Contribution of Wood Smoke to Particle Matter Levels in Connecticut:

Source Characterization of Outdoor Wood Furnaces

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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

On-Site Video for testing methods overview:

Fall 2007 (rotating disk dilutor):
http://tinyurl.com/3gdswx [Low-Res, 25 mb]
http://tinyurl.com/46us8g [Hi-Res, 520 mb]

Spring 2008 (EPA dilution tunnel):
http://tinyurl.com/3o63vp [Low-Res, 30 mb]
http://tinyurl.com/3z9t2v [Part 1 HiRes, 215 mb]
http://tinyurl.com/4jpkj5 [Part 2 HiRes, 300 mb]

A link to all the above:
http://tinyurl.com/3fm983

Other Pollutants of Concern

==> SO2 and mercury... varies with where the tree grew.

Elemental analysis of OWB owner's wood:

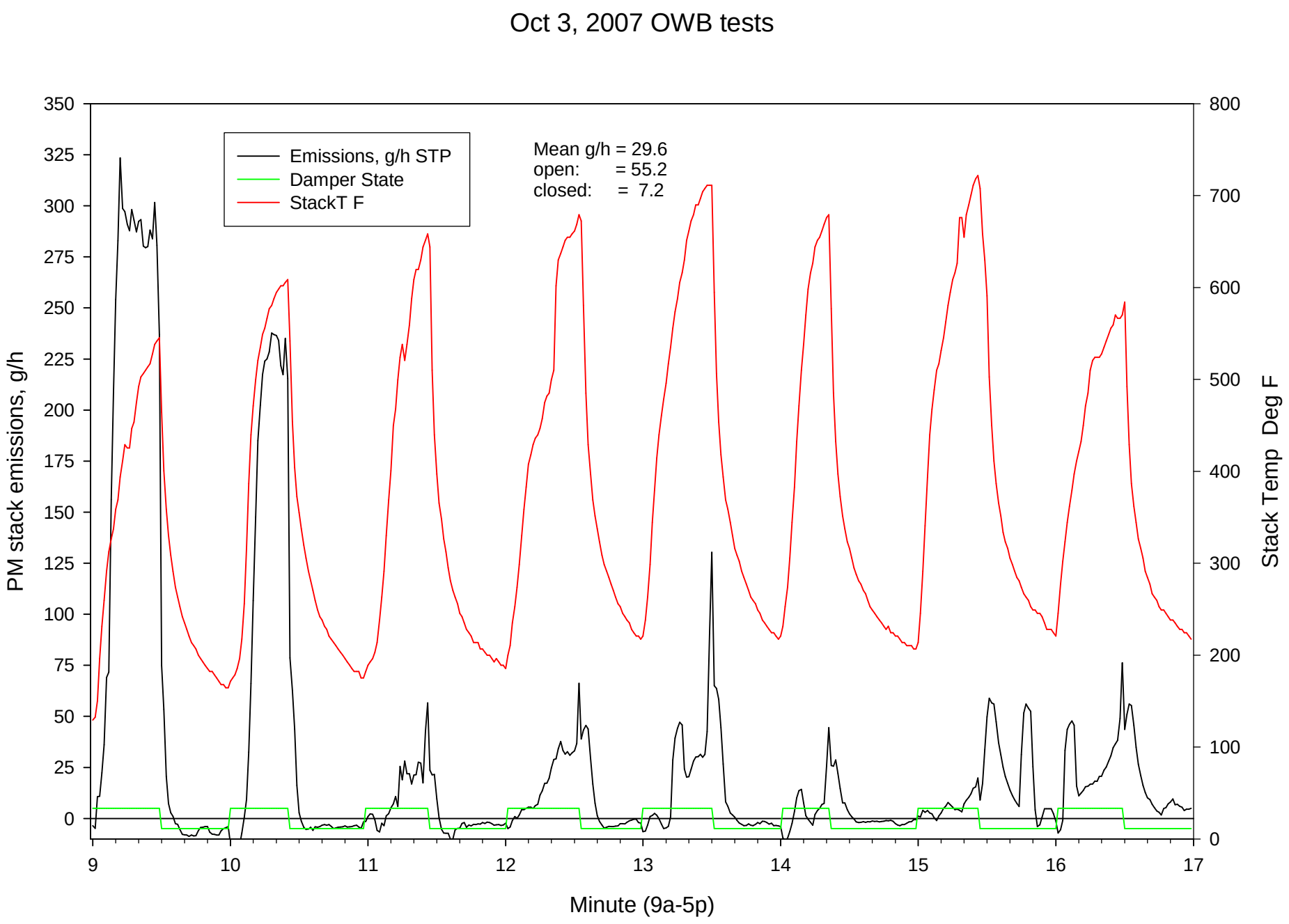
PANalytical

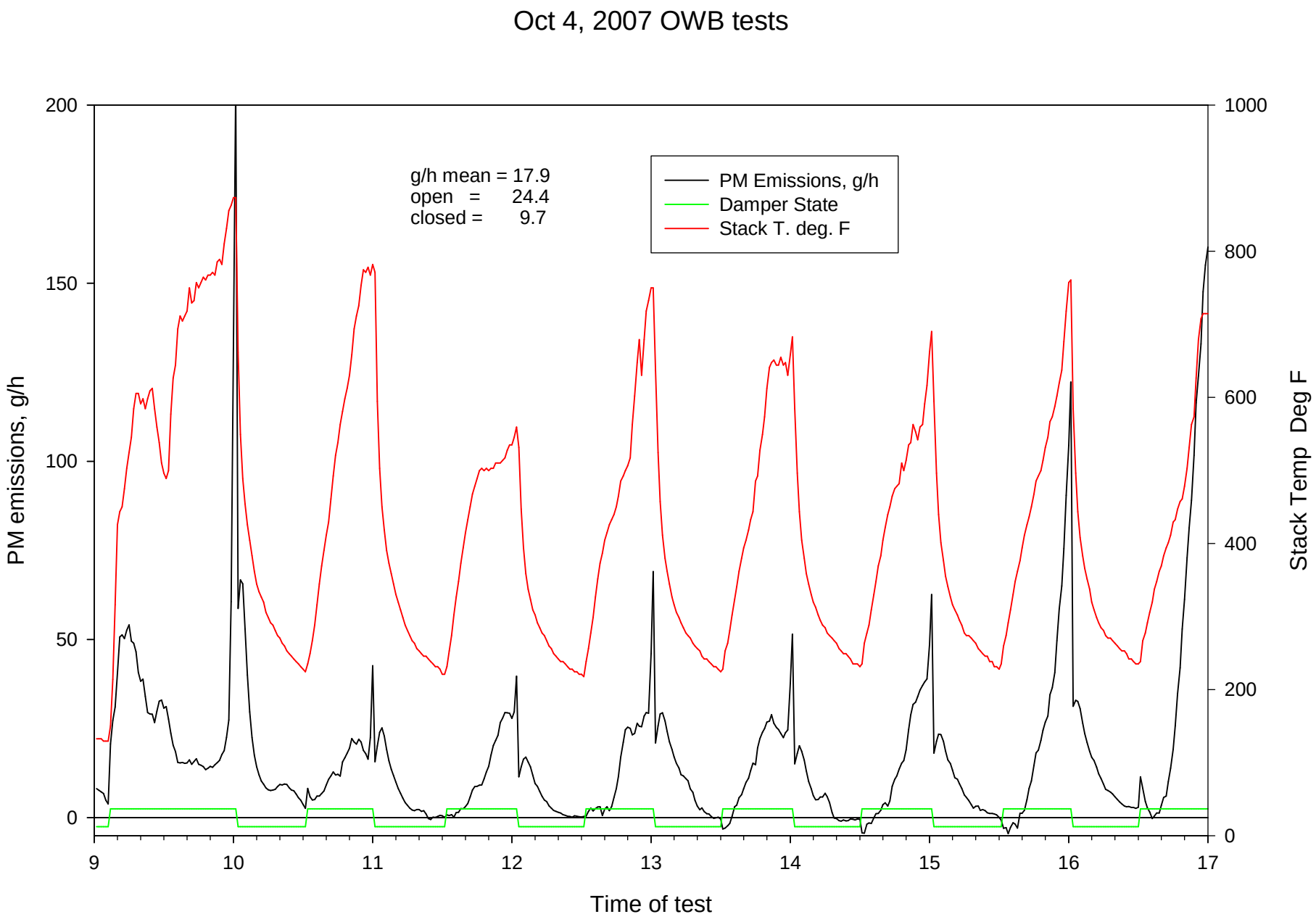
Sample WOOD

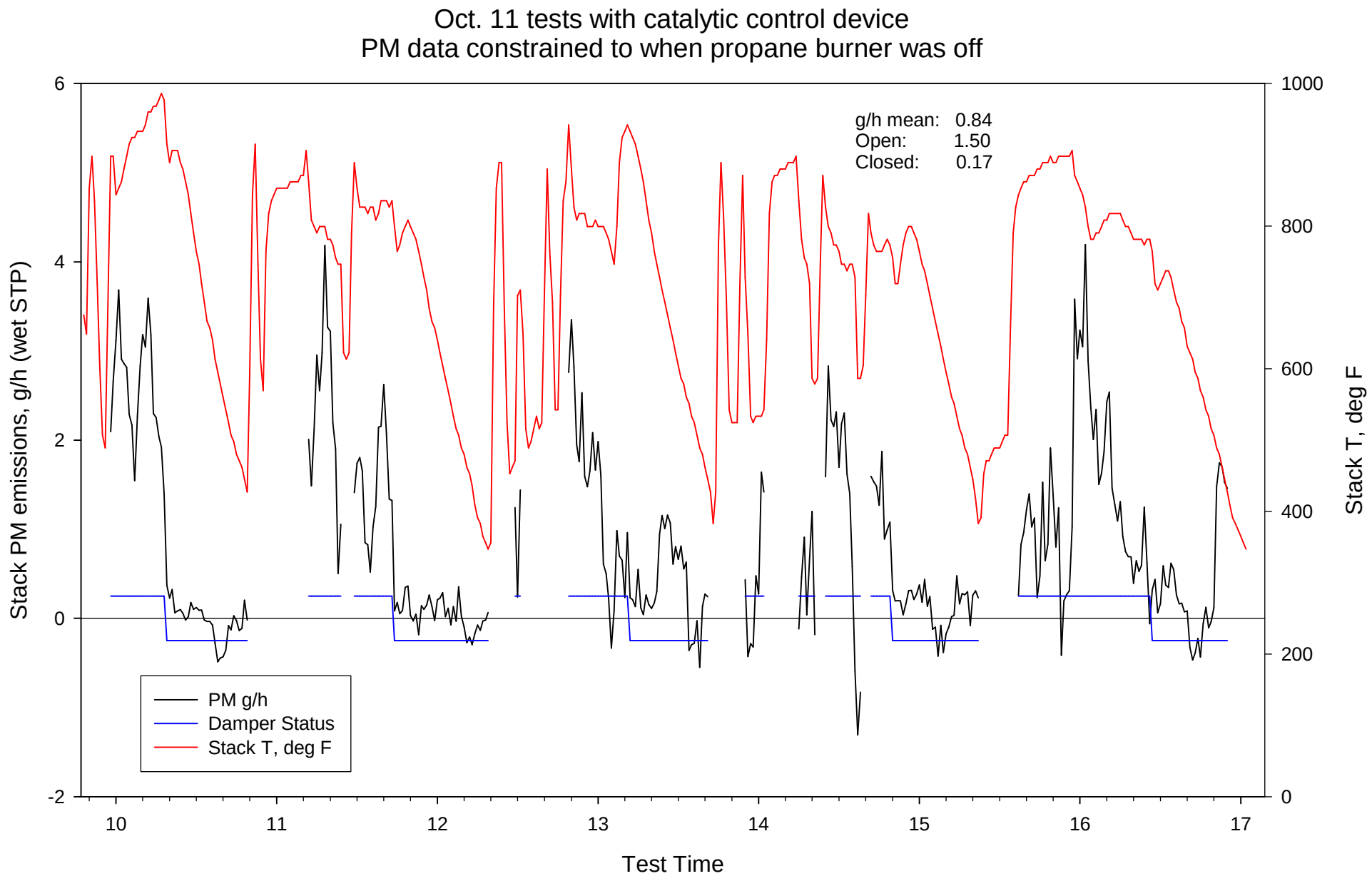
IQ+ concentrations of sample WOOD

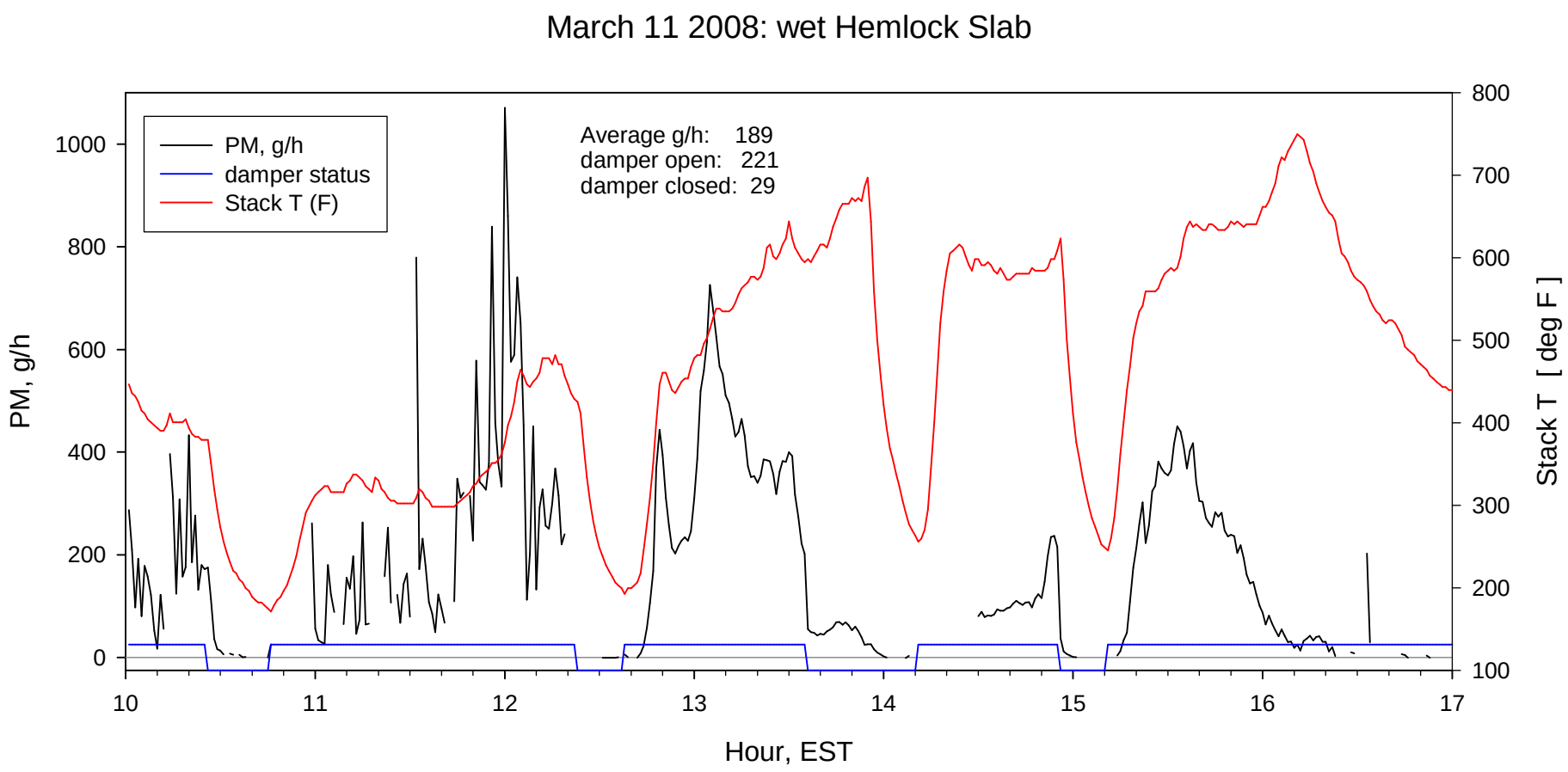
	Compound Name	Conc. (%)	Absolute Error (%)
1	C6H10O5	(99.77)	
2	Mg	0.008653	0.001
3	Al	0.04703	0.001
4	Si	0.01665	0.001
5	P	0.001100	0.001
6	S	0.01134	0.001
7	K	0.07914	0.001
8	Ca	0.05234	0.001
9	Mn	0.008213	0.001
10	Fe	0.009439	0.001

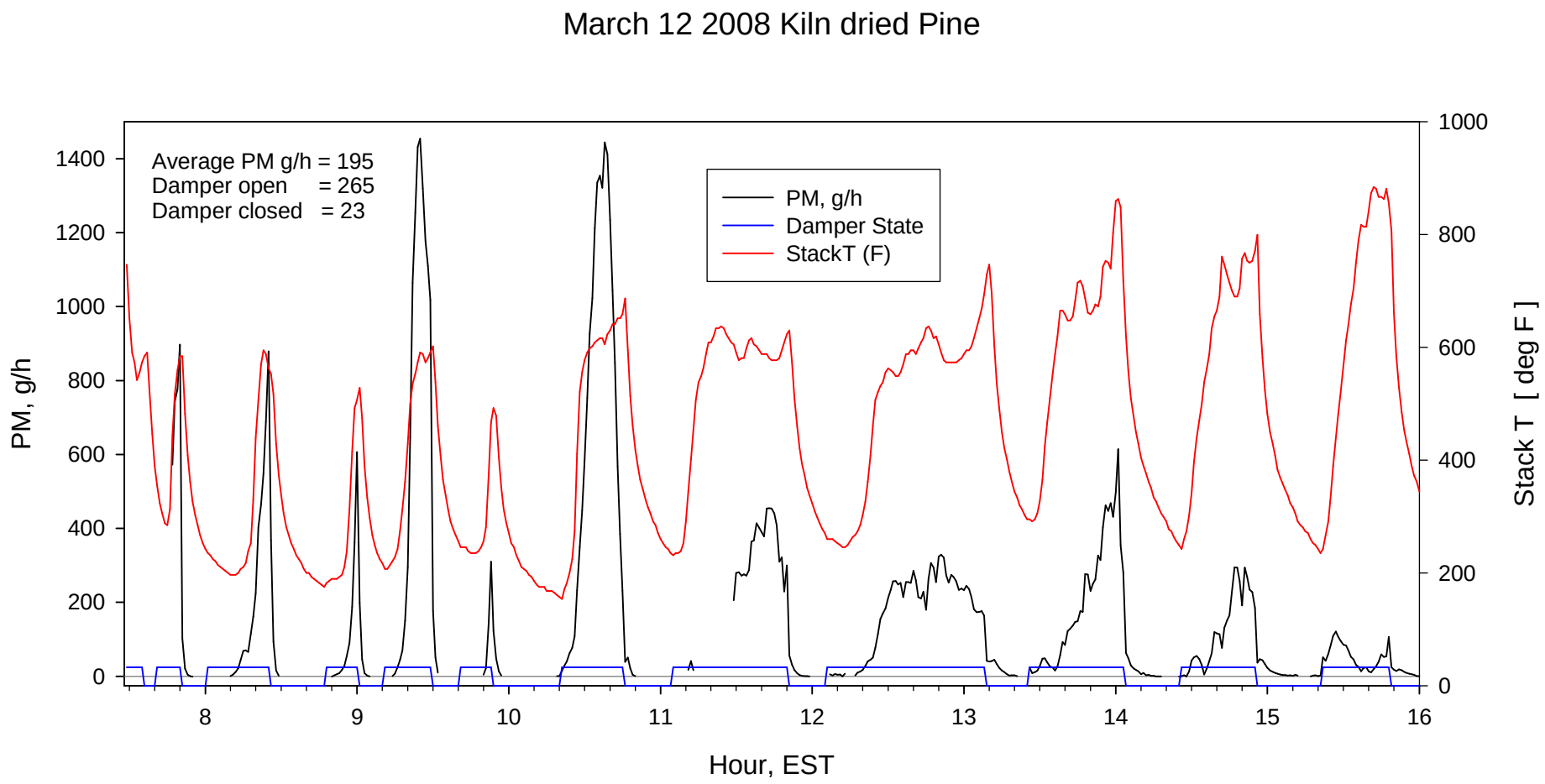
Normalised to: 100. %

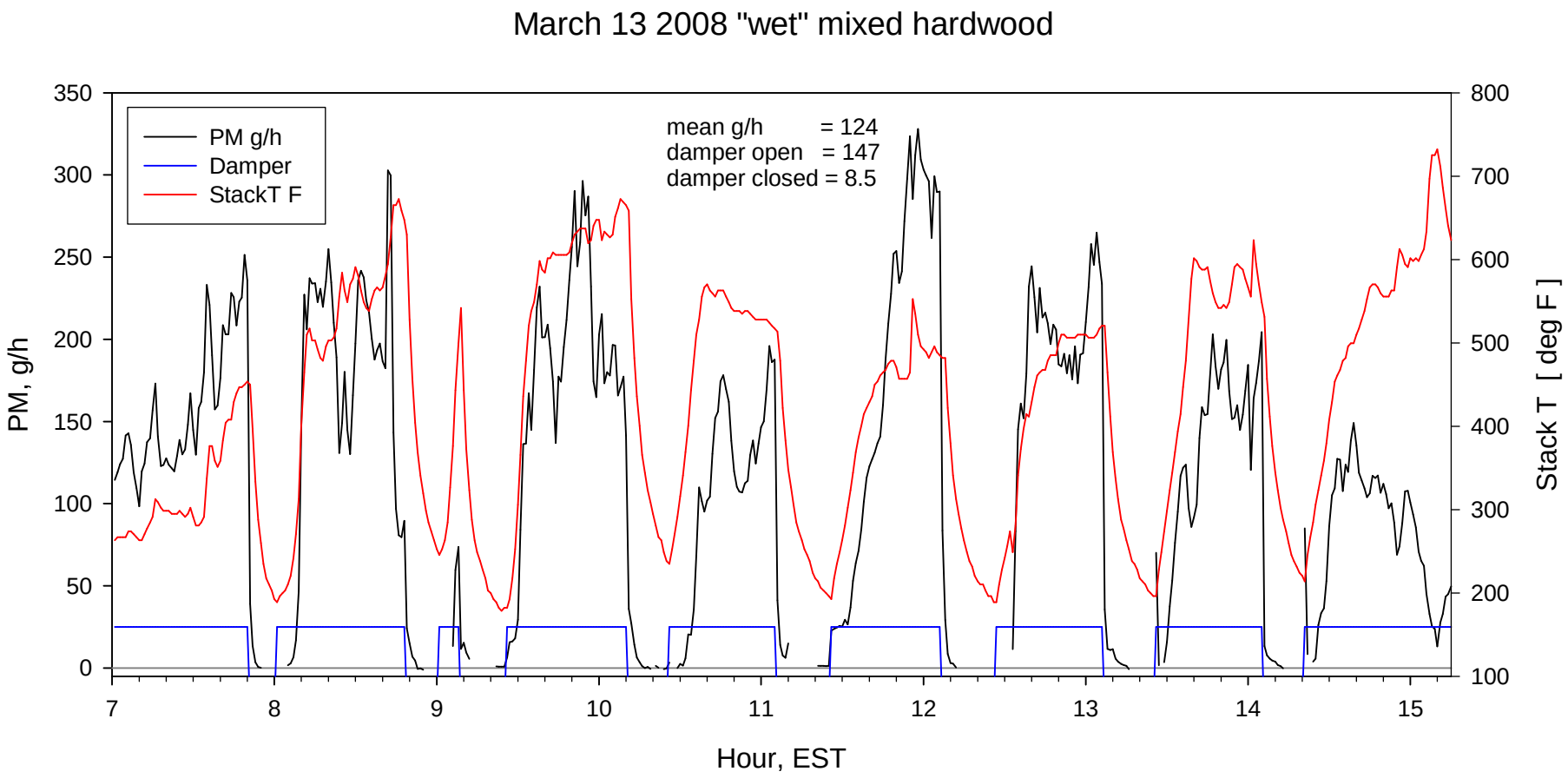

Oct 3, 2007 OWB tests
Emissions, g/h STP
Damper State
StackT F
Mean g/h = 29.6
open: = 55.2
closed: = 7.2
PM stack emissions, g/h
Stack Temp Deg F
Minute (9a-5p)
350
325
300
275
250
225
200
175
150
125
100
75
50
25
0
800
700
600
500
400
300
200
100
0
9
10
11
12
13
14
15
16
17

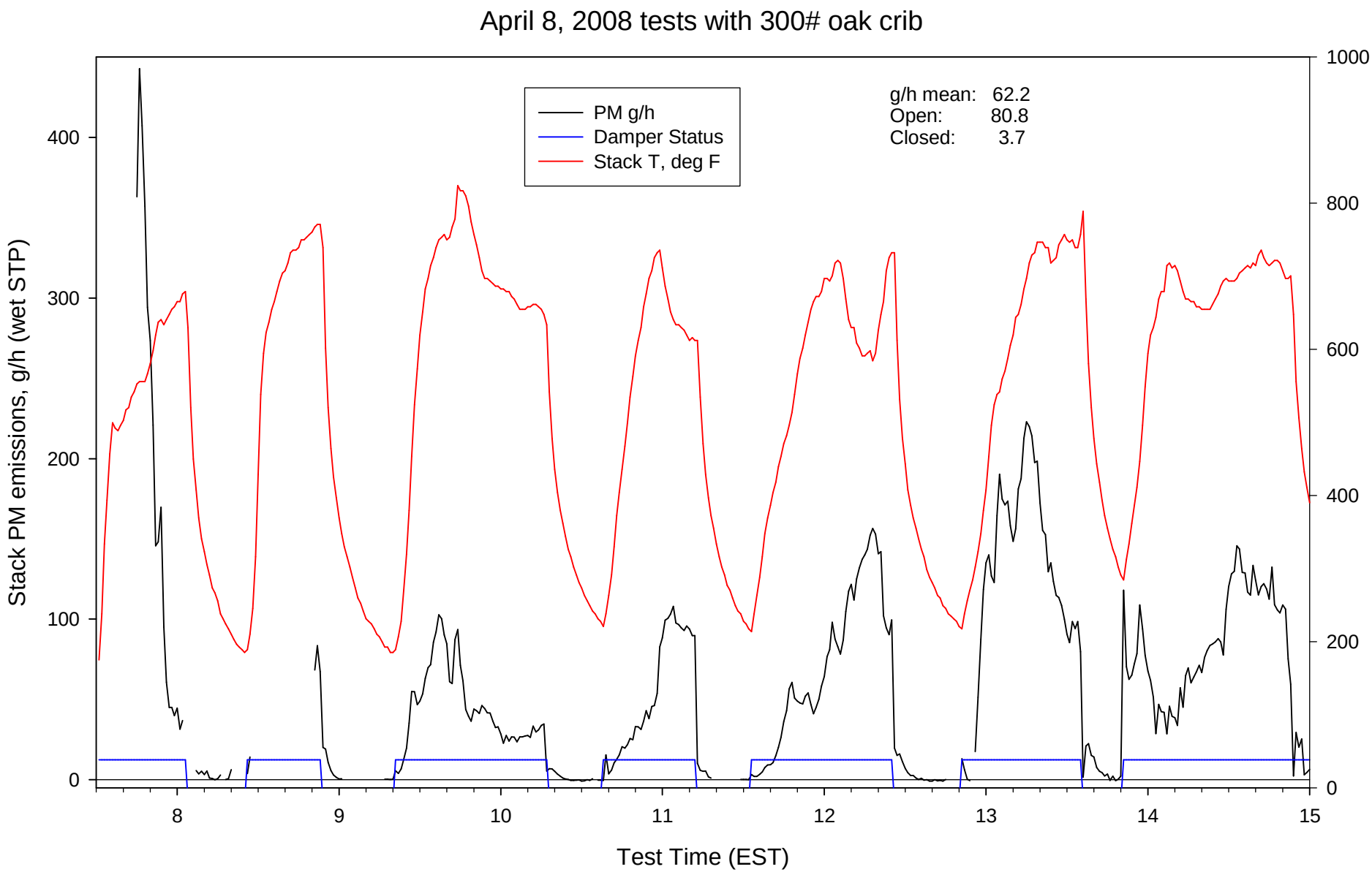

Oct 4, 2007 OWB tests
g/h mean = 17.9
open = 24.4
closed = 9.7
PM Emissions, g/h
Damper State
Stack T. deg. F
PM emissions, g/h
Stack Temp Deg F
Time of test
200
150
100
50
0
1000
800
600
400
200
0
9
10
11
12
13
14
15
16
17

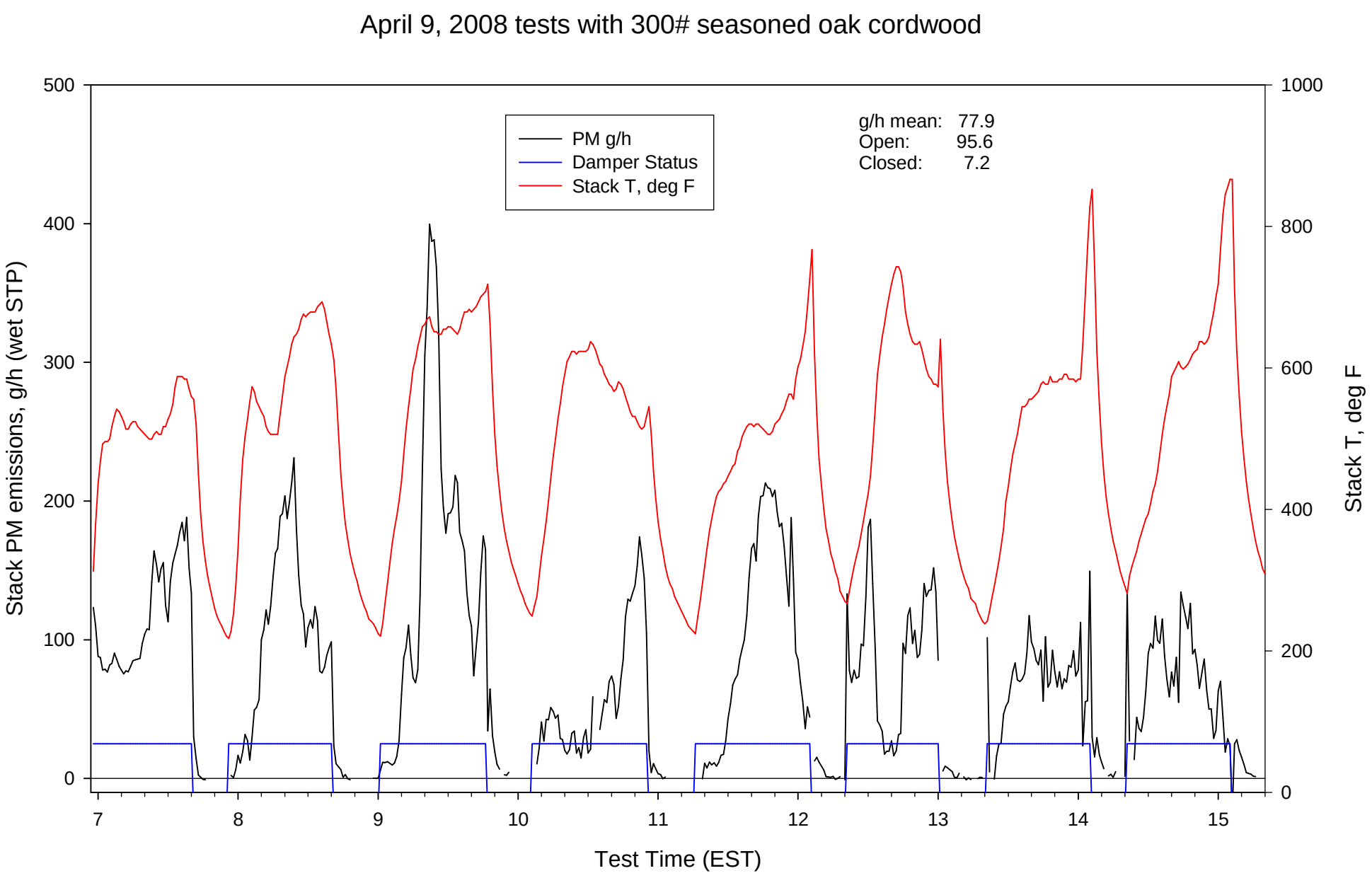

Oct. 11 tests with catalytic control device
PM data constrained to when propane burner was off
g/h mean: 0.84
Open: 1.50
Closed: 0.17
PM g/h
Damper Status
Stack T, deg F
Stack PM emissions, g/h (wet STP)
Stack T, deg F
Test Time
6
4
2
0
-2
1000
800
600
400
200
0
10
11
12
13
14
15
16
17

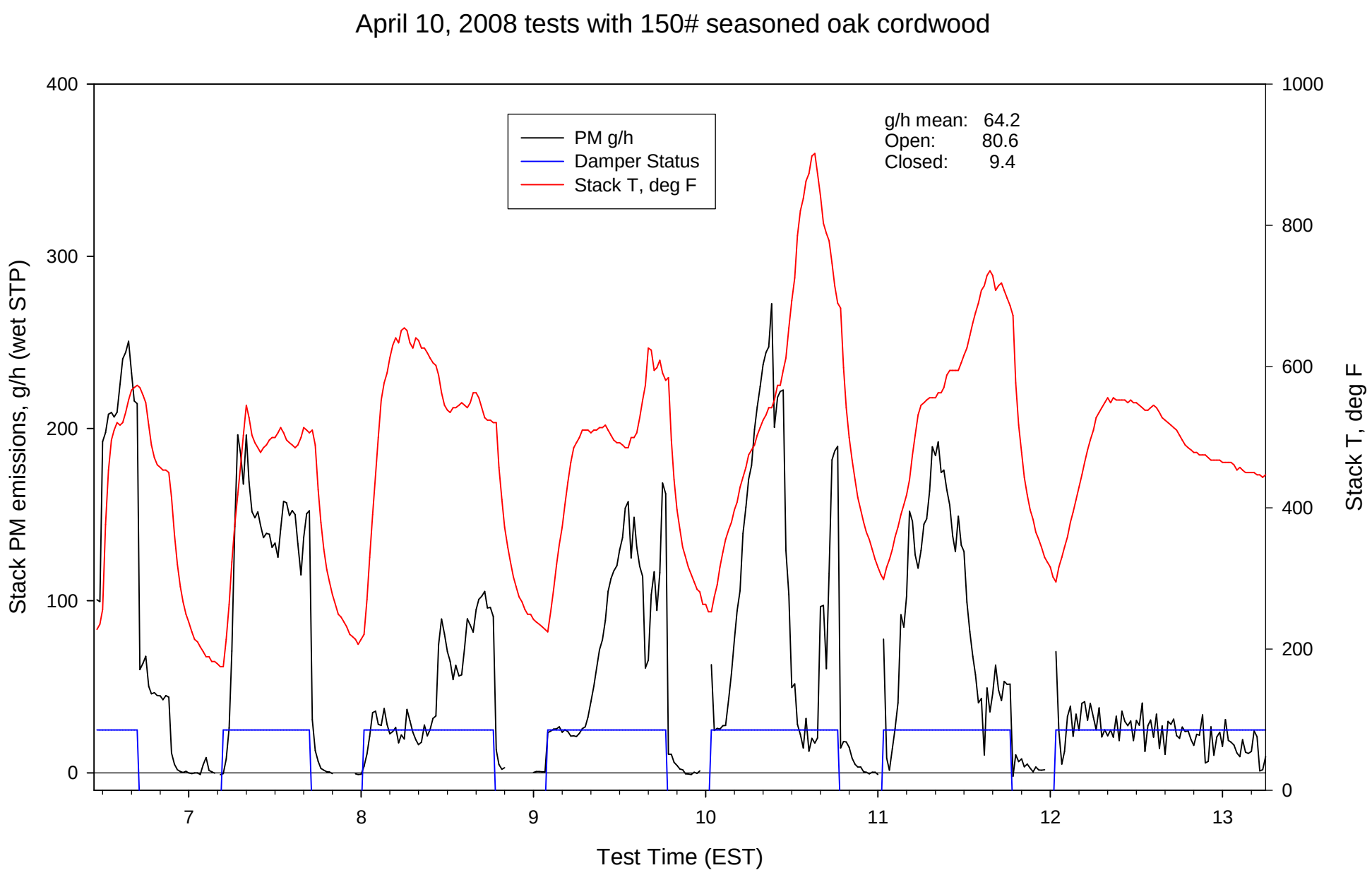

March 11 2008: wet Hemlock Slab
PM, g/h
damper status
Stack T (F)
Average g/h: 189
damper open: 221
damper closed: 29
PM, g/h
Stack T [deg F]
Hour, EST
0
200
400
600
800
1000
100
200
300
400
500
600
700
800
10
11
12
13
14
15
16
17


March 12 2008 Kiln dried Pine
Average PM g/h = 195
Damper open = 265
Damper closed = 23
PM, g/h
Damper State
StackT (F)
PM, g/h
Stack T [deg F]
Hour, EST
0
200
400
600
800
1000
1200
1400
0
200
400
600
800
1000
8
9
10
11
12
13
14
15
16

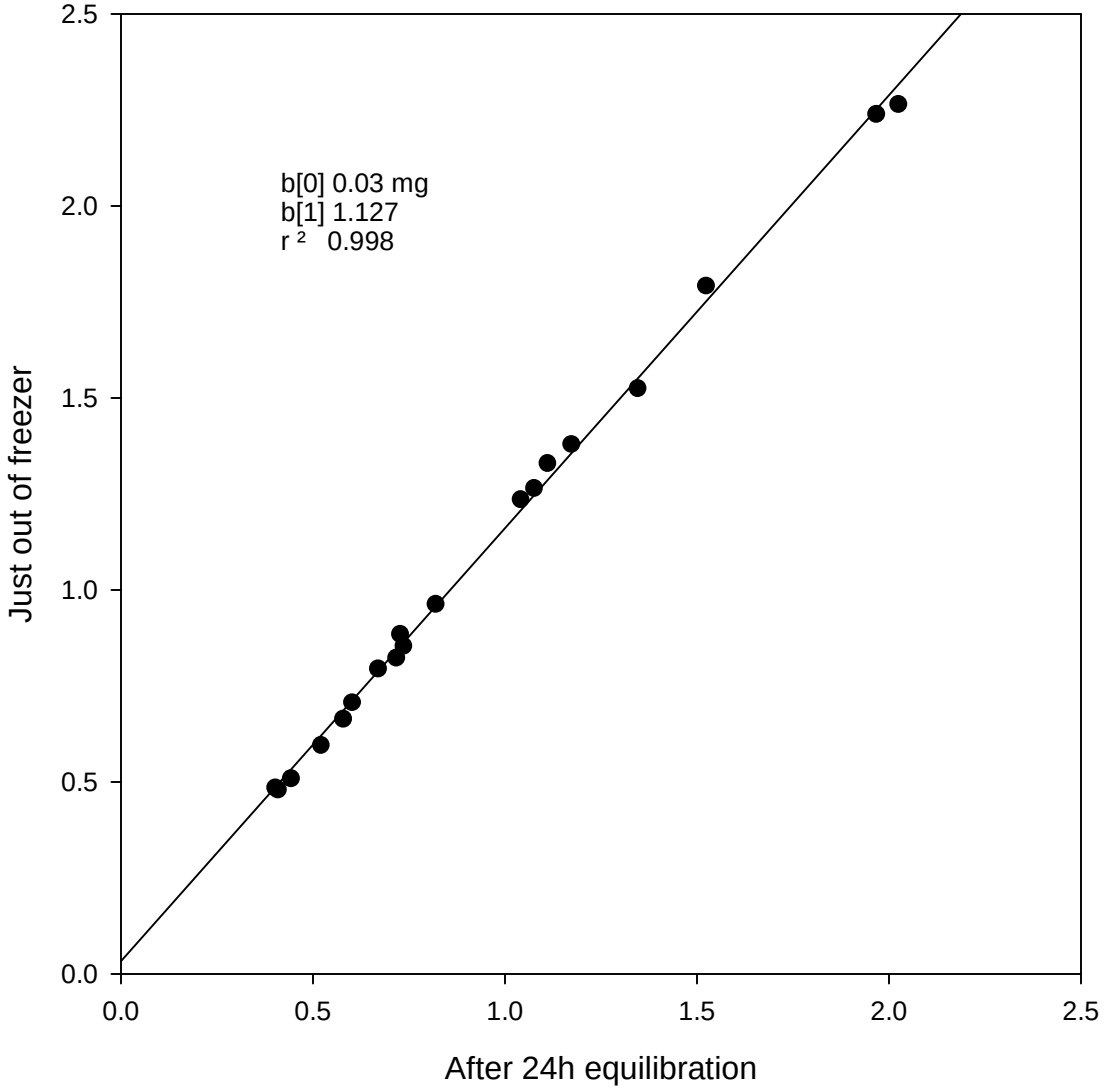

March 13 2008 "wet" mixed hardwood
PM g/h
Damper
StackT F
mean g/h = 124
damper open = 147
damper closed = 8.5
PM, g/h
Stack T [deg F]
Hour, EST
350
300
250
200
150
100
50
0
800
700
600
500
400
300
200
100
7
8
9
10
11
12
13
14
15

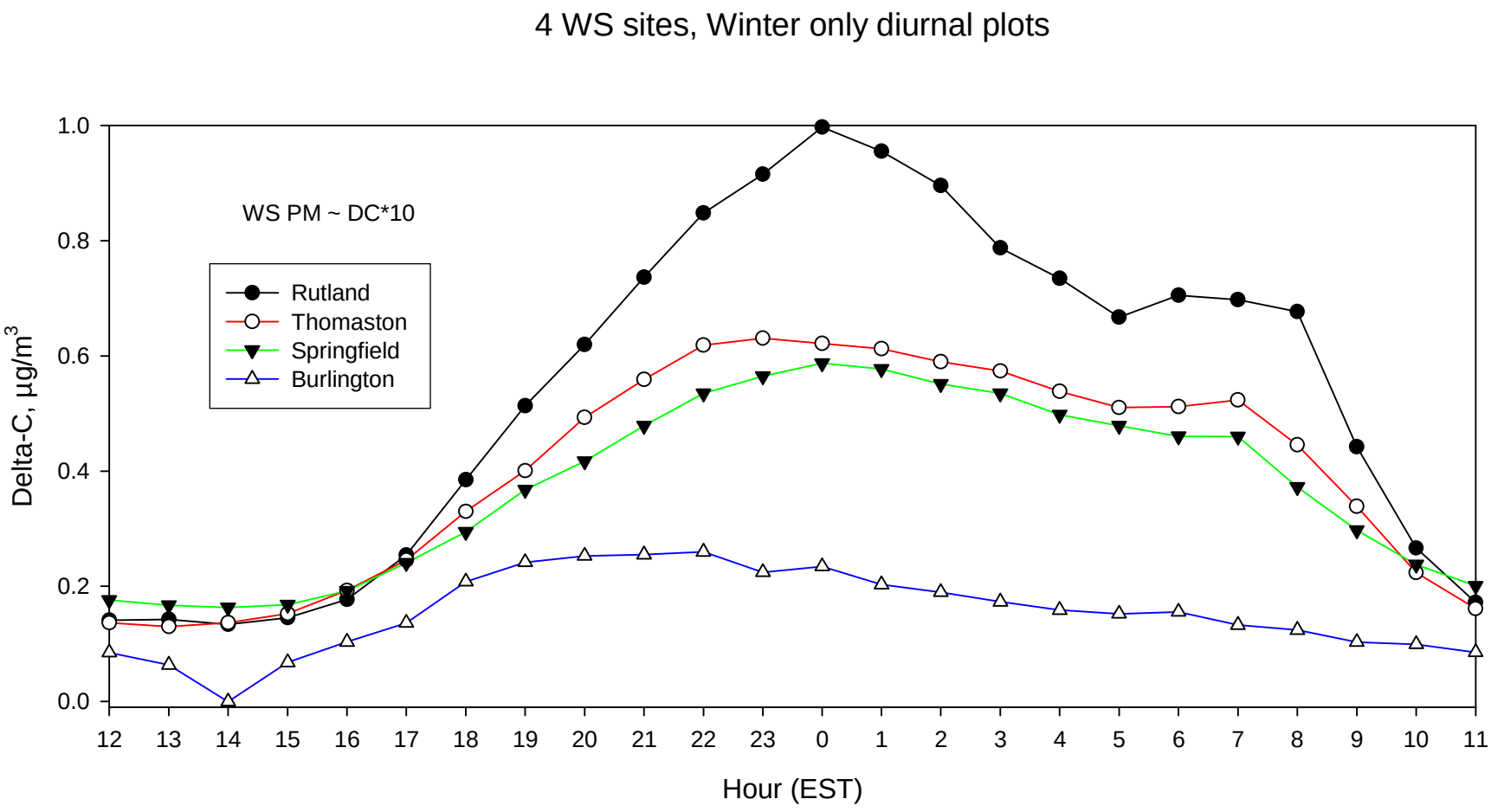

April 8, 2008 tests with 300# oak crib
PM g/h
Damper Status
Stack T, deg F
g/h mean: 62.2
Open: 80.8
Closed: 3.7
Stack PM emissions, g/h (wet STP)
Test Time (EST)
0
100
200
300
400
0
200
400
600
800
1000
8
9
10
11
12
13
14
15


April 9, 2008 tests with 300# seasoned oak cordwood
PM g/h
Damper Status
Stack T, deg F
g/h mean: 77.9
Open: 95.6
Closed: 7.2
Stack PM emissions, g/h (wet STP)
Stack T, deg F
Test Time (EST)
0
100
200
300
400
500
0
200
400
600
800
1000
7
8
9
10
11
12
13
14
15


April 10, 2008 tests with 150# seasoned oak cordwood
PM g/h
Damper Status
Stack T, deg F
g/h mean: 64.2
Open: 80.6
Closed: 9.4
Stack PM emissions, g/h (wet STP)
Stack T, deg F
Test Time (EST)
0
100
200
300
400
0
200
400
600
800
1000
7
8
9
10
11
12
13

OWB Week 4 Teflon filters
Net Mass in mg




4 WS sites, Winter only diurnal plots
WS PM ~ DC*10
Rutland
Thomaston
Springfield
Burlington
Delta-C, µg/m3
1.0
0.8
0.6
0.4
0.2
0.0
12
13
14
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10
11
Hour (EST)