Emissions from the drying of Douglas-fir lumber

Report to

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Report by

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Summary

Two charges of 2x4 Douglas-fir lumber were dried from green in a small kiln at Oregon State University. The kiln dry- and wet-bulb temperatures were based on a schedule provided by Hampton Lumber. The second charge was done because the kiln wet-bulb was not operating properly during the first charge. Results from the first charge would not be representative of Hampton's schedule. The maximum temperature was 200°F (91.1°C). The air velocity was 750 feet per minute (3.7 m/s). The kiln was indirectly heated with steam. The amount of air entering the kiln was regulated to control humidity.

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

TABLE 1. Summary of total hydrocarbon results to 15% moisture content for charge 2 only. VOC units are pounds per thousand board feet.

Charge	Initial MC	Final MC[A]	Time to 15%[A]	VOC[B]
	%	%	hr:min	lb/mbf
Douglas-fir	69.3	15	20:50	0.66

[A] actual time to 10.3% MC was 28:45 hours
[B] as carbon

NCASI Method ISS/FP-A105.01 was used to measure the MACT HAP emissions. The results are shown in Table 2. The sum of the HAPs emitted was 0.12 lb/mbf for Douglas-fir.

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

Charge	Methanol	Phenol[A]	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
Douglas-fir	0.080	0.0	0.003	0.037	0.0006	0.0017

[A]none detected in any sample

1. Description of source

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

Mill personnel reported that the logs came from Weyerhaeuser's Vail tree farm approximately 30 miles east of Chehalis. The harvest was done in early January. Sawing occurred on January 9, 2012.

Enough wood for three charges of lumber was delivered to Oregon State by Nate Morris of Hampton Lumber on January 10, 2012. The wood was wrapped in plastic lumber wrap at the mill to prevent predying and loss of organic compounds during transit. The wood appeared to be very fresh. There was no mold on the sapwood.

On January 10, 2012 the wood was separated into three charges at OSU. Two charges were wrapped in plastic (in sets of nine boards) and placed in a freezer (Figure 1, right). The other charge was wrapped in plastic and placed in a cooler at 35°F (Figure 1, left). The charge from the cooler was dried starting on January 12. One charge from the freezer was allowed to thaw starting January 22 and dried starting on January 24.

FIGURE 1. Wood in refrigerator (left) and freezer (right).

2. Date and time of test

The first charge was dried from January 12, 2012 at 11:44 am to January 13, 2012 at 4:52 pm. The second charge was dried from January 24, 2012 at 8:34 am to January 25, 2012 at 1:19 pm. Drying was done under the supervision of Mike Milota at Oregon State University. Students were used to monitor parts of the test.

3. Results

Total hydrocarbon

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

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

Figure 2 shows total hydrocarbon concentration (left scale) and dry gas vent rate (right scale) versus time. Concentration peaks at 6.21 hours as the kiln is coming to temperature and venting is low. The vent rate shows an increase at approximately 12-14 hours when the wet-bulb changes from 170°F to 165°F.

Figure 3 shows the cumulative hydrocarbon emissions (left scale, smooth line) and the rate of emissions (right scale, jagged line) versus time. The cumulative emissions is the emissions up to any point in time in the schedule. The rate of emissions is how much is coming out per unit time. The maximum emission rate occurs at 6.41 hours as the kiln starts to vent and the concentration is high. It then steadily decreases as the moisture loss from the wood slows.

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

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

Charge 2

Time	Average	Flow rate		THC concentration		THC mass	THC rate	Average		
	Humidity	Dry @68	Wet @68	wet	dry	as C	as C	Wood MC	Air MC	Anal. MC
hrs	kg/kg	l/min	l/min	ppmv	ppmv	lbs/mbf	lb/hr/mbf	%	%	%
4.41	0.089	217.2	248.5	42.5	48.4	0.11	0.025	67.9	12.6	5.2
6.96	0.557	83.7	158.9	183.6	299.1	0.37	0.054	50.3	47.3	16.8
6.66	0.576	59.1	113.8	98.3	157.2	0.14	0.021	28.1	48.1	17.1
2.80	0.543	37.3	70.0	110.6	172.8	0.04	0.015	17.5	46.6	16.3
20.83						**0.66**				
	0.441	99.3	147.8	108.7	169.4		0.028			
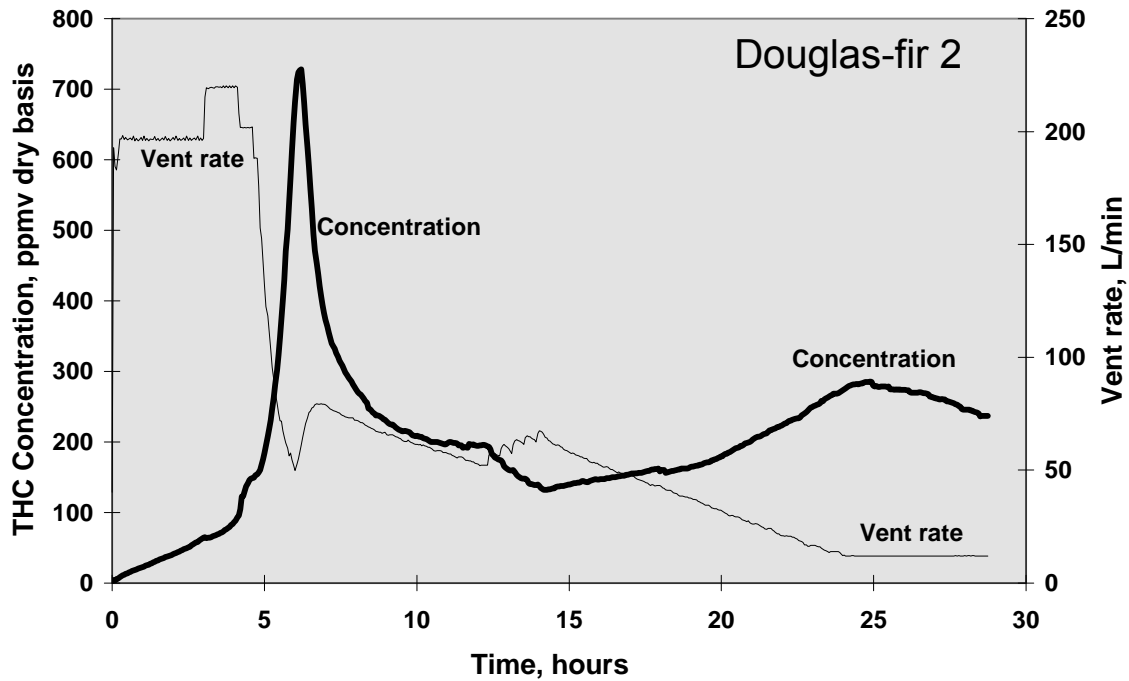
FIGURE 2. Hydrocarbon concentration and vent rate versus time.
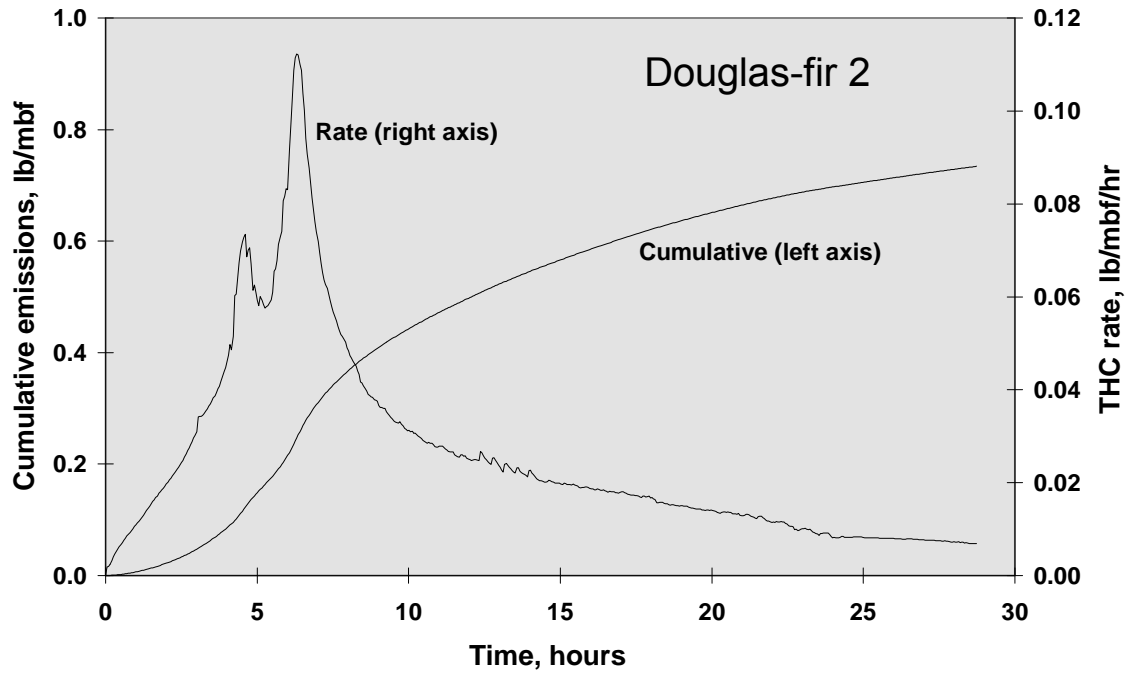
FIGURE 3. Cumulative and rate of emissions (as carbon) versus time.
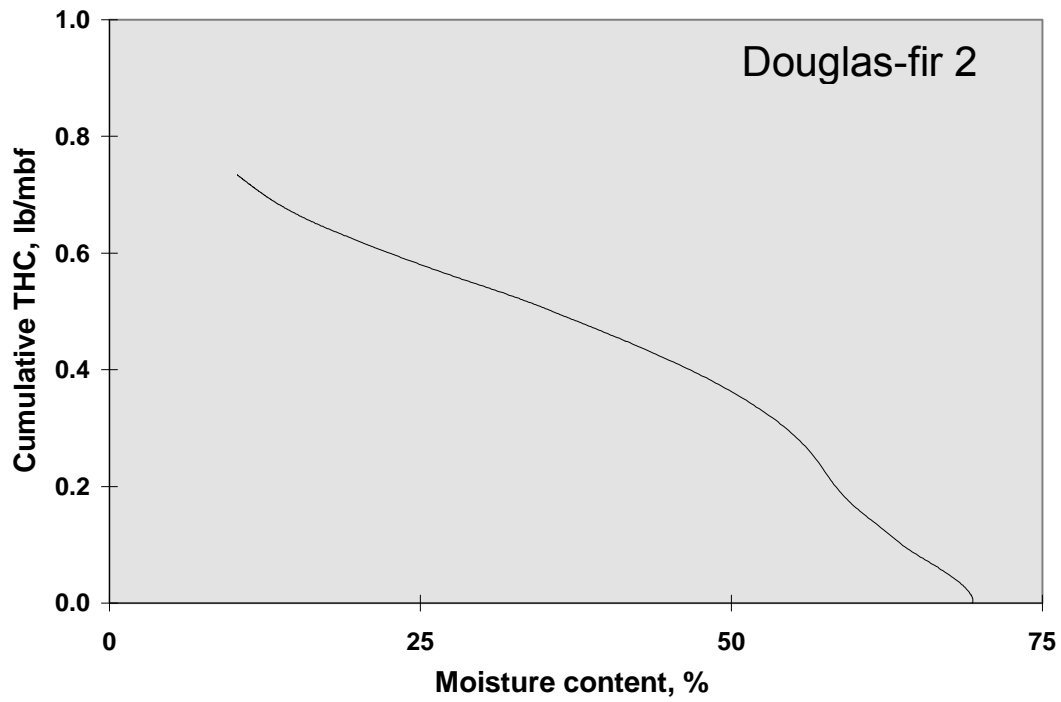
FIGURE 4. Total hydrocarbon versus moisture content of wood.

HAPs

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

A summary of the kiln conditions for each sampling interval is in Table 4. A collection interval is the time the impingers were on and sampling occurred, approximately 1:15. An adjusted interval is the period spanning the midpoints between collection intervals, about three hours. The mass calculations are adjusted to represent emissions during the adjusted interval. For example, if a collection interval was one hour and the adjusted interval was three hours, the amount of HAP in the impinger is multiplied by three. Sampling occurred for approximately 40% of the drying time.

The MACT HAP emissions and the emissions of ethanol and acetic acid are shown in Table 5. The total HAP emissions were 0.12 lb/mbf for Douglas-fir (does not include the non-HAPs, ethanol and acetic acid). Methanol is the HAP emitted in the greatest quantity followed by acetaldehyde. Phenol was not detected in any sample.

The HAP emissions as a function of time and wood moisture content during the cycle are shown in Figures 5 and 6, respectively. The rate of HAP emissions peak in the middle of the schedule and decrease with decreasing moisture content.

TABLE 4. Summary of HAP sampling intervals.

Sample Run ID	Collection Interval	Adjusted Interval	Dry gas mass	Average Dry gas flow rate	Molar Humidity	Moisture Content	
						Mid	End
	hours	hours	kg	kg/min	mol/mol	%	%
1	1.52	2.25	34.269	0.254	0.045	69.4	68.8
2	1.25	3.16	46.398	0.245	0.212	65.4	59.6
3	1.32	3.16	17.317	0.091	0.660	53.4	47.4
4	1.25	3.00	14.288	0.079	0.684	42.0	37.1
5	1.27	2.45	11.187	0.076	0.643	34.2	29.6
6	1.25	3.66	15.223	0.069	0.563	24.2	20.6
7	1.30	3.11	8.643	0.046	0.562	17.6	15.5
8	1.27						
9	1.25						
10	1.28						
SUM		20.78					

TABLE 5. Emissions of the MACT HAPs, ethanol, and acetic acid for each adjusted interval.

Sample Run ID	Interval Endpoint	Wood Moisture Content	Unit mass leaving kiln							
			Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	hours	%	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	2.25	68.8	0.0019	0.0000	0.0017	0.0047	0.00004	0.0017	0.00001	0.00000
2	5.41	59.6	0.0058	0.0000	0.0124	0.0237	0.00021	0.0066	0.00003	0.00000
3	8.56	47.4	0.0110	0.0000	0.0129	0.0312	0.00072	0.0094	0.00016	0.00046
4	11.57	37.1	0.0140	0.0000	0.0116	0.0256	0.00067	0.0066	0.00012	0.00044
5	14.02	29.6	0.0128	0.0000	0.0075	0.0184	0.00053	0.0042	0.00009	0.00027
6	17.68	20.6	0.0190	0.0000	0.0093	0.0224	0.00075	0.0052	0.00011	0.00032
7	20.78	15.5	0.0154	0.0000	0.0057	0.0157	0.00056	0.0037	0.00009	0.00021
		Sums:	0.080	0.000	0.061	0.142	0.003	0.037	0.0006	0.0017
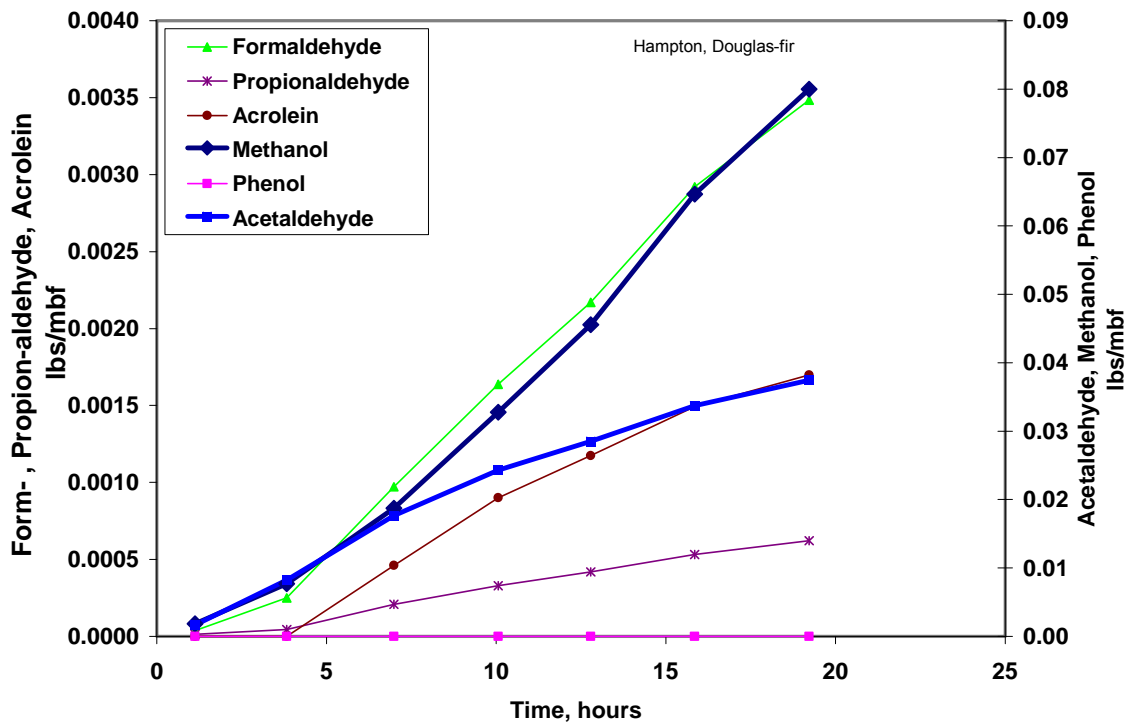
FIGURE 5. HAP emissions as a function of time for Douglas-fir.

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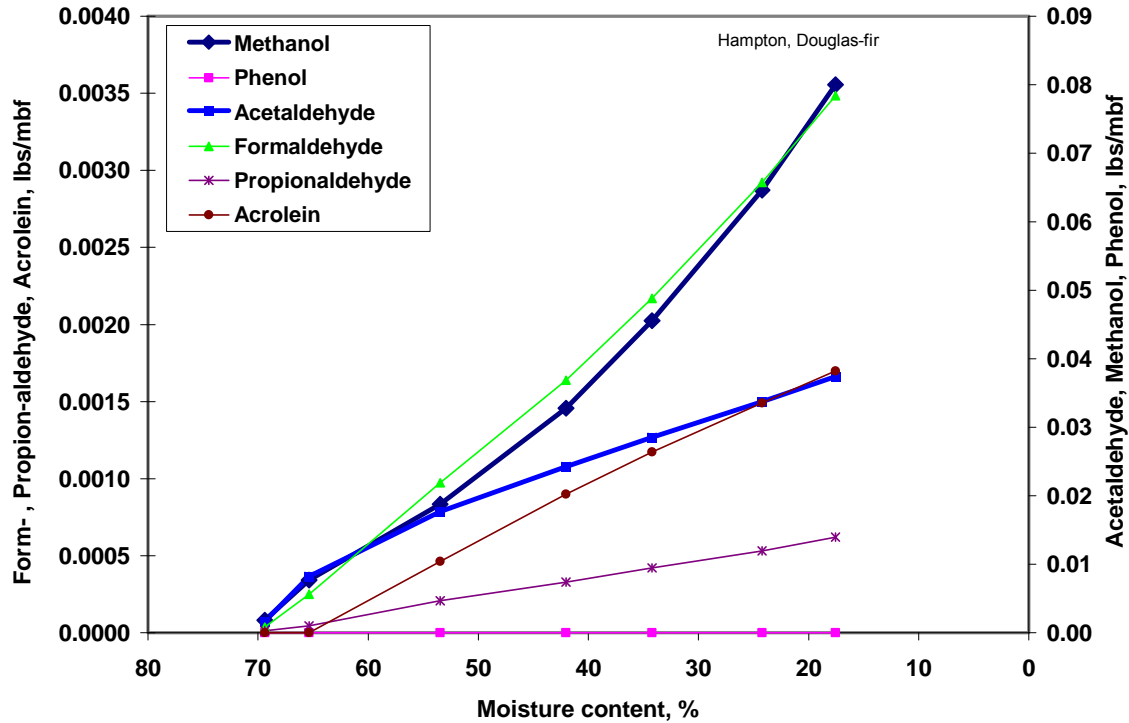
FIGURE 6. HAP emissions as a function of wood moisture content for Douglas-fir.

The detection limits for the GC instrument were
    Methanol – 3.8 µg/mL in the aqueous phase
    Phenol – 0.18 µg/mL in the aqueous phase
    Ethanol – 0.38 µg/mL in the aqueous phase
    Acetic acid – 1.78 µg/mL in the aqueous phase
    Formaldehyde - 0.04 µg/mL in the hexane phase
    Acetaldehyde – 0.08 µg/mL in the hexane phase
    Propionaldehyde – 0.08 µg/mL in the hexane phase
    Acrolein – 0.24 µg/mL in the hexane phase
The method detection limit varies with gas flow through the impingers and the amount of
solution in the impingers. Typical (based on the flow conditions and impinger volumes for
sample 5) method detection limits in the sampled gas are
    Methanol - 4.1 ppm in the kiln exhaust
    Phenol - 0.1 ppm in the kiln exhaust
    Ethanol – 0.3 in the kiln exhaust
    Acetic acid – 1.0 in the kiln exhaust
    Formaldehyde - 0.01 ppm in the kiln exhaust
    Acetaldehyde - 0.02 ppm in the kiln exhaust
    Propionaldehyde - 0.01 ppm in the kiln exhaust
    Acrolein - mean = 0.04 ppm in the kiln exhaust

Samples DF2-1 (the first interval) had methanol, propionaldehyde, and acrolein concentrations below the detection limits. Similarly, sample DF2-2 had acetaldehyde and acrolein concentrations below detection limits. All other compounds in all samples were above the detection limits except that all phenol samples were zero (agrees with all past work that phenol is not emitted during lumber drying). When one-half the detection limit is substituted for values below the detection limit, the results from Table 5 are essentially unchanged as shown below.

Unit mass leaving kiln							
Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
0.080	0.000	0.061	0.142	0.003	0.037	0.0006	0.0018

Field spikes (Table 6) were run by operating two impinger trains simultaneously. An aliquot of the aldehydes or aqueous compounds was added to one impinger train. Spike recovery percentage is the mass of a compound detected in the lab compared to mass added to the impinger.   Of the 16 spike tests, 15 had recoveries within the method limits (70 to 130% or 50 to 150%, depending on concentration). Acetic acid in one run was 130.8%, slightly higher. The acetic acid simply does not work well by this method.

The results for a field blank collected during run nine are shown in Table 7. Acetic acid appeared in the blank, but we feel this was anomaly that has to do with the GC integration at low concentrations (as shown below for MeOH). In a rerun of the sample, acetic acid was detected at 2.0 ppm instead of 10.
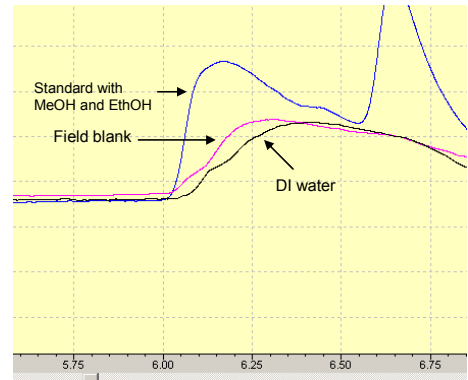
Methanol was detected in the field blank at 0.4 ppm. This too is an artifact of the integration. The figure to the right shows chromatograms from three runs, distilled water, the field blank, and a low concentration standard. There could be a slight carryover from needle rinsing, but the field blank is very similar to the distilled water.

Formaldehyde appeared in the field blank at 0.08 ppm but this was below the concentration in the samples by a factor of 50. We think there is some carryover in the GC needle or injection contributing to this rather than a dirty field blank. The figure to the right shows small peaks in three of four pure hexane injections.
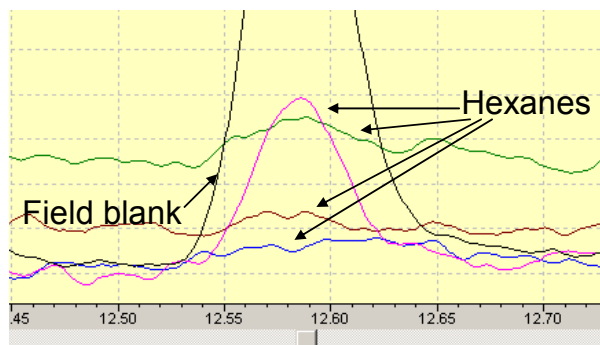
All other blanks were either zero or well below the detection limits.

TABLE 6. Results for field spike recoveries.

	Alcohol Spike								
Run	Mass in impinger				Impinger flow	Mass corrected for flow			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
3	767.1	0.0	898.5	2164.9	324.9	770.1	0.0	902.0	2173.5
302	2689.9	211.9	2952.6	6838.8	326.1	2689.9	211.9	2952.6	6838.8
Spike mass	Spike concentrations					Spike recoveries			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
1.63	1069.2	122.7	1180.3	2186.2		110.2	106.0	106.6	130.9

	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
4	52.9	524.7	9.7	34.8	323.3	71.0	703.8	13.0	46.7
402	159.1	1926.4	46.8	134.8	433.7	159.1	1926.4	46.8	134.8
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		%	%	%	%
1.55	41.9	486.4	11.3	42.2		89.3	106.9	127.4	88.7

	Alcohol Spike								
Run	Mass in impinger				Impinger flow	Mass corrected for flow			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
7	2115.9	0.0	781.3	2161.1	325.9	2838.7	0.0	1048.2	2899.4
702	5593.0	385.2	4157.6	9626.1	437.2	5593.0	385.2	4157.6	9626.1
Spike mass	Spike concentrations					Spike recoveries			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
3.51	1069.2	122.7	1180.3	2186.2		73.4	89.5	75.1	87.7

	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	103.2	707.4	15.3	37.9	325.5	138.8	951.9	20.5	51.0
802	293.2	3065.3	80.8	215.9	438.1	293.2	3065.3	80.8	215.9
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		%	%	%	%
3.07	41.9	486.4	11.3	42.2		79.0	93.3	114.7	83.8

TABLE 7. Results for the field blank.

Field blank							9C
Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.4	0.0	0.0	10.2	0.1	0.0	0.0	0.0

Duplicate samples were run by operating two impinger trains simultaneously. The results of duplicates are shown in Table 6. The percentage is the difference between the gas concentrations detected by each impinger. Phenol was not detected so duplicates could not be compared. All of the 21 other duplicates were within the test limits. Percents are calculated after adjusting the micrograms in the impinger for the gas flow rae.

TABLE 8. Results for duplicate runs.

Duplicate								
	Mass in impinger							Impinger flow
Run	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	µg	µg	µg	µg	mL/min
4	1113.8	0.0	921.0	2033.7	52.9	524.7	9.7	34.8	323.3
403	788.8	0.0	598.8	1390.0	36.7	360.4	6.8	25.3	217.4
Difference, %	4.2	#DIV/0!	2.7	1.3	2.6	1.7	3.3	6.4	

Duplicate								
	Mass in impinger							Impinger flow
Run	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	µg	µg	µg	µg	mL/min
7	2115.9	0.0	781.3	2161.1	77.5	511.4	12.3	28.5	325.9
703	1349.8	0.0	477.1	1313.2	67.8	435.4	11.0	23.7	219.6
Difference, %	4.4	#DIV/0!	7.9	8.2	21.4	19.2	23.1	17.3	

Duplicate								
	Mass in impinger							Impinger flow
Run	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	µg	µg	µg	µg	mL/min
8	2788.1	0.0	710.8	2219.3	103.2	707.4	15.3	37.9	325.5
803	1814.5	0.0	453.2	1429.2	67.1	452.2	7.3	34.7	219.1
Difference, %	2.7	#DIV/0!	4.3	3.5	2.8	4.1	26.8	25.3	

4. Control system and operating conditions

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

Humidity control

A 200 L/min MKS mass flow meter controlled the amount of air entering the kiln. It was factory calibrated and checked using a bubble meter. The amount of air entering the kiln is based on the wet-bulb temperature - if it is above setpoint, the airflow is increased and if it is below setpoint the airflow is decreased. This is analogous to venting for a commercial kiln. A minimum of 12 L/min entered the kiln at all times, more than removed by the analyzer (1.6 L/min). Putting air into the kiln at a rate of 100 L/min causes the pressure in the kiln to be 60 to 130 Pa above ambient, depending on location in the kiln (high-pressure or low-pressure side). Thus, any fugitive leakage should be out of the kiln. Two additional flow meters can be manually set to provide additional airflow. Flow meter two was used during charge two between hours 3 and 4. Flow meter three was not used.

Temperature control

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

The dry- and wet-bulb temperatures recorded for each charge are shown in Figure 8. The poor wet-bulb control for charge 1 is evident in this figure and is the reason we did not report the charge 1 data. For charge 2, the control was very good.
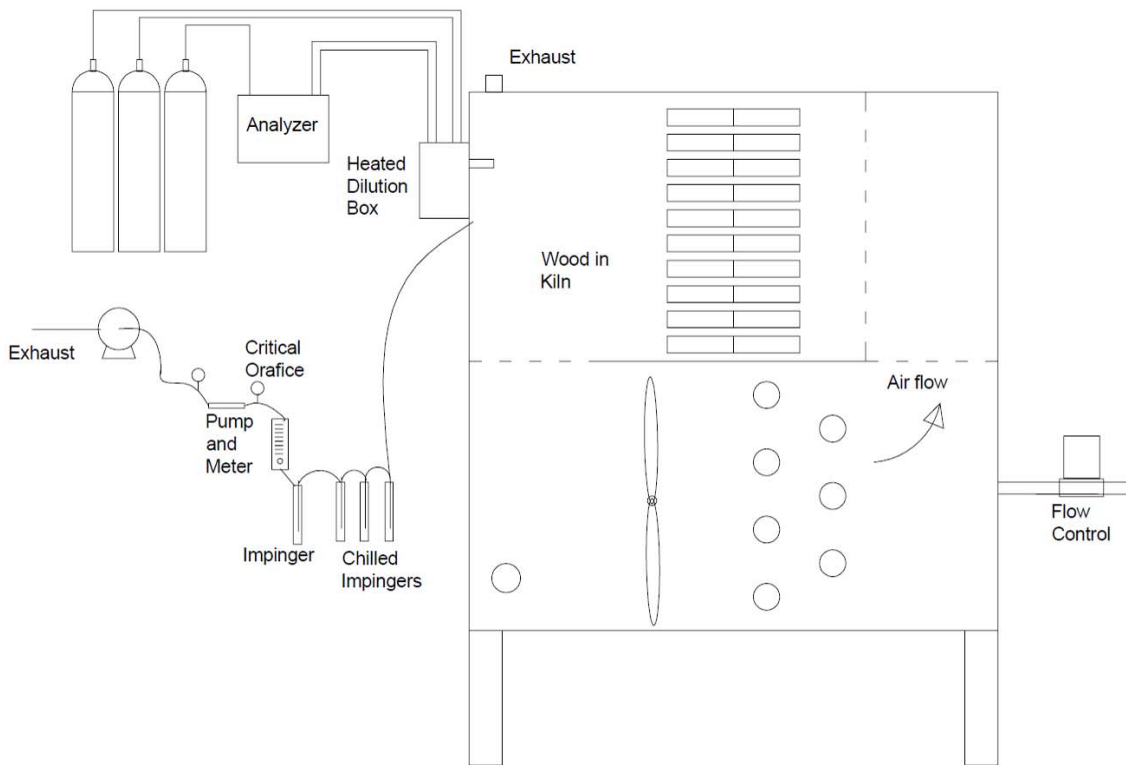
FIGURE 7. Schematic of kiln and sampling system (top) and photo of kiln charges (bottom photos, charge 1 right and charge 2 left).
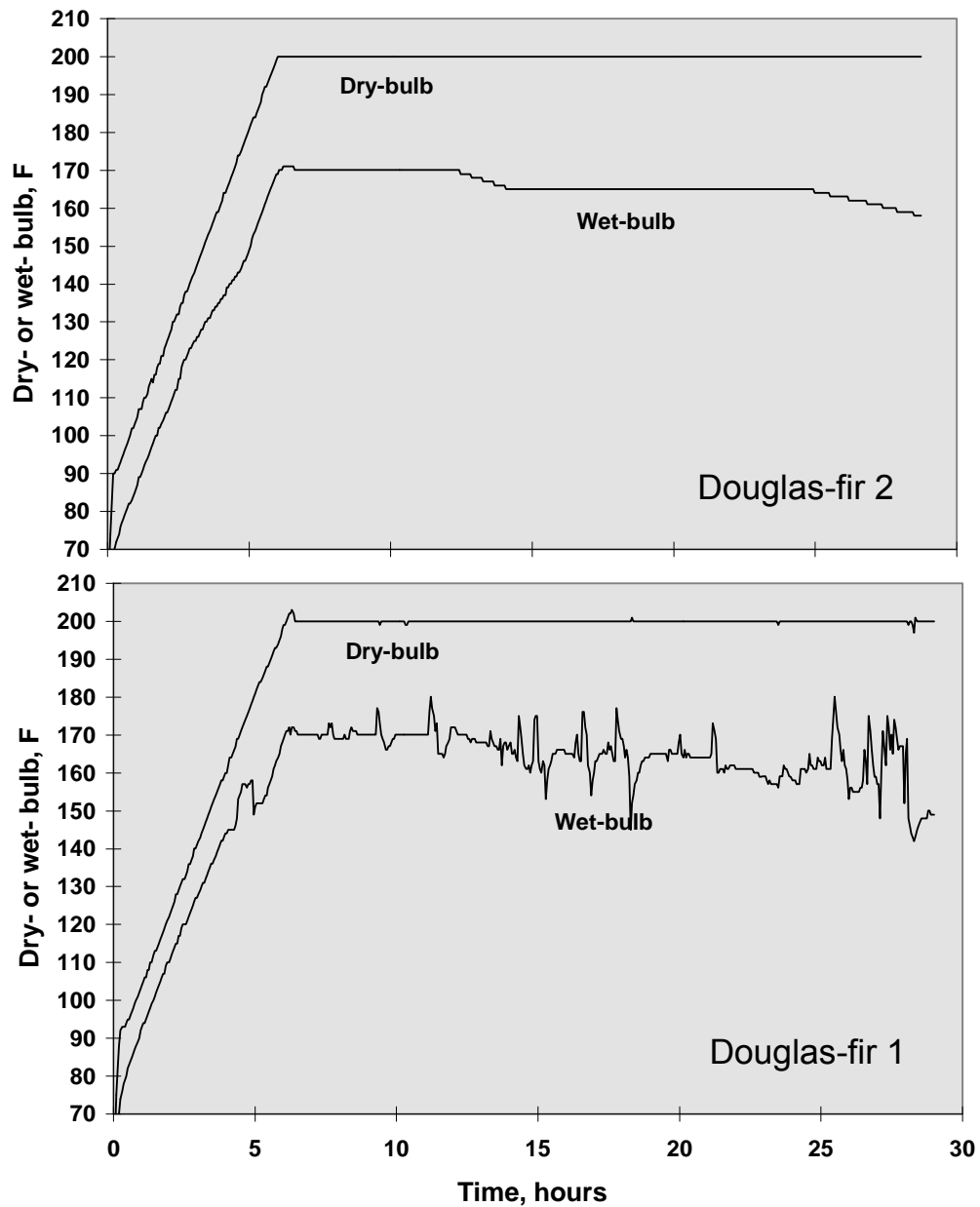
FIGURE 8. Dry- and wet-bulb temperatures for charge 1 (bottom) and charge 2 (top). Emissions data from charge 2 is reported because of the poor wet-bulb control shown in the bottom chart.

5. Production-related parameters

Kiln operation

The sequence of dry- and wet-bulb temperatures (drying schedule) provided by the mill is shown in Figure 9. The actual operating conditions during the charge are shown in Figure 8. The mill's schedules and the test conditions matched well.
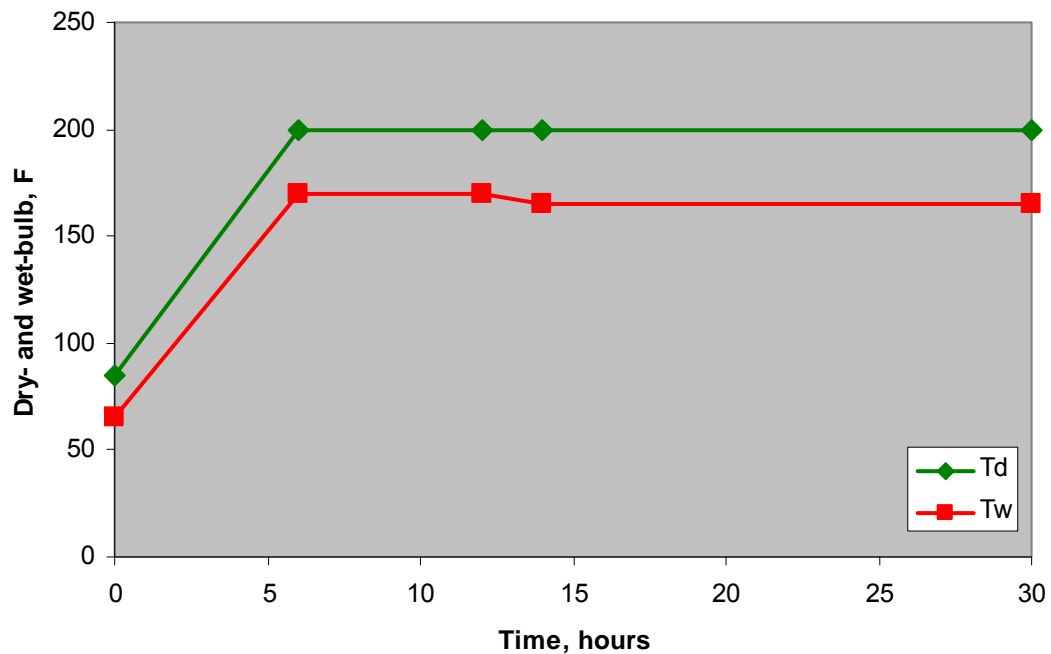
FIGURE 9. Dry- and wet-bulb setpoints provided by the mill.

Wood quantity

The wood quantity was determined using the nominal wood dimensions (2x4 in this case) which provides for 0.66 board feet per lineal foot There were 36 pieces in the kiln at 44" in length for charge 2. The board footage was therefore 87.12 board feet.

This quantity was used to express the emissions from the drying cycle on a production basis of lb/mbf (pounds per thousand board feet).

Wood quality

The wood quality measurements are shown in Table 9. Individual measurements can be found in the Excel file "Weights, Hampton Morton.XLS" in Appendix 2.

TABLE 9. Wood properties.

Charge	Knots		Heartwood	Ring Count	Pith in
	Number	Diameter			
	#	in	%	#/inch	#
2	6.1	0.58	70	5.3	3 of 36

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

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

The knots were counted on all faces of each board and averaged. This was a count of all knots, so a knot that intersected two faces was counted twice. Knot diameter is an average of the knots present. The knots occupied approximately 1% of the boards' faces.

6. Test methods

Charge Sequence

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

Sampling Methodologies

Hydrocarbon

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

Figures 10 and 11 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 250°F. 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 275°F.   The 3-way valve at the back of the analyzer was heated to 295°F.

The fuel gas was hydrogen. The span gas was EPA Protocol 610 ppm propane in air, the mid-gas was EPA Protocol 99 ppm propane. The zero gas was 0.1 ppm air. Detailed sampling procedures are in Appendix 1.
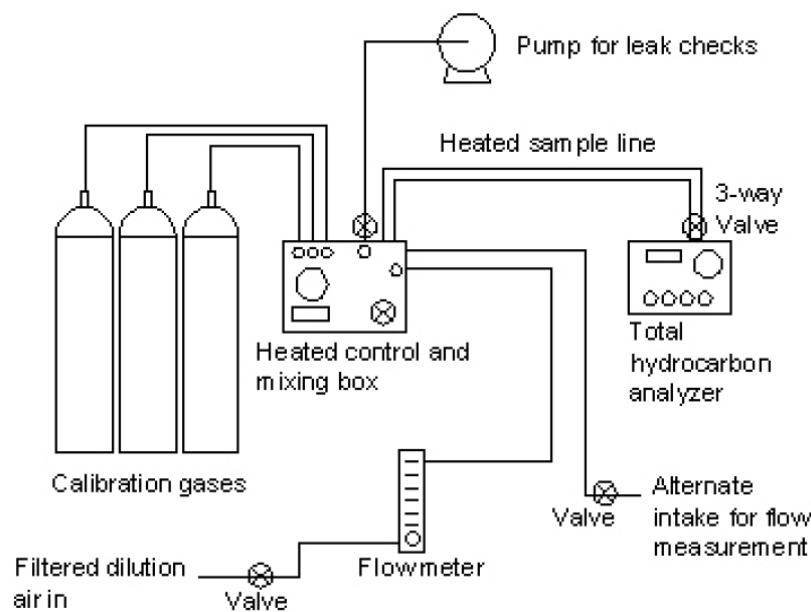
FIGURE 10. Schematic of heated filter box with air dilution system, heated sample line, and analyzer. Sample enters heated box from back of drawing (box is attached to kiln).
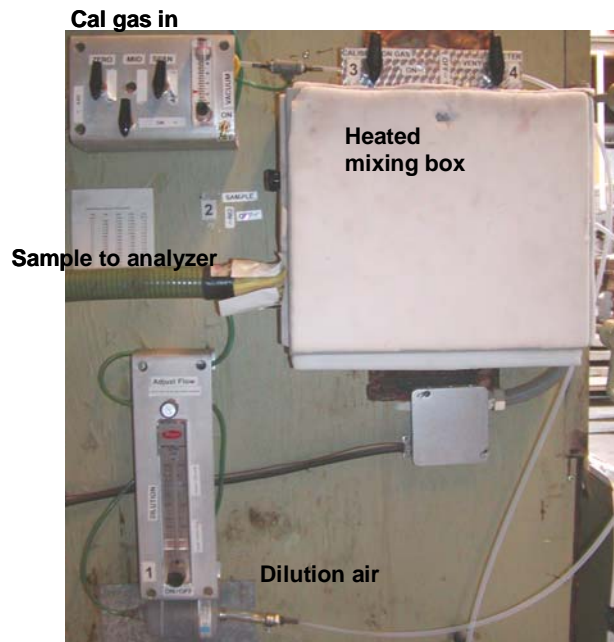
FIGURE 11. Photo of VOC sampling system showing heated mixing box (with white insulation), valves and flow meter for calibration gases (upper left), on/off valve for calibration gas (3 at upper center right), heated sample line to analyzer (green tube, middle left), valve for sample (2 at center left), toggle valve to vacuum pump (near calibration gas valves), and vent/flowmeter valve (4 at upper right).

HAPs

The sampling train for NCASI Method 105 is shown in Figure 12. The impingers were in a glycol solution maintained at -1 C. Prior to each sampling interval, the impingers were laboratory-washed and 10 to 15 mL of BHA solution were added to the first and second impingers. The third impinger was left empty. The fourth impinger was present in the system to prevent any overflow from reaching the critical orifice. The system was then assembled and a vacuum check was performed with the valves at each end closed. Less than 1" Hg of pressure change over 2 minutes was acceptable. This was met. The flow rate through the system was then measured using a Gilibrator flow meter to take four flow readings at the probe tip. This was approximately 240-500 mL/min, depending on the sampling train. The probe tip was then inserted into the kiln and the sampling interval begun. The collection interval time was approximately 1:15.

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

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

The local airport altimeter setting and the lab temperature were recorded at the beginning and end of each interval so the flow rates could be adjusted to standard conditions.
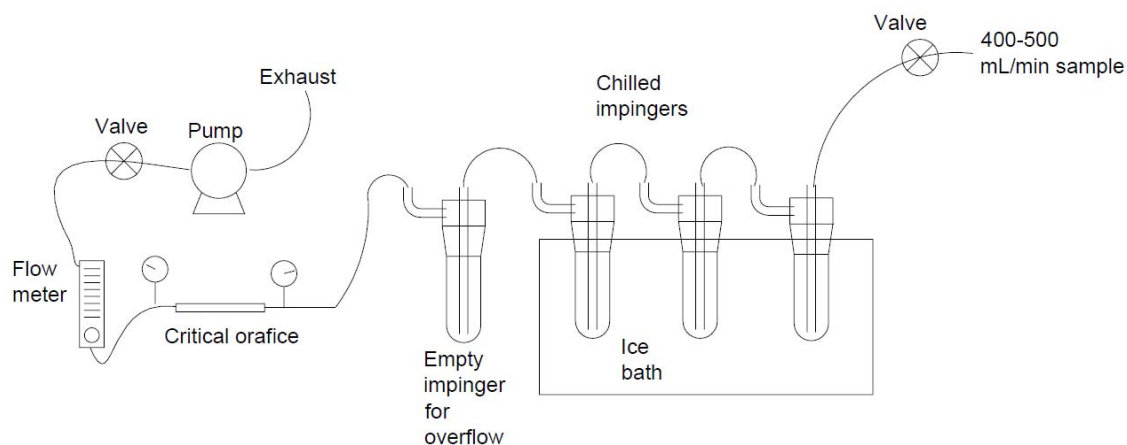
FIGURE 12. HAPs sampling train.

7. Analytical procedures

Hydrocarbon

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

Total flow and sample flow to the analyzer were checked using an NIST-traceable flow meter. Total flow is measured with the dilution gas off and is equal to both the sample flow from the kiln when the dilution is off and the total volume drawn by the analyzer. Sample flow is measured with dilution gas on and is the volume of gas sampled from the kiln when the dilution gas is on. This was done at the beginning and end of each sampling interval. The meter was attached to the system near the probe tip within the heated box. The valves were repositioned so that the sample came from the flow meter

(attached to the alternate intake in Figure 10) rather than the kiln. Readings of flow were made with the dilution gas both off and on. The flow readings were verified by observing the analyzer reading for span gas with the dilution gas off and on. The dilution ratio calculated based on the analyzer readings was always within 5% of that determined by the flow meter and usually within 2%.

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

HAPs

Lab analysis for aldehydes

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

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

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

Standards for methanol, phenol, ethanol, and acetic acid were prepared by the volumetric dilution of neat reagents in water.   The mixed standard was prepared at a concentration of 500 milligrams per liter (mg/L). Additional standards were prepared by the volumetric dilution of the mixed standard at a range from 0.75 mg/L to 500 mg/L. Aliquots of these were placed into autosampler vials with 20 µL of 30,000 ppm cyclohexanol internal standard.

Samples (from the field) were prepared by transferring aliquots of the previously hexane-extracted aqueous fractions into autosampler vials and adding internal standard. The analytical instrument was a Shimadzu GC model 2010 with a FID detector. The column was a 60-meter Restek Stabilwax capillary with a 0.53 mm diameter and a stationary phase thickness of 1.5 µm. The oven schedule was: 3 minutes at 80°C, 10°C/min ramp to 225°C, and 14 minutes at 225°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 steel plunger.

8. Field data sheets and sample calculations

Field data sheets

Samples of field data sheets are shown in Figures 13 to 16. All field data sheets are in Appendix 2 this report in electronic format (pdf).

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - AFTER

Operator: MRM   Event (kiln charge): Hampton 2

Run (sample): 3   Laboratory temperature: 75 °F

END TIME: 2:30A   (20:04 smt)

Range setting on Analyzer: 3   on Computer: 3

Reset range to 3.   Range: 3

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

	Analyzer reading	Computer, ppm
Span$_{Diluted}$	2.15	2.15

Sample flow rate (SFR): 590.9 mL/min   [1= on, 2, 3 = off, 4=meter]

Read dilution meter: 2.2 scfh

Total flow rate (TFR): 1654 mL/min   [1, 2, 3 = off, 4=meter]
(label print out)

Dilution ratio (DR$_{Flow}$): 0.357   [SFR / TFR]

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

	Analyzer reading	Computer, ppm	Within range	Pot settings
span	6.11	6.11	590 to 625	323
mid	0.99	0.99	96 to 102	480
zero	0	0	-18 to +18	

Dilution ratio (DR$_{span}$): 0.352   [Span$_{Diluted}$ / Span]

Dilution ratio difference: 14 %   [100*(Abs(DR$_{span}$ - DR$_{Flow}$))/DR$_{Flow}$]

End time for check: 2:36

Comments: To Range 3 at 8:14pm

Jan 7, 2005   2   Hydrocarbon analyzer Instructions

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FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - BEFORE

BACKGROUND INFORMATION

Event (kiln charge): Hampton 2   Dry-bulb temperature: 86

Run: 3 MRM   Wet-bulb temperature: 170

Operator: MRM   Target Dilution Ratio (TDR): 0.33

Date: 1-24-12   Laboratory temperature: 75 °F

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

	Range	Analyzer, reading	Computer, ppm	Within range	Pot settings
zero	3	0.00 (0)	0.02 (0)		480
span	3	6.10 (6.10)	6.10 (610)		374
mid	3	1.00 (0.99)	1.00 (99)	96 to 102	
mid	2	9.63 (9.9)	.		

Reset range to 3.   Range: 3

SET DILUTION FLOW BEFORE RUN (do not change pots)

Total flow rate (TFR): 1663 mL/min   [Valves 1, 2, 3 = off; 4=meter]

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

Set and read dilution meter: 2.2 scfh   [scfh = mL/min * 0.00212]

Sample flow rate (SFR): 590.5 mL/min   [1 = on; 2, 3 = off; 4=meter]

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

	Analyzer	DR$_{Span}$ [Span$_{Diluted}$/Span]	DR$_{Flow}$ [SFR / TFR]	Difference, % 100*(DR$_{Span}$ - DR$_{Flow}$)/DR$_{Flow}$
Span$_{Diluted}$	2.17	0.357	0.355	0.4%

START TIME: 20:04 (clock)   [1, 2, 5 = on;   3, 4 = off; tank valves off]

ANALYZER RANGE: 2   [0.6 < reading < 7.5]

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

FIGURE 13. Sample of field data sheet for hydrocarbon analyzer.

Charge: Hampton 2		Date	Time			Page: 1
	Start	1/25/2012	8:34AM		Log sheet	
	End					

Clock time	Elapsed time	Run #	Temperatures						Flows							Vacuum		
			T dry °F	T wet °F	Box °F	Line °F	Valve °F	Chiller °C	Flow 1 L/min	Flow 2 L/min	Flow 3 L/min	Dilution SCFM	Line 1 ml/min	Line 2 ml/min	Line3 ml/min	Line 1 inHG	Line 2 inHG	Line3 inHG
8:34	0	1	66	59	248	298	23	-1	196	0	0	2.0	350	—	380	28.5	—	—
9:31	57	1	103	85	250	298	275	-1	200	0	0	20	350	—	—	285	—	—
10:40	2:06	1	125	106	250	298	225	-1	200	0	0	2.0	30	—	—	28,	—	—
12:09	3:36	1	154	131	250	295	275	-1	195	27.1	0	20		450		28	28	
13:11	4:38	2	174	143	250	294	275	-1	199	0	0	2.2	—	—	—	—	—	—
14:15	5:41	2	194	144	250	295	23	-1	62.7	0	0	2.2	—	—	—	—	—	—
15:00	6:26	2	200	171	250	291	23	-1	75	0	0	2.2	350	450	390	275	275	280
17:00	8:26	2	200	170	250	290	23	-1	70	0	0	2.2	—	—	—	—	—	—
18:00	9:26	2	200	170	250	297	23	-1	648	0	0	3.2	350	45	390	28	275	28
19:07	10:33	2	200	170	250	292	23	-1	59.2	0	0	2.2	380	450	390	28	28	28
20:05	11:32	3	200	170	250	295	225	-1	55.5	0	0	2.2	35-	—	—	—	—	—
20:51	12:18	3	200	169	250	296	275	-1	52.7	0	0	2.2	350	~	~	28.5	—	—
21:59	13:25	3	200	167	250	298	275	-1	62.8	0	0	2.1	350	—	—	28.5	—	—
23:00	14:26	3	200	165	250	287	275	-1	62.5	0	0	2.2	—	—	—	—	—	—
23:56	15:22	4	200	165	250	288	275	-1	56.3	0	0	2.2	—	—	—	—	—	—
1:02	16:29	4	200	165	250	294	275	-1	48.4, 49.9		0	2.2	—	450	—	—	28	—
1:30	16:56	4	200	165	250	297	275	-1	48.3	0	0	2.2	—	—	—	—	—	—

FIGURE 14. Sample of field data sheet for kiln log.

FIGURE 15. Sample of field data sheet for flow measurement.

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

Operator: MRM
Event (kiln charge): Hampton 2
Run (sample): 5 -A

Altimeter setting: 30.04 inHg
Sample line rinse vial: 19.03 g (with ~5 mL DIW)
Lab temperature: 75 °F
Remove sample line from kiln Clock time: 22:16
Elapsed time: 13:43
(rinse sample line then measure flow rate)
Sample flow rate: 369.0 mL/min [Average of 4. Label printout]
(take impingers to scale from kiln)
Sample line rinse vial: 13.76 g (empty)
Empty bottle weight: 17.15 g (with lid)

IMPINGER WEIGHTS (transfer sample to bottle)

	Wet Weight, g	Dry Weight, g	Water removed, g
Impinger #1A	72.83	41.71	
Impinger #1B	55.62	42.41	
Impinger #1C	42.56	42.54	

Bottle weight without impinger rinse: 176.49 g (with lid)
(rinse impingers with 10 ml DI water)
Bottle weight with impinger rinse: 186.87 g (with lid)
(rinse impingers with 5 ml hexane)
Filled bottle weight: 191.62 g (with lid)
Fluids lost during handling: _____ mL
Comments:

[estimate]

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

Operator: MRM
Event (kiln charge): Hampton 2
Date: 1-24-12
Run (sample): 5 -A

Altimeter setting: 30.01 inHg
Isopropanol rinse or lab wash: ☒

IMPINGER WEIGHTS (add BHA to impingers)

	Dry Weight, g	Wet Weight, g	BHA added, g
Impinger #1A	41.54	62.65	(~10 mL)
Impinger #1B	42.22	55.47	(~15-20 mL)
Impinger #1C	42.33	---	-------

Total BHA added: _____

Optional Spike: X g   Spike type: Alcohol □ Aldehyde □
(take impingers to kiln from scale)
Lab temperature: 75 °F
Leak check: Vacuum 15.2 inHg Lost after 2 minutes 0
Sample flow rate: 364.0 mL/min [Average of 4. Label printout]
Put sample line in kiln   CLOCK TIME: 21:00
ELAPSED TIME: 12:27
Is the sample line in the kiln?
Is gas flowing (look at flow meters)?

FLOW METER READINGS DURING TEST (every 20 minutes)

Clock time	21:24	21:54
Vacuum, inHg	28.5	28.5
Flow rate, mL/min	350	350

FIGURE 16. Sample of field data sheet for HAP sample train.

Calculations

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

Humidity

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

$$P_{vp} = P_{ambient} * 10^{(16.373 - 2818.6/(Td+273.16) - 1.6908*LOG10(Td+273.16) - 0.0057546*(Td+273.16) + 0.0000040073*(Td+273.16)^2)}$$

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

$$MolHum = AbHum * MW_{air} / MW_{water}$$

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

Flows

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

$$DryGasV = (FlowMeter1 + FlowMeter2 + FlowMeter3) * (1/(1+MolHum_{In}))$$

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

$$DryGas \ (kgmol/min) = DryGasM / MW_{air}$$

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

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

Moisture content

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

$$\text{MC} = \text{MC}_{Previous} - 100 * (\text{WaterVented} / (1000 \text{ g/kg}) / \text{ODWoodWt})$$

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

Hydrocarbon

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

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

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

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

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

Column W is the integral of column V over time, the cumulative hydrocarbon released up to that point in the schedule (in grams). Column X is the cumulative unit emissions, that is, column W divided by the oven-dry weight of the wood in the kiln. Column AI is the

cumulative emissions in pounds per thousand board feet and column AH is the rate of emissions release ($lb \cdot mbf^{-1} \cdot hr^{-1}$)

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

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

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

Moisture content and board weight data are on the "Define" worksheet and the original data are in the files named "Weights, Hampton Morton.XLS".

HAPs

Within the file "HAPs, Hampton.xls", the summary page presents the data by run interval. It is copied from the other pages to make the spreadsheet more readable.

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

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

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

$$ImpgrFlowStd = ImpgrFlow * (273.16K / T_{meter}) / (P_{meter} / 101.33 \text{ kPa})$$

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

$$ImpgrFlwDry\_mL = ImpgrFlow * (1 - MolHum / (1 + MolHum))$$

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

$$\text{ImpgrFlwDry\_g} = =MW_{air} * \text{ImpgrFlwDry\_mL} *P / (T * R)$$

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

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

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

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

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

The remaining pages in "HAPs, Hampton.xls" are for graphing purposes.

9. Chain of custody information

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

10. Calibration documentation

SENSIDYNE, INC.

CALIBRATION CERTIFICATE

CELL S/N: 0905001-S   DATE: 05 - 05 - 2009

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

Results:

REFERENCE MCS-102 cc/min	S/N 0905001-S cc/min	RELATIVE DIFF. cc/min	PERCENT DIFF.
2002	1997	-5	-0.25
2004	1997	-7	-0.35
2002	1997	-5	-0.25
2004	1997	-7	-0.35
2002	1997	-5	-0.25
2002	1994	-8	-0.4
2002	1996	-6	-0.3
2001	1996	-5	-0.25
2001	1997	-4	-0.2
2002	1996	-6	-0.3

| MAX | | -8 | -0.4 |
| MEAN 2002.2 | 1996.4 | | |

CALIBRATED BY _Sladjana Pavic_   DATE: 05 - 05 - 2009

CODE 000

FIGURE 17. Flow meter calibration**.**

Airgas
Specialty Gases
1171 S. Alameda Street
Los Angeles, CA 90059-2130
(323) 357-6851
FAX: (323) 357-8566

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Part Number:	E02AI99E15A1472	Reference Number:	48-124221446-2
Cylinder Number:	SG9133882	Cylinder Volume:	146 Cu.Ft.
Laboratory	ASG - Los Angeles - CA	Cylinder Pressure:	2015 PSIG
Analysis Date:	Jun 04, 2010	Valve Outlet:	590

Expiration Date: Jun 04, 2013

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 Uncertainty
PROPANE	600.0 PPM	609.6 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	000519	SG9107376	483.6PPM PROPANE/	Jul 01, 2013

ANALYTICAL EQUIPMENT

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

Triad Data Available Upon Request

Notes:

Approved for Release

Airgas

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Airgas Specialty Gases
1171 S. Alameda Street
Los Angeles, CA 90059-2130
(323) 357-885
Fax (323) 357-8526
www.airgas.com

Part Number:	E02AI99E15A0465	Reference Number:	48-124230531-1
Cylinder Number:	SG9107334	Cylinder Volume:	146 Cu.Ft.
Laboratory	ASG - Los Angeles - CA	Cylinder Pressure:	2015 PSIG
Analysis Date:	Aug 19, 2010	Valve Outlet:	590

Expiration Date: Aug 19, 2013

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 Uncertainty
PROPANE	100.0 PPM	98.79 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	090617	CC301749	97.82PPM PROPANE/AIR	Oct 02 2013

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
Nicolet 6700 Propane	FTIR	Aug 18, 2010

Triad Data Available Upon Request

Notes:

Approved for Release

FIGURE 18. Certificates for calibration gases.

11. Anomalies

The wet-bulb did not function well during the first charge as shown in Figure 8. We therefore have not reported the data from charge 1 except as shown below.

Charge	VOC	MeOH	EthOH	AceticA	FormA	AcetA	PropA	Acrol
	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	0.80	0.065	0.054	0.252	0.003	0.035	0.0006	0.0021
2	0.66	0.080	0.061	0.142	0.003	0.037	0.0006	0.0017

The VOC concentration and venting for charge 1 are shown to the right (shown for in Figure 2 for charge 2). The uneven wet-bulb control causes large swings in the venting and, in turn, large swings in the VOC concentration.

There were no other anomalies.
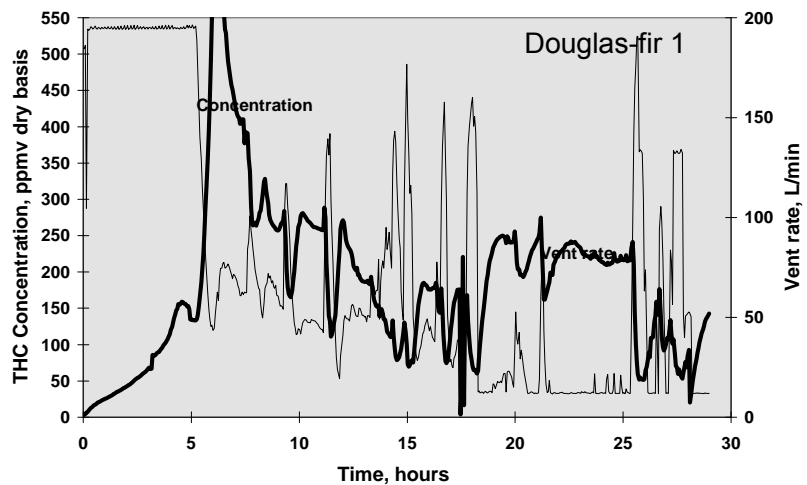
12. Statement of validity

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

Michael R Milota

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Appendix 1. Detailed sampling procedures

Kiln

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 230°F.

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 250°F.

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.

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 12 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°F, call Mike

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

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

Line temperature: Read from gray box on wall above analyzer. It should read about 240°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 in the notes. Also, enter it onto the computer screen

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.

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 – use date VOC run will start if close to midnight

AMBIENT DATA
Read the laboratory temperature from the thermometer.

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

Open the zero gas tank valve
      set analyzer to range 3
      zero valve on, others off
      set flow to 3 L/min using regulator on tank
      wait for a stable reading (about 30 to 60 seconds)
      use the zero dial (pot) on THA to get a zero reading
      read the analyzer
      read computer
      note pot setting
      close valve on zero gas tank

Open span gas tank valve
      span valve on, others off
      set flow to 3 L/min using regulator on tank
      wait for a stable reading (about 30 to 60 seconds)
      use the span dial (pot) on THA to get a reading of 610ppm
      read the analyzer and record, eg, record 6.10
      read computer (should read about 610)
      record pot setting

leave span tank valve open

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

SET DILUTION FLOW BEFORE RUN (BEFORE SIDE OF SHEET)

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

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

Calculate the next two values -
>Target dilution flow rate (TDFR)   is the TFR 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
>Slowly open lower valve on dilution flow meter (1=ON)
>Use upper valve on dilution flow meter to adjust flow
>Do not adjust this meter after this point
>Read the meter that you just set and record the value in SCFH
>Calculate and record L/min

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

CHECK DILUTION FLOW BEFORE RUN (BEFORE SIDE OF SHEET)

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

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

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

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

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

**** check calculations, check that values for ppm and flows make sense, remeasure everything. If it still does not agree, call Mike (541)752-0648

START RUN (BOTTOM OF BEFORE SIDE OF SHEET)

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

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

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

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

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

POST-SAMPLE PROCEDURE

AT END OF RUN (AFTER SIDE OF SHEET)

Record your name as the operator.
Event = the drying cycle. Run = number of the 3-hour interval.
Operator, that's you. .

AMBIENT DATA

Read the laboratory temperature from the thermometer.

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

END TIME

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

CHECK DILUTION FLOW AFTER RUN (AFTER SIDE OF SHEET)

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

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

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

       Use the Gilibrator to take 4 readings of the sample flow rate (SFR). This is the
          flow through the analyzer with dilution on.
       Make sure the average does not include any "bad" readings
       Record the average in L/min
       Write Run # and "Post-SFR" on the Gilibrator printout.

       Read dilution flow meter

To calculate the L/min, divide scfh by 2.12
Turn off dilution flow meter using valve 1 (lower dilution valve)

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

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

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

CHECK CALIBRATION OF ANALYZER (AFTER SIDE OF SHEET)

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

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

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

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

read analyzer (do not adjust pot settings)
read computer
note pot setting

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

Calculate % difference in the two dilution ratios as $100 * \{$Absolute Value $(DR_{Span}-DR_{Flow})\} / DR_{Flow}$

Record the time now as the end time for check.

Start Pre-Sample procedure for next run.

HAP 105 Collection

BACKGROUND DATA

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

PRE RUN DATA
Call 9-541- 754-0081 and get altimeter setting.

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

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

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

LEAK CHECK

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

SAMPLE FLOW RATE

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

START TIME

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

FLOW READINGS DURING TEST

Note flow meter reading at least 20 minutes
Run test for 1:15 hours or less if impingers fill

POST RUN DATA

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

END TIME

Remove probe from kiln
Record time

SAMPLE FLOW RATE

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

IMPINGER WEIGHTS

Lift impingers from chiller, take to scale, and place onto rack

Dry the outside of the impingers
Remove U tubes connecting the impingers together
Weigh sample bottle
Weigh the impingers (without stoppers) with the catch and record
Transfer the impinger contents to the sample bottle
Weigh the sample bottle and record
Rinse impingers with 10 mL DIW (save the rinse in the sample bottle)
Weigh the sample bottle and record
Rinser impingers with 5 mL hexane (save the rinse in the sample bottle)
Weigh the sample bottle and record
Place the sample bottle into cold storage
Note: The glassware must be washed with detergent before the next use
Note: Record the volume of any liquids lost during this procedure.

Appendix 2. Electronic copy of calculations