



**Contribution of Wood Smoke to  
Particle Matter Levels in Connecticut:  
Source Characterization of Outdoor Wood Furnaces**

**SIPRAC, July 10, 2008**

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# Introduction

Outdoor wood furnaces (OWBs): large sources of wood smoke

Lab tests are ideal conditions

– unlikely to reflect real-world “in-use” PM emissions

This work:

several PM emission tests on a typical OWB (500,000 Btu/h)  
under a range of burn conditions.

Objective 1: Gain a better understanding of how "burn practices" can effect stack PM emissions

Objective 2: Determine the range of particle emissions that could be expected to be found from an in-use uncontrolled OWB

# Methods

Continuous PM measurements made with TEOM

allow observation of short-term variations in PM emissions  
segregate damper open from damper closed emissions

Testing Protocols:

11 test burn days during four different weeks

limited number of speciated (gas and particle) PAH samples

2 test days with prototype oxidation catalyst

Burn practices:

type of wood (hard or soft cord-wood, hemlock slab)

moisture content (seasoned or "green" wood)

size (weight) of load relative to volume of the burn chamber

EPA method 28 "crib" for one test day (dimensional lumber)

## Summary of OWF Testing Results – Damper open

Date of Test	PM emissions, grams/hour STP	Wood Load Description	Wood Moisture Content Range (%)
10/2/07	71	611 # user's hardwood, split	14-29
10/3/07	55	614 # user's hardwood, split	14-29
10/4/07	24	continued burn of 10/3 load	n/a
10/10/07 (Catalyst)	12	610 # user's hardwood, split	14-29
10/11/07 (Catalyst)	1.5	continued burn of 10/10 load	n/a
3/11/08	221	300 # wet Hemlock Slab, 48" lengths	21-35
3/12/08	265	300 # "kiln dry" white Pine split	11-28

3/13/08	147	300 # “wet” mixed hardwood split	26-36
4/8/08	81	300 # EPA Crib	14-29
4/9/08	96	300 # seasoned hardwood, split	13-39
4/10/08	81	150 # seasoned hardwood, split	15-37 (same woodpile as 4/9)

## Take-home points:

1. Softwoods burn MUCH dirtier than hardwood.
2. Emissions from a fresh load are higher than a charred load.
3. Test Crib emissions similar to seasoned hard cordwood.
4. Control technologies can reduce PM emissions by ~ 10 times  
– also reduce gas-phase organic emissions

The report and appendices:

<http://www.nescaum.org/documents/source-characterization-of-outdoor-wood-furnaces>

Or:

[tinyurl.com/4m6jpp](http://tinyurl.com/4m6jpp)

or:

[tinyurl.com/owb-stack-tests](http://tinyurl.com/owb-stack-tests)

video:

<ftp://airbeat.org/private/george>

# Other Pollutants of Concern

==> SO<sub>2</sub> and mercury... varies with where the tree grew.

Elemental analysis of OWB owner's wood:

PANalytical

**Sample WOOD**

**IQ+ concentrations of sample WOOD**

	Compound Name	Conc. (%)	Absolute Error (%)
1	C6H10O5	(99.77)	
2	Mg	0.008653	0.001
3	Al	0.04703	0.001
4	Si	0.01665	0.001
5	P	0.001100	0.001
6	S	0.01134	0.001
7	K	0.07914	0.001
8	Ca	0.05234	0.001
9	Mn	0.008213	0.001
10	Fe	0.009439	0.001

Normalised to: 100. %

### 3.2.4 PAH results

**Table 3-1. PAH Emissions**

PAH Date	PAH Emissions in Grams per Hour @ STP, Wet				
	<u>10/2/2007</u>	<u>10/3/2007</u>	<u>10/3/2007</u>	<u>10/4/2007</u>	<u>10/4/2007</u>
naphthalene	0.83283	0.51363	3.60259	5.17109	4.94183
2-methylnaphthalene	0.02023	0.05119	0.08455	0.18409	0.07079
acenaphthylene	0.00060	0.00164	0.00169	0.00236	0.00320
acenaphthene	0.00093	0.00187	0.00180	0.00234	0.00212
fluorene	0.00116			0.00311	
phenanthrene	0.00151	0.00381	0.00323	0.00405	0.00185
anthracene		0.00023		0.00023	
fluoranthene	0.00128	0.00504	0.00216	0.00121	0.00169
pyrene	0.00192	0.00650	0.00308	0.00268	
benzo(a)anthracene	0.00283	0.00596	0.00143	0.00063	0.00078
chrysene	0.00353	0.00736	0.00168	0.00061	0.07594
benzo(b)fluroanthene	0.00315			0.00047	
benzo(k)fluroanthene		0.00687	0.00184		0.00035
benzo(e)pyrene	0.00094		0.00087	0.00029	0.00008
benzo(a)pyrene	0.00127	0.00149	0.00102	0.00026	0.00008
perylene	0.00018		0.00021	0.00027	0.00002
indeno(1,2,3-c,d)pyrene	0.00043	0.00083	0.00034	0.00013	0.00012
dibenzo(a,h)anthracene	0.00011	0.00024	0.00011	0.00003	
benzo(g,h,i)perlene	0.00055	0.00104	0.00047	0.00014	0.00013
<b>PM g/h @ STP, Wet</b>	30.7	42.9	14.5	17.1	14.5
Percent damper open:	34.7	48.3	41.3	54.7	51.3

Notes: Oct. 2 and 3 runs are with new full wood load; Oct. 4 is with Oct. 3's load.

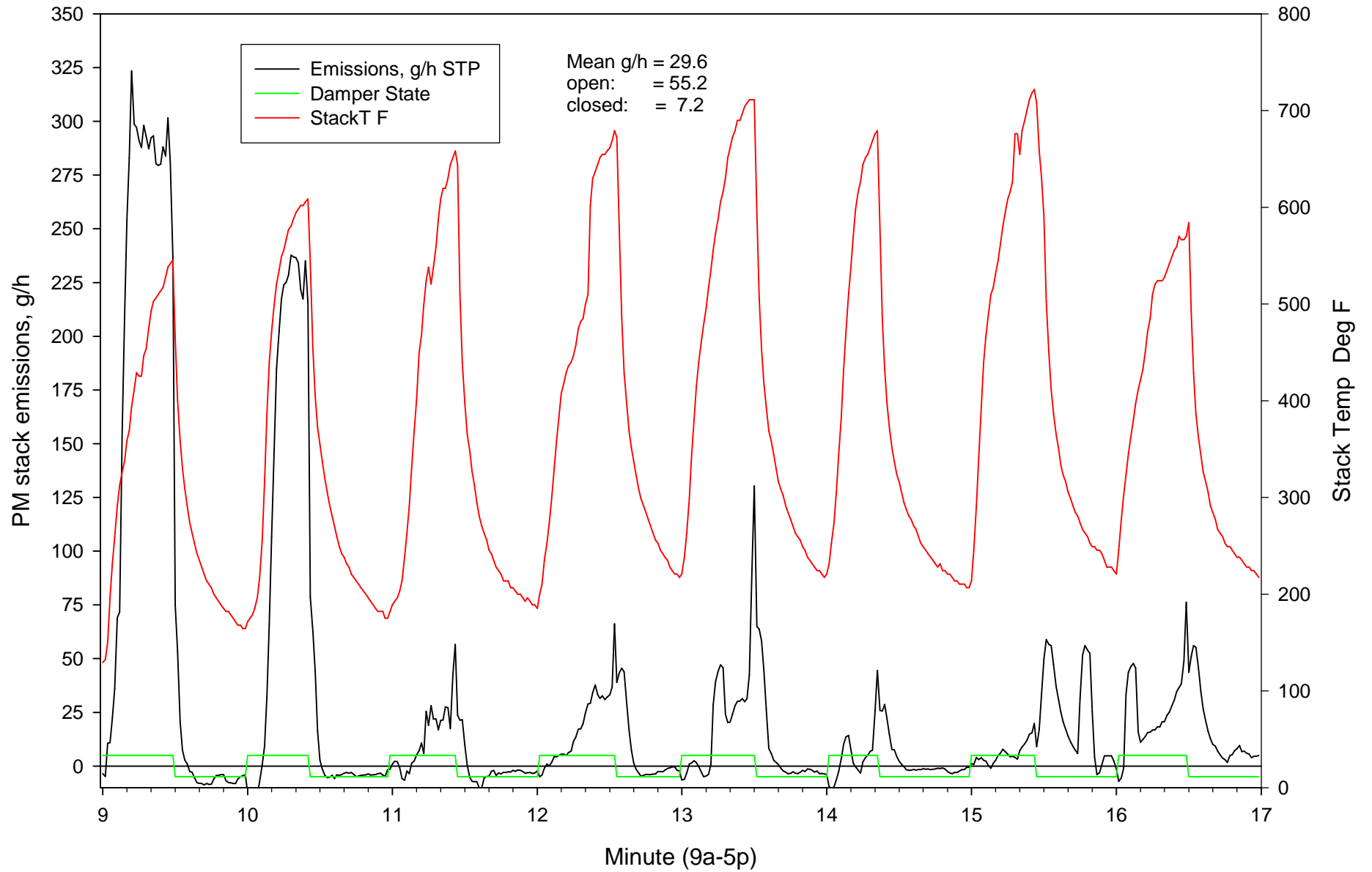
Empty cells indicate non-detects. Values are the sum of gas and vapor phase PAH.

PM emissions match PAH sample collection time.

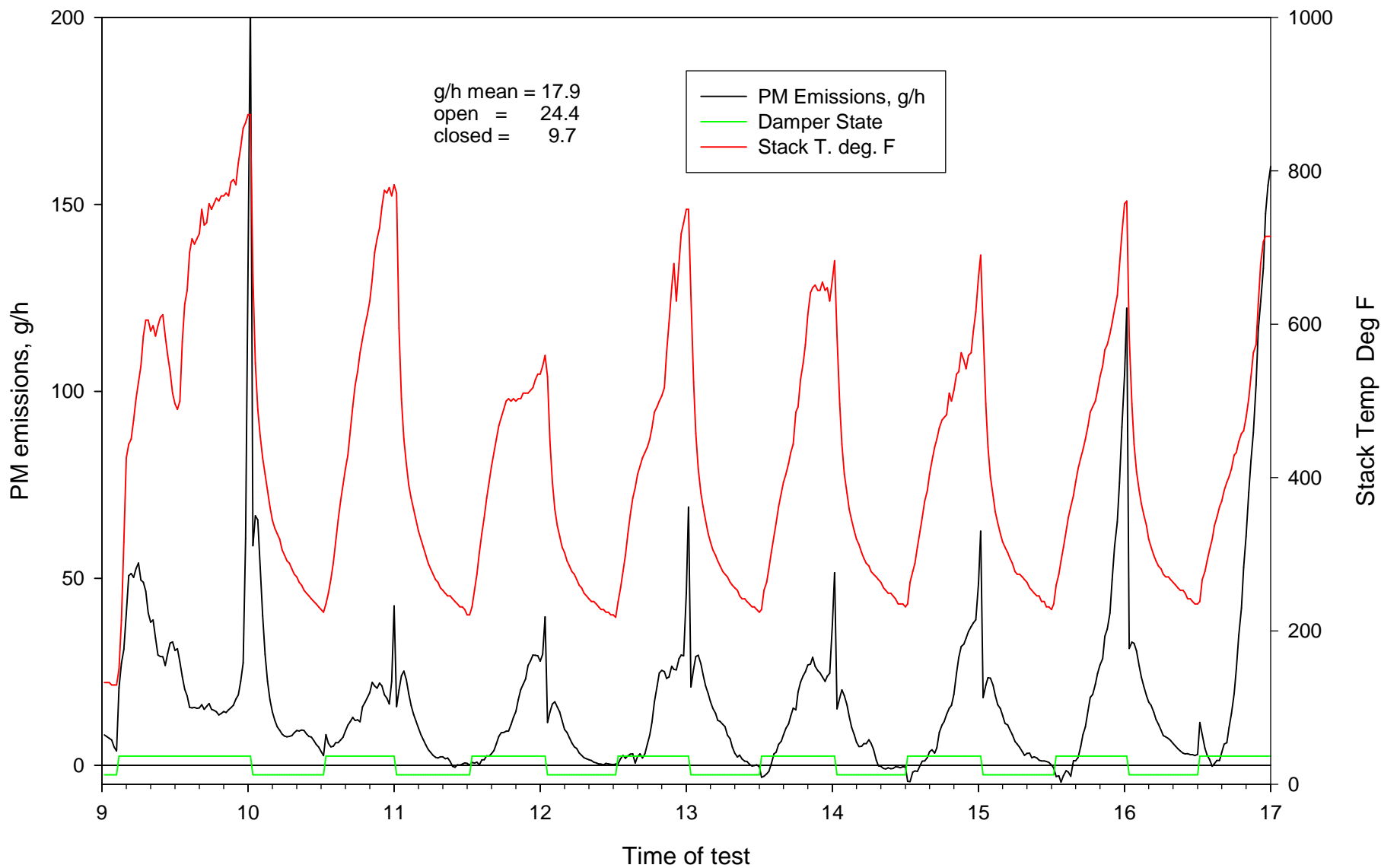
Virtually all the PAH by mass is naphthalene for all the samples. For the last three samples, it makes up 25 to 30 percent of the total PM emissions. While this does not mean PAHs make up that amount of the PM (since gas phase PAH is included here), it does indicate that OWBs can be very large sources of naphthalene. Additional detail on the PAH sampling method is included in the appendix to this report.



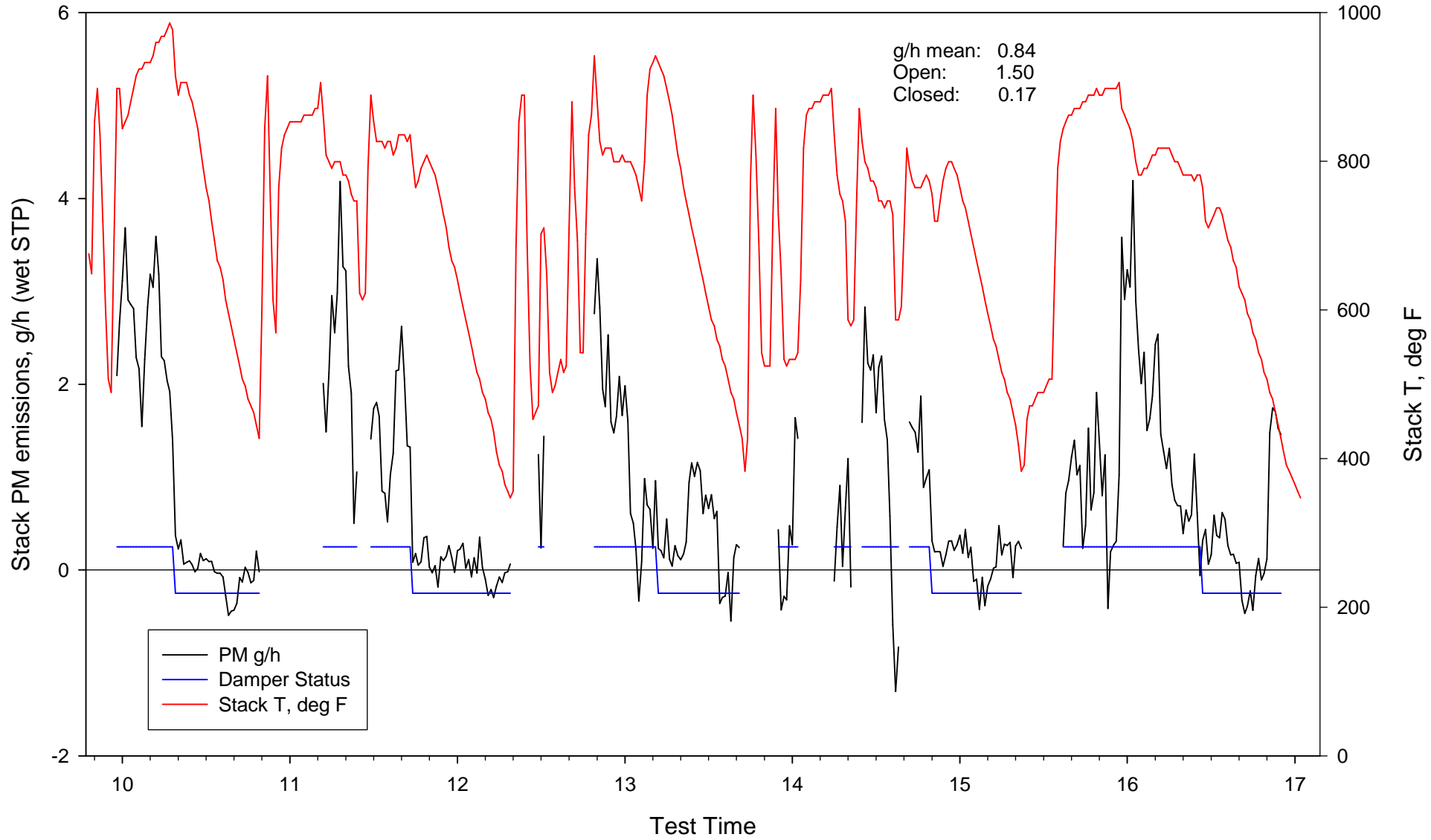
# Oct 3, 2007 OWB tests



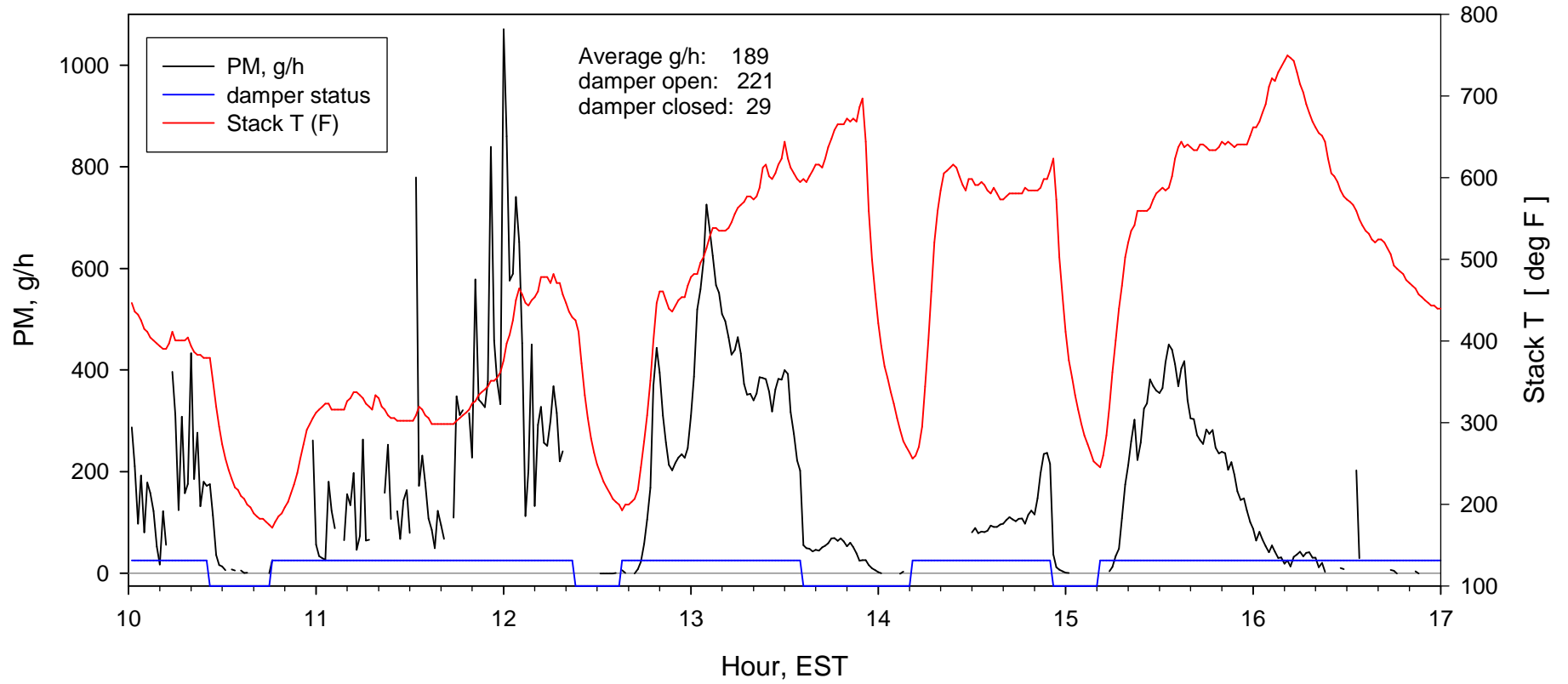
# Oct 4, 2007 OWB tests



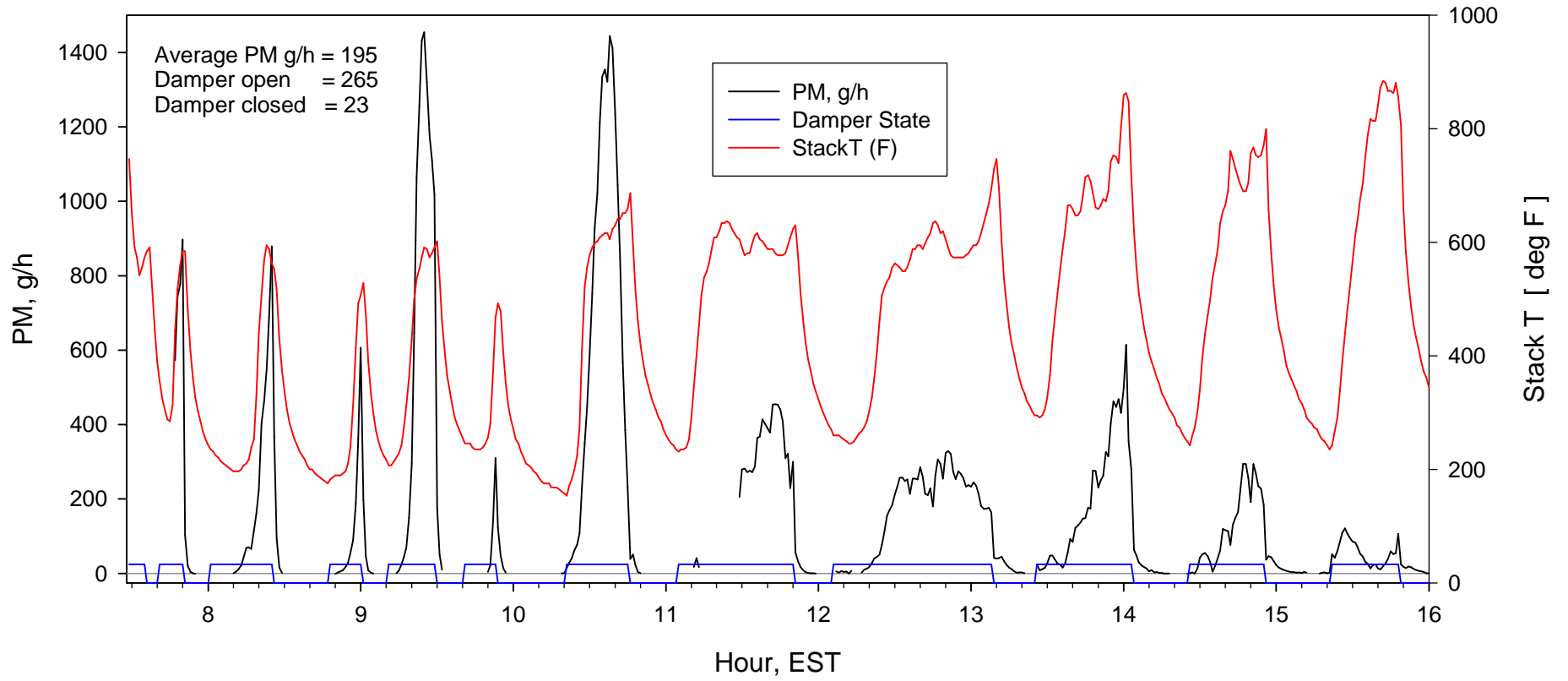
Oct. 11 tests with catalytic control device  
PM data constrained to when propane burner was off



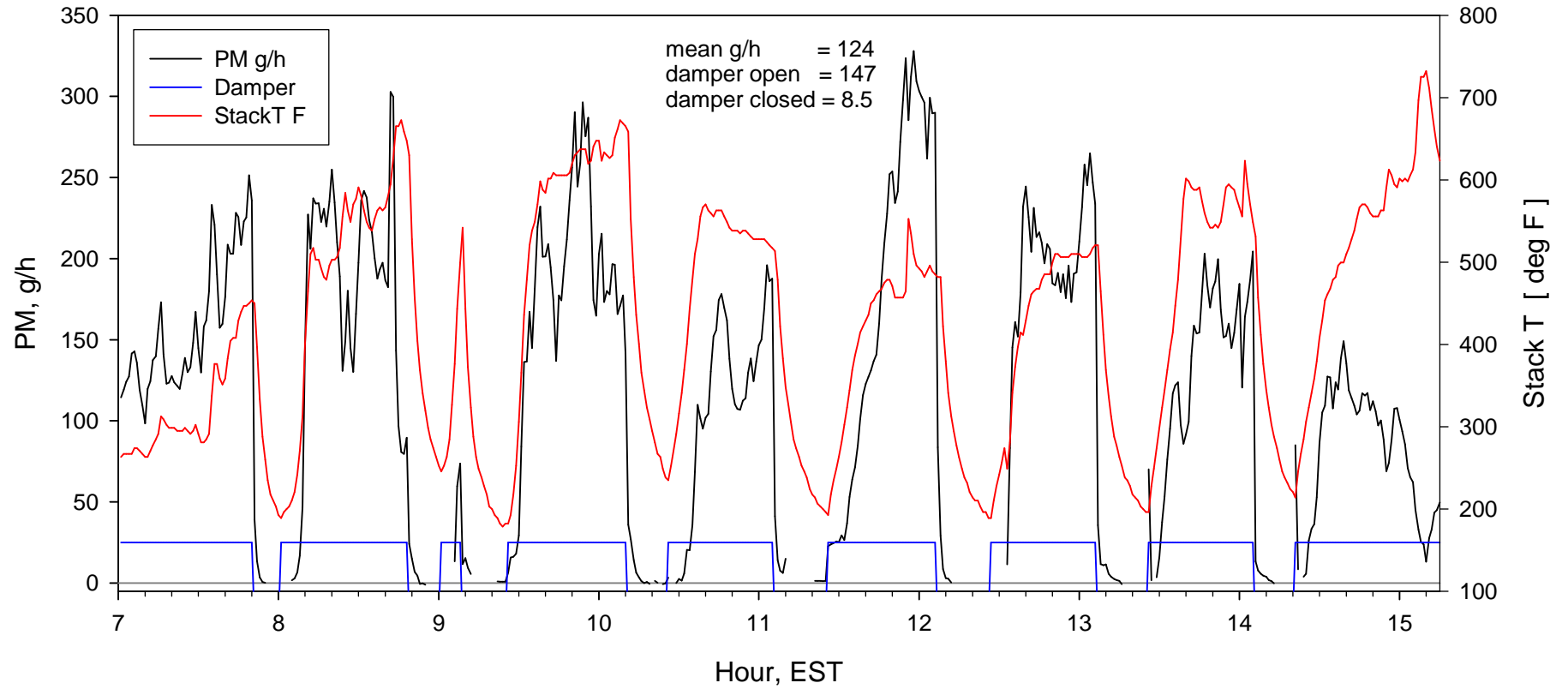
### March 11 2008: wet Hemlock Slab



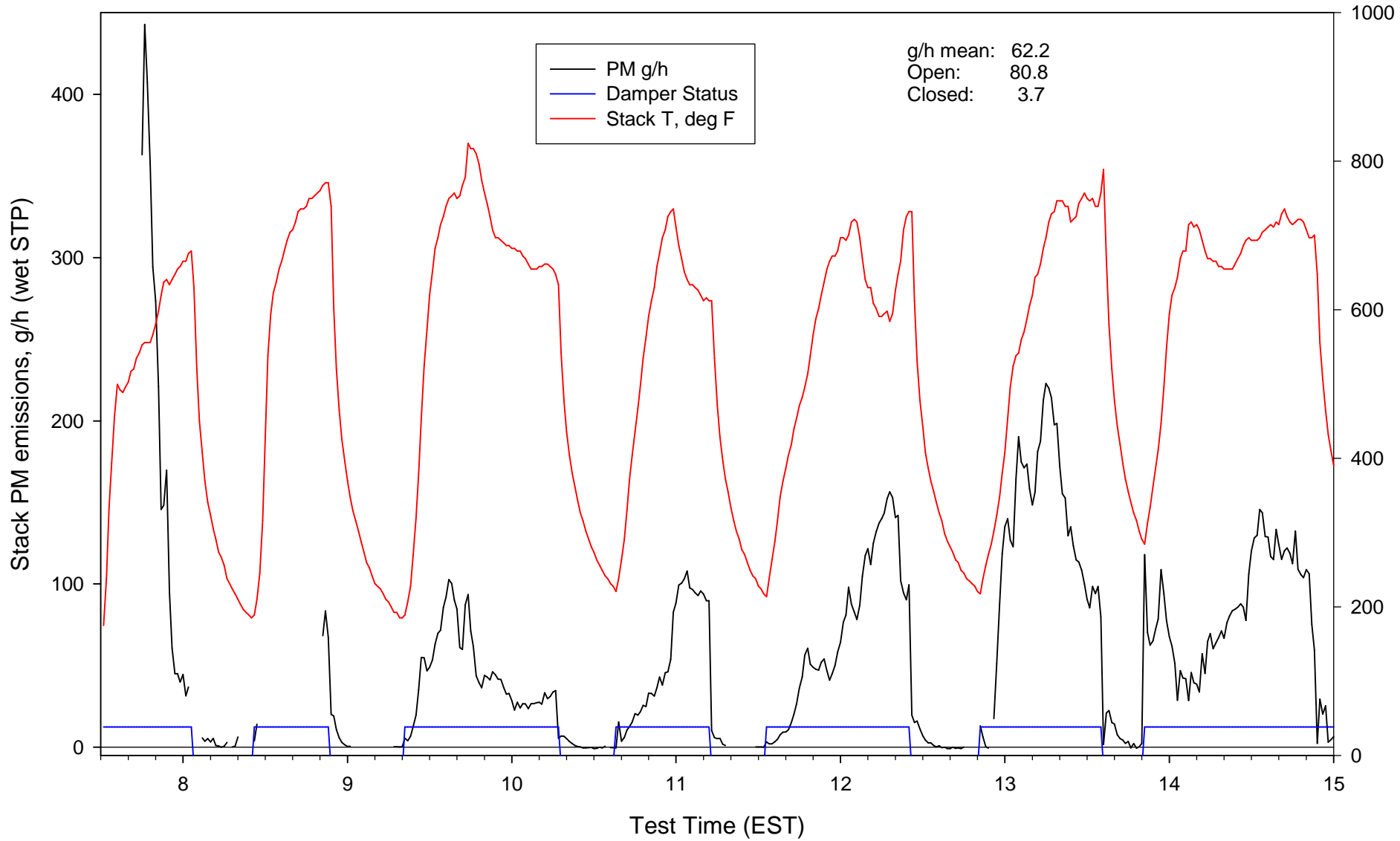
# March 12 2008 Kiln dried Pine



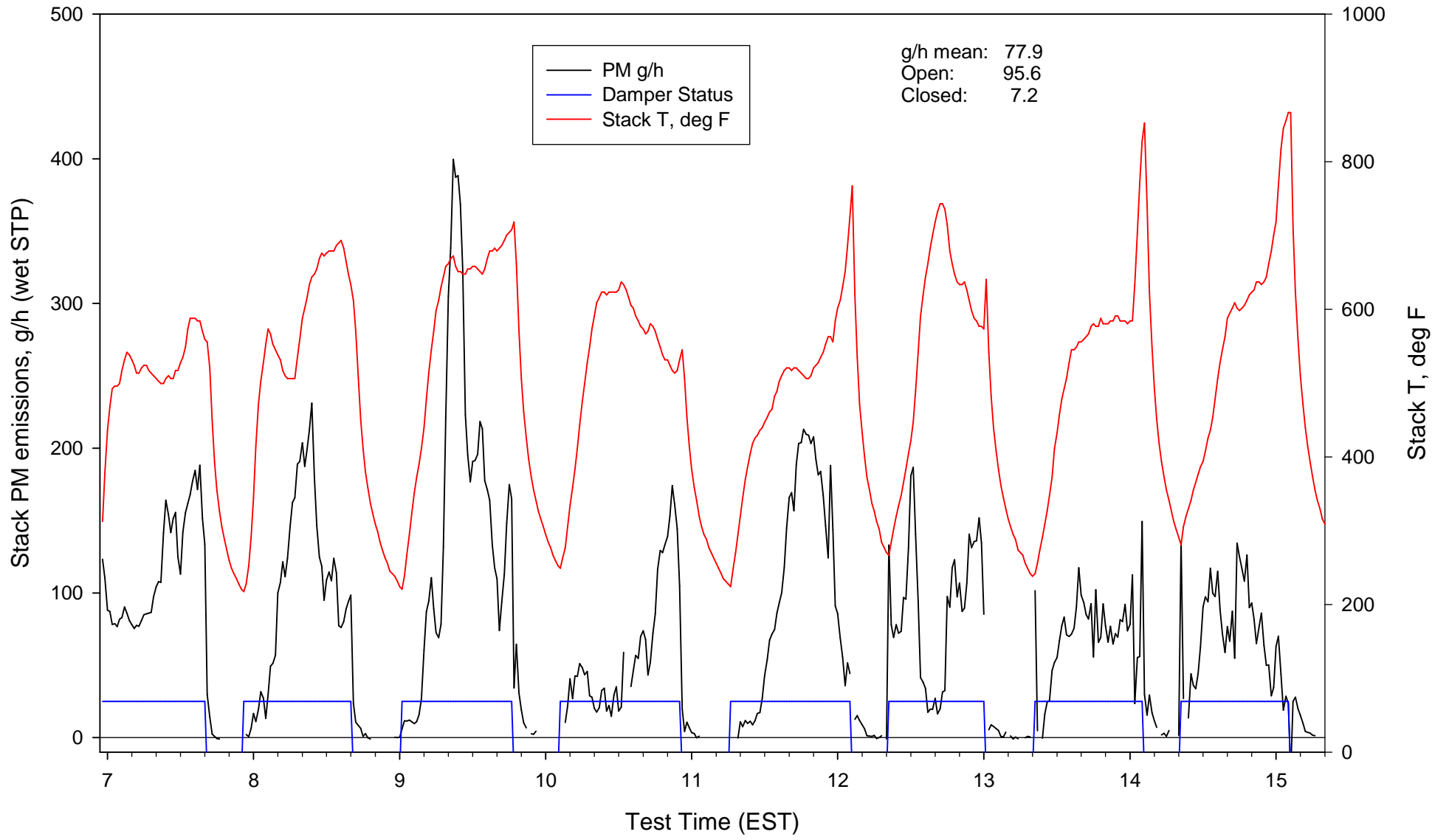
### March 13 2008 "wet" mixed hardwood



# April 8, 2008 tests with 300# oak crib

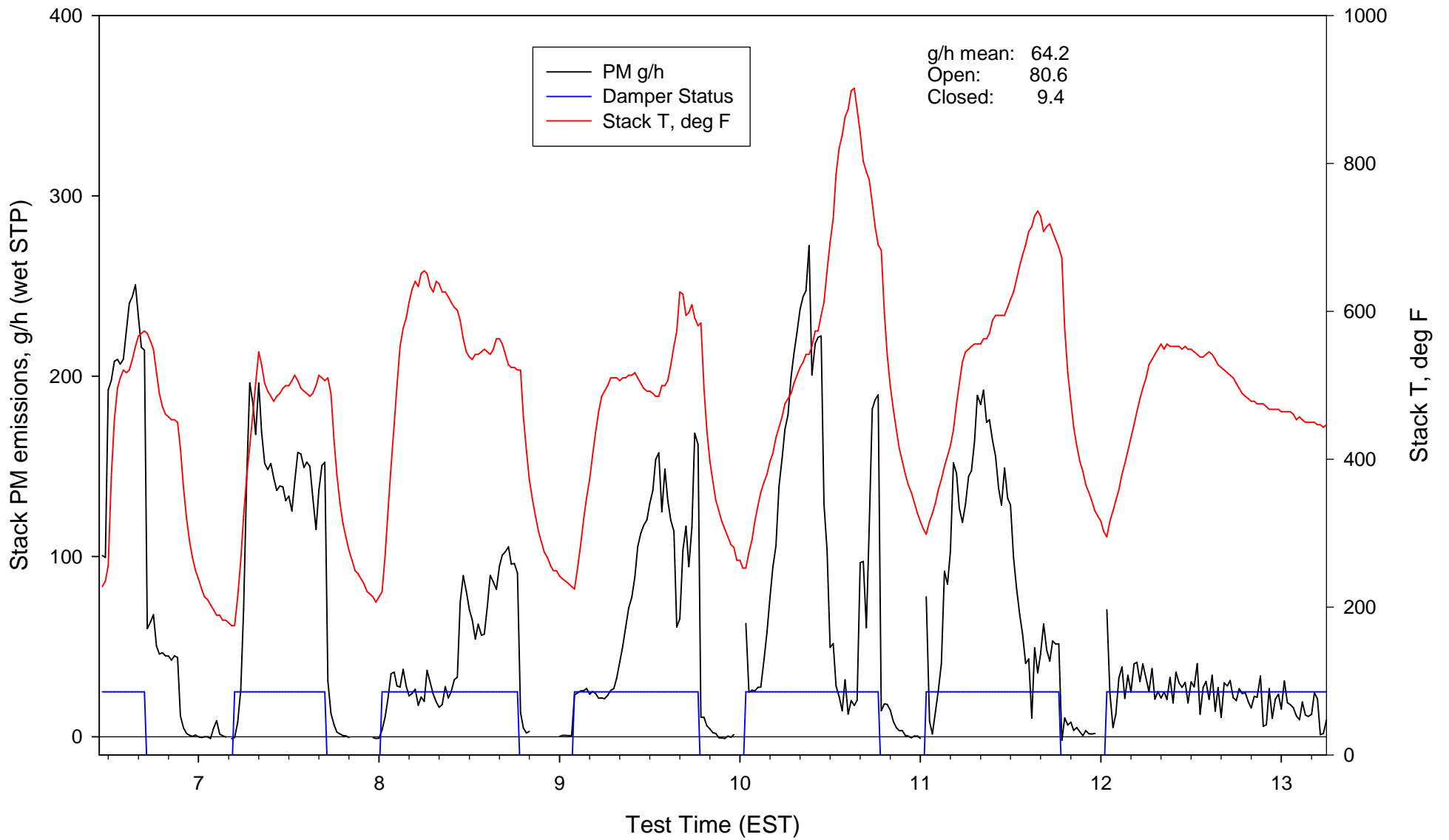


# April 9, 2008 tests with 300# seasoned oak cordwood

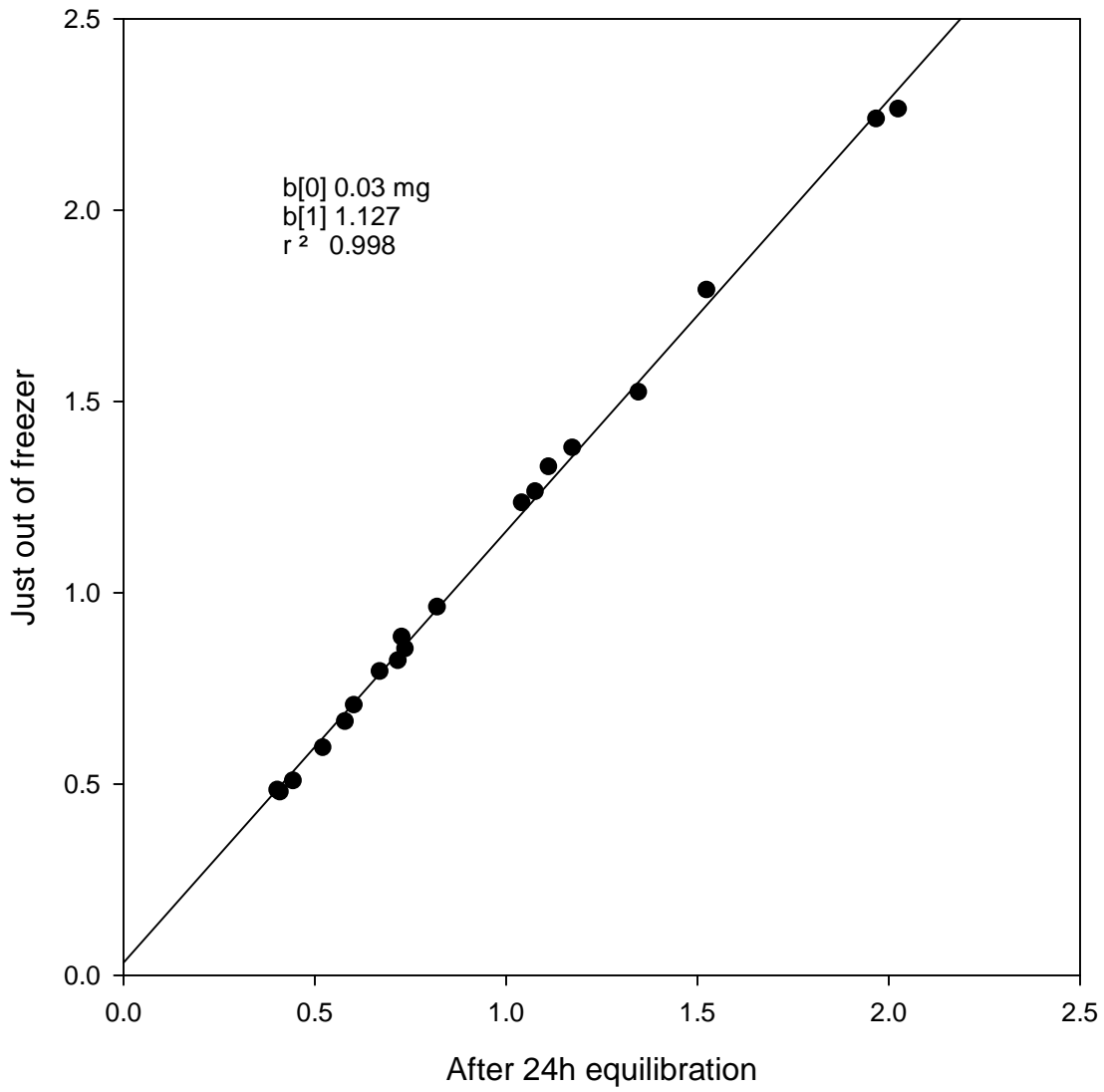




# April 10, 2008 tests with 150# seasoned oak cordwood



OWB Week 4 Teflon filters  
Net Mass in mg



4 WS sites, Winter only diurnal plots

