of water collected. Therefore they vary for each sample. They are approximately - 0.17 ppm for methanol and 0.03 ppm for formaldehyde.

VI. Sampling Results

Hydrocarbon

The hydrocarbon emissions are summarized graphically here. All emission data is presented in detail in electronic form in Appendix 2. The moisture content at the end of the cycle was less than 15% so the time to 15% was estimated and the emissions are reported from green to this value.

Figure 5 shows total hydrocarbon concentration and vent rate versus time. Higher vent rates for the ESLP and the Douglas-fir are due to the lower wet-bulb temperatures and low humidities. The concentration remains low while the vent rate is high, then increases. The sudden change at 15 hours for hemlock is due to a change in the schedule.

Figure 6 shows the cumulative hydrocarbon emissions and the rate of emissions 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.

Figure 7 shows the wood moisture content versus time. The estimated moisture content should most accurately represent the MC-time relationship because the initial and final moisture contents match the oven-dry test. The initial moisture content and the final moisture contents are based on the oven-dry method, ASTM D-4442.

Figure 8 shows the cumulative hydrocarbon emissions versus moisture content. The hydrocarbon emissions for drying to any moisture content can be read from this graph. This is often very linear, especially at low moisture contents. Some deviation from linearity occurred for the hemlock, probably due to the schedule change.

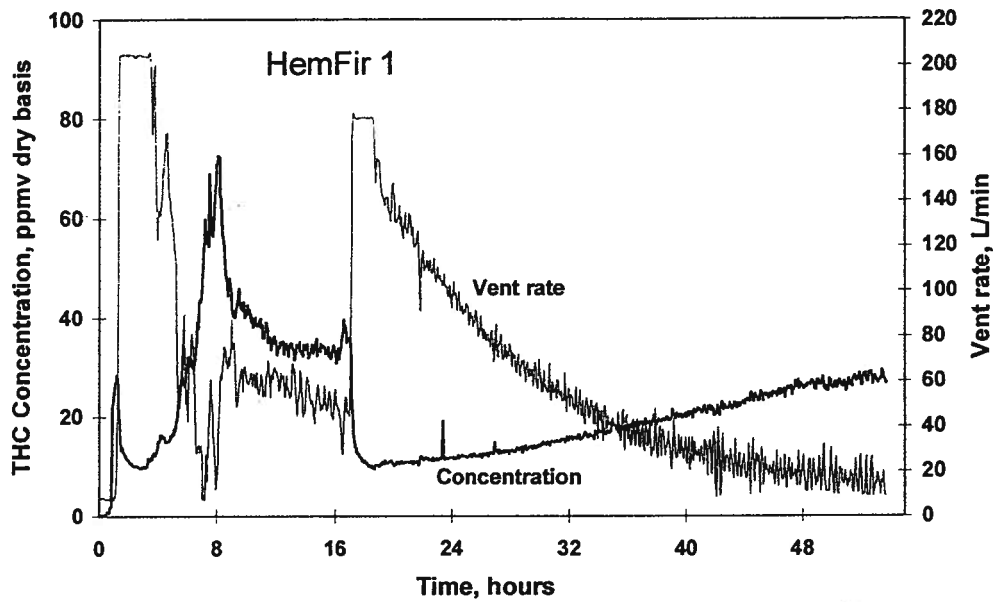


FIGURE 5A. Hydrocarbon concentration and vent rate versus time for hemlock.

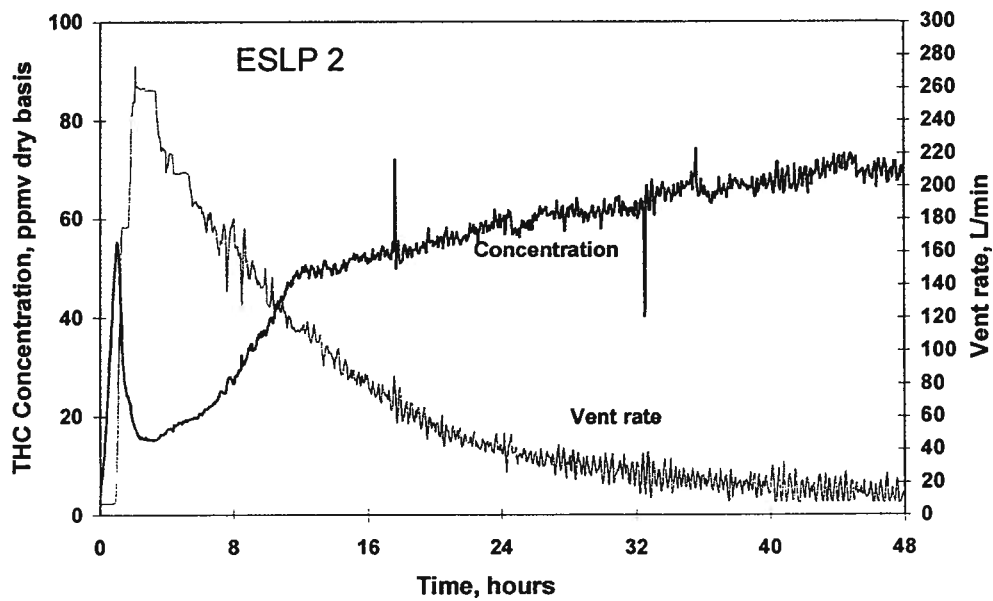


FIGURE 5B. Hydrocarbon concentration and vent rate versus time for ESLP.

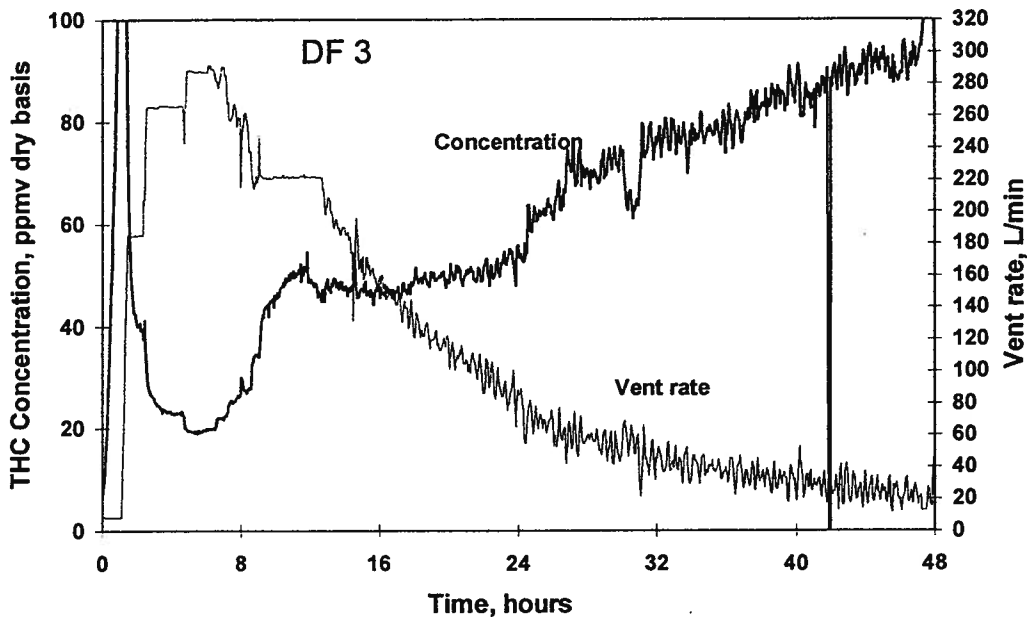


FIGURE 5C. Hydrocarbon concentration and vent rate versus time for Douglas-fir.

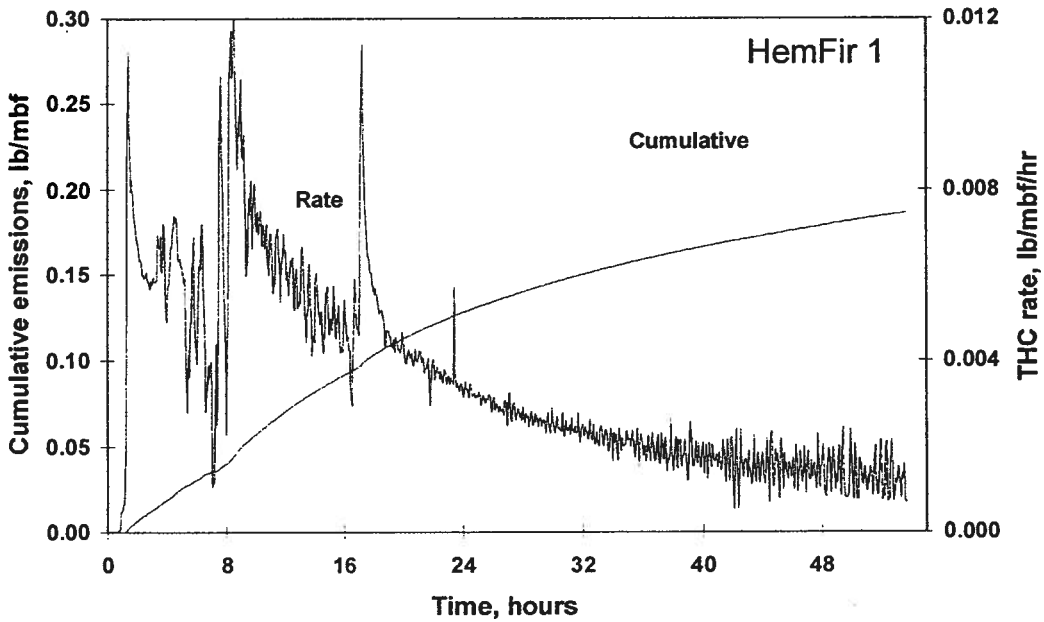


FIGURE 6A. Cumulative and rate of emissions versus time (as carbon) for hemlock.

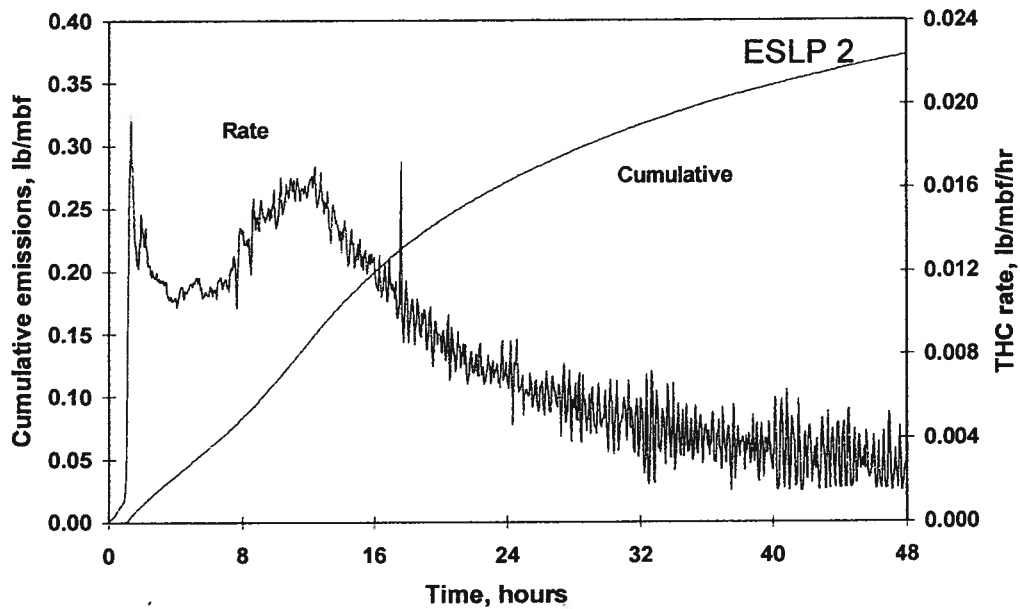


FIGURE 6B. Cumulative and rate of emissions versus time (as carbon) for ESLP.

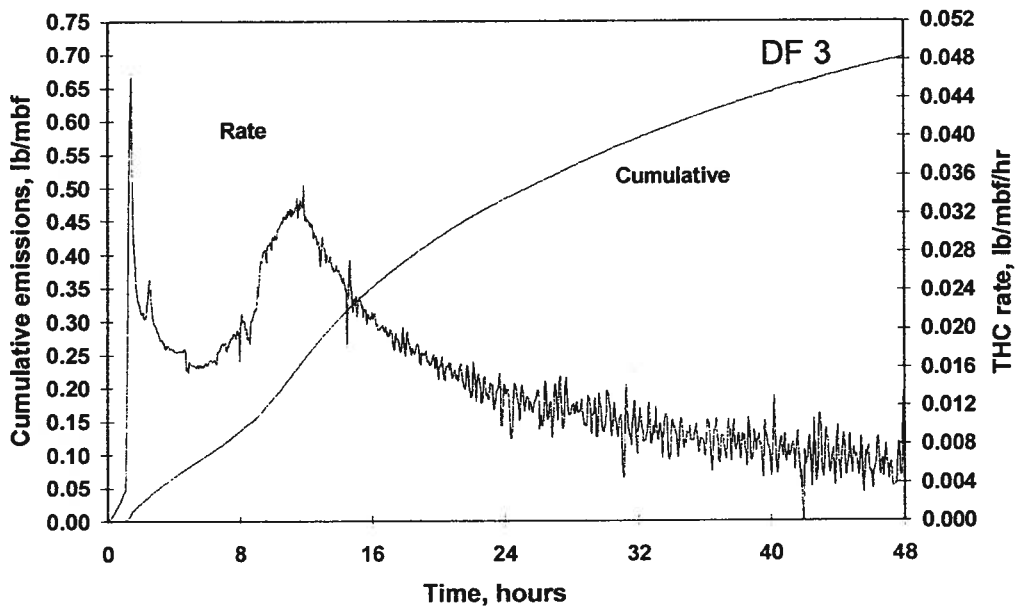


FIGURE 6C. Cumulative and rate of emissions versus time (as carbon) for Douglas-fir.

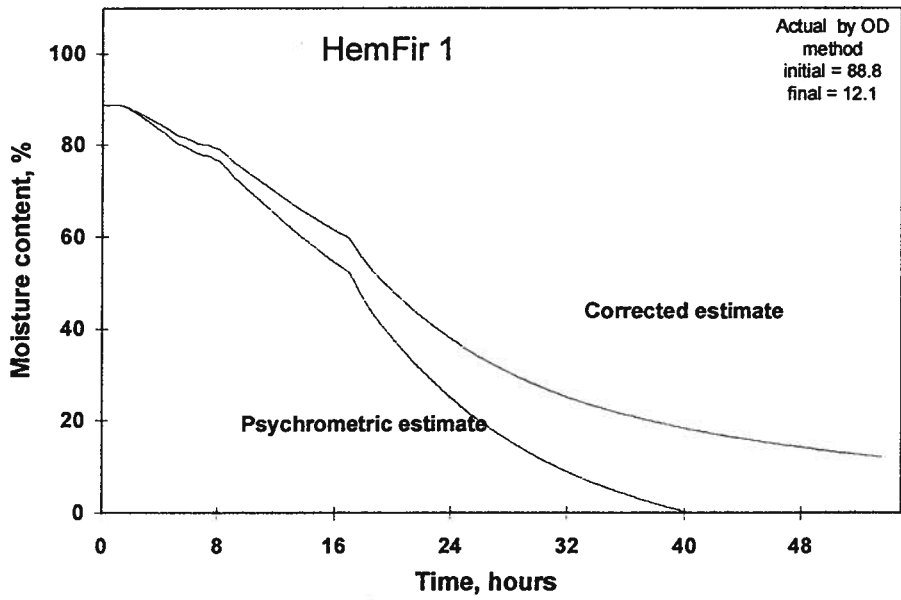


FIGURE 7A. Moisture content versus time for hemlock.

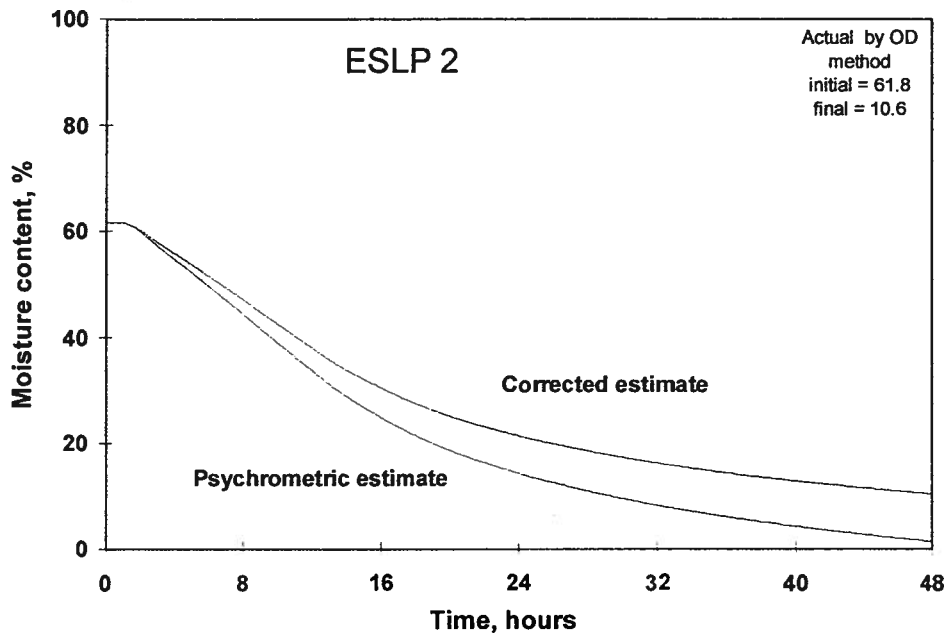


FIGURE 7B. Moisture content versus time for ESLP.

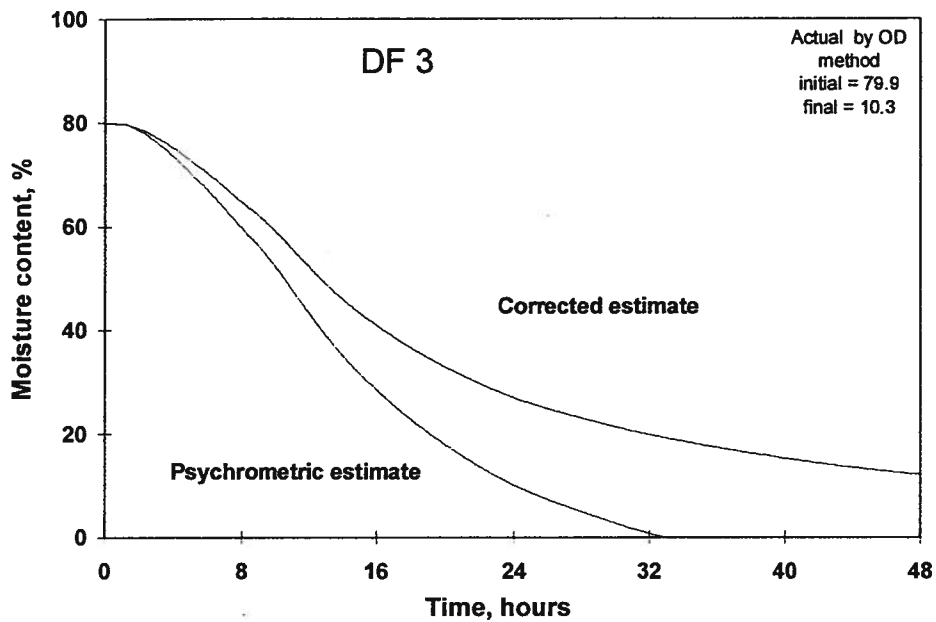


FIGURE 7C. Moisture content versus time for Douglas-fir.

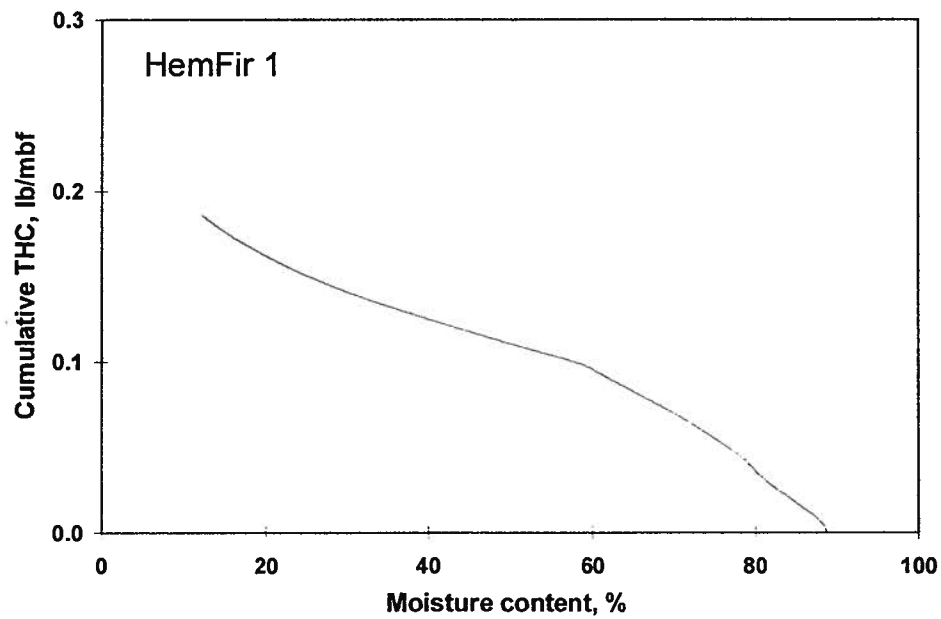


FIGURE 8A. Cumulative emissions versus moisture content (as carbon) for hemlock.

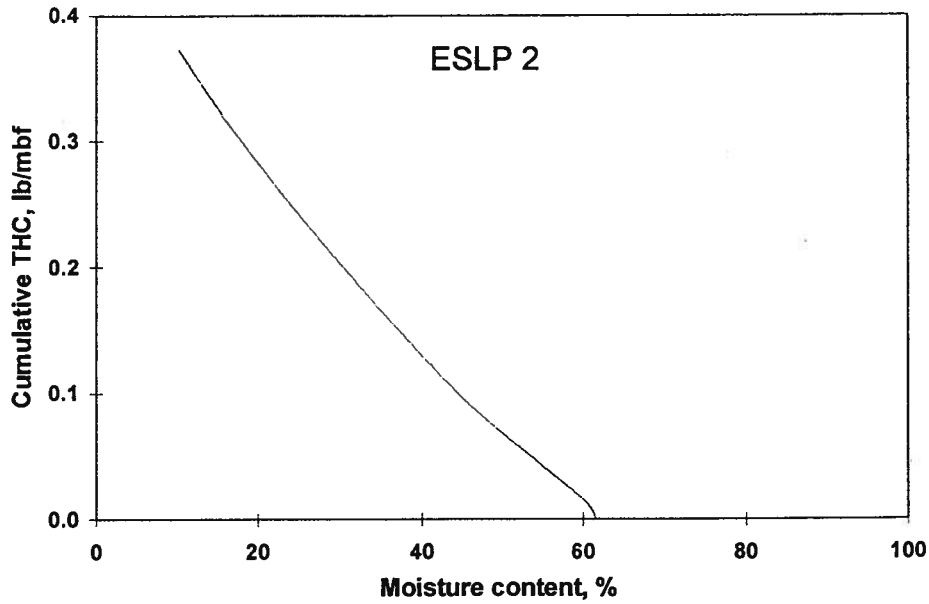


FIGURE 8B. Cumulative emissions versus moisture content (as carbon) for ESLP.

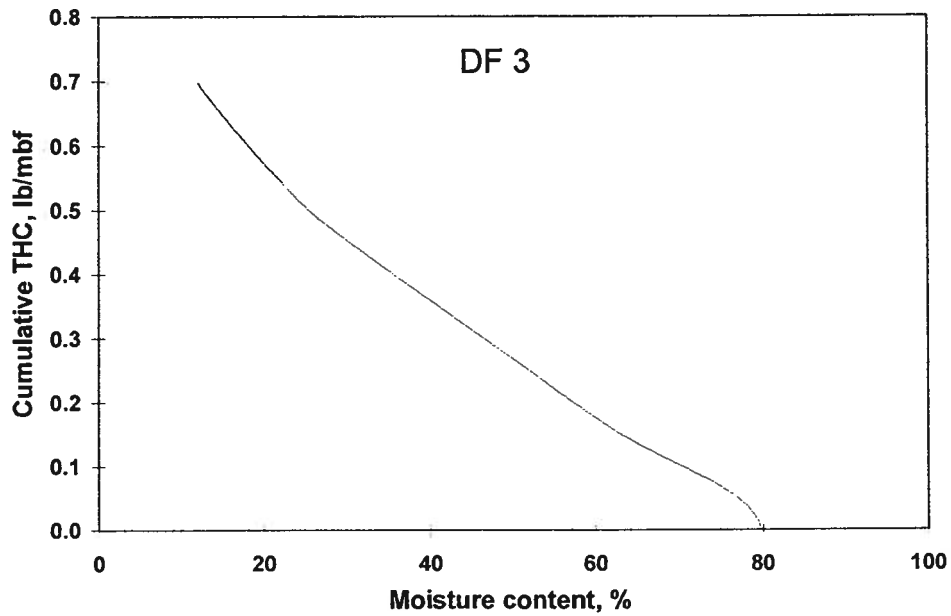


FIGURE 8C. Cumulative emissions versus moisture content (as carbon) for Douglas-fir.

Table 3 shows the VOC results by run for the charges. The interval time periods shown in the table include the times between sampling and mass calculations are adjusted to account for these. Sampling occurred for approximately 95% of the drying time. Sample copies of field sampling sheets, including dilution system and heated component data are given in Appendix 3.

TABLE 3A. Summary of sample runs for analysis of total hydrocarbon for hemlock.

Appears to be results from Douglas Fir

Sample Run (DF3)	Time hrs	Cumulative		Average Humidity kg/kg	Flow @68F		THC mass as C g	THC wet conc ppmv	THC dry conc ppmv	THC mass as C lbs/mbf	THC rate as C lb/hr/mbf	Average Wood MC %	Average Air MC %	Average Anal. MC %
		Dry Gas kg	Water kg		Dry l/min	Wet l/min								
1	3.15	30.70	1.52	0.049	134.7	145.4	0.45	9.8	10.5	0.0345	0.0043	88.0	7.4	7.4
2	4.05	33.26	3.32	0.100	113.5	131.8	0.73	19.0	23.5	0.0745	0.0054	82.6	13.8	13.8
3	3.90	16.94	4.60	0.272	60.0	86.3	0.98	33.6	48.5	0.0371	0.0075	76.2	30.4	14.9
4	5.80	24.10	6.55	0.272	57.4	82.6	1.03	23.7	34.3	0.0935	0.0053	65.4	30.4	11.8
5	3.70	43.71	7.41	0.170	163.3	207.9	0.65	9.9	12.9	0.1464	0.0053	52.5	21.5	8.5
6	2.55	23.13	3.62	0.156	125.4	157.0	0.32	8.9	11.2	0.0532	0.0038	43.0	20.1	10.4
7	3.60	25.51	4.04	0.158	97.9	122.9	0.38	9.6	12.1	0.0490	0.0032	36.0	20.3	9.3
8	3.10	16.68	2.60	0.156	74.4	93.0	0.28	10.6	13.4	0.0403	0.0027	30.1	20.1	12.5
9	2.20	9.67	1.50	0.155	60.7	75.9	0.18	11.8	15.0	0.0299	0.0024	26.4	20.0	12.5
10	2.60	9.42	1.47	0.156	50.1	62.7	0.19	13.0	16.4	0.0173	0.0022	23.7	20.1	12.6
11	6.30	16.61	2.59	0.156	36.5	45.6	0.39	15.2	19.2	0.0351	0.0019	19.9	20.1	12.5
12	3.35	6.43	1.01	0.157	26.5	33.2	0.18	17.4	22.1	0.0283	0.0016	16.8	20.2	12.4
13	1.90	3.19	0.50	0.155	23.2	29.0	0.10	19.2	24.3	0.0090	0.0015	15.5	20.0	11.9
Sum	46.20	259.3	40.7				5.9			0.648				
Average				0.163	78.7	98.0		15.5	20.3		0.0036			

TABLE 3B. Summary of sample runs for analysis of total hydrocarbon for ESLP.

Sample Run (ESLP2)	Time hrs	Cumulative		Average Humidity kg/kg	Flow @68F		THC mass as C g	THC wet conc ppmv	THC dry conc ppmv	THC mass as C lbs/mbf	THC rate as C lb/hr/mbf	Average Wood MC %	Average Air MC %	Average Anal. MC %
		Dry Gas kg	Water kg		Dry l/min	Wet l/min								
1	2.95	32.56	1.61	0.049	152.6	164.7	0.86	23.4	25.3	0.0260	0.0088	60.6	7.4	7.4
2	2.45	42.38	2.37	0.056	239.1	260.6	0.91	15.7	17.3	0.0273	0.0111	55.5	8.3	8.3
3	3.05	41.08	3.07	0.075	186.2	208.6	1.21	21.0	23.8	0.0363	0.0119	49.5	10.7	10.7
4	3.20	33.56	3.31	0.099	145.0	168.0	1.62	33.4	39.3	0.0486	0.0152	42.5	13.7	13.7
5	5.80	41.09	4.80	0.117	97.9	116.4	2.59	42.5	51.0	0.0779	0.0134	33.1	15.8	9.4
6	3.50	15.98	1.88	0.118	63.1	75.1	1.08	45.5	54.7	0.0326	0.0093	26.1	15.9	9.5
7	3.45	11.82	1.38	0.117	47.4	56.3	0.85	48.2	57.9	0.0255	0.0074	22.6	15.8	9.9
8	4.30	11.49	1.36	0.119	36.9	44.0	0.86	50.2	60.4	0.0259	0.0060	19.6	16.0	10.1
9	2.80	6.23	0.74	0.119	30.8	36.7	0.48	51.2	61.7	0.0143	0.0051	17.3	16.1	10.2
10	3.15	5.77	0.69	0.119	25.3	30.2	0.46	52.7	63.4	0.0137	0.0044	15.7	16.1	10.3
Sum	34.65	242.0	21.2				10.9			0.328				
Average				0.099	102.4	116.1		38.4	45.5		0.0093			

TABLE 3C. Summary of sample runs for analysis of total hydrocarbon for Douglas-fir.

Sample Run (HF 1)	Time hrs	Cumulative		Average Humidity kg/kg	Flow @68F		THC mass			THC Concentration		Average Wood MC %	Average Air MC %	Average Anal. MC %
		Dry Gas kg	Water kg		Dry l/min	Wet l/min	as C g	wet ppmv	dry ppmv	as C lbs/mbf	as C lb/hr/mbf			
1	2.35	16.61	0.77	0.046	97.7	105.0	1.15	58.2	62.5	0.0136	0.0147	79.5	6.9	6.9
2	4.15	87.91	5.04	0.057	292.8	319.8	2.48	20.9	23.1	0.0219	0.0179	74.0	8.5	8.5
3	1.95	39.96	2.93	0.073	283.3	316.8	1.24	22.0	24.9	0.0294	0.0190	66.2	10.6	10.6
4	3.25	56.03	5.55	0.099	238.3	276.3	3.11	37.9	44.5	0.0309	0.0288	58.6	13.8	13.8
5	6.05	82.61	8.66	0.105	188.7	220.6	4.87	40.2	47.5	0.0196	0.0242	44.3	14.5	9.2
6	3.10	28.80	3.02	0.105	128.4	150.1	1.77	41.9	49.5	0.0097	0.0171	34.1	14.5	9.2
7	3.55	25.47	2.66	0.104	99.2	115.8	1.63	43.8	51.7	0.0115	0.0138	28.8	14.4	9.2
8	3.30	16.58	1.71	0.103	69.5	81.0	1.34	55.3	65.2	0.0083	0.0122	24.8	14.3	9.6
9	2.65	11.36	1.20	0.105	59.3	69.3	0.99	59.8	70.6	0.0054	0.0113	22.1	14.5	9.5
10	1.75	6.52	0.67	0.103	51.5	60.0	0.58	60.7	71.5	0.0057	0.0099	20.4	14.2	9.2
11	3.85	12.12	1.27	0.105	43.5	50.9	1.17	65.7	77.6	0.0119	0.0091	18.5	14.5	9.4
12	3.45	9.22	0.97	0.106	37.0	43.3	0.94	69.6	82.3	0.0053	0.0082	16.5	14.5	9.5
13	1.15	2.80	0.30	0.106	33.6	39.4	0.30	72.7	86.1	0.0029	0.0078	15.3	14.6	9.5
Sum	40.55	396.0	34.8				21.6			0.176				
Average				0.094	124.8	142.2		49.9	58.2		0.0149			

Methanol and formaldehyde

Results of the lab analyses for methanol and formaldehyde are summarized in Table 4 and complete results are in Appendix 2. Table 5 shows a summary of the methanol and formaldehyde analyses by run during the charge.

TABLE 4. Results of laboratory analyses for hemlock (left), ESLP (middle), and Douglas-fir impinger samples.

Impinger concentrations (HF 1)			Impinger concentrations (ESLP 2)			Impinger concentrations (DF3)		
Sample Run	Methanol mg/L	Formaldehyde mg/L	Sample Run	Methanol mg/L	Formaldehyde mg/L	Sample Run	Methanol mg/L	Formaldehyde mg/L
1	8.2	0.15	1	7.2	0.10	1	6.7	0.12
2	13.3	0.24	2	4.8	0.12	2	4.2	0.14
3	23.9	0.31	3	8.3	0.29	3	2.6	0.16
4	37.2	0.44	4	7.5	0.29	4	5.1	0.30
5	17.5	0.31	5	30.0	1.16	5	13.5	0.56
6	16.8	0.34	6	29.4	0.94	6	10.4	0.47
7	24.4	0.42	7	39.3	1.26	7	13.3	0.43
8	28.4	0.43	8	40.5	1.13	8	17.4	0.52
9	25.6	0.35	9	56.2	1.44	9	20.0	0.57
10	28.5	0.37	10	53.0	1.27	10	19.8	0.53
11	77.0	0.93	11	56.2	1.27	11	30.5	0.75
12	60.9	0.67	12	56.3	1.23	12	28.6	0.70
13	85.1	0.86	13	67.7	1.43	13		
14	38.9	0.36	14	76.0	1.49	14		
15	105.4	0.91	15	2.2	0.02	15	24.9	0.57

Impinger liquid concentrations			Impinger liquid concentrations			Impinger liquid concentrations		
Sample Run	Methanol ppm	Formaldehyde ppm	Sample Run	Methanol ppm	Formaldehyde ppm	Sample Run	Methanol ppm	Formaldehyde ppm
1	13.3	0.28	1	78.1	0.49	1	2.9	0.18
3	27.3	0.27	3	6.7	0.24	3	124.1	2.64
15	163.7	1.19	15	78.5	0.27	15	18.4	0.51

TABLE 5A. Summary of sample runs for methanol and formaldehyde for hemlock.

(Hemlock) Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass	Moisture Content		Mass leaving kiln		Mass per kg of dry wood		Mass 1000 board feet		Concentration in dry gas		Concentration in wet gas	
	hours	hours		kg	Mid %	End %	MeOH g	CHOH g	MeOH mg/kg	CHOH mg/kg	MeOH lb/mbf	CHOH lb/mbf	MeOH ppm	CHOH ppm	MeOH ppm
1	3.20	3.45	35.365	87.8	85.5	0.008	0.000	0.74	0.003	0.0032	0.00000	0.20	0.00	0.17	0.00
2	3.95	4.25	29.951	82.0	79.5	0.076	0.001	1.38	0.025	0.0023	0.00000	2.81	0.05	1.50	0.02
3	2.75	3.15	14.348	76.0	72.3	0.243	0.003	3.86	0.050	0.0034	0.00000	13.47	0.19	8.74	0.12
4	5.25	5.75	24.115	66.0	60.4	0.512	0.005	2.27	0.110	0.0154	0.00000	16.23	0.24	10.69	0.16
5	3.40	3.75	42.302	53.5	47.1	0.144	0.003	2.61	0.047	0.0016	0.00000	3.05	0.05	2.05	0.03
6	3.00	3.25	29.310	42.8	38.8	0.106	0.002	1.87	0.038	0.0024	0.00000	2.19	0.07	2.15	0.05
7	3.35	3.55	24.245	35.2	31.9	0.091	0.002	1.84	0.028	0.0027	0.00000	3.39	0.36	2.24	0.04
8	3.00	3.05	15.958	29.5	27.4	0.073	0.001	1.62	0.020	0.0022	0.00000	4.18	0.07	2.59	0.04
9	2.05	2.10	9.007	26.1	24.8	0.048	0.001	0.77	0.011	0.0013	0.00000	0.28	0.05	2.07	0.04
10	2.15	2.00	7.245	23.8	22.8	0.039	0.001	0.88	0.012	0.0015	0.00000	5.07	0.08	3.79	0.05
11	6.70	6.60	17.700	20.1	17.8	0.194	0.002	3.51	0.042	0.0038	0.00000	1.92	0.03	5.19	0.08
12	3.15	3.20	6.161	16.9	16.0	0.124	0.001	2.25	0.024	0.0037	0.00000	18.23	0.21	11.42	0.13
13	4.00	2.10	3.542	15.5	15.0	0.008	0.001	1.78	0.018	0.0030	0.00000	23.16	0.27	15.71	0.17
SUM										0.052	0.00071				

TABLE 5B. Summary of sample runs for methanol and formaldehyde for ESLP.

(ESLP) Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass	Moisture Content		Mass leaving kiln		Mass per kg of dry wood		Mass 1000 board feet		Concentration in dry gas		Concentration in wet gas	
	hours	hours		kg	Mid %	End %	MeOH g	CHOH g	MeOH mg/kg	CHOH mg/kg	MeOH lb/mbf	CHOH lb/mbf	MeOH ppm	CHOH ppm	MeOH ppm
1	2.80	2.85	30.559	60.7	58.3	0.009	0.000	0.17	0.002	0.0003	0.00000	0.26	0.00	0.22	0.00
2	3.05	3.45	57.519	54.6	50.9	0.020	0.001	0.40	0.010	0.0006	0.00000	0.32	0.01	0.21	0.01
3	3.10	3.60	44.643	46.9	42.8	0.055	0.002	1.10	0.038	0.0017	0.00000	1.12	0.04	0.73	0.03
4	1.35	1.60	15.554	41.0	39.2	0.041	0.002	0.81	0.031	0.0012	0.00000	2.36	0.10	1.56	0.06
5	5.75	5.90	42.157	33.3	28.4	0.223	0.009	4.44	0.171	0.0067	0.00026	4.89	0.20	3.19	0.13
6	3.45	3.70	16.838	26.0	24.0	0.169	0.005	3.37	0.107	0.0051	0.00016	9.11	0.34	6.14	0.21
7	3.40	3.80	12.813	22.3	20.7	0.156	0.004	2.70	0.087	0.0041	0.00018	9.62	0.33	6.24	0.21
8	3.50	3.65	9.559	19.4	18.2	0.110	0.003	2.19	0.061	0.0033	0.00009	10.44	0.31	6.56	0.19
9	3.25	3.60	7.849	17.2	16.2	0.100	0.003	1.99	0.051	0.0030	0.00008	11.56	0.32	7.22	0.20
10	2.20	2.50	4.493	15.6	15.0	0.110	0.003	2.18	0.052	0.0033	0.00008	22.15	0.37	15.85	0.35
SUM										0.029	0.00093				

TABLE 5C. Summary of sample runs for methanol and formaldehyde for Douglas-fir.

(Doug-fir) Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass kg	Moisture Content		Mass leaving kiln		Mass per kg of dry wood		Mass 1000 board feet		Concentration in dry gas		Concentration in wet gas	
	hours	hours		Mid %	End %	MeOH g	CHOH g	MeOH mg/kg	CHOH mg/kg	MeOH lb/mbf	CHOH lb/mbf	MeOH ppm	CHOH ppm	MeOH ppm	CHOH ppm
	1	2.65	2.70	23.277	79.3	77.7	0.007	0.000	0.18	0.002	0.0002	0.0000	0.27	0.01	0.23
2	3.35	3.55	75.664	73.9	69.6	0.014	0.001	0.27	0.009	0.0004	0.0000	0.17	0.01	0.11	0.00
3	2.30	2.40	49.048	66.3	63.0	0.012	0.001	0.27	0.017	0.0004	0.0000	0.27	0.02	0.17	0.01
4	2.90	2.95	50.801	58.5	53.5	0.008	0.002	0.31	0.036	0.0004	0.0000	0.53	0.04	0.33	0.02
5	5.95	6.05	83.329	44.6	37.2	0.095	0.004	1.76	0.073	0.0028	0.00012	1.03	0.05	0.38	0.03
6	3.05	3.10	28.949	34.3	31.5	0.056	0.002	1.04	0.047	0.0017	0.0000	1.75	0.05	1.13	0.06
7	3.35	3.40	25.024	29.0	26.7	0.047	0.002	0.87	0.028	0.0014	0.0000	1.89	0.06	1.11	0.04
8	2.65	3.05	15.506	25.1	23.7	0.046	0.001	0.86	0.026	0.0014	0.0000	2.69	0.09	1.69	0.05
9	2.40	2.85	12.307	22.5	21.3	0.038	0.001	0.88	0.019	0.0011	0.0000	2.67	0.08	1.67	0.05
10	2.10	2.30	8.766	20.4	19.6	0.021	0.001	0.57	0.015	0.0004	0.0000	3.15	0.09	1.97	0.06
11	3.15	3.35	10.569	18.5	17.5	0.060	0.001	0.33	0.023	0.0015	0.0000	4.23	0.11	2.98	0.07
12	2.90	3.35	9.036	16.6	15.8	0.057	0.001	1.07	0.026	0.0017	0.0000	5.8	0.15	3.6	0.09
13	2.25	1.50	3.704	15.4	15.0	0.027	0.001	0.50	0.011	0.0006	0.0000	6.6	0.16	4.1	0.10
SUM										0.015	0.0054				

The total emissions released as a function of time are shown in Figure 9. Figure 10 shown total emissions as a function of moisture content. Figure 10 suggests the HAP emissions are a strong function of final moisture content.

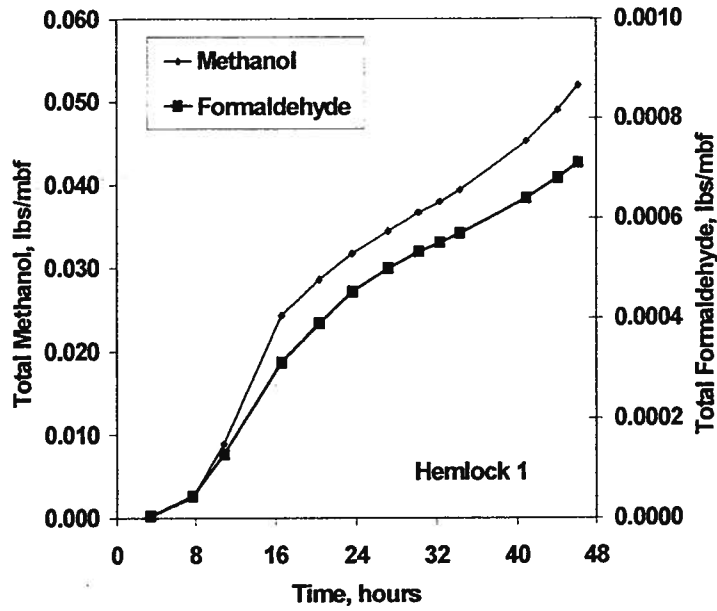


FIGURE 9A. Cumulative methanol and formaldehyde emissions versus time for hemlock.

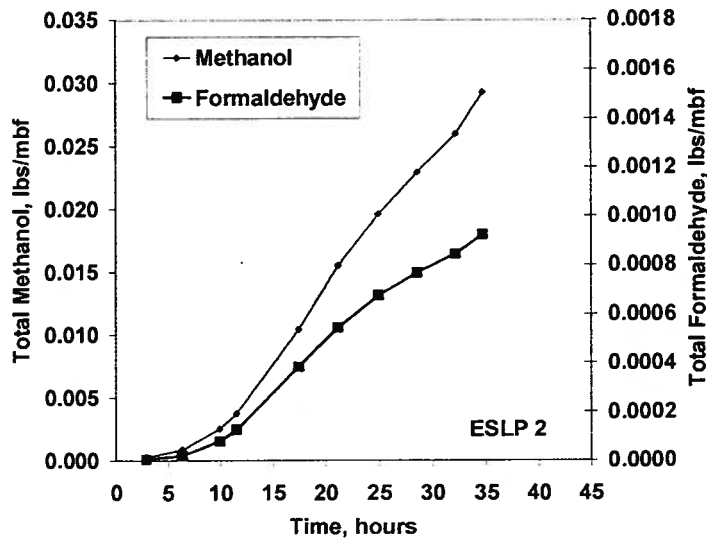


FIGURE 9B. Cumulative methanol and formaldehyde emissions versus time for ESLP.

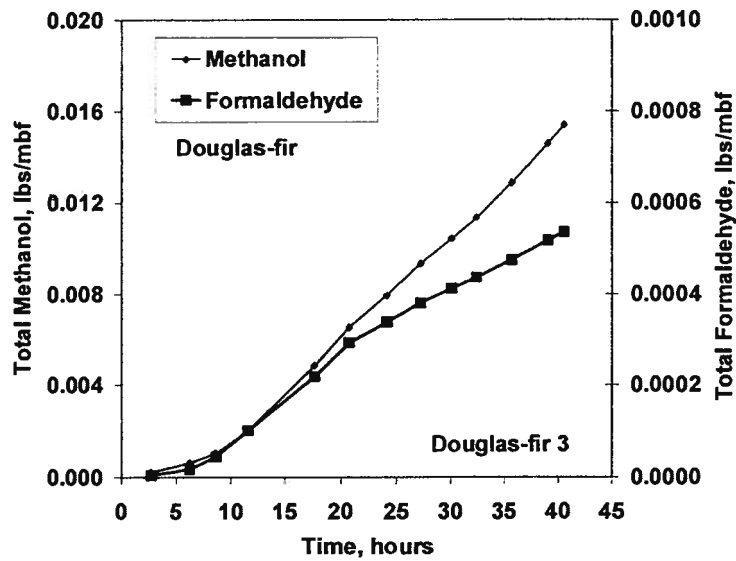


FIGURE 9C. Cumulative methanol and formaldehyde emissions versus time for Douglas-fir.

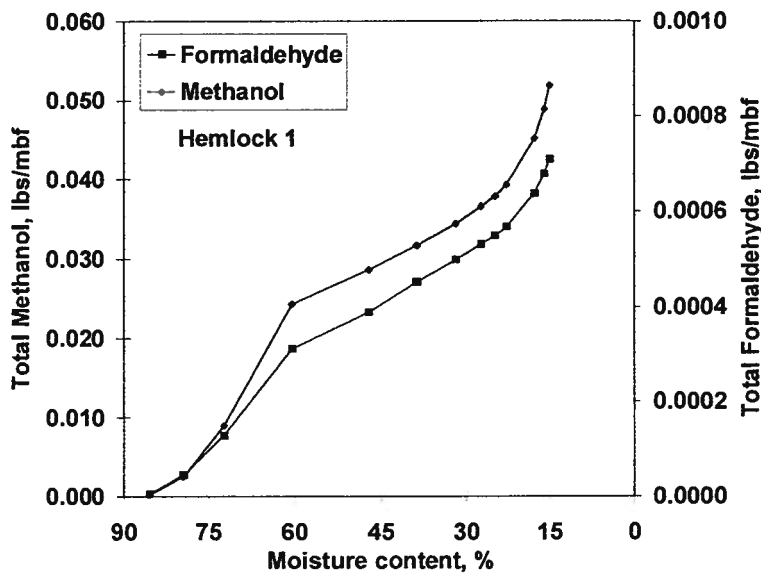


FIGURE 10A. Cumulative methanol and formaldehyde emissions versus wood moisture content for hemlock.

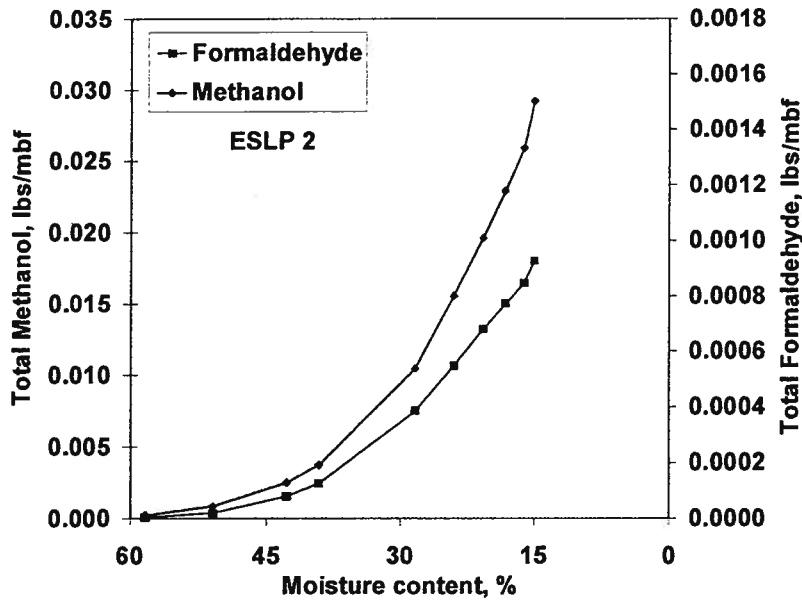


FIGURE 10B. Cumulative methanol and formaldehyde emissions versus wood moisture content for ESLP.

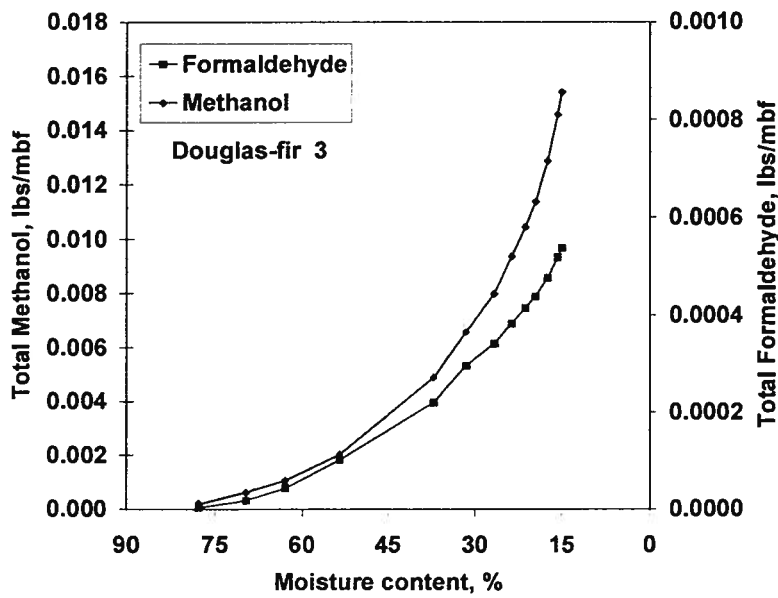


FIGURE 10C. Cumulative methanol and formaldehyde emissions versus wood moisture content for Douglas-fir.

Comparison to past work

A comparison of the total hydrocarbon and methanol and formaldehyde emissions from this study to past work is shown in Table 6. Notice how HAP emissions are related to temperature.

TABLE 6. Comparison of results to past work.

Species ^A	Tested by	Dry-bulb Temperature °F	VOC	Methanol	Formaldehyde
			lb./mbf	lb/mbf	lb/mbf
Hemlock (this work)	OSU	180	0.18 ^{0.65}	0.038 ^{0.052}	0.0005 ^{0.00071}
Hemlock (for Hampton in Sept, 2004)	OSU	200	0.20	0.057	0.0014
Hemlock (for Hampton in August, 2004)	OSU	180	0.16	0.031	0.0008
Hemlock (for Hampton in May, 2004)	OSU	215	0.34	0.138	0.0043
Hemlock (for Hampton in April, 2004)	OSU	215	0.34	-	-
		180	0.40		
Hemlock (for Hampton in Feb, 2002)	OSU	180	0.12	-	-
Southern pine	OSU/NCASI	235	3.6	0.265	0.019
White fir	OSU	240	0.61	0.420	0.0160
White fir	OSU	180	0.24	0.122	0.0028
Ponderosa pine	OSU	180	1.38	0.065	0.0029
Lodgepole	OSU	230	1.08	0.060	0.004
Douglas-fir	OSU	170	0.49	0.023	0.0010

^A Lodgepole, and ponderosa to 12% moisture content. Other species to 15%.

VII. Quality Assurance

Leak checks

Leak checks were performed on the VOC system before and after drying and on the impinger sample train before each run.

Calibration

Data for the calibration gases are given in Appendix 3. The mid gas was named at 420 ppm. The calibration sheet for the flow meter is also included is also included in Appendix 4 as is the thermocouple calibration check.

Spikes, duplicates, and blanks

Spikes were run for each charge by putting a known quantity of water containing methanol and formaldehyde into the first impinger of a duplicate sampling train. Both trains were run simultaneously and the difference between the recovered chemicals and the expected recovery without the spike was calculated. These are shown in Table 7.

Duplicates sample were taken for one run from each charge. The difference between duplicates was 1.2% for methanol and 1.5% for formaldehyde.

Field blanks (samples of the impinger water) indicated the water used in the impingers was clean.

Lab blanks of the water used for formaldehyde analysis indicated that it contained no formaldehyde.

Anomalies

One spike (Hemlock-3) had a formaldehyde recovery of 66%, below the 70% required by the method. However, we did not spike this enough (the difference between the sample concentration and the spike concentration was too small). A second spike (Hemlock-15) had good recoveries.

One duplicate (Douglas-fir-2) showed a difference of 48%. However, the concentrations were very low compared to normal samples because they were taken too early in the charge. A second duplicate set (Douglas-fir-10) had good replication.

There were no other anomalies during the schedule that would significantly affect the data.

TABLE 7A. Summary of quality assurance for hemlock.

Spike								
Methanol	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
Run	μg	mL/min	μg	μg	g	ppmw	μg	%
3	859.8	456	245.0					
31	1728.4	417.7	728.4	478.4	2	300	500	79.7

Need conc

Spike								
Methanol	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
Run	μg	mL/min	μg	μg	g	ppmw	μg	%
15	5474.0	421.1	3952.8					
151	7851.2	458.8	7851.2	1888.3	7.25	300	2145	36.8

Spike								
Formaldehyde	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
Run	μg	mL/min	μg	μg	g	ppmw	μg	%
3	17.7	456.1	16.2					
31	17.3	417.7	17.0	1.1	2	0.837	1.674	65.5

Spike								
Formaldehyde	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
Run	μg	mL/min	μg	μg	g	ppmw	μg	%
15	47.5	421.1	51.8					
151	57.0	458.8	57.0	5.3	7.25	0.837	6.06825	36.6

Duplicate				
Methanol	Mass in impinger	Impinger flow	Corrected mass	Mass difference
Run	μg	mL/min	μg	%
2	735.0	458.8	685.9	
21	646.9	428.4	646.9	6.0

Duplicate				
Formaldehyde	Mass in impinger	Impinger flow	Corrected mass	Mass difference
Run	μg	mL/min	μg	%
2	13.0	458.8	12.2	
21	13.6	428.4	13.6	10.4

TABLE 7B. Summary of quality assurance for ESLP.

Spike								
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
	µg	mL/min	µg	µg	g	ppmw	µg	%
3	346.8	456.1	318.2					
31	3121.8	419.8	3121.8	2803.1	9.8	300	2940	95.3

Spike								
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
	µg	mL/min	µg	µg	g	ppmw	µg	%
15	79.8	428.0	94.7					
151	2318.5	502.1	2318.5	2218.6	8.08	300	2424	91.5

Spike								
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
	µg	mL/min	µg	µg	g	ppmw	µg	%
3	12.2	456.1	11.2					
31	19.5	419.0	19.5	8.8	9.8	0.837	8.2026	101.7

Spike								
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Spike Concentration	Mass in Spike	Recovery
	µg	mL/min	µg	µg	g	ppmw	µg	%
15	0.8	428.0	1.0					
151	7.9	502.1	7.9	6.9	8.08	0.837	6.76296	102.1

Duplicate				
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
4	237.8	455.0	218.9	
41	236.0	419.6	286.0	7.6

Duplicate				
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
4	9.2	455.0	8.6	
41	8.6	419.6	8.6	116

TABLE 7C. Summary of quality assurance for Douglas-fir.

Spike								
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Sipke Concentration	Mass in Spike	Recovery
	µg	mL/min	µg	µg	g	ppmw	µg	%
9	791	455.5	129.3	3.9	4.18	1000	4180	97.6
91	4810	420	4810.4	4076.5	4.18	1000	4180	97.6

Spike								
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference	Spike mass	Sipke Concentration	Mass in Spike	Recovery
	µg	mL/min	µg	µg	g	ppmw	µg	%
9	227.6	455.5	129.3	3.9	4.18	20	83.6	97.5
91	102.3	420	102.3	84.5	4.18	20	83.6	97.5

Duplicate				
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
2	140.5	455.5	129.3	3.9
21	134.5	419.1	134.5	3.9

Duplicate				
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
10	737	455.9	671.6	6.0
101	671.4	423.3	671.4	6.0

Duplicate				
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
2	227.6	455.5	129.3	3.9
21	102.3	419.1	102.3	3.9

Duplicate				
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
10	197	455.9	180	3.4
101	186	423.3	186	3.4

Appendix 1. Detailed Sampling Procedures

INSTRUCTIONS FOR CHECKS OF EMISSIONS KILN

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 metal electrical box under desk, left controller. The top and bottom numbers should be similar on the box should be similar, about 126 C..

Valve temperature: Read from metal electrical box under desk, right controller. The top and bottom numbers should be similar on the box should be similar, about 154 C..

Dry-bulb temperature: Read from computer screen. Compare to 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 or Mark.

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

If it is too low, it means that the kiln atmosphere is too dry. Check the flow meters. If Flow1 is about 10 L/min (its lower limit), make sure that Flow2 and Flow3 are turned off

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. 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 C, call Mike or Mark.

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 or Mark.

Line temperature: Read from gray box on wall above analyzer. It should read about 275°F.

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 10 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

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

F/M Flow: Read from rotometer. This should be about 400 to 500 cc/min.

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

INSTRUCTIONS - FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER PRE-SAMPLE PROCEDURE

BACKGROUND INFORMATION

Get the dry- and wet-bulb temperatures from the kiln schedule or off the computer. Use the highest expected values for the run.

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 and time are now, as you start the data collection process.

AMBIENT DATA

Call 9-754-0081 and get altimeter setting.

Read the laboratory temperature from the thermometer.

ANALYZER CALIBRATION

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

zero toggle switch up (on), others down (off)

set flow to 3.5 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

span toggle switch up (on), others down (off)

set flow to 3.5 L/min using regulator on tank

set analyzer to range 3

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

use the span dial (pot) on THA to get a reading of 905 ppm

read the analyzer, record, for example, 9.05 or 900

read computer (should read about 905)

note pot setting

Open mid gas tank valve

mid toggle switch up (on), others down (off)

set flow to 3.5 L/min using regulator on tank

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

read analyzer (do not adjust pot settings), record, for example, 4.12 or 412

read computer (should about 412)

check for within tolerance

turn off mid gas

all toggle switches off

SET DILUTION FLOW BEFORE RUN

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 2.6 L/min

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

Record the average, L/min = cc/min / 1000

Write the Event, 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 (on meter with valve 1)

Slowly open lower valve on dilution flow meter (1=on; 2, 3=off; 4=meter)

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

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, L/min = cc/min / 1000

Write "Pre-SFR" on the Gilibrator printout.

CHECK DILUTION FLOW BEFORE RUN

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 toggle switch up (on), others down (off)

set flow to 3.5 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 toggle switches off

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

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 $100 \cdot (DR_{\text{Span}} - DR_{\text{Flow}}) / DR_{\text{Flow}}$ 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 or Mark

START RUN

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

Record the start time. Use the computer clock for all times or set your watch to the computer time.

Make sure analyzer is on appropriate range, usually range 3, to keep THC reading on computer between 60 and 750.

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

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

POST-SAMPLE PROCEDURE

AT END OF RUN

Record your name as the operator.

Event = the drying cycle. Run = the 3-hour interval.

Operator, that's you. Date and time are now, as you start the data collection process.

AMBIENT DATA

Call 9-754-0081 and get temperature and altimeter

Local pressure = (Altimeter - 0.23) x 3.3867

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 yet.

CHECK DILUTION FLOW AFTER RUN

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 toggle switch up (on), others down (off)

set flow to 3.5 L/min using regulator on tank

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

record

all toggle switches off

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 5 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, L/min = cc/min / 1000

Write "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

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 5 readings of the total flow rate (TFR). This is the total flow drawn by the analyzer and should be about 2.6 L/min
Make sure the average does not include any "bad" readings
Record the average, L/min = cc/min / 1000
Write "Post-TFR" on the Gilibrator printout.

CHECK CALIBRATION OF ANALYZER

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 toggle switch up (on), others down (off)
set flow to 3.5 L/min using regulator on tank
set analyzer to range 4
wait for a stable reading (about 30 -60 seconds)
read analyzer (do not adjust pot settings), record, for example, 1.50 as 1500
read computer (should read about 152 due to range 4 setting)
note pot setting
check for within tolerance - between 1483 and 1573

Open mid gas tank valve
mid toggle switch up (on), others down (off)
set flow to 3.5 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, 8.50 as 850
read computer (should read same as analyzer)
check for within tolerance

Open the zero gas tank valve
zero toggle switch up (on), others down (off)
set flow to 3.5 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

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

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

Calculate % difference as $100 * \{ \text{Absolute Value} (DR_{\text{Span}} - DR_{\text{Flow}}) \} / DR_{\text{Flow}}$

Record the time now as the end time for check.

Tear off the four sets of Gilibrator readings (Pre-TFR, Pre-SFR, Post-SFR, Post-TFR) and staple to paper with other records.

Start Pre-Sample procedure for next run.

INSTRUCTIONS FOR FORMALDEHYDE / METHANOL COLLECTION AND HAPS SAMPLING

BACKGROUND DATA

Operator, that's you.

Date and time are now, as you start the data collection process.

Event = Kiln Charge

Run = sequence of M/F measurement

PRE RUN DATA

Call 9-754-0081 and get altimeter setting.

Read the laboratory temperature from the thermometer.

Attach Summa canister to port after vacuum pump

IMPINGER WEIGHTS

Shake the water out of the impingers, Dry the outside.

Weigh the impingers.

Put 10 mL of boiled DI water in impinger #1.

Put 20 mL of boiled DI water in impinger #2.

Impinger #3 is not filled. It is for overflow.

Reweigh the impingers with water.

Install impingers and lower into chiller

LEAK CHECK

Close valve to sample probe.

Turn on pump

Evacuate to 15 to 18 " Hg

Close valve that is near pump

Turn off 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.

Slowly open valve near probe tip. When bubbles are no longer seen, open completely

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
Open port on Summa canister
Record time.

FLOW READINGS DURING TEST

Note flow meter reading at least every hour
Run test for 3 to 6 hours, less if impingers fill, or up to Summa canister time limit

POST RUN DATA

Call 9-754-0081 and get altimeter setting.
Read the laboratory temperature from the thermometer
Label a clean vial with the Event and Run numbers

END TIME

Remove probe from kiln
Close summa canister valve
Record time

SAMPLE FLOW RATE

Rinse probe with 5 mL of DI water
Attach probe tip to Gilibrator
Take 5 readings
Make sure all readings in average are "good" readings
Record the average
Lift impingers from chiller
Remove impingers

IMPINGER WEIGHTS

Dry the outside of the impingers
Weigh the impingers with the water and record
Combine the water from the two (or three) impingers into the labeled vial.
Place vial into refrigerator
Reweigh the empty impingers
Note any water lost during this procedure
Tag and box Summa canister

Appendix 2. Data in Electronic Form

Appendix 3. Calibration

Airgas

Certificate of Analysis: EPA Protocol Gas Mixture

Airgas Specialty Gases
 12722 S. Wentworth Avenue
 Chicago, IL 60628
 1-733-785-3000
 Fax: 1-733-785-1928

Cylinder Number: CC44350 Reference Number: 54-124076439-1
 Cylinder Pressure: 2000.6 PSIG Expiration Date: 10/4/2009
 Certification Date: 10/4/2006 Laboratory: ASG - Chicago - IL

Certified Concentrations

Component	Concentration	Accuracy	Analytical Principle	Procedure
PROPANE	611.3 PPM	+/- 1%	FID	G1
Air	Balance			

Certification performed in accordance with "EPA Traceability Protocol (Sept. 1997)" using the assay procedures listed. Analytical Methodology does not require correction for analytical interferences.

Notes:

Do not use cylinder below 150 psig.

Approval Signature _____

Reference Standard Information

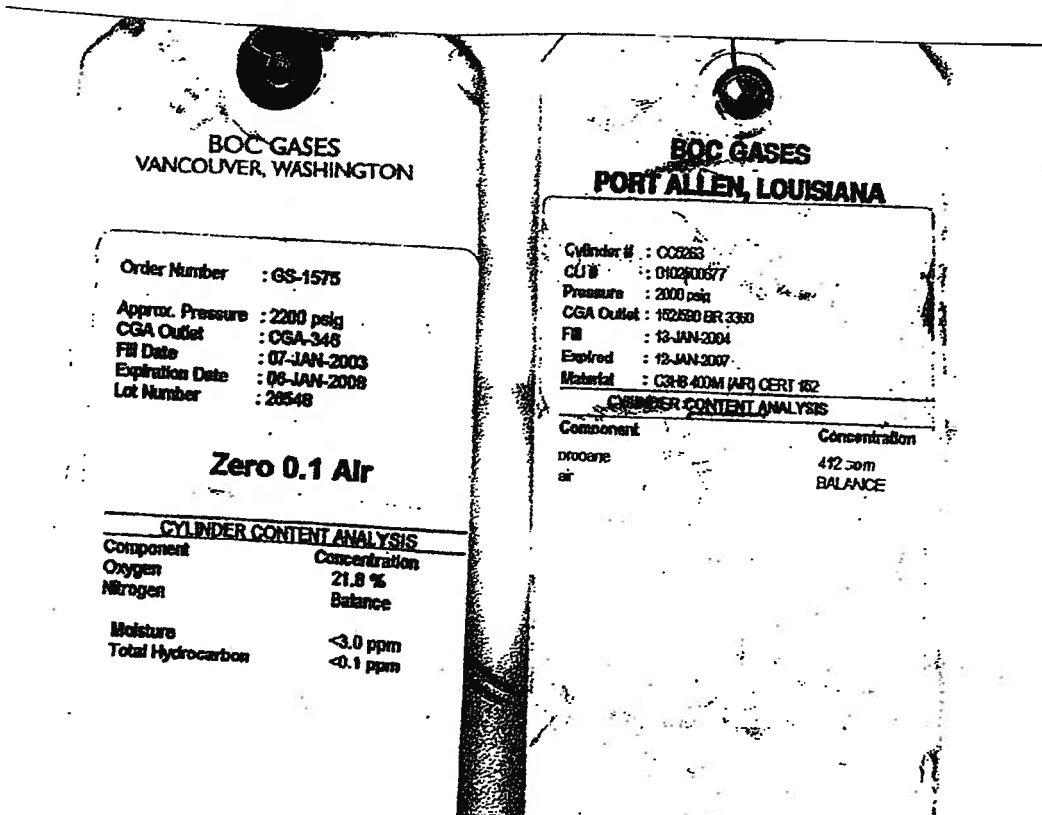
Type	Balance Gas	Component	Cyl. Number	Concentration
NTRM 51819		PROPANE	SG9101963ALB	483.6 PPM

Analytical Results

1st Component **PROPANE**

1st Analysis Date: 10/04/2006

R 310807 S 391575 Z 0 Conc 609.7 PPM
 S 393458 Z 0 R 310893 Conc 612.6 PPM
 Z 0 R 316077 S 392797 Conc 611.6 PPM
 AVG: 611.3 PPM



SENSIDYNE, INC.

CALIBRATION CERTIFICATE

CELL S/N: 912442-S

DATE: 01 - 16 - 2006

This is to certify that the above referenced Gilibrator Flow Cell was calibrated using film flowmeter MCS-102-A, which has been calibrated by instruments directly traceable to the National Institute of Standards and Technology. NIST Report 8361604.

Results:

REFERENCE	S/N	RELATIVE	PERCENT
MCS-102-A	912442-S	DIFF.	DIFF.
cc/min	cc/min	cc/min	
2013	2016	3	0.15
2017	2018	1	0.05
2017	2018	1	0.05
2013	2016	3	0.15
2014	2014	0	0.0
2014	2016	2	0.1
2013	2010	-3	-0.15
2017	2017	0	0.0
2014	2017	3	0.15
2014	2013	-1	-0.05

MAX 3 0.15

MEAN 2014.6 2015.5

CALIBRATED BY

Agnes Banfield

DATE: 01 - 16 - 2006

CODE 100