CASCADE HARDWOOD

P.O. Box 269, Chehalis, WA. 98532 ◦ (360) 748-0178 ph ◦ (360) 748-1052 fax ◦ www.cascadehardwood.com

Uri ____
Randy ____
Paul ____
Wess ____
Clint ____
John ____
Vannessa
Jerry ____
Brian ____
Duane ____
Allison ____
Chip ____
Traci ____
Tina ____
File ____

March 11, 2015

Wess Safford, Air Quality Engineer
South West Clean Air Agency
11815 NE 99th Street, Suite 1294
Vancouver, WA 98682

Re: 2015 Kiln Emissions Testing

Enclosed is the 2015 kiln emission testing results conducted by Michael Milota at OSU on February 1, 2015.

If you have any additional questions or comments, please feel free to contact me.

Thank You,

Jason Thompson
Safety / Environmental Manager
360-748-0178
thompsonjr@chwa.com

RECEIVED
MAR 13 2015
SOUTHWEST CLEAN AIR AGENCY

Uri
Randy
Paul
Wess
Clint
John
Vannessa
Jerry
Brian
Duane
Allison
Chip
Traci
Tina
File

Total hydrocarbon and HAP emissions from the drying of red alder lumber

Report to
Cascade Hardwood LLC
158 Ribelin Road,
Chehalis, WA 98532
Phone: 360-748-0178
Fax: 360-740-5118
Contact: Jason Thompson
Air Discharge Permit #04-2566R2

Report by

Michael R. Milota
Department of Wood Science and Engineering
Oregon State University
Corvallis, OR 97331
541-737-4210
Mike.Milota@OregonState.edu

March 5, 2015

RECEIVED
MAR 13 2015
SOUTHWEST CLEAN AIR AGENCY

Table of Contents

Table of Contents i
List of Figures iii
List of Tables iv
Summary 1
1. Description of source 2
2. Date and time of test 2
3. Results 2
  Total hydrocarbon 2
  HAPs 5
4. Control system and operating conditions 12
  Humidity control 12
  Temperature control 12
5. Production-related parameters 14
  Wood quantity 14
  Wood properties 14
6. Test methods 16
  Charge Sequence 16
  Sampling Methodologies 16
    Hydrocarbon 16
    HAPs 18
7. Analytical procedures 19
  Hydrocarbon 19
  HAPs 19
    Lab analysis for aldehydes 19
    Lab analysis for alcohols 20
8. Field data sheets and sample calculations 21
  Field data sheets 21
  Calculations 23
    Humidity 23
    Flows 23
    Moisture content 24

Hydrocarbon 24
HAPs 25
9. Chain of custody information 26
10. Calibration documentation 27
11. Anomalies 29
12. Statement of validity 29
Appendix 1. Detailed sampling procedures 30
Checks of kiln to record on log 30
Total hydrocarbon analyzer 32
HAP 105 Collection 38
Appendix 2. Electronic copy of data and calculations 40

List of Figures

Figure 1. Hydrocarbon concentration and vent rate versus time 1. 4

Figure 2. Cumulative hydrocarbon emissions (left scale, smooth line) and the rate of emissions (right scale, jagged line) versus time. 4

Figure 3. Total hydrocarbon emissions as a function of wood moisture content. 5

Figure 4. HAP emissions as a function of time. 7

Figure 5. HAP emissions as a function of moisture content. 8

Figure 6. Schematic of kiln and sampling system (top) and photo of charge in kiln (bottom). 13

Figure 7. Schedules followed (top) and schedule provided by mill (bottom)..... 15

Figure 8. Schematic of heated filter box with air dilution system, heated sample line, and analyzer (top). Sample enters heated box from back of drawing through a heated sampling line. Calibration gas valves and dilution air valves are to left. Line to analyzer is the green line on the left in the left photo............................ 17

Figure 9. HAPs sampling train. 18

Figure 10. Sample of field data sheet for hydrocarbon analyzer. 21

Figure 11. Sample of field data sheet for HAPs collection................................ 22

Figure 12. Sample of kiln log data sheet. 22

Figure 13. Sample of flow measurement record.. 23

Figure 14. Flow meter calibration. 27

Figure 15. Certificates for calibration gases. 28

List of Tables

Table 1. Summary of total hydrocarbon results to 8% moisture content. VOC units are pounds per thousand board feet as carbon.. 1

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

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

Table 4. Summary of HAP sampling intervals.. 6

Table 5. Summary of the HAP, acetic acid, and ethanol emissions................... 7

Table 6. Spike test results.. 10

Table 7. Results for the field blank.. 11

Table 8. Results for duplicate runs... 11

Table 9. Wood properties.. 14

Summary

One charge of red alder 5/4 lumber was dried in a small kiln at Oregon State University. The kiln dry- and wet-bulb temperatures were based on a schedule provided by Cascade Hardwoods. The maximum temperature was 170°F (77°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 8% moisture content. VOC units are pounds per thousand board feet as carbon.

Charge	Initial MC	Final MC	Time to 8%	VOC[B]
	%	%	hr:min	lb/mbf
Red alder	106.1	8.0[A]	89:28	0.284

[A] actual time to 6.7% MC was 106:53 hours
[B] VOCs are reported at 8% moisture content

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 0.127 lb/mbf for the red alder.

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

	Methanol	Phenol[A]	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
Red alder	0.062	0.0	0.0007	0.0623	0.0005	0.0007

[A] None detected

1. Description of source

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

Mill personnel reported that the harvest location was Southwest Washington and Northern Oregon. The logs were stored in the logyard for 10 days on pavement without sprinkling. The logs were sawed on February 5, 2015, wrapped, and loaded to be delivered to OSU on February 5, 2015.

Enough 4-foot pieces of wood for three charges of lumber were delivered to Oregon State by an employee of Cascade Hardwoods. The wood was palletized and wrapped in plastic at the mill to prevent moisture loss during transport. The wood appeared to be fresh.

At OSU, the 4-foot pieces were sorted February 5. One third was randomly pulled from the pile and used for the charge. It was wrapped and stored in a cooler at 40°F. The remaining wood was wrapped in plastic and placed in a freezer at 10°F.

2. Date and time of test

The charge was dried from February 9 at 6 am until 5 pm February 13, 2015. 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 (Table 3) and the hydrocarbon emissions are summarized graphically (Figures 1-3) here. All emission data is presented in detail in electronic form in Appendix 2.

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 1 shows total hydrocarbon concentration (left scale) and dry gas vent rate (right scale) versus time. Concentration has a large peak at 12.6 hours during the period when venting is low. Concentration is reduced by 24 hours due to a much higher vent rate. In general, the concentration then increases though the schedule as venting decreases. The vent rate is quite variable in the beginning of the schedule due to heating of the wood and a high rate of moisture release from the wood.

Figure 2 shows the cumulative hydrocarbon emissions (left scale, smooth line) and the rate of emissions (right scale, jagged line) versus time. The cumulative value is the emissions up to any point in time in the schedule. The rate is how much is coming out per unit time. The maximum emission rates occurred between 12 and 36 hours, after which it steadily decreases as the moisture loss from the wood slows. Spikes in the lines correspond to schedule changes.

Figure 3 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. As is typical, the hydrocarbon release rate is linear with moisture loss at the lower moisture content.

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

Sample	Time	Average	Flow rate		THC mass	THC concentration		THC rate	THC mass	THC rate	Average		
Run		Humidity	Dry @68	Wet @68	as C	wet	dry	as C	as C	as C	Wood MC	Air MC	Anal. MC
	hrs	kg/kg	l/min	l/min	g	ppmv	ppmv	g/hr	lbs/mbf	lb/hr/mbf	%	%	%
1	3.51	0.041	35.8	38.2	0.04	3.0	3.1	0.01	0.001	0.0003	106.0	6.2	6.2
2	5.06	0.071	156.8	174.8	0.57	7.2	8.1	0.11	0.014	0.0028	103.2	10.3	10.3
3	3.56	0.121	45.1	53.9	0.48	36.1	44.5	0.14	0.012	0.0033	98.9	16.3	16.3
4	5.96	0.180	57.1	73.6	1.30	35.7	46.1	0.22	0.032	0.0053	95.6	22.4	13.5
5	5.21	0.170	108.3	137.9	1.24	21.3	27.3	0.24	0.030	0.0058	88.8	21.5	12.9
6	6.71	0.153	189.0	235.6	1.66	11.7	14.5	0.25	0.041	0.0060	73.8	19.8	11.9
7	1.05	0.151	189.4	235.3	0.25	11.2	13.9	0.24	0.006	0.0058	63.1	19.5	11.7
8	5.01	0.151	173.7	215.9	1.24	12.8	15.9	0.25	0.030	0.0061	55.1	19.5	11.9
9	6.06	0.150	149.4	185.5	1.31	13.0	16.2	0.22	0.032	0.0053	42.4	19.5	11.9
10	5.81	0.150	99.1	123.0	0.93	14.5	18.0	0.16	0.023	0.0039	31.5	19.5	11.9
11	5.91	0.150	66.0	81.9	0.68	15.7	19.4	0.11	0.017	0.0028	24.9	19.4	11.8
12	8.11	0.149	55.1	68.4	0.73	15.0	18.6	0.09	0.018	0.0022	18.5	19.4	12.2
13	4.01	0.149	25.5	31.6	0.22	19.4	24.0	0.05	0.005	0.0013	14.9	19.4	13.0
14	5.96	0.149	25.5	31.6	0.33	19.5	24.2	0.06	0.008	0.0014	13.1	19.4	13.0
15	6.01	0.148	16.7	20.7	0.23	20.2	25.1	0.04	0.006	0.0009	11.3	19.3	12.9
16	6.16	0.148	11.5	14.2	0.16	20.0	24.8	0.03	0.004	0.0006	10.1	19.3	13.2
17	5.41	0.147	21.6	26.7	0.23	18.3	22.6	0.04	0.006	0.0010	8.7	19.1	13.1
Sum	89.47				11.6				0.284				
Average		0.140	83.9	102.9		17.3	21.6	0.13		0.0032			

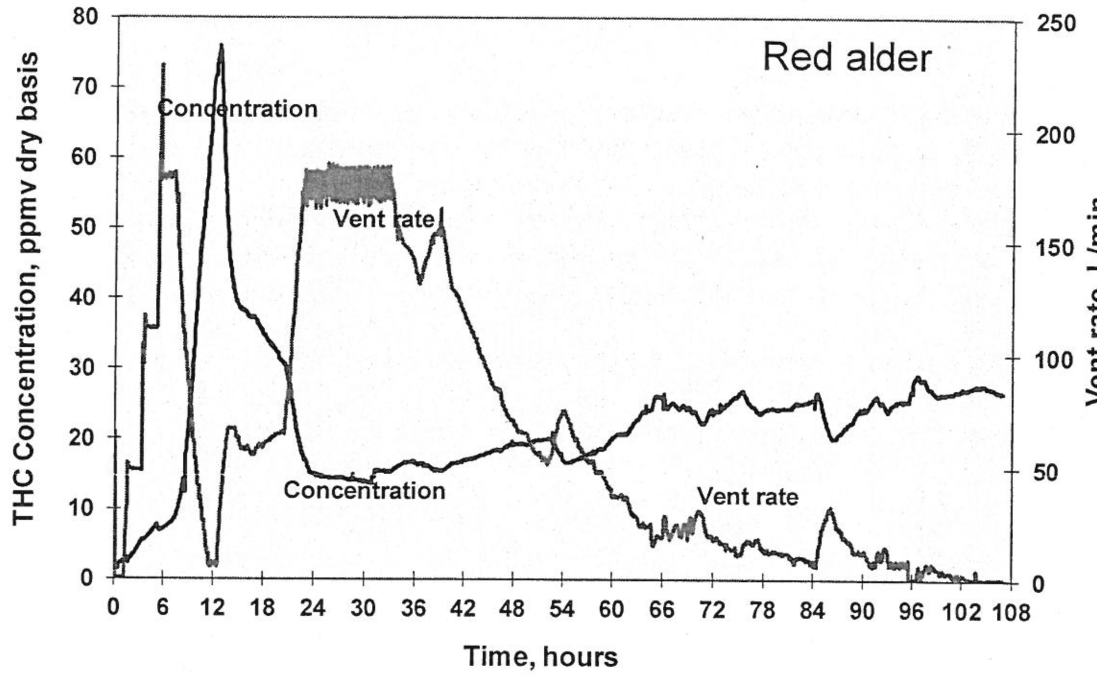

Figure 1. Hydrocarbon concentration and vent rate versus time 1.

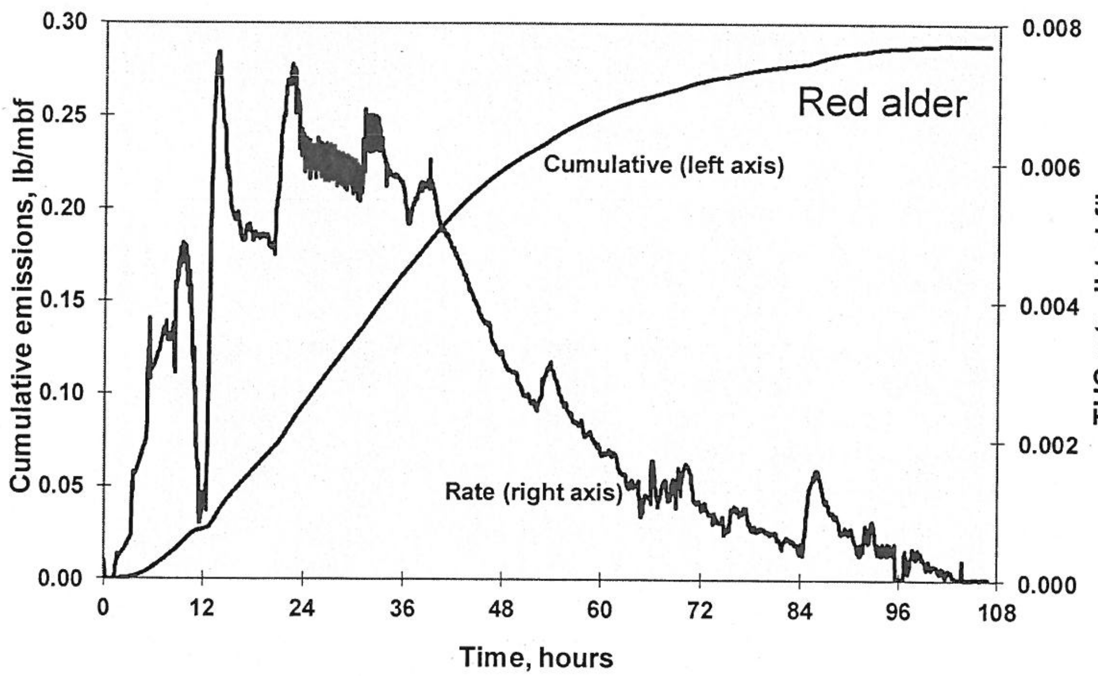

Figure 2. Cumulative hydrocarbon emissions (left scale, smooth line) and the rate of emissions (right scale, jagged line) versus time.

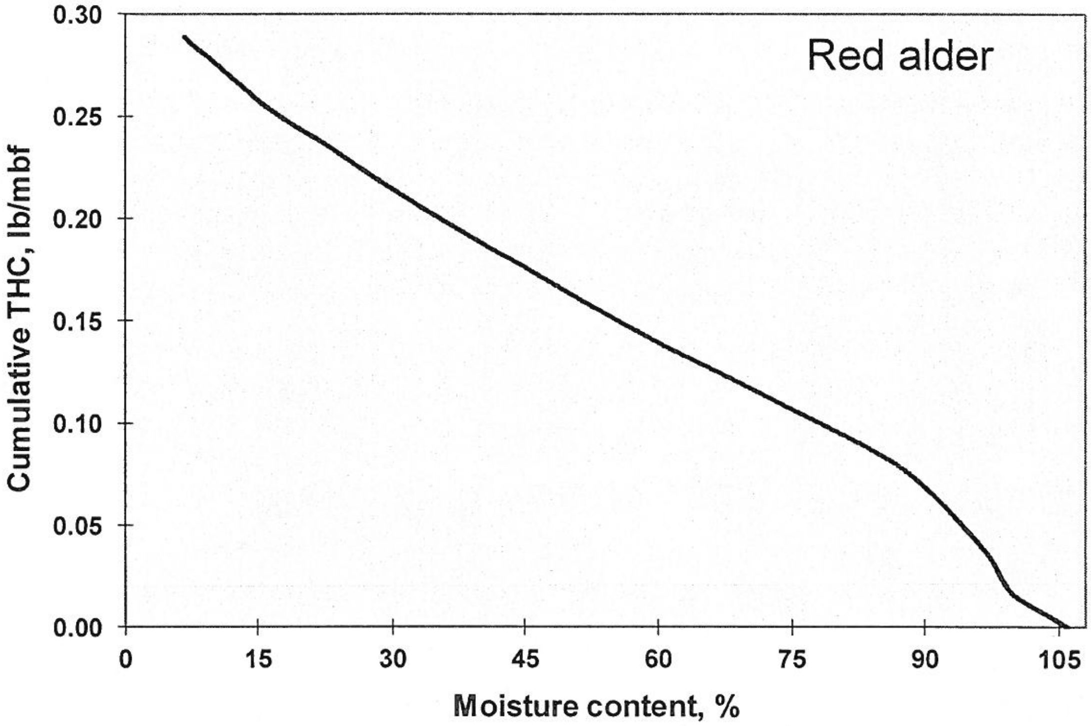

Figure 3. Total hydrocarbon emissions as a function of wood moisture content.

HAPs

See Table 2, page 1, for a summary of the HAP results. Details for each sampling interval are tabulated (Table 4) and the HAP emissions are summarized graphically (Figures 4 and 5) 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 shown in Table 4. A collection interval is the time the impingers were on and sampling occurred, approximately 90 minutes. An adjusted interval is the period spanning the midpoints between collection intervals, about six hours. For example, if the impingers were on from 12:00 to 13:30, 18:00 to 19:30, and 00:00 to 1:30, the 18:00 to 19:30 impinger set represents the adjusted interval from 15:45 to 21:45. The mass calculations are adjusted proportionally to represent emissions during the adjusted interval. For example, if a collection interval was 90 minutes and the adjusted interval was six hours, the amount of HAPs in the impinger is multiplied by four. Sampling occurred for approximately 28% 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 0.13 lb/mbf for the red alder (does not include the non-HAPs, ethanol and acetic acid). Acetaldehyde and methanol were emitted in nearly equal quantities, 0.062 and 0.063 lb/mbf, respectively. Other HAPs (formaldehyde, propionaldehyde, and acrolein) are present and comprise only 1.6% of all the HAPs. Phenol was not detected in any sample.

The HAP emissions as a function of time and wood moisture content during the cycle are shown in Figures 4 and 5, respectively. The rate of HAP emissions decreases with time throughout the schedule (lines are mostly concave downward in Figure 4). The rate of HAP emissions per percent moisture content change are greatest (lines in Figure 5 are concave upward) at low moisture content (even though they are lowest per unit of time because of the slow drying rate at low moisture content).

Table 4. Summary of HAP sampling intervals.

Sample Run ID	Interval	Interval	mass	Dry gas flow rate	Humidity	Content Mid	Content End
	hours	hours	kg	kg/min	mol/mol	%	%
1	1.50	3.66	10.358	0.047	0.057	106.1	105.5
2	1.50	5.96	62.682	0.175	0.126	102.7	99.2
3	1.52	5.96	18.363	0.051	0.268	98.1	95.1
4	1.57	6.06	31.383	0.086	0.287	91.9	87.7
5	1.83	6.06	80.956	0.223	0.253	79.2	70.9
6	1.52	5.96	81.109	0.227	0.243	62.8	54.6
7	1.48	5.96	68.084	0.190	0.242	47.9	41.0
8	1.55	6.01	52.652	0.146	0.242	35.1	30.5
9	1.55	6.01	31.904	0.089	0.242	26.9	24.1
10	1.55	6.01	28.697	0.080	0.241	21.2	18.5
11	1.52	5.96	17.525	0.049	0.240	16.5	15.0
12	1.52	6.01	10.285	0.029	0.240	14.0	12.9
13	1.57	6.01	8.801	0.024	0.239	11.9	11.2
14	1.50	6.01	6.384	0.018	0.239	10.5	9.9
15	1.48	6.01	7.921	0.022	0.238	9.5	8.4
16	1.50	1.85	2.224	0.020	0.236	7.8	8.0
SUM		89.47					

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

Sample Run ID	Interval Endpoint	Wood Moisture Content	Unit mass leaving kiln							
			Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	hours	%	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	3.66	105.5	0.0000	0.0000	0.0004	0.0003	0.00001	0.0000	0.00000	0.00000
2	9.61	99.2	0.0008	0.0000	0.0315	0.0020	0.00006	0.0024	0.00002	0.00000
3	15.57	95.1	0.0026	0.0000	0.0836	0.0021	0.00003	0.0184	0.00004	0.00009
4	21.63	87.7	0.0057	0.0000	0.0786	0.0064	0.00004	0.0046	0.00003	0.00007
5	27.69	70.9	0.0050	0.0000	0.0553	0.0158	0.00008	0.0039	0.00003	0.00008
6	33.65	54.6	0.0084	0.0000	0.0630	0.0302	0.00010	0.0042	0.00004	0.00010
7	39.60	41.0	0.0065	0.0000	0.0435	0.0293	0.00011	0.0048	0.00006	0.00012
8	45.61	30.5	0.0067	0.0000	0.0304	0.0270	0.00006	0.0041	0.00004	0.00007
9	51.62	24.1	0.0050	0.0000	0.0232	0.0219	0.00005	0.0042	0.00004	0.00006
10	57.63	18.5	0.0054	0.0000	0.0127	0.0195	0.00004	0.0031	0.00003	0.00003
11	63.59	15.0	0.0048	0.0000	0.0070	0.0124	0.00005	0.0037	0.00004	0.00004
12	69.59	12.9	0.0020	0.0000	0.0042	0.0066	0.00002	0.0028	0.00003	0.00003
13	75.60	11.2	0.0014	0.0000	0.0037	0.0074	0.00002	0.0021	0.00003	0.00002
14	81.61	9.9	0.0031	0.0000	0.0024	0.0049	0.00002	0.0016	0.00002	0.00002
15	87.62	8.4	0.0044	0.0000	0.0028	0.0064	0.00005	0.0024	0.00008	0.00003
16	89.47	8.0	0.0003	0.0000	0.0001	0.0004	0.00000	0.0002	0.00001	0.00000
		Sums:	0.062	0.000	0.443	0.192	0.0007	0.063	0.0005	0.0007

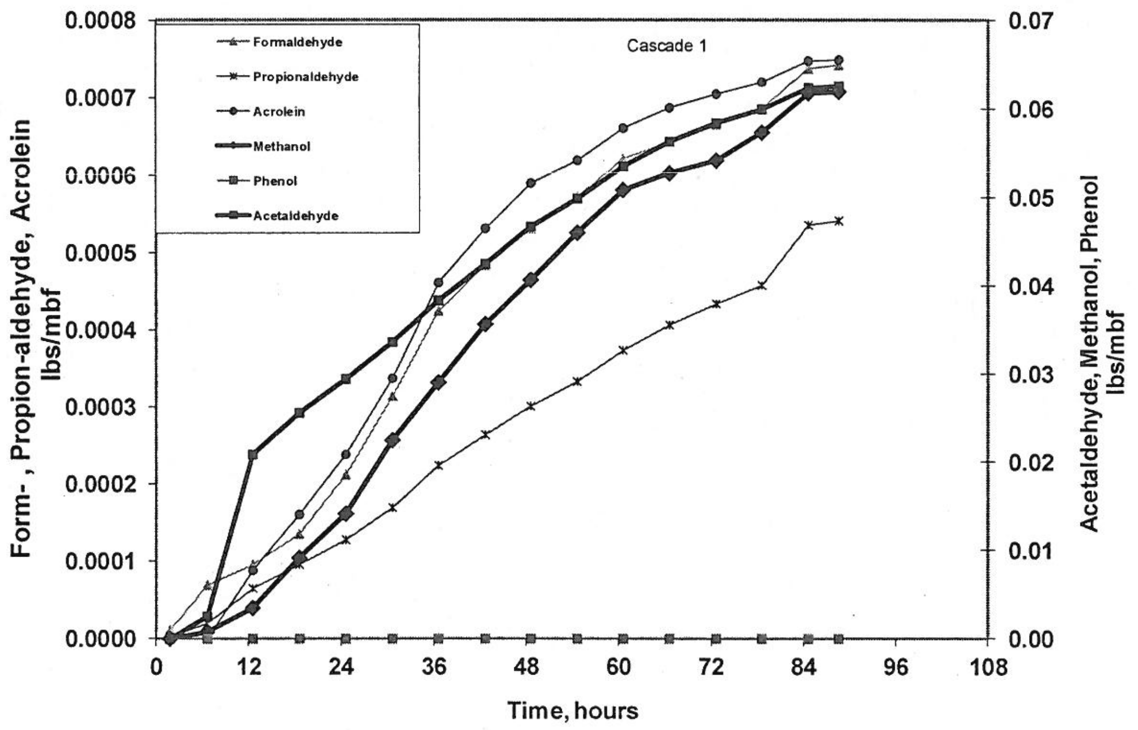

Figure 4. HAP emissions as a function of time.

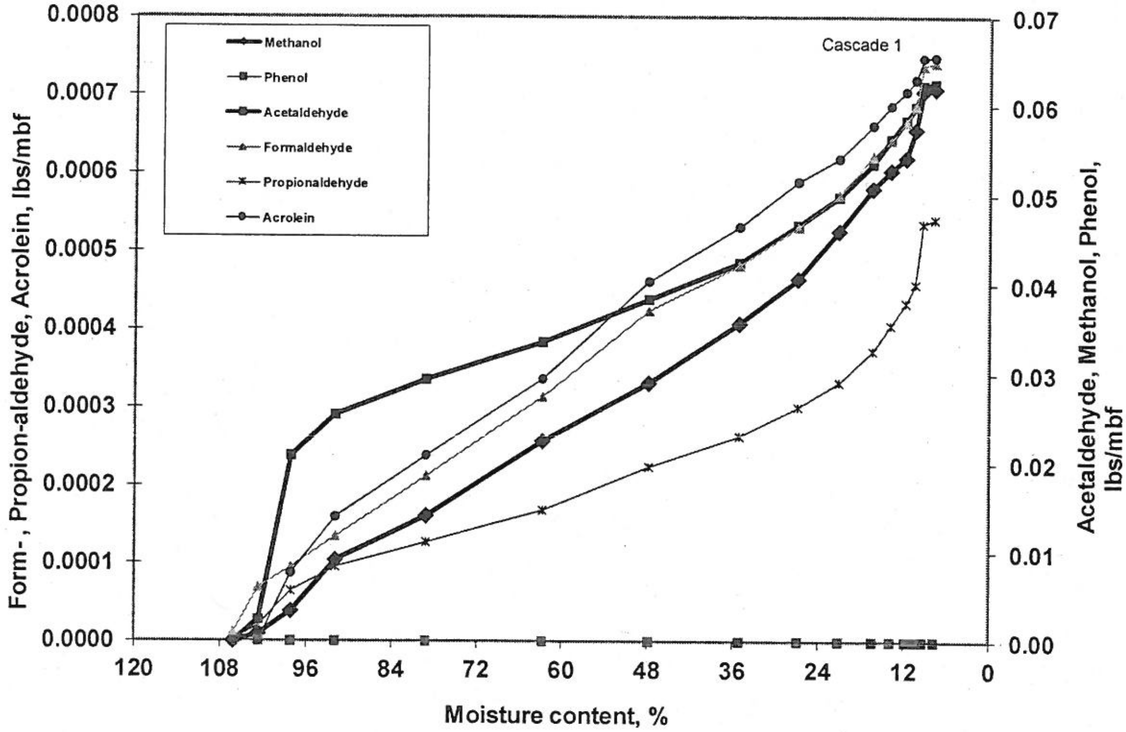

Figure 5. HAP emissions as a function of moisture content.

The detection limits for the GC instrument were

Methanol – 1.54 µg/mL in the aqueous phase
Phenol – 0.89 µg/mL in the aqueous phase
Ethanol – 0.98 µg/mL in the aqueous phase
Acetic acid – 4.85 µg/mL in the aqueous phase
Formaldehyde - 0.05 µg/mL in the hexane phase
Acetaldehyde – 0.05 µg/mL in the hexane phase
Propionaldehyde – 0.05 µg/mL in the hexane phase
Acrolein – 0.06 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. Based on the flow conditions and impinger volumes for the 16 impinger samples, the method detection limits in the sampled gas (wet kiln exhaust) were

Methanol - 0.9-1.2 ppm
Phenol - 0.2-0.34 ppm
Ethanol – 0.4-0.56 ppm
Acetic acid – 1.5-2.0 ppm

Formaldehyde – 0.01-0.02 ppm
Acetaldehyde - 0.009 – 0.014 ppm
Propionaldehyde - 0.006-0.01 ppm
Acrolein - mean = 0.008-0.013 ppm

Methanol and acetic acid were below the detection limits in the first two samples. Acrolien was not detected in the first two samples, but was above detection limits in all the other samples. All other samples were above the detection limits. The table below shows the amounts emitted if one-half the detection limit is substituted for all samples below the detection limit. The total HAPs remain essentially unchanged at 0.127 lb/mbf.

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
0.063	0.000	0.443	0.192	0.0007	0.063	0.0005	0.0007

Field spikes were run by operating two impinger trains simultaneously. An aliquot of the compounds was added to one impinger train. Spike recovery percentage is the mass of a compound detected in the lab compared to mass added to the impinger. Table 6 shows the field spike recoveries. The method requires between 70% and 130% recovery if the concentration of the compound in the gas phase is greater than 1.5 ppm in the dry gas. All spike recoveries were within +/- 30%. The spike levels (the amount in the spiked impinger should be between three to five times that in the unspiked impinger) were correct in at least one spike for methanol, ethanol, acetic acid and acetaldehyde. Formaldehyde, propionaldehyde, and acrolien were closest in the run 6 spike. We were attempting the "bracket method" with a high and low spike; however the concentrations in the catch were lower than anticipated. Recoveries were excellent, however.

The results for a field blank are shown in Table 7. None of the target compounds were detected in the blank above the detection limits. Formaldehyde was detected at approximately 10% of the detection limit and 20x lower than the typical sample concentration. Acetic acid was detected at approximately half of the detection limit and 10x lower than the typical sample concentration.

Duplicate samples were run by operating two impinger trains simultaneously. The results of duplicates are shown in Table 8. The percentage is the difference between the gas concentrations detected by each impinger. Phenol was not detected so duplicates could not be compared. Differences ranged from 2 to 26%, all within the limits of the method.

Table 6. Spike test results.

Alcohol Spike									
Run	Mass in impinger				Impinger	Mass corrected for flow			
	Methanol	Phenol	Ethanol	Acetic	flow	Methanol	Phenol	Ethanol	Acetic
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
6	205.2	0.0	1534.6	734.3	409.1	223.1	0.0	1668.0	798.2
602	507.1	61.2	4038.3	3406.3	444.6	507.1	61.2	4038.3	3406.3
Spike mass	Spike concentrations					Spike recoveries			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
0.5	600.0	118.0	4753.2	5051.8		94.7	103.6	99.7	103.3

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
6	2.5	103.4	1.0	2.4	409.1	1.0	41.3	0.4	1.0
603	169.2	772.0	28.6	102.8	163.5	169.2	772.0	28.6	102.8
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		%	%	%	%
0.57	369.5	1014.0	91.5	159.3		79.8	126.4	54.0	112.2

Alcohol Spike									
Run	Mass in impinger				Impinger	Mass corrected for flow			
	Methanol	Phenol	Ethanol	Acetic	flow	Methanol	Phenol	Ethanol	Acetic
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
9	315.4	0.0	1469.9	1387.5	409.0	144.6	0.0	674.0	636.2
903	802.2	134.6	5680.7	6140.7	187.5	802.2	134.6	5680.7	6140.7
Spike mass	Spike concentrations					Spike recoveries			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
1.12	600.0	118.0	4753.2	5051.8		97.9	101.8	94.0	97.3

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
9	3.0	265.1	2.3	3.7	409.0	3.3	291.1	2.6	4.0
902	328.6	1209.4	87.0	158.7	449.1	328.6	1209.4	87.0	158.7
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		%	%	%	%
1.07	369.5	1014.0	91.5	159.3		82.3	84.6	86.2	90.7

Alcohol Spike									
Run	Mass in impinger				Impinger	Mass corrected for flow			
	Methanol	Phenol	Ethanol	Acetic	flow	Methanol	Phenol	Ethanol	Acetic
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
13	334.1	0.0	865.9	1712.2	410.7	367.3	0.0	951.9	1882.4
1303	1681.7	243.7	10103.7	11566.8	451.6	1681.7	243.7	10103.7	11566.8
Spike mass	Spike concentrations					Spike recoveries			
	Methanol	Phenol	Ethanol	Acetic		Methanol	Phenol	Ethanol	Acetic
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
2.05	600.0	118.0	4753.2	5051.8		106.9	100.7	93.9	93.5

Aldehyde Spike									
Run	Mass in impinger				Impinger flow	Mass corrected for flow			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
	µg	µg	µg	µg	mL/min	µg	µg	µg	µg
13	5.3	481.2	6.6	4.3	410.7	2.5	226.5	3.1	2.0
1302	403.5	2189.3	85.9	280.4	193.3	403.5	2189.3	85.9	280.4
Spike mass	Spike concentrations					Spike recoveries			
	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein		Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
g	µg/mL	µg/mL	µg/mL	µg/mL		%	%	%	%
2.07	272.4	1062.7	46.9	152.7		71.1	89.2	85.4	88.1

Table 7. Results for the field blank.

Field blank							FB
Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
0.000	0.000	0.000	1.590	0.006	0.000	0.000	0.000

Table 8. Results for duplicate runs.

Duplicate									
Run	Mass in impinger								Impinger flow
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	mL/min
5	144.8	0.0	1611	459.1	2.2	112.4	0.9	2.3	404.3
502	154.5	0.0	1629	461.3	2.4	129.0	1.1	2.6	444.0
Difference, %	2.9	#DIV/0!	8.3	8.9	2.2	4.4	9.1	5.2	

Duplicate									
Run	Mass in impinger								Impinger flow
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	mL/min
10	376.5	0.0	888.5	1364.4	2.9	218.8	2.2	2.1	407.7
1002	494.8	0.0	1033.5	1633.2	3.0	240.9	2.4	4.5	444.7
Difference, %	18.6	#DIV/0!	6.4	9.3	6.0	0.9	4.1	65.3	

Duplicate									
Run	Mass in impinger								Impinger flow
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	mL/min
14	968.8	0.0	725.9	1512.5	6.4	482.1	7.4	4.7	412.6
1402	1329.1	0.0	983.8	2128.1	6.2	537.7	8.3	5.2	447.8
Difference, %	23.3	#DIV/0!	22.1	25.8	12.7	2.7	3.8	0.8	

4. Control system and operating conditions

A schematic of the kiln is shown in Figure 6 (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 2 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.

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 7. The schedule provided by the mill is also shown.

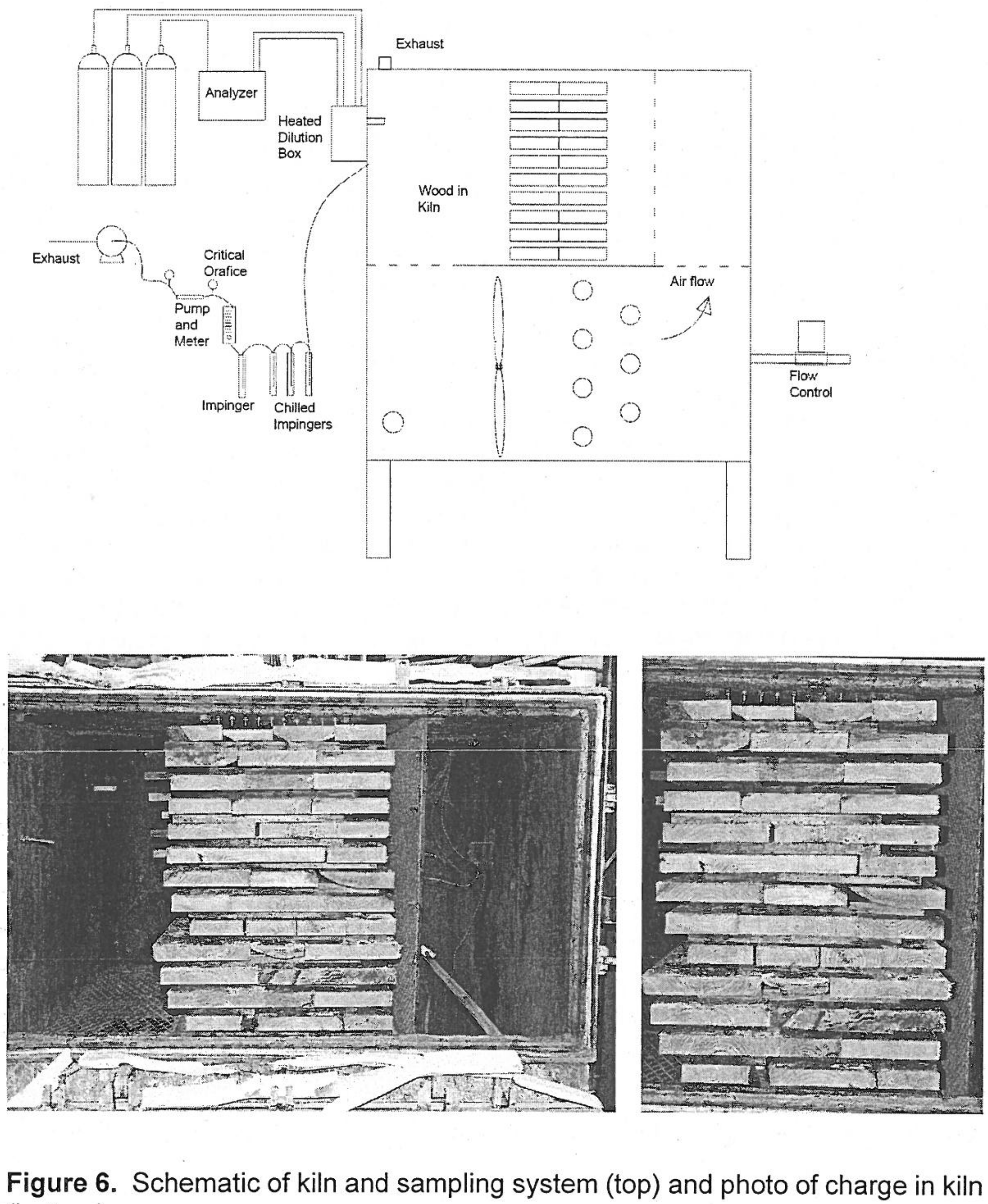

Figure 6. Schematic of kiln and sampling system (top) and photo of charge in kiln (bottom).

5. Production-related parameters

Wood quantity

The wood properties were determined using the nominal wood dimensions (5/4 in this case) which provides for 1.25 board feet per square foot of board face. There were 42 pieces in the kiln at 44" in length. The sum of the 42 board widths was 226 inches. The board footage was therefore 90.04 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 properties

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

Occasional tension wood was noted. The amount seemed typical for red alder.

Heartwood percentage was not determined because is cannot be easily distinguished from sapwood in red alder.

The average ring count was determined by counting the rings over a 1" radial distance and averaging for all boards.

The number of knots were counted on the top face of each board and averaged. Knot diameter is an average of the knots present. The knots occupied approximately 0.3% of the boards' faces.

Table 9. Wood properties.

Knots		Heartwood	Ring	Pith
Number	Diameter		Count	In
#	in	%	#/inch	Y/N
2.3	0.6	N/D	7.9	3

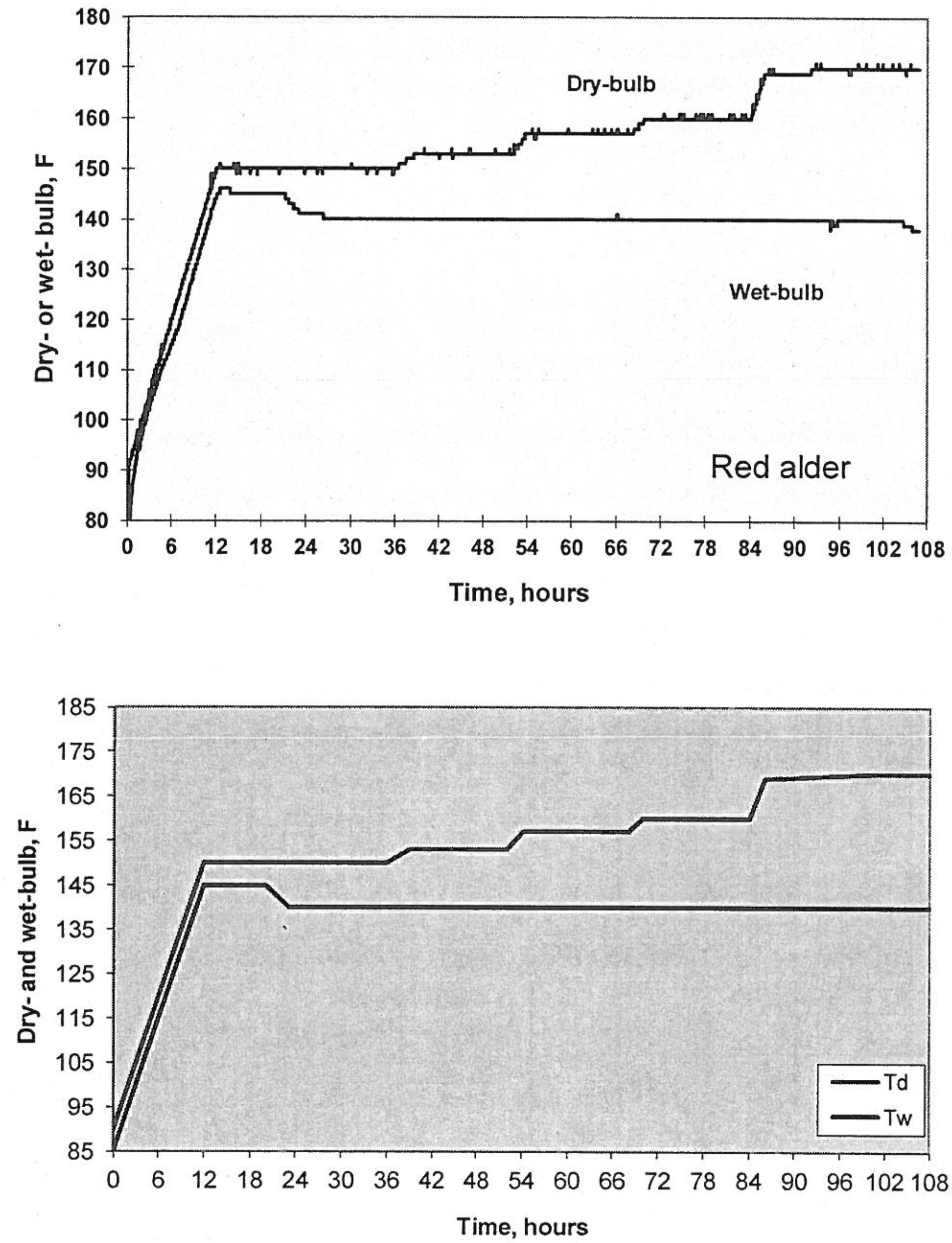

Figure 7. Schedules followed (top) and schedule provided by mill (bottom).

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 6 (top). The concentration obtained from the hydrocarbon analyzer and the amount of air entering the kiln allow the total hydrocarbon emissions to be calculated.

Figure 8 shows the hydrocarbon sampling system. Unlike stack testing, all necessary equipment is located in a lab 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 into a heated dilution/filter box. The box was heated to 235-245°F. Heated dilution gas was added to the hydrocarbon sample gas to lower the gas moisture content to the detector (except for runs 1 and 2) 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 245°F. The 3-way valve at the back of the analyzer was heated to 250°F.

The fuel gas was hydrogen. The span gas was EPA Protocol 197 ppm propane in air, the mid-gas was EPA Protocol 50 ppm propane in air. The zero gas was <0.1 ppm air. Detailed sampling procedures are in Appendix 1.

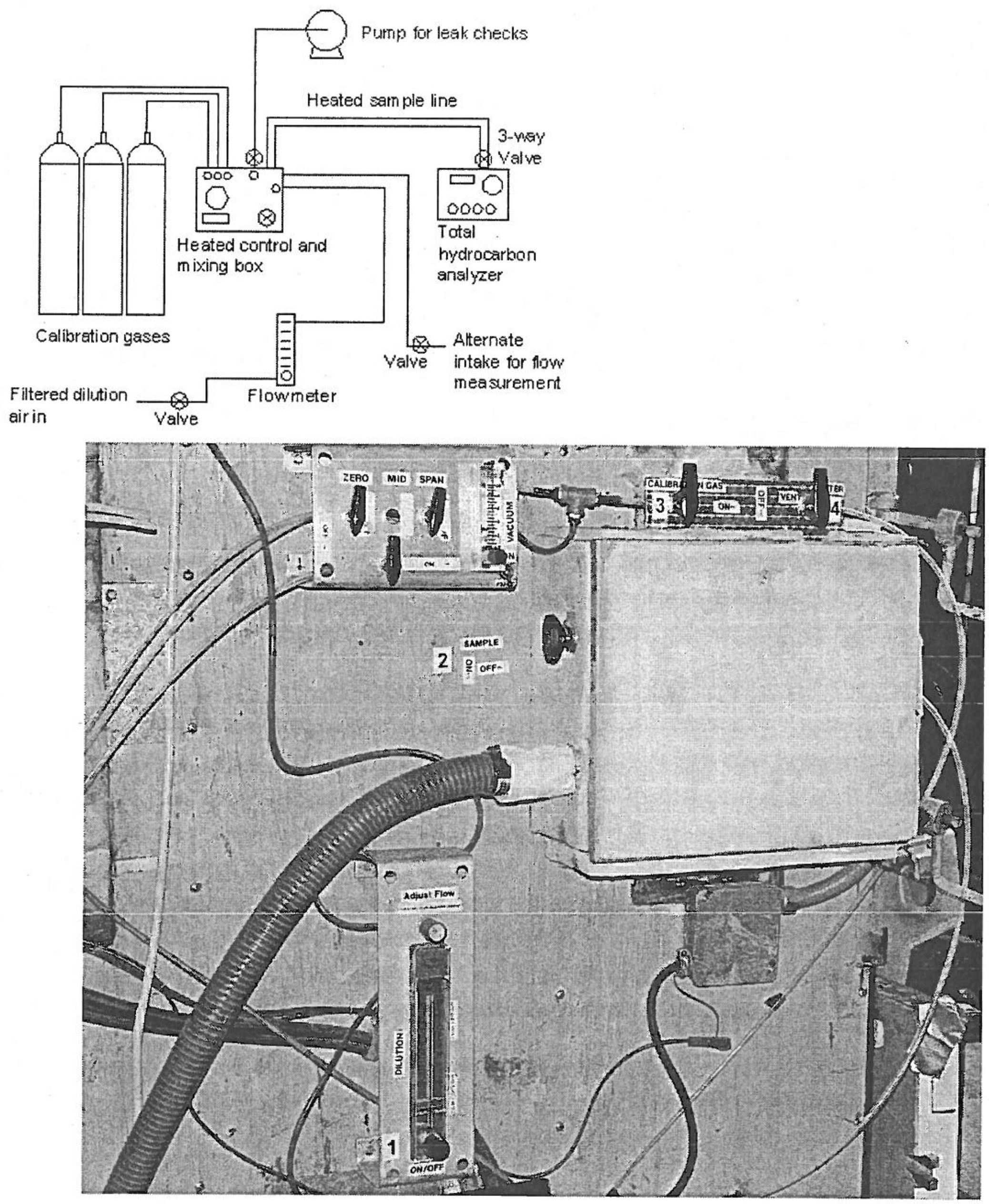

Figure 8. Schematic of heated filter box with air dilution system, heated sample line, and analyzer (top). Sample enters heated box from back of drawing through a heated sampling line. Calibration gas valves and dilution air valves are to left. Line to analyzer is the green line on the left in the left photo.

HAPs

The sampling train for NCASI Method 105 is shown in Figure 9. The impingers were in a glycol solution maintained at -1 C. Prior to each sampling interval, the impingers were laboratory-washed and 10 to 15 mL of BHA solution were added to the first and second impingers. The third impinger was left empty. The fourth impinger was present in the system to prevent any overflow from reaching the critical orifice. The system was then assembled and a vacuum check was performed with the valves at each end closed. Less than 1" Hg of pressure change over 2 minutes was acceptable. This was met for each interval. The flow rate through the system was then measured using a Gilibrator flow meter to take four flow readings at the probe tip. This was approximately 200-500 mL/min, depending on the sampling train. A valve at the probe tip was then turned to sample from the kiln and the sampling interval begun. The collection interval time was approximately 1:30 and an interval was started approximately every six hours.

The flow rate was measured after each sampling interval. 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.

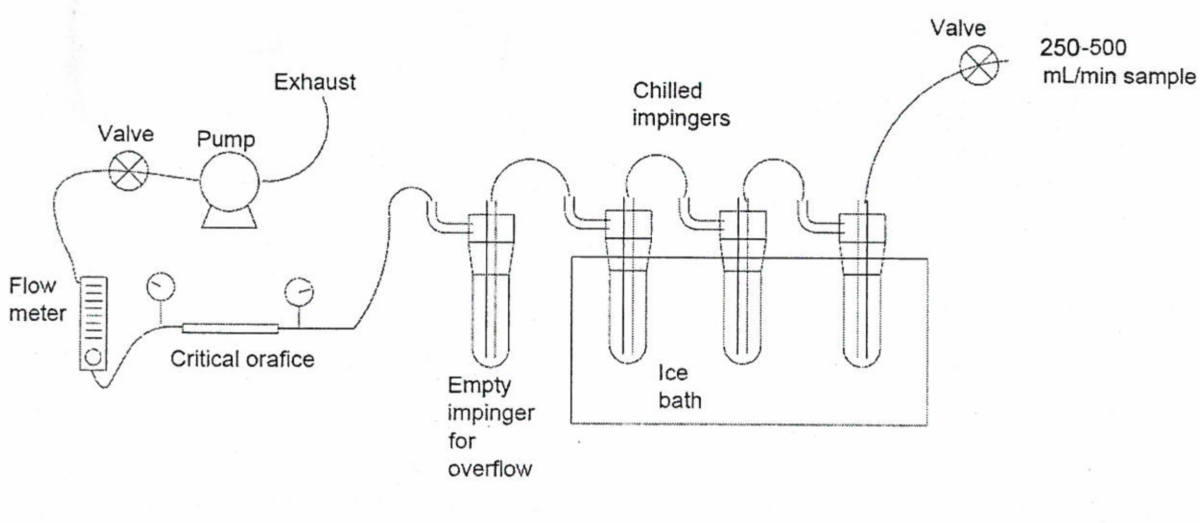

Figure 9. HAPs sampling train.

7. Analytical procedures

Hydrocarbon

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

Total flow and sample flow to the analyzer were checked using an NIST-traceable flow meter. Total flow is measured with the dilution gas off and is equal to both the sample flow from the kiln when the dilution is off and the total volume drawn by the analyzer. Sample flow is measured with dilution gas on (if used for that interval) and is the volume of gas sampled from the kiln when the dilution gas is on. This was done at the beginning and end of each sampling interval. The meter was attached to the system near the probe tip within the heated box. The valves were repositioned so that the sample came from the flow meter 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 almost always within 2%. Note that dilution was not actually used for runs 1 and 2 because the kiln wet-bulb was low enough initially that the gas moisture content was less than 15% until the wet-bulb temperature was greater than 130-135°F.

Calibration of the zero and span of the detector was done at the beginning of each run (about every six hours). The calibration gas was introduced by setting the valves so the calibration gas entered the system in the white heated mixing box 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 dilution of neat aldehydes in water (to 400 ppm for formaldehyde, propionaldehyde, acrolein and acetaldehyde). This stock solution was mixed a BHA solution [from ortho-benzylhydroxylamine hydrochloride (BHA) and deionized water (30g BHA per liter of water)]. The stock solution-BHA mixture 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 300 ppm stock solution in hexane. This was diluted by mass to make standards down to 0.25 ppm. 1.8 mL aliquots were place in GC autosampler vials with 10 µL of 27,830 ppm nitrobenzene added to each as an internal standard.

The samples (from the bottles collected in field) were prepared by performing three extractions in a separatory funnel. The first extraction was with the hexane added in the field plus a 3.5 mL aliquot. The second extraction was with a 7-mL aliquot of hexane again placed in the jar with the liquid fraction. The final extraction was done with 7 mL of clean hexane in the separatory funnel after rinsing the jar with the hexane. The total hexane volume was approximately 20 mL. The volumes of the two phases were calculated from their weights. A 1.8 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 900 milligrams per liter (mg/L). Additional standards were prepared by the volumetric dilution of the mixed standard at a range from 0.5 mg/L to 500 mg/L. Aliquots of these were placed into autosampler vials with 10 µL of 29,455 ppm cyclohexanol internal standard.

Samples were prepared by transferring aliquots of the previously hexane-extracted aqueous fractions into autosampler vials and adding internal standard. The analytical instrument was a Shimadzu GC model 2010 with a FID detector. The column was a 60-meter Restek Stabilwax capillary with a 0.53 mm outside diameter and a stationary phase thickness of 1.5 µm. The oven schedule was: 3 minutes at 60°C, 10°C/min ramp to 80°C, 3 minutes at 80°C, 10°C/min ramp to 230°C, and 10 minutes at 230°C. The column flow was 30 cm/sec, with 3 mL/min septum purge, and a 1:10 split ratio with a glass wool packed split injection liner. The detector make up He was set to 25 mL/min and the H_2 was set to 50 mL/min. The air was set to 500 mL/min. The He and H_2 gases were grade 5 and the air was grade 0.1. The injector temperature was 175°C and the detector temperature

250°C. An AOC-20i autosampler was used to perform 1 µL injections using a 10 µL syringe with a PTFE plunger.

8. Field data sheets and sample calculations

Field data sheets

Samples of field data sheets are shown in Figures 10 to 13. All field data sheets are in Appendix 2 this report in electronic format (pdf).

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - BEFORE

BACKGROUND INFORMATION

Event (kiln charge): Cascade - 1 Dry-bulb temperature: 156
Run: 3 Wet-bulb temperature: 145
Operator: MRM Target Dilution Ratio (TDR): 0.60
Date: 2-9-15 Laboratory temperature: 76 °F

ANALYZER CALIBRATION [illegible] [R to L: 5=off 4=vent; 3=on; 2,1= off]

	Range	Analyzer, reading	Computer, ppm	Within range	Pot settings
zero	3	0.00	000		4.95
span	3	1.92	1.98		2.59
mid	3	0.50	0.50	45 to 55	
mid	2	5.00			

Reset range to 3. Range: 3

SET DILUTION FLOW BEFORE RUN [illegible]

Total flow rate (TFR): 1756 mL/min [Valves 3 = off; 4=meter (5,2,1=off)]
Target dilution flow rate (TDFR): 703 mL/min [TFR x (1 - DR)]
Set and read dilution meter: 1.5 scfh [scfh = mL/min * 0.00212]
Sample flow rate (SFR): 1053 mL/min [1 and 5 = on]

CHECK DILUTION FLOW BEFORE RUN [illegible] [4=vent; 3=on (2=off, 1,5=on)]

	Analyzer	DR span [Span/Span]	DR flow [SFR / TFR]	Difference, % 100*(DR span - DR flow)/DR flow
Span	1.19	0.601	0.599	0.3%

START TIME: 14:43 (clock) [L to R: 1, 2,= on; 3, 4 = off; 5=on]

ANALYZER RANGE: 2 [0.5 < reading < 7.5; All valves vertical, tanks off]

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

TURN OFF TANKS

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - AFTER

Operator: KMM Event (kiln charge): Cascade - 1
Run (sample): 3 Laboratory temperature: 77 °F

END TIME: 16:03

Range setting on Analyzer: 2 on Computer: 2

Reset range to 3. Range: 3 [tanks on]

CHECK DILUTION FLOW AFTER RUN [illegible] [4=vent; 3=on; 2=off; (1,5=on)]

	Analyzer reading	Computer, ppm
Span	1.19	1.19

Sample flow rate (SFR): 1065 mL/min [3 = off, 4=meter (2=off 1,5=on)]
Read dilution meter: 1.5 scfh
Total flow rate (TFR): 1761 mL/min [1, 5 = off; (4=meter 2,3 =off)]
(as per print out)
Dilution ratio (DR_{flow}): .604 [SFR / TFR]

CHECK OF ANALYZER CALIBRATION [illegible] [3=on, 4=vent (1,2,5 =off)]

	Analyzer reading	Computer, ppm	Within range	Pot settings
span	1.98	1.99	187 to 206	279
mid	0.51	0.51	45 to 55	
zero	0.01	0.00	-5 to +5	444

Dilution ratio (DR_{span}): .601 [Span diluted / Span]
Dilution ratio difference: .5 % [100*(Abs(DR_{span} - DR_{flow}))/DR_{flow}]
End time for check: 16:11
Comments:

Figure 10. Sample of field data sheet for hydrocarbon analyzer.

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

Operator: MM
Date: 2-9-15
Event (kiln charge): Cascade -1
Run (sample): 3 -A

Altimeter setting: 29.9 inHg
Isopropanol rinse or lab wash: IS

IMPINGER WEIGHTS (add BHA to impingers)

	Dry Weight, g	Wet Weight, g	BHA added, g
Impinger #1A	41.54	56.06	(~5 mL)
Impinger #1B	47.31	63.77	(~5 mL)
Impinger #1C	42.33	----	—
		Total BHA added:	

Optional Spike: ____ g Spike type: Alcohol □ Aldehyde □

(take impingers to kiln from scale)

Lab (ambient) temperature: 77 °F

Leak check: Vacuum 16.5 inHg ✓ Vacuum check ok

Sample flow rate: 4568 mL/min [Average of 4. Label printout]

Set probe valve to sample from kiln — CLOCK TIME: 18:00 ELAPSED TIME: 11:53

Is the probe valve set to sample?
Is gas flowing (look at flow meters)?

FLOW METER READINGS DURING TEST (every 20 minutes)

Clock time	18:01	18:51	19:01
Vacuum, inHg	28	28	28
Flow rate, mL/min	4.5	4.5	4.5

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

Operator: MM
Event (kiln charge): Cascade -1
Run (sample): 3 -A

Altimeter setting: ____ inHg
Sample line rinse vial: 30.84 g (with ~5 mL DW)
Lab (ambient) temperature: 76 °F
Change position of valve at the kiln — Clock time: 19:51:50 Elapsed time: 13:43:50

(rinse sample line then measure flow rate)
Set probe valve to measure sample flow rate. Shut off other flows using lower valves.

Sample flow rate: 4553 mL/min [Average of 4. Label printout]

(take impingers to scale from kiln)
Sample line rinse vial: 13.95 g (empty)
Empty bottle weight: 131.18 g (with lid) 131.18

IMPINGER WEIGHTS (transfer sample to bottles)

	Wet Weight, g	Dry Weight, g	Water removed, g
Impinger #1A	69.94		
Impinger #1B	62.25		
Impinger #1C	42.42		

Bottle weight without impinger rinse: 174.28 g (with lid)
(rinse impingers with 10 mL DI water)
Bottle weight with impinger rinse: 179.24 g (with lid)
(rinse impingers with 5 mL hexane)
Filled bottle weight: 181.82 g (with lid)
Fluids lost during handling: 0 mL [estimate]
Comments:

Figure 11. Sample of field data sheet for HAPs collection.

Charge: Cascade-1

	Date	Time
Start	2/9/2015	6:08
End		

Page 1

Clock time	Elapsed time	Run #	Temperatures: T dry °F	T wet °F	Valve °F	G line °F	Box °F	Chiller °C	Flows: 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	Vacuum: Line 1 inHG	Line 2 inHG	Line3 inHG
6:08	0:00	1	69	64	250	245	240	-1	55	0	0	0	425	—	—	270	—	—
6:38	0:30	1	92	93	250	245	240	-1	55	0	0	0	425	—	—	265	—	—
7:48	1:39	1	98	96	250	245	240	-1	51.5	0	0	0	—	—	—	—	—	—
9:25	3:17	1	102	104	250	245	240	-1	48	0	0	0	—	—	—	—	—	—
9:42	3:34	2	109	105	250	245	241	-1	85	35	0	0	—	—	—	—	—	—
10:07	3:59	2	110	107	250	245	240	-1	79	32	0	0	—	—	—	—	—	—
11:40	5:32	2	118	113	250	245	239	-1	162	63	0	0	—	—	—	—	—	—
13:18	7:10	2	126	120	250	245	240	-1	150	0	0	0	—	450	—	—	27	—
14:32	8:30	2	132	128	250	245	240	-1	109	0	0	0	—	—	—	—	—	—
17:21	11:13	3	146	141	250	245	239	-1	133	0	0	1.5	—	—	—	—	—	—
17:52	11:44	3	148	143	250	245	240	-1	785	0	0	1.5	—	—	—	—	—	—
6:53	[illegible]	4	150	146	250	245	240	-1	[illegible]	0	0	1.5	465	—	—	[illegible]	—	—
10:53	3:45	4	150	146	250	245	240	-1	[illegible]	0	0	1.5	—	—	—	—	—	—
20:54	[illegible]	4	150	145	250	245	241	-1	533	0	0	1.5	—	—	—	—	—	—
21:53	[illegible]	4	150	145	250	245	240	-1	[illegible]	0	0	1.5	—	—	—	—	—	—
22:53	16:45	4	150	145	250	245	240	-1	553	0	0	1.5	—	—	—	—	—	—
23:53	17:45	4	150	145	250	245	240	-1	550	0	0	1.5	—	—	—	—	—	—

Figure 12. Sample of kiln log data sheet.

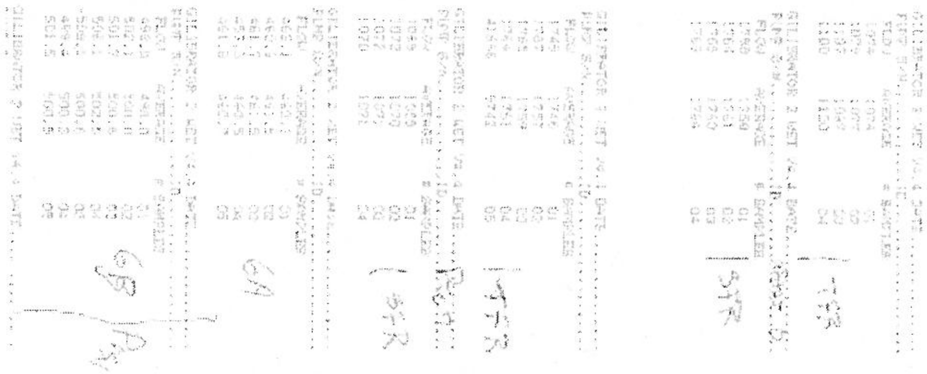

Figure 13. Sample of flow measurement record.

Calculations

The "FlowCalc" worksheet in the Excel files "Kiln, Cascade.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•min^{-1}). These values are for the dry gas vented from the kiln.

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

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

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

The water removal rate (WaterVented, g•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.

$$WaterVented = (AbHum - AbHum_{In}) * (DryGasM * 1000\ g\cdot kg^{-1})$$

Moisture content

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

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

This amount is then adjusted by adjusting the wet-bulb temperature to make the ending moisture content match that measured 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 9-minute period before and the 9-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).

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

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.

THC_{Vented} = DryGas * (THC_{Dry} / 10^6) * $MW_{Propane}$ * (1000 $g \bullet kg^{-1}$) * (0.81818 $g_{Carbon} \bullet g_{Propane}^{-1}$)

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 ($lb \bullet mbf^{-1} \bullet hr^{-1}$)

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, Cascade.XLS".

HAPs

Within the file "HAPs, Cascade.xls", the summary page presents the data by run interval. The data is copied from the other pages to provide a concise summary.

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

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

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

$ImpgrFlow_{Std\_mL}$ =ImpgrFlow * (273.16K / T_{meter}) / (P_{meter} / 101.33 kPa)

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

$ImpgrFlow_{Dry\_mL}$ = $ImpgrFlow_{Std\_mL}$ / (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.

$ImpgrFlow_{Dry\_g} = MWair * ImpgrFlw_{Dry\_mL} * P / (T * R)$

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

$Mass_i = (Concentration_i) / (DenSolvent) * (Mass\ solvent)$

The "Kiln Calculations" page uses a ratio of the dry gas flow through the kiln (calculated in the spreadsheets named "Kiln, Cascade.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, Cascade.xls" are for graphing purposes.

9. Chain of custody information

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

10. Calibration documentation

Sensidyne, LP

CALIBRATION CERTIFICATE

Cell S/N: 1302015-S   Date: February 07, 2013

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 1302015-S cc/min	RELATIVE DIFF. cc/min	PERCENT DIFF.
1998	2001	3	0.15
2002	2001	-1	-0.05
1996	2004	8	0.40
2004	2005	1	0.05
1996	2004	8	0.40
2001	2002	1	0.05
2000	2004	4	0.20
2001	2002	1	0.05
1994	2004	10	0.50
2001	2004	3	0.15
MAX		10.0	0.5
MEAN 1999.3	2003.1		

Calibrated by ____________ Date: February 07, 2013

CODE 100

Figure 14. Flow meter calibration.

Airgas

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Part Number:	E02AI99E15A0456	Reference Number:	48-124285452-2
Cylinder Number:	CC172274	Cylinder Volume:	146.2 CF
Laboratory:	ASG - Los Angeles - CA	Cylinder Pressure:	2015 PSIG
PGVP Number:	B32011	Valve Outlet:	590
Gas Code:	PPN,BALA	Certification Date:	Oct 13, 2011

Expiration Date: Oct 13, 2019

Certification performed in accordance with "EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards (May 2012)" document EPA 600/R-12/531, using the assay procedures listed. Analytical Methodology does not require correction for analytical interference. 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 100 psig, i.e. 0.7 megapascals

ANALYTICAL RESULTS

Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty	Assay Dates
PROPANE	50.00 PPM	50.33 PPM	G1	+/- 1% NIST Traceable	10/13/2011
AIR	Balance				

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Uncertainty	Expiration Date
NTRM	[illegible]	CC263042	49.62 PPM PROPANE/AIR	+/- 0.6%	Jul 15, 2012

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
Nicolet 6700 AHR0801551 C3H8	FTIR	Sep 21, 2011

Triad Data Available Upon Request

Notes:

Signature on file

Approved for Release

Airgas

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Airgas Specialty Gases
11711 South Alameda Street
Los Angeles, CA 90059
(323) 568-2203 Fax: (323) 567-3686
www.airgas.com

Part Number:	E02AI99E15A1511	Reference Number:	48-124370716-1
Cylinder Number:	SG9115165BAL	Cylinder Volume:	146.2 CF
Laboratory:	ASG - Los Angeles - CA	Cylinder Pressure:	2015 PSIG
PGVP Number:	B32013	Valve Outlet:	590
Gas Code:	PPN,BALA	Certification Date:	Apr 23, 2013

Expiration Date: Apr 23, 2021

Certification performed in accordance with "EPA Traceability Protocol for Assay and Certification of Gaseous Calibration Standards (May 2012)" document EPA 600/R-12/531, using the assay procedures listed. Analytical Methodology does not require correction for analytical interference. 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 100 psig, i.e. 0.7 megapascals

ANALYTICAL RESULTS

Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty	Assay Dates
PROPANE	[illegible] PPM	[illegible] PPM	G1	+/- [illegible] NIST Traceable	04/23/2013
AIR	Balance				

CALIBRATION STANDARDS

Type	Lot ID	Cylinder No	Concentration	Uncertainty	Expiration Date
NTRM	[illegible]	[illegible]	[illegible] PPM PROPANE/NITROGEN	+/- [illegible]	Jun 22, 2016

ANALYTICAL EQUIPMENT

Instrument/Make/Model	Analytical Principle	Last Multipoint Calibration
Nicolet 6700 AHR0801551 C3H8	FTIR	Apr 11, 2013

Triad Data Available Upon Request

Notes:

Approved for Release

Figure 15. Certificates for calibration gases.

11. Anomalies

There were no anomalies.

12. Statement of validity

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

Michael R. Milota

Oregon Wood Innovation Center
Department of Wood Science and Engineering
136 Richardson Hall Oregon State University
Corvallis, OR 97331-5751
(541) 737-4210 V
(541) 737-3385 F

Appendix 1. Detailed sampling procedures

Checks of kiln to record on log

Purpose: Ensure kiln is operating correctly

Clock time: Record from computer

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

Box temperature: Read from plastic electrical enclosure on wall or on computer screen. The top and bottom numbers on controller should be similar and greater than the kiln temperature, 240°F.

Line temperature: Read from plastic electrical enclosure on wall or on computer screen. The top and bottom numbers on controller should be similar and greater than the box temperature, 245°F.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Total hydrocarbon analyzer

BACKGROUND INFORMATION

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

Read absolute humidity off the psychrometric chart or table.
Calculate or read from tables -

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 computer or thermometer.

ANALYZER CALIBRATION (BEFORE SIDE OF SHEET)

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

Open the zero gas tank valve

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

Close valve on zero gas tank

Open span gas tank valve (may be 197 or 794 ppm gas)

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 7.96
read computer (should read about 794)

record pot setting
Leave span tank valve open

Open mid gas tank valve (197 or 50 ppm gas)
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 (should already be open)
- span panel valve right (on), others down (off)
- set flow to 3 L/min using regulator on tank
- set analyzer to range 3
- wait for a stable reading (about 30 to 60 seconds), record
- turn off all calibration gas tank valves
- all calibration gas panel valves off

All tank valves off

Calculate the dilution ratio based on gas flow by dividing the Sample Flow Rate by the Total Flow Rate. DR = 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 ratio calculated from the span gas and the dilution ration calculated from the flow do not agree within 5% - DO NOT PROCEED****. Check the calculations, then redo the measurements.

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

START RUN (BOTTOM OF BEFORE SIDE OF SHEET)

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

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

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

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

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

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

Record your name as the operator.

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

AMBIENT DATA

Read the laboratory temperature from the thermometer.

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

END TIME

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

CHECK DILUTION FLOW AFTER RUN (AFTER SIDE OF SHEET)

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

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

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

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

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

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

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

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

CHECK CALIBRATION OF ANALYZER (AFTER SIDE OF SHEET)

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

Span gas tank valve should be open

- span panel valve ON, others down OFF
- set flow to 3 L/min using regulator on tank
- set analyzer to range 3
- wait for a stable reading (about 30 -60 seconds)
- read analyzer (do not adjust pot settings),
- record, for example, 7.94 as 794
- read computer (should read about the same)
- note pot setting
- check for within tolerance

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, 1.97 as 197
- read computer (should read same as analyzer)
- check for within tolerance

Open the zero gas tank valve

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

Close all tank valves if charge is ending

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

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

Record the time now as the end time for check.

Start Pre-Sample procedure for next run.

HAP 105 Collection

BACKGROUND DATA

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

PRE RUN DATA

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

IMPINGER WEIGHTS

Verify that the impinger weights match the prerecorded weights on the 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 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 (or turn valve to sample kiln) and record time.
Check meters to make sure gas is flowing

FLOW READINGS DURING TEST

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

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

END TIME
Remove probe (or turn valve to meter setting) 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 with lid
Weigh the impingers (without stoppers) with the catch and record
Transfer the impinger contents to the sample bottle
Weigh the sample bottle with lid and record
Rinse impingers (last to first) with 10 mL DIW (save in the sample bottle)
Weigh the sample bottle with lid and record
Rinser impingers (last to first) with 5 mL hexane (save in the sample bottle)
Weigh the sample bottle with lid and record
Place the sample bottle into cold storage
Record the volume of any liquids lost during this procedure.
Wash glassware with phosphate-free detergent and set out to dry.

Appendix 2. Electronic copy of data and calculations