



## Project Summary

# Test Method Evaluations and Emissions Testing for Rating Wood Stoves

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The U.S. Environmental Protection Agency has decided to develop a New Source Performance Standard (NSPS) for wood burning stoves. During the development process several issues must be resolved. One of the more critical issues is the selection of an emission sampling method and stove operating procedure. This report addresses the comparison of three candidate sampling methods: the EPA Modified Method 5 (MM5), the Oregon Method 7 (OM7), and the ASTM proposed Method P180. It also addresses the effect emission format (g/hr, g/kg wood burned,  $\mu\text{g}/\text{J}$  heat output) has on the intermethod correlations.

Five stoves (i.e., two catalytic, one noncatalytic generic, one noncatalytic high efficiency, and one catalytic fireplace insert) were tested. The stoves were nominally operated according to the State of Oregon's certification procedure. Simultaneous tests were conducted using MM5 and OM7 in the stove flue and MM5, OM7, and ASTM in the (ASTM) dilution tunnel. Quality assurance tests using duplicate sampling trains were also conducted. Proportional sampling, using  $\text{SO}_2$  as a tracer gas, was conducted in the flue, and isokinetic sampling was conducted in the dilution tunnel.

Results showed good correlations between the total train emissions obtained with each method. The strength of the correlations varied with the emission format; the grams per hour format showed the strongest correlation. POM emissions showed a general (but weak) correlation with total emissions when the grams per

hour format was used; there were no correlations when the emissions were expressed in either of the other two formats.

*This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).*

### Introduction

The purpose of this test program was to collect emission testing data to evaluate emission measurement procedures that have been applied to certification of wood stoves and to develop an acceptable procedure for application to a New Source Performance Standard (NSPS) for the wood stove source category.

The primary objectives of the project were:

- To collect emission testing data for evaluating the effectiveness of the Oregon Department of Environmental Quality (DEQ) emission sampling method (OM7) in distinguishing between low and high emissions of total particulate matter, condensable organic matter, and polycyclic organic matter (POM), using EPA Modified Method 5 (MM5) as the reference.
- To collect emission testing data for evaluating the accuracy and precision of the OM7 sampling method and the applicability of the dilution tunnel emission sampling approach (as used

with the American Society for Testing Materials (ASTM) home heating appliance emission sampling method) to the OM7 sampling method.

- To collect emission testing data for evaluating the representativeness of the ASTM emission sampling method, using MM5 as the reference.

The three sampling methods (MM5, OM7, and ASTM) have slightly different objectives which may account for slight differences in the actual emissions measured. MM5 was designed to collect isokinetic samples of particulate and condensable and semivolatile organic components. The method captures the semivolatile organic fraction on a sorbent resin.

The OM7 method was designed for the collection of particles and condensable organic matter. Isokinetic sampling is not required for sampling wood stove emissions, but the method does require proportional sampling.

The ASTM method assumes that the particles in the diluted gas stream are small and behave as a gas. The sample rate is held constant ( $\pm 2\%$ ) throughout the test, and gas is measured at varying intervals depending on the burn rate. Since the sample is collected at basically ambient temperature and moisture conditions, the sample train filter is not heated. The ASTM method specifies that the sample rate be based on the filter loading and the filter face velocity (2 to 30 ft/min, or 0.6 to 9.1 m/min). During these tests, all sampling trains were operated at fixed points in the stack or dilution tunnel, as appropriate.

The five stoves tested included three catalytic stoves (a Timbereze Model 477, a Blaze King Catalyst Stove—King Model KEJ-1101, and a Fisher Tech IV fireplace insert), one conventional non-catalytic stove (Lakewood), and one low emission non-catalytic stove (BOSCA FS-500).

## Summary of Results

The results of the 22 test burns are presented in Table 1. Duplicate sample results are included below the matching sample run. The stove heat input was determined from the weight of dry wood burned per hour and the analyzed heat content of the fuel. The stack flow rate was calculated using  $F_c$ , and F factor for wood (40 CFR 60.45, July 1985). Dilution tunnel flows and moisture contents were standardized to the OM7 train.

Some of the data have been qualified in Table 1:

- All sample runs conducted during test burns "Blaze King" 3 and "BOSCA" -3 (High Efficiency -3). These burns could not be sampled to completion. This prohibited calculations according to procedure OM7 and did not provide an emission measurement representative of a complete burn. Results were calculated using the  $F_c$  factor.

- An isokinetic sampling conducted for OM7 and MM5 sample runs in the dilution tunnel was designated with: an "h" when sample rates were over 100% of isokinetic and a "c" when sampling rates were below 90% of isokinetic.

- Two torn second filters in OM7 sample trains (located between the third and fourth impingers) were identified with an "f."

- Two test burns were not adequately conducted under procedure OM7 stove operating guidelines. The doors were opened during sampling, and the coals and woodpieces stirred during two Timbereze test burns.

- Several OM7 and MM5 sample runs were conducted with the heated filter box temperature below the specified lower limit of 106°C. In all of those cases except BD-OM7-5, the average temperatures were between 93 and 106°C.

Total gravimetric emissions for each sampling method consist of the combined individual analyses of the following fractions:

- MM5
  - front half  $\text{MeCl}_2$  rinse drydown residue
  - filter catch
  - XAD extraction
  - semivolatile organics (extracted from back-half water) by GC plus water drydown residue
  - semivolatile organics (in rinse solvent) by GC plus solvent drydown residue
  - condensate extraction
  - semivolatile organics by GC plus drydown residue
- OM7
  - front half solvent rinse drydown residue
  - front filter catch
  - back half extraction drydown residue
  - back half water drydown residue

- back half rinse drydown residue
- back filter catch

- ASTM
  - front half and between-filter solvent rinse drydown residue
  - front filter catch
  - back filter catch

Table 1 also includes results of organic sampling and analyses conducted on MM5 samples for total chromatographable organics (TCOs), phenol, and POM. TCOs were determined on the combined back half fractions of each MM5 sample. POM and phenol were analyzed in a combined aliquot from the front and back half fractions of each MM5 sample. The POM values presented in Table 1 are the sum of the individual values for the 21 specific compounds quantified. The values in Table 1 do not represent total POM, but may indicate the relative change in total POM from one burn to another.

**Table 1. Summary of Wood Stove Emission Test Results Using ORSAT Data and  $F_c$ —Grams Per Hour.**

Burn No.	F Factor Heat Input (Btu/ hr) <sup>a</sup>	Burn Rate (dry kg/ hr)	Particulate					TCO		Phenol		POM	
			Stack Emissions		Dilution Tunnel Emissions			Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel
			MM5	OM7	MM5	OM7	ASTM						
<b>Timbereze</b>													
1 <sup>b</sup>	17,285	0.90	17.0	8.01	11.4 <sup>c</sup>	6.16 <sup>c</sup>	4.26	6.13	4.12 <sup>c</sup>	0.103	0.0507 <sup>c</sup>	0.0971	0.0816 <sup>c</sup>
2 <sup>b</sup>	23,218	1.22	14.6	7.55	13.2	4.89	3.37	4.55	3.44	0.111	0.0298	0.0813	0.0376
2 <sup>b,d</sup>	23,218	1.22					0.999						
<b>Blaze King</b>													
4	11,607	0.60	23.1	7.99	10.7	7.99 <sup>e</sup>	4.50	12.7	4.22	0.101	0.0908	0.0319	0.0474
4 <sup>d</sup>	11,607	0.60				3.96							
1	20,898	1.09	7.13	4.59 <sup>i</sup>	10.9	4.15	2.66	2.66	3.39	0.0576	0.0570	0.0355	0.0381
1 <sup>d</sup>	20,898	1.09		4.16			2.34						
5 <sup>a</sup>	31,964	1.64	10.5	3.22 <sup>e,i</sup>	13.4	9.27 <sup>e</sup>	4.96	4.47	3.56	0.156	0.0996	0.0877	0.0731
5 <sup>d,g</sup>	31,964	1.64	9.11		15.3			3.21	3.65	0.150	0.112	0.0856	0.0790
2	53,615	2.77	20.8	10.8	24.1	10.7	8.55	6.66	6.75	0.239	0.258	0.139	0.176
2 <sup>d</sup>	53,615	2.77		10.3 <sup>e</sup>									
3 <sup>b</sup>	6,620	0.34	5.45	2.50	15.8 <sup>h</sup>	9.43	2.91	2.18	2.99 <sup>h</sup>	0.0223	0.0493 <sup>h</sup>	0.0316	0.0404 <sup>h</sup>
<b>Lakewood</b>													
1	17,148	0.89	54.7	29.2 <sup>e</sup>	54.1	24.4 <sup>e</sup>	27.2	19.3	19.4	0.411	0.461	0.148	0.186
3	22,667	1.17	56.4	32.1 <sup>e</sup>	74.8	27.0	33.1	26.3	29.2	0.444	0.741	0.228	0.5341
3 <sup>d</sup>	22,667	1.17		35.0	53.2				24.8		0.655		0.503
2	29,004	1.51	45.3	26.9 <sup>e</sup>	54.5	28.5	22.1	18.9	23.9	0.782	1.10	0.337	0.492
4	139,443	17.17	216	61.3	170	54.6	97.1	109	81.8	9.11	3.90	19.3	12.8
4 <sup>d</sup>	139,443	17.17	216			89.0 <sup>h</sup>		95.1		6.46		16.9	
<b>Bosca</b>													
2	10,466	0.54	27.3	19.0	18.5	8.27	12.2	10.9	6.21	1.74	0.0558	0.0827	0.0343
2 <sup>d</sup>	10,466	0.54				12.8 <sup>e</sup>							
4	21,299	1.08	14.7	8.49	28.6	8.66 <sup>e</sup>	9.10	6.00	7.85	0.351	0.251	0.396	0.385
1	28,082	1.46	12.6	9.39	32.7	10.7	9.85	5.70	5.90	0.199	0.222	0.508	0.791
1 <sup>d</sup>	28,082	1.46		7.10			8.76						
5	64,001	3.10	22.3	11.5	68.3	37.2	20.4	10.7	21.6	1.02	1.50	1.98	4.55
3 <sup>b</sup>	11,447	0.60	17.2	6.97	56.4	20.2 <sup>h</sup>	19.7	7.50	14.0	0.402	0.549	0.476	1.06
3 <sup>b,d</sup>	11,447	0.60	16.7 <sup>e</sup>		59.6 <sup>e</sup>			7.05 <sup>e</sup>	20.4 <sup>e</sup>	0.252 <sup>e</sup>	0.815 <sup>e</sup>	0.252 <sup>e</sup>	1.47 <sup>e</sup>
<b>Fisher</b>													
2	10,621	0.55	8.54	4.63	22.6 <sup>c</sup>	10.7	4.17	2.55	3.25 <sup>c</sup>	0.0547	0.0815 <sup>c</sup>	0.0173	0.0371 <sup>c</sup>
2 <sup>d</sup>	10,621	0.55			14.9				2.70		0.0641		0.0220
4	18,501	0.95	15.9	10.8	23.9 <sup>h</sup>	13.1	6.24	4.72	4.03 <sup>h</sup>	0.128	0.0753 <sup>h</sup>	0.0415	0.0247 <sup>h</sup>
4 <sup>d</sup>	18,501	0.95			28.3				3.94		0.108		0.0320
3	30,279	1.58	19.7	16.1	48.0	21.3	13.4	5.55	6.73	0.184	0.240	0.0836	0.124
1	38,911	2.02	38.9	29.2	71.6	37.0	30.3	12.0	12.9	0.415	0.413	0.149	0.146

<sup>a</sup> - 1 Btu/hr = 0.29W.

<sup>b</sup> - Test burn was not consistent with specified stove operating procedures.

<sup>c</sup> - Sample rate below 90% isokinetic.

<sup>d</sup> - Result of duplicate run.

<sup>e</sup> - Data presented but quality is uncertain due to low filter temperatures.

<sup>f</sup> - Second filter torn.

<sup>g</sup> -  $F_c$  calculated using CEMS data because of bad ORSAT.

<sup>h</sup> - Sample rate in excess of 110% isokinetic.

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*The complete report, entitled "Test Method Evaluations and Emissions Testing for Rating Wood Stoves, (Order No. PB 87-119 897/AS; Cost: \$18.95, subject to change) will be available only from:*

*National Technical Information Service*

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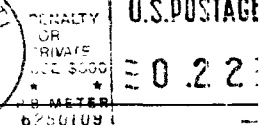
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