

Vermont Evaluation of PM Emissions and Control Systems for Institutional Wood Chip Boilers

Vermont Agency of Natural Resources

April 27, 2010

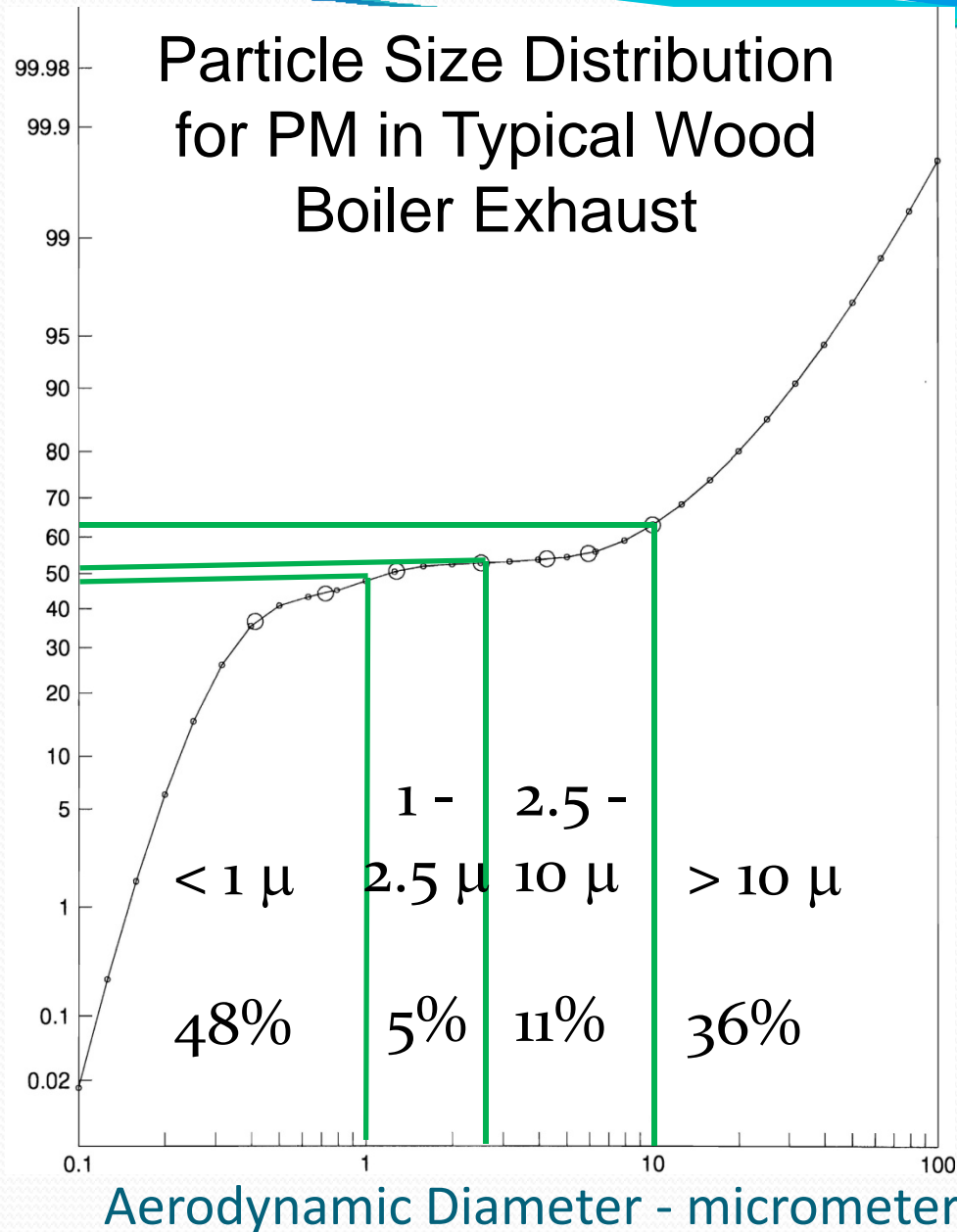
Outline

- ✓ Why do this testing?
- ✓ Criteria for host facilities
- ✓ PM Control Devices
- ✓ Sampling plan
- ✓ Operating conditions
- ✓ Wood fuel
- ✓ Results of Testing

Why do this testing?

- ✓ Concern with fine PM from small wood boilers (roughly 5-20 mmbtu/hr heat input)
- ✓ Assumption that most (>90%) of the uncontrolled PM from small wood boilers is PM_{2.5}, so why bother to use a single cyclone?
- ✓ Old state PM regulation (0.20 gr/dscf ~ 0.44 lb/MMBtu) not very restrictive – using Air Toxics regulation require lower PM emission limits.
- ✓ Concerns with validity of AP-42 for small wood boilers.
- ✓ Most of the testing in VT was just filterable PM.
- ✓ VT Department of Forest and Parks found grant money.

Cumulative weight below size



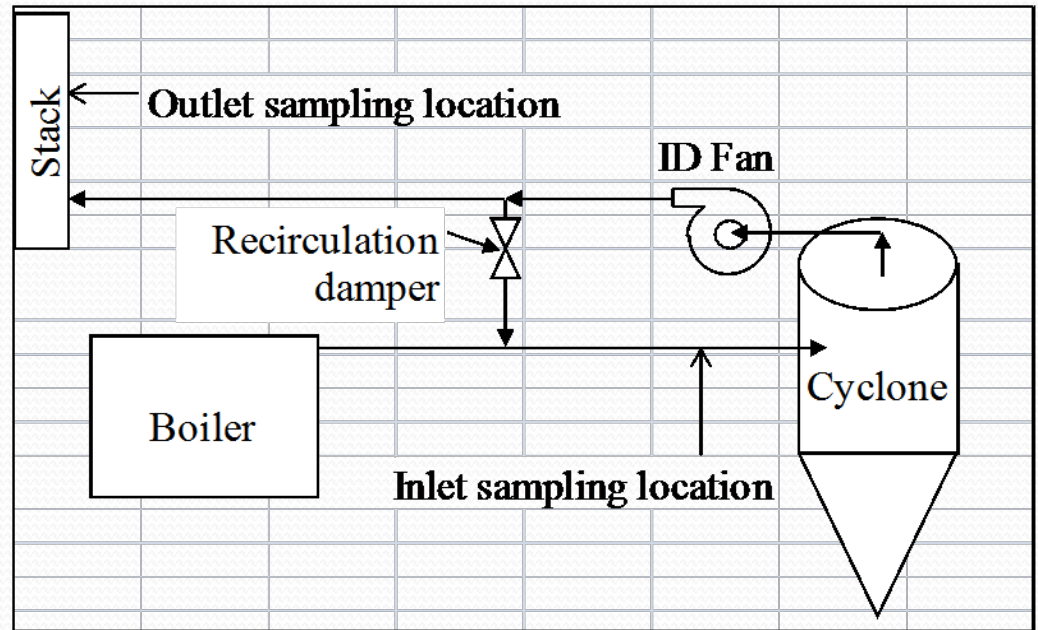
Criteria for Facilities to be tested

- ✓ Voluntary participation
- ✓ Institutional wood fired boilers
- ✓ Different types of PM control devices
- ✓ Acceptable duct length for sampling

PM Control Devices Evaluated

- ✓ Single cyclone
- ✓ High efficiency multi-cyclone
- ✓ Two multi-cyclones – in series
- ✓ Core Separator ®
- ✓ Baghouse with a multi-cyclone

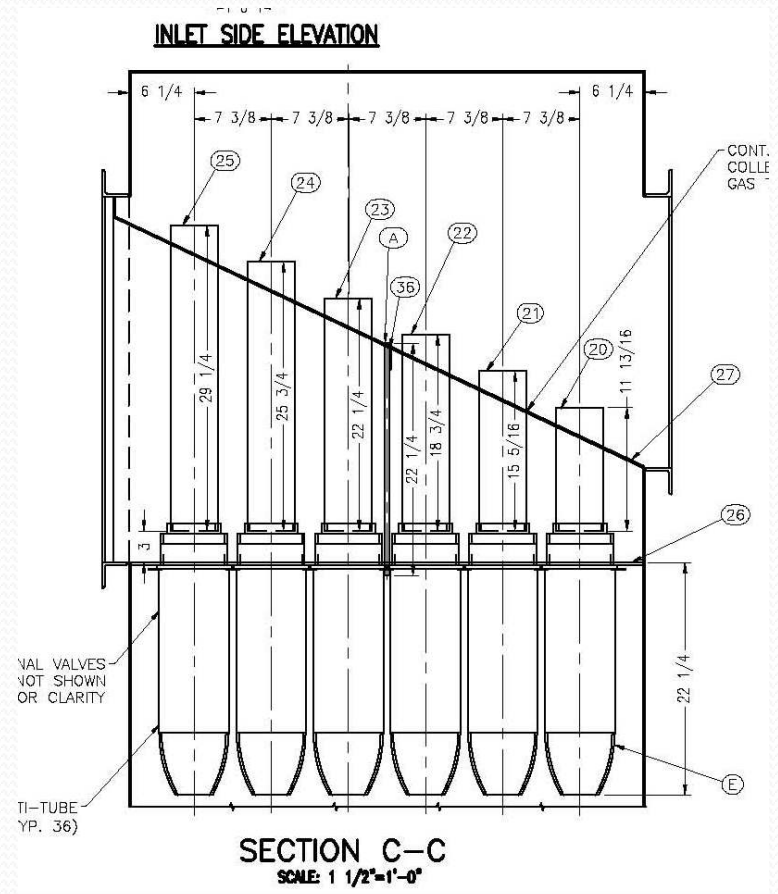
Single Cyclone



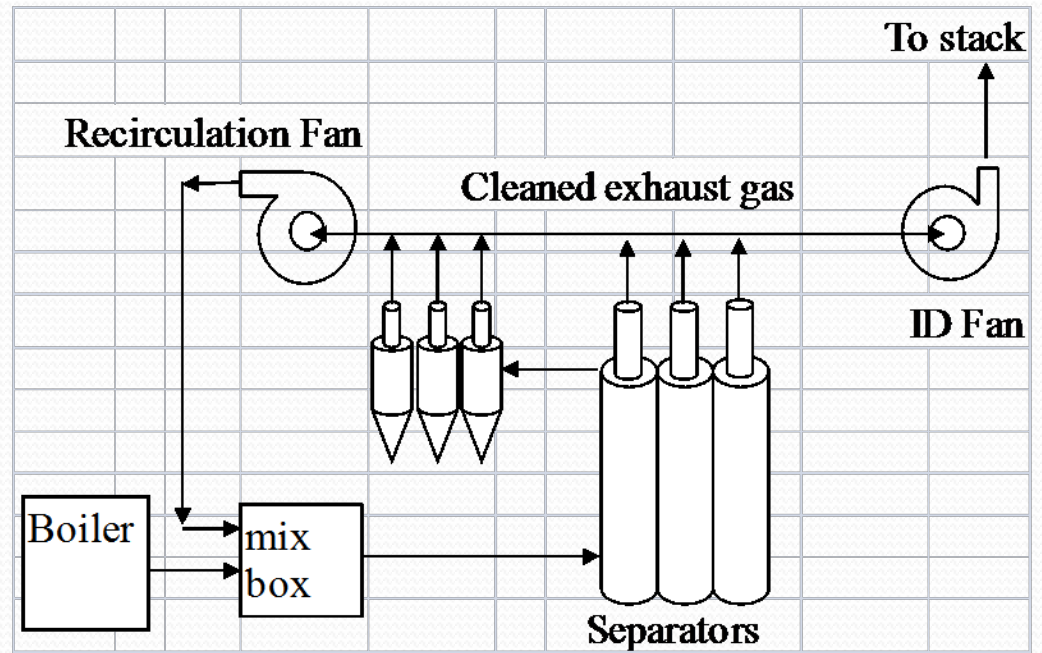
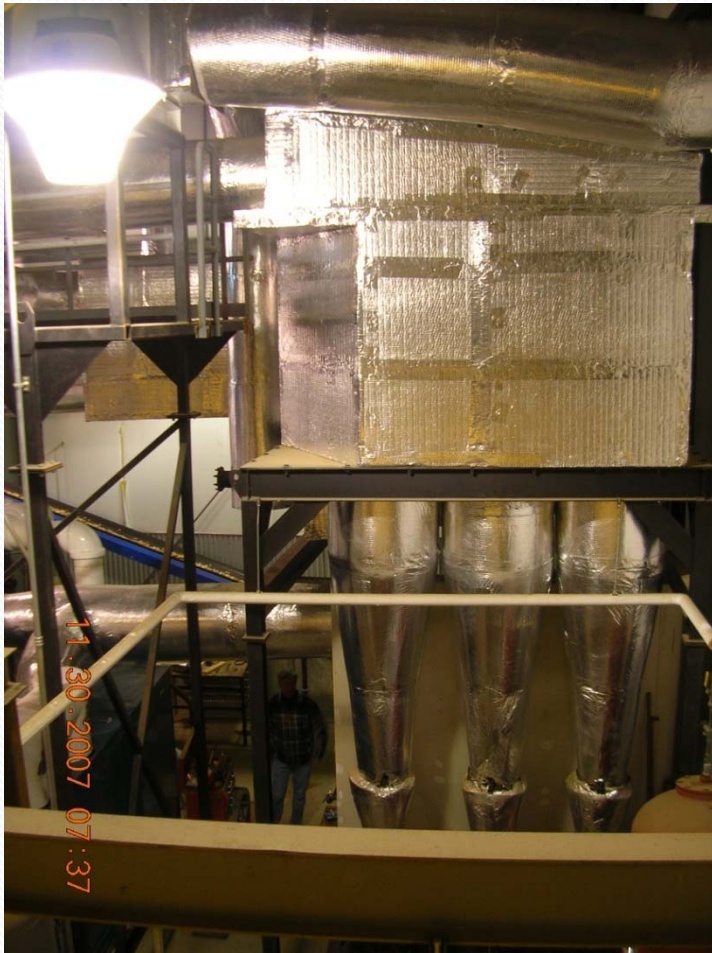
High Efficiency Multi-cyclone



Two Multi-cyclones in Series



Core Separator[®]



Multi-cyclone & Baghouse



Summary of Facilities

Facility	Location	Boiler	PM Control Device	Fuel Type
Champlain Valley Union High School (CVUHS)	Hinesburg, VT	Messersmith combustor (stoker with inclined grate) with Hurst boiler	Single cyclone	Mill end chips (hardwood)
Ponaganset High School (PHS)	North Scituate, RI	Chiptec – close coupled gasifier with Burnham boiler	High efficiency multi-cyclone	Mill end chips (hardwood)
Bennington College (BC)	Bennington, VT	AFS Energy Systems (stoker with pneumatic feed) with Burnham boiler	Two multi-cyclones in series	Whole tree chips (hardwood)
Brattleboro Union High School (BUHS)	Brattleboro, VT	Messersmith combustor (stoker with inclined grate) with Hurst boiler	Core Separator [®]	Mill end chips (hardwood)
Crotched Mountain Rehabilitation Center (CMRC)	Greenfield, NH	Messersmith combustor (stoker with inclined grate) with Hurst boiler	Multi-cyclone & baghouse	Bole tree chips (hardwood)

Sampling Plan

- ✓ Filterable PM (EPA Method 5)
- ✓ Condensable PM (EPA Method 202)
- ✓ Particle size distribution (Anderson Mark III cascade impactor with 8 stages).
- ✓ Each run consisted of simultaneous inlet and outlet sampling.
- ✓ Two 1 hour runs with Methods 5 & 202.
- ✓ One run with cascade impactor & Method 202.
- ✓ Complete all sampling in one day.

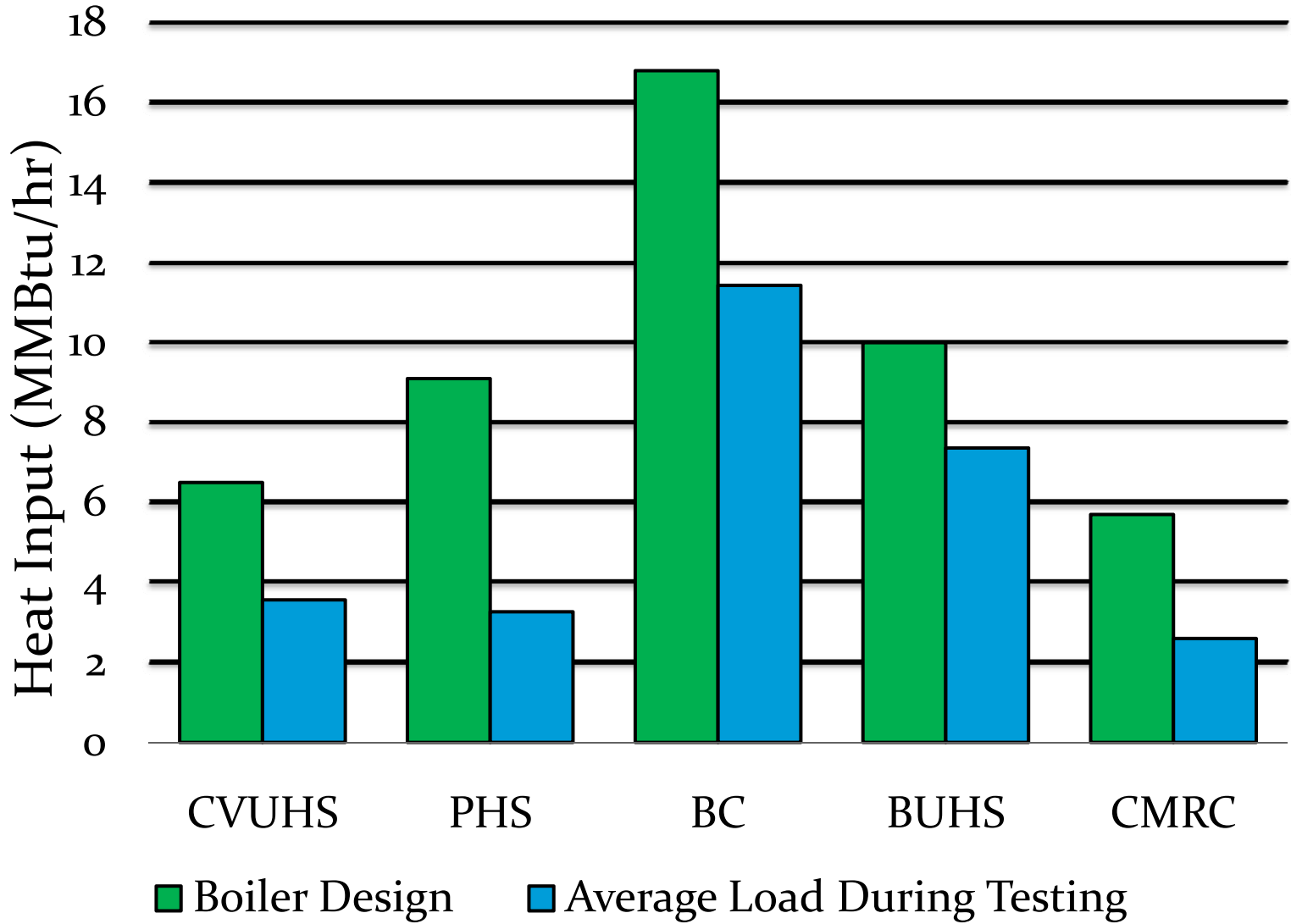
Boiler Operating Conditions

- ✓ Normal facility heat demand during the test day (except Ponaganset).
- ✓ Typical fuel supply for facility
- ✓ Routine ash management

Boiler Operating Load

Test Site	Run	Heat input (MMBtu/hr)		% of Design
		Boiler Design	Calculated Load	
CVUHS	1	6.5	4.0	55%
	2		3.6	
	3		3.1	
PHS	1	9.1	3.3	36%
	2		3.3	
	3		3.2	
BC	1	16.8	11.9	68%
	2		11.7	
	3		10.7	
BUHS	1	10	7.7	74%
	2		7.3	
	3		7.1	
CMRC	1	5.7	2.9	45%
	2		2.6	
	3		2.3	

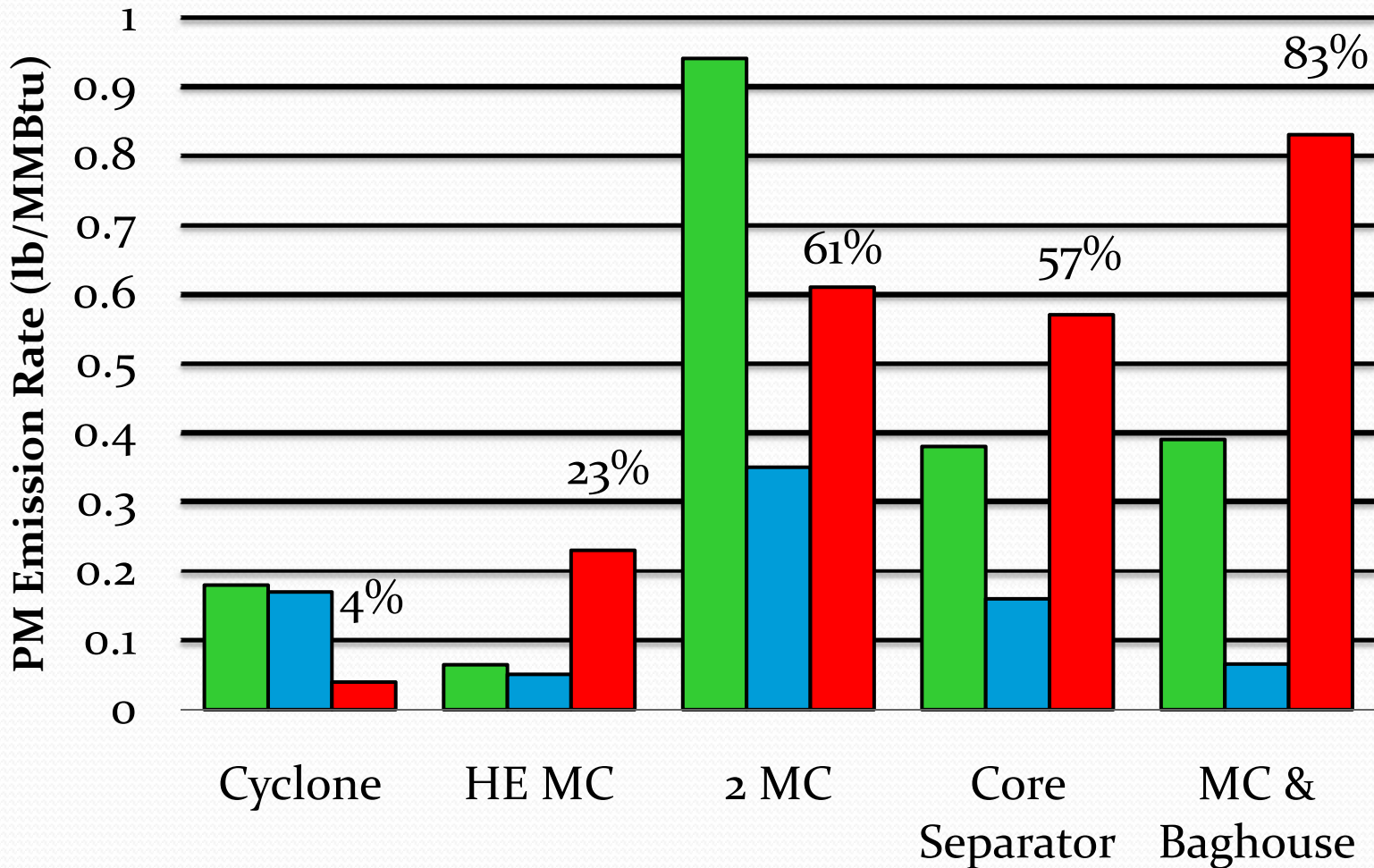
Boiler Operating Load



Filterable PM Collection Efficiency

Test Site	Inlet (lb/MMBtu)	Outlet (lb/MMBtu)	Collection Efficiency (%)
CVUHS (cyclone)	0.18	0.17	4
PHS (HE MC)	0.065	0.051	23
BC (2 MC)	0.94	0.35	61
BUHS (Core Separator)	0.38	0.16	57
CMRC (MC & baghouse)	0.39	0.066	83

Filterable PM Collection Efficiency



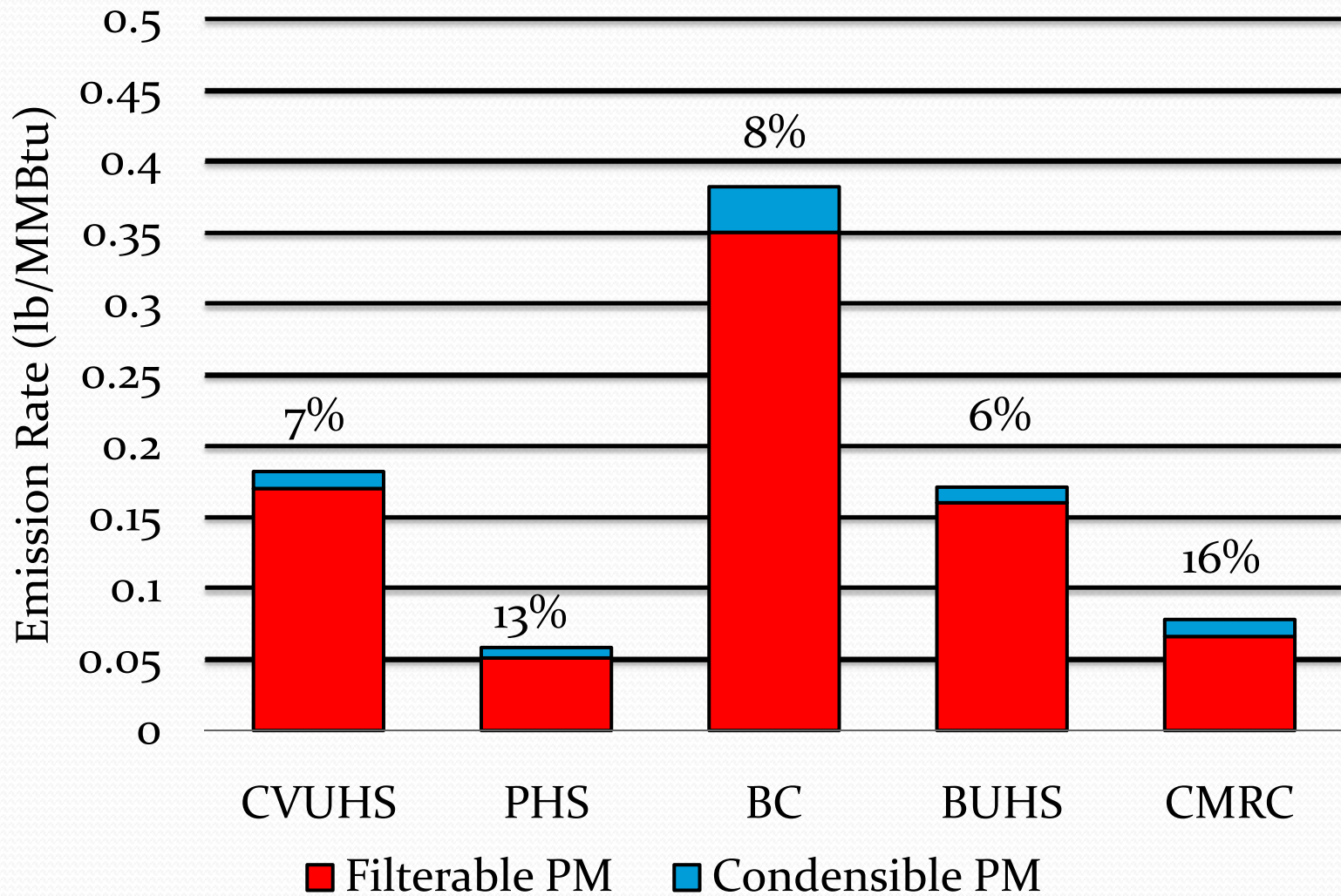
■ Inlet (lb/MMBtu)
 ■ Outlet (lb/MMBtu)
 ■ Collection Efficiency (%)

Filterable & Condensable PM Emissions After PM Control Device

Test Site	Filterable PM (lb/MMBtu)	Condensable PM (lb/MMBtu)	Total PM (lb/MMBtu)	Condensable PM (% of Total PM)
CVUHS	0.17	0.012	0.18	7%
PHS	0.051	0.0073	0.058	13%
BC	0.35	0.032	0.38 ¹	8%
BUHS	0.16	0.011	0.17	6%
CMRC	0.066	0.012	0.078	16%
Average	0.16	0.015	0.17	10%

¹ Subsequent compliance testing yielded a total PM emission rate of 0.14 lb/MMBtu

Filterable & Condensible PM Emissions After PM Control Device



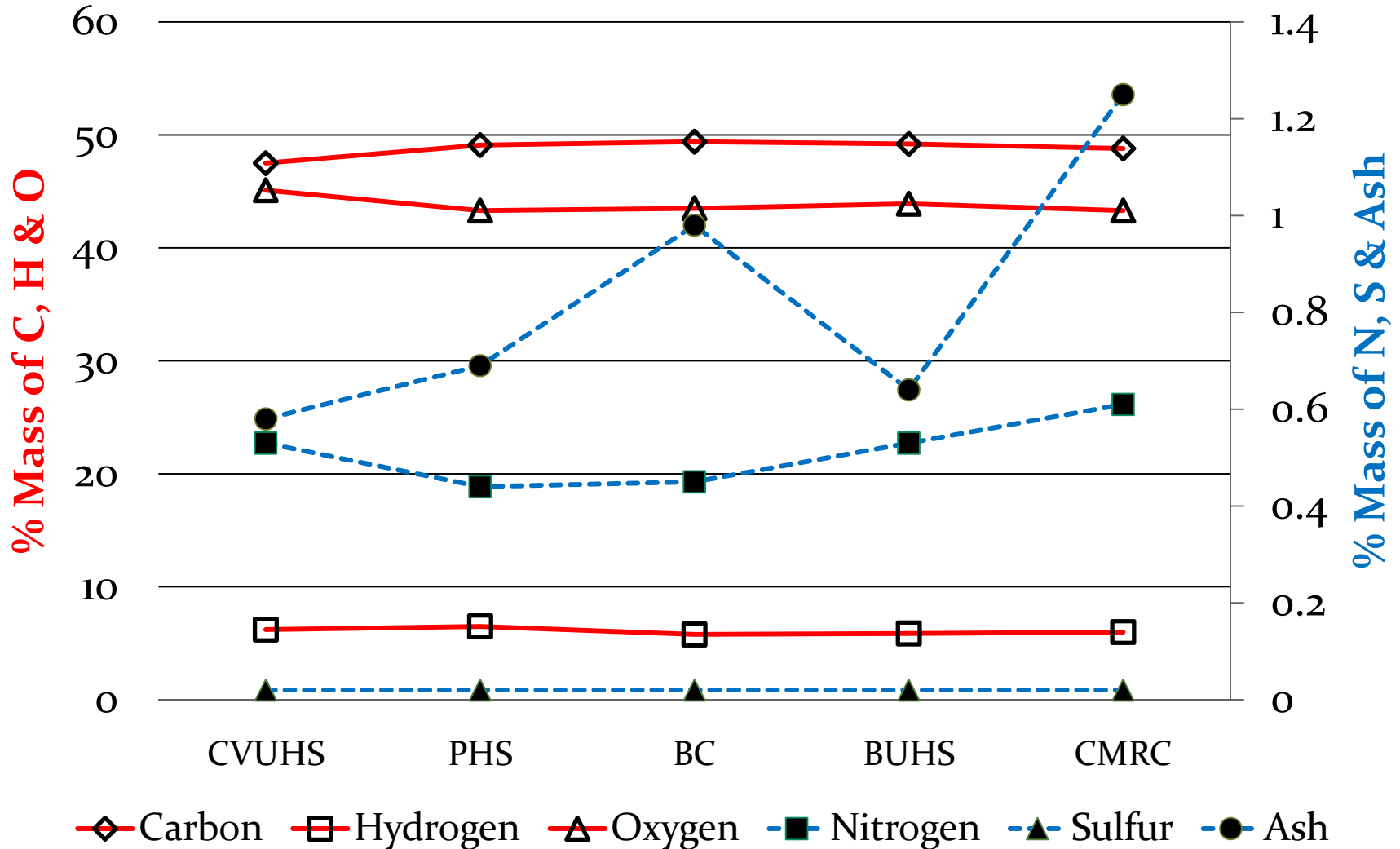
Filterable PM Mass Fraction Smaller than 2.5 μm (Aerodynamic Diameter)

Test Site	Inlet	Outlet
CVUHS	88 %	86 %
PHS	89 %	93 %
BC	32 %	70 %
BUHS	53 %	94 %
CMRC	56 %	79 %

Wood Fuel Analysis

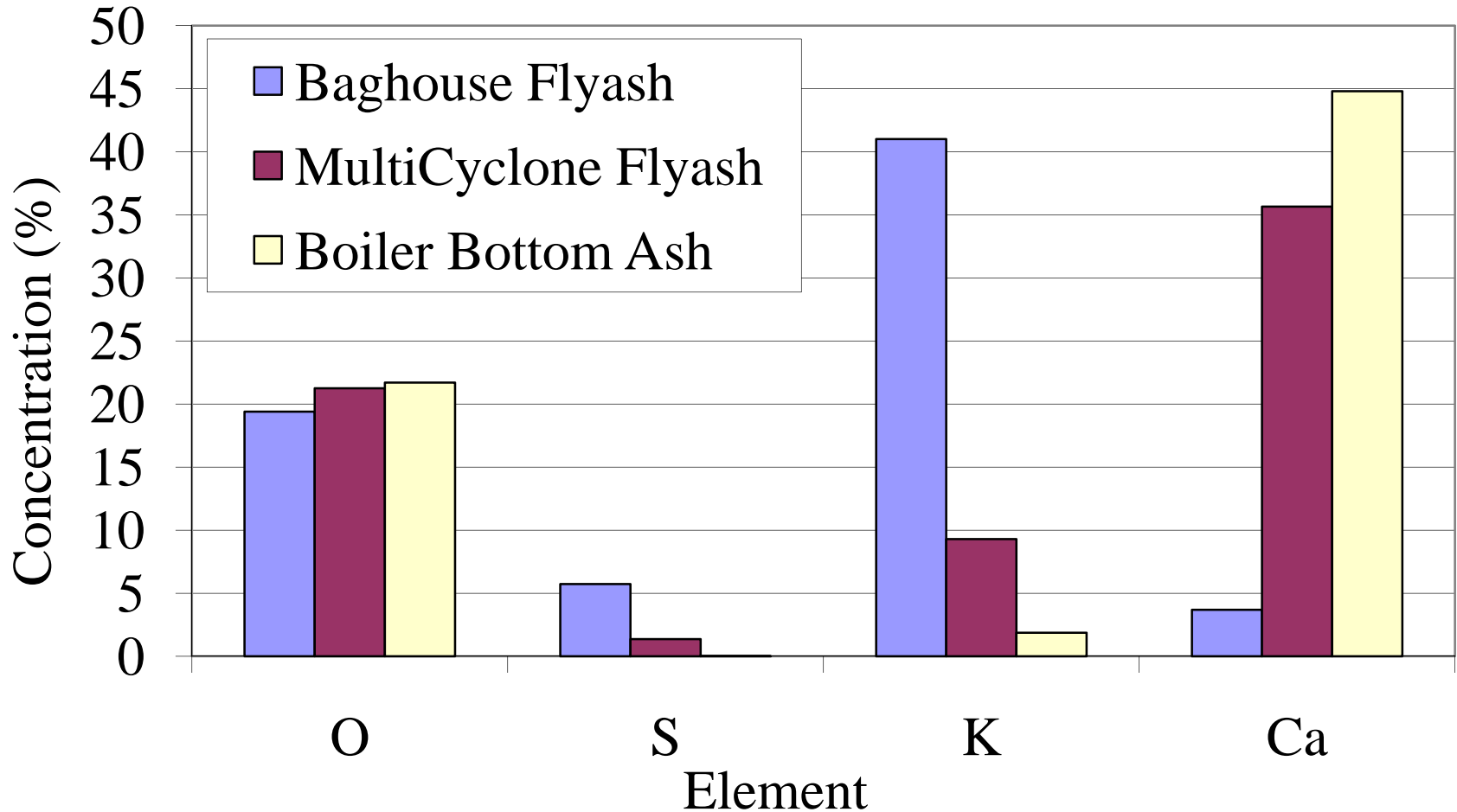
		CVUHS	PHS	BC	BUHS	CMRC
	Chip Type	Mill end HW chip	Mill end HW chip	Whole tree HW chip	Mill end HW chip	Bolewood HW chip
Heating Value (Btu/lb)	as received	5150	4720	4710	4300	4990
	dry basis	8350	8370	8220	8070	8190
Percent Mass (dry basis)	% H ₂ O	38.3	43.6	42.7	46.7	39.1
	Carbon	47.5	49.1	49.4	49.2	48.8
	Hydrogen	6.21	6.49	5.78	5.87	5.99
	Nitrogen	0.53	0.44	0.45	0.53	0.61
	Oxygen	45.1	43.3	43.5	43.9	43.3
	Sulfur	0.02	0.02	0.02	0.02	0.02
	Ash	0.58	0.69	0.98	0.64	1.25

Wood Fuel Analysis



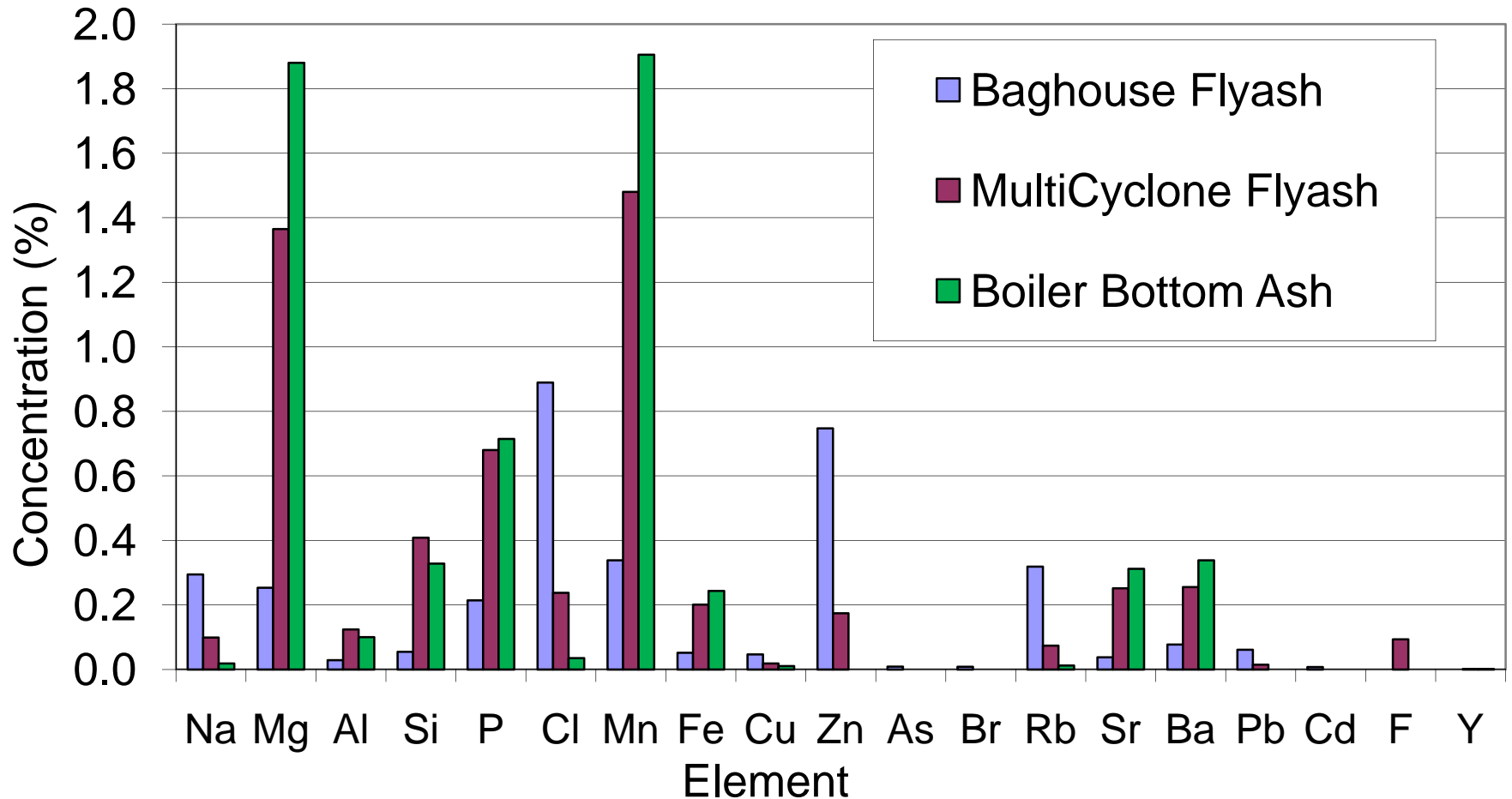
Wood Ash Analysis - CMRC

Elements > 2% Concentration



Wood Ash Analysis - CMRC

Elements < 2% Concentration



Contact Information

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Links to report and appendices:

<http://www.anr.state.vt.us/air/cfm/AirWhatsNew.cfm#general>