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VOC Emissions from Western Hemlock Lumber

Report to

Hampton Affiliates, Cowlitz Division
P.O. Box 189
Randle, WA 98377

Report by

Michael R. Milota
Department of Wood Science and Engineering
Oregon State University
Corvallis, OR 97331

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in Randle's source test
Report

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VOC Emissions from western hemlock Lumber

I. Results Summary

Three charges, 73.3 board feet each, of 2x4 western hemlock lumber were dried in a small-scale kiln at Oregon State University. The kiln dry- and wet-bulb temperatures were provided by Hampton Lumber. The dry-bulb temperature was ramped to 120°F (49°C) over 30 minutes, then to 180°F (82°C) over 24 hours. The wet-bulb temperature was ramped to 110°F (43°C) over 30 minutes, then to 130°F (54°C) over 24 hours¹. The air velocity was 750 feet per minute (2.5 m/s). The kiln was indirectly heated with steam. There was no humidification. Regulating the amount of air entering the kiln controlled venting.

A JUM 3-200 total hydrocarbon analyzer was used to measure organic emissions following EPA Method 25A. It has been demonstrated through past studies (Lavery and Milota, 2000, Forest Products Journal, NCASI/Georgia-Pacific SEP project) that this method in this small-scale kiln gives results similar to a large-scale kiln. The data for the three charges is summarized in the Table 1.

TABLE 1. Summary of results.

Charge	Wood Source	Initial MC	Final MC	VOC ^a	Time to 15%
		%	%	lb/mbf	hrs
1	Randle	114.8	12.9	0.17	45.0
2	Morton	103.1	11.2	0.07	40.7
3	Morton/Randle	98.0	11.9	0.12	37.5
^a Adjusted to a final MC of 15%, reported as carbon					

¹The actual wet-bulb temperature was higher than this during the first part of charges 1 and 2 because the kiln had inadequate venting capacity. The third charge the temperatures were ramped to 180/130 over 3 hours and held with good control. Past research indicates that wet-bulb temperature has no effect on VOC emissions (Wu and Milota, Forest Product Journal, 1999)

II. Lumber Source and Handling

Three charges of lumber were delivered to Oregon State University on February 4, 2002, two to be dried and one as a backup. Each charge was wrapped in plastic at the mill to prevent predrying and loss of organic compounds.

Mill personnel reported that the log source was southwest Washington State and the log storage times at the Randle and Morton mills are typically 90 days and two weeks, respectively.

The charges were stored outside under cover and let wrapped until needed. The ambient temperature was near or below freezing at night and in the 30s to low 40s during the day. The first charge (from Randle) only stored at OSU for one day prior to the start of drying. It was left wrapped during this period. The second charge (from Morton) was stored for three days prior to drying. The backup charge (a mix of wood from the two mills) was stored eight days.

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

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 exactly analogous to venting for a commercial kiln. A minimum of 10 L/min entered the kiln at all times, more than removed by the analyzer (< 2.5 L/min). Putting air into the kiln at a rate of 100 L/min causes the pressure in the kiln to be 60 to 130 Pa above ambient, depending on location in the kiln (high-pressure or low-pressure side). Thus, any fugitive leakage should be out of the kiln. Two additional flow meters can be manually set to provide additional airflow. The steam spray line is disabled, so no water vapor is added to the kiln atmosphere.

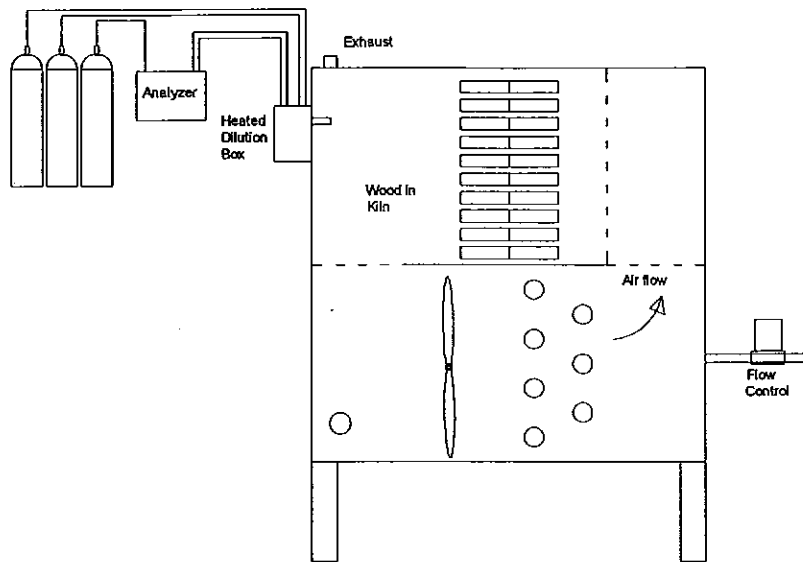


FIGURE 1. Schematic of kiln and sampling system.

Temperature

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 schedule supplied by the mill is shown in Table 2. The actual dry- and wet-bulb temperature used was similar to the schedule for charges 1 and 2. The wet-bulb temperature tended to drift above the schedule set point because the venting capacity of the kiln was reached. The actual temperatures are presented in Figure 2.

The third charge was dried by ramping the dry-bulb temperature to 180°F and a wet-bulb temperature of 140°F and holding until dry. The schedule was different because this charge was originally designated as a backup charge. It was dried as a part of an undergraduate class and the VOC measurements were made to take advantage of the opportunity and provide an additional data point for this report.

Previous studies at OSU have demonstrated that the wet-bulb temperature does not affect the level of emissions. (Published as: Wu and Milota, 1999. Effect of temperature and humidity on the total hydrocarbon emissions from Douglas-fir lumber Forest Products Journal 49(6):52-60 and Milota, 2002. Temperature and humidity effects on emissions of volatile organic compounds from ponderosa pine lumber. Drying Technology. 8/01. In review). Therefore, the wet-bulb deviation should have little or no impact on the results from charges one and two. Although ramp time to temperature was not specifically studied in past work, it is likely that the key factor (other than wood species and source) in the emissions quantity is the dry-bulb temperature. This was the same in all three charges.

TABLE 2. Drying schedule for charges 1 and 2.

Step time, hours	Ramp time, hours	Dry-bulb, °F	Wet-bulb, °F
1	0.5	120	110
44	24	180	130
15	1	180	150

Charge Sequence

The kiln was made ready and 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 provided. Sampling for hydrocarbon 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.

IV. Sampling Systems and Methodologies

Figures 3a and 3b show the hydrocarbon sampling system. The fuel gas was hydrogen. The span gas was EPA Protocol 1527 ppm propane in air, the mid-gas was certified 881 ppm propane. The zero gas was Grade 5 air. Detailed sampling procedures are in Appendix 1 and a summary is presented below.

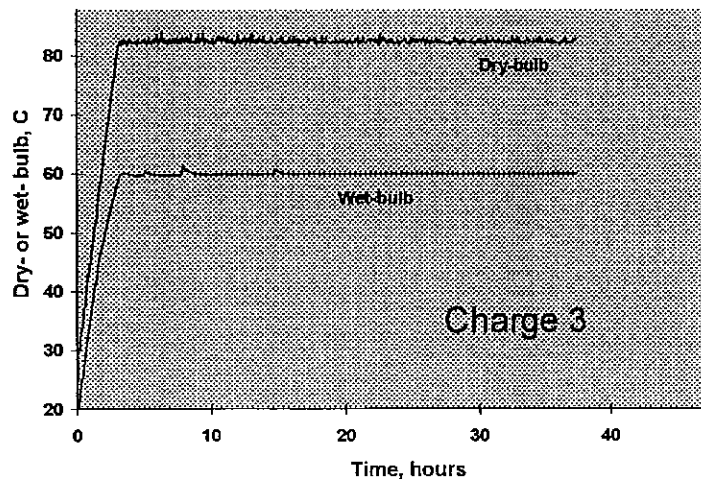
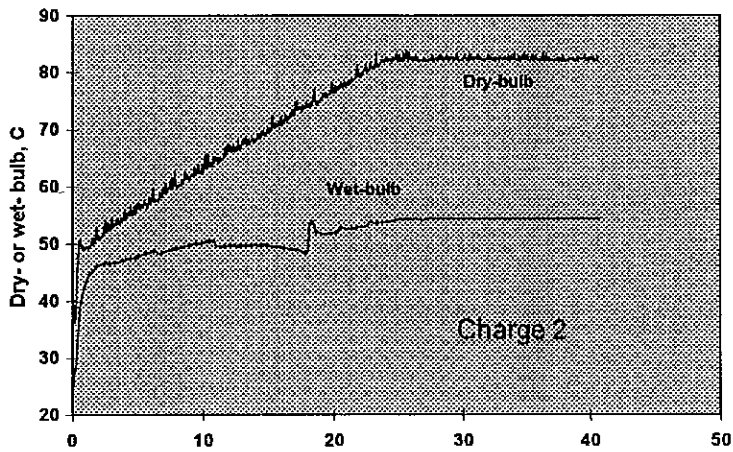
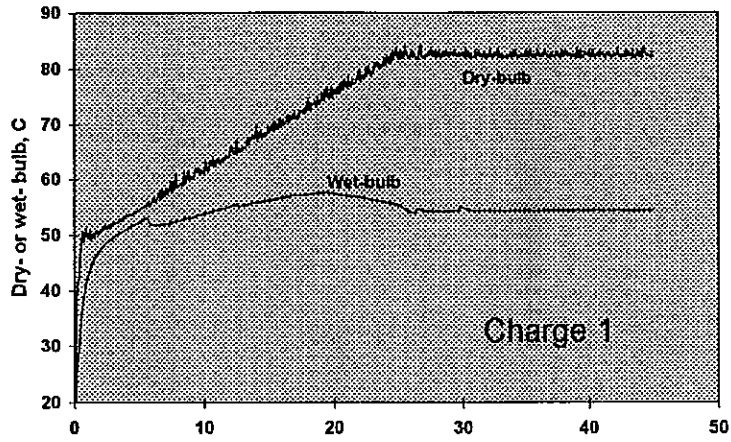


FIGURE 2. Dry- and wet-bulb temperatures during the drying cycles.

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 126°C. It is assumed 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 sample line from the box to the analyzer was heated to 146°C. The valve at the back of the analyzer was heated to 154°C.

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 20 inHg vacuum. Less than one inHg pressure change during two minutes is acceptable and this was met for five out of six checks. During the last check after charge three, the decrease in vacuum was slightly greater than 2 inHg. It should be noted that the system does not operate under significant pressure or vacuum when it is in operation so this is very minor and indicates a need for preventative maintenance, not an invalid test.

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 meter rather than the kiln. Readings made with the dilution gas off and on indicated the dilution ratio used to lower the gas moisture content to the detector. The flow readings were verified by observing the change in the analyzer reading for span gas before and after the dilution gas was turned on. The dilution ratio calculated based on the analyzer readings was generally within 1% of that determined by the flow meter. Dilution was only used at the end of charges 1 and 2 and during charge 3, times 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 hours with one six-hour interval each night). 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 the four days of sampling.

V Data Reduction and Treatment

The "FlowCalc" page in the files "*", Kiln.XLS" in Appendix 2 show the calculations for each 3-minute interval during the charge. 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 (files “*, Kiln.XLS” in Appendix 2) 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.

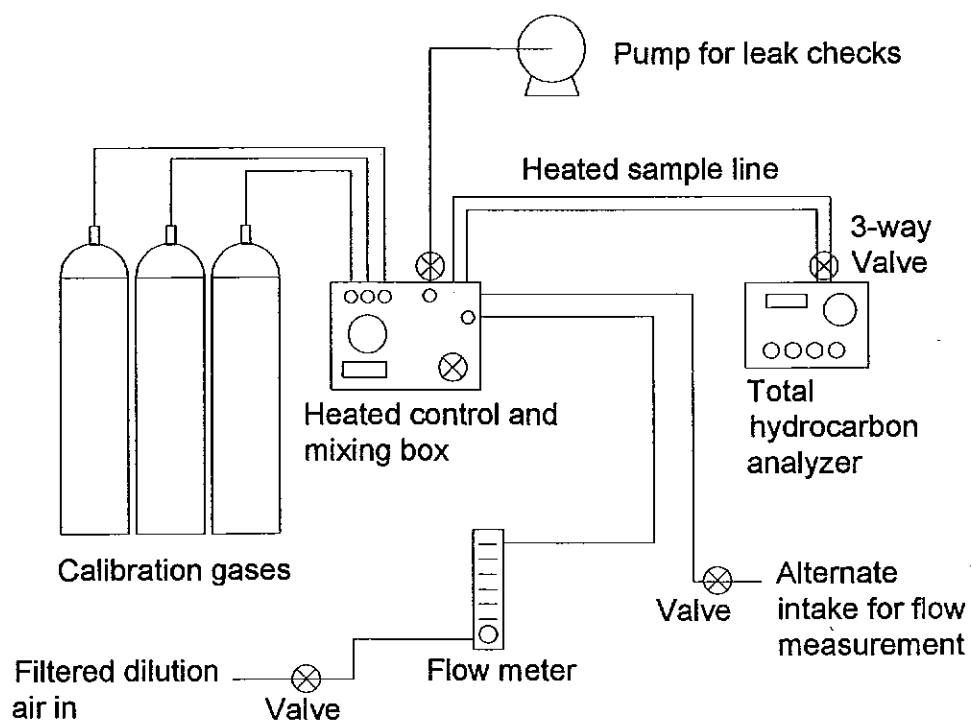


FIGURE 3A. Schematic of heated filter box with air dilution system, heated sample line, and analyzer. Sample enters heated box from back of drawing (box is attached to kiln).

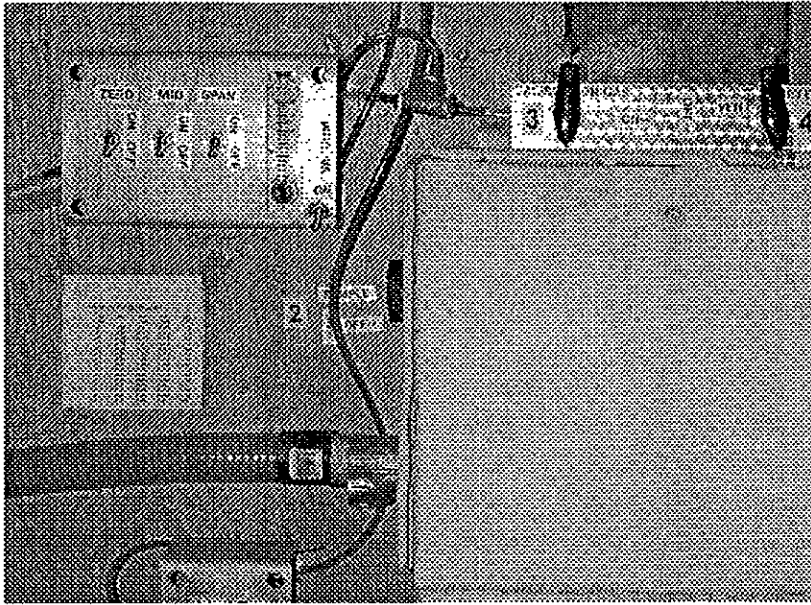


FIGURE 3B. Photo of VOC sampling system showing heated sample box (with white insulation), toggle valves and flow meter for calibration gases (upper left), on/off valve for calibration gas (3 at upper center right), heated sample line to analyzer (green tube, lower left), valve for sample (2 at center),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

Moisture calculations

The water removal rate in g/min (column L) (files "*", Kiln.XLS" in Appendix 2) 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 based on the amount of water leaving the kiln during the previous 3-minute interval.

Total hydrocarbon calculations

The original total hydrocarbon analyzer reading is shown in column O (files "*", Kiln.XLS" in Appendix 2). In column P this has been corrected to compensate for the range setting switch on the analyzer. Also in column P, the THA data between sampling runs has been adjusted to the average of the data during the 15-minute periods before and

after the down 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/min as carbon 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 obtain the average gas moisture contents. The corrected wood moisture content, as discussed in section VI, is shown in column AC. The kiln air and analyzer air moisture contents are shown in columns AD and AE.

At the end (bottom) of the FlowCalc spreadsheet are summaries by run of the flow data for the total hydrocarbon run intervals.

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." A file extension ".prn" indicates raw data as collected.

VI. Sampling Results

The hydrocarbon emissions are summarized graphically here. All emission data is presented in detail in Appendix 2.

Figure 4 shows total hydrocarbon concentration and vent rate versus time. These are presented together because they tend to change in opposite directions. That is, for a given rate of emission release, the concentration could be high with a low vent rate, or the concentration low with a high vent rate. The vent rate in charges 1 and 2 is very high for the first 20 to 24 hours, then decreases. The higher wet-bulb temperature (140°F compared to 130°F) in charge 3 allows the vent rate to be lower throughout the schedule.

Figure 5 shows the cumulative hydrocarbon emissions and the rate of emissions versus time. The cumulative emissions (in grams) is the emissions up to any point in time in the schedule. The rate of emissions (in grams per minute) is how much is coming out per unit time. The spike at 7 in charge 1 corresponds to an increase in venting. This does

not appear for charge 2 or 3 because the venting was not changed as abruptly.

Figure 6 shows the wood moisture content versus time. The measured moisture content is obtained by doing a mass balance on the gas steams, then subtracting the water leaving the kiln from the initial moisture content of the wood. The mass balance was within three moisture content percentage points of the moisture loss that actually occurred based on the change in board weight. The estimated moisture content should most accurately represent the MC-time relationship because the initial and final moisture contents match the oven-dry test.

Charge 1 had a higher initial moisture content (115%) and took 45 hours to reach 15% moisture content. Charge 2, starting at 103% moisture content, took only 40.7 hours. The schedule for charge 3 was more aggressive and it reached 15% moisture content in 37.5 hours. The starting moisture content for charge 3, a mix of wood from the two mills, was 98%, but within what might be expected given normal sampling variability. We do not believe this decreasing trend in moisture content is due to storage time.

Figure 7 shows the cumulative hydrocarbon emissions versus moisture content. The emissions for drying to any moisture content can be read from this graph. If, for example, a mill wanted to dry to 19% instead of 15%, the total hydrocarbon emissions could be estimated.

Tables 3a to 3c show the VOC results by run for the charges. These have been truncated to the time when 15% moisture content was reached. The interval time periods shown in the table include the times between sampling and mass calculations are adjusted to account for these. The interval time periods sum to the drying time to eight percent moisture content. Sampling occurred for 96% of the total drying time as it took 5 to 10 minutes to check and calibrate the analyzer and set up dilution between three-hour sampling periods.

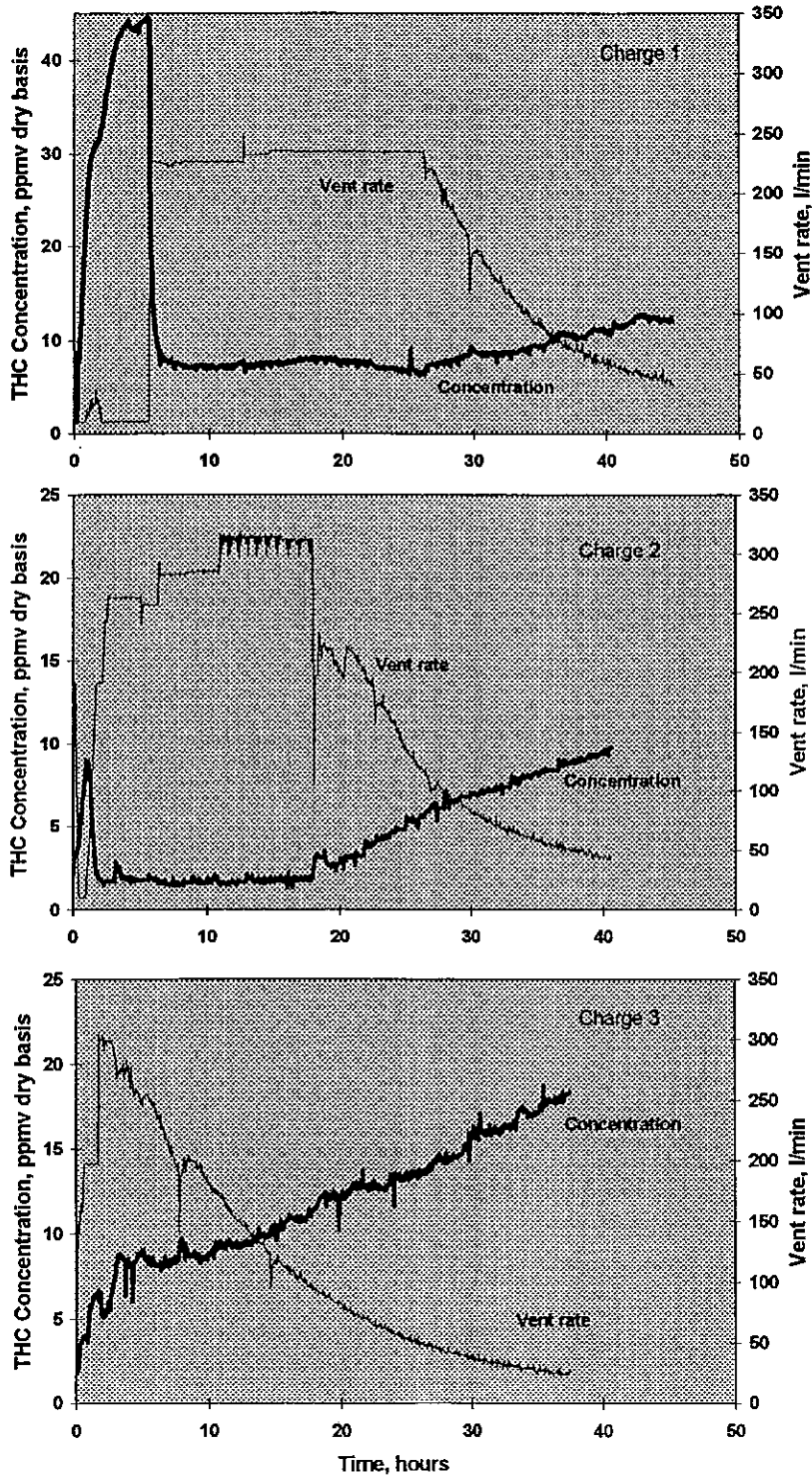


FIGURE 4. Hydrocarbon concentration and vent rate versus time.

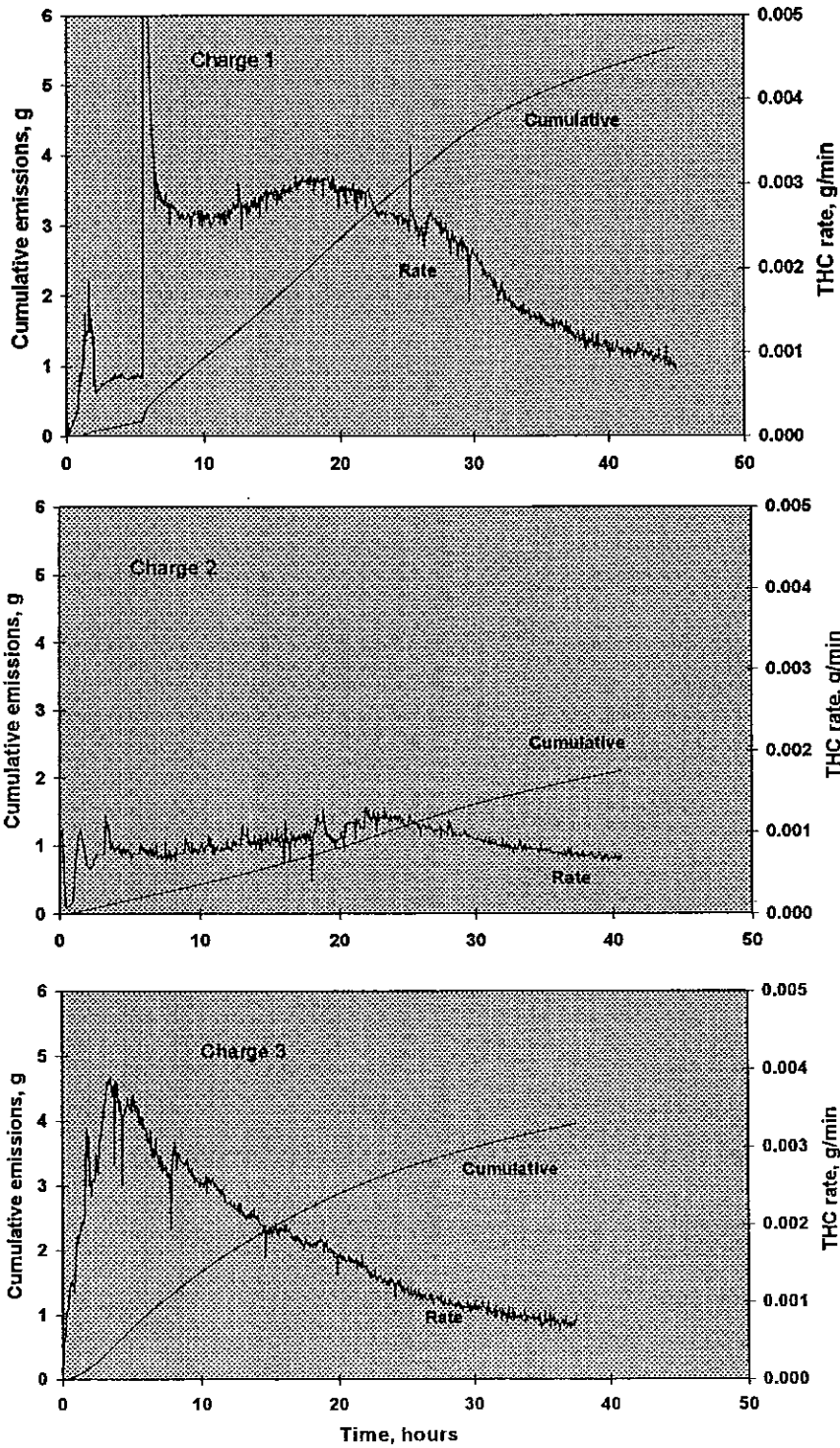


FIGURE 5. Cumulative emissions and rate of emissions versus time.

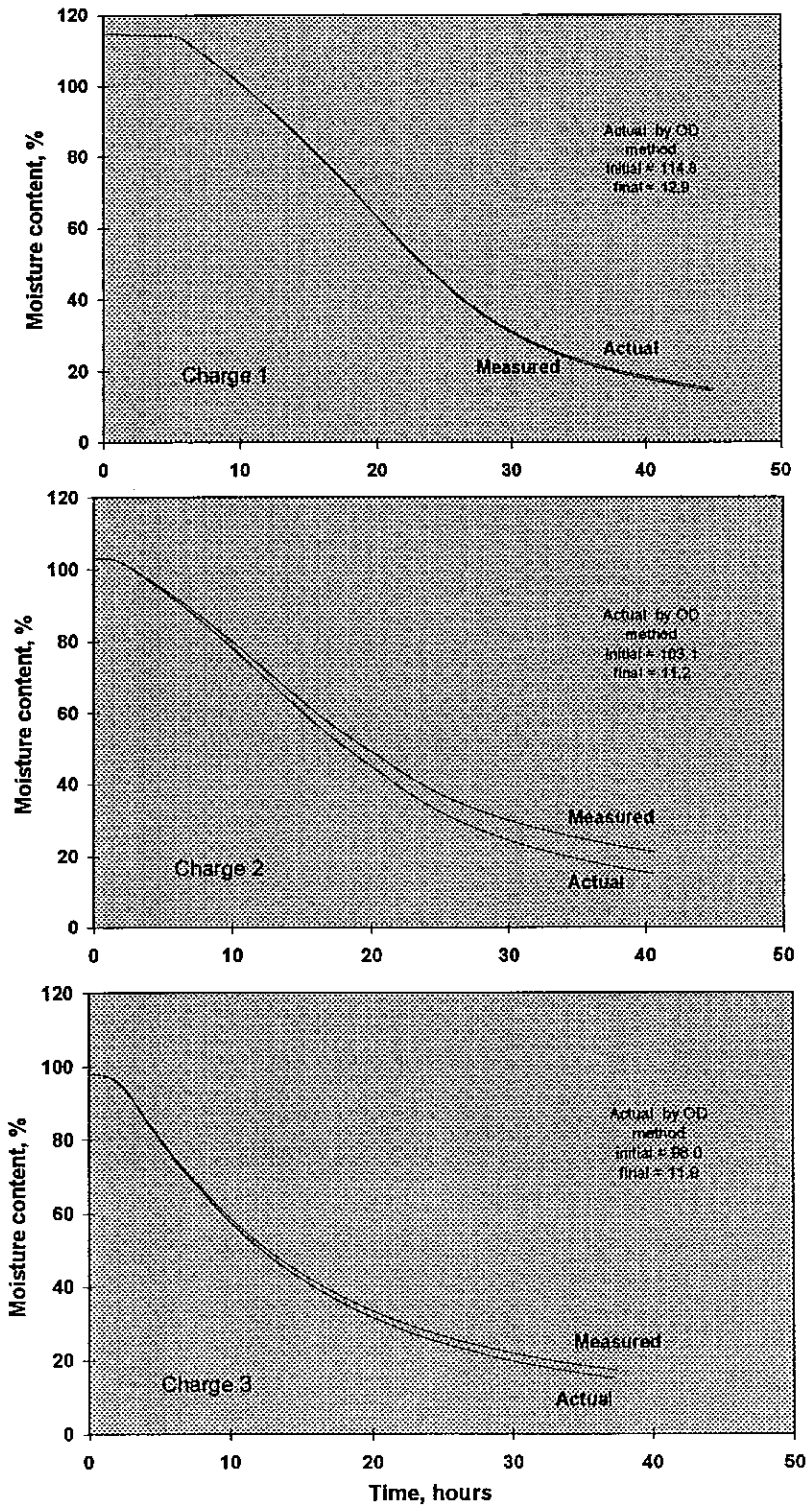


FIGURE 6. Moisture content versus time for the charge.

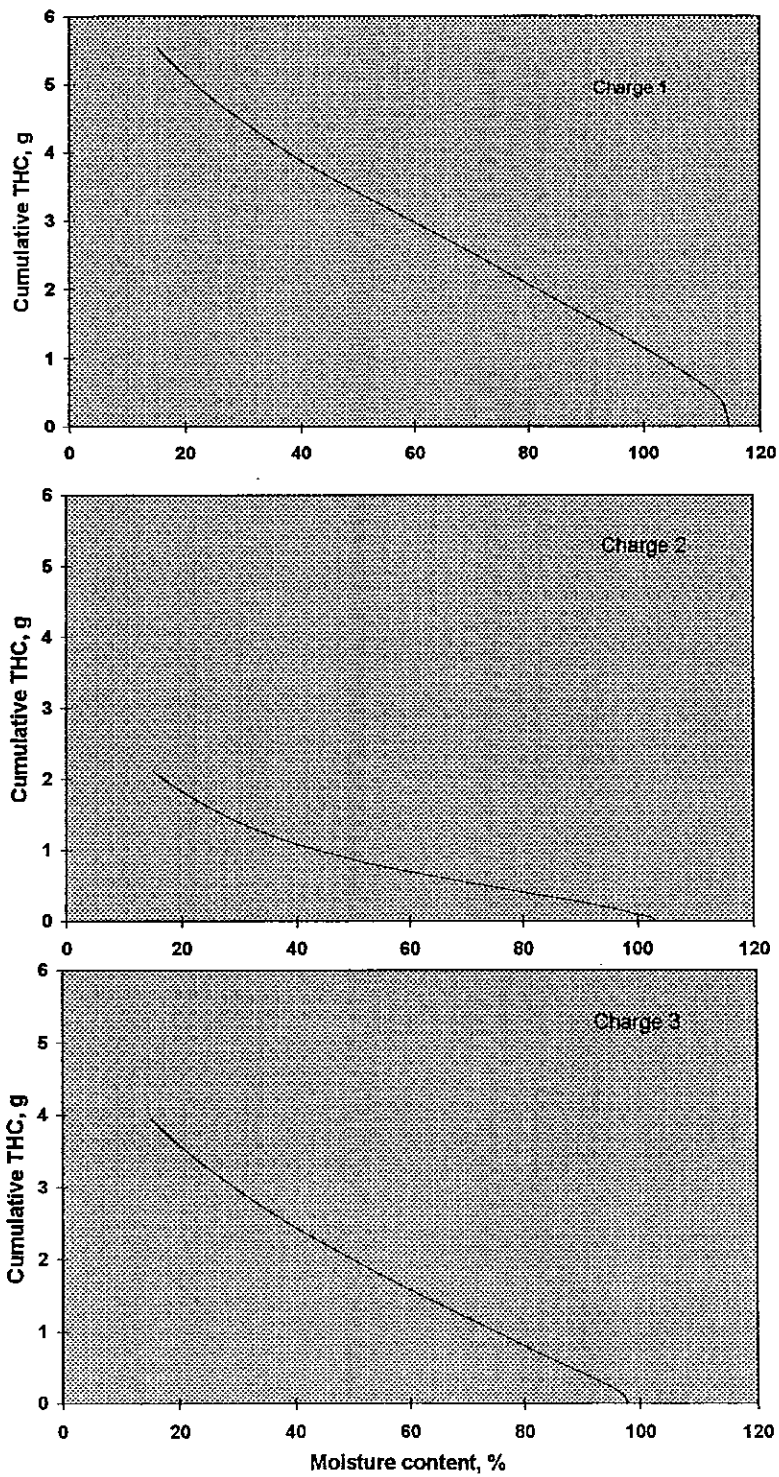


FIGURE 7. Cumulative emissions versus moisture content of the charge.

TABLE 3a. Summary of sample runs for charge 1.

Sample Run	Time	Dry Flow Rate @68	Wet Flow Rate @68	THC wet conc	THC mass as C	THC rate as C	Average		
							Wood MC	Air MC	Anal. MC
							%	%	%
1	3.75	16	18	26.3	0.005	0.001	114.6	7.7	7.7
2	3.30	118	135	25.6	0.015	0.005	113.1	12.4	12.4
3	2.35	243	279	6.3	0.011	0.005	106.2	12.8	12.8
4	3.05	244	283	6.1	0.015	0.005	97.7	13.9	13.9
5	4.15	252	297	6.3	0.021	0.005	84.9	15.0	15.0
6	5.65	253	300	6.5	0.030	0.005	65.6	15.7	15.7
7	3.00	253	311	6.0	0.014	0.005	49.1	18.8	18.8
8	2.25	240	276	6.1	0.010	0.005	40.4	12.9	12.9
9	2.65	188	215	7.0	0.011	0.004	33.9	12.9	12.9
10	3.45	137	157	7.4	0.011	0.003	27.8	12.9	12.9
11	3.15	95	110	7.4	0.008	0.002	27.8	12.9	12.9
12	3.80	70	81	9.3	0.008	0.002	19.6	12.9	12.9
13	4.45	53	61	10.5	0.008	0.002	16.5	12.9	12.9
Sum	45.02				0.17				
Average		166	194	10.1		0.004		13.4	13.4

TABLE 3b. Summary of sample runs for charge 2.

Sample Run	Time	Dry Flow Rate @68	Wet Flow Rate @68	THC wet conc	THC mass as C	THC rate as C	Average		
							Wood MC	Air MC	Anal. MC
							%	%	%
1	2.45	126	136	4.1	0.003	0.001	102.5	7.5	7.5
2	2.60	282	310	1.7	0.004	0.001	97.4	9.2	9.2
3	3.30	294	326	1.5	0.004	0.001	89.0	9.9	9.9
4	4.15	318	355	1.5	0.006	0.001	76.6	10.5	10.5
5	5.95	324	360	1.7	0.010	0.002	58.9	9.9	9.9
6	3.10	229	258	2.6	0.006	0.002	44.9	11.5	11.5
7	2.95	188	214	3.1	0.006	0.002	40.9	12.2	12.2
8	3.00	130	149	4.8	0.006	0.002	30.4	12.8	12.8
9	1.95	102	117	5.6	0.003	0.002	26.5	12.9	12.9
10	3.05	83	95	6.1	0.005	0.002	23.3	12.9	12.9
11	3.55	66	76	6.9	0.005	0.001	19.9	12.9	12.9
12	4.60	52	60	7.8	0.006	0.001	16.6	12.9	12.9
Sum	40.67				0.06				
Average		183	205	4.0		0.002		11.3	11.3

TABLE 3c. Summary of sample runs for charge 3.

Sample Run	Time hrs	Dry Flow	Wet Flow	THC	THC mass	THC rate	Average		
		Rate @68	Rate @68	wet conc	as C	as C	Wood MC	Air MC	Anal. MC
		l/min	l/min	ppmv	lbs/mbf	lb/hr/mbf	%	%	%
1	1.85	213	224	4.4	0.005	0.003	97.5	4.9	4.9
2	2.90	299	356	6.1	0.017	0.006	89.2	15.9	12.3
3	4.05	236	288	6.9	0.022	0.005	71.3	18.0	13.9
4	6.00	168	205	7.6	0.025	0.004	51.6	17.9	13.6
5	2.65	117	143	8.6	0.009	0.003	39.3	18.0	14.4
6	2.50	96	117	9.6	0.008	0.003	33.9	17.9	14.0
7	6.20	68	83	10.5	0.015	0.002	27.1	18.0	14.0
8	3.15	47	58	11.5	0.006	0.002	21.7	18.0	14.4
9	3.45	38	46	12.9	0.006	0.002	19.0	18.0	14.2
10	4.70	29	36	14.1	0.007	0.001	16.3	18.0	14.2
Sum	37.46				0.12				
Average		131	156	9.2		0.003		16.5	13.0

Copies of all field sampling sheets, including dilution system and heated component data, are available at OSU. An example of these is included in Appendix 3. To include all sheets would add approximately 100 pages to the appendix and most data has been already been transferred to some other part of the report, either in tables or graphs.

VII Quality Assurance

Leak checks

Leak checks were performed before on the VOC system and after each charge was dried.

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. The calibration sheet for the flow meter is also included is also included in Appendix 4 as is the thermocouple calibration check.

VIII Discussion

There were no anomalies during the charges or unexpected problems that would affect the data.

The values obtained are comparable or slightly lower than the values for white fir obtained in a study done for the Intermountain Forest Association (IFA). In that case the VOC emissions were 0.14 to 0.16 lbs/mbf as carbon. The average for the three charges in this study is 0.12 lb/mbf. The value for wood from the Randle mill agrees well with the IFA study.

Charge 1 was from the Randle mill and had VOC emissions of 0.167 lb/mbf. Charge 2 was from the Morton mill and had VOC emissions of 0.063 lb/mbf. The wood in charge 3 was a mix of these two sources and the VOC emissions of 0.120 reflect this mix almost exactly. An average of the two mills would be 0.115 based on charges 1 and 2. This suggests that the difference in VOC emissions between the two mills is real, at least for the sample obtained. The emission value from the Morton mill, 0.063 lb/mbf is the lowest we have ever measured from any species.

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.

Analyzer temperature: Push the temperature button on the analyzer. It should be in the 160 to 190°C range. When the lab is hot, it will read lower. Analyzer should usually be on range setting 3. All lights on the front of the analyzer should be green. The pressure should read about 200. Does the reading make sense - is it the same before and after an analyzer check, does increasing dilution cause a lower reading?

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.

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.

Appendix 1. Detailed Sampling Procedures

**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.

Calculate

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

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

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 temperature and altimeter setting.

Local pressure in Pascals = (Altimeter - 0.23) x 3.3867

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 4

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

use the span dial (pot) on THA to get a reading of 1527 ppm

read the analyzer, record, for example, 1.53 as 1530

read computer (should read about 153 due to range 4 setting)

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

set analyzer to range 3

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

read analyzer (do not adjust pot settings), record, for example, 8.50 as 850

read computer (should about 850 with analyzer on range 3)

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 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 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 5 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
- wait for a stable reading (about 30 to 60 seconds)
- if reading is >9.99, switch to range 4
- record
- set analyzer to range 3
- 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 $100 * \{ \text{Absolute Value} (DR_{\text{span}} - DR_{\text{Flow}}) \} / DR_{\text{Flow}}$

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.

Appendix 3. Samples of field data sheets.

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - POST

Operator: MRM
 Time now: 10:51

Event (kiln charge): Hampton 1
 Run (sample): 15

AMBIENT DATA

Airport pressure: 29.82 inHg

Laboratory temperature: 20 °C

END TIME: 10:51

CHECK DILUTION FLOW AFTER RUN

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

	Analyzer	Computer
Span _{Diluted}	908	off

Sample flow rate (SFR): 1.460 L/min [1= on, 2, 3 = off, 4=meter]

Read dilution meter: 2 scfh _____ L/min [L/min = scfh*0.472]

Total flow rate (TFR): 2.429 L/min [1, 2, 3 = off; 4=meter]
 (attach print out with all four sets of data)

Dilution ratio (DR_{Flow}): 0.601 [SFR / TFR]

CHECK OF ANALYZER CALIBRATION

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

	Analyzer	Computer	Within range	Pot settings
span	1510		1481 to 1573	393
mid	877		804 to 957	none
zero	0.0		-45 to +45	451

Dilution ratio (DR_{Span}): 0.601 [Span_{Diluted} / Span]

Dilution ratio difference: 0.0 % [100*(Abs(DR_{Span} - DR_{Flow}))/DR_{Flow}]

End time for check: 10:56

Comments: Leke ✓ 10:58:00 19.6" → 11:01 19.4"

Event: Hampton 1
 Date: 2-5-02

2-9-02
 7:52A

Board	Weights			Moisture contents		Number	Knots	Area	Other properties			Size	
	Initial Wt. kg	Final Wt. kg	Oven kg	Initial %	Final %				Wane in	Heart %	Rings #/in	Thickness in	Width in
1	3.280	1.860	1.710	#DIV/0!	#DIV/0!			0.00					
2	4.030	2.150	1.835	#DIV/0!	#DIV/0!			0.00					
3	4.170	1.945	1.720	#DIV/0!	#DIV/0!			0.00					
4	2.605	2.005	1.795	#DIV/0!	#DIV/0!			0.00					
5	4.940	2.280	2.000	#DIV/0!	#DIV/0!			0.00					
6	4.350	2.205	1.805	#DIV/0!	#DIV/0!			0.00					
7	3.835	1.810	1.640	#DIV/0!	#DIV/0!			0.00					
8	4.130	1.775	1.580	#DIV/0!	#DIV/0!			0.00					
9	4.515	1.950	1.730	#DIV/0!	#DIV/0!			0.00					
10	3.260	2.095	1.860	#DIV/0!	#DIV/0!			0.00					
11	3.225	2.210	1.945	#DIV/0!	#DIV/0!			0.00					
12	4.470	2.010	1.800	#DIV/0!	#DIV/0!			0.00					
13	2.535	1.650	1.525	#DIV/0!	#DIV/0!			0.00					
14	2.725	1.905	1.705	#DIV/0!	#DIV/0!			0.00					
15	4.750	2.265	1.980	#DIV/0!	#DIV/0!			0.00					
16	4.605	1.750	1.585	#DIV/0!	#DIV/0!			0.00					
17	4.540	1.780	1.610	#DIV/0!	#DIV/0!			0.00					
18	3.920	2.100	1.870	#DIV/0!	#DIV/0!			0.00					
19	3.015	1.795	1.635	#DIV/0!	#DIV/0!			0.00					
20	3.245	2.165	1.805	#DIV/0!	#DIV/0!			0.00					
21	4.035	1.925	1.750	#DIV/0!	#DIV/0!			0.00					
22	3.350	2.110	1.730	#DIV/0!	#DIV/0!			0.00					
23	2.660	1.435	1.330	#DIV/0!	#DIV/0!			0.00					
24	3.380	2.125	1.860	#DIV/0!	#DIV/0!			0.00					
25	4.630	1.895	1.705	#DIV/0!	#DIV/0!			0.00					
26	3.020	1.985	1.770	#DIV/0!	#DIV/0!			0.00					
27	4.520	2.315	2.055	#DIV/0!	#DIV/0!			0.00					
28	2.875	2.110	1.890	#DIV/0!	#DIV/0!			0.00					
29	4.105	2.155	1.930	#DIV/0!	#DIV/0!			0.00					
30	4.915	2.065	1.770	#DIV/0!	#DIV/0!			0.00					

W/W

Sums: 0.000 0.000 0.000 0 0.00 0.00 0
 Averages: #DIV/0! #DIV/0! #DIV/0! #DIV/0! 0.0 #DIV/0! #DIV/0! #DIV/0! #DIV/0! #DIV/0!

Charge: 1
 Hampton Affiliates
 Page: 2

Date
 Time
 Start:
 End:

Clock	Run time	Run #	Temperatures						Flows			Line Vac.		
			Box °C	Valve °C	Dry-bulb °C	Wet-bulb °C	Line °F	Anlz °C	Chiller °C	Flow 1 L/min	Dilution		F/M ml/min	
2-6-02														
2:10	18:25	7	126	154	82.3	55.7	296	194		165/44/58				
9:01	19:58	7	125	154	82.4	55.2	296	194		165/44/58				
10:07	20:07	8	126	154	82.8	53.8	296	194		160/48				
11:16	21:85	8	126	154	82.1	54.1	295	194		160/48				
13:30	24:1	8	126	154	82.9	54.6	295	193		160/48				
14:27	25:04	10	122	154	82.7	54.2	295	194		148				
17:19	27:91	10	122	154	82.4	54.3	295	194		107				
18:37	29:24	10	126	154	82.1	54.4	296	194		92				
19:36	30:08	11	126	154	82.1	54.4	296	194		85				
20:35	31:19	12	127	154	82.5	54.4	295	194		77				
21:37	32:21	12	126	154	82.7	54.4	295	194		70				
22:31	33:13	12	126	154	83.1	54.4	295	194		64				
0:00	34:62	12	126	154	82.3	54.4	295	194		57				
6:58	40:5	13	124	153	82.1	54.4	295	193		41				
6:32	41:1	14	127	154	82.3	54.4	295	193		43				
9:47	42:3	14	126	154	82.2	50.8	295	193		10				
8:16	42:8	14	127	154	82.7	62.1	296	194		10				
9:46	44:3	15	126	154	82.1	63.3	296	194		10				

Appendix 4. Calibration Data



Flow
Calibration Record Sheet
(200 SLM)

ERA #: 128989W

Customer: OREGON STATE UNIVERSITY

MKS Transfer Standard Type: 1559A-200L-SV

Serial Number: WS 136

MKS Primary Standard Type: A-200-1

Serial Number: 14952-1-1

Standard Flow Rate (SLM)	UUT Flow Rate (SLM)	UUT Error (SLM)	Percent of full scale Error
0.00	0.000	0.000	0.000%
50.000	50.880	0.880	0.440%
100.000	99.880	-0.120	-0.060%
150.000	150.040	0.040	0.020%
200.000	200.000	0.000	0.000%

UUT Model: 1559A-200L-SV

UUT Process Gas: N2

Process Gas used: N2

Date of Calibration: 05/10/00

UUT Serial #: 000317785

UUT Range: 200 SLM

Calibrated by: DP

Verified by:

Notes:

1. All units must be operated on regulated heat (Power on) for a minimum of one hour before any adjustment is made.
2. Flowmeters and/or Controllers are Calibrated at atmospheric pressure.
3. This Calibration is referenced to 0 Degrees Centigrade and 760 Torr.

3350 Scott Blvd., Bldg. #4, Santa Clara, CA 95054

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TC Calibration
6-4-00

Omega Calibrator	PC Readout
30 °C	29.8
50	50.0
70	69.9
90	90.1
110	110.2

BOC GASES
VANCOUVER, WASHINGTON

Cylinder # : 12005
P.O. # :
Approx. Pressure: 2200 psig
CGA Outlet : CGA346
Fill Date : 25-JUL-2000
Expired Date : 24-JUL-2005
Test # : YAJ-01-23051
Material: Air, Zero 0.1

CYLINDER CONTENT ANALYSIS

Component	Concentration
Oxygen	20.6 %
Nitrogen	Balance
Moisture	<3.0 PPM
Total Hydrocarbons	<0.10 PPM

BOC GASES
RIVERTON, NEW JERSEY

Cylinder # : 388284
CU # : 4036900
Pressure : 2000 psig
CGA Outlet : 200650 ER 3360
Fill : 19-JUL-2000
Expired : 19-JUL-2003
Material : 2 COMP MIX BAL AIR

CYLINDER CONTENT ANALYSIS

Component	Concentration
propane	981 ppm
air	BALANCE

BOC GASES
VANCOUVER, WASHINGTON

Cylinder Number CC85608
Fill Date : 5/1/00
Cyl. Pressure : 2000
Cyl. Size : 152
CGA Outlet : S90
Amount : 1527 PPM

Test # 99060814

Contents
PROPANE 1500 PPM
AIR BALANCE