

**VOC Emissions
From the Drying of Douglas-fir Lumber**

Report to

**Columbia Vista Corp.
18637 SE Evergreen Hwy
Vancouver, WA 98684
Phone: 360-892-0770 Fax: 360-944-8229
Contact: Devin Sanders
DSanders@ColumbiaVista.com.
Air Discharge Permit 09-2854**

Report by

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

November 12, 2010

Table of Contents

Table of Contents.....	ii
List of Figures	iii
List of Tables	iii
Summary	1
1. Description of source	1
2. Date and time of test.....	2
3. Results.....	3
Total hydrocarbon	3
HAPs	6
4. Control system and operating conditions	11
Humidity control.....	13
Temperature control	13
5. Production-related parameters.....	14
Kiln operation	14
Wood quantity	14
Wood quality	15
6. Test methods	15
Charge Sequence	15
Sampling Methodologies	15
Hydrocarbon	15
HAPs	17
7. Analytical procedures.....	18
Hydrocarbon.....	18
HAPs	19
8. Field data sheets and sample calculations	20
Field data sheets	20
Calculations.....	24
Humidity.....	24
Flows	24
Moisture content	25
Hydrocarbon	25
HAPs	26
9. Chain of custody information	27
10. Calibration documentation	28
11. Anomalies	30
12. Statement of validity.....	30
Appendix 1. Detailed sampling procedures.....	31
Kiln	31
Total hydrocarbon analyzer	33
HAP 105 Collection	40
Appendix 2. Electronic copy of calculations	43

List of Figures

FIGURE 1. Wood in refrigerator (left) and freezer (right).	2
FIGURE 2. Hydrocarbon concentration and vent rate versus time.	4
FIGURE 3. Cumulative and rate of emissions (as carbon) versus time.	5
FIGURE 4. Total hydrocarbon versus moisture content of wood.	5
FIGURE 5. HAP emissions as a function of time.	8
FIGURE 6. HAP emissions as a function of wood moisture content.	8
FIGURE 7. Schematic of kiln and sampling system (top) and photo of kiln loaded (bottom).	12
FIGURE 8. Dry- and wet-bulb temperatures.	13
FIGURE 9. Dry- and wet-bulb setpoints provided by the mill.	14
FIGURE 10. Schematic of heated filter box with air dilution system, heated sample line, and analyzer.	16
FIGURE 11. Photo of VOC sampling system showing.	17
FIGURE 12. HAPs sampling train.	18
FIGURE 13. Sample of field data sheet for hydrocarbon analyzer.	21
FIGURE 14. Sample of field data sheet for kiln log.	22
FIGURE 15. Sample of field data sheet for flow measurement.	22
FIGURE 16. Sample of field data sheet for HAP sample train.	23
FIGURE 17. Flow meter calibration.	28
FIGURE 18. Certificates for calibration gases.	29

List of Tables

TABLE 1. Summary of total hydrocarbon results.	1
TABLE 2. Summary of HAP results for moisture content and time in Table 1.	1
TABLE 3. Summary of results for each sampling interval for total hydrocarbon. .	3
TABLE 4. Summary of HAP sampling intervals.	6
TABLE 5. Interval by interval emissions for the MACT HAPs and ethanol and acetic acid.	7
TABLE 6. Results for field spike recoveries.	10
TABLE 7. Results for field blanks.	11
TABLE 8. Results for duplicate runs.	11

Summary

One charge of approximately 117 board feet of nominal 4x4 Douglas-fir lumber was 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 Columbia Vista Corp. The maximum temperature was 180°F (82.2°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.

Charge	Initial MC	Final MC ^A	Time ^A	VOC ^B
	%	%	hr:min	lb/mbf
1	44.7	15	111.2	0.845

^A actual time was 143 hours to 8.3%

^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 0.149 lb/mbf.

TABLE 2. Summary of HAP results for moisture content and time in Table 1.

Charge	Methanol	Phenol	Form- aldehyde	Acet- aldehyde	Propion- aldehyde	Acrolein
	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf	lb/mbf
1	0.084	0.000	0.0019	0.061	0.0003	0.0007

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 wood was sawn at Columbia Vista on October 6, 2010. The log source was the Olympia-Capital Forests region of Washington. The trees were coastal and 70-80 years of age. They were harvested with 60 days of the sawing date.

Enough wood for three charges of lumber was delivered to Oregon State by Columbia Vista Corp. on October 7, 2010. The wood was wrapped in plastic at the mill to prevent predying and loss of organic compounds during transit. The wood appeared to be very fresh and still had a white color to the sapwood.

On October 7, 2010 the wood was separated into three charges at OSU. One charge was wrapped in plastic (in six sets of four boards) and placed in a freezer (Figure 1). The other two charges were wrapped in plastic (each charge was wrapped separately) and placed in a cooler at 35°F. A charge of lumber was constructed on 10-11-10 using one of the charges from the cooler.



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

2. Date and time of test

The charge was dried from October 11, 2010 at 7:50 am to October 17, 2010 at 6:50 am. 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 6 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 94% of the drying time.

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

Sample Run	Time hrs	Flow rate		THC concentration		THC mass	THC rate	Average		
		Dry @68 l/min	Wet @68 l/min	wet ppmv	dry ppmv	as C lbs/mbf	as C lb/hr/mbf	Wood MC %	Air MC %	Anal. MC %
1	5.01	22.9	24.4	184.0	205.4	0.024	0.0048	44.6	6.1	6.1
2	5.06	12.8	18.3	664.6	852.8	0.094	0.0186	44.0	29.8	17.6
3	6.36	12.9	19.4	507.0	675.8	0.094	0.0147	42.6	33.6	12.1
4	5.36	12.8	19.5	354.5	476.5	0.055	0.0103	41.2	34.4	12.2
5	6.01	12.8	19.8	292.5	396.9	0.052	0.0086	39.7	35.2	12.5
6	6.26	12.7	20.1	279.2	384.9	0.052	0.0083	38.1	36.7	13.0
7	6.11	12.8	20.4	254.8	354.6	0.047	0.0077	36.3	37.5	13.1
8	5.66	12.7	20.7	237.2	333.6	0.041	0.0072	34.6	38.4	14.8
9	6.01	12.8	20.8	220.8	309.8	0.040	0.0067	32.9	38.2	14.5
10	6.21	12.8	20.8	212.8	299.9	0.040	0.0065	31.1	38.6	14.7
11	5.96	12.8	21.0	203.9	287.9	0.037	0.0063	29.2	38.7	14.3
12	5.81	12.8	21.0	201.2	285.1	0.036	0.0062	27.4	39.1	14.6
13	5.96	17.7	28.0	178.7	251.3	0.040	0.0067	25.3	36.5	13.7
14	6.36	12.8	20.8	190.2	266.9	0.037	0.0058	23.3	38.2	14.3
15	5.81	12.8	20.4	197.1	272.9	0.034	0.0059	21.5	37.0	14.3
16	5.96	12.8	19.9	189.7	258.8	0.033	0.0056	19.9	35.7	13.4
17	5.86	12.8	19.8	186.5	252.5	0.032	0.0055	18.4	35.0	13.7
18	6.01	12.8	19.2	175.8	233.6	0.030	0.0051	16.9	33.2	12.6
19	5.46	12.8	18.8	173.6	227.3	0.027	0.0049	15.6	31.8	12.7
Sum	111.21					0.845				
Average		13.6	20.7	258.1	348.8		0.0076			

Figure 2 shows total hydrocarbon concentration (left scale) and dry gas vent rate (right scale) versus time. The vent rate remains constant throughout the schedule because of difficulty maintaining the wet-bulb temperature. The thicker lumber does not give off water as fast as thin lumber so there was not enough humidity in the kiln to maintain the wet-bulb temperature.

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 rates occur early in the schedule. The rate of emissions is very low at the end of the schedule.

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.

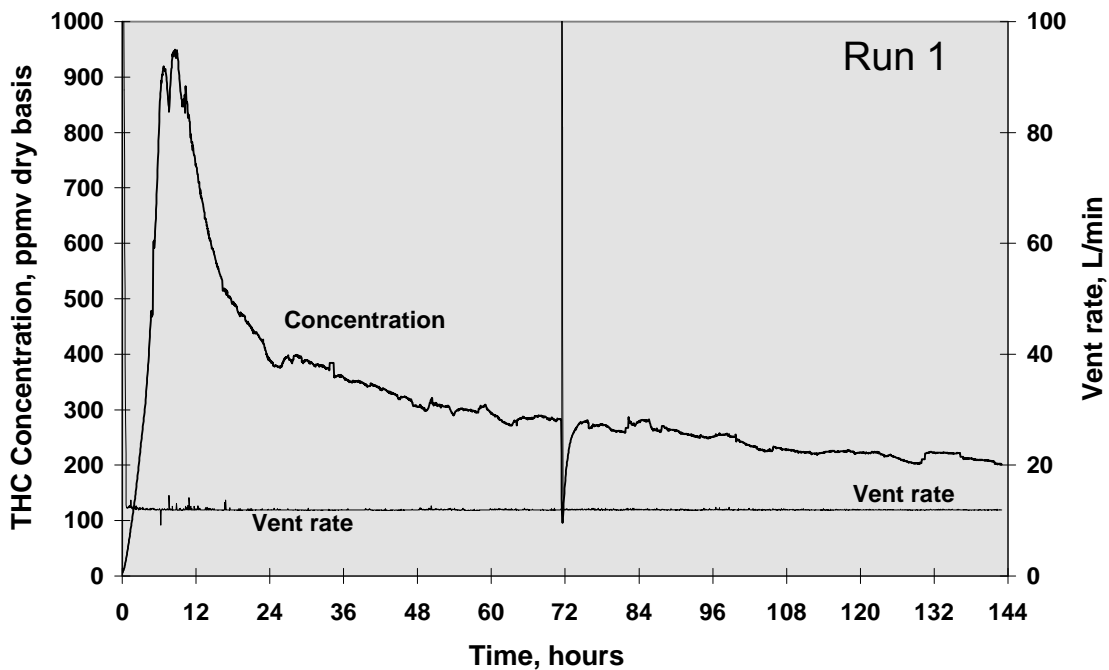


FIGURE 2. Hydrocarbon concentration and vent rate versus time.

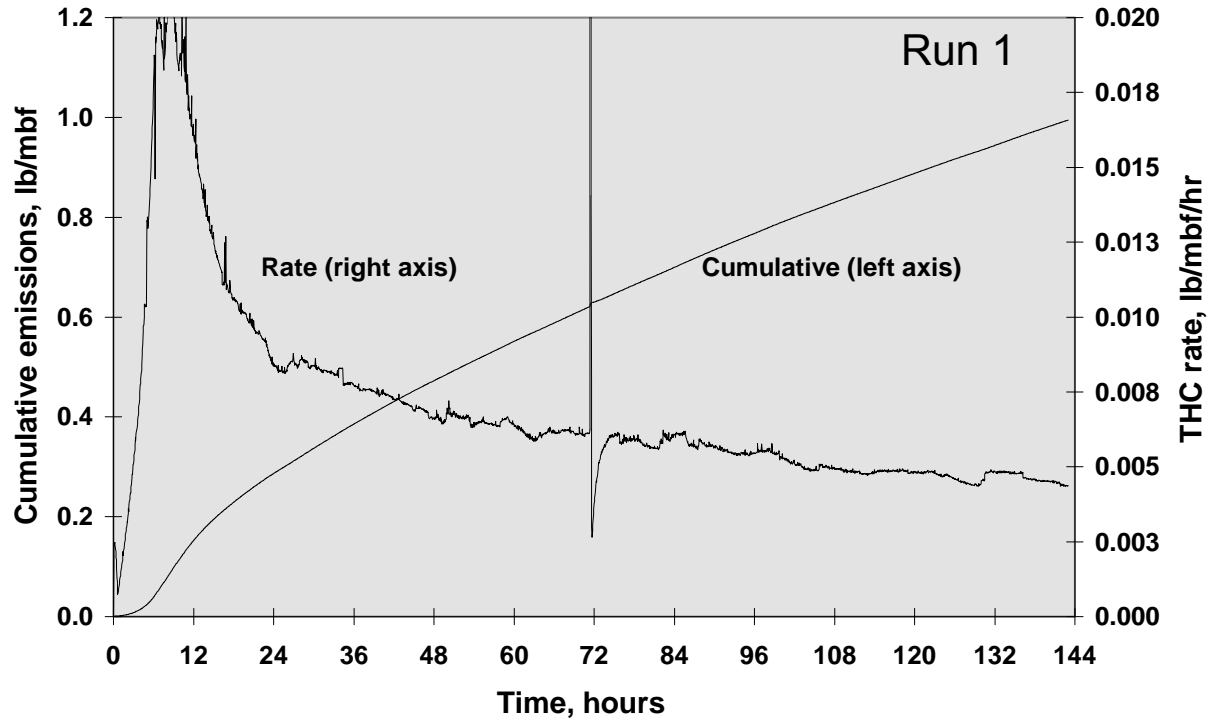


FIGURE 3. Cumulative and rate of emissions (as carbon) versus time.

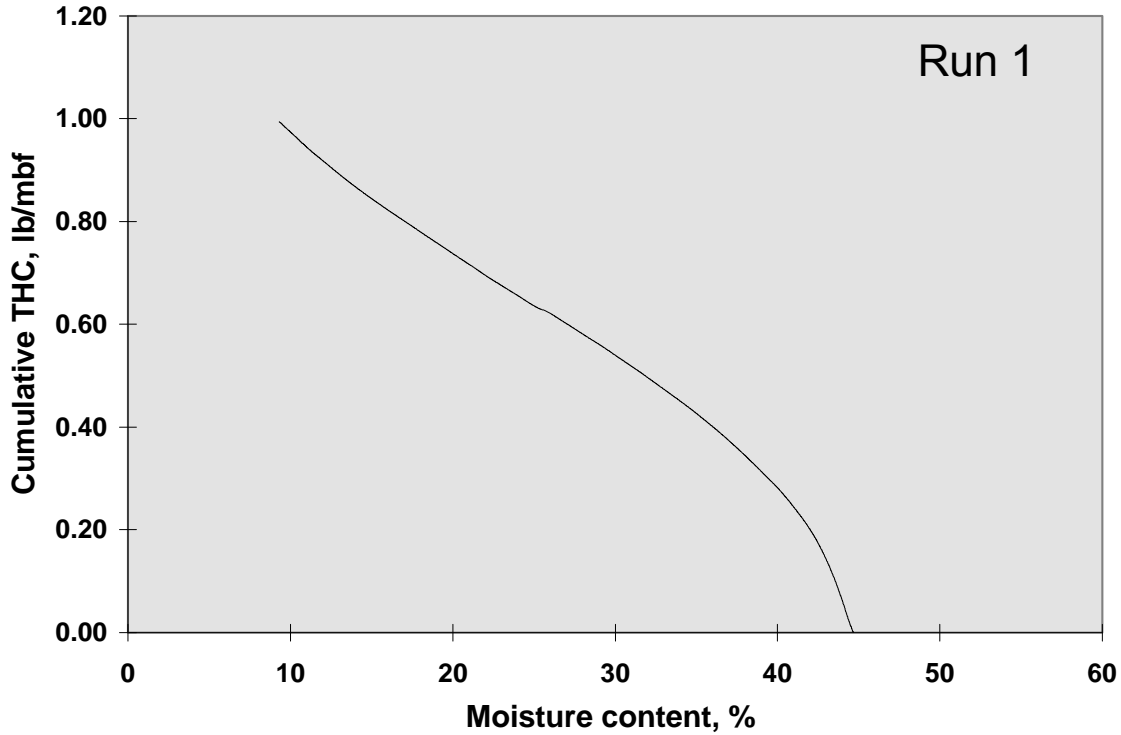


FIGURE 4. Total hydrocarbon versus moisture content of wood.

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 [“adjusted interval”] is in Table 4. An interval is the period spanning the midpoints between collection intervals, about 6 hours. HAPs were collected during the collection interval for approximately 1:15 at the center of each sample interval. The sample [adjusted] interval time periods shown in the table include the times between collection intervals and mass calculations are adjusted to account for these. Sampling occurred for approximately 21% of the drying time. More frequent sampling occurred during the initial part of drying when the kiln temperature was changing rapidly.

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	
	hours	hours	kg	kg/min	mol/mol	Mid %	End %
1	1.42	1.70	5.176	0.051	0.037	44.7	44.7
2	1.35	2.25	2.134	0.016	0.090	44.6	44.6
3	1.57	3.91	3.640	0.016	0.224	44.3	43.9
4	1.05	5.31	4.958	0.016	0.328	43.3	42.6
5	1.25	6.11	5.665	0.015	0.337	41.9	41.1
6	1.30	6.06	5.604	0.015	0.351	40.4	39.6
7	1.28	5.96	5.502	0.015	0.369	38.8	38.0
8	1.32	6.06	5.591	0.015	0.385	37.1	36.3
9	1.32	5.96	5.503	0.015	0.401	35.4	34.5
10	1.30	6.01	5.554	0.015	0.408	33.6	32.7
11	1.25	6.11	5.685	0.016	0.403	31.8	30.9
12	1.13	6.01	5.559	0.015	0.412	30.0	29.1
13	1.23	5.91	5.478	0.015	0.413	28.2	27.3
14	1.27	5.96	7.629	0.021	0.409	26.2	25.0
15	1.27	6.16	5.732	0.016	0.407	24.1	23.1
16	1.28	5.81	5.393	0.015	0.391	22.3	21.5
17	1.28	6.06	5.618	0.015	0.375	20.6	19.8
18	1.30	5.96	5.523	0.015	0.357	19.0	18.3
19	1.27	6.01	5.574	0.015	0.340	17.5	16.8
20	1.25	6.01	5.570	0.015	0.317	16.1	15.4
21	1.25	1.90	1.763	0.015	0.300	15.2	15.0
SUM		111.21					

The MACT HAP emissions and the emissions of ethanol and acetic acid are shown in Table 5. The total HAP emissions were 0.149 lb/mbf (does not include the non-HAPs, ethanol and acetic acid). The HAP emissions as a function of time and wood moisture content during the cycle are shown in Figures 5 and 6, respectively.

TABLE 5. Interval by interval emissions for the MACT HAPs and ethanol and acetic acid.

Sample Run ID	Interval Endpoint hours	Wood Moisture Content %	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
1	1.70	44.7	0.0002	0.0000	0.0005	0.0000	0.00000	0.0008	0.00000	0.00001
2	3.96	44.6	0.0003	0.0000	0.0006	0.0000	0.00000	0.0012	0.00000	0.00000
3	7.86	43.9	0.0010	0.0000	0.0030	0.0022	0.00001	0.0043	0.00001	0.00001
4	13.17	42.6	0.0023	0.0000	0.0045	0.0050	0.00003	0.0086	0.00002	0.00003
5	19.28	41.1	0.0032	0.0000	0.0036	0.0052	0.00005	0.0081	0.00002	0.00005
6	25.33	39.6	0.0036	0.0000	0.0030	0.0059	0.00006	0.0063	0.00002	0.00006
7	31.29	38.0	0.0044	0.0000	0.0031	0.0073	0.00008	0.0048	0.00002	0.00005
8	37.35	36.3	0.0041	0.0000	0.0028	0.0074	0.00009	0.0044	0.00002	0.00006
9	43.31	34.5	0.0045	0.0000	0.0019	0.0064	0.00011	0.0038	0.00002	0.00006
10	49.32	32.7	0.0054	0.0000	0.0026	0.0079	0.00012	0.0034	0.00002	0.00005
11	55.43	30.9	0.0048	0.0000	0.0016	0.0075	0.00013	0.0030	0.00003	0.00005
12	61.44	29.1	0.0048	0.0000	0.0012	0.0078	0.00014	0.0024	0.00003	0.00004
13	67.34	27.3	0.0058	0.0000	0.0012	0.0122	0.00016	0.0022	0.00003	0.00005
14	73.30	25.0	0.0081	0.0000	0.0013	0.0164	0.00005	0.0007	0.00001	0.00001
15	79.46	23.1	0.0039	0.0000	0.0002	0.0095	0.00015	0.0016	0.00002	0.00004
16	85.27	21.5	0.0056	0.0000	0.0008	0.0113	0.00014	0.0014	0.00002	0.00003
17	91.33	19.8	0.0055	0.0000	0.0007	0.0113	0.00014	0.0013	0.00002	0.00003
18	97.29	18.3	0.0055	0.0000	0.0007	0.0116	0.00013	0.0009	0.00001	0.00003
19	103.29	16.8	0.0051	0.0000	0.0002	0.0099	0.00013	0.0010	0.00001	0.00003
20	109.30	15.4	0.0050	0.0000	0.0000	0.0088	0.00012	0.0009	0.00002	0.00002
21	111.21	15.0	0.0016	0.0000	0.0001	0.0023	0.00004	0.0002	0.00000	0.00001
Sums:			0.084	0.000	0.034	0.1559	0.0019	0.061	0.0003	0.0007

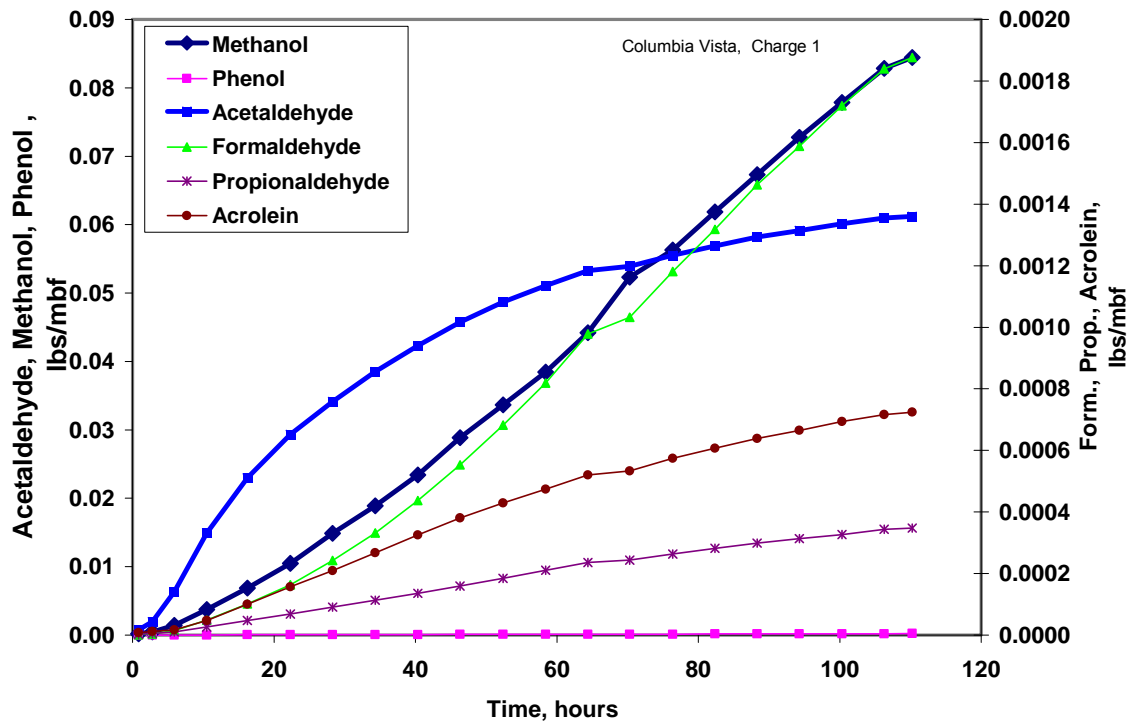


FIGURE 5. HAP emissions as a function of time.

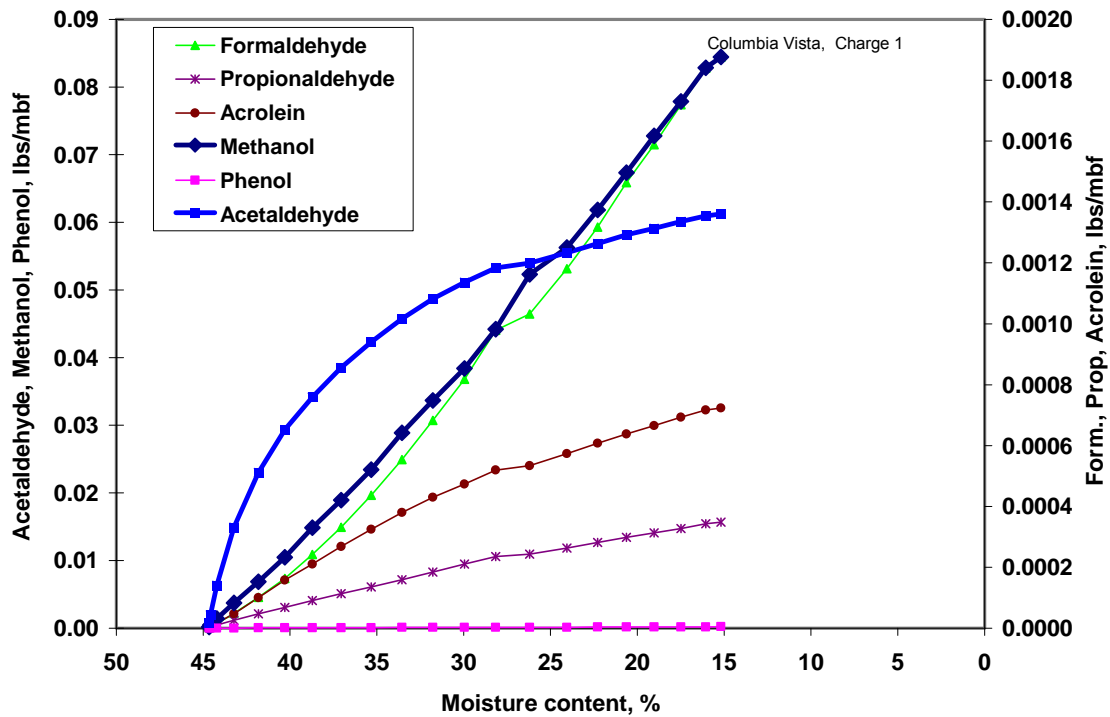


FIGURE 6. HAP emissions as a function of wood moisture content.

The detection limits for the GC instrument were

Methanol - 0.66 µg/mL in the aqueous phase

Phenol - 0.76 µg/mL in the aqueous phase

Formaldehyde - 0.12 µg/mL in the hexane phase

Acetaldehyde - 0.19 µg/mL in the hexane phase

Propionaldehyde - 19 µg/mL in the hexane phase

Acrolein - 0.48 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 method detection limits in the sampled gas are

Methanol - mean = 0.17 ppm, standard deviation = 0.03 ppmvd

Phenol - mean = 0.07 ppm, standard deviation = 0.01 ppmvd

Formaldehyde - mean = 0.03 ppm, standard deviation = 0.01 ppmvd

Acetaldehyde - mean = 0.02 ppm, standard deviation = 0.004 ppmvd

Propionaldehyde - mean = 0.02 ppm, standard deviation = 0.003 ppmvd

Acrolein - mean = 0.04 ppm, standard deviation = 0.01 ppmvd

Samples 1 and 2 were below the detection limits for propionaldehyde and acrolein. All samples were below the detection limit for phenol (agrees with all past work that phenol is not emitted during lumber drying). One half the detection limit was used for acrolein and propionaldehyde in the values reported in Table 5; although, there is not enough difference to affect the values after rounding compared to using zero for these values.

Field spikes (Table 6) were run by operating three impinger trains simultaneously. An aliquot of the aldehydes was added to one impinger train while the aqueous solutes were added to another. Spike recovery percentage is the mass of a compound detected in the lab compared to mass added to the impinger. All spikes were recovered within the method limits (+/-30 to 50% depending on concentration) with the exception of acetic acid in run ten. Acetic acid is difficult to quantify with the NCASI method. The QA results suggest that the acetic acid emission reported should be treated as an estimate.

The results for field blanks collected are shown in Table 7. The only anomaly is 0.4 ppm methanol in blank 7. A value of 0.4 ppm is quite small since the methanol samples ranged up to 61 ppm. Blank 14 was from the same BHA solution and rinse water as blank 7 and it did not contain methanol. We attribute the low concentration in blank 7 to noise on the GC. Some modifications in the GC program were made to get a better response for acetic acid and this seems to have caused difficulties with the peak integration of methanol and ethanol. We do not believe that this had an impact on the results. To convince ourselves of this we used peak height instead of peak area and recalculated the HAP analysis and got the same result (0.148 lb/mbf compared to 0.149 lb/mbf of HAPs using peak area).

TABLE 6. Results for field spike recoveries.

Alcohol Spike									
Run	Mass in impinger				Impinger flow mL/min	Mass corrected for flow			
	Methanol µg	Phenol µg	Ethanol µg	Acetic µg		Methanol µg	Phenol µg	Ethanol µg	Acetic µg
10	2320.6	4.2	1104.1	3362.6	441.7	2344.1	4.2	1115.3	3396.7
1002	2959.0	555.9	1696.5	5033.2	446.2	2959.0	555.9	1696.5	5033.2
Spike mass g	Spike concentrations					Spike recoveries			
	Methanol µg/mL	Phenol µg/mL	Ethanol µg/mL	Acetic µg/mL		Methanol %	Phenol %	Ethanol %	Acetic %
1.02	741.3	680.7	830.7	1186.5		81.3	79.5	68.6	135.2

Aldehyde Spike									
Run	Mass in impinger				Impinger flow mL/min	Mass corrected for flow			
	Form-aldehyde µg	Acet-aldehyde µg	Propion-aldehyde µg	Acrolein µg		Form-aldehyde µg	Acet-aldehyde µg	Propion-aldehyde µg	Acrolein µg
10	49.6	1447.6	9.9	23.2	441.7	42.1	1229.8	8.4	19.7
1003	59.7	2602.5	20.8	36.2	375.3	59.7	2602.5	20.8	36.2
Spike mass g	Spike concentrations					Spike recoveries			
	Form-aldehyde µg/mL	Acet-aldehyde µg/mL	Propion-aldehyde µg/mL	Acrolein µg/mL		Form-aldehyde %	Acet-aldehyde %	Propion-aldehyde %	Acrolein %
1.02	15.1	1119.4	13.0	14.6		75.2	79.2	61.3	73.1

Aldehyde Spike									
Run	Mass in impinger				Impinger flow mL/min	Mass corrected for flow			
	Form-aldehyde µg	Acet-aldehyde µg	Propion-aldehyde µg	Acrolein µg		Form-aldehyde µg	Acet-aldehyde µg	Propion-aldehyde µg	Acrolein µg
15	59.6	635.5	7.8	16.0	439.5	60.4	643.7	7.9	16.2
1502	97.9	3509.4	36.0	47.2	445.3	97.9	3509.4	36.0	47.2
Spike mass g	Spike concentrations					Spike recoveries			
	Form-aldehyde µg/mL	Acet-aldehyde µg/mL	Propion-aldehyde µg/mL	Acrolein µg/mL		Form-aldehyde %	Acet-aldehyde %	Propion-aldehyde %	Acrolein %
2.08	15.1	1119.4	13.0	14.6		78.7	81.1	68.4	67.3

Alcohol Spike									
Run	Mass in impinger				Impinger flow mL/min	Mass corrected for flow			
	Methanol µg	Phenol µg	Ethanol µg	Acetic µg		Methanol µg	Phenol µg	Ethanol µg	Acetic µg
15	1578.6	2.6	97.1	3812.8	439.5	1347.9	2.2	82.9	3255.6
1503	3282.6	1102.5	1688.6	6892.3	375.3	3282.6	1102.5	1688.6	6892.3
Spike mass g	Spike concentrations					Spike recoveries			
	Methanol µg/mL	Phenol µg/mL	Ethanol µg/mL	Acetic µg/mL		Methanol %	Phenol %	Ethanol %	Acetic %
2.06	741.3	680.7	830.7	1186.5		126.7	78.5	93.8	148.8

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 is too low in concentration to be reliably duplicated. Methanol and ethanol each pass on one of the duplicates. We attribute the other duplicate to the noise described above. Acetic acid was duplicated well. The replication on all aldehydes is excellent.

TABLE 7. Results for field blanks.

Field blank					7
Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm
0.4	0.0	0.0	0.0	0.0	0.0

Field blank					14
Methanol	Phenol	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein
ppm	ppm	ppm	ppm	ppm	ppm
0.0	-0.2	0.0	0.0	0.0	0.0

TABLE 8. Results for duplicate runs.

Run	Duplicate								Impinger flow mL/min
	Mass in impinger								
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	
11	1919.1	4.7	651.8	3012.7	51.8	1202.8	10.3	20.0	442.5
1102	1312.2	6.2	616.6	3049.9	51.7	1232.5	9.2	20.8	443.9
Difference, %	37.9	27.5	5.9	0.9	0.5	2.1	11.0	3.5	

Run	Duplicate								Impinger flow mL/min
	Mass in impinger								
	Methanol	Phenol	Ethanol	Acetic acid	Form-aldehyde	Acet-aldehyde	Propion-aldehyde	Acrolein	
	µg	µg	µg	µg	µg	µg	µg	µg	
19	2114.8	-0.8	88.1	4140.0	54.7	413.6	6.0	11.8	445.1
1902	2055.8	-3.8	149.4	3364.9	58.3	439.6	7.4	12.1	447.7
Difference, %	3.4	-130.2	51.2	21.3	5.8	5.5	20.4	1.8	

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.

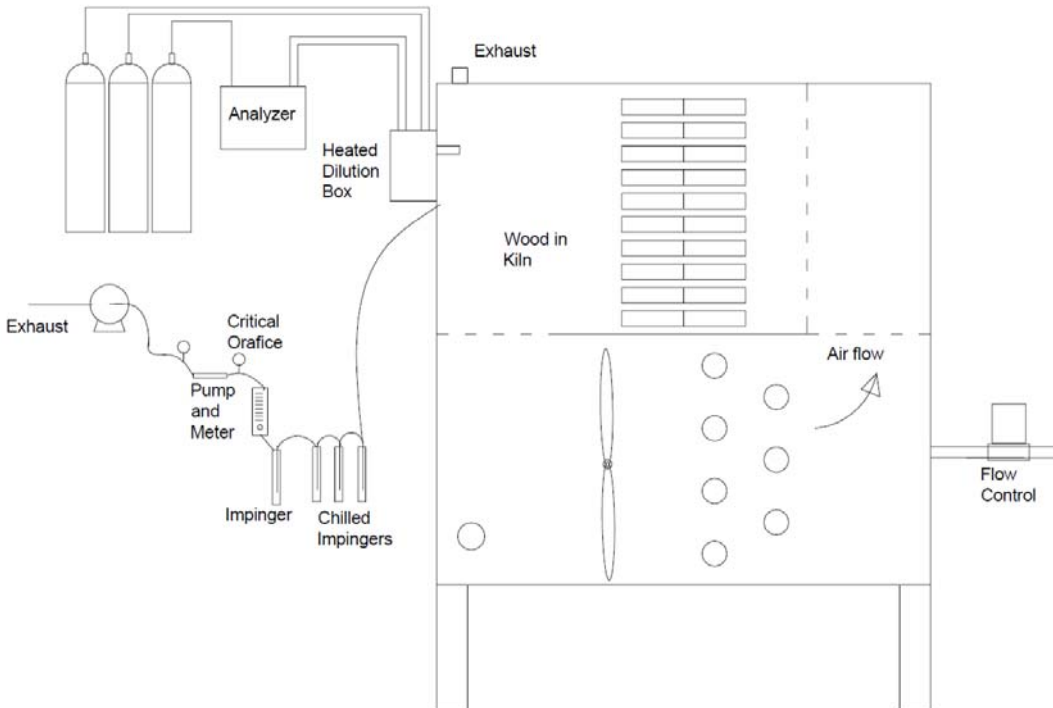


FIGURE 7. Schematic of kiln and sampling system (top) and photo of kiln loaded (bottom).

Humidity control

A 200 L/min MKS mass flow meter controlled and measured the amount of air entering the kiln. It was factory calibrated and checked using a bubble meter. The amount of air entering the kiln is based on the wet-bulb temperature - if it is above setpoint, the airflow is increased and if it is below setpoint the airflow is decreased. This is analogous to venting for a commercial kiln. A minimum of 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. These were not used.

Temperature control

Temperature in the kiln is controlled by indirect steam heating. When the average of the four dry-bulb thermocouples is below setpoint, the steam pressure in the coil is increased. When it is above setpoint, steam flow to the coil is reduced. The dry- and wet-bulb temperatures used are shown in Figure 8.

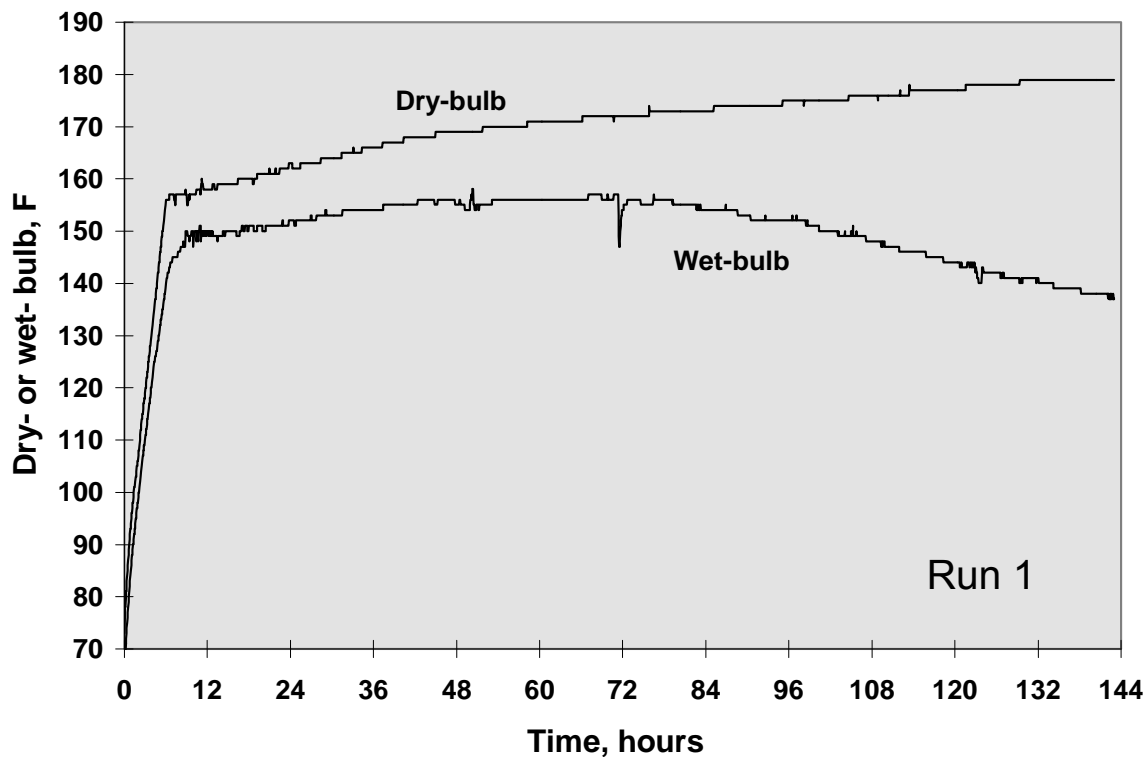


FIGURE 8. Dry- and wet-bulb temperatures.

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 wet-bulb depression exceeded the mill wet-bulb depression by a few degrees early in the schedule, then by a larger amount late in the schedule. There was insufficient humidity in the kiln from evaporation as the wood dried.

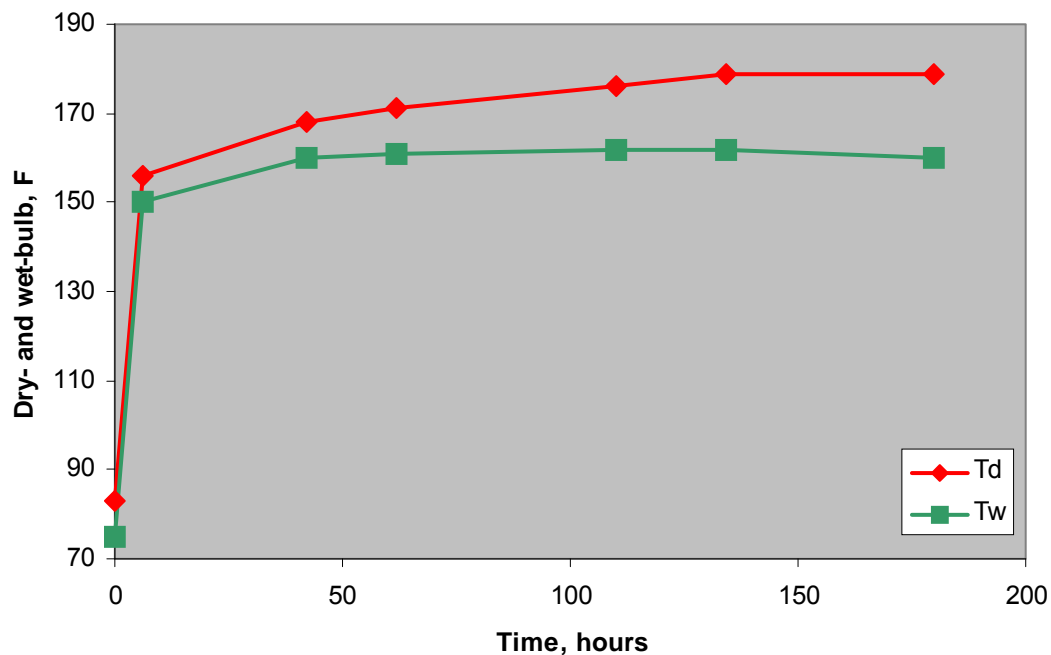


FIGURE 9. Dry- and wet-bulb setpoints provided by the mill.

Wood quantity

The wood quantity was determined using the nominal wood dimensions (4x4 in this case) which provides for 1.33 board feet per lineal foot. There were 24 pieces in the kiln at 44" in length or 88 lineal feet. The board footage was therefore 117 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 was 85% heartwood. This was determined by estimating the heartwood percent at each end of the board and averaging over the 24 pieces.

The average ring count was 5.7 rings per inch. This was determined by counting the rings over a 2" radial distance, dividing by two, and averaging for all boards.

There was an average of 12 knots visible on the faces of each board. This was a count of all knots, so a knot that intersected two faces was counted twice. Knots tended to be small, especially when many were present. Knot area per board averaged 3.3 in² while the total face area was 616 in². The knots occupied approximately 0.5% of the boards' faces.

Five boards out of 24 contained pith.

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 230°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 240°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 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.

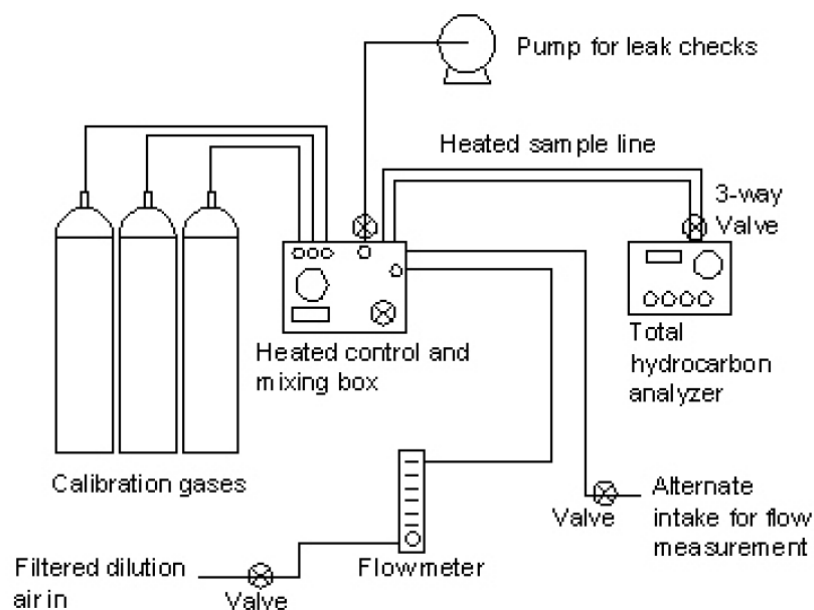


FIGURE 10. Schematic of heated filter box with air dilution system, heated sample line, and analyzer. Sample enters heated box from back of drawing (box is attached to kiln).

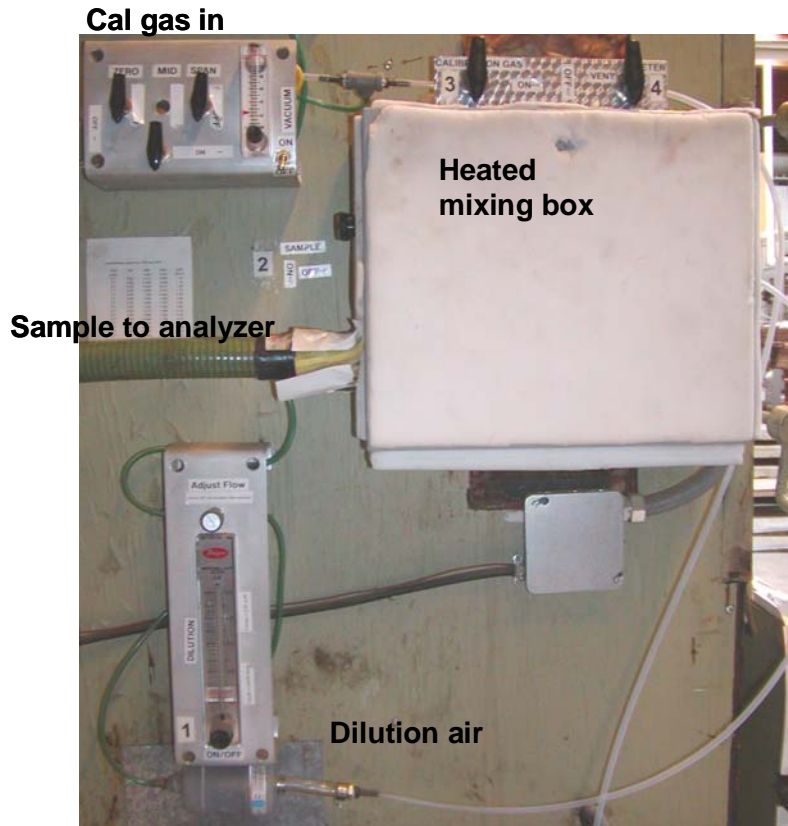


FIGURE 11. Photo of VOC sampling system showing heated mixing box (with white insulation), valves and flow meter for calibration gases (upper left), on/off valve for calibration gas (3 at upper center right), heated sample line to analyzer (green tube, middle left), valve for sample (2 at center left), 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 400-500 mL/min. 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 two weeks after sample collection.

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

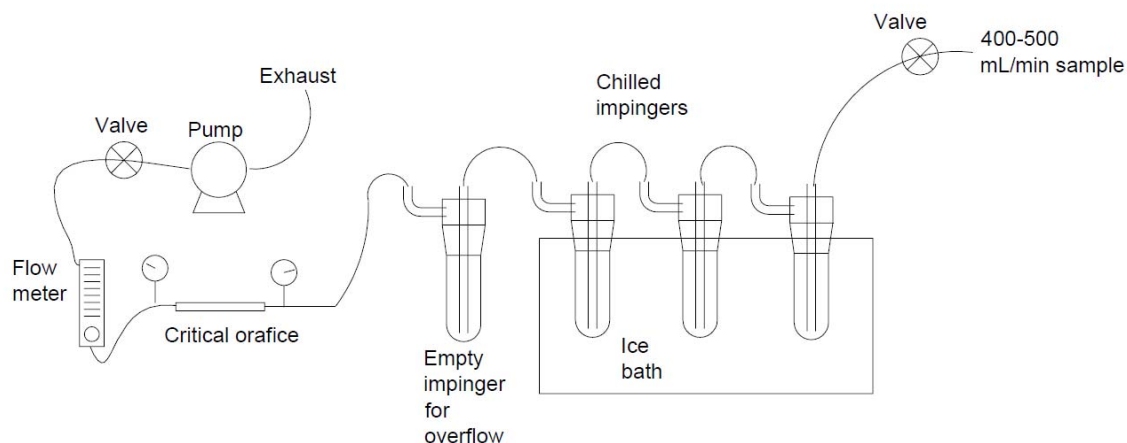


FIGURE 12. HAPs sampling train.

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 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 (0 – 50 ppm for formaldehyde, propionaldehyde, and acrolein and 0-1000 ppm for acetaldehyde). The standards were then 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 solutions were extracted with three aliquots of hexane to create standards. One mL aliquotes were place in GC autosampler vials with 100 mg/L of nitrobenzene 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 25 mL. The volumes of the two phases were calculated from their weights. A 1 mL aliquot of the hexane fraction was transferred to an autosampler vial and spiked with internal standard.

The analytical instrument was a Shimadzu GC model 2010 with a flame thermionic detector (FTD), the Shimadzu equivalent of a nitrogen phosphorous detector (NPD). The column was a 105-meter Restek RTX-5 capillary with a 0.25 mm outside diameter and a stationary phase thickness of 0.25 μ m. 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 H₂ 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 H₂ 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 1000 milligrams per liter (mg/L). Additional standards were prepared by the volumetric dilution of the mixed standard at a range from 4 mg/L to 1000 mg/L. Aliquots of these were placed into autosampler vials.

Samples were prepared by transferring aliquots of the previously hexane extracted aqueous fractions into autosampler vials. The analytical instrument was a Shimadzu GC model 2010 with a FID detector. The column was a 60-meter Restek Stabilwax capillary with a 0.53 mm outside diameter and a stationary phase thickness of 1.5 µm. The oven schedule was: 3 minutes at 80°C, 10°C/min ramp to 240°C, and 10 minutes at 240°C. The column flow was 30 cm/sec, with 3 mL/min septum purge, and a 1:10 split ratio with a glass wool packed split injection liner. The detector make up He was set to 25 mL/min and the H₂ was set to 50 mL/min. The air was set to 500 mL/min. The He and H₂ gases were grade 5 and the air was grade 0.1. The injector temperature was 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 13 to 16. All field data sheets are in Appendix 2 this report in electronic format (pdf).

924

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - BEFORE

BACKGROUND INFORMATION

Event (kiln charge): Columbia/Vista1 Dry-bulb temperature: 16.0
 Run: 9 Wet-bulb temperature: 16.8
 Operator: MJM Target Dilution Ratio (TDR): 04
 Date: 10-13-10 Laboratory temperature: 73 °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	0.0 (0)	0.3 (0)		48
span	6.10 (6.10)	6.09 (6.10)		49
mid	0.99408 (0.99)	1.01 (0.99)	96 to 102	
mid	9.67 (9.9)			

Reset range to 3. Range: 3

SET DILUTION FLOW BEFORE RUN (do not change pots)

Total flow rate (TFR): 1549 mL/min [Valves 1, 2, 3 = off, 4=meter]
 Target dilution flow rate (TDFR) ~855 mL/min [TFR x (1 - DR)]
 Set and read dilution meter: 820 scfh [scfh = mL/min * 0.00212]
 Sample flow rate (SFR): 959 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/Range/Span]	DR _{Flow} [SFR/TFR]	Difference, % 100*(DR _{Span} - DR _{Flow})/DR _{Flow}
Span _{FullScale}	2.33	0.382	0.8

START TIME: 5:42 (clock) [1, 2, 5 = on; 3, 4 = off; tank valves off]
 ANALYZER RANGE: 32 [0.6 < reading < 7.5]

ANALYZER RANGE ON COMPUTER (set to match analyzer): 32
 All blank values correct!
 Show off values at tanks

FIELD DATA SHEET FOR TOTAL HYDROCARBON ANALYZER - AFTER

Operator: MJM Event (kiln charge): Columbia/Vista1
 Run (sample): 9 Laboratory temperature: 72 °F
 END TIME: 11:36
 Range setting on Analyzer: 2 on Computer: 2

Reset range to 3. Range: 3

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

Span _{FullScale}	Analyzer reading	Computer, ppm
	2.33	2.38

Sample flow rate (SFR): 582.2 mL/min [1= on, 2, 3 = off, 4=meter]
 Read dilution meter: 2 scfh
 Total flow rate (TFR): 1534 mL/min [1, 2, 3 = off, 4=meter] (label print out)
 Dilution ratio (DR_{Flow}): 0.379 [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	6.23	580 to 825	49
mid	1.02	96 to 102	
zero	0.00	-18 to +18	48

Dilution ratio (DR_{Span}): 0.382 [Span_{FullScale} / Span]
 Dilution ratio difference: 0.8 % [100*(Abs(DR_{Span} - DR_{Flow}))/DR_{Flow}]
 End line for check: 11:40
 Comments:

Charge: ColumbiaVista1

	Date	Time
Start	10-12-10	
End		

Page: 2

Clock time 10-12-10	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	Line 3 ml/min	Line 1 inHG	Line 2 inHG	Line 3 inHG
1:01	17:11	4	160	150	235	240	250	-1	12	0	0	2	-	-	-	-	-	-
5:14	21:24	4	161	151	237	241	250	-1	12	0	0	2	-	-	-	-	-	-
5:41	21:51	5	162	151	232	240	250	-1	12	0	0	2	435	-	-	29	-	-
6:56	23:06	5	162	151	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
7:52	24:07	5	163	152	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
8:55	25:05	5	162	152	229	240	250	-1	12	0	0	2	-	-	-	-	-	-
10:16	26:26	5	163	152	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
11:18	27:28	5	163	152	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
12:12	28:22	6	164	153	229	240	250	-1	12	0	0	2	475	240	440	28	275	285
13:26	29:36	6	164	153	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
14:25	30:36	6	164	153	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
18:12	34:22	7	166	154	230	240	250	-1	12	0	0	2	500	-	-	29	-	-
19:18	35:28	7	166	154	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
21:12	37:22	7	167	154	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
22:09	38:19	7	167	155	231	240	250	-1	12	0	0	2	-	-	-	-	-	-
23:14	39:24	7	167	155	230	240	250	-1	12	0	0	2	-	-	-	-	-	-
12:00	40:10	8	167	155	231	240	250	-1	12	0	0	2	500	-	-	29	-	-

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

GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	4 SFR
FLOW AVERAGE	554.3	01	02	PA
	555.2	02	03	
	553.3	03	04	
	551.6	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	5A Post
FLOW AVERAGE	490.8	01	02	
	497.0	02	03	
	490.7	03	04	
	495.7	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	6A Post
FLOW AVERAGE	486.3	01	02	
	490.2	02	03	
	489.1	03	04	
	488.9	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	4 SFR
FLOW AVERAGE	549.9	01	02	
	555.5	02	03	
	554.2	03	04	
	555.8	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	4 Post
FLOW AVERAGE	1548	01	02	
	1551	02	03	
	1551	03	04	
	1552	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	5 TFR Post
FLOW AVERAGE	1551	01	02	
	1551	02	03	
	1552	03	04	
	1553	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	5 SFR Post
FLOW AVERAGE	556.3	01	02	
	555.8	02	03	
	554.2	03	04	
	554.4	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	6A Post
FLOW AVERAGE	490.4	01	02	
	490.7	02	03	
	490.5	03	04	
	486.4	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	7A Post
FLOW AVERAGE	490.8	01	02	
	491.8	02	03	
	491.5	03	04	
	497.7	04		
GILIBRATOR 2 MET V4.4 DATE.....	PUMP S/N.....	ID.....	# SAMPLES	
FLOW AVERAGE				

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

5

FIELD DATA SHEET, 106 HAPS MEASUREMENT
TRAIN #1 - BEFORE SAMPLE
 Operator: MRM Event (kiln charge): Columbia Vista 1
 Date: 10-11-10 Run (sample): 2-A

Altimeter setting: 30.48 inHg
 Isopropanol rinse or lab wash:

IMPINGER WEIGHTS			
	Dry Weight, g	Wet Weight, g	BHA added, g
Impinger #1A	41.54	52.79	(-10 mL)
Impinger #1B	42.22	56.35	(-15-20 mL)
Impinger #1C	39.84		
Total BHA added:			

Optional Spike: g Spike type: Alcohol Aldehyde
 (take impingers to bin from scale)
 Lab temperature 66 °F
 Leak check: Vacuum 17.1 inHg Lost after 2 minutes 0.8
 Sample flow rate: 486.1 mL/min [Average of 4. Label printout]
 Put sample line in kiln CLOCK TIME: 9:54
 ELAPSED TIME: 2:04

Is the sample line in the kiln?
 Is gas flowing (look at flow meters)?

FLOW METER READINGS DURING TEST (every 20 minutes)		
Clock time	9:55	10:17
Vacuum, inHg	29	29
Flow rate, mL/min	500	475

FIELD DATA SHEET, 106 HAPS MEASUREMENT
TRAIN #1 - AFTER SAMPLE
 Operator: MRM Event (kiln charge): Columbia Vista 1
 Run (sample): 2-A

Altimeter setting: 30.47 inHg
 Sample line rinse vial: 15.1 g (with -3 mL DW)
 Lab temperature: 68 °F
 Remove sample line from kiln Clock time: 11:15
 Elapsed time: 3:25
 (rinse sample line then measure flow rate)
 Sample flow rate: 482.5 mL/min [Average of 4. Label printout]
 (take impingers to scale from bin)
 Sample line rinse vial: 13.64 g (empty)
 Empty bottle weight: 124.54 g (with lid)

IMPINGER WEIGHTS			
	Wet Weight, g	Dry Weight, g	Water removed, g
Impinger #1A	64.02		
Impinger #1B	51.01		
Impinger #1C	39.75		

Bottle weight without impinger rinse: 157.55 g (with lid)
 (rinse impingers with 10 mL DI water)
 Bottle weight with impinger rinse: 169.97 g (with lid)
 (rinse impingers with 5 mL DI water)
 Filled bottle weight: 169.42 g (with lid)
 Water lost during handling: 0 mL
 Comments:

Calculations

The “FlowCalc” worksheet in the Excel file “Kiln, ColumbiaVista1.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, $\text{kg}_{\text{water}} \cdot \text{kg}_{\text{air}}^{-1}$) is shown in column I and the molal humidity ($\text{mol}_{\text{water}} \cdot \text{mol}_{\text{air}}^{-1}$) in column J. These are calculated based on the dry-bulb temperature (T_d , °C) and wet-bulb temperature (T_w , °C),

$$P_{vp} = P_{\text{ambient}} * 10^{(16.373 - 2818.6/(T_d+273.16) - 1.6908 * \text{LOG}_{10}(T_d + 273.16) - 0.0057546 * (T_d + 273.16) + 0.0000040073 * (T_d + 273.16)^2)}$$

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

$$\text{MolHum} = \text{AbHum} * \text{MW}_{\text{air}} / \text{MW}_{\text{water}}$$

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

Flows

The volumetric dry gas flow rate (DryGasV, $\text{L} \cdot \text{min}^{-1}$) 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, $\text{kg} \cdot \text{min}^{-1}$) and in column M is the same information is expressed as a molal flow rate (DryGas, $\text{kgmol} \cdot \text{min}^{-1}$). These values are for the dry gas vented from the kiln.

$$\text{DryGasV} = (\text{FlowMeter1} + \text{FlowMeter2} + \text{FlowMeter3}) * (1/(1+\text{MolHum}_{\text{In}}))$$

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

$$\text{DryGas (kgmol/min)} = \text{DryGasM} / \text{MW}_{\text{air}}$$

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.

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

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.

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

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 X) 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).

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

In column V, the hydrocarbon flow rate (THC_{Vented}, g_{Carbon}·min⁻¹) is calculated in a manner analogous to the water flow rate using the dry gas flow rate and the hydrocarbon concentration.

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

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

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 file named “Weights, ColumbiaVista1.XLS.”

HAPs

At the end of the FlowCalc spreadsheet (at the bottom) are summaries by run of the flow data for the total HAP run intervals (interval summary button will reposition spreadsheet, then go down a few more lines below the hydrocarbon summary). This spreadsheet provides the kiln flow data for HAPs calculation and is copied to columns C to H of the “Kiln Calculations” worksheet in the file “HAPs, ColumbiaVista1.xls”.

Data from the lab analysis for HAPs is shown in the file “HAPs, AQU, GCSheet, Columbuavista1.xls” and “HAPs, HEX, GCSheet, Columbuavista1.xls”. This, in turn, appears on the “Laboratory Data” page of the file “HAPs, ColumbiaVista1.xls”.

Within the file “HAPs, ColumbiaVista1.xls”, the summary page presents the data by run interval. 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.

On the “Impinger Calculations” page, the field data and kiln data are used to give a dry gas flow rate through the impingers (columns J and K) and the mass HAPs in the impingers (columns L to Q). Flow rates were adjusted to standard conditions in column F/G.

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

A dry gas flow rate is calculated in column H/I

$$\text{ImpgrFlwDry_mL} = \text{ImpgrFlow} * (1 - \text{MolHum} / (1 + \text{MolHum}))$$

The average of the two impingers (column J) is then converted to a mass basis in column K.

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

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, ColumbiaVista1.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.

The remaining pages in “HAPs, ColumbiaVista1.XLS” are for graphing purposes.

9. Chain of custody information

Wood was collected by mill personnel and delivered to Oregon State by Devin Sanders of Columbia Vista Corp. Wood was retained by Oregon State after delivery as documented in section 1. Field samples remained at Oregon State University.

10. Calibration documentation

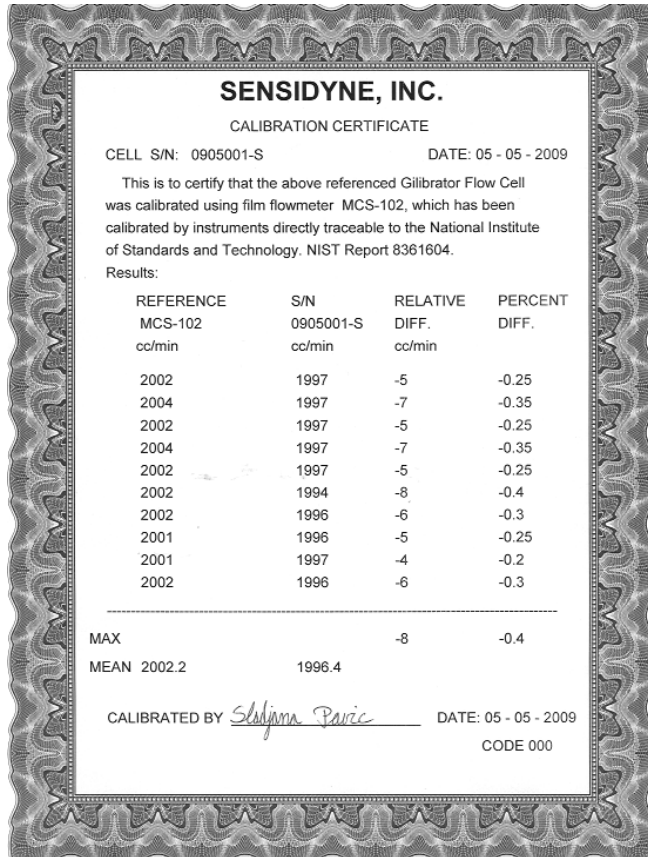


FIGURE 17. Flow meter calibration.



Specialty Gases
 11715 Amsted Street
 Los Angeles, CA 90062-7150
 (323) 387-8861
 FAX: (323) 507-0699

CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Part Number: E02A199E15A1472 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

Certificate performed in accordance with EPA Traceable by 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 the calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
 Do Not Use This Cylinder below 150 psig, a 1/2" Nipple Pencil.

ANALYTICAL RESULTS				
Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty
PROPANE	800.0 PPM	809.8 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS				
Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	000819	SG9107376	483.6PPM PROPANE/AIR	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



CERTIFICATE OF ANALYSIS
Grade of Product: EPA Protocol

Airgas Specialty Gases
 11715 Amsted Street
 Los Angeles, CA 90062-7150
 (323) 387-8861
 Fax: (323) 507-0698
 www.airgas.com

Part Number: E02A199E15A0465 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

Certificate performed in accordance with EPA Traceable by 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 the calibration mixture. All concentrations are on a volume/volume basis unless otherwise noted.
 Do Not Use This Cylinder below 150 psig, a 1/2" Nipple Pencil.

ANALYTICAL RESULTS				
Component	Requested Concentration	Actual Concentration	Protocol Method	Total Relative Uncertainty
PROPANE	100.0 PPM	98.78 PPM	G1	+/- 1% NIST Traceable
Air	Balance			

CALIBRATION STANDARDS				
Type	Lot ID	Cylinder No	Concentration	Expiration Date
NTRM	090817	GC301749	87.82PPM 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

At approximately 72 hours the kiln vented to the maximum, then decreased back to 12 L/min over the next few minutes. This is apparent from the spike in Figure 3. However, this was brief and there was no visible impact on the cumulative emissions line (Figure 3 and 4).

Blank 7 showed a trace of methanol as a contaminant. However, blank 14 from the same reagents two days later came up clean. This leads us to believe that sample 7 was not actually contaminated.

The GC data for the aqueous fraction tended to be noisier than what we normally see and more difficult to integrate. We feel the average data is accurate because calculating the emissions by peak height (thereby avoiding the integration) produced results that were less than 1% different. The GC aqueous procedure was modified somewhat to try to get more reproducible results for acetic acid. We attribute the noise to this modification.

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

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 -

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

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

Event = the name of the drying cycle.

Run = the number of the 3-hour interval.

Operator, that's you.

Date – 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 $TFR \times (1 - DR)$

Target sample flow rate (TSFR) is the $TFR \times DR$

Check that the sum of these is the Total Flow Rate

Set dilution flow

Set red pointer to desired dilution flow

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. $DR = \text{Absolute value of } [100 * (DR_{\text{Span}} - DR_{\text{Flow}}) / DR_{\text{Flow}}]$

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

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
Rinse 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