HAP Emissions from the Drying of Hemlock and Douglas-fir Lumber by NCASI 98.01 and 105

Report to
Hampton Affiliates

Report by

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VOC and HAP emissions from the drying of hemlock and Douglas-fir lumber

I. Results Summary

Two charges, containing approximately 75 board feet of 2x4 lumber were dried in a small kiln at Oregon State University to less than 15% moisture content. The kiln dry- and wet-bulb temperatures were based on schedules provided by Hampton. The maximum temperature was 180°F (82.2°C) for hemlock and 170°F (76.7°C) for Douglas-fir. 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 the humidity.

A JUM VE-7 total hydrocarbon analyzer was used to measure organic emissions following EPA Method 25A. A chilled impinger sampling trains were used to sample for methanol and formaldehyde following NCASI Method 105 and NCASI Method 98.01. The results are shown in Table 1.

TABLE 1. Summary of results. Both methods for HAP measurement were run simultaneously.

Methods 25A & 98.01	Initial MC %	Time[a] hr:min	VOC[b] lb/mbf	Methanol lb/mbf	Formaldehyde lb/mbf
Hemlock	102.3	49:27	0.14	0.083	0.0013
Doug-fir	56.9	27:30	0.24	0.026	0.0008

Method 105[c]	Methanol lb/mbf	Form- aldehyde lb/mbf	Acet- aldehyde lb/mbf	Propion aldehyde lb/mbf	Acrolein lb/mbf
Hemlock	0.075	0.0014	0.078	0.0020	0.0012
Doug-fir	0.024	0.0008	0.030	0.0004	0.0005

[a] time is to 15% moisture content
[b] as carbon from green to 15% moisture content
[c] phenol was not detected so it is not included in table

II.   Lumber Source and Handling

Hemlock lumber was delivered to Oregon State on March 16 and Douglas-fir on April 20. The wood was delivered in a covered vehicle. Upon arrival at OSU the wood was wrapped in plastic and stored at 5°C until used.   The charges were dried between March 19-21 and April 23-25, 2007

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

FIGURE 1. Schematic of kiln and sampling system.

a commercial kiln. A minimum of 8-12 L/min entered the kiln at all times, more than removed through the analyzer and impinger trains (< 3.2 L/min combined). 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. One of these was used for small segments of the charges. The steam spray line is disabled, so no water vapor is added to the kiln atmosphere.

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.

Schedules

The drying schedules used were based on drying conditions supplied by the mill and are 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. These compare well with what the mill uses.

Charge Sequence

After removing from the refrigerator and unwrapped, 2" were trimmed from each end of each board to give 44" samples. These were then weighed, placed in the kiln as shown in the photo to the right, and dried according to the one of the schedules 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 (oven-dry method).

TABLE 2a. Drying schedule used for hemlock. Actual final moisture content was 14.7%.

Step time, hr:min	Ramp time, hr:min	Run time, hr:min	Dry-bulb, °F	Wet-bulb, °F
0	-	-	110	95
8	8	8	180	165
42.27	0:30	50:27	180	150

TABLE 2b. Drying schedule used for Douglas-fir. Actual final moisture content was 8.8%.

Step time, hr:min	Ramp time, hr:min	Run time, hr:min	Dry-bulb, °F	Wet-bulb, °F
0	-	-	90	80
0:30	0:06	0:30	120	110
49:30	11	50	170	140

FIGURE 2a. Dry- and wet-bulb temperatures during hemlock drying.   15% moisture content was reached at 27.5 hours .

FIGURE 2b. Dry- and wet-bulb temperatures during Douglas-fir drying. 15% moisture content was reached at 49.45 hours.

IV.   Sampling Systems and Methodologies

Sampling for total hydrocarbon, methanol, and formaldehyde is done directly from the kiln as shown in Figure 1 (except there are three sets of impingers). The concentration obtained from the hydrocarbon analyzer and the amount of air entering the kiln allow the total hydrocarbon emissions to be calculated. The concentration obtained from the impingers, the amount of air flowing through the impingers, and the amount of air entering the kiln allow the HAP emissions to be calculated.

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. 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 125°C. Heated dilution gas can be added to the hydrocarbon sample gas to lower the gas moisture content to the detector. Dilution air was 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 135°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 611 ppm propane in air, the mid-gas was EPA Protocol 300 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. Total flow is measured with the dilution gas off. Sample flow is measured with it 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 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 2% of that determined by the flow meter.

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, center left), valve for sample (2 at center), toggle valve to vacuum pump (near calibration gas valves).

Calibration of the zero and span of the detector was done at the beginning of each measurement interval (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 five percent of full scale for a run and generally less than one percent. The zero drift was minimal during entire drying cycles.

HAPs sampling

The sampling train for NCASI Method 105 (modified to have an extra impinger) is shown in Figure 4. 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 each impinger. The fourth impinger was not used. 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. 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 2 to about 3 hours, depending on the condensation rate of water.

FIGURE 4. Sampling train for the methanol and formaldehyde.

At the end of each interval, the flow rate was again measured. The sampling line(s) was rinsed. The fluid in the three impingers was weighed, placed in a vial. The impingers were than rinsed with 10 mL of water followed by 3 to 5 mL of hexane. The rinses were also placed in the vial and it was sealed. Samples were kept refrigerated and in the dark until lab analysis was done. Lab analysis was done within two weeks after 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.

Sampling by the NCASI Method 98.01 was the same as described above for NCASI 105 with the following exceptions. The first impingers were filled with 15 and 10 mL of water, respectively, instead of BHA solution. No water was put in the third impinger. There is no water rinse or hexane rinse after sample collection.

Lab analysis for aldehydes (105)

The aldehyde standard was prepared by the volumetric dilution of neat aldehydes into 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 15 minutes to allow for derivatization of the aldehydes into aldoximes. The derivatized aldehyde solution was extracted with three aliquots of hexane and brought to volume to make 1000 mg/L. A standard curve was prepared by volumetric dilution in hexane at a range from 1 to 100 mg/L as aldehydes into autosampler vials with 100 mg/L of nitrobenzene as an internal standard.

The samples were prepared by extraction in a separatory funnel with three aliquots of hexane for a total hexane volume of approximately 25 mL. The volumes of the two phases were calculated from their weights. A 1 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 .25 µm. 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 H_2 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 H_2 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 (105)

The methanol standard was prepared by the volumetric dilution of neat methanol into water. The phenol standard was prepared by the gravimetric addition of solid phenol to a known volume of water. The alcohol mixed standard was prepared by volumetric addition of methanol to a gravimetrically prepared phenol standard. The mixed standard was prepared at a concentration of 1000 milligrams per liter (mg/L). A standard curve was prepared by the volumetric dilution of the mixed standard at a range from 5 mg/L to 1000 mg/L into autosampler vials.

Samples were prepared by transferring aliquots of the previously hexane extracted aqueous fractions into autosampler vials.

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 H_2 was set to 50 mL/min. The air was set to 500 mL/min. The He and H_2 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.

Lab analysis for methanol (98.01)

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 H_2 was set to 50 mL/min. The air was set to 500 mL/min. The He and H_2 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.

Lab analysis for formaldehyde (98.01)

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 7.5 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, RunName.XLS" in Appendix 2 shows the calculations for each 3-minute interval during the charges (RunName="Hampton, DF4" or "Hampton HF4"). 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 of water at the wet-bulb temperature. The absolute humidity is shown in column G and the molal humidity in column H. These are calculated based on the dry-bulb temperature, wet-bulb temperature, vapor pressure.

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. These values are for the dry gas vented from the kiln.

Moisture calculations

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

The moisture content of the wood at each time interval in the event (column N) was determined by reducing the MC of the wood from the previous time interval by accounting for the amount of water leaving the kiln during the interval. This amount has been adjusted by adjusting the wet-bulb temperature to make the ending moisture content match.

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 period before 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 using the molar humidity (column H).

In column T, the hydrocarbon flow rate in g_{carbon}/min is calculated in a manner analogous to the water flow rate using the dry gas flow rate from column K and the hydrocarbon concentration from column S. 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 obtain the average gas moisture contents. The uncorrected wood moisture content is shown in column AC. This is the MC in column N before adjustment of the wet-bulb to make the beginning and ending MCs match the oven-dry test. The kiln air and analyzer air moisture contents (based on volume) are shown in columns AD and AE.

At the end of the FlowCalc spreadsheet (below the data) are summaries by run of the flow data for the total hydrocarbon run intervals. Further down are summaries by impinger interval. These are the tables that appear in the body of the report. The other pages in the files "Kiln, RunName.XLS" are graphs of the data in the FlowCalc page.

Moisture content and board weight data are in the files named "Weights, RunName.XLS."

HAP calculations (105)

Data from the lab analysis for HAPs is shown in Appendix 3. The laboratory data reduction for the HAPs (from the field data sheets and lab analysis) is shown in electronic form in the file named "HAPs, RunName.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 sheets (samples of actual sheets included in Appendix 3 and PDF versions are included in Appendix 2) and includes the ambient pressure, lab temperature, flow rate through the impingers, and run start and stop times. The "Laboratory Data" page includes the results of the lab analyses on the impinger catch or hexane fraction. 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 HAPs in the impingers (columns L to Q).

The "Kiln Calculations" page uses a ratio of the dry gas flow through the kiln (calculated in the spreadsheets named "Kiln, RunName.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 (columns I to N).

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 (columns B-G) or per mbf basis (columns H-M). Concentrations leaving the kiln are given in columns N to Y.

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.

The remaining pages in "HAPs, RunName.XLS" are for graphing purposes.

HAP calculations (98.01)

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, RunName.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.

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 time to 15% moisture content was estimated by interpolation and the emissions are reported from green to 15% moisture content.

Figure 5 shows total hydrocarbon concentration (left scale) and dry gas vent rate (right scale) versus time. Profiles are similar in replicate charges.

The total hydrocarbon concentration is very dependent on the venting early in the schedule with a high vent rate resulting in a low hydrocarbon concentration and vice versa. Once the venting increases, the total hydrocarbon concentration decreases. In the lower-temperature schedules, the total hydrocarbon concentration remains low until the venting starts to decrease. In the higher-temperature schedules, the total hydrocarbon decreases, probably because the drying rate decreases, then increases as the vent rate decreases.

Note that total hydrocarbon concentration is not indicative of the amount of hydrocarbon emissions unless one also considers the vent rate. These two factors combined determine the emissions.

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. The maximum emission rates occur early in the schedules.

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 contents and final moisture contents based on the oven-dry method are shown on each plot.

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. In agreement with past studies, there is a fairly linear relationship between the emissions and the decrease in moisture content.

FIGURE 5a. Hydrocarbon concentration and vent rate versus time for the Douglas-fir charge.

FIGURE 5b. Hydrocarbon concentration and vent rate versus time for the hemlock charge.

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

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

FIGURE 7a. Moisture content versus time for the Douglas-fir charge.

FIGURE 7b. Moisture content versus time for the hemlock charge.

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

FIGURE 8b. Cumulative emissions versus moisture content (as carbon) for the hemlock charge.

Table 3 shows the VOC results by run for the charges. A run is an interval between analyzer calibrations, about three to four hours of data. 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 with full PDF format versions in Appendix 2.

TABLE 3a. Summary of sample runs for analysis of total hydrocarbon for the Douglas-fir charge.

Sample Run	Time	Cumulative		Average Humidity	Dry Flow Rate @68	THC mass as C	THC			Average MC		
		Dry Gas	Water				wet conc	as C	as C	Wood	Air	Anal
	hrs	kg	kg	kg/kg	l/min	g	ppmv	lbs/mbf	lb/hr/mbf	%	%	%
1	3.90	67.43	3.39	0.050	239.0	0.26	3.5	0.008	0.0020	99.5	7.5	7.5
2	4.05	31.35	4.36	0.139	107.0	0.61	14.6	0.018	0.0045	91.0	18.3	18.3
3	2.85	14.66	4.21	0.287	71.1	0.56	21.0	0.017	0.0059	82.8	31.6	12.5
4	3.55	16.02	4.74	0.296	62.4	0.57	19.4	0.017	0.0049	73.9	32.3	12.9
5	5.90	48.66	9.73	0.200	114.0	0.90	13.5	0.027	0.0046	60.4	24.4	10.0
6	4.15	33.47	5.60	0.167	111.5	0.45	8.5	0.013	0.0032	44.0	21.2	8.7
7	2.60	15.18	2.50	0.164	80.7	0.23	9.6	0.007	0.0027	36.2	20.9	12.0
8	3.45	15.88	2.67	0.168	63.6	0.26	10.2	0.008	0.0022	31.1	21.3	12.1
9	3.50	12.20	2.02	0.165	48.2	0.22	11.4	0.007	0.0019	26.4	21.0	12.0
10	3.95	10.38	1.73	0.167	36.3	0.21	12.7	0.006	0.0016	22.7	21.2	12.1
11	5.70	10.52	1.76	0.167	25.5	0.25	14.9	0.007	0.0013	19.2	21.2	12.1
12	4.90	6.48	1.09	0.168	18.3	0.17	16.6	0.005	0.0011	16.5	21.3	12.1
13	1.20	1.39	0.23	0.164	16.0	0.04	17.8	0.001	0.0010	15.2	20.9	12.0
Sum	49.70	283.6	44.0			4.7		0.142				
Average				0.177	76.4		13.4		0.0028			

TABLE 3b. Summary of sample runs for analysis of total hydrocarbon for the hemlock charge.

Sample Run	Time	Cumulative		Average Humidity	Dry Flow Rate @68	THC mass as C	THC			Average MC		
		Dry Gas	Water				wet conc	as C	as C	Wood	Air	Anal
	hrs	kg	kg	kg/kg	l/min	g	ppmv	lbs/mbf	lb/hr/mbf	%	%	%
1	3.05	33.57	1.84	0.055	152.1	1.24	36.8	0.034	0.0111	55.8	8.1	8.1
2	3.65	68.82	4.60	0.067	260.6	1.45	15.2	0.040	0.0109	49.9	9.7	9.7
3	4.80	74.41	6.85	0.092	214.3	2.17	20.4	0.059	0.0124	39.8	12.9	12.9
4	4.25	42.59	4.94	0.116	138.5	1.60	25.2	0.044	0.0103	29.4	15.7	9.8
5	4.15	26.38	3.02	0.115	87.9	1.06	27.2	0.029	0.0070	22.7	15.6	9.8
6	3.50	14.83	1.71	0.115	58.6	0.68	30.9	0.019	0.0053	18.7	15.6	9.8
7	3.30	9.71	1.11	0.114	40.7	0.50	35.1	0.014	0.0042	16.3	15.6	9.8
8	0.80	1.95	0.22	0.113	33.8	0.11	37.7	0.003	0.0037	15.2	15.3	9.9
Sum	27.50	272.3	24.3			8.8		0.241				
Average				0.098	123.3		28.6		0.0081			

HAP results (105)

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.

The HAPs released are plotted as a function of time in Figure 9. In Figure 9, acetaldehyde and methanol are plotted with bold lines and correspond to the axis with larger values. The other HAPs are plotted on the smaller-scale axis.

The total HAPs released is a nonlinear function of moisture content (Figure 10), with the rate increasing with decreasing moisture content.

TABLE 4a. Results of NCASI 105 laboratory analyses for the hemlock charge.

Aqueous concentrations			Hexane concentrations					
Sample Run	Methanol µg/mL	Phenol µg/mL	Sample Run	Formaldehyde µg/mL	Acetaldehyde µg/mL	Propionaldehyde µg/mL	Acrolein µg/mL	Mass g
1	1.7	0.00	1	0.2	41.0	0.6	0.1	11.42
2	3.9	0.00	2	0.4	55.7	1.2	0.3	13.84
3	13.6	0.00	3	0.7	103.9	2.7	1.5	13.04
4	22.5	0.00	4	1.6	82.6	2.5	1.6	12.53
5	18.9	0.00	5	1.4	46.6	1.4	1.0	12.56
6	11.7	0.00	6	0.6	27.0	0.8	0.6	14.82
7	16.3	0.00	7	0.9	36.4	1.1	0.8	12.63
8	18.6	0.00	8	1.0	30.1	0.8	0.7	14.66
9	23.1	0.00	9	0.8	31.3	0.9	0.7	14.28
10	29.5	0.00	10	1.4	40.1	1.1	1.1	14.67
11	34.2	0.00	11	1.4	43.4	1.3	1.2	13.35
12	41.1	0.00	12	1.7	51.3	1.5	1.4	13.39
13	47.8	0.00	13	1.6	50.3	1.6	1.5	14.27

TABLE 4b. Results of NCASI 105 laboratory analyses for the Douglas-fir charge.

Aqueous concentrations			Hexane concentrations					
Sample Run	Methanol µg/mL	Phenol µg/mL	Sample Run	Formaldehyde µg/mL	Acetaldehyde µg/mL	Propionaldehyde µg/mL	Acrolein µg/mL	Mass g
1	4.3	0.00	1	0.3	36.7	0.2	0.0	15.08
2	3.6	0.00	2	0.3	16.1	0.2	0.0	13.79
3	4.2	0.00	3	0.5	16.9	0.1	0.0	13.76
4	6.1	0.00	4	0.7	17.0	0.2	0.8	15.00
5	9.5	0.00	5	1.1	24.9	0.4	1.4	12.10
6	16.5	0.00	6	1.0	23.6	0.5	1.3	11.75
7	14.9	0.00	7	0.8	16.9	0.4	0.0	15.37
8	22.0	0.00	8	1.0	21.6	0.5	1.0	14.13
9	31.0	0.00	9	1.4	29.9	0.8	1.2	16.79
10	27.1	0.00	10	1.5	27.4	0.8	1.2	13.89
11	31.3	0.00	11	1.5	28.9	0.8	1.2	13.19
12	29.4	0.00	12	1.4	24.1	0.9	2.3	13.42

TABLE 5a. Summary of NCASI 105 sample runs for HAPs for the hemlock charge.

Sample Run ID	Mass					
	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	0.0022	0.0000	0.0001	0.0122	0.0002	0.00004
2	0.0036	0.0000	0.0001	0.0113	0.0002	0.00006
3	0.0060	0.0000	0.0001	0.0111	0.0003	0.00016
4	0.0076	0.0000	0.0002	0.0091	0.0003	0.00018
5	0.0109	0.0000	0.0003	0.0103	0.0003	0.00022
6	0.0070	0.0000	0.0001	0.0060	0.0002	0.00013
7	0.0076	0.0000	0.0001	0.0048	0.0001	0.00011
8	0.0063	0.0000	0.0001	0.0034	0.0001	0.00008
9	0.0052	0.0000	0.0001	0.0026	0.0001	0.00006
10	0.0062	0.0000	0.0001	0.0027	0.0001	0.00007
11	0.0051	0.0000	0.0001	0.0020	0.0001	0.00005
12	0.0042	0.0000	0.0001	0.0015	0.0000	0.00004
13	0.0029	0.0000	0.0000	0.0009	0.0000	0.00003
SUM	0.075	0.0000	0.0014	0.078	0.0020	0.0012

Sample Run ID	Concentration in dry gas						Concentration in wet gas					
	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	1.11	0.00	0.03	4.42	0.05	0.01	1.03	0.00	0.03	4.11	0.05	0.01
2	3.03	0.00	0.07	6.99	0.11	0.03	2.54	0.00	0.06	5.87	0.09	0.02
3	9.34	0.00	0.13	12.57	0.25	0.14	6.41	0.00	0.09	8.63	0.17	0.10
4	12.63	0.00	0.32	11.07	0.25	0.17	8.59	0.00	0.22	7.52	0.17	0.12
5	8.47	0.00	0.26	5.82	0.13	0.10	6.44	0.00	0.20	4.42	0.10	0.08
6	5.92	0.00	0.13	3.70	0.08	0.06	4.66	0.00	0.10	2.91	0.07	0.05
7	9.89	0.00	0.16	4.57	0.11	0.08	7.80	0.00	0.13	3.60	0.08	0.07
8	12.23	0.00	0.23	4.70	0.10	0.09	9.63	0.00	0.18	3.70	0.08	0.07
9	14.93	0.00	0.20	5.41	0.12	0.10	11.81	0.00	0.16	4.28	0.09	0.08
10	17.52	0.00	0.28	5.61	0.12	0.12	13.81	0.00	0.22	4.42	0.09	0.09
11	21.00	0.00	0.28	5.87	0.13	0.13	16.55	0.00	0.22	4.63	0.10	0.10
12	24.11	0.00	0.32	6.37	0.14	0.13	18.97	0.00	0.25	5.01	0.11	0.11

TABLE 5b. Summary of NCASI 105 sample runs for HAPs for the Douglas-fir charge.

Sample Run ID	Mass					
	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	0.0024	0.0000	0.0001	0.0075	0.0001	0.00000
2	0.0028	0.0000	0.0001	0.0057	0.0001	0.00000
3	0.0042	0.0000	0.0002	0.0058	0.0000	0.00000
4	0.0048	0.0000	0.0002	0.0048	0.0001	0.00022
5	0.0041	0.0000	0.0001	0.0030	0.0001	0.00017
6	0.0030	0.0000	0.0001	0.0018	0.0000	0.00010
7	0.0020	0.0000	0.0001	0.0012	0.0000	0.00000
8	0.0010	0.0000	0.0000	0.0004	0.0000	0.00002
SUM	0.024	0.0000	0.0008	0.030	0.0004	0.0005

Sample Run ID	Concentration in dry gas						Concentration in wet gas					
	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
1	2.67	0.00	0.07	6.04	0.03	0.00	2.45	0.00	0.07	5.55	0.03	0.00
2	1.36	0.00	0.05	2.06	0.02	0.00	1.23	0.00	0.05	1.87	0.02	0.00
3	1.84	0.00	0.08	1.86	0.01	0.00	1.61	0.00	0.07	1.63	0.01	0.00
4	3.39	0.00	0.15	2.47	0.03	0.09	2.86	0.00	0.12	2.08	0.02	0.07
5	5.26	0.00	0.19	2.83	0.04	0.13	4.44	0.00	0.16	2.38	0.03	0.11
6	6.75	0.00	0.19	2.91	0.05	0.13	5.69	0.00	0.16	2.45	0.04	0.11
7	6.63	0.00	0.20	3.02	0.05	0.00	5.64	0.00	0.17	2.54	0.04	0.00
8	11.15	0.00	0.20	2.88	0.05	0.11	9.44	0.00	0.17	2.44	0.04	0.09

FIGURE 9a. Cumulative HAP emissions versus time for the hemlock charge (105).

FIGURE 9b. Cumulative HAP emissions versus time for the Douglas-fir charge (105).

FIGURE 10a. Cumulative HAP emissions versus wood moisture content for the hemlock charge (105).

FIGURE 10b. Cumulative HAP emissions versus wood moisture content for the Douglas-fir charge (105).

Methanol and formaldehyde (98.01)

Results of the lab analyses for methanol and formaldehyde are summarized in Table 6 and complete results are in Appendix 2. Table 7 shows a summary of the methanol and formaldehyde analyses by run during the charge.

The total emissions released as a function of time are shown in Figure 11. Figure 12 shown total emissions as a function of moisture content.

TABLE 6. Results of laboratory analyses for Douglas-fir (left) and hemlock impinger samples.

Impinger liquid concentrations			Impinger liquid concentrations		
Sample Run	Methanol mg/L	Formaldehyde mg/L	Sample Run	Methanol mg/L	Formaldehyde mg/L
1	3.9	0.06	1	7.5	0.15
2	6.9	0.15	2	3.8	0.00
3	21.3	0.32	3	5.2	0.00
4	27.0	0.33	4	9.5	0.35
5	20.3	0.28	5	14.6	0.28
6	16.8	0.35	6	20.6	0.52
7	24.3	0.45	7	20.3	0.47
8	28.9	0.48	8	32.3	0.10
9	33.9	0.48	9	43.2	0.38
10	47.1	0.58	10	46.7	0.76
11	58.5	0.72	11	54.5	0.79
12	64.7	0.73	12	55.9	0.78
13	78.8	0.82	13	54.2	0.69

TABLE 7A. Summary of sample runs for methanol and formaldehyde for hemlock.

Hemlock Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass	Average Dry gas flowrate	Molar Humidity	Moisture Content		Mass 1000 board feet		Concentration in dry gas		Concentration in wet gas	
						Mid	End	MeOH	CHOH	MeOH	CHOH	MeOH	CHOH
	hours	hours	kg	kg/min	mol/mol	%	%	lb/mbf	lb/mbf	ppm	ppm	ppm	ppm
1	3.10	3.35	60.577	0.301	0.076	100.1	96.7	0.0025	0.00004	1.23	0.02	1.15	0.02
2	3.20	3.80	35.406	0.155	0.191	92.4	88.4	0.0033	0.00007	2.80	0.07	2.35	0.06
3	3.20	4.10	19.347	0.079	0.456	83.2	77.5	0.0070	0.00011	10.95	0.18	7.52	0.12
4	2.90	4.05	18.093	0.074	0.471	72.1	67.0	0.0072	0.00009	11.93	0.16	8.11	0.11
5	3.05	4.35	38.841	0.149	0.317	60.1	51.8	0.0131	0.00018	10.16	0.15	7.71	0.11
6	3.10	4.20	35.724	0.142	0.269	45.5	40.0	0.0086	0.00018	7.25	0.16	5.72	0.13
7	2.95	4.00	23.090	0.096	0.268	36.0	32.4	0.0076	0.00014	9.97	0.20	7.87	0.16
8	2.80	3.65	15.632	0.071	0.270	29.6	27.2	0.0065	0.00011	12.52	0.22	9.86	0.18
9	2.45	3.30	10.583	0.053	0.264	25.4	23.7	0.0054	0.00008	15.47	0.24	12.23	0.19
10	2.95	4.40	10.694	0.041	0.269	21.9	20.2	0.0075	0.00009	21.14	0.28	16.66	0.22
11	2.90	4.05	7.301	0.030	0.269	18.9	17.8	0.0060	0.00007	24.75	0.32	19.51	0.26
12	3.05	3.75	5.250	0.023	0.271	16.9	16.0	0.0049	0.00006	28.31	0.34	22.28	0.27
13	3.05	2.70	3.114	0.019	0.269	15.5	15.0	0.0034	0.00003	32.65	0.36	25.73	0.28
SUM								0.083	0.00125				

TABLE 7B. Summary of sample runs for methanol and formaldehyde for Douglas-fir.

Douglas-fir Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass	Average Dry gas flowrate	Molar Humidity	Moisture Content		Mass 1000 board feet		Concentration in dry gas		Concentration in wet gas	
						Mid	End	MeOH	CHOH	MeOH	CHOH	MeOH	CHOH
	hours	hours	kg	kg/min	mol/mol	%	%	lb/mbf	lb/mbf	ppm	ppm	ppm	ppm
1	2.65	2.85	29.806	0.174	0.088	56.0	54.1	0.0023	0.00005	2.51	0.05	2.31	0.05
2	3.10	3.55	66.913	0.314	0.106	50.5	46.5	0.0024	0.00009	1.19	0.05	1.07	0.04
3	3.65	4.70	75.275	0.267	0.144	40.7	34.9	0.0037	0.00024	1.62	0.11	1.42	0.10
4	3.10	4.55	46.631	0.171	0.186	29.9	25.6	0.0046	0.00017	3.26	0.13	2.75	0.11
5	3.10	4.00	25.904	0.108	0.185	22.9	20.5	0.0040	0.00008	5.12	0.10	4.32	0.09
6	2.90	3.40	14.836	0.073	0.185	18.9	17.5	0.0034	0.00009	7.69	0.21	6.49	0.17
7	2.45	3.20	9.800	0.051	0.185	16.5	15.6	0.0041	0.00010	13.79	0.34	11.64	0.29
8	3.25	1.25	3.110	0.041	0.181	15.3	15.0	0.0011	0.00000	12.06	0.04	10.21	0.03
SUM								0.026	0.00080				

FIGURE 11A. Cumulative methanol and formaldehyde emissions versus time for hemlock (98.01).

FIGURE 11B. Cumulative methanol and formaldehyde emissions versus time for Douglas-fir (98.01).

FIGURE 12A. Cumulative methanol and formaldehyde emissions versus wood moisture content for hemlock (98.01).

FIGURE 12B. Cumulative methanol and formaldehyde emissions versus wood moisture content for Douglas-fir (98.01).

Discussion of results

Total hydrocarbon

The average values for the total hydrocarbon emissions in this study were 0.14 lbs_c/mbf (pounds as carbon per thousand board feet) for hemlock and 0.24 lbs_c/mbf for Douglas-fir. The total hydrocarbon value for hemlock is a little low, but consistent with past work. For example, the correlation in Milota and Mosher (Forest Product Journal, May 2006) would predict total hydrocarbon emissions of 0.2 to 0.25 lbs_c/mbf for the hemlock tested. In February, we measured 0.18 lbs_c/mbf for hemlock from Hampton. For Douglas-fir, past studies have measured total hydrocarbon emissions from 0.49 (Milota, Forest Product Journal, July 2006) to 1.19 lbs_c/mbf (Wu and Milota, Forest Products Journal, June, 1999), higher than in this study. In February, we measured 0.65 lbs_c/mbf for Douglas-fir from Hampton dried at the same temperatures. The Douglas-fir in this study had a slightly lower initial moisture content, 56%, compared to 80% for that dried in February.

HAPs

The two methods, NCASI 105 and NCASI 98.01, had surprisingly good agreement (See Table 1, page 1) for the methanol and formaldehyde. We expected the NCASI 105 method to give a lower value for formaldehyde based on past work, but this was not the case.

Methanol - The methanol emitted from hemlock, an average of 0.079 lb/mbf, was twice that measured in February, but lower than would be predicted by Milota and Mosher (Forest Product Journal, May 2006), approximately 0.15 to 0.2 lb/mbf. The methanol emitted from Douglas-fir averaged 0.025 lb/mbf. This is very consistent with the work for Hampton last February (0.024 lb/mbf) and also with 0.023 lb/mbf predicted by Milota, 2006 (Forest Product Journal, July 2006).

Phenol - Phenol was not detected. This is consistent with past results.

Formaldehyde - The formaldehyde emitted from hemlock, 0.0013 lb/mbf, was higher than the 0.0005 lb/mbf measured for Hampton in February but consistent with that predicted by Milota and Mosher (Forest Product Journal, May 2006), approximately 0.0018 lb/mbf. The formaldehyde emitted from Douglas-fir, 0.0008 lb/mbf, was higher than the 0.0005 lb/mbf measured for Hampton in February but consistent with that predicted by Milota (Forest Product Journal, July 2006), approximately 0.001 lb/mbf.

Acetaldehyde - The acetaldehyde emissions for hemlock, 0.078 lb/mbf, were lower than those reported for Rosboro lumber earlier in the year (0.13 lb/mbf). The acetaldehyde emissions did, however, exceed the methanol emissions. The acetaldehyde emissions

for Douglas-fir, 0.030 lb/mbf, were lower than the average reported for Rosboro lumber earlier in the year (0.057 lb/mbf) but within the range of that data (0.043 to 0.071 lb/mbf). The acetaldehyde emissions did also exceed the methanol emissions.

Propionaldehyde - The propionaldehyde emissions for hemlock, 0.0020 lb/mbf, were higher than those reported for Rosboro lumber earlier in the year (0.009 lb/mbf) The propionaldehyde emissions for Douglas-fir, 0.0004 lb/mbf, were consistent with that reported for Rosboro lumber earlier in the year (0.0005-0.0006 lb/mbf)

Acrolein - The acrolein emissions. 0.0012 lb/mbf for hemlock and 0.0005 lb/mbf for Douglas-fir were within the range of the work for Rosboro.

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 8.

TABLE 8. Comparison of results to past work.

Species[A]	Tested by	Dry-bulb Temperature °F	VOC lb$_c$/mbf	Methanol lb/mbf	Formaldehyde lb/mbf
Hemlock (this work)	OSU	180	0.14	0.079	0.0013
Hemlock (for Hampton in Feb. 2007)	OSU	180	0.18	0.038	0.0005
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 (this work)	OSU	170	0.24	0.024	0.0008
Douglas-fir (for Hampton in Feb. 2007)	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 4. The mid gas was not named because the analyzer was within tolerance without naming.

Detection limits (105)

The instrument detection limits were -

Methanol - 0.66 µg/mL in the aqueous phase
Phenol - 0.76 µg/mL in the aqueous phase
Formaldehyde - 0.12 µg/mL in the hexane phase
Acetaldehyde - 0.19 µg/mL in the hexane phase
Propionaldehyde - 0.19 µg/mL in the hexane phase
Acrolein - 0.48 µg/mL in the hexane phase

All samples were present in the aqueous or hexane phase at concentrations above the instrument detection limits except acrolein.

For hemlock, acrolein concentrations in the first two samples were below the instrument detection limit. Calculating the acrolein emissions with ½ the instrument detection limit for these samples changes the acrolein emissions from 0.0012 lb/mbf to 0.0013 lb/mbf. Calculating the acrolein emissions with the full detection limit of 0.48 ppm for these samples changes the acrolein emissions from 0.0012 lb/mbf to 0.0014 lb/mbf.

For Douglas-fir, acrolein concentrations in four samples were below the instrument detection limit. Calculating the acrolein emissions with ½ the instrument detection limit for these samples changes the acrolein emissions from 0.0005 lb/mbf to 0.0007 lb/mbf. Calculating the acrolein emissions with the full detection limit of 0.48

ppm for these samples changes the acrolein emissions from 0.0005 lb/mbf to 0.0010 lb/mbf.

The method detection limit varies with gas flow through the impingers and the amount of water collected. We have calculated these for each sample in each charge by using the instrument method detection limit to calculate the concentration in the kiln gas) and averaged them below:

Hemlock:
    Methanol - mean = 0.32 ppmvd standard deviation = 0.05 ppmvd
    Phenol - mean = 0.12 ppmvd standard deviation = 0.02 ppmvd
    Formaldehyde - mean = 0.024 ppmvd standard deviation = 0.004 ppmvd
    Acetaldehyde - mean = 0.026 ppmvd standard deviation = 0.005 ppmvd
    Propionaldehyde - mean = 0.020 ppmvd standard deviation = 0.004 ppmvd
    Acrolein - mean = 0.052 ppmvd standard deviation = 0.009 ppmvd

Douglas-fir:
    Methanol - mean = 0.40 ppmvd standard deviation = 0.06 ppmvd
    Phenol - mean = 0.16 ppmvd standard deviation = 0.02 ppmvd
    Formaldehyde - mean = 0.024 ppmvd standard deviation = 0.003 ppmvd
    Acetaldehyde - mean = 0.025 ppmvd standard deviation = 0.003 ppmvd
    Propionaldehyde - mean = 0.019 ppmvd standard deviation = 0.003 ppmvd
    Acrolein - mean = 0.050 ppmvd standard deviation = 0.007 ppmvd

Detection limits (98.01)

No samples were near the detection limits for this method.

Spikes, duplicates, and blanks

Spikes were run by putting a known quantity of water containing methanol, phenol, formaldehyde, acetaldehyde, propionaldehyde, and acrolein 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. The results are shown in Table 7 and 8.

Methanol had spike recoveries of 90.7, 97, 104.3, and 84.2 for Method 105 and 96, 102, and 69% for Method 98.01, The one low value (>70% and <130% is acceptable) was spiked with a relatively low concentration.

Formaldehyde had spike recoveries of 63, 75, 68, and 85 for Method 105. These are lower than for Method 98.01 but within the acceptable range of 50% to 150% for concentrations less then 0.5 ppmvd. For Method 98.01 the spike recoveries were 98 and 101% (>70% and <130% is acceptable). The formaldehyde spike associated with Douglas-fir run 2 did not work due to clouding of the sample as noted in the anomalies section below.

Acetaldehyde had spike recoveries of 72, 72, 86, and 89%. The range of 70% to 130% is acceptable for gas concentrations greater than 1.5 ppmvd. It should be noted that these are all towards the low end suggesting that some acetaldehyde is not being recovered.

Propionaldehyde had spike recoveries of 71, 71, 87, and 84. The range of 50% to 150% is acceptable for gas concentrations less than 0.5 ppmvd. Again, these are all towards the low end suggesting that some propionaldehyde is not being recovered.

Acrolein had spike recoveries of 60, 59, 73, and 84%. The range of 50% to 150% is acceptable for concentrations less then 0.5 ppmvd. Again, these are all towards the low end suggesting that some acrolein is not being recovered.

Duplicate sample runs were made for each charge. These results of these are shown in Tables 7 and 8. All values under 30% are acceptable for methanol and acetaldehyde and 50% for the other compounds.

The difference between duplicates in Method 105 was 13 and 27% for methanol. In Method 98.01 the diferences were 9, 4, and 21%

The difference between duplicates in Method 105 was 5 and 1% for formaldehyde. In Method 98.01 the differences were 42 and 21%. The high

value (42%) was on a duplicate early in a charge when the concentrations are lower.

The difference between duplicates for acetaldehyde was 2 and 1%

The difference between duplicates for propionaldehyde was 3 and 9%

The difference between duplicates for acetaldehyde was 6%. In the second duplicate run, one sample was a "no detect" so a second recovery could not be calculated.

The NCASI 98.02 (chilled impingers with no BHA) gave similar results for the overall methanol and formaldehyde emissions as measures by Method 105.

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

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

Formaldehyde 98.01 samples two and three for the Douglas-fir clouded when exposed to the acetylacetone reagent. A repeat of the test yielded the same results - a cloudy solution on which the attenuation of visible light cannot be determined. We therefore use the formaldehyde released during the first interval for the second. For the third interval we used the formaldehyde value from the fourth interval.

In run 8 of the hemlock, the student did not record the weight of the spike. He was very consistent at filling the impingers, so we estimated the spike mass. There was a second spike for that charge so we are not depending on run 8 to validate the results.

TABLE 9a. Summary of quality assurance for the hemlock charge (NCASI 105).

	Alcohol Spike (105)									
Run	Mass in impinger		Impinger flow	Corrected mass		Spike mass	Spike concentrations		Spike recoveries	
	Methanol	Phenol		Methanol	Phenol		Methanol	Phenol	Methanol	Phenol
	µg	µg	mL/min	µg	µg	g	µg/mL	µg/mL	%	%
8	1264.5	0.0	431.3	1234.2	0.0					
108	4407.0	0.0	420.9	4407.0	0.0	3.5	1000.0	0.0	90.7	#DIV/0!

(estimated spike amount)

	Aldehyde Spike								
Run	Mass in impinger				Impinger flow	Mass corrected for flow			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
8	22.4	669.1	18.9	15.9	431.3	21.9	653.1	18.4	15.6
108	54.7	4427.7	55.5	47.0	420.9	54.7	4427.7	55.5	47.0

Spike mass	Spike concentrations					Spike recoveries			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
3.5	15.0	1500.0	15.0	15.0		62.6	71.9	70.6	59.9

	Duplicate						
Run	Mass in impinger						Impinger flow
	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	mL/min
8	708.3	0.0	14.2	806.9	18.1	12.9	449.4
108	762.6	0.0	14.1	584.5	16.6	11.5	424.9
Difference, %	12.9	#DIV/0!	4.5	1.6	3.1	5.6	

Field blank					
Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm
0.0	0.0	0.0	0.0	0.0	0.0

	Alcohol Spike (105)									
Run	Mass in impinger		Impinger flow	Corrected mass		Spike mass	Spike concentrations		Spike recoveries	
	Methanol	Phenol		Methanol	Phenol		Methanol	Phenol	Methanol	Phenol
	µg	µg	mL/min	µg	µg	g	µg/mL	µg/mL	%	%
13	3372.3	0.0	467.2	3291.5	0.0					
113	8849.0	0.0	430.9	8849.0	0.0	5.73	1000.0	0.0	97.0	#DIV/0!

	Aldehyde Spike								
Run	Mass in impinger				Impinger flow	Mass corrected for flow			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
13	34.0	1089.5	34.0	33.4	467.2	32.1	1026.8	32.1	31.5
113	96.2	7232.0	92.7	82.4	430.9	96.2	7232.0	92.7	82.4

Spike mass	Spike concentrations					Spike recoveries			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
g	µg	µg	µg	µg		%	%	%	%
5.73	15.0	1500.0	15.0	15.0		74.6	72.2	70.5	59.3

TABLE 9b. Summary of quality assurance for the Douglas-fir charge (NCASI 105).

Run	Alcohol Spike (105)									
	Mass in impinger		Impinger flow	Corrected mass		Spike mass	Spike concentrations		Spike recoveries	
	Methanol	Phenol	flow	Methanol	Phenol	mass	Methanol	Phenol	Methanol	Phenol
	µg	µg	mL/min	µg	µg	g	µg/mL	µg/mL	%	%
3	253.7	0.0	441.3	253.8	0.0					
103	4681.8	0.0	441.5	4681.8	0.0	4.13	1000.0	0.0	104.3	#DIV/0!

Run	Aldehyde Spike								
	Mass in impinger				Impinger flow	Mass corrected for flow			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	flow	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
3	10.7	353.1	2.9	0.0	441.3	10.7	353.2	2.9	0.0
103	52.8	5700.4	58.6	52.2	441.5	52.8	5700.4	58.6	52.2

Spike mass	Spike concentrations					Spike recoveries			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
4.13	15.0	1500.0	15.0	15.0		67.9	86.3	86.7	84.3

Run	Duplicate						
	Mass in impinger						Impinger flow
	Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	flow
	µg	µg	µg	µg	µg	µg	mL/min
7	633.8	0.0	18.2	393.3	8.5	0.0	452.1
107	782.1	0.0	17.0	383.1	8.6	16.7	419.8
Difference, %	27.3	#DIV/0!	1.0	0.6	8.9	200.0	

Field blank					
Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm
0.0	0.0	0.0	0.0	0.0	0.0

Run	Alcohol Spike (105)									
	Mass in impinger		Impinger flow	Corrected mass		Spike mass	Spike concentrations		Spike recoveries	
	Methanol	Phenol	flow	Methanol	Phenol	mass	Methanol	Phenol	Methanol	Phenol
	µg	µg	mL/min	µg	µg	g	µg/mL	µg/mL	%	%
13	1302.0	0.0	419.6	1302.4	0.0					
113	3660.7	0.0	421.0	3660.7	0.0	2.8	1000.0	0.0	84.2	#DIV/0!

Run	Aldehyde Spike								
	Mass in impinger				Impinger flow	Mass corrected for flow			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	flow	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
8	22.0	462.5	10.8	21.7	419.6	22.1	464.1	10.9	21.8
109	57.8	4199.0	46.2	52.5	421.0	57.8	4199.0	46.2	52.5

Spike mass	Spike concentrations					Spike recoveries			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
2.8	15.0	1500.0	15.0	15.0		84.9	83.9	84.1	73.3

TABLE 10a. Summary of quality assurance for the hemlock charge (NCASI 98.01).

				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	%
7	1098.7	432.1	1066.8					
71	3987.8	423.4	3987.8	2901.0	3.00	1000	3000	96.7

				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	%
7	20.2	432.1	19.8					
71	64.1	423.4	64.1	44.3	3.00	15	45	98.4

		Duplicate		
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
2	333.9	434.6	318.7	
21	350.1	414.9	350.1	8.9

Field blank	
Concentrations	
Methanol	Formald.
ppm	ppm
0.0	0.0

		Duplicate		
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
2	7.4	434.8	7.1	
21	12.2	414.9	12.2	41.9

TABLE 10b. Summary of quality assurance for the Douglas-fir charge (NCASI 98.01).

				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	%
2	138.9	440.7	132.2					
102	4367.3	419.3	4367.3	4235.2	4.13	1000	4130	102.5

				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	%
2	5.0	440.7	4.8					
102	0.0	419.3	0.0	-4.8	4.13	15	61.95	-7.7

		Duplicate		
Methanol Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
12	2381.3	452.3	2345.3	
112	2252.0	445.4	2252.0	4.1

Field blank	
Concentrations	
Methanol	Formald.
ppm	ppm
0.0	0.0

		Duplicate		
Formaldehyde Run	Mass in impinger	Impinger flow	Corrected mass	Mass difference
	µg	mL/min	µg	%
12	33.2	452.3	32.7	
112	27.0	445.4	27.0	20.9

				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	%
9	2126.7	476.6	1964.0					
109	4792.0	440.1	4792.0	2828.0	4.13	1000	4130	68.5

				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	%
9	18.8	476.6	17.4					
109	80.0	440.1	80.0	62.7	4.13	15	61.95	101.2

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 -

Percent moisture = 100 / [1 + 1 / 1.61*AbHum]
Target Dilution Ratio (TDR) = 15 / 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 x (1 - DR)
Target sample flow rate (TSFR) is the TFR x 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 $100*(DR_{Span} - DR_{Flow})/DR_{Flow}$ 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 $100 * \{\text{Absolute Value } (DR_{Span} - DR_{Flow})\} / DR_{Flow}$

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 HAP measurement

PRE RUN DATA
Call 9-754-0081 and get altimeter setting.
Read the laboratory temperature from the thermometer.

IMPINGER WEIGHTS
Lab wash impingers, Dry the outside.
Weigh the impingers.

Put 15 mL BHA solution in impinger #1. (10 mL distilled water for 98.01 and 99.02)
Put 15 mL BHA solution impinger #2   (20 mL distilled water for 98.01 and 99.02)
Put 15 mL BHA solution in impingeer   (Empty for 98.01 and 99.02)

Reweigh the impingers.
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 (99.02 only)
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 (98.01). 99.02 is limited by Summa canister time limit. Run < 3 hours for 98.01.

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 cannister
Record time

SAMPLE FLOW RATE

Rinse probe with 5 mL of DI water (weighed)
Attach probe tip to Gilibrator
Take 4 readings
Make sure all readings in average are "good" readings
Record the average
Lift impingers from chiller
Remove impingers

IMPINGER WEIGHTS

Pre weigh and label sample bottle and lid
Dry the outside of the impingers
Weigh the impingers with the water (no tops) and record
Combine the water from the two (or three) impingers into the labeled bottle
Weight the bottle with its lid (105 only)
Rinse the impingers with 10 mL distilled water - #3 then #2 then #1 (105 only)
Put the rinse into the vial and weigh the vial with its lid (105 only)
Rinse the impingers with 5 mL hexane - #3 then #2 then #1 (105 only)
Put the rinse into the vial and weigh the vial with its lid (105 only)
Place sealed vial into refrigerator
Note any liquid lost during this procedure

Appendix 3. Samples of field data sheets.

Hampton Klem PM

| Charge: | 1 |
| Page: | 2 |

	Date	Time
Start	3-19-07	9:56
End	3-21-07	12:27

Clock	Run	Run	Temperatures						Flows							Line 1	Line 2	Line 3
time	time	#	Box	Valve	Dry-bulb	Wet-bulb	Line	Chiller	Flow 1	Flow 2	Flow 3	Dilution	Line 1	Line 2	Line 3	Vac.	Vac.	Vac.
	hrs		°C	°C	°C	°C	°C	°C	L/min	L/min	SCFH	SCFM	ml/min	ml/min	ml/min	inHg	inHg	inHg
10:27	26:05	10	125	145	28.4	22.0	135	-1	27	/	/	1.5	500	450	/	28	27.5	/
12:55	2:02	10	122	145	28.4	25.0	135	-1	18	/	/	1.5	500	450	/	28	27.5	/
13:50	37:54	10	125	145	28.2	25.0	135	-1	31	/	/	1.5	500	450	/	92	27.5	/
1:28	39:32	11	122	145	28.5	25.5	135	-1	25	/	/	1.5	500	450	1	92	92	/
8:47	3-20-07 46:53	11	125	145	82.6	25.9	135	-1	22	1	1	1.5	500	450	1	28	28	/
4:45	43:48	12	125	145	82.4	25.8	135	-1	14	1	1	1.5	500	450	1	28	28	/
7:22	45:22	12	125	145	82.8	25.9	135	-1	17	1	1	1.5	500	450	1	28	28	/
05:04	69:04	13	125	146	82.6	26.9	135	-1	17	0	0	1.5	500	450	500	28	27.5	27

82-146

Hampton Heutir

BACKGROUND INFORMATION

Operator: _P. Mosher_

Date: _3-19-07_

Time now: _13:40_

TRAIN #1 - BEFORE

Event (kiln charge): _4_

Run (sample): _2a_

PRE RUN DATA

Altimeter setting: _29.87_ inHg   Laboratory temperature: _21.2_ °C

Isopropanol rinse or lab wash: ☒

IMPINGER WEIGHTS

	Dry Weight, g	Wet Weight, g	Water added, g
Impinger #1	42.85	66.90	(~10 mL)
Impinger #2	42.23	66.97	(~15-20 mL)
Impinger #3	39.63	65.88	-----
		Total added:	

LEAK CHECK _∅_ inHg after 2 minutes

SAMPLE FLOW RATE: _494.3_ mL/min   [Average of 4. Label printout]

START   CLOCK TIME: _13:49_

EVENT TIME: _3:52_ (elapsed time)

FLOW READINGS DURING TEST (hourly)

Clock time			
Flow rate, mL/min			
Vent flow, L/min			

FIELD DATA SHEET, 105 HAPS MEASUREMENT - AFTER SAMPLING

BACKGROUND INFORMATION

Operator: __P. Mosher__

Time now : __16:50__

TRAIN #1 - AFTER

Event (kiln charge): __4__

Run (sample): __2a__

POST RUN DATA

Altimeter setting: __29.88__ inHg   Laboratory temperature: __21.2__ °C

END   CLOCK TIME: __16:50__

          EVENT TIME: __6:53__ (elapsed time)

EMPTY BOTTLE WEIGHT: __125.92__ g

SAMPLE LINE RINSE : __22.06__ g   __13.96__ g   (~5 mL)

SAMPLE FLOW RATE : __496.4__ mL/min   [Average of 4. Label printout]

IMPINGER WEIGHTS

	Wet Weight, g	Dry Weight, g	Water removed, g
Impinger #1	75.74	42.85	32.89
Impinger #2	73.40	42.23	31.17
Impinger #3	71.21	39.63	31.58

BOTTLE WEIGHT WITHOUT RINSE: __221.56__ g

BOTTLE WEIGHT WITH RINSE: __226.23__ g

HEXANE RINSE: ~~X~~

FILLED BOTTLE WEIGHT: __231.47__ g

Water lost during handling: _____ mL   [estimate]

Comments:

_____

_____

_____

579-637

FIELD DATA SHEET, 98.01 HAPS MEASUREMENT - BEFORE SAMPLING

BACKGROUND INFORMATION   #1

Operator: J. Kosber

Date: 3-20-07

Time now : 1:36

TRAIN #2 - BEFORE

Event (kiln charge): 7

Run (sample): Bg

PRE RUN DATA

Altimeter setting: 30.14 inHg   Laboratory temperature: 22.0 °C

IMPINGER WEIGHTS

	Dry Weight, g	Wet Weight, g	Water added, g
Impinger #1	42.94	52.64	9.7 (~10 mL)
Impinger #2	42.39	59.09	16.7 (~15-20 mL)
Impinger #3	39.71	-----	-----
		Total added:	26.4

LEAK CHECK _____ inHg after 2 minutes

SAMPLE FLOW RATE : 0.4985 mL/min   [Average of 4. Label printout]

START   CLOCK TIME: 14:29

              EVENT TIME: 20:32 (elapsed time)

FLOW READINGS DURING TEST (hourly)

Clock time			
Flow rate, mL/min			
Vent flow, L/min			

FIELD DATA SHEET, 98.01 HAPS MEASUREMENT - AFTER SAMPLING

S49-68

BACKGROUND INFORMATION

Operator: _P. Mosher_

Time now : _17:00_

TRAIN #2 - AFTER

Event (kiln charge): _7_

Run (sample): _8a_

POST RUN DATA

Altimeter setting: _30.16_ inHg   Laboratory temperature: _23.0_ °C

END   CLOCK TIME: _17:17_

EVENT TIME: _31:21_ (elapsed time)

SAMPLE LINE RINSE ☒   (~5 mL)

SAMPLE FLOW RATE : _501.1_ mL/min   [Average of 4. Label printout]

IMPINGER WEIGHTS

	Wet Weight, g	Dry Weight, g	Water removed, g
Impinger #1	72.54		
Impinger #2	59.28		
Impinger #3	39.86		

Water lost during handling: _____ mL   [estimate]

Comments:

_____

_____

_____

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - BEFORE

618-688

BACKGROUND INFORMATION

Event (kiln charge): Hampton

Run (sample): 9

Operator: P. Mosher

Date: 3-20-07

Time now: 16:37

Dry-bulb temperature: _____

Wet-bulb temperature: _____

Target Dilution Ratio (TDR): 0.63

AMBIENT DATA

Laboratory temperature: 22.4 °C

ANALYZER CALIBRATION   [1, 2 = off; 3=on; 4=vent]

	Analyzer, ppm	Computer	Within range	Pot settings
zero	0 (0)	0	does not apply	470
span	611 (611)	611	does not apply	468
mid	305 (412)	305	~~382 to 442~~	none

New 300 ppm

SET DILUTION FLOW BEFORE RUN

Total flow rate (TFR): 1.677 L/min   [1, 2, 3 = off; 4=meter]

Target

dilution flow rate (TDFR) _____ L/min   [TFR x (1 - DR)]

sample flow rate (TSFR) _____ L/min   [TFR x DR]

Set and read dilution meter: _____ scfh   [scfh = L/min * 2.12]

Sample flow rate (SFR): 0.9581 L/min   [1 = on; 2, 3 = off; 4=meter]

CHECK DILUTION FLOW BEFORE RUN   [1, 3=on; 2=off; 4=vent]

	Analyzer	DR_{Span} [$Span_{Diluted}$/Span]	DR_{Flow} [SFR / TFR]	Difference, % $100*(DR_{Span} - DR_{Flow})/DR_{Flow}$
$Span_{Diluted}$	348	0.5696	0.5713	0.3

START TIME: 16:43   [1, 2, 5 = on; 3, 4 = off; tank valves off]

ANALYZER RANGE: 2   [60 < computer reading < 750]

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - AFTER

Operator: J. Keiber

Event (kiln charge): Hampton 4 Hem Fir

Time now: 19:57

Run (sample): 9

AMBIENT DATA

Laboratory temperature: 22.4 °C

END TIME: 19:57

CHECK DILUTION FLOW AFTER RUN
[1, 3=on; 2=off; 4=vent]

	Analyzer	Computer
Span$_{Diluted}$	349	350

Sample flow rate (SFR) : 0.9514 L/min   [1= on, 2, 3 = off, 4=meter]

Read dilution meter: _____ scfh _____ L/min   [L/min = scfh*0.472]

Total flow rate (TFR): 1.668 L/min   [1, 2, 3 = off; 4=meter]
(attach print out with all four sets of data)

Dilution ratio (DR$_{Flow}$): 0.5704   [SFR / TFR]

CHECK OF ANALYZER CALIBRATION
[1, 2=off; 3=on, 4=vent]

	Analyzer	Computer	Within range	Pot settings
span	613	613	593 to 629	468
mid	305	305	394 to 430	none
zero	0	0	-18 to +18	470

Dilution ratio (DR$_{Span}$): 0.5693   [Span$_{Diluted}$ / Span]

Dilution ratio difference: 0.1874 %   [100*(Abs(DR$_{Span}$ - DR$_{Flow}$))/DR$_{Flow}$]

End time for check: ~~8:05~~ 20:02

Comments:

_____

_____

_____

_____

Appendix 4. Calibration Data

Airgas

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Part Number:	E02AI99E15A0453	Reference Number:	54-124086894-1
Cylinder Number:	XC031356B	Cylinder Volume:	146 Cu.Ft.
Laboratory:	ASG - Chicago - IL	Cylinder Pressure:	2015 PSIG
Analysis Date:	Feb 09, 2007	Valve Outlet:	590

Expiration Date: Feb 09, 2010

Certification performed in accordance with "EPA Traceability Protocol (Sept. 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 below 150 psig i.e. 1 Mega Pascal

ANALYTICAL RESULTS

Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainity
PROPANE	300.000 PPM	299.9 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	51919	SG9101963ALB	483.6PPM PROPANE/	Jul 01, 2009

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
VARIAN CP3800	FID	Feb 02, 2007

Triad Data Available Upon Request

Notes:

QA Approval

Airgas

Certificate of Analysis: EPA Protocol Gas Mixture

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 51919		PROPANE	SG9101963A-B	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