

TEST METHOD EVALUATIONS AND EMISSIONS TESTING FOR RATING WOOD STOVES

by

Lawrence E. Cottone

Engineering-Science

Two Flint Hill

10521 Rosenhaven Street
Fairfax, Virginia 22030

EPA Contract 68-02-3996, Work Assignments 7, 12, 13, and 15

and

Edward Messer

Radian Corporation

P.O. Box 13000

Research Triangle Park, North Carolina 27709

EPA Contract 68-02-3994, Work Assignment 38

EPA Contract 68-02-3850, Work Assignment 22

EPA Project Officers:

Robert C. McGrillis

Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

and

Peter R. Westlin

Emission Standards and Engineering Division
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

TECHNICAL REPORT DATA (Please read instructions on the reverse before completing)			
1 REPORT NO EPA/600/2-86/100		3 RECIPIENT'S ACCESSION NO PB87 119897/AS	
4 TITLE AND SUBTITLE Test Method Evaluations and Emissions Testing for Rating Wood Stoves		5 REPORT DATE October 1986	
		6 PERFORMING ORGANIZATION CODE	
7 AUTHOR(S) Lawrence E. Cottone (ES) and Edward Messer (Radian)		8 PERFORMING ORGANIZATION REPORT NO	
9 PERFORMING ORGANIZATION NAME AND ADDRESS Engineering Science, 10521 Rosehaven St., Fairfax, VA 22030; and Radian Corp., P.O. Box 13000, Research Triangle Park, NC 27709		10 PROGRAM ELEMENT NO	
		11 CONTRACT/GRANT NO 68-02-3996, Tasks 7, 12, 13, 15; 68-02-3994, Task 38*	
12 SPONSORING AGENCY NAME AND ADDRESS EPA, Office of Research and Development Air and Energy Engineering Research Laboratory Research Triangle Park, NC 27711		13 TYPE OF REPORT AND PERIOD COVERED Task Final: 6/85 - 4/86	
		14 SPONSORING AGENCY CODE EPA/600/13	
15 SUPPLEMENTARY NOTES AEERL project officer is Robert C. McCrillis, Mail Drop 65, 919/541-2733. (*) Also 68-02-3850, Task 22. Cofunded by EPA/OAQPS: project officer Peter R. Westlin, Mail Drop 19, 919/541-2237.			
16 ABSTRACT The report gives results of a comparison of three sampling methods for wood burning stoves: the EPA Modified Method 5 (MM5), the Oregon Method 7 (OM7), and the ASTM proposed Method P180. It also addresses the effect that emission format (grams per hour, grams per kilogram wood burned, micrograms per joule heat output) has on the intermethod correlations. (The comparison was used as a basis for the selection of an emission sampling method and stove operating procedure which are, in turn, being used by EPA to develop a New Source Performance Standard (NSPS) for wood burning stoves.) Five stoves (two catalytic, one noncatalytic generic, one noncatalytic high efficiency, and one catalytic fireplace insert) were tested. Test 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.			
17 KEY WORDS AND DOCUMENT ANALYSIS			
a DESCRIPTORS		b IDENTIFIERS/OPEN ENDED TERMS	c COSATI Field/Group
Pollution Evaluation Stoves Sampling Wood Combustion Emission Tests		Pollution Control Stationary Sources Wood Stoves	13B 13A 11L 21B 14G 14B
18 DISTRIBUTION STATEMENT Release to Public		19 SECURITY CLASS (This Report) Unclassified 20 SECURITY CLASS (This page) Unclassified	21 NO OF PAGES 148 22 PRICE

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

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, ug/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 SO₂ 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.

CONTENTS

Figures	v
Tables	vi
Abbreviations	vii
1. Introduction	1
2. Summary of Results	3
3. Test Facility and Stove Descriptions	25
4. Sampling Procedures	28
5. Quality Assurance and Special Considerations	37

Appendix

Analytical Results	A1
--------------------	----

FIGURES

<u>Number</u>	<u>Page</u>
1 Schematic of Stove Exhaust and Dilution System With Sample Locations	26
2 Schematic of Modified Method 5 Sampling Train	30
3 Schematic of OM7 Sampling Train	31
4 Schematic of ASTM Sampling Train	32

TABLES

<u>Number</u>	<u>Page</u>
1a Summary of Woodstove Emission Test Results Using Oregon Combustion Program and Actual Dilution Tunnel Gas Flows - Grams per Hour	4
1b Summary of Woodstove Emission Test Results Using Oregon Woodstove Combustion Program and Actual Dilution Tunnel Gas Flows - Grams per Kilogram	6
1c Summary of Woodstove Emission Test Results Using Oregon Woodstove Combustion Program and Actual Dilution Tunnel Gas Flows - Micrograms per Joule	8
2a Summary of Woodstove Emission Test Results Using Oregon Method 7 to Standardize Dilution Tunnel Flow - Grams per Hour	10
2b Summary of Woodstove Emission Test Results Using Oregon Method 7 to Standardize Dilution Tunnel Flow - Grams per Kilogram	12
2c Summary of Woodstove Emission Test Results Using Oregon Method 7 to Standardize Dilution Tunnel Flow - Microgram per Joule	14
3a Summary of Woodstove Emission Test Results Using Orsat Data and F_C - Grams per Hour	16
3b Summary of Woodstove Emission Test Results Calculated and F_C - Grams per Kilograms	18
3c Summary of Woodstove Emission Test Results Calculated Orsat Data and F_C - Micrograms per Joule	20
4 Average emission rates per stove - Arithmetic Average	23
5 Validation Criteria - Sampling Trains	38
6 Validation Criteria - Woodstove Operation	39
7a Summary of Timber-Eze Sampling Conditions	40
7b Summary of Blaze King Sampling Conditions	41
7c Summary of Lakewood Sampling Conditions	42

Tables (Cont.)

<u>Number</u>		<u>Page</u>
7d	Summary of Bosca Sampling Conditions	43
7e	Summary of Fisher Sampling Conditions	44
8	Results of Train Blank Sample Analyses Gravimetric Residue, Milligrams	46
9	Results of Train Blank Analyses for Organics and Modified Method 5 Samples	47
10	Summary of Duplicate Samples (Grams/Hour)	49
11	Comparison of Average CEMS CO ₂ , O ₂ , and CO With Concurrent Orsat Results	50
12	Heat Input and Gas Flow Calculated Using F _C Factors and Wood Heat Content Compared to Heat Output and Gas Flows Calculated by Oregon Stove Combustion Program	52
13	Comparison of Moisture Determinations in the Stack Gas as Measured by MM5, Wet Bulb/Dry Bulb, and OM7	53

LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

ACF	-- Actual Cubic Feet
ASTM	-- American Society of Testing Materials
Btu	-- British thermal units
CEMS	-- continuous emission monitoring system
DB	-- dry bulb temperature
g	-- grams
j	-- joules
kg	-- kilograms
mg	-- milligrams
MM5	-- Modified Method 5
ng	-- nanograms
OM7	-- Oregon Method 7
POM	-- polycyclic organic matter
sm ³	-- standard cubic meters (20° centigrade, 760 millimeters mercury)
TCO	-- total chromatographable organics
WB	-- wet bulb temperature

SYMBOLS

CO	-- carbon monoxide
CO ₂	-- carbon dioxide
O ₂	-- oxygen
MeCl ₂	-- methylene chloride

SECTION 1

INTRODUCTION

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

The primary objectives of the project as defined by EPA were:

- o 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, condensible organic matter, and polycyclic organic matter POM, using EPA Modified Method 5 (MM5) as the reference.
- o To collect emission testing data for evaluating the accuracy and precision of the Oregon DEQ (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 Oregon DEQ OM7 sampling method.
- o To collect emission testing data for evaluating the representativeness of the ASTM emission sampling method using MM5 as the reference.

SAMPLING METHODS

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

The Oregon sampling method was designed for the collection of particles and condensible organic matter. Isokinetic sampling is not required for sampling woodstove emissions, but the method does require proportional sampling.

The ASTM method makes the assumption that the particles in the diluted gas stream are small and behave as a gas. The sample rate is held constant (± 2%) throughout the test and gas measurements are taken at varying time

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). During these tests, all sampling trains were operated at fixed points in the stack or dilution tunnel as appropriate.

DESCRIPTION OF FACILITIES

The five stoves tested included three catalytic stoves (a Timber-eze 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).

PROJECT PARTICIPANTS

Project participants and their goals and responsibilities included:

- o EPA AEERL - to evaluate stove emissions and available control strategies for the purpose of standards development.
- o EPA OAQPS - to evaluate the procedures used in the collection of existing data and select a representative and reliable procedure for future testing of woodstove emissions.
- o Radian Corporation - to specify woodstove design and operating parameters that should be tested in order to provide the necessary information for this program and to perform analyses on all samples collected by the MM5, OM7, and ASTM sampling methods.
- o Engineering-Science - to develop a detailed stove operation and emission test and quality assurance approach to fulfill the goals of AEERL and OAQPS; to operate the woodstoves and collect emission samples according to those plans; and, to summarize the conditions, methodologies, and results of the test program.

TEST LOCATION

All tests were conducted at the ES test facility in Research Triangle Park, North Carolina. An air conditioned trailer was used to house the continuous analyzers and data recorders.

SECTION 2

SUMMARY OF RESULTS

Sampling problems and inconsistencies (discussed in Section 5) resulted in each data point being calculated using three different approaches. Briefly, those approaches are as follows:

Tables 1a, 1b and 1c: The stove heat outputs and stack flows were calculated using the Oregon woodstove test method of carbon, hydrogen, oxygen balance (CHO balance). The dilution tunnel flows and moisture contents were determined for each of the samples collected at that location. Possible problems with the CEMS data and definite problems with the tracer gas method made the CHO balance results suspect. Differences in the methods for measuring dilution tunnel flows and moisture specified by the different sampling methods introduced minor differences in calculations of the emission rates measured simultaneously in the dilution tunnel.

Tables 2a, 2b and 2c: The stove heat outputs and stack flows were calculated as described for Tables 1a, 1b and 1c. The dilution tunnel flows and moisture contents were standardized to those results of the OM7 train, which uses EPA Reference Method 4 for moisture measurements.

Tables 3a, 3b and 3c: The stove heat input was determined from the kilograms 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 as in Tables 2a, 2b and 2c.

The results of the 22 test burns are presented in three emission formats: grams per hour (Tables 1a, 2a and 3a, grams per kilogram of wood burned (Tables 1b, 2b and 3b) and micrograms per joule (Tables 1c, 2c and 3c). Duplicate sample results are included below the matching sample run.

Some of the data have been qualified in the summary tables. Those data include the following:

- o 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 the Oregon woodstove test procedure and did not provide an emission measurement representative of a complete burn. Results were calculated using the F_c factor and are reported in Tables 3a, 3b and 3c.

TABLE 1a. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING OREGON WOODSTOVE COMBUSTION PROGRAM AND ACTUAL DILUTION TUNNEL GAS FLOWS DETERMINED BY EACH SAMPLE TRAIN - GRAMS PER HOUR

Stove Burn Number	Heat Output (Btu/ hr)	Burn Rate (dry kg/ hr)	Particulate					TCO		Phenol		FORM	
			Stack Emissions		Dilution Tunnel Emissions			Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel
			MM5	OM7	MM5	OM7	ASTM						
<u>Timberaze</u>													
1A	10,772	0.90	9.38	4.43	11.5L	6.17L	4.31	3.39	4.171	0.0567	0.0510L	0.0537	0.08221
2A	15,006	1.22	20.2	10.4	12.8	4.90	3.13	6.29	3.36	0.154	0.0288	0.112	0.0365
2A*	15,006	1.22					0.953						
<u>Blaze King</u>													
4	7,220	0.0	17.4	6.02	10.7	7.98Q	4.08	9.55	4.22	0.0762	0.0906	0.0240	0.0473
4*	7,220	0.60				3.95							
1	11,185	1.09	5.75	3.71X	11.0	4.13	2.54	2.15	3.40	0.0467	0.0575	0.0206	0.0381
1*	11,185	1.09		3.36			2.50						
5	22,201	1.64	9.76	3.00XQ	13.3	9.30Q	4.90	4.17	3.54	0.145	0.0990	0.0817	0.0726
5*	22,201	1.64	8.49		15.2			2.29	3.63	0.140	0.111	0.0798	0.0785
2	32,170	2.77	15.6	8.07	23.7	10.7	7.98	4.98	6.62	0.178	0.255	0.104	0.173
2*	32,170	2.77		7.64Q									
3A													
<u>Lakewood</u>													
1	9,812	0.89	44.5	23.8Q	51.9	24.3Q	27.4	15.7	19.4	0.335	0.460	0.121	0.185
3	13,277	1.17	42.9	24.5Q	75.3	27.0	33.0	20.0	29.5	0.338	0.747	0.174	0.539
3*	13,277	1.17		26.7	53.5				24.9		0.659		0.505
2	16,587	1.51	32.9	19.6Q	54.4	28.5	22.4	13.8	23.9	0.569	1.10	0.245	0.492
4	96,474	7.17	184.	52.0Q	168.0	54.5	99.0	92.5	80.8	7.71	3.86	16.4	12.6
4*	96,474	7.17	184.			88.3H		80.8		5.49		14.4	

(continued)

TABLE 1a (continued)

Stove Burn Number	Heat Output (Btu/ hr)	Burn Rate (dry kg/ hr)	Particulate					TCO		Phenol		MM		
			Stack Emissions		Dilution Tunnel Emissions			Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	
			MM5	OM7	MM5	OM7	ASTM							
S	<u>Rosca</u>													
	2	7,972	0.54	30.5	21.2	18.5	8.26	12.3	12.1	6.21	0.194	0.0557	0.0923	0.0342
	2*	7,972	0.54				12.8Q							
	4	13,999	1.08	16.0	9.26	28.4	8.66Q	9.93	6.55	7.76	0.303	0.249	0.432	0.384
	1	19,511	1.46	20.6	15.4	33.0	10.7	10.1	9.36	5.94	0.327	0.225	0.833	0.801
	1*	19,511	1.46		11.6			8.98						
	5	40,591	3.10	50.3	25.9	67.1	37.1	20.5	24.2	21.3	2.32	1.48	4.50	4.48
	3A													
	3*A													
	<u>Fisher</u>													
2	8,752	0.55	9.94	5.38	22.6L	10.7	4.17	2.97	3.22L	0.0637	0.0371L	0.0202	0.0815	
2*	8,752	0.55			14.9				2.68		0.0220		0.0641	
4	14,273	0.95	17.3	11.8	23.8H	13.1	6.12	5.13	3.99H	0.140	0.0246H	0.0451	0.0750H	
4*	14,273	0.95			27.5				3.0*		0.0312		0.105	
3	23,570	1.58	19.6	16.0	47.7	21.4	13.6	5.53	6.67	0.183	0.123	0.0833	0.238	
1	29,223	2.02	40.5	30.4	71.9	37.1	31.2	12.6	13.0	0.432	0.146	0.155	0.415	

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter box temperatures

X - Back filter torn

L - Sample rate below 90% isokinetics

H - Sample rate above 110% isokinetics

A - Test burn was not consistent with specified stove operating procedures

TABLE 1b. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING OREGON WOODSTOVE COMBUSTION PROGRAM AND
ACTUAL DILUTION TUNNEL GAS FLOWS DETERMINED BY PAUL SAMPLE TRAIN - GRAMS/KILOGRAMS

Stove Burn Number	Heat Output (Btu/ hr)	Burn Rate (dry kg/ hr)	Particulate					TCO		Phenol		PM	
			Stack Emissions		Dilution Tunnel Emissions			Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel
			MM5	OM7	MM5	OM7	ASTM						
Timberaze													
1A	10,772	0.90	10.4	4.92	12.8L	6.85L	4.79	3.76	4.64L	0.0630	0.0567L	0.0596	0.0913L
2A	15,006	1.22	16.6	8.55	10.5	4.02	2.57	5.16	2.75	0.126	0.0236	0.0921	0.0299
2A*	15,006	1.22					0.781						
Hiase King													
4	7,220	0.60	29.0	10.0	17.8	13.3Q	6.80	15.9	7.03	0.127	0.151	0.0406	0.0700
4*	7,220	0.60				6.58							
1	11,185	1.09	5.28	3.40X	10.1	3.79	2.33	1.97	3.12	0.0428	0.0527	0.0263	0.0352
1*	11,185	1.09		3.08		2.29							
5	22,281	1.64	5.95	1.83XQ	8.13	5.67Q	2.99	2.54	2.16	0.0887	0.0604	0.0498	0.0443
5*	22,281	1.64	5.18		9.24			1.82	2.21	0.0852	0.0678	0.0487	0.0479
2	32,170	2.77	5.62	2.91	8.56	3.87	2.88	1.80	2.39	0.0644	0.0919	0.0376	0.0625
2*	32,170	2.77		2.76Q									
3A													
Lakewood													
1	9,812	0.89	50.0	26.7Q	60.6	27.3Q	30.8	17.6	21.8	0.376	0.517	0.136	0.208
3	13,277	1.17	36.7	20.9Q	64.4	23.1	28.2	17.1	25.2	0.289	0.639	0.149	0.460
3*	13,277	1.17		22.9	45.7				21.2		0.563		0.432
2	16,587	1.51	21.8	13.0Q	36.0	18.9	14.8	9.12	15.8	0.377	0.729	0.162	0.326
4	96,474	7.17	25.6	7.26Q	23.5	7.60	13.8	12.9	11.3	1.08	0.538	2.28	1.76
4*	96,474	7.17	25.6			12.3H		11.3		0.765		2.01	

(continued)

TABLE 1b (continued)

Stove Burn Number	Heat Output (Btu/ hr)	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						
<u>Bosca</u>													
2	7,972	0.54	56.4	39.3	34.2	15.3	22.8	22.4	11.5	0.359	0.103	0.171	0.0633
2*	7,972	0.54				23.7Q							
4	13,999	1.08	14.8	8.58	26.3	8.02Q	9.20	6.06	7.18	0.355	0.131	0.400	0.355
1	19,511	1.46	14.1	17.6	22.6	7.30	6.90	6.41	4.07	0.224	0.154	0.571	0.549
1*	19,511	1.46		7.98			6.15						
5	40,591	3.10	16.2	8.37	21.7	12.0	6.63	7.80	6.86	0.74	0.476	1.45	1.44
3A													
3*A													
<u>Fisher</u>													
2	8,752	0.55	18.1	9.79	41.2L	19.5	7.59	5.40	5.86L	0.116	0.0674L	0.0367	0.140L
2*	8,752	0.55			27.1				4.87		0.0401		0.117
4	14,273	0.95	18.2	12.4	25.1H	13.8	6.45	5.40	4.20H	0.147	0.0253H	0.0475	0.0789H
4*	14,273	0.95			29.0				4.01		0.0328		0.110
3	23,570	1.58	12.4	10.1	30.2	13.5	8.58	3.50	4.22	0.116	0.0780	0.0527	0.151
1	29,223	2.02	20.1	15.1	35.6	18.3	15.4	6.22	6.42	0.214	0.0724	0.0767	0.205

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter box temperatures

X - Back filter torn

L - Sample rate below 90% isokinetic

H - Sample rate above 110% isokinetic

A - Test burn was not consistent with specified stove operating procedures

TABLE 1c. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING OREGON WOODSTOVE COMBUSTION PROGRAM AND
ACTUAL DILUTION TUNNEL GAS FLOWS DETERMINED BY EACH SAMPLE TRAIN - MICROGRAMS/JOULE

Stove Burn Number	Heat Output (Btu/ hr)	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						
<u>Timbereze</u>													
1A	10,772	0.90	0.826	0.390	1.01L	0.543L	0.379	0.298	0.367L	0.00499	0.00449L	0.00472	0.00724L
2A	15,006	1.22	1.287	0.659	0.611	0.310	0.198	0.398	0.212	0.00973	0.00182	0.00710	0.00231
2*A	15,006	1.22					0.0603						
<u>Blaze King</u>													
4	7,220	0.60	2.29	0.790	1.40	1.05Q	0.536	1.26	0.554	0.0100	0.0119	0.00315	0.00621
4*	7,220	0.60				0.518							
1	11,185	1.09	0.488	0.314X	0.935	0.350	0.215	0.182	0.288	0.00396	0.00487	0.00243	0.00325
1*	11,185	1.09		0.285			0.212						
5	22,281	1.64	0.415	0.128XQ	0.568	0.396Q	0.209	0.177	0.151	0.00619	0.00422	0.00348	0.00309
5*	22,281	1.64	0.361		0.645			0.127	0.154	0.00595	0.00473	0.00340	0.00334
2	32,170	2.77	0.459	0.238	0.62	0.316	0.235	0.147	0.195	0.00526	0.00751	0.00307	0.00510
2*	32,170	2.77		0.225Q									
3A													
<u>Lakewood</u>													
1	9,812	0.89	4.31	2.30Q	5.21	2.35Q	2.65	1.52	1.88	0.0324	0.0444	0.0117	0.0179
3	13,277	1.17	3.07	1.75Q	5.38	1.93	2.36	1.43	2.11	0.0241	0.0534	0.0124	0.0385
3*	13,277	1.17		1.91	3.82				1.78		0.0471		0.0361
2	16,587	1.51	1.88	1.12Q	3.11	1.64	1.28	0.787	1.36	0.0325	0.0630	0.0140	0.0281
4	96,474	7.17	1.81	0.512Q	1.65	0.536	0.973	0.910	0.794	0.0760	0.0379	0.161	0.124
4*	96,474	7.17	1.81			0.868H		0.795		0.0539		0.141	

(continued)

TABLE 1c (continued)

Stove Burn Number	Heat Output (Btu/ hr)	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						
<u>Bosca</u>													
2	7,972	0.54	3.62	2.53	2.20	0.982	1.47	1.44	0.739	0.0231	0.00663	0.0110	0.00406
2*	7,972	0.54				1.52Q							
4	13,999	1.08	1.09	0.628	1.92	0.587Q	0.673	0.444	0.526	0.0260	0.0169	0.0292	0.0260
1	19,511	1.46	1.00	0.749	1.60	0.518	0.490	0.455	0.289	0.0159	0.0109	0.0405	0.0390
1*	19,511	1.46		0.566			0.437						
5	40,591	3.10	1.18	0.606	1.57	0.868	0.480	0.565	0.497	0.0541	0.0345	0.105	0.105
3A													
3*A													
<u>Fisher</u>													
2	8,752	0.55	1.08	0.583	2.45L	1.16	0.452	0.322	0.349L	0.00690	0.00402L	0.00219	0.00883L
2*	8,752	0.55			1.62				0.290		0.00239		0.00695
4	14,273	0.95	1.15	0.783	1.58H	0.868	0.407	0.341	0.265H	0.00928	0.00164H	0.00300	0.00498H
4*	14,273	0.95			1.83				0.253		0.00207		0.00696
3	23,570	1.58	0.789	0.643	1.92	0.860	0.546	0.222	0.268	0.00738	0.00496	0.00335	0.00959
1	29,223	2.02	1.32	0.988	2.34	1.20	1.01	0.407	0.421	0.0140	0.00474	0.00503	0.0135

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter box temperatures

X - Back filter torn

L - Sample rate below 90% isokinetics

H - Sample rate above 110% isokinetics

A - Test burn was not consistent with specified stove operating procedures

TABLE 2a. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING OREGON METHOD 7 TO
STANDARDIZE DILUTION TUNNEL FLOW & MOISTURE CONTENT GRAMS PER HOUR

Stove Burn Number	Heat Output (Btu/ hr)	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						
Timbereze													
1A	10,772	0.90	9.38	4.43	11.4L	6.16L	4.26	3.39	4.12	0.0567	0.0507	0.0537	0.0816
2A	15,006	1.22	20.2	10.4	13.2	4.89	3.37	6.29	3.44	0.154	0.0298	0.112	0.0376
2A*	15,006	1.22					0.999						
Blaze King													
4	7,220	0.60	17.4	6.02	10.7	7.99Q	4.50	9.55	4.22	0.0762	0.0908	0.0240	0.0474
4*	7,220	0.60				3.96							
1	11,185	1.09	5.75	3.71X	10.9	4.15	2.66	2.15	3.39	0.0467	0.0570	0.0286	0.0301
1*	11,185	1.09		3.36			2.34						
5	22,281	1.64	9.76	3.00XQ	13.4	9.27Q	4.9%	4.17	3.56	0.145	0.0996	0.0817	0.0731
5*	22,281	1.64	8.49		15.3			2.99	3.65	0.140	0.112	0.0798	0.0790
2	32,170	2.77	15.6	4.07	24.1	10.7	8.5%	4.98	6.75	0.178	0.258	0.104	0.176
2*	32,170	2.77		7.64Q									
Lakewood													
1	9,812	0.89	44.5	23.8Q	54.1	24.4Q	27.2	15.7	19.4	0.335	0.461	0.121	0.186
3	13,277	1.17	42.9	24.5Q	74.8	27.0	33.1	20.0	29.2	0.338	0.741	0.174	0.5341
3*	13,277	1.17		26.7	53.2				24.8		0.655		0.503
2	16,587	1.51	32.9	19.6Q	54.5	28.5	22.1	13.8	23.9	0.569	1.10	0.245	0.492
4	96,474	7.17	184.	52.0Q	170.	54.6	97.1	92.5	81.8	7.73	3.90	16.4	12.8
4*	96,474	7.17	184.			89.0H		80.8		5.49		14.4	

(continued)

TABLE 2a (continued)

Stove Burn Number	Heat Output (Btu/ hr)	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						
<u>Bosca</u>													
2	7,972	0.54	30.5	21.2	18.5	8.27	12.2	12.1	6.21	0.194	0.0558	0.0923	0.0343
2*	7,972	0.54				12.8Q							
4	13,999	1.08	16.0	9.26	28.6	8.66Q	9.10	6.55	7.85	0.383	0.251	0.432	0.385
1	19,511	1.46	20.6	15.4	32.7	10.7	9.85	9.36	5.90	0.327	0.222	0.833	0.791
1*	19,511	1.46		11.6		8.76							
5	40,591	3.10	50.3	25.9	68.3	37.2	20.4	24.2	21.6	2.32	1.50	4.50	4.55
<u>Fisher</u>													
2	8,752	0.55	9.94	5.28	22.6L	10.7	4.17	2.97	3.25	0.0637	0.0815	0.0202	0.0371
2*	8,752	0.55			14.9				2.70		0.0641		0.0220
4	14,273	0.95	17.3	11.8	23.9H	13.0	6.23	5.13	4.03	0.140	0.0753	0.0451	0.0247
4*	14,273	0.95			28.3				3.94		0.108		0.0320
3	23,570	1.58	19.6	16.0	48.0	21.3	13.4	5.53	6.73	0.183	0.240	0.0833	0.124
1	29,223	2.02	40.5	30.4	71.6	37.0	30.3	12.6	12.9	0.432	0.413	0.155	0.146

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter box temperatures

X - Back filter torn

L - Sample rate below 90% isokinetics

H - Sample rate above 110% isokinetics

A - Test burn was not consistent with specified stove operating procedures

TABLE 2b. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING OREGON METHOD 7 TO STANDARDIZE
DILUTION TUNNEL FLOW & MOISTURE CONTENT GRAMS PER KILOGRAM

Stove Burn Number	Heat Output (Btu/ hr)	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						
Timbereze													
1A	10,772	0.90	10.4	4.92	12.6	6.84	4.73	3.76	4.58	0.0630	0.0563	0.0596	0.0906
2A	15,006	1.22	16.6	8.55	10.9		2.76	5.16	2.82	0.126	0.0244	0.0921	0.0308
2A*	15,006	1.22					0.818						
Blaze King													
4	7,220	0.60	29.0	10.0	17.8	13.3	7.50	15.9	7.04	0.127	0.151	0.0400	0.0790
4*	7,220	0.60				6.61							
1	11,185	1.09	5.28	3.40X	10.0	3.81	2.44	1.97	3.11	0.0428	0.0523	0.0263	0.0350
1*	11,185	1.09		3.08			2.15						
5	22,281	1.64	5.95	1.83XQ	8.17	5.66	3.03	2.54	2.17	0.0887	0.0607	0.0498	0.0446
5*	22,281	1.64	5.18		9.31			1.82	2.22	0.0852	0.0682	0.0487	0.0482
2	32,170	2.77	62	2.91	8.72	3.87	3.09	1.80	2.44	0.0644	0.0931	0.0376	0.0635
2*	32,170	2.77		2.76Q									
Lakewood													
1	9,812	0.89	50.0	26.70	60.7	27.4	30.6	17.6	21.8	0.376	0.518	0.136	0.209
3	13,277	1.17	36.7	20.90	63.9	23.1	28.3	17.1	25.0	0.289	0.633	0.149	0.457
3*	13,277	1.17		22.9	45.5				21.2		0.560		0.430
2	16,587	1.51	21.8	13.0Q	36.1	18.8	14.6	9.12	15.9	0.377	0.730	0.162	0.320
4	96,474	7.17	25.6	7.26Q	23.7	7.61	13.5	12.9	11.4	1.08	0.545	2.28	1.78
4*	96,474	7.17	25.6			12.4		11.3		0.765		2.01	

(continued)

TABLE 2b (continued)

Stove Burn Number	Heat Output (Btu/ hr)	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	ASTH						
<u>Bosca</u>													
2	7,972	0.54	56.4	39.3	34.3	15.3	22.5	22.4	11.5	0.359	0.103	0.171	0.0635
2*	7,972	0.54				23.7							
4	13,999	1.08	14.8	8.58	26.4	8.02	8.43	6.06	7.27	0.355	0.232	0.400	0.357
1	19,511	1.46	14.1	10.6	22.4	7.30	6.75	6.41	4.04	0.224	0.152	0.571	0.542
1*	19,511	1.46		7.98		6.00							
5	40,591	3.10	16.2	8.37	22.0	12.0	6.59	7.80	6.97	0.747	0.483	1.45	1.47
<u>Fisher</u>													
2	8,752	0.55	18.1	9.79	41.0	19.5	7.58	5.40	5.91	0.116	0.148	0.0367	0.0675
2*	8,752	0.55			27.1				4.91		0.117		0.0400
4	14,273	0.95	18.2	21.4	25.2	13.7	6.57	5.40	4.24	0.147	0.0792	0.0473	0.0260
4*	14,273	0.95			29.8				4.15		0.114		0.0337
3	23,570	1.58	12.4	10.1	30.4	13.5	8.45	3.50	4.26	0.116	0.152	0.0527	0.0783
1	29,223	2.02	20.1	15.1	35.4	18.3	15.0	6.22	6.38	0.214	0.204	0.0767	0.0721

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter box temperatures

X - Back filter torn

L - Sample rate below 90% isokinetics

H - Sample rate above 110% isokinetics

A - Test burn was not consistent with specified stove operating procedures

TABLE 2c. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING OREGON METHOD 7 TO STANDARDIZE
DILUTION TUNNEL FLOW & MOISTURE CONTENT PER MICROGRAMS/JOULE

Stove Burn Number	Heat Output (Btu/ hr)	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						
Timbereze													
1A	10,772	0.90	0.826	0.390	1.00	0.542	0.375	0.298	0.363	0.00499	0.00446	0.00472	0.00718
2A	15,006	1.22	1.287	0.659	0.837	0.309	0.213	0.398	0.217	0.00973	0.00188	0.00710	0.00237
2A*	15,006	1.22					0.0631						
Blaze King													
4	7,220	0.60	2.29	0.790	1.41	1.05	0.591	1.26	0.555	0.0100	0.0119	0.00315	0.00623
4*	7,220	0.60				0.521							
1	11,185	1.09	0.408	0.314X	0.928	0.352	0.226	0.182	0.287	0.00396	0.00483	0.00243	0.00323
1*	11,185	1.09		0.285			0.199						
5	22,281	1.64	0.415	0.128XQ	0.571	0.395	0.211	0.177	0.151	0.00619	0.00424	0.00348	0.00311
5*	22,281	1.64	0.361		0.650			0.127	0.155	0.00595	0.00476	0.00340	0.00336
2	32,170	2.77	0.459	0.238	0.712	0.316	0.252	0.147	0.199	0.00526	0.00761	0.00307	0.00518
2*	32,170	2.77		0.225Q									
Lakewood													
1	9,812	0.89	4.31	2.30Q	5.23	2.36	2.63	1.52	1.88	0.0324	0.0445	0.0117	0.0180
3	13,277	1.17	3.07	1.75Q	5.34	1.93	2.37	1.43	2.09	0.0241	0.0529	0.0124	0.0382
3*	13,277	1.17		1.91	3.80				1.77		0.0468		0.0359
2	16,587	1.51	1.88	1.12Q	3.12	1.63	1.26	0.787	1.37	0.0325	0.0631	0.0140	0.0281
4	96,474	7.17	1.81	0.512Q	1.67	0.537	0.955	0.910	0.804	0.0760	0.0384	0.161	0.126
4*	96,474	7.17	1.81			0.875		0.795		0.0539		0.141	

(continued)

TABLE 2c (continued)

Stove Burn Number	Heat Output (Btu/ hr)	Burn Rate (dry) (kg/ hr)	Particulate					TCO		Phenol		POM		
			Stack Emissions		Dilution Tunnel Emissions			Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	Stack	Di u- ti , Tunnel	
			MM5	OM7	MM5	OM7	ASTM							
Bosca														
2	7,972	0.54	3.62	2.53	2.20	0.983	1.45	1.44	0.739	0.0231	0.00664	0.0110	0.00408	
2*	7,972	0.54				1.52								
4	13,999	1.08	1.09	0.628	1.94	0.587	0.617	0.444	0.532	0.0260	0.0170	0.0292	0.0261	
1	19,511	1.46	1.00	0.749	1.59	0.518	0.479	0.455	0.287	0.0159	0.0108	0.0405	0.0385	
1*	19,511	1.46		0.566			0.426							
5	40,591	3.10	1.18	0.606	1.60	0.670	0.478	0.565	0.505	0.0541	0.0350	0.105	0.106	
Fisher														
2	8,752	0.55	1.08	0.583	2.45	1.16	0.452	0.322	0.352	0.00690	0.00883	0.00219	0.00402	
2*	8,752	0.55			1.62				0.292		0.00695		0.00238	
4	14,273	0.95	1.15	0.783	1.59	0.867	0.415	0.341	0.268	0.00928	0.00500	0.00300	0.00164	
4*	14,273	0.95			1.89				0.262		0.00717		0.00213	
3	23,570	1.58	0.789	0.643	1.93	0.859	0.537	0.222	0.271	0.00738	0.00965	0.00335	0.00499	
1	29,223	2.02	1.32	0.988	2.32	1.20	0.982	0.407	0.418	0.0140	0.0134	0.00503	0.00472	

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter box temperatures

X - Back filter torn

L - Sample rate below 90% isokinetics

H - Sample rate above 110% isokinetics

A - Test burn was not consistent with specified stove operating procedures

TABLE 3a. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS USING ORSAT DATA AND P_c - GRAMS PER HOUR

Burn Number	P Factor	Heat Input (Btu/hr)	Burn Rate (dry kg/hr)	Particulate					TCO		Phenol		POH	
				Stack Emissions		Dilution Tunnel Emissions			Stack	Dilution Tunnel	Stack	Dilution Tunnel	Stack	Dilution Tunnel
				MM5	OM7	MM5	OM7	ASTM						
Timbereze														
1A	17,285	0.90	17.0	8.01	11.4L	6.16L	4.26	6.13	4.12L	0.103	0.0507L	0.0971	0.0816L	
2A	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	
2A*	23,218	1.22					0.999							
Blaze King														
4	11,607	0.60	23.1	7.99	10.7	7.99Q	4.50	12.7	4.22	0.101	0.0908	0.0319	0.0474	
4*	11,607	0.60				3.96								
1	20,898	1.09	7.13	4.59X	10.9	4.15	2.66	2.66	3.39	0.0576	0.0570	0.0355	0.0381	
1*	20,898	1.09		4.16		2.34								
5P	31,964	1.64	10.5	3.22XQ	13.4	9.27Q	4.96	4.47	3.56	0.156	0.0996	0.0877	0.0731	
5P*	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*	53,615	2.77		10.3Q										
3A P	6,620	0.34	5.45	2.50	15.9H	9.43	2.91	2.18	2.99H	0.0223	0.0493H	0.0316	0.0474	
Lakewood														
1	17,148	0.89	54.7	29.2Q	54.1	24.4Q	27.2	19.3	19.4	0.411	0.461	0.148	0.186	
3	22,667	1.17	56.4	32.1Q	74.8	27.0	33.1	26.3	29.2	0.444	0.741	0.228	0.5341	
3*	22,667	1.17		35.0	52.2				24.8		0.655		0.503	
2	29,004	1.51	45.3	26.9Q	54.5	28.5	22.1	18.9	23.9	0.782	1.10	0.337	0.492	
4	139,443	17.17	216.	61.3Q	170.	54.6	97.1	109.	81.8	9.11	3.90	19.3	12.8	
4*	139,443	17.17	216.			89.0H		95.1		6.46		16.9		

(continued)

TABLE 3a (continued)

Burn Number	P Factor Heat Input (Btu/ hr)	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						
Bosca													
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*	10,466	0.54				12.8Q							
4	21,299	1.08	14.7	8.49	28.6	8.66Q	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*	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
3AP	11,447	0.60	17.2	6.97	56.4	20.2H	19.7	7.50	14.0	0.402	0.549	0.476	1.06
3*AP	11,447	0.60	16.7Q		59.6Q			7.05Q	20.4Q	0.252Q	0.815Q	0.252Q	1.47Q
Fisher													
2	10,621	0.55	8.54	4.63	22.6L	10.7	4.17	2.55	3.25L	0.0547	0.0815L	0.0173	0.0371L
2*	10,621	0.55			14.9				2.70		0.0641		0.0220
4	18,501	0.95	15.9	10.8	23.9H	13.1	6.24	4.72	4.03H	0.128	0.0753H	0.0415	0.0247H
4*	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

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter temperatures

X - Second filter torn

H - Sample rate in excess of 110 percent isokinetic

L - Sample rate below 90 percent isokinetic

A - Test burn was not consistent with specified stove operating procedures

P - P_c calculated using CEMS data because of bad orsat

TABLE 3b. SUMMARY OF WOODS ROVE EMISSION TEST RESULTS CALCULATED AND F_C - GRAMS PER KILOGRAMS

Burn Number	F Factor	Heat input (wtu/hr)	Burn Rate (dry) (kg/hr)	Particulate					TCO		Phenol		PM	
				Stack Emissions		Dilution Tunnel Emissions			Stack	Dilution Tunnel	Stack	Dilution Tunnel	Stack	Dilution Tunnel
				MM5	OM7	MM5	OM7	AsTm						
<u>Timberze</u>														
1A	17,205	0.90	18.9	8.90	12.6L	6.84L	4.73	6.81	4.58L	0.114	0.0563I	0.108	0.0906L	
2A	23,218	1.22	12.0	6.19	10.9	4.01	2.76	3.73	2.82	0.0913	0.0244	0.0657	0.0308	
2A*	23,218	1.22					0.818							
<u>Blaze King</u>														
4	11,607	0.60	38.5	13.3	17.8	13.3Q	7.50	21.2	7.04	0.169	0.151	0.0332	0.0790	
4*	11,607	0.60				6.61								
1	20,898	1.09	6.54	4.21X	10.0	3.81	2.44	2.44	3.11	0.0530	0.0523	0.0325	0.0350	
1*	20,898	1.09		1.82			2.15							
5P	31,964	1.64	6.39	1.97QX	8.17	5.66Q	3.03	2.73	2.17	0.0952	0.0607	0.0534	0.0446	
5P*	31,964	1.64	5.55		9.31			1.95	2.22	0.0914	0.0682	0.0522	0.0482	
2	53,615	2.77	7.52	3.90	8.72	3.87	3.09	2.41	2.44	0.0861	0.0931	0.0503	0.0635	
2*	53,615	2.77		3.69Q										
3A	6,620	0.34	16.0	7.34	46.6H	27.7	8.56	6.41	8.79H	0.0656	0.145H	0.0429	0.119H	
<u>Lakewood</u>														
1	17,148	0.89	61.4	32.8Q	60.7	27.4Q	30.6	21.6	21.8	0.461	0.518	0.167	0.209	
3	22,667	1.17	48.2	27.5Q	63.9	23.1	28.8	22.5	25.0	0.379	0.633	0.195	0.457	
3*	22,667	1.17		30.0	45.5				21.2		0.560		0.430	
2	29,004	1.51	30.0	17.8Q	36.1	18.8	14.6	12.5	15.9	0.518	0.730	0.223	0.326	
4	139,443	7.17	30.2	8.55Q	23.7	7.61	13.5	15.2	11.4	1.27	0.545	2.69	1.78	
4*	139,443	7.17	30.2			12.4A		13.3		0.901		2.3e		

(continued)

TABLE 3b (continued)

Burn Number	P Factor	Heat Input (Btu/ hr)	Burn Rate (dry) (kg/ hr)	Particulate					TCO		Phenol		KOM	
				Stack Emissions		Dilution Tunnel Emissions			Stack	Dilution Tunnel	Stack	Dilution Tunnel	Stack	Dilution Tunnel
				MM5	OM7	MM5	OM7	ASPM						
<u>Bosca</u>														
2		10,466	0.54	50.5	35.2	34.3	15.3	22.5	20.1	11.5	0.322	0.103	0.153	0.0635
2*		10,466	0.54				23.7							
4		21,299	1.08	13.6	7.86	26.4	8.02Q	8.43	5.56	7.27	0.325	0.232	0.366	0.357
1		28,082	1.46	8.61	6.43	22.4	7.30	6.75	3.91	4.04	0.137	0.152	0.348	0.542
1*		28,082	1.46		4.86			6.00						
5		64,001	3.10	7.18	3.70	22.0	12.0	6.59	3.45	6.97	0.330	0.483	0.639	1.47
3A		11,447	0.60	28.7	11.6	94.0	33.7H	32.8	12.5	23.3	0.669	0.915	0.793	1.76
3*A		11,447	0.60	27.9Q		99.3Q			11.7Q	34.0Q	0.420Q	1.36Q	0.420Q	2.45Q
<u>Fisher</u>														
2		10,621	0.55	15.5	8.41	41.0L	19.5	7.58	4.64	5.91L	0.0995	0.148L	0.0315	0.0675L
2*		10,621	0.55			27.1				4.91		0.117		0.0400
4		18,501	0.95	16.8	11.4	25.2A	13.7	6.57	4.96	4.24H	0.135	0.0792H	0.0437	0.0260H
4*		18,501	0.95			29.8				4.15		0.114		0.0337
3		30,279	1.58	12.5	10.2	30.4	13.5	8.45	3.51	4.26	0.117	0.152	0.0529	0.0783
1		38,911	2.02	19.2	14.4	35.4	18.3	15.0	5.96	6.38	0.205	0.204	0.0736	0.0721

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter temperatures

X - Second filter torn

H - Sample rate in excess of 110% isokinetic

L - Sample rate below 90% isokinetic

A - Test burn was not consistent with specified stove operating procedures

TABLE 3c. SUMMARY OF WOODSTOVE EMISSION TEST RESULTS CALCULATED OPSAT DATA & η_c - MICROGRAMS PER JOULE

Burn Number	F Factor	Heat Input (Btu/hr)	Burn Rate (dry) (kg/hr)	Particulate					TCO		Phenol		POM	
				Stack Emissions		Dilution Tunnel Emissions			Stack	Dilution Tunnel	Stack	Dilution Tunnel	Stack	Dilution Tunnel
				MM5	OM7	MM5	OM7	ASTM						
Timberaze														
1A	17,285	0.90	0.932	0.440	0.624	0.33HL	0.234	0.336	0.226L	0.00563	0.00278L	0.00533	0.00448	
2A	23,218	1.22	0.597	0.308	0.541	0.200	0.137	0.186	0.141	0.00455	0.00122	0.00332	0.00153	
2A*	23,218	1.22					0.041							
Blaze King														
4	11,607	0.60	1.83	0.653	0.874	0.653Q	0.368	1.04	0.345	0.00828	0.00742	0.00261	0.00387	
4*	11,607	0.60				0.324								
1	20,898	1.09	0.323	0.20HX	0.497	0.188	0.121	0.121	0.154	0.00262	0.00259	0.00161	0.00173	
1*	20,898	1.09		0.189			0.106							
5P	31,964	1.64	0.311	0.0956XQ	0.398	0.275Q	0.147							
5P*	31,964	1.64	0.270		0.453			0.0953	0.108	0.00445	0.00332	0.00254	0.00234	
2	53,615	2.77	0.369	0.191	0.427	0.150	0.151	0.118	0.119	0.00422	0.00456	0.00246	0.00311	
2*	53,615	2.77		0.181Q										
3A	6,620	0.34	0.781	0.358	2.27H	1.35	0.417	0.312	0.428H	0.00319	0.00702H	0.00452	0.00574H	
Lakewood														
1	17,148	0.89	3.02	1.62Q	2.99	1.35Q	1.51	1.07	1.07	0.0227	0.0255	0.00921	0.0103	
3	22,667	1.17	2.30	1.34Q	3.13	1.13	1.39	1.10	1.22	0.0186	0.0310	0.00956	0.0224	
3*	22,667	1.17		1.47	2.23				1.04		0.0272		0.0210	
2	29,004	1.51	1.48	0.880Q	1.78	0.931	0.721	0.619	0.783	0.0256	0.0371	0.0110	0.0161	
4	139,443	7.17	1.47	0.417Q	1.16	0.371	0.661	0.741	0.556	0.0619	0.0266	0.131	0.0868	
4*	139,443	7.17	1.47			0.605H		0.647		0.0439		0.115		

(continued)

TABLE 3c (continued)

Burn Number	P factor	Heat Input (Btu/hr)	Burn Rate (dry) (kg/hr)	Particulate					TCO		Phenol		POM		
				Stack Emissions		Dilution Tunnel Emissions			Stack	Dilution Tunnel	Stack	Dilution Tunnel	Stack	Dilution Tunnel	
				MM5	OM7	MM5	OM7	ASTM							
Boaca															
2		10,466	0.54	2.47	1.72	1.68	0.749	1.10	0.984	0.561	0.0158	0.00506	0.00749	0.00311	
2*		10,466	0.54				1.16Q								
4		21,299	1.08	0.654	0.378	1.27	0.386Q	0.405	0.267	0.350	0.0156	0.0112	0.0176	0.0172	
1		28,082	1.46	0.425	0.317	1.10	0.360	0.333	0.193	0.199	0.00674	0.00750	0.0171	0.0267	
1*		28,082	1.46		0.240			0.296							
5		64,001	3.10	0.330	0.170	1.01	0.552	0.303	0.158	0.320	0.0152	0.0222	0.0293	0.0674	
3A		11,447	0.60	1.43	0.578	4.67	1.68H	1.63	0.622	1.16	0.0333	0.0455	0.0394	0.0877	
3*A		11,447	0.60	1.39Q		4.94Q			0.584Q	1.69Q	0.0209Q	0.0675Q	0.0209Q	0.122Q	
Fisher															
2		10,621	0.55	0.762	0.413	2.02L	0.957	0.372	0.228	0.290L	0.00489	0.00728L	0.00155	0.00331L	
2*		10,621	0.55			1.33				0.241		0.00572		0.00196	
4		18,501	0.95	0.816	0.556	1.23H	0.669	0.320	0.242	0.207H	0.00658	0.00386H	0.00213	0.00126H	
4*		18,501	0.95			1.45				0.202		0.00553		0.00164	
3		30,279	1.58	0.617	0.503	1.50	0.669	0.418	0.174	0.211	0.00577	0.00751	0.00262	0.00388	
1		38,911	2.02	0.947	0.711	1.74	0.902	0.738	0.293	0.314	0.0101	0.0101	0.00362	0.00355	

* Indicates results of duplicate runs

Q - Data presented but quality is uncertain due to low filter temperatures

X - Second filter torn

H - Sample rate in excess of 110% isokinetic

L - Sample rate below 90% isokinetic

A - Test burn was not consistent with specified stove operating procedures

- o Anisokinetic sampling conducted for OM7 and MM5 sample runs in the dilution tunnel were designated with an "H" when sample rates were over 110 percent of isokinetic and an "L" when sampling rates were below 90 percent of isokinetic.
- o Two torn second filters in OM7 sample trains (located between the third and fourth impingers) were identified with an "X".
- o Two test burns were not adequately conducted under the Oregon wood-stove test procedure stove operating guidelines. The doors were opened during sampling and the coals and woodpieces stirred during two Timber-eze test burns.
- o Several OM7 and MM5 sample runs were conducted with the heated filter box temperature below the specified lower limit of 223°F. In all of those cases except BD-OM7-5 the average temperatures were between 200 and 223°F.

These conditions are discussed in greater detail in Section 5.

Total gravimetric emissions for each of the sampling methods are comprised of the combined individual analyses of the following fractions:

- o MM5 - front half MeCl₂ rinse drydown residue
 filter catch
 XAD extraction
 semi-volatile organics (extracted from back-half water) by GC
 plus water drydown residue
 semi-volatile organics (in rinse solvent) by GC plus solvent
 drydown residue condensate extraction semi-volatile organics
 by GC plus drydown residue
- o 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
- o ASTM - front half and between-filter solvent rinse drydown residue
 front filter catch
 back filter catch

The summary tables also include results of organic sampling and analyses conducted on MM5 samples for total chromatographable organics (TCO), phenol and POM. TCO were determined on the combined back half fractions of the MM5 samples. POM and phenol were analyzed in combined aliquots from all front and back half fractions of the MM5 samples.

Table 4 presents arithmetic averages on a per stove basis for the results presented in Tables 3a through 3c. Averages were calculated for all

TABLE 4. AVERAGE EMISSION RATES PER STOVE ARITHMETIC AVERAGE

Burn Num- ber	Stove	Particulate					TCO		Phenol		FOM	
		Stack Emissions		Dilution Tunnel Emissions		ASTM	Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel	Stack	Dilu- tion Tunnel
		MM5	OM7	MM5	OM7							
AVERAGE GRAMS PER HOUR												
4	Blaze King	14.1 (5)	7.65(3)	14.9 (5)	6.27(3)	4.60(5)	3.54(5)	4.31(5)	0.141(5)	0.123(5)	0.0759(5)	0.0827
4	Lakewood	117. (5)	35.0 (1)	81.3 (5)	36.7 (3)	44.9 (4)	53.7 (5)	35.8 (5)	3.44 (5)	1.37 (5)	7.38 (5)	2.90 (5)
4	Bosca	19.2 (4)	11.1 (5)	37.0 (4)	18.7 (3)	12.1 (5)	8.33(4)	10.4 (4)	0.828(4)	0.507(4)	0.742 (4)	1.44 (4)
4	Fisher	20.8 (4)	15.2 (4)	40.7 (4)	20.5 (4)	13.5 (4)	6.2 (4)	6.57(4)	0.195(4)	0.206(4)	0.0729(4)	0.0810(4)
AVERAGE GRAMS PER KILOGRAM OF DRY WOOD BURNED												
4	Blaze King	12.9 (5)	8.15(3)	10.8 (5)	4.76(3)	3.94(4)	6.15(5)	3.40(5)	0.0989(5)	0.0851(5)	0.0483(5)	0.0541(5)
4	Lakewood	40.0 (5)	30.0 (1)	46.0 (5)	16.5 (3)	21.9 (4)	17.0 (5)	19.1 (5)	0.706 (5)	0.597 (5)	1.13 (5)	0.640 (5)
4	Bosca	20.0 (5)	11.6 (5)	26.5 (4)	14.6 (4)	13.9 (6)	8.26(4)	7.45(4)	0.279 (4)	0.243 (4)	0.377 (4)	0.608 (4)
4	Fisher	16.0 (4)	11.10(4)	30.7 (4)	16.3 (4)	9.4 (4)	4.77(4)	4.93(4)	0.139 (4)	0.147 (4)	0.0504(4)	0.0560(4)
AVERAGE MICROGRAMS PER JOULE												
4	Blaze King	0.633(5)	0.344(3)	0.530(5)	0.234 (3)	0.179(5)	0.344(4)	0.182(4)	0.00449(4)	0.00447(4)	0.00231(4)	0.00276(4)
4	Lakewood	1.96 (5)	1.47 (1)	2.27 (4)	0.811 (3)	1.07 (4)	0.835(5)	0.934(5)	0.0345 (5)	0.0293 (5)	0.0549 (5)	0.0313 (5)
4	Bosca	0.970(4)	0.565(5)	1.27 (4)	0.554 (3)	0.487(5)	0.401(4)	0.358(4)	0.0133 (4)	0.0115 (4)	0.0179 (4)	0.0286 (4)
4	Fisher	0.786(4)	0.546(4)	1.51 (4)	0.799 (4)	0.462(4)	0.234(4)	0.242(4)	0.00684(4)	0.0072 (4)	0.00248(4)	0.0276 (4)

pollutants measured by each method. None of the data qualified with Q, X, H, L or A in Tables 3a through 3c were used in calculating the arithmetic average. The number of samples used to determine each average is in parentheses in the table.

SECTION 3

TEST FACILITY AND STOVE DESCRIPTIONS

The test facility was designed to conform as closely as practicable to both the Oregon and ASTM facility requirements (Figure 3). The test stove was mounted on a platform scale. The accuracy of the scale used for most of these tests was 0.2 pounds. The 8-inch stove pipe was equipped with a water seal which isolated the sampling location from the stove and scale. This minimized interference with the weight measurements by sampling activities in the stack.

The ASTM dilution hood was located above the stove pipe exit. The draft was measured on several occasions at the top of the stack to insure that less than 0.005 inches of water draft was induced on the stack with no fire in the stove. The dilution tunnel was constructed of 8-inch stove pipe. Sampling was conducted in a downcomer upstream of the blower. The blower was operated at a constant rate during the test program.

APPLIANCE TESTED AND TEST CONDITIONS

Five stoves were tested under this test program. The units are identified below:

- o Timber-eze Model 477 Catalytic Heater
- o Blaze King Catalyst Stove - King Model KEJ-1101
- o Lakewood Cottager (non-catalytic)
- o Bosca - Model 500 (high efficiency noncatalyst stove)
- o Fisher Tech IV Fireplace Insert (catalytic)

Test charges for the Timber-eze were approximately 8.2 kg, Blaze King 13.7 kg, Lakewood 7.9 kg, Bosca 4.2 kg, and Fisher 7.6 kg. Fuel moisture was checked prior to each test. Air dried Douglas fir having a moisture content between 19 and 25% on a dry basis was used for all tests.

Stove operation followed the Oregon procedures with a few exceptions. Those exceptions are presented in Section 5 under "Other Considerations".

SELECTION OF SAMPLING LOCATION

The test locations were selected according to the OM7 and ASTM criteria. The stove pipe test location was 8 feet above the scale platform (Figure 3). The MM5 and the OM7 trains sampling in the stack were located at the same

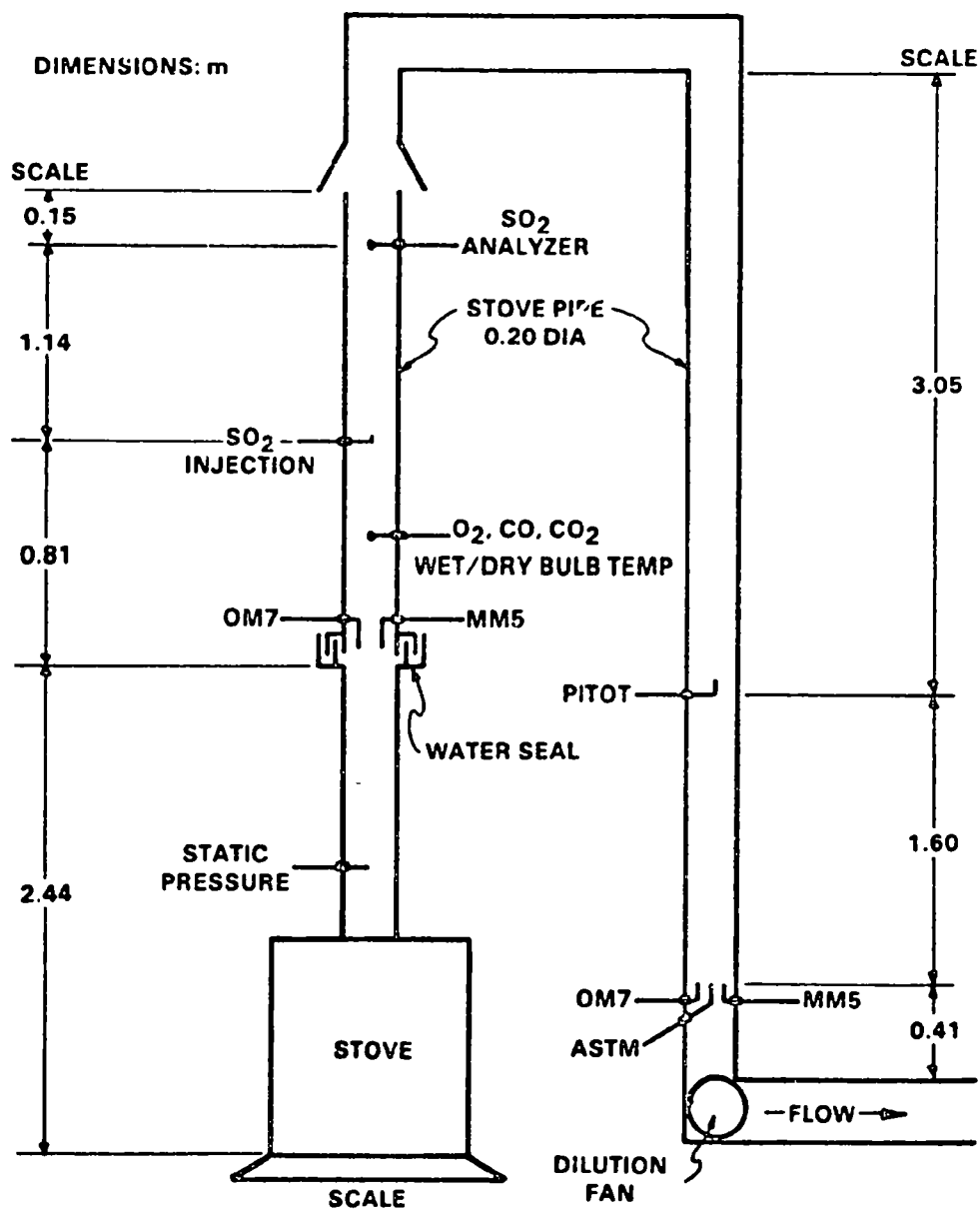


Figure 1. Schematic of stove exhaust and dilution system with sample locations.

elevation to avoid any possible discrepancies in results because of loss of particulate on the stack wall or other reasons. No traverse was attempted due to the small duct diameter and multiple sample probes (OM7 and MM5) being located at the same elevation.

The wet bulb and dry bulb thermometers were located approximately 10 inches downstream of the sampling probes. The continuous analyzer sample probe was at the same elevation as the thermocouples.

The SO₂ tracer gas injection was 36 inches downstream of the OM7 and MM5 sampling points as specified in the method. The stack height allowed the SO₂ gas sample to be extracted at a point 46 inches downstream of the injection point which does not meet the 8 duct diameters criteria of the method.

The test location in the dilution tunnel was selected to meet ASTM criteria except that the sampling trains were 8 duct diameters downstream of the pitot tube. Three sample probes were at the same elevation (ASTM, OM7, and MM5) in the tunnel. The ASTM method specifies that the pitot tube be located approximately 2 tunnel diameters (16 inches) downstream of the pitot tube. The various draft EPA procedures (1A, 2C, 5C) which deal with sampling small ducts dictate 8 duct diameters of undisturbed flow upstream of both the pitot and probe locations. EPA criteria were followed for selecting the dilution tunnel test points. The sample probes were inserted at 90° angles to each other. Nozzles were inserted 2 inches into the stack. The thermocouple was inserted 6 inches downstream of the sample probe.

SECTION 4

SAMPLING PROCEDURES

Due to the nature of the test program and the source category to be tested, some compromises were required between the specifics of the various test procedures. The basic procedures followed were:

- o Modified Method 5 prepared for EPA, ORD, EPA Project Officer Raymond Merrill.
- o Oregon Department of Environmental Quality Standard Method for Measuring the Emissions and Efficiencies of Woodstoves, June 8, 1984.
- o ASTM Standard Test Method for Heating Performance and Emissions of Residential Wood-Fired Closed Combustion Chamber Heating Appliances, Revised November 1984.

Those methods are referred to in this document as MM5, OM7, and ASTM, respectively. Certain other reference and draft procedures were used in conjunction with those basic methods. The specific ancillary methods used varied with the test location.

- o Stack MM5 - EPA Method 3 - molecular weight
EPA Method 4 - moisture
EPA Method 5C - particulate matter in small ducts
- o Stack OM7 - OM4 - moisture
OM5 - particulate matter emissions
OM7 - condensible matter emissions
EPA Method 10 - CO, CO₂
EPA Method 20 - oxygen
ASTM D3286.77 - higher heating value
or ASTM D2015.77 - higher heating value
OM4 - alternate, wet bulb/dry bulb
- o Dilution Tunnel MM5 - EPA-2C - velocity in small ducts
EPA-3 - molecular weight
EPA-4 - moisture
EPA-5C - particulate matter in small ducts
- o Dilution Tunnel OM7 - OM4 - moisture
OM5 - particulate emissions
OM7 - condensible matter emissions

- o Dilution Tunnel ASTM - as specified in the method

Figures 2, 3, and 4 illustrate the MM5, OM7, and ASTM sample trains, respectively.

The emissions sampling on the Timber-eze stove began within 5 minutes after the stove was loaded with the fuel charge. This was a deviation from the Oregon procedure and was corrected for all subsequent burns. All other test burns were conducted with the emissions sampling starting one minute or less before the stove test charge was placed in the firebox.

SAMPLE RECOVERY

The solvents specified for OM7 sample recovery are acetone (front half) and acetone and water (back half). For the ASTM method acetone and methanol are specified. Those recoveries were made according to the procedures. In addition, a methylene chloride rinse of the OM7 front and back halves was made and recovered separately.

The MM5 train was recovered using methylene chloride. Methanol was used on runs H-2, H-3, H-4, and H-5 after the MeCl_2 rinse because the MeCl_2 did not seem to clean the trains satisfactorily. Those fractions were recovered separately.

Following sample recovery, all samples were sealed and safely stored until transported to the laboratory for analysis. Samples were delivered to the lab within 1 week of their collection.

Sample containers were borosilicate glass bottles with Teflon® lined caps. Prior to the test program all sample containers and sample train glassware were washed with soap and water rinsed with distilled water and a final rinse with methylene chloride.

Filters for the test program were tare weighed by ES. Tare weights were given to Radian for determination of final weights.

EPA-MM5

Two front half fractions and four back half fractions were collected for the MM5 sample trains. The fractions were:

- o Front half
 - methylene chloride probe and front half rinse
 - filter
- o Back half
 - condensate, including rinse of all glassware between the filter and the XAD-2 module and the MeCl_2 rinse of the condensate impinger bottle

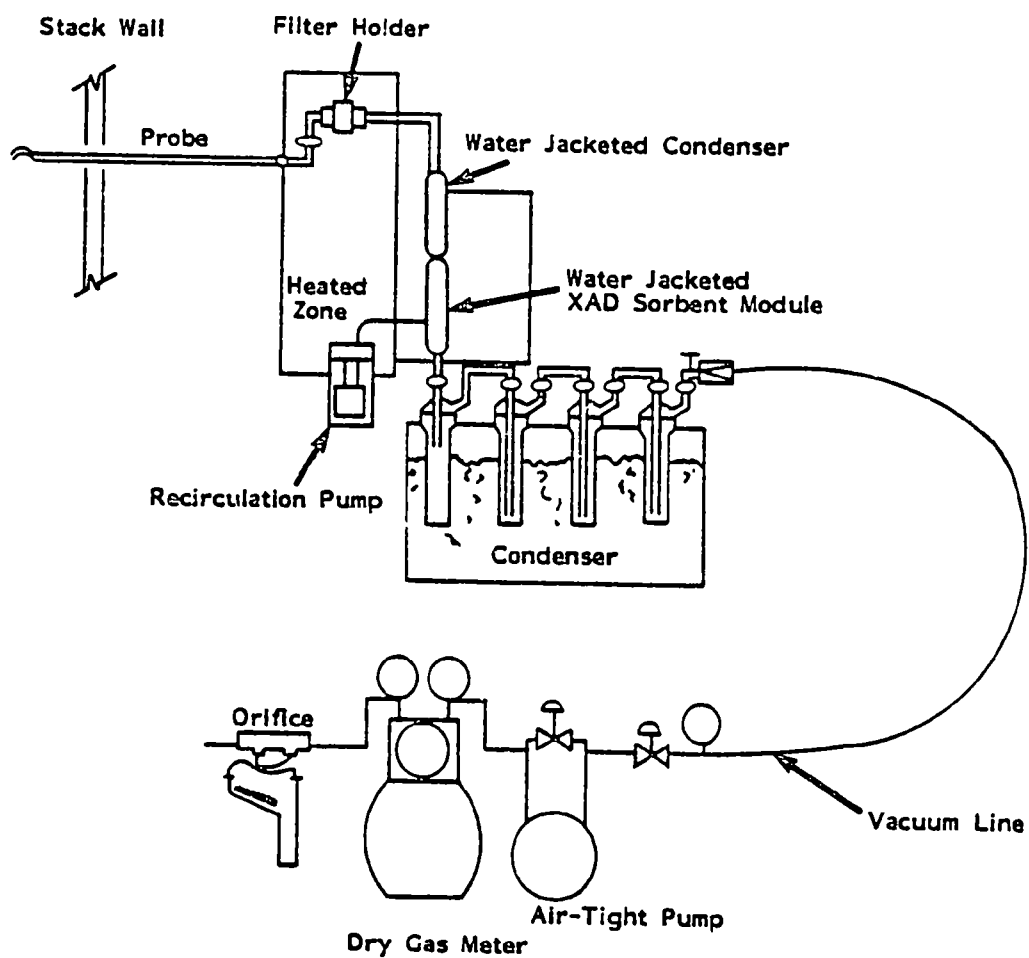


Figure 2. Schematic of Modified Method 5 Sample Train

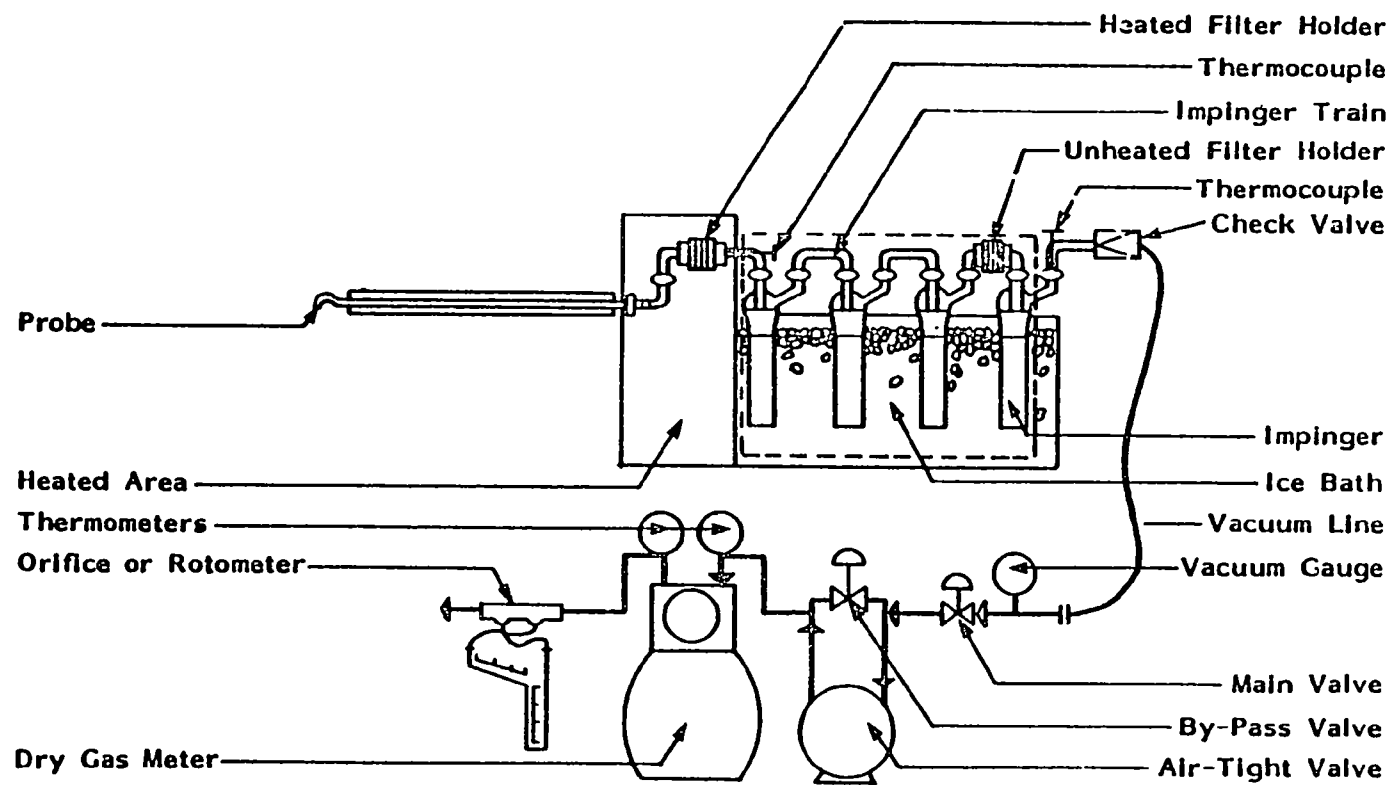


Figure 3. Schematic of OM7 Sampling Train

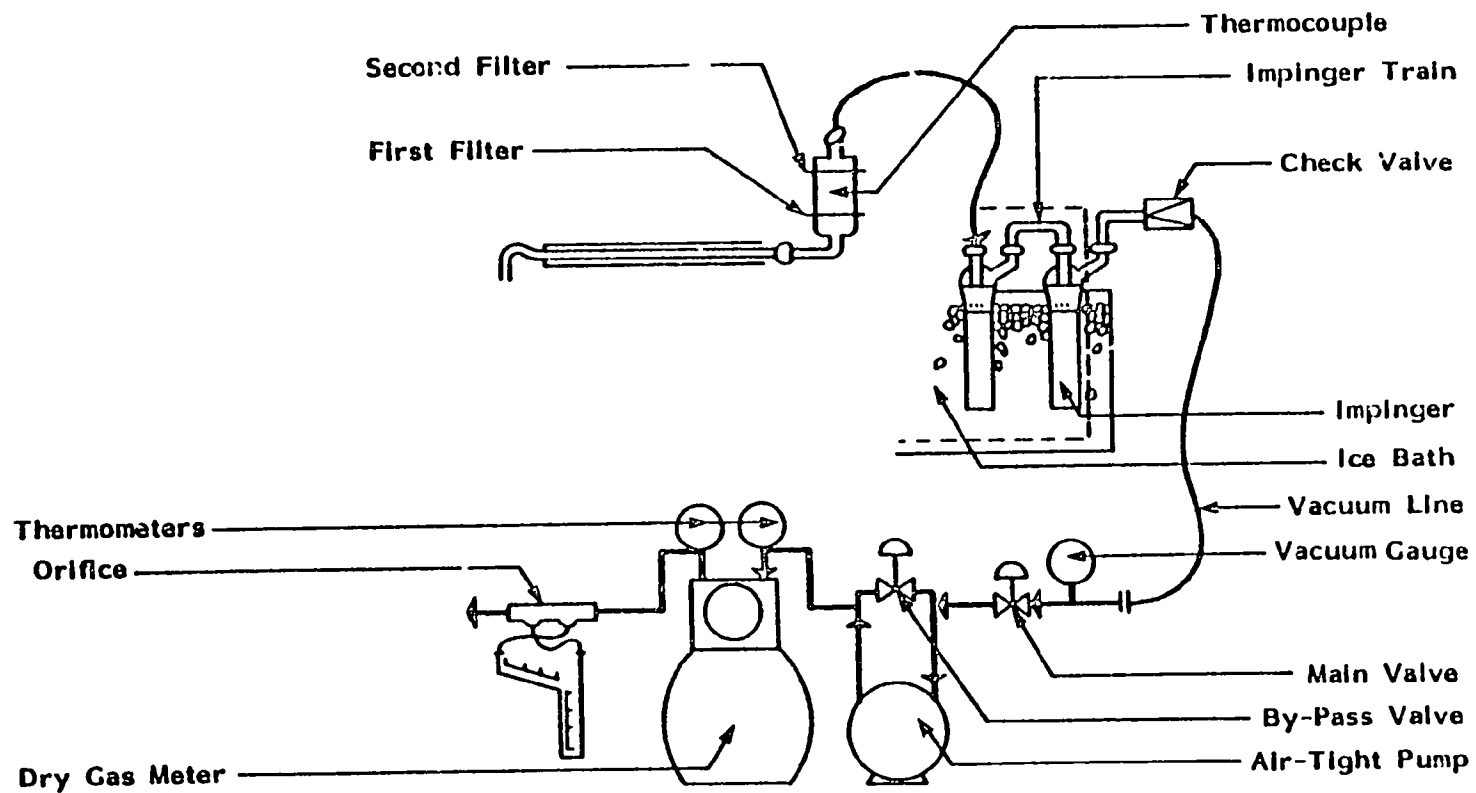


Figure 4. Schematic of ASTM Sample Train

- YAD-2 module
- back half water from the second and third impingers including a rinse
- silica gel

OM7

The OM7 sample recovery resulted in the following fractions (OM7, 8.0):

- o Front half
 - acetone rinse of probe and front half
 - filter
 - MeCl_2 rinse of probe and front half (in addition to OM7 procedure)
- o Back half
 - water catch and impinger water wash
 - acetone rinse of back half
 - MeCl_2 rinse of back half (in addition to OM7 procedure)
 - filter
 - silica gel

ASTM

Sample fractions from each ASTM train included (ASTM, 10.11, 11.12):

- o Front half:
 - acetone/methanol rinse of probe and front half
 - first filter
 - second filter
 - MeCl_2 rinse of front half (in addition to ASTM procedure)
- o Back half
 - none

Although the ASTM method does not specify, the glass surfaces exposed to the sample between the two filters were rinsed with acetone then methanol and both rinses added to the front half acetone/methanol rinse bottle.

SAMPLE IDENTIFICATION AND LOG

Each sample fraction was given an identifying code number which designated the sample location, stove number, method type, sample fraction and run number. Application of the code simplified tracking samples throughout the collection, handling, analysis and reporting processes.

The sample numbering system had 5 components which were applied in the following order:

- o Stove ID - Sample Location - Method - Fraction - Run Number

The specific codes are listed below:

- o Stove ID: B - Blaze King
 T - Timber-eze
 G - Generic (Lakewood)
 H - High Efficiency (Bosca)
 F - Fisher
- o Sample locations: S - Stack
 D - Dilution Tunnel
- o Method: MM5 - Modified Method 5
 OM7 - Oregon Method 7
 AST - ASTM
- o Fraction: PR - Probe and Front Half Rinse
 F - Filter
 F2 - Second Filter (ASTM and OM7)
 C - Condensate and Glassware Rinse
 BH - Back Half Water Rinse (with MeCl_2 impinger
 rinse for MM5)
 BR - Back Half Acetone Rinse (OM7 only)
 X1 - XAD Module
 PM - Probe and Front Half MeCl_2 Rinse (OM7 only)
 BM - Back Half MeCl_2 Rinse (OM7 only)
- o Run Numbers: 1 - First Burn Rate
 2 - Second Burn Rate
 3 - Third Burn Rate
 4 - Fourth Burn Rate
 5 - Fifth Burn Rate
 B - Blank

SAMPLE ANALYSES

All sample analyses were conducted by the Radian Corporation under a separate contract. A copy of the laboratory report is provided in Appendix D. Analytical Methods are described there.

CO/CO₂, OXYGEN ANALYZERS

Carbon monoxide (CO) and carbon dioxide (CO₂) were monitored using an Anarad Model AR-412 infrared analyzer. The analyzer has a 0 to 5 percent CO range and a 0 to 20 percent CO₂ range. The O₂ analyzer was an MSA stack gas analyzer which uses a fuel cell detector. That instrument has a range of 0 to 20.9 percent. The gas sample was extracted using a stainless steel probe bent into the gas flow. A glass fiber filter was used to remove particulate material. A gas sample conditioner including two impingers with water in an ice bath, was upstream of the filter.

The instruments were calibrated with gases certified to be within ± 2 percent of the specified cylinder value. The gases were in concentrations to

generate analyzer responses of approximately 20-30%, 45-55% and 70-80% of full scale. Daily pre- and post-test calibrations were conducted by direct introduction of the zero and span gases to the analyzers. The analyzer operation was acceptable if the analyzer response was $\pm 2\%$ of the cylinder value. After the pretest multipoint calibration, a single span gas was introduced at the sample probe according to EPA Method 20, Figure 20-1. This latter calibration check demonstrated performance of the system. If any calibration checks did not comply with the ± 2 percent criteria, corrections to the system were made and the calibrations repeated. Span checks were made using a single gas every 2 to 3 hours during each test and after each test.

An evaluation of the CEMS, CO_2 , O_2 , and CO data is presented in Section 5. Drift problems did occur during most test burns. Corrections were made for each span or zero drift but the accuracy of the CEMS data remains suspect based upon a fuel factor test as described in EPA Reference Method 3, 40 CFR 60 Appendix A, July 1985. This is discussed further in Section 5.

SO_2 TRACER GAS

SO_2 was injected into the stack 32 inches (4 duct diameters) downstream of the OM7 sample point. The SO_2 was injected at a rate that resulted in a downstream concentration of less than 5000 ppm (OM7 6.3). A critical orifice was used to control the injection rate. The orifice was calibrated using bubble meters prior to the test program.

The procedure followed for the tracer gas analyzer calibration was similar to that followed for CO, CO_2 and O_2 . Span gases were on hand to calibrate the instrument to 1000 ppm. Calibration gases were certified by the manufacturer to be ± 2 percent of the cylinder value.

Problems with the tracer gas system were identified after the first test but it was not until an audit was conducted that the problem was determined to be apparent reactions of the SO_2 in the system. The SO_2 was used as a guide for proportional sampling but the accuracy of the actual values collected are suspect.

TEMPERATURES

Type K thermocouples were used to monitor flue gas temperatures in both the stack and the dilution tunnel. The ASTM procedure specifies measuring the stack gas temperature 8 feet above the top of the scale using an array of 5 thermocouples (ASTM 6.12). That array would interfere with the OM7 and MM5 sample systems and was not used for this test program.

Flue gas temperatures were measured at the center of the stack approximately 1 duct diameter downstream of the sampling location. The dilution tunnel temperature was measured at a similar point in that duct.

Thermocouples were calibrated as per EPA Method 2.

MOISTURE MEASUREMENTS

The Oregon test Method specifies use of an alternate moisture determining technique, which is based on wet bulb/dry bulb temperatures. Wet bulb and dry bulb temperatures were monitored and recorded every 5 minutes at a location 1 foot diameter downstream of the stack sample collection point (OM 3.3, 3.8).

Moisture catch in the OM7 and MM5 sample trains were also used to determine stack gas moisture according to EPA Method 4 and Oregon Method 4. A comparison of stack gas moisture measurements resulting from the three methods is presented in Section 5.

The dilution tunnel moisture content was measured using the OM7 and MM5 samples.

FUEL HEAT CONTENT AND DENSITY

The heat content of the fuel was determined for each piece of wood burned during the test program. Sawdust was collected when the wood was cut to build fuel cribs. The shavings were placed in plastic bags and labeled to identify the specific cribs constructed from that particular board. Blocks of wood were also collected at the same time and sealed in plastic bags.

The dust and wood blocks were submitted to a subcontract laboratory for heat content and density analysis respectively. The heat contents for each crib were used in the F_c calculations discussed in Section 2. The laboratory report is provided in Appendix D.

SECTION 5

QUALITY ASSURANCE/QUALITY CONTROL

QAPP VALIDATION CRITERIA

This test program required an AEERL Level 1 Quality Assurance Program Plan (QAPP), which was prepared by Engineering-Science and approved by EPA. The Radian Corporation prepared a separate plan for the laboratory analysis portion of the program. In addition to adhering as closely as possible to the test procedure described in Section 4, validation criteria were identified for the sampling program. Validation criteria for sampling train and wood-stove operation are presented in Tables 5 and 6 respectively.

A systems audit was conducted by Research Triangle Institute (RTI) at the woodstove test facility during the sampling program. Following submittal of the first draft report RTI conducted a data quality audit. The draft audit report gave this sampling program and the resulting data an acceptable rating with qualifications.

The qualification was lifted from the audit rating after ES responded to the draft audit report indicating that the validation criteria specified in the QAPP would be compared to the actual sampling and stove operating conditions. The comparison must be made with an understanding of the relative importance of the criteria in order to make valid qualifications of the data. A brief discussion of the criteria is included at the end of Appendix E in response to comments made in the auditors report.

Tables 7a through 7e present a summary of sampling conditions for each of the samples collected. The parameters considered most critical were included in the table and used to characterize the data from each sample run. Nonisokinetic sampling was considered to make the results of the corresponding sample unacceptable (u). Average filter box temperatures outside the 248°F plus or minus 25°F were considered sufficient deviation from the CM7 and MM5 procedures to require qualification of those data. A total mass catch of less than 30 milligrams was considered significant enough to require qualifying the data if the sample volume was below the criteria volume. If either the mass catch was in excess of 30 milligrams or the sample volume was larger than the criteria volume then the results were considered acceptable.

Several of the sample train validation criteria were satisfactory for all samples collected. These included post test leak rate, condenser outlet temperature, and orsat leak rate.

TABLE 5. VALIDATION CRITERIA - SAMPLING TRAINS

MM5 Stack - Leak Rate		≤ 0.001 cfm
Filter Temperature		$248^{\circ}\text{F} \pm 25^{\circ}\text{F}$
Condenser Outlet Temperature		$< 70^{\circ}\text{F}$
Sample Volume		> 30 cf (meter cond.)
Sample Rate		= approximately 1-3 liters/minute
Orsat Leak Rate		= 0
OM7 Stack - Leak Rate		≤ 0.005 cfm
Filter Temperature		$250^{\circ}\text{F} \pm 25^{\circ}\text{F}$
Sample Volume		> 30 cr (meter cond.)
Sample Rate		= approximately 0.1 cfm
MM5		
Dilution		
Tunnel - Leak Rate		≤ 0.02 cfm
Filter Temperature		$248^{\circ}\text{F} \pm 25^{\circ}\text{F}$
Condenser Outlet Temperature		$< 70^{\circ}\text{F}$
Sample Volume		> 120 cf
Orsat Leak Rate		= 0
OM7		
Dilution		
Tunnel - Leak Rate		≤ 0.02 cfm
Filter Temperature		$250^{\circ}\text{F} \pm 25^{\circ}\text{F}$
Sample Volume		> 120 cf
ASTM		
Dilution		
Tunnel - Leak Rate		≤ 0.02 cfm
Filter Temperature		$70-90^{\circ}\text{F}$
Sample Rate		0.1 - 1.5 cfm
Continuous		
Analyzers - Zero Drift		5% of scale
Span Drift		2% of scale

TABLE 6. VALIDATION CRITERIA - WOODSTOVE OPERATION

Fuel Moisture	16-20% (19-25% dry)
Fuel Crib Photo	
Fuel Load - Blaze King	27-33 pounds
- Timbereze	17-20.8 pounds
Fuel Density	28.7-37/4 pounds/cubic foot
Ambient Temperature in Room	65-90°F
Surface Temperature	$\bar{X} \pm 125^{\circ}\text{F}$
Low Burn	<10,000 Btu/hr
Low Mid Burn	10,000-15,000 Btu/hr
High Mid Burn	15,000-25,000 Btu/hr
High Burn	Maximum heat output
Dilution Tunnel Temperature	<125°F
Dilution Tunnel Flow	100-400 pounds/pound wood

TABLE 7a. A SUMMARY OF TIMBER-EZE SAMPLING CONDITIONS

Sample Number	Sample Duration (Minutes)	Sample Volume (ACF)	Filter Box Temperature (°F)	Percent Isokinetics	Total Mass Collected (mg)	Evaluation ^(a) Rating
TS-MM5-1	297.5	14.039	250		213	A
TS-MM5-2	307.5	24.722	248		179	A
TD-MM5-1	400	391.642	230	<u>79</u>	135	U
TD-MM5-2	320	160.96	249	<u>104</u>	70	A
TS-OM7-1	297.0	13.189	257		170	A
TS-OM7-2	207.5	46.086	256		92	A
TD-OM7-1	377	370.893	245	<u>83</u>	70	U
TD-OM7-2	320	155.562	249	<u>100</u>	26	A
TD-AST-1	366	244.725	85		32	A
TD-AST-2	320	195.828	85		<u>22</u>	A
TD-AST-2	317	194.230	84		<u>7</u>	A

(a) A - Acceptable
Q - Qualified
U - Unacceptable

TABLE 7b. SUMMARY OF BLAZE KING SAMPLING CONDITIONS

Sample Number	Sample Duration (Minutes)	Sample Volume (ACF)	Filter Box Temperature (°F)	Percent Isokinetics	Total Mass Collected (mg)	Evaluation(a) Rating
BS-MM5-1	640	60.998	249		448	A
BS-MM5-2	238	17.529	251		197	A
BS-MM5-3	221	16.052	257		130	A
BS-MM5-4	1,185	103.320	263		2,263	A
BS-MM5-5	415	24.481	245		210	A
BS-MM5-5Q	415	18.524	256		159	A
BD-MM5-1	640	306.077	248	105	120	A
BD-MM5-2	238	119.033	233	103	94	A
BD-MM5-3	222	112.356	248	111	57	U
BD-MM5-4	1,185	523.820	244	97	185	A
BD-MM5-5	350	160.874	249	105	74	A
BD-MM5-Q	350	154.754	235	102	81	A
BS-OM7-1	640	44.226	263		232	A
BS-OM7-1Q	640	84.428	242		363	A
BS-OM7-2	238	22.734	249		133	A
BS-OM7-2Q	238	14.430	250		87	A
BS-OM7-3	221	15.740	262		57	A
BS-OM7-4	1,185	103.150	254		779	A
BS-OM7-5	415	24.528	220		68	Q
BD-OM7-1	640	277.088	248	96	41	A
BD-OM7-2	232	193.758	247	100	41	A
BD-OM7-3	222	117.213	245	102	35	A
BD-OM7-4	1,185	594.102	203	109	156	Q
BD-OM7-4Q	1,185	543.834	248	108	76	A
BD-OM7-5	345	171.306	178	105	54	Q
BD-AST-1	639	397.303			39	A
BD-AST-1Q	639	389.082			33	A
BD-AST-2	236	144.810			42	A
BD-AST-3	230	134.056			13	A
BD-AST-4	1,185	562.049			84	A
BD-AST-5	411	174.566			30	

(a) A - Acceptable
 Q - Qualified
 U - Unacceptable

TABLE 7c. SUMMARY OF LAKEWOOD SAMPLING CONDITIONS

Sample Number	Sample Duration (Minutes)	Sample Volume (ACF)	Filter Box Temperature (°F)	Percent Isokinetics	Total Mass Collected (mg)	Evaluation ^(a) Rating
BS-MM5-1	640	60.998	249		448	A
GS-MM5-1	410	<u>22.269</u>	245		2,478	A
GS-MM5-2	260	<u>15.852</u>	250		888	A
GS-MM5-3	340	<u>18.379</u>	245		1,455	A
GS-MM5-4	60	<u>3.099</u>	253		262	A
GS-MM5-4Q	60	<u>2.452</u>	244		227	A
GD-MM5-1	410	188.778	249	98	325	A
GD-MM5-2	260	123.279	252	98	223	A
GD-MM5-3	340	161.956	249	96	401	A
GD-MM5-3Q	340	169.199	247	102	297	A
GD-MM5-4	58	<u>27.258</u>	250	109	159	A
GS-OM7-1	415	<u>22.933</u>	<u>222</u>		1,351	Q
GS-OM7-2	260	<u>15.884</u>	<u>221</u>		526	Q
GS-OM7-3	340	<u>18.007</u>	<u>223</u>		809	Q
GS-OM7-Q3	340	<u>13.322</u>	<u>252</u>		726	A
GS-OM7-4	60	<u>2.989</u>	<u>223</u>		71	Q
GD-OM7-1	405	212.500	<u>211</u>	108	171	Q
GD-OM7-2	260	118.459	<u>256</u>	102	113	A
GD-OM7-3	340	155.727	<u>233</u>	102	140	A
GD-OM7-4	57	<u>25.696</u>	250	99	49	A
GD-OM7-Q4	57	<u>29.034</u>	251	<u>119</u>	90	U
GD-AST-1	408	204.141	70		186	A
GD-AST-2	251	132.681	68		100	A
GD-AST-3	235	172.604	70		193	A
GD-AST-4	53	17.531	72		60	A

(a) A - Acceptable
Q - Qualified
U - Unacceptable

TABLE 7d. SUMMARY OF BOSCA SAMPLING CONDITIONS

Sample Number	Sample Duration (Minutes)	Sample Volume (ACF)	Filter Box Temperature (°F)	Percent Isokinetics	Total Mass Collected (mg)	Evaluation(a) Rating
HS-MM5-1	145	<u>6.499</u>	247		109	A
HS-MM5-2	360	<u>20.83</u>	246		1,061	A
HS-MM5-3	90	<u>7.72</u>	253		419	A
HS-MM5-3Q	90	<u>1.92</u>	<u>219</u>		111	Q
HS-MM5-4	200	<u>15.345</u>	249		395	A
HS-MM5-5	65	<u>5.853</u>	251		243	A
HD-MM5-1	150	<u>67.77</u>	242	100	74	A
HD-MM5-2	360	<u>162.70</u>	243	94	101	A
HD-MM5-3	90	<u>39.934</u>	244	91	75	A
HD-MM5-3Q	80	<u>36.345</u>	246	101	73	A
HD-MM5-4	200	<u>86.952</u>	240	100	85	A
HD-MM5-5	65	<u>28.861</u>	245	98	64	A
HS-OM7-1	145	<u>3.298</u>	246		45	A
HS-OM7-1Q	145	<u>13.30</u>	254		126	A
HS-OM7-2	360	<u>21.57</u>	250		765	A
HS-OM7-3	90	<u>8.207</u>	259		179	A
HS-OM7-4	200	<u>15.889</u>	239		234	A
HS-OM7-5	65	<u>6.065</u>	246		128	A
HD-OM7-1	150	<u>69.299</u>	257	104	<u>25</u>	A
HD-OM7-2	360	<u>187.88</u>	250	109	52	A
HD-OM7-2Q	360	<u>166.12</u>	<u>217</u>	95	71	Q
HD-OM7-3	91	<u>47.05</u>	244	<u>115</u>	32	U
HD-OM7-4	200	<u>89.765</u>	<u>202</u>	<u>96</u>	<u>27</u>	Q
HD-OM7-5	65	<u>30.193</u>	242	102	37	A
HD-ASTM-1	149	74.673	70		<u>25</u>	A
HD-ASTM-1Q	150	78.224	75		<u>24</u>	A
HD-ASTM-2	359	182.49	70		<u>75</u>	A
HD-ASTM-3	89	45.895	76		31	A
HD-ASTM-4	200	100.067	71		32	A
HD-ASTM-	66	33.010	72		<u>23</u>	A

(a) A - Acceptable

Q - Qualified

U - Unacceptable

TABLE 7e. SUMMARY OF FISHER SAMPLING CONDITIONS

Sample Number	Sample Duration (Minutes)	Sample Volume (ACF)	Filter Box Temperature (°F)	Percent sokinetics	Total Mass Collected (mg)	Evaluation ^(a) Rating
FS-MM5-1	190	<u>14.013</u>	250		429	A
FS-MM5-2	620	<u>26.035</u>	251		483	A
FS-MM5-3	220	<u>17.076</u>	252		334	A
FS-MM5-4	375	<u>14.954</u>	251		310	A
FD-MM5-1	190	<u>86.131</u>	249	100	205	A
FD-MM5-2	610	<u>256.632</u>	237	<u>86</u>	190	U
FD-MM5-2Q	620	289.182	236	19	142	A
FD-MM5-3	220	<u>100.739</u>	248	105	159	A
FD-MM5-4	375	<u>190.196</u>	246	<u>100</u>	154	U
FD-MM5-4Q	375	165.545	250	2	159	A
FS-OM7-1	190	<u>14.530</u>	246		333	A
FS-OM7-2	620	<u>31.293</u>	243		313	A
FS-OM7-3	220	<u>17.573</u>	248		277	A
FS-OM7-4	375	<u>15.814</u>	249		223	A
FD-OM7-1	190	<u>87.884</u>	255	97	109	A
FD-OM7-2	610	283.173	249	106	100	A
FD-OM7-3	220	<u>103.014</u>	250	103	73	A
FD-OM7-4	375	<u>168.749</u>	246	101	74	A
FD-ASTM-1	190	<u>99.940</u>	-		103	A
FD-ASTM-2	609	<u>322.743</u>	-		44	A
FD-ASTM-3	220	<u>118.053</u>	-		52	A
FD-ASTM-4	305	<u>190.709</u>	-		40	A

(a) A - Acceptable
Q - Qualified
U - Unacceptable

Continuous emission monitor zero and span checks were done at approximately 2 to 3 hour intervals during each test burn. At least one of the analyzers monitoring O₂, CO₂ or CO had one or more periods of instrument drift in excess of 2 percent during all test burns except High Efficiency (BOSCA) -4 and Fisher -3. Zero and span drift corrections were made assuming a gradual linear drift between the two span checks showing the drift. These data were entered into the woodstove program (Appendix C).

Several test burns that do not reliably reflect actual emissions according to Oregon stove operating procedures must be qualified. Those are listed below with an explanation for the reason for their qualification:

- o Timber-eze -1 Stove doors were opened during the test burn.
- o Timber-eze -2 Stove doors were opened during the test burn.
- o Blaze King -3 Fire died after less than 3 pounds of wood were burned. Sampling stopped after 220 minutes.
- o High Efficiency (BOSCA) -3 Regional power failure ended sampling after 70 minutes.

These data were not entirely deleted from the results because they can be considered useful for test method evaluation.

The dilution tunnel flow criteria were neglected during this test program. Most flows were greatly in excess of the 100:1 to 400:1 range of air to wood ratios specified in the ASTM procedure. This criteria was not used to qualify or invalidate any samples.

BLANKS

Two types of blanks were collected in the field and submitted to the laboratory for analysis. Solvent blanks were collected for each solvent and sample media (filters, XAD-2 modules) used for sample collection and recovery. Those blanks were for use by the lab in making blank corrections.

Train blanks were collected to demonstrate the efficiency of sample recovery and possible contamination of samples in the stove test facility environment. Those blanks were obtained by charging a sample train as if it were an actual sample. The sample train was then leak checked, sealed, allowed to sit overnight and leak checked again. The train blank was then recovered following sample recovery procedures for the appropriate train types (MM5, OM7 or ASTM). Tables 8 and 9 present the results of analyses of train blanks. Many of the train blank results are higher than normal acceptable levels. The MM5 water fraction was consistently high. Since the water used for charging the MM5 trains was from the same container as the water used to charge the OM7 trains that source of contamination can be eliminated as a possibility. As mentioned in Section 4, the methylene chloride did not appear to be a satisfactory solvent for the material collected during sampling. Ineffective sample recovery using MeCl₂ may have left residue in the sample trains which would then result in high train blanks.

TABLE 6. RESULTS OF TRAIN BLANK SAMPLE ANALYSES
GRAVIMETRIC RESIDUE, MILLIGRAMS

	Front Rinse	Filter	Back Rinse	Back Water	Back Filter
TS-OM7	1.0	0.9	0.1	4.3	0.3
TD-OM7	0.7	0.5	1.1	1.7	2.2
BS-OM7	1.9	0.7	2.5	17.2	0.9
BD-OM7	2.6	1.3	2.4	9.8	0.3
GS-OM7	1.4	1.3	0.2	0.3	0.2
GD-OM7	1.1	0.0	0.9	1.5	1.0
HS-OM7	1.1	0.9	0.1	4.3	0.3
HD-OM7	2.3	0.0	0.7	0.4	0.3

	Front Rinse	Filter	Extract XAD, TCO	Condensate, Rinse Back Water
TS-MM5	1.2	14.2	0.0	27
TD-MM5	0.5	0.3	0.0	16
BS-MM5	NA	NA	NA	NA
BD-MM5	NA	NA	NA	NA
GS-MM5	1.2	2.2	0.0	31
GD-MM5	0.3	0.0	0.0	23
HS-MM5	1.3	0.8	0.0	140
HD-MM5	0.9	0.0	0.0	16
FS-B	NA	NA	NA	NA
FS-B	NA	NA	0.3	119

	Front Rinse	Filter # 1	Filter # 2
TD-ASTM	NA	NA	NA
BD-ASTM	NA	NA	NA
GD-ASTM	1.3	0.1	0.2
HD-ASTM	1.3	0.6	0.4

NA = no analysis or no sample collected

TABLE 9. RESULTS OF TRAIN BLANK ANALYSES FOR ORGANICS
AND MODIFIED METHOD 5 SAMPLES

	TCO (mg)	Phenol (micrograms)	POM (micrograms)
TS-BM7	0.0	9.4	0.0
TD-B	0.0	0.0	0.0
BS-B	NA	NA	NA
BD-B	NA	NA	NA
GS-B	0.0	26.2	0.0
GD-B	0.0	7.2	0.0
HS-B	0.0	26.4	0.0
HD-B	0.0	13.1	0.0
FS-B	0.3	0.0	1809.5
FS-B	NA	NA	NA

NA = no analysis or no sample collected

DUPLICATE SAMPLES

Duplicate samples were collected to demonstrate the precision of the sampling methods at each location. Table 10 presents the results of the duplicate samples in units of grams per hour except for the samples collected in the stack during test burn H-3. That burn was not completed and no stack flow rate could be calculated using the Oregon woodstove program. Those results were calculated using the F_C calculations.

DATA PROCESSING QC/QA

One hundred eighteen individual sample runs were conducted during this program. The large amount of resulting data underwent multiple checks to minimize the number of errors. All data reduction was done twice by two different data handlers. The two sets of data were then compared. Any inconsistencies resulted in a third check of that particular portion of the data to resolve the discrepancy.

The example calculations were prepared by the field team leader and given to the data processor for input to the computer. Calculations were then done using a calculator by an engineer not familiar with the project, and the results compared to the computer output.

EVALUATION OF CEMS DATA - O_2 , CO_2 , AND CO

During the sampling program, the CEMS data were reduced as five minute averages. As an added QA check, the fuel factor (F_O) was calculated according to EPA Reference Method 3 (40 CFR 60, Appendix A, July 1985). Reference Method 3 specifies a range for F_O of 1.000 to 1.120 for wood. Table 11 presents the average CEMS CO_2 , O_2 , and CO values for each test burn and the corresponding orsat analyses. F_O was calculated for both CEM and Orsat data for each burn. The F_O for most of the CEMS data were outside the acceptable range specified in the Reference Method. Some of the project participants are concerned with the accuracy of these data since they are the basis for calculating stack gas flow rates and heat outputs which are used to calculate emission rates.

This F_O measure had not been identified as one of the validation criteria in the QAPP. The CEMS criteria were a 5 percent zero drift and a 2 percent span drift. The effect of these drift allowances on the F_O can be significant. For example for the test burn for B-4 the CO_2 was 5.5 percent and the O_2 was 14.6 percent. The worst case span drift situations allowable under the validation criteria would be for a negative 1.9 percent O_2 span drift and a negative 1.9 percent CO_2 span drift. In this case the average O_2 and CO_2 values would have been 14.2 percent and 5.1 percent respectively, resulting in an F_O of 1.298 rather than the calculated 1.079. Thus, it appears that the F_O calculation is highly sensitive to instrument drift.

The F_O is an oxygen balance evaluation. The instrument used for this test program uses a zirconium oxide detector which operates at a temperature of 760° C. Oxygen is consumed by combustibles in the sample gas at that

TABLE 10. SUMMARY OF DUPLICATE SAMPLES (GRAMS/HOUR)(a)

	Stack		Dilution Tunnel			TCO		Phenol (X 10 ³)		POM (X 10 ³)	
	Particulate Emissions		Particulate Emissions			Dilution		Dilution		Dilution	
	MM5	OM7	MM5	OM7	ASTH	Stack	Tunnel	Stack	Tunnel	Stack	Tunnel
T-2					3.37 (0.999)						
B-4				7.99Q (3.96)							
B-1		4.59 (4.16)			2.66 (2.34)						
B-5	10.5 (9.11)		13.4 (15.3)			4.47 (3.21)	3.56 (3.65)	0.156 (0.150)	0.0996 (0.112)	0.0877 (0.0856)	0.073 (0.079)
B-2		10.8 (10.3)									
G-3		32.1 (35.0)	74.8 (53.2)				29.2 (24.8)		0.741 (0.655)		0.534 (0.503)
G-4	216 (216)			54.6 (89.0)H		109 (95.1)		9.11 (6.46)		19.3 (16.9)	
H-2				8.27 (12.8)							
H-1		9.39 (7.10)			9.85 (8.76)						
H-3	17.2 (16.7)		56.4 (59.6)Q			7.50 (7.05)Q	14.0 (20.4)Q	0.402 (0.252)Q	0.549 (0.815)	0.476 (0.252)Q	1.06 (1.47)Q
P-2			22.6L (14.9)				3.25 (2.70)		0.0815L (0.0641)		0.0371L (0.0220)
P-4			23.9H (28.3)				4.03H (3.94)		0.0753H (0.108)		0.0247H (0.0320)

(a) All data from Table 3a, Section 2.

TABLE 11. COMPARISON OF AVERAGE CEMS CO₂, O₂, AND CO WITH CONCURRENT ORSAT RESULTS ^(b)

	Heat Stack Output (Btu/Hour)	Woodstove CHO % Combustion Efficiency	CEM (%)			CEM (a)	Orsat (%)			Orsat (a)
			CO ₂	O ₂	CO	F _O	CO ₂	O ₂	CO	F _O
T-1	10,772	81.9	4.5	16.7	0.1	0.942	3.0	17.9	0.0	1.000
T-2	15,006	130.2	2.3	18.0	0.1	1.126	2.3	18.6	0.0	1.000
B-1	11,185	74.5	4.1	16.9	0.1	0.836	4.4	16.4	0.0	1.023
B-2	32,170	79.9	6.3	15.3	0.2	0.912	5.8	14.8	0.0	1.052
B-3	NA	NA	NA	NA	NA	NA	1.0	19.6	0.0	1.300
B-4	7,220	103.4	3.2	17.3	0.3	1.177	2.0	18.6	0.0	1.150
B-5	22,281	96.1	5.5	14.6	0.1	1.079	1.0	19.6	0.0	1.300
G-1	9,812	71.6	5.6	14.5	1.8	0.980	5.4	13.9	1.6	1.114
G-2	16,587	74.3	6.7	14.1	1.4	0.941	6.0	14.0	0.9	1.065
G-3	13,277	75.7	5.9	14.4	1.5	0.980	5.1	14.3	1.4	1.123
G-4	96,474	93.8	11.0	7.3	1.8	1.141	8.9	11.2	0.0	1.090
H-1	19,511	106.7	4.7	14.5	0.8	1.232	6.8	12.8	0.7	1.127
H-2	7,972	115.9	3.8	15.2	1.0	1.310	3.0	15.3	1.0	1.525
H-3	NA	NA	NA	NA	NA	NA	6.4	12.7	1.0	1.176
H-4	13,999	87.3	5.5	14.3	1.1	1.091	6.7	13.6	0.9	1.020
H-5	40,591	87.7	7.7	11.8	1.0	1.047	10.1	8.2	1.7	1.148
F-1	29,223	100.3	5.9	14.1	0.3	1.128	7.0	13.6	0.1	1.043
F-2	8,752	110.9	4.5	15.4	0.2	1.201	5.4	14.6	0.1	1.155
F-3	23,570	96.5	5.9	14.4	0.2	1.082	6.1	13.4	0.1	1.218
F-4	14,273	105.9	4.7	15.2	0.3	1.176	4.1	14.2	0.4	1.533

(a) Calculated according to 40 CFR 60, Appendix A, Reference Method 3:

$$F_O = \frac{20.9 - (\% O_2 - 0.5\% CO)}{(\% CO_2 + \% CO)}$$

(b) CEMS data were corrected for zero and span drifts.

NA Insufficient data were collected to complete these calculations.

temperature which results in low oxygen readings. Preliminary testing done showed C₁ through C₇ hydrocarbons on catalyst and non-catalyst equipped woodstoves averaging 1.0 milligram per liter of flue gas. This could result in a 1:1 decrease in detected O₂ for each carbon combusted in the detector furnace. Errors in the CEMS measurements would result in errors in the stack gas flows calculated using the CHO balance which would result in a proportional and direct error in the calculated MM5 and CM7 stack emission rates. Since the dilution tunnel flows were measured using a standard pitot tube, errors in the CEMS would not cause an error in those emission rates. It can be assumed that combustible levels in emissions from non-catalyst stoves would be significantly higher than those from catalyst-equipped stoves.

EVALUATION OF SO₂ TRACER GAS MEASUREMENTS

The Oregon DEQ Standard Method for Measuring the Emissions and Efficiencies of Woodstoves (June 8, 1984) recommends the use of sulfur dioxide as a tracer gas for determining the stack gas flow rate and for maintaining proportional sampling in the stack. Many problems were experienced with span checks of the tracer gas analyzer. It was finally determined that the SO₂ was apparently reacting with other components of the flue gas including material condensed in the SO₂ sample line or material collected on the filter. Span checks were erratic. The SO₂ concentrations have an effect on the output of the Oregon CHO balance calculation. Increasing the SO₂ concentration entered into the calculation increases the stove heat output, the percent oxygen and overall combustion efficiency while decreasing the wood combustion efficiency, stack gas flow rate, and percent CO₂. Inaccurate SO₂ measurements precluded reliable proportional sampling in the stack.

RESULTS CALCULATED USING ORSAT DATA AND F FACTOR

Table 12 compares the stack flow and heat output data used for calculating results presented in Section 2 tables 1a, 1b and 1c with the stack flow and heat input values calculated using F_c factor calculations as presented in 40 CFR 60.45. The dry fuel composition was assumed to be 51 percent carbon, 7.3 percent hydrogen, and 41 percent oxygen as described in the Oregon procedure. F_c was calculated using the heat content determined for each crib used during the test program (Appendix D). The resulting heat input and stack flows were used to calculate the results summarized in tables 3a, 3b and 3c of Section 2.

MOISTURE DETERMINATIONS IN THE STACK

Moisture determinations were made in conjunction with MM5 and CM7 using procedures following EPA Reference Method 4 (40 CFR 60, Appendix A). In addition, wet bulb/dry bulb measurements were made as required by the Oregon procedure. Table 13 summarizes the moistures for each run.

OTHER CONSIDERATIONS

Following is a list of events which occurred during the sampling program and which should be considered when evaluating the results.

TABLE 12. HEAT INPUT AND GAS FLOWS CALCULATED USING F_c FACTORS AND WOOD HEAT CONTENT COMPARED TO HEAT OUTPUT AND GAS FLOWS CALCULATED BY OREGON STOVE COMBUSTION PROGRAM

Stove	Run Number	Oregon Program		F_c Factor	
		Heat Output (Btu/hr)	Stack Flow (SM ³ /hr)	Heat Input (Btu/hr)	Stack Flow (SM ³ /hr)
Timbereze	1	10,772	16.4	17,285	29.7
	2	15,006	71.8	23,218	52.0
Blaze King	1	11,185	19.8	20,898	24.5
	2	32,170	35.3	53,615	47.2
	3	a	a	6,620	17.4
	4	7,220	20.1	11,607	26.7
	5	22,281	27.9	31,964	29.9 ^b
Lakewood	1	9,812	10.3	17,148	12.6
	2	16,587	15.2	29,004	20.9
	3	13,277	13.8	22,667	18.1
	4	96,474	58.2	139,443	68.5
Bosca	1	19,511	32.2	28,082	19.6
	2	7,972	15.4	10,466	13.8
	3	a	a	11,447	8.3
	4	13,999	16.3	21,299	14.2
	5	40,501	32.0	64,001	28.5
Fisher	1	29,223	34.7	38,911	33.3
	2	8,752	13.9	10,621	12.0
	3	23,570	26.4	30,279	26.5
	4	14,273	21.6	18,500	19.8

a Test burn was not complete. No Oregon Program run.

b Calculated using average CO₂ and CO from CEMS because Orsat had apparently leaked during the test.

$$c \quad F_c \frac{\text{sm}^3 \text{CO}_2}{\text{J}} = \frac{20.0 (\% \text{ C in wood})}{\text{GCV}}$$

where: GCV = higher heating value of wood

$$F_c \text{ stack flow} = F_c \times \frac{\text{J}}{\text{hour}} \times \frac{100\%}{\% \text{CO}_2 + \% \text{CO}}$$

TABLE 13. COMPARISON OF MOISTURE DETERMINATIONS IN THE STACK GAS AS MEASURED BY MM5, WET BULB/DRY BULB, AND OM7^a

Burn Number	Stove	Heat Output (Btu/hour)	Burn Rate (dry) (kg/hr)	Stack Moisture (%)		
				MM5	WB/DB	OM7
1	Timber-eze	10,772	0.9	6.6	5.0	7.1
2	Timber-eze	15,006	1.22	3.8	4.0	8.9
4	Blaze King	7,220	0.60	6.8	2.0	8.1
1	Blaze King	11,185	1.06	8.1	7.1	7.2 (7.1)
5	Blaze King	22,281	1.64	6.2 (7.9)	7.0	9.5
2	Blaze King	32,170	2.77	6.8	4.0	10.8 (9.3)
3	Blaze King	NC	NC	3.9	NC	5.5
1	Lakewood	9,812	0.89	6.8	5.0	8.6
3	Lakewood	13,277	1.17	8.7	7.0	9.9 (11.8)
2	Lakewood	16,587	1.51	9.4	5.0	11.0
4	Lakewood	96,474	7.17	18.5 (14.0)	12.0	19.5
2	Bosca	7,972	0.54	6.5	5.0	9.1
4	Bosca	13,999	1.08	10.2	3.0	9.3
1	Bosca	19,511	1.51	9.6	6.0	18.6 (8.7)
5	Bosca	40,591	3.10	13.1	3.0	14.5
3	Bosca	NC	NC	13.5 (27.6)	NC	9.6
2	Fisher	8,752	0.55	5.7	9.6	6.8
4	Fisher	14,273	0.95	4.5	6.8	7.9
3	Fisher	23,570	1.58	5.5	7.9	7.9
1	Fisher	29,223	2.02	5.5	7.9	9.6

^a Numbers in parentheses indicate results of duplicate runs.

NC - Not calculated because of insufficient data from partial test burn.

1. TS-MM5-1: Tube came loose from meter box coarse adjust valve. Sampling ended immediately. Tube repaired and train leak checked.
2. TD-MM5-1: Silica gel spent.
3. TD-QM7-1: Lost power 3 times for a total of 16 minutes. Test run short due to a fourth power loss.
4. TD-AST-1: Data recorded at 5 minute intervals rather than on a percent of fuel burned basis.
5. TD-AST-2: Data recorded at 5 minute intervals rather than on a percent of fuel burned basis.
6. BS-QM7-1: Second filter tore during run, probably during pretest leak check.
7. BS-QM7-2Q: Second filter installed backwards in sample train.
8. DU-QM7-2: Pump failed after 134 minutes. A second meter box was used for the duration of the test. Six minutes of sample time were lost. Meter gamma was corrected by proportioning the two calibrations based on percent of the respective gas volumes.
9. BD-MM5-5
BD-QM7-5
BD-AST-5
BD-MM5-5Q: QM7 filter heater failed. All dilution tunnel samplers shutdown for 70 minutes while repairs were made. Sampling restarted simultaneously. Stack samplers continued operating during the shutdown.
10. BD-MM5-5Q: Operator failed to record meter temperature. Meter temperature estimated to be 95° for the test.
11. BD-QM7-5: Operator failed to record meter temperature for first 13 readings of 35 reading test. Average recorded readings used for calculations.
12. GD-QM7-1: Lost power after 5 minutes of sampling. Power restored and testing resumed after 5 minutes downtime.
13. HS-MM5-1: After testing was completed the elbow between the condenser and XAD module was broken as the operator was removing the sample train from the stack. No post-test leak check was conducted.
14. H-3: Lost power to samplers and stove scale. Test ended after 70 minutes of burn.
15. T-1: Stove charged, doors were closed then testing started. Sixty minutes into the test, power was lost to the scale

and the scale automatically rezeroed itself. Readings continued adding the final weight, prior to the power loss, to the scale reading. Stove doors were opened for 5 minutes after 65 minutes of burn. Stove doors were opened for 6 minutes after 90 minutes of burn. Stove doors were opened for 1 minute after 400 minutes of burn.

16. T-2: Stove doors open for first 10 minutes of test. Stove doors opened for 5 minutes after 65 minutes of burn. Stove doors opened for 5 minutes after 125 minutes of burn. Stove doors opened for 3 minutes after 161 minutes of burn. Stove doors opened for 1 minute after 305 minutes of burn.
17. B-3: Fire died after 220 minutes. Less than 3 pounds of wood burned.

APPENDIX
ANALYTICAL RESULTS

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
LIST OF FIGURES	A-3
LIST OF TABLES	A-4
1.0 INTRODUCTION	A-5
2.0 PROJECT ORGANIZATION	A-6
3.0 TECHNICAL APPROACH	A-8
3.1 Sample Preparation	A-8
3.2 Analysis	A-12
3.3 Sample Preparation Protocol	A-18
4.0 ANALYTICAL RESULTS	A-33
5.0 QUALITY ASSURANCE AND QUALITY CONTROL	A-53

LIST OF FIGURES

<u>Number</u>	<u>Page</u>
2-1 Radian project organization	A-7
3-1 Oregon Method 7 sample fractions and analytical matrix	A-10
3-2 ASTM sample fractions and analytical matrix	A-11
3-3 EPA MM5 sample fractions and analytical matrix	A-13
5-1 TCO QC standard analysis	A-55
5-2 Artifact peak of GC/MS analysis	A-64
5-3 GRAV analysis modification	A-66
5-4 Modification to woodstove QAPP	A-68
5-5 TCO calibration modification	A-69
5-6 GRAV analysis corrections	A-70
5-7 GC/MS unit correction	A-71
5-8 Systems audit checklist	A-72

LIST OF TABLES

<u>Number</u>	<u>Page</u>
3-1 Sample Preparation	A-9
3-2 Target Compounds for Quantitative Analysis by GC/MS	A-14
3-3 GC/MS Analytical Conditions	A-16
3-4 Estimated Quantifiable Limit	A-17
3-5 Sample BS-2	A-19
3-6 Sample GS-2	A-25
4-1 Woodstove Gravimetric Results	A-34
4-2 Total Chromatographable Organics	A-41
4-3 Amount of Target Compounds in Sample, ng	A-44
5-1 Woodstoves Response Factor Database	A-56
5-2 Linear Regression, Woodstove Database	A-58
5-3 Daily Calibration Checks	A-59
5-4 Analyses of Check Sample	A-60
5-5 Daily Percent Recoveries (Check Sample)	A-61
5-6 Woodstove Duplicates	A-62
5-7 QA/QC Audit GC/MS Samples	A-81
5-8 QA/QC Audit TCO and GRAV	A-83

1.0 INTRODUCTION

In an effort to provide heating at a cost lower than the combustion of fossil fuels, woodstoves are becoming increasingly popular. However, when woodstoves are used, products of both complete and incomplete combustion of wood are emitted. Three sampling methods are currently being used to collect samples to characterize woodstove emissions: 1) the EPA Modified Method 5 (MM5) sampling train; 2) the Oregon Method 7 (OM7) for sampling condensible emissions from stationary sources apparatus; and 3) the draft ASTM dilution tunnel method. The first two methods both collect a sample directly from the stack, while the third method requires dilution of the entire stack flow first, with subsequent collection of a sample from these diluted gases. For the Modified Method 5 sampling train, the following components are analyzed: probe wash, filters, XAD-2 resin, XAD-2 cartridge rinse, condensate, condensate impinger rinse, impinger water, and impinger rinse. For Oregon Method 7, the following components are analyzed: probe wash, filters, impinger water, and impinger rinse. For the ASTM dilution tunnel, filters and probe wash are analyzed. The analytical determinations will be GRAV (gravimetric analysis), TCO (determination of total chromatographable organic content), and qualitative/quantitative determination of polynuclear organic materials (POMs) using capillary GC/MS techniques.

2.0 PROJECT ORGANIZATION

The organization of the personnel involved in the woodstoves project is depicted in Figure 2-1. The Radian Program Manager was Susan Fernandes, and the Project Director was Edward Messer. The Project Director was responsible for coordinating all analytical tasks through the direct involvement of task leaders. The task leaders served complementary roles in areas of project coordination, overseeing sample preparation, gas chromatography (TCO) and gravimetric (GRAV) analysis, GC/MS, quality control, and data analysis and validation. The three task leaders were Joann Rice (GC/TCO), Ed Messer (GRAV/Sample Prep), and Joan Bursey (GC/MS). The task leaders also enacted quality assurance procedures described in the Quality Assurance Project Plan with supervision by and coordination with both the Project Director and Quality Assurance (QA) officer. The Quality Assurance Staff consisted of Donna Holder (QA Officer) with assistance from Deborah Benson (QA Assistant). The overall laboratory project was reviewed periodically by Jim McGaughey and Denny Wagoner, who served as Senior Technical Advisors for this project.

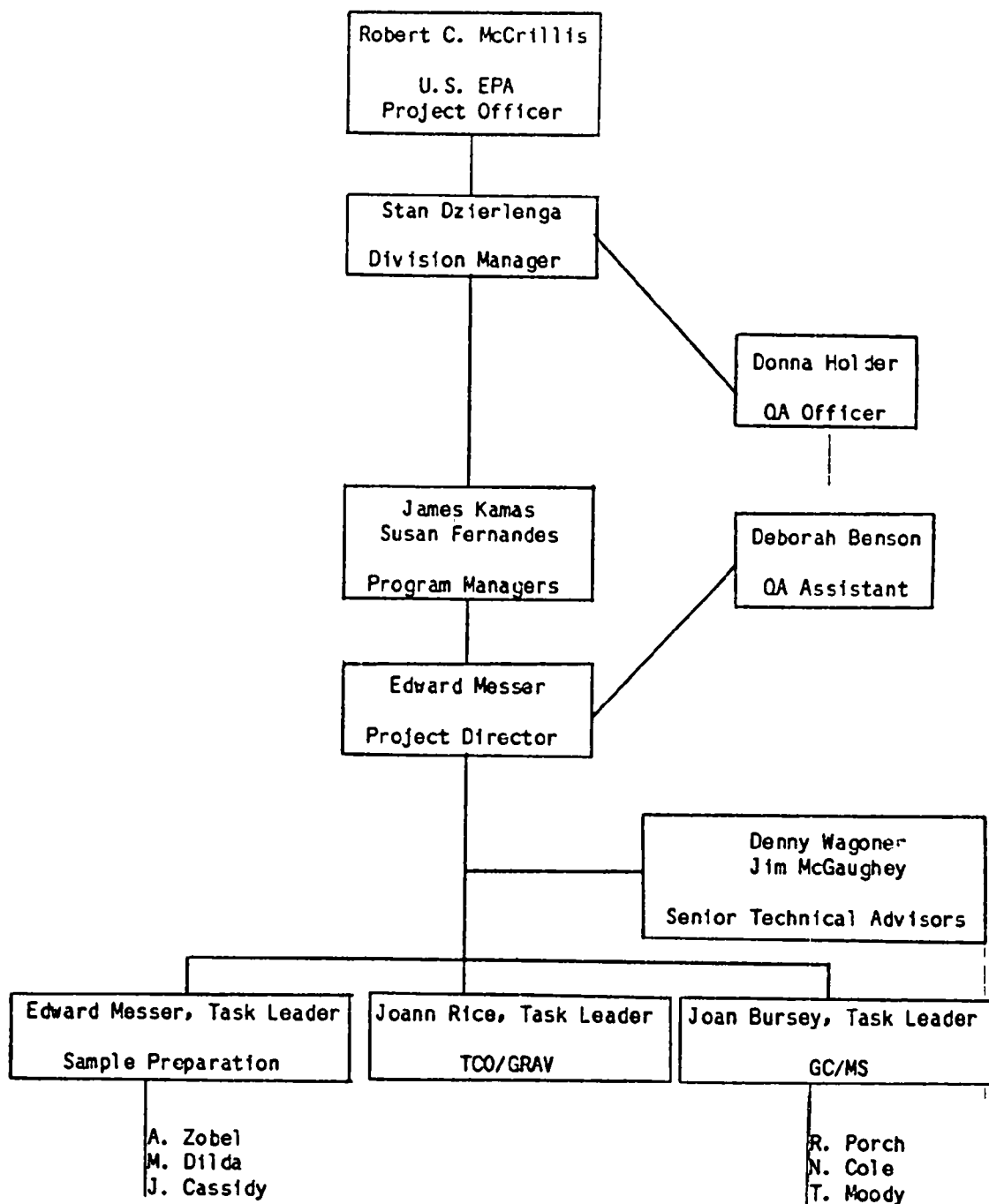


Figure 2-1. Radian project organization.

3.0 TECHNICAL APPROACH

3.1 SAMPLE PREPARATION

The sample preparation was performed as shown in Table 3-1. The samples were provided by Engineering Science and consisted of the following:

Modified Method 5 - MeCl_2 and MeOH probe washes, filter(s), XAD-2 resin, MeCl_2 rinse of XAD-2 cartridge, condensate, MeCl_2 rinse of condensate impinger, impinger water, and MeCl_2 rinse of the impingers.

Oregon Method 7 - Probe wash (acetone), front filter(s), impinger water, impinger rinse (acetone), and back filter(s).

ASTM - Filters and probe rinses.

The field sampling program consisted of four burns from each of five stoves for a total of twenty burns; additional duplicate burns increased the total to a maximum of twenty-four. Each burn produced one MM5 and OM7 taken in the stack, and one MM5, OM7, and ASTM taken in the dilution tunnel for a total of five sample sets. For QA purposes selected burns employed dual MM5s in the stack which resulted in as many as seven sample sets for analysis. The sample collection period was during the months of September, October, and November. Engineering Science recovered the samples at the test facility and delivered them, with the proper documentation, to Radian's RTP laboratory.

The analysis of OM7 samples followed procedures published by the state of Oregon as shown in Figure 3-1. Analysis of ASTM samples followed the procedures defined in the draft standard method and as depicted in Figure 3-2. Analysis of the MM5 samples followed published AEERL Level 1 procedures with the following exceptions:

Table 3-1. SAMPLE PREPARATION

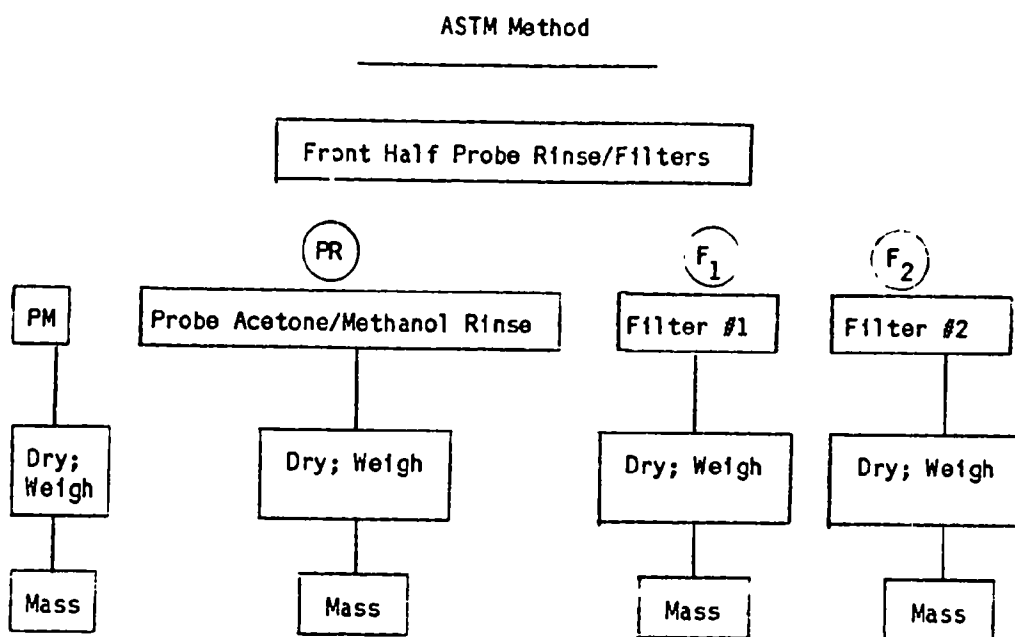
TRAIN COMPONENT	OREGON METHOD 7	EPA MODIFIED METHOD 5	ASTM
PROBE WASHES	DESICCATE AND WEIGH	DESICCATE, WEIGH EXTRACT WITH FILTER	DESICCATE AND WEIGH
FRONT FILTER	DESICCATE AND WEIGH	DESICCATE, WEIGH EXTRACT WITH PROBE RESIDUE	DESICCATE AND WEIGH
XAD-2	NA	SOXHLET EXTRACTION BY LEVEL 1 PROCEDURE	NA
CONDENSATE incl. rinse	NA	LIQUID PARTITION EXTRACTION BY LEVEL 1	NA
IMPINGERS incl. rinse	EXTRACT BY OREGON PROCEDURE	EXTRACT WITH CONDENSATE	NA
BACK FILTER	DESICCATE AND WEIGH	NA	NA

Analysis Matrix for Stack Samples

Sampling Method	Weighing	Level 1 Soxhlet Extraction	Level 1 Partition Extraction	Oregon Partition Extraction	TCO	GRAV	POM
MM5	25	50	25	--	25	25	25
OM7	50	--	--	25	--	25	--

Analysis Matrix for Dilution Tunnel Samples

MM5	25	50	25	--	25	25	25
OM7	25	--	--	25	--	25	--
ASTM	75	--	--	--	--	--	--
Total	~200	100	50	50	50	100	50



ASTM METHOD

PR - Acetone/MeOH probe rinse
 PM - MeCl₂ probe rinse
 F₁ - First Filter
 F₂ - Second Filter

Figure 3-2. ASTM sample fractions and analytical matrix.

1. Probe washes were desiccated at room temperature and weighed.
2. The filters were desiccated at room temperature and weighed.
3. The dried probe residues and filters were combined and Soxhlet extracted with methylene chloride.
4. The XAD-2 resin and XAD-2 cartridge rinse were placed in a Soxhlet and extracted according to Level 1 procedures.
5. The condensate, condensate impinger rinse, impinger water, and impinger rinse were combined and extracted by the Level 1 partition procedure.
6. The extracts from steps 4 and 5 were combined and then analyzed for TCO, GRAV organics, and selected polynuclear organics as shown in Figure 3-3.

3.2 ANALYSIS

The Total Chromatographable Organics (TCO) method was used to provide semi-quantitative data on the sample extracts for organic compounds with boiling points between 100°C and 300°C. This method is based on separating the components of a mixture in a GC column and measuring the separated components with a Flame Ionization Detector (FID). Quantitative calibration of the TCO procedure for the purpose of mass determination was accomplished by the use of mixtures of known concentration of the normal hydrocarbons decane, dodecane, and tetradecane. The peak area due to the FID response of the sample extract was summed over a TCO retention time window (C7 to C17) and a corresponding TCO value (mg/mL) was determined from the calibration curve.

The gravimetric (GRAV) method was used for the quantitation of organic compounds with boiling points of 300°C and greater. This method is applicable to organic liquids, solid sample extracts, aqueous extracts, and extracts from the Modified Method 5 sampling train sorbent module. The analysis was performed after the sample material was concentrated in order to have sufficient GRAV material to weigh in an accurate manner.

Qualitative and quantitative analysis was performed by high resolution capillary gas chromatography/mass spectrometry for the target compound listed in Table 3-2. Quantitation standards were d₁₀-phenanthrene and d₁₂-chrysene; these compounds were added to the samples immediately prior to analysis.

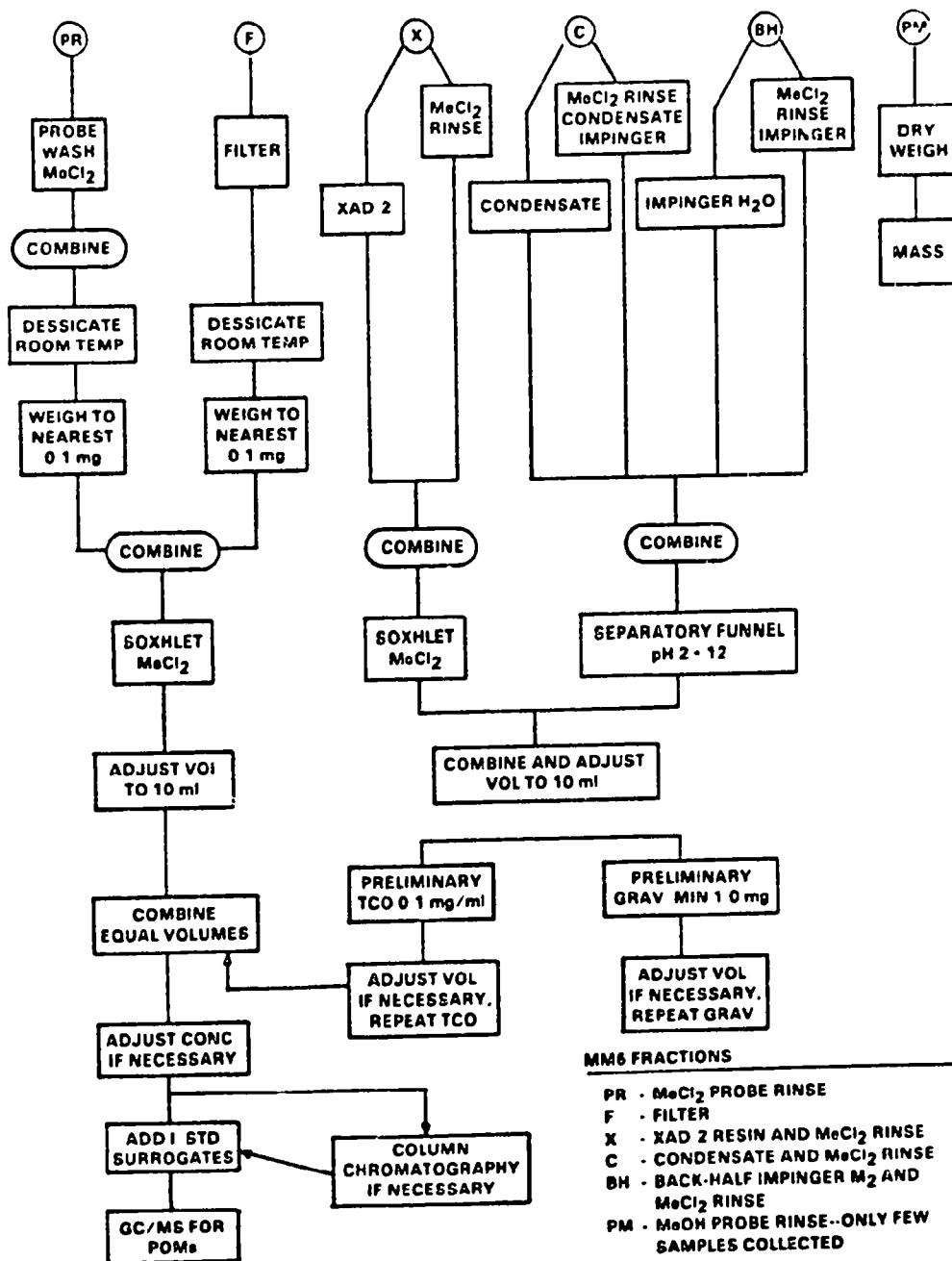


Figure 3-3 EPA MM5 sample fractions and analytical matrix.

Table 3-2. TARGET COMPOUNDS FOR QUANTITATIVE ANALYSIS BY GC/MS

acenaphthene	1-nitronaphthalene
anthracene	9-methylcholanthrene
benzo(a)anthracene	carbazole
benzo(a)pyrene	acridine
benzo(b)fluoranthene	9-phenanthrol
benzo(g,h,i)perylene	pyrenequinone
benzo(k)fluoranthene	
chrysene	
dibenzo(a,h)anthracene	
fluoranthene	
fluorene	
indeno(1,2,3-cd)pyrene	
naphthalene	
phenanthrene	
phenol	
pyrene	

Samples were analyzed by a Finnigan 4500 GC/MS data system with a DB-5 fused silica capillary column (30 m, 0.32 mm ID, 1 μ film thickness). Chromatographic conditions were selected to optimize both peak resolution and analysis time. The mass spectrometer was tuned to meet criteria for decafluorotriphenylphosphine (DFTPP). No samples were analyzed until tune criteria were met. Target compounds were identified using characteristic ions and retention times established by the analysis of standards. The analysis was performed in the full scan mode. Analytical conditions are shown in Table 3-3.

The GC/MS was calibrated by analyzing a solution containing quantitation standards and target compounds. The target compounds were put into the calibration solution at five concentration levels and each solution was analyzed to establish a response factor database. Quantitation of compounds was performed by the method of relative response factors. An estimated quantifiable limit for the compounds of interest is shown in Table 3-4. This is a quantifiable limit for the GC/MS instrumentation only, not for the method. The numbers in the table were obtained by looking at the system response for the lowest-level calibration sample and determining the number of area units obtained per nanogram of compound (assuming linearity of system response from 5 to 1 ng). The number of area units per nanogram was then multiplied by an appropriate factor (i.e., number of nanograms) to obtain a value in the range of 1000-1500 area units, which is usually readily reproducible upon repeated injection by the analytical system. Note that the number is representative of the Quantifiable Limit, not the Limit of Detection. A determination of the quantifiable limit for the overall method would require a determination of compound recoveries over the range of interest and incorporation of this recovery factor into the determination. Daily analysis included a demonstration of DFTPP tune, daily calibration check, a quality control sample, and analytical samples.

In addition to the qualitative/quantitative analyses performed for the list of target compounds, two of the sample extracts were characterized in order to obtain an indication of the types of compounds present in the samples. The qualitative analysis was performed by a semi-automated method. The sample peaks were selected by a computer program developed by Lynn Wright (EPA, RTP). The peaks selected by

Table 3-3. GC/MS ANALYTICAL CONDITIONS

Instrument:	Finnigan MAT 5100
Column:	30m DB-5 wide bore (0.32mm), thick film (1 u) fused silica capillary
GC Program:	45 ^o (4 min), 290 ^o C at 10 ^o /min, hold at 290 ^o C
Emission Current:	0.3 mA
Electron Energy:	70 eV
Separator Oven Temperature:	290 ^o C
Transfer Line Temperature:	290 ^o C
Injector Temperature:	290 ^o C
Manifold Temperature:	105 ^o C
Injection Mode:	Splitless 0.6 min, then 10:1 split
Scan Cycle:	0.95 s scan, 0.05 hold
Column Head Pressure:	8 psi

Table 3-4. ESTIMATED QUANTIFIABLE LIMIT

<u>Compound</u>	<u>Quantifiable Limit, ng</u>
phenol	0.8
naphthalene	0.5
acenaphthylene	0.6
acenaphthene	0.9
fluorene	0.9
nitronaphthalene	3.0
phenanthrene	0.7
anthracene	0.6
acridine	0.7
carbazole	0.7
fluoranthene	0.8
phenanthrol	6.0
pyrene	0.7
benzo(a)anthracene	0.8
chrysene	0.9
benzo(b)fluoranthene	1.0
benzo(k)fluoranthene	1.0
benzo(a)pyrene	1.2
methylcholanthrene	3.0
benzo(g,h,i)perylene	1.1
dibenzo(a,h)anthracene	1.4
indeno(1,2,3-cd)pyrene	1.3

Dr. Wright's program were plotted in an automated mode and a library search against the 40,000 compound NBS reference library was obtained. The spectra and results of the library search were inspected and manual interpretation was superimposed upon the automated computerized interpretation. The data are reported as scan number, compound(s) identified at that elution time, and three parameters reported from the NBS library search algorithm which aid in estimating the quality of the identification. However, if a compound was not identified in the library search, the results are reported as (manual). It is also important to keep in mind that the Purity and Rfit criteria are determined by the spectral integrity. That is, if components coelute, these parameters can be quite low because the spectrum does not represent a pure component. However, the identification can still be entirely valid. Results of the qualitative analysis are reported in Tables 3-5 and 3-6.

3.3 SAMPLE PREPARATION PROTOCOL

Each of the three sampling methods (OM7, ASTM, and MM5) have specific analytical schemes which are outlined as flow diagrams in Figures 3-1 through 3-3.

Flow diagram (Figure 3-1) shows the analytical matrix of the Oregon Method 7 (OM7). As illustrated this method matrix is comprised of five major components: 1) front-half probe rinses (PR and PM); 2) front filter (F_1); 3) back-half impinger water/ MeCl_2 rinses (BH and BM); 4) back-half impinger acetone rinse (BR); and 5) back filter (F_2). The front-half probe rinses (PR and PM) were combined and evaporated to dryness in a tared beaker, then put in the desiccator for 24 hours. The samples were weighed and checked every 2 hours until constant weight was established.

The back-half impinger rinse (BR) was treated in the same manner as the PR and PM rinses - desiccated, dried, and weighed until constant. The back-half impinger solutions (BH and BM) were combined and put into separatory funnels (the bottles rinsed with distilled H_2O and this added) and vigorously shaken with 25 mL of chloroform (CHCl_3) for one minute. Fractions were allowed to separate, and the lower chloroform

Table 3-5. SAMPLE BS-2

Scan	Compound	Purity	Fit	Rfit
186	cyclohexene	854	987	863
199	trichloroethylene	954	990	960
232	3-penten-2-one	965	991	965
240	C ₉ H ₂₀	734	876	762
242	2-methylfuran	785	930	809
253	2,3-butanedione	709	951	739
258	unknown			
270	methyl butenoate	262	879	286
275	methyl 2-oxopropanoate	939	972	946
288	toluene	952	993	952
297	cyclopentanone	865	977	879
330	furfural	729	856	832
359	C ₅ H ₆ O ₂ (manual)			
363	tetrachloroethylene	845	874	966
367	C ₅ H ₄ O ₂	867	894	964
374	C ₆ H ₁₀ O (manual)			
381	C ₆ H ₁₂ O ₂	621	845	654
409	C ₇ H ₁₆ O (manual)			
430	cyclohexenone	710	874	756
435	methyl 2-oxobutanoate	203	931	203
441	ethylbenzene	789	990	789
455	xylene	280	910	302
	phenylacetylene (manual)			
472	methylcyclohexenone	406	878	439
480	styrene	694	934	699
488	1-(2-furanyl)ethanone	782	986	790
	xylene (manual)			
494	2,5-hexanedione	903	932	950
499	2,3-dihydro-2,5-dimethylfuran	777	883	804
511	pyranone	326	950	373

continued

Table 3-5. continued

Scan	Compound	Purity	Fit	Rfit
520	5,5-dimethyl-2(5H)furanone	737	830	871
535	tetramethylcyclohexadiene	762	974	762
551	1-(acetyloxy)-2-butanone	769	808	816
555	C ₆ H ₁₀ O ₃	906	978	919
560	methylfurancarboxaldehyde benzaldehyde (manual)	590	922	624
582	C ₁₀ H ₁₆ benzonitrile (manual)	528	934	545
587	C ₃ -alkylbenzene (manual) C ₈ H ₁₂ O (manual)			
595	phenol	909	988	919
616	C ₁₀ H ₁₆	709	994	709
622	benzofuran	803	948	840
627	C ₁₀ H ₁₆	798	993	798
635	unknown			
642	C ₆ H ₈ O ₂	862	998	862
655	cyclohexenylethanone	604	815	674
658	C ₈ H ₁₄	716	901	716
662	C ₃ -alkylbenzene (manual) indane (manual)			
666	C ₄ -alkylbenzene	613	982	613
	hydroxybenzaldehyde	411	969	422
678	C ₁₀ H ₁₆	841	971	841
684	cresol	578	976	587
	indene (manual)			
693	acetophenone	637	941	658
	C ₈ H ₁₂ O (manual)			
698	methylbenzaldehyde	856	993	861
708	cresol	897	987	897
713	methylbenzaldehyde (manual)			

continued

Table 3-5. continued

Scan	Compound	Purity	Fit	Rfit
723	trimethylcyclopentenone	784	942	792
738	dimethylstyrene	432	930	454
	hydroxymethylpyranone	419	920	438
745	dimethylphenol	461	957	472
751	methylbenzofuran	695	961	718
756	phenylpropenal	547	959	567
769	C ₈ H ₁₂ O (manual)			
776	ethylphenol	416	909	433
	C ₄ -alkylbenzene	413	959	420
	methylhydroxybenzaldehyde (manual)			
783	C ₁₀ H ₁₆	797	978	807
789	dimethylphenol	886	995	886
798	propylphenol	500	944	511
804	benzoic acid	412	937	432
	methylindan (manual)			
809	dimethylphenol (manual)			
	methylindan (manual)			
814	pentanoic acid (?)	287	905	299
	C ₄ -alkylbenzene (manual)			
819	dimethylphenol	367	938	387
826	methylacetophenone	756	935	806
836	ethylbenzenediol	781	927	781
839	naphthalene	880	974	895
845	C ₁₀ H ₁₆	403	912	430
	C ₁₀ H ₁₈ O	531	942	561
854	phenylpropenal	752	973	752
869	dimethylbenzofuran	616	951	633
879	C ₃ -alkylphenol	670	985	670
895	ethylbenzoic acid	747	843	770

continued

Table 3-5. continued

Scan	Compound	Purity	Fit	Rfit
907	methylbenzenedicarboxaldehyde	561	937	596
	hexanoic acid (?)	229	894	236
915	indanone	734	980	746
921	dihydroxyacetophenone	671	994	671
930	hydroxybenzaldehyde	782	925	844
948	methylnaphthalene	737	959	765
963	methylnaphthalene	791	981	794
972	dimethoxyphenol	348	868	401
990	methoxypropenylphenol	744	997	744
995	C ₆ -alkylbenzene (manual)			
	decanoic acid	488	976	491
1002	C ₁₃ H ₁₀ (manual)			
1013	hydroxymethoxybenzaldehyde	885	993	888
1019	biphenyl	811	995	811
1029	C ₉ H ₈ O (manual)			
	C ₇ -alkylbenzene (manual)			
1036	dimethylbenzofuranone	410	951	420
	dimethylnaphthalene (manual)			
1042	carboxylic acid (manual)			
1050	acenaphthene	367	882	400
	benzopyranone	378	932	404
1060	dimethyltetralin	332	953	339
	C ₁₃ H ₁₀ (manual)			
1063	dimethylnaphthalene	459	885	513
1077	ethyltetralin	302	744	381
	dimethylnaphthalene	305	736	386
1084	acenaphthylene	595	945	618
	C ₁₀ H ₁₁ CO ₂ H (manual)			
1089	hydroxymethoxyacetophenone	804	980	817
1093	C ₆ -alkylbenzene	615	974	620

continued

Table 3-5. continued

Scan	Compound	Purity	Fit	Rfit
1108	naphthofuran	128	973	134
1115	naphthalenecarboxaldehyde	483	968	483
1123	hydroxymethoxyphenylpropanone	740	912	801
1139	dibenzofuran	905	975	917
1159	dodecanoic acid	786	998	758
1167	C ₁₁ H ₁₆ O ₂ (manual)			
1172	phthalate ester (manual)			
1180	naphthofuran	392	957	392
1192	fluorene	629	946	652
1203	C ₃ -alkylnaphthalene (manual)			
1216	hydroxymethoxybenzeneacetic acid	724	947	724
1221	methyldibenzofuran	696	964	719
1232	biphenylcarboxaldehyde	808	936	879
1300	fluorenone	824	953	862
1303	tetradecanoic acid	749	989	750
1335	d ₁₀ -phenanthrene (manual)			
1338	phenanthrene	863	987	870
1345	anthracene (manual)			
1350	dimethylacetophenone	378	948	388
1389	heptadecanol	824	979	826
1430	phthalate ester	904	991	905
1437	hexadecanoic acid (manual)			
1440	C ₁₄ H ₂₇ CHO (manual)			
1485	unknown			
1504	C ₁₆ H ₂₉ CHO (manual)			
1516	hexadecanol	803	991	805
1524	pyrene (manual)			
1538	C ₁₇ H ₃₁ CHO (manual)			
	fluoranthene (manual)			

continued

Table 3-5. concluded

<u>Scan</u>	<u>Compound</u>	<u>Purity</u>	<u>Elt</u>	<u>Rfit</u>
1546	C ₁₈ H ₃₃ OH (manual)			
1562	dodecanediol	791	986	797
1590	hydrocarbon			
1606	N-phenylnaphthylamine	830	971	830
1615	C ₄ -alkylphenanthrene	618	877	684
1619	C ₁₈ H ₃₃ CHO (manual)			
1632	oxygenated compound			
1645	oxygenated compound			
1698	docosane	808	960	837
1751	d ₁₂ -chrysene (manual)			
1768	diisooctyl phthalate	918	977	937
1855	naphthalenylbenzothiophene	308	670	425

Table 3-6. SAMPLE GS-2

Scan	Compound	Purity	Fit	Rfit
190	C ₆ H ₁₀	902	990	902
210	2,5-dimethylfuran	831	902	912
223	methyl butanoate	816	898	894
234	3-penten-2-one	968	992	968
242	C ₉ H ₂₀	737	889	765
256	2,3-butanedione	721	947	759
261	2,2-dimethylpropanoic acid	674	843	723
278	methyl 2-oxopropanoate[C ₄ H ₆ O ₃]	891	916	900
291	toluene	955	994	955
302	2-methyltetrahydrofuran-2-ol	718	821	860
333	furfural	715	864	807
361	methylfuran	431	947	431
367	C ₅ H ₄ O ₂ [2H-pyran-2-one]	818	880	818
377	unknown			
383	1-(1-methylethoxy)-2-propanone	541	791	632
391	cresol (? detection too soon!)	406	884	431
404	2-cyclohexen-1-one	470	843	492
411	1,2-ethanediol diacetate	848	956	886
424	2,4-hexadienal	718	882	769
433	cyclohexenone	723	903	747
437	C ₆ H ₁₂ O (manual)			
442	ethylbenzene	820	992	820
456	xylene	501	978	509
	phenylacetylene (manual)			
464	pentenoic acid (manual)			
474	C ₈ H ₁₄	663	740	734
481	styrene	685	984	690
	C ₆ H ₈ (manual)			
489	xylene (manual)			
	1,(2-furanyl)ethanone	683	964	705

continued

Table 3-6. continued

Scan	Compound	Purity	Fit	Rfit
496	2,5-hexanedione	899	930	950
501	cyclohexanone	849	884	896
522	5,5-dimethyl-2(5H)-furanone	790	852	902
533	C ₇ H ₁₀ O, C ₇ H ₁₂ O (manual)			
551	C ₈ H ₁₈ O (manual)			
555	1-acetyloxy-2-butanone	932	978	944
560	5-methyl-2-furancarboxaldehyde	583	921	620
	benzaldehyde	291	850	319
588	C ₃ -alkylbenzene	542	976	551
	C ₈ H ₁₂ O (manual)			
596	phenol	939	999	939
608	methylstyrene	602	942	633
	C ₃ -alkylbenzene	470	889	474
616	C ₇ H ₁₁ CHO (manual)			
623	benzofuran	767	936	816
629	methylstyrene	775	995	775
	C ₃ -alkylbenzene (manual)			
636	C ₉ H ₁₄ O (manual)			
642	C ₆ H ₈ O ₂ (2-hydroxy-3-methyl-2-cyclopenten-1-one)	875	997	875
649	methylanisole	825	991	825
655	1-(1-cyclohexen-1-yl)ethanone	686	851	761
659	C ₇ H ₁₀ O (manual)			
663	benzeneacetaldehyde	393	843	464
	methylstyrene (manual)			
667	hydroxybenzaldehyde	616	994	616
	C ₄ -alkylbenzene	404	937	410
678	C ₁₀ H ₁₆ C ₈ H ₁₂ O (manual)	474	970	474
685	cresol	746	996	746
	indene (manual)			

continued

Table 3-6. continued

Scan	Compound	Purity	Fit	Rfit
693	acetophenone	716	943	741
	unsaturated C ₄ -alkylbenzene (manual)			
698	methylbenzaldehyde	795	991	799
708	cresol	914	988	914
713	methylbenzaldehyde	552	935	589
723	trimethylcyclopentenone	786	938	795
729	C ₁₀ H ₁₂	408	840	470
732	methyl benzoate	485	935	511
	unsaturated C ₄ -alkylbenzene (manual)			
739	hydroxymethylpyranone	859	986	859
	unsaturated C ₄ -alkylbenzene	811	975	826
745	dimethylphenol	623	990	623
	propynyloxybenzene	452	983	452
751	3-phenyl-2-propenal	772	991	772
756	methylbenzofuran	838	968	862
761	C ₁₀ H ₁₀	330	835	381
	C ₉ H ₁₀ O (manual)			
769	C ₉ H ₁₈ O	584	926	584
776	ethylphenol	563	971	570
	C ₄ -alkylbenzene (manual)			
	methoxybenzaldehyde (manual)			
783	C ₃ -alkylphenol	435	909	458
	C ₄ -alkylbenzene (manual)			
	C ₉ H ₁₆ (manual)			
789	dimethylphenol	902	992	902
798	propylphenol	562	955	569
802	trimethylphenol	725	757	929
806	ethylphenol	815	926	880
809	dimethylphenol	712	988	712
	C ₁₀ H ₁₀ (manual)			

continued

Table 3-6. continued

Scan	Compound	Purity	Fit	Rfit
813	C ₁₀ H ₁₆ O (manual)			
	methylacetophenone	562	865	617
820	dimethylphenol	437	942	460
826	methylacetophenone	791	933	841
836	demethoxybenzene	681	959	691
839	naphthalene	946	980	963
843	5-(hydroxymethyl)furancarboxaldehyde	844	976	854
849	trimethylphenol	756	955	787
854	C ₉ H ₈ O	432	966	432
861	dimethylbenzofuran	572	888	592
869	dimethylbenzofuran	655	970	663
879	ethylmethylphenol	811	997	811
883	bifuran	531	969	537
891	dihydrobenzopyranol	434	845	471
897	3-methyl-1,2-benzenediol	716	947	716
	C ₃ -alkylphenol (manual)			
907	2-methyl-1,4-benzenedicarboxaldehyde	773	982	784
915	indanone	838	979	851
921	dihydroxyacetophenone	697	985	702
924	methylbenzenediol	783	974	794
929	hydroxybenzaldehyde	693	969	712
935	C ₄ -alkylphenol (manual)			
948	2-methylnaphthalene	757	958	786
950	hydroxymethylacetophenone	801	887	882
959	unsaturated C ₆ -alkylbenzene	316	961	327
963	1-methylnaphthalene	781	972	793
990	methoxypropenylphenol	670	995	670
996	C ₆ -alkylbenzene (manual)			
	C ₁₀ H ₁₄ O ₂ (manual)			
1002	methoxypropylphenol	788	923	819

continued

Table 3-6. continued

Scan	Compound	Purity	Fit	Rfit
1007	hydroxybenzoic acid	359	921	369
1014	hydroxymethoxybenzaldehyde	869	994	869
1019	biphenyl	708	975	719
1029	trimethylbenzaldehyde	426	955	426
1039	C ₈ H ₁₅ CO ₂ H (manual)			
1050	C ₁₂ H ₁₀	378	880	408
1060	dimethylnaphthalene	464	908	487
	dimethyldecalin (manual)			
	unsaturated C ₅ -alkylbenzene (manual)			
1063	dimethylnaphthalene (manual)			
	C ₅ -alkylbenzene (manual)			
1065	ethenylnaphthalene	876	924	932
1069	methoxypropenylphenol	798	986	798
1075	C ₉ H ₁₉ CO ₂ H (manual)			
1084	biphenylene	735	977	740
1089	hydroxymethoxyacetophenone	789	993	793
1093	C ₆ -alkylbenzene	584	949	600
1108	diphenylmethane	391	873	433
1118	naphthalenecarboxaldehyde	515	978	520
1124	C ₁₂ H ₂₀ O (manual)			
1139	dibenzofuran	878	979	892
1156	dimethylbenzenebutanoic acid	721	968	721
1161	methyl ketone (manual)			
1167	C ₈ H ₇ -benzene (manual)			
1189	C ₇ -alkylbenzene (manual)			
1192	fluorene	767	958	783
1208	methylfluorene	361	824	373
1216	hydroxymethoxyphenylacetic acid	695	939	703
1221	methyldibenzofuran	672	959	694
1232	9H-xanthene	720	929	750

continued

Table 3-6. concluded

Scan	Compound	Purity	Fit	Rfit
1238	naphthofuran	445	991	445
1261	biphenylol	745	859	857
1275	anthracene (manual)			
1301	fluorenone	578	965	591
1309	methoxyfluorene	378	766	434
1317	dibenzodioxin	729	956	756
1324	oxygenated compound			
1335	d10phenanthrene			
1345	phenanthrene	756	970	773
1376	nonanediol	594	983	594
1389	pentadecanol	749	969	765
1404	C ₉ H ₁₂ O	462	872	505
1408	benzocinnoline	834	953	867
1416	methylanthracene	647	898	710
1430	phthalate ester (manual)			
1437	methylanthracene (manual)			
1440	C ₁₂ H ₂₅ CHO (manual)			
1453	phenanthrenedione	575	871	645
1459	phenylnaphthalene	450	860	515
1497	ethoxyloxyoctadecane	389	835	453
1502	C ₁₆ H ₂₉ CHO (manual)			
1516	alkene or alcohol			
1524	fluoranthene	781	964	802
1538	pyrene	918	958	953
1613	tetramethylphenanthrene	750	823	874
1619	aldehyde			
1644	benzo(c)fluorene	242	749	257
1695	C ₁₀ H ₁₂ O ₂	418	894	457
1751	d ₁₂ -chrysene			
1768	phthalate ester			
1985	benzo(a)pyrene	454	565	795

layer was transferred into a tared beaker. The chloroform extraction was repeated twice more with addition of the bottom CHCl_3 layers to the tared beaker. Extraction was repeated three times on the BH and BM fractions using diethyl ether in place of chloroform. The ether layers were transferred to the same beaker used for chloroform. The combined solvent extract was evaporated to dryness and desiccated 24 hours. Samples were weighed until constant (<0.5 mg change for two weighings). The extracted water layers were transferred to separate tared beakers and evaporated at 105°C to dryness. Samples were next desiccated for 24 hours and weighed until constant. Solvent blanks were determined by evaporating 75 mL of both chloroform and diethyl ether to a dry constant weight (<0.5 mg change). The two filters (F_1 and F_2) were also desiccated at room temperature for 24 hours and weighed to constant value (<0.5 mg change). All data were recorded in the sample log notebook and entered into the Sample and Analysis Management (SAM) computer program.

Flow diagram (Figure 3-2) shows the analytical matrix of the ASTM method. As illustrated this method matrix consists of three major fractions: 1) the probe rinses (PR); 2) the first filter (F_1); and 3) the second filter (F_2). In this scheme an additional probe rinse of MeCl_2 (PM) was included, and these were analyzed separately in the same manner as the original probe rinse (PR). The probe rinses were put into tared beakers and desiccated at room temperature. After reaching complete dryness the samples were desiccated for 8 hours. After obtaining the initial weight, the samples were weighed every 2 hours or until constant (<0.5 mg change). The filters were left at room temperature for 24 hours and weighed. Then the filters were desiccated 16 hours, weighed, desiccated 2 hours and reweighed. All data were entered into sample log notebook and the SAM computer program.

The final flow diagram (Figure 3-3) shows the analytical matrix for the Modified Method 5 (MM5) procedure. As shown this method matrix includes five major sample components: 1) probe rinse MeCl_2 (PR); 2) filter (F); 3) XAD-2 resin (X); 4) condensate solutions (C); and 5) impinger solutions (DH). The condensate (C) and impinger rinses (BH) were combined and a Method 3530 A/BN extraction performed.

The XAD-2 resin (X) and MeCl_2 rinses were Soxhlet extracted for 16 hours using MeCl_2 as the solvent. The XAD extracts were added to the organic fraction from the Method 3530 Extraction (BH and C), and the final volume adjusted to 10 mL. Preliminary Gravimetric Analysis (GRAV) was done on the combined extracts (X, C, and BH) to determine if the GRAV value was less than 30 mg/mL. If necessary, the volume was adjusted with MeCl_2 until the GRAV value was between 0.1 and 30 mg/mL. After reaching an acceptable GRAV value, GC/TCO analysis was done. Again, the volume of the extract was adjusted to maximize the GC/TCO results. The values from the GC/TCO analyses were used to determine correct dilution volumes for the GC/MS samples. This GC/TCO screen also indicated that a column chromatography step was not warranted. The probe rinse (PR) in MeCl_2 was evaporated at room temperature in a tared beaker, desiccated, and weighed to the nearest 0.5 mg. The weighing was repeated every 2 hours until a constant (<0.5 mg change) value was reached. The filter was desiccated for 24 hours and weighed. Weighing was repeated every 2 hours until constant (within 0.5 mg) weight was reached. The probe rinse (PR) and filter (F) were combined in a Soxhlet apparatus and extracted with MeCl_2 for 16 hours. The final volume was adjusted to 10 mL and this fraction was combined in equal parts with the organic fractions of the XAD-condensate-impinger (X, C, and BH) extractions.

The final step involves adding quantitation standards before the sample was submitted for GC/MS analysis. Since column chromatography was not performed, no surrogate compounds were added.

4.0 ANALYTICAL RESULTS

The reliability and acceptability of environmental analytical information depends upon the rigorous completion of all requirements outlined in the QA/QC protocol.

The data were carefully logged into sample notebooks on a daily basis by the analysts to minimize the collection of invalid data. Daily control checks consisted of examination of reproducibility of duplicate injections, sample blanks, and quality control samples that were analyzed during the daily analysis cycle. The analysts recorded any unusual instances in the daily cycles (such as power loss or fluctuations, temporary leaks or adjustments, or operator error). Problems were documented as detected and appropriate corrective action taken to maximize the validity of the database.

The analysts on each task double checked all data entries to ensure accurate transcriptions and calculations. The data were then reviewed by each respective Task Leader and corrections made if necessary. Finally, all data were reviewed and calculations spot-checked by QA Officer to verify the integrity of the data. After validation of the database, data tables were prepared and are shown in Summary Tables 4-1, 4-2, and 4-3.

Table 4-1. Woodstove Gravimetric Results

MODIFIED METHOD 5					
SAMPLE ID	PMeOH (mg)	PR (mg)	FILTER (mg)	XAD, C, & BH	
				TCO (mg)	GRAV (mg)
BD-1	NA	1.0	6.3	37.4	76
BD-QC1	NA	NA	NA	NA	NA
BD-2	NA	0.5	7.8	26.5	60
BD-3	NA	1.0	9.9	10.7	35
BD-4	NA	1.2	8.5	73.1	102
BD-QC4	NA	NA	NA	NA	NA
BD-5	NA	0.5	7.7	19.5	46
BD-QC5	NA	1.0	7.2	19.4	54
BD-B	NA	NA	NA	NA	NA
BS-1	NA	32.0	52.6	168.0	195
BS-QC1	NA	NA	NA	NA	NA
BS-2	NA	5.8	28.9	62.9	99
BS-QC2	NA	NA	NA	NA	NA
BS-3	NA	1.4	14.3	51.5	62
BS-4	NA	51.1	249.4	1240.0	723
BS-5	NA	11.8	32.0	89.6	76
BS-QC5	NA	15.9	12.1	56.0	75
BS-B	NA	NA	NA	NA	NA
GD-1	NA	1.9	134.0	117.0	72
GD-2	NA	1.6	53.8	97.7	70
GD-3	NA	1.5	128.6	157.0	114
GD-QC3	NA	0.9	31.5	138.0	127
GD-4	NA	0.7	30.6	76.5	52
GD-QC4	NA	NA	NA	NA	NA
GD-B	NA	0.3	0.0	0.0	23
GS-1	NA	48.7	699.0	872.0	858
GS-2	NA	39.5	215.6	371.0	262
GS-3	NA	23.9	260.6	680.0	490
GS-QC3	NA	NA	NA	NA	NA
GS-4	NA	8.4	37.6	132.0	84
GS-QC4	NA	9.8	38.2	99.6	79
GS-B	NA	1.2	2.2	0.0	31
G-LOADING BLANK	NA	NA	NA	NA	NA

continued

Table 4-1. Woodstove Gravimetric Results continued

MODIFIED METHOD 5					
SAMPLE ID	PMeOH (mg)	PR (mg)	FILTER (mg)	XAD, C, & BH	
				TCO (mg)	GRAV (mg)
HD-1	NA	0.7	5.0	13.4	55
HD-QC1	NA	NA	NA	NA	NA
HD-2	1.1	0.2	7.4	33.7	59
HD-QC2	NA	NA	NA	NA	NA
HD-3	1.7	0.2	11.3	18.6	44
HD-QC3	1.2	0.3	9.4	25.0	38
HD-4	1.6	0.2	17.6	23.3	24
HD-5	1.6	0.9	9.5	20.4	32
HD-B	0.4	0.9	0.0	0.0	16
HS-1	NA	3.7	14.1	49.2	42
HS-QC1	NA	NA	NA	NA	NA
HS-2	11.6	13.6	147.1	422.0	478
HS-3	17.7	8.0	91.1	183.0	137
HS-QC3	8.5	9.2	17.0	46.7	38
HS-4	15.2	10.0	100.7	161.0	123
HS-5	10.0	10.4	45.8	117.0	70
HS-B	1.1	1.3	0.8	0.0	140
TD-1	NA	1.7	12.8	49.2	72
TD-2	NA	1.8	6.4	18.3	44
TD-QC2	NA	NA	NA	NA	NA
TD-B	NA	0.5	0.3	0.0	16
TS-1	NA	12.5	35.1	76.7	88
TS-2	NA	15.0	21.9	56.2	86
TS-3	NA	8.3	130.5	186.0	176
TS-QC3	NA	NA	NA	NA	NA
TS-B	NA	1.2	14.2	0.0	27
BLANK XAD MODULE	NA	NA	NA	0.0	11

continued

Table 4-1. Woodstove Gravimetric Results continued

MODIFIED METHOD 5					
SAMPLE ID	PMeOH (mg)	PR (mg)	FILTER (mg)	XAD, C, & BH	
				TCO (mg)	GRAV (mg)
FD-1	1.0	3.6	26.5	36.9	138
FD-2	1.5	0.2	3.5	27.2	159
FD-QC2	2.7	0.3	5.2	25.5	110
FD-3	0.0	1.3	10.6	22.3	125
FD-4	1.2	1.0	4.4	26.0	123
FD-QC4	2.7	3.6	21.3	22.1	112
FS-1	32.1	14.0	81.7	133.0	200
FS-2	17.2	28.3	98.3	144.0	212
FS-3	13.4	12.0	30.4	94.3	198
FS-4	13.8	7.9	32.6	92.3	178
FS-B	NA	NA	NA	0.3	119

continued

Table 4-1. Woodstove Gravimetric Results continued

OREGON METHOD 7						
SAMPLE ID	PR & PM (mg)	FRONT FILTER (mg)	BH & BM CHC13/ETHER EXTRACTION		BR (mg)	BACK FILTER (mg)
			WATER FRACTION (mg)	CHC13/ETHER FRACTION (mg)		
BD-1	1.3	7.3	16.2	14.9	1.0	0.7
BD-QC1	NA	NA	NA	NA	NA	NA
BD-2	0.8	5.8	21.1	7.9	2.1	2.8
BD-3	0.5	4.8	20.8	5.4	1.0	2.4
BD-4	61.2	11.7	35.2	41.2	2.4	3.8
BD-QC4	1.5	13.7	45.4	13.2	2.2	0.0
BD-5	4.8	18.0	18.4	8.8	0.8	2.9
BD-QC5	NA	NA	NA	NA	NA	NA
BD-B	2.6	1.3	9.8	1.8	0.6	0.3
BS-1	31.1	34.7	64.2	35.2	43.0	24.0
BS-QC1	46.9	59.4	122.7	61.2	54.8	17.9
BS-2	29.0	19.2	34.9	11.2	19.4	19.3
BS-QC2	23.0	15.7	26.2	12.6	4.6	5.3
BS-3	9.5	7.5	10.9	2.0	11.3	16.2
BS-4	49.4	78.2	184.0	117.0	144.8	205.2
BS-5	24.4	10.1	13.5	5.3	11.4	2.9
BS-QC5	NA	NA	NA	NA	NA	NA
BS-B	1.9	0.7	17.2	1.1	1.4	0.9
GD-1	5.6	101.7	46.2	13.6	3.2	0.6
GD-2	2.4	24.7	37.8	38.9	5.6	3.8
GD-3	8.2	103.1	19.5	7.3	2.3	0.0
GD-QC3	NA	NA	NA	NA	NA	NA
GD-4	1.0	27.6	10.6	4.7	4.7	0.5
GD-QC4	0.7	50.5	20.1	9.8	8.2	0.7
GD-B	1.1	0.0	1.5	0.0	0.9	0.1
GS-1	160.1	731.4	161.3	98.6	125.7	73.9
GS-2	132.8	289.3	28.0	59.4	11.5	4.7
GS-3	164.8	381.6	45.1	36.1	144.3	37.3
GS-QC3	174.0	424.1	35.2	45.5	19.0	25.1
GS-4	23.2	34.8	5.0	3.1	4.6	0.6
GS-QC4	NA	NA	NA	NA	NA	NA
GS-B	1.4	1.3	0.3	0.0	0.2	0.2
G-LOADING BLANK	NA	0.0	NA	NA	NA	NA

continued

Table 4-1. Woodstove Gravimetric Results continued

OREGON METHOD 7						
SAMPLE ID	PR & PM (mg)	FRONT FILTER (mg)	BH & BM CHC13/ETHER EXTRACTION		BR (mg)	BACK FILTER (mg)
			WATER FRACTION (mg)	CHC13/ETHER FRACTION (mg)		
HD-1	1.8	3.9	14.8	2.8	1.6	0.0
HD-QC1	NA	NA	NA	NA	NA	NA
HD-2	2.6	16.3	25.5	4.3	2.2	1.0
HD-QC2	1.8	34.9	14.2	19.4	0.5	0.3
HD-3	1.5	5.5	16.5	3.0	1.7	3.8
HD-QC3	NA	NA	NA	NA	NA	NA
HD-4	1.2	12.8	8.8	0.6	2.2	1.1
HD-5	2.6	7.2	16.6	7.9	1.4	1.4
HD-B	2.3	0.0	0.6	0.4	0.1	0.3
HS-1	18.6	12.7	3.7	1.4	5.7	3.2
HS-QC1	42.4	20.5	9.3	4.6	19.4	29.7
HS-2	70.4	334.6	60.4	189.2	29.3	81.0
HS-3	44.0	77.6	11.9	34.8	8.3	2.8
HS-QC3	NA	NA	NA	NA	NA	NA
HS-4	76.0	74.1	19.6	6.5	29.6	26.2
HS-5	27.3	67.4	7.8	18.0	4.3	3.2
HS-B	1.1	0.5	0.4	3.8	0.0	0.7
TD-1	3.6	10.0	24.4	25.9	2.1	4.2
TD-2	2.7	6.2	0.0	13.5	2.5	0.6
TD-QC2	NA	NA	NA	NA	NA	NA
TD-B	0.7	0.5	1.7	0.9	0.2	2.2
TS-1	12.4	12.5	7.5	21.1	17.0	21.5
TS-2	19.4	33.0	38.3	20.2	32.8	26.6
TS-3	23.9	170.6	45.4	30.0	78.6	47.0
TS-QC3	11.4	90.6	54.4	120.4	30.0	103.6
TS-B	1.0	0.9	4.3	0.0	0.1	0.3
FD-1	2.0	37.1	28.4	21.6	18.9	1.4
FD-2	4.3	9.7	55.5	14.9	12.1	3.0
FD-3	2.2	5.0	18.5	14.4	21.7	10.9
FD-4	2.2	10.0	39.4	9.3	11.7	1.8
FS-1	69.6	66.9	41.3	39.2	58.0	57.7
FS-2	33.6	37.3	57.0	39.1	92.0	53.8
FS-3	61.8	39.7	45.9	39.6	58.1	32.3
FS-4	36.6	27.2	28.7	26.7	50.3	53.5

continued

Table 4-1. Woodstove Gravimetric Results continued

SAMPLE ID	ASTM		FILTER ONE (mg)	FILTER TWO (mg)
	PR (mg)	PM (mg)		
BD-1	3.2	1.9	32.7	1.1
BD-QC1	0.7	0.4	30.4	1.6
BD-2	1.4	1.6	38.0	0.8
BD-3	0.0	2.2	9.9	0.5
BD-4	3.3	1.6	77.6	1.4
BD-QC4	NA	NA	NA	NA
BD-5	4.8	1.9	22.5	0.4
BD-QC5	NA	NA	NA	NA
BD-B	NA	NA	NA	NA
BS-1	NA	NA	NA	NA
BS-QC1	NA	NA	NA	NA
BS-2	NA	NA	NA	NA
BS-QC2	NA	NA	NA	NA
BS-3	NA	NA	NA	NA
BS-4	NA	NA	NA	NA
BS-5	NA	NA	NA	NA
BS-QC5	NA	NA	NA	NA
BS-B	NA	NA	NA	NA
GD-1	2.7	1.4	180.3	1.2
GD-2	0.2	0.7	98.3	0.7
GD-3	2.2	1.7	187.6	1.3
GD-QC3	NA	NA	NA	NA
GD-4	2.8	1.1	55.8	0.6
GD-QC4	NA	NA	NA	NA
GD-B	0.0	1.3	0.1	0.2
GS-1	NA	NA	NA	NA
GS-2	NA	NA	NA	NA
GS-3	NA	NA	NA	NA
GS-QC3	NA	NA	NA	NA
GS-4	NA	NA	NA	NA
GS-QC4	NA	NA	NA	NA
GS-B	NA	NA	NA	NA
G-LOADING BLANK	NA	NA	NA	NA

continued

Table 4-1. Woodstove Gravimetric Results concluded

SAMPLE ID	ASTM			
	PR (mg)	PM (mg)	FILTER ONE (mg)	FILTER TWO (mg)
HD-QC1	0.0	0.6	21.8	1.1
HD-2	1.8	0.1	73.0	0.0
HD-QC2	NA	NA	NA	NA
HD-3	0.6	0.1	30.1	0.0
HD-QC3	NA	NA	NA	NA
HD-4	0.6	0.1	31.3	0.0
HD-5	0.8	0.9	20.8	0.0
HD-B	0.0	1.3	0.6	0.4
HS-1	NA	NA	NA	NA
HS-QC1	NA	NA	NA	NA
HS-2	NA	NA	NA	NA
HS-3	NA	NA	NA	NA
HS-QC3	NA	NA	NA	NA
HS-4	NA	NA	NA	NA
HS-5	NA	NA	NA	NA
HS-B	NA	NA	NA	NA
TD-1	0.7	0.4	29.2	1.6
TD-2	3.0	0.0	17.6	1.7
TD-QC2	2.9	0.3	1.3	2.0
TD-B	NA	NA	NA	NA
TS-1	NA	NA	NA	NA
TS-2	NA	NA	NA	NA
TS-3	NA	NA	NA	NA
TS-QC3	NA	NA	NA	NA
TS-B	NA	NA	NA	NA
FD-1	2.3	2.1	97.8	0.4
FD-2	4.2	1.2	37.8	0.6
FD-3	5.7	0.8	45.0	0.8
FD-4	2.9	*	37.2	0.0

* sample was contaminated

Table 4-2. TOTAL CHROMATOGRAPHABLE ORGANICS (TCO)

SAMPLE I.D. #	AREA COUNTS	AREA COUNTS	PERCENT DIFF.	MEAN AREA CTS.	TCO MG/ML *	TCO MG/10ML	DILUTION FACTOR	TOTAL MG (MINUS BLANK)
BD-1-9472	806693	753929	6.76192	730311.00	3.74	15.0	2.50	37.4
BD-2-9621	655360	650203	0.790004	652781.50	3.10	12.4	2.14	26.5
BD-3-9653	320854	316162	1.47312	318508.00	1.42	5.67	1.88	10.7
BD-4-9657	523689	518962	0.906727	521325.50	2.44	9.75	7.50	73.1
BD-5-9869	502905	476307	5.43253	489606.00	2.28	9.11	2.14	19.5
BD-QC5-9868	583475	580577	0.497916	582026.00	2.74	11.0	1.76	19.4
HD-B-10343	38510	34106	12.130	36308.00	-0.00205	-0.00820	1.67	0.00
HD-1-10095	482961	478901	0.844196	480931.00	2.23	8.93	1.50	13.4
HD-2-9982	1041390	1040210	0.1133743	1040800.00	5.05	20.2	1.67	33.7
HD-3-10249	658221	648705	1.45624	653463.00	3.10	12.4	1.50	18.6
HD-QC3-10247	870733	862725	0.923934	866729.00	4.17	16.7	1.50	25.0
HD-4-11345	744691	713644	4.25787	729167.50	3.48	13.9	1.67	23.3
HD-5-10347	787064	776312	1.37548	781688.00	3.75	15.0	1.36	20.4
GD-B-10091	45549	45199	0.77137	45374.00	0.0435	0.174	2.14	0.00
GD-1-9875	822436	810342	1.48140	816389.00	3.92	15.7	7.50	117.0
GD-2-9979	625690	618503	1.15529	622096.50	2.94	11.8	8.33	97.7
GD-3-10097	880337	658789	2.4780	869563.00	4.19	16.8	9.40	157.0
GD-QC3-10098	876839	845955	3.58534	861397.00	4.15	16.6	8.33	138.0
GD-4-10094	394087	392965	0.285115	393526.00	1.79	7.18	10.7	76.5
TD-B-9622	106738	103581	3.00211	105159.50	0.344	1.38	1.50	0.00
TD-1-9380	1239730	1215790	1.949892	1227760.00	5.99	24.0	2.14	49.2
TD-2-9897	712725	712513	0.0297494	712619.00	3.40	13.6	1.50	18.3
10251-B	27637	26923	2.6173	27280.00	-0.0474	-0.190	1.50	0.00

* TCO mg/ml VALUES ARE MULTIPLIED BY 4.0 IN ORDER TO DETERMINE THE TOTAL mg IN THE ORIGINAL 10 ml SAMPLE VOLUME.

Table 4-2. TOTAL CHROMATOGRAPHABLE ORGANICS (TCO)

SAMPLE I.D. #	AREA COUNTS	AREA COUNTS	PERCENT DIFF.	MEAN AREA CTS.	TCO MG/ML	TCO MG/10ML	DILUTION FACTOR	TOTAL MG (MINUS BLANK)
BS-1-9473	1159930	1146520	1.162826	1153225.00	5.61	56.1	3.00	168.0
BS-2-9619	1288290	1285310	0.2315822	1286800.00	6.29	62.9	1.00	62.9
BS-3-9654	1066210	1056260	0.9375869	1061235.00	5.15	51.5	1.00	51.5
BS-4-9655	2278920	2274590	0.1901830	2276755.00	11.26	113.0	11.0	1240.0
BS-5-9980	1824090	1812090	0.6600333	1818090.00	8.96	89.6	1.00	89.6
BS-QC5-9870	1208010	1091780	10.10788	1149895.00	5.60	56.0	1.00	56.0
GS-B-10092	54836	51986	5.3360	53411.00	0.0839	0.839	1.00	0.00
GS-1-9871	1619120	1611780	0.4543626	1615450.00	7.94	79.4	11.0	872.0
GS-2-9978	1096410	1090610	0.5304021	1093510.00	5.31	53.1	7.00	371.0
GS-3-10090	1269700	1264480	0.4119676	1267090.00	6.19	61.9	11.0	680.0
GS-4-10099	700054	651817	1.18359	695935.50	3.31	33.1	4.00	132.0
GS-QC4-10096	610215	605054	0.849359	607634.50	2.87	28.7	3.50	99.6
HS-B-10344	35982	33563	6.9566	34772.50	-0.00977	-0.098	2.50	0.00
HS-1-10093	1017840	1012350	0.5408361	1015095.00	4.92	49.2	1.00	49.2
HS-2-9981	1459520	1409550	3.483359	1434535.00	7.03	70.3	6.00	422.0
HS-3-10250	968215	923908	4.683311	946061.50	4.57	45.7	4.00	183.0
HS-QC3-10248	965806	964448	0.140707	965127.00	4.67	46.7	1.00	46.7
HS-4-10346	837083	835220	0.222807	836151.50	4.02	40.2	4.00	161.0
HS-5-10348	617263	616897	0.0593116	617080.00	2.92	29.2	4.00	117.0
TS-B-9620	50905	49948	1.8978	50426.50	0.0689	0.689	1.00	0.00
TS-1-9378	1653150	1499350	9.757335	1576250.00	7.74	77.4	1.00	76.7
TS-2-9898	1180350	1155300	2.145013	1167825.00	5.69	56.9	1.00	56.2
TS-3-9901	981629	944681	3.83614	963155.00	4.66	46.6	4.00	186.0

continued

Table 4-2. TOTAL CHROMATOGRAPHABLE ORGANICS (TCO)

SAMPLE I.D. #	AREA COUNTS	AREA COUNTS	PERCENT DIFF.	MEAN AREA CTS.	TCO MG/ML	TCO MG/10ML	DILUTION FACTOR	TOTAL MG (MINUS BLANK)
FS-1-11003	1029080	1026140	0.28610	1027610	5.32	133.0 #	1.00	133.0
FS-2-10997	1107000	1117390	0.93419	1112195	5.78	144.0 #	1.00	144.0
FS-3-10999	738797	740158	0.18405	739478	3.77	94.3 #	1.00	94.3
FS-4-10995	725372	723700	0.23077	724536	3.69	92.3 #	1.00	92.3
FS-X-B-11002	41768	44274	5.82506	43021	0.03	0.3	1.00	0.3
FD-1-11001	713080	735121	3.04391	724101	3.69	36.9	1.00	36.9
FD-2-11005	526761	560554	6.21586	543658	2.72	27.2	1.00	27.2
FD-QC2-11000	513078	511878	0.23416	512478	2.55	25.5	1.00	25.5
FD-3-11004	452527	454417	0.41678	453472	2.23	22.3	1.00	22.3
FD-4-10998	521125	520283	0.16170	520704	2.60	26.0	1.00	26.0
FD-QC4-10996	454640	444136	2.33740	449388	2.21	22.1	1.00	22.1

concluded

indicates mg/25 ml

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE BD-1	BD-2	BD-3	BD-4	BD-5	BDQC-5
94	phenol	629.8	1018.0	176.3	1567.5	547.8	596.5
128	naphthalene	290.4	470.3	93.8	490.0	235.6	238.7
152	acenaphthylene	55.0	16.2	24.9	100.7	53.3	57.6
154	acenaphthene	6.0	5.7	Trace	Trace	4.5	4.5
166	fluorene	17.2	19.7	5.4	37.6	15.6	16.9
173	nitronaphthalene						
178	phenanthrene	52.0	82.7	16.4	105.0	58.6	63.7
178	anthracene		6.7	Trace	17.4	7.1	8.3
174	acridine						
167	carbazole						
202	fluoranthene		17.3	3.5	35.2	14.4	15.7
194	phenanthrol						
202	pyrene		13.1	Trace	31.9	8.5	13.8
228	benzo(a)anthracene						
228	chrysene					4.0	
252	benzo(b)fluoranthene						
252	benzo(k)fluoranthene						
252	benzo(a)pyrene						
263	3-methylcholanthrene						
276	benzo(g,h,i)perylene						
278	dibenzo(a,h)anthracene						
276	indeno(1,2,3cd)pyrene						

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE BS-1	BS-2	BS-3	BS-4	BS-5	OSOC-5
94	phenol	3656.6	2248.8	526.9	9934.2	3131.7	2617.9
128	naphthalene	1359.2	871.6	172.0	2084.3	1031.1	947.0
152	acenaphthylene	281.3	131.7	55.5	486.2	210.6	170.2
154	acenaphthene			7.6		19.1	17.1
166	fluorene	104.2	56.4	23.2	189.4	61.7	54.1
173	nitronaphthalene						
178	phenanthrene	277.0	165.1	50.6	363.6	212.7	174.1
178	anthracene	44.7	15.1	20.7	Trace	31.0	25.4
174	acridine						
167	carbazole						
202	fluoranthene	90.3	57.1	24.9	Trace	64.6	51.3
194	phenanthrol						
202	pyrene	80.9	41.0	23.7	Trace	52.9	45.9
228	benzo(a)anthracene			34.9			
228	chrysene			35.2		18.7	15.5
252	benzo(b)fluoranthene			41.5			
252	benzo(k)fluoranthene			43.9			
252	benzo(a)pyrene			50.9			
263	3-methylcholanthrene						
276	benzo(g,h,i)perylene			52.5			
278	dibenzo(a,h)anthracene			53.7			
276	indeno(1,2,3cd)pyrene			55.9			

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE GD-1	GD-2	GD-3	GDQC-3	GD-4	GD-8
94	phenol	2768.2	4512.5	3978	3659	3653	7.2
128	naphthalene	752.6	1359.9	1796	1794	7026	
152	acenaphthylene	139.8	235.0	360.5	346.9	1638	
154	acenaphthene	Trace	21.1	30.5	29.2	72.9	
166	fluorene	48.9	73.0	123.4	107.4	379.3	
173	nitronaphthalene						
178	phenanthrene	107.1	199.4	305.5	280.3	1299	
178	anthracene	16.5	28.8	43.3	45.3	189.2	
174	acridine						
167	carbazole						
202	fluoranthene	29.0	50.0	92.2	100.5	650	
194	phenanthrol						
202	pyrene	22.3	41.5	65.9	77.5	Trace	
228	benzo(a)anthracene			22.2		151.8	
228	chrysene			27.6	26.0	146.6	
252	benzo(b)fluoranthene					239.8	
252	benzo(k)fluoranthene						
252	benzo(a)pyrene					177.0	
263	3-methylcholanthrene						
276	benzo(g,h,i)perylene						
278	dibenzo(a,h)anthracene						
276	indeno(1,2,3cd)pyrene						

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE GS-1	GS-2	GS-3	GS-4	GSQC-4	GS-B
94	phenol	18618.2	15328.6	11466.6	11041.6	6765.0	26.2
128	naphthalene	4168.2	4391.0	4364.9	11016.9	9165.9	
152	acenaphthylene	862.9	713.4	905.5	3891.0	2910.8	
154	acenaphthene		Trace		208.9	152.9	
166	fluorene	291.6	244.5	289.2	931.0	679.4	
173	nitronaphthalene						
178	phenanthrene	626.6	669.3		2873.3	1760.1	
178	anthracene	Trace	101.8		496.3	328.9	
174	acridine						
167	carbazole						
202	fluoranthene	228.6	218.9	193.0	1254.6	839.5	
194	phenanthrol						
202	pyrene	224.5	174.6	157.9	1136.9	763.3	
228	benzo(a)anthracene				284.3		
228	chrysene	309.0	92.3		273.3	196.7	
252	benzo(b)fluoranthene				500.5	374.0	
252	benzo(k)fluoranthene						
252	benzo(a)pyrene					271.1	
263	3-methylcholanthrene						
276	benzo(g,h,i)perylene				213.0	145.9	
278	dibenzo(e,h)anthracene						
276	indeno(1,2,3cd)pyrene				251.7	171.3	

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE HD-1	HD-2	HD-3	HDQC-3	HD-4	HD-5	HD-B	TD-1	TD-2	TD-D
94	phenol	505.5	302.4	731.7	994.4	747.8	1415.6	13.1	604.3	158.2	
128	naphthalene	872.0	103.3	824.9	1008.7	676.1	2383.1		627.0	117.4	
152	acronaphthylene	292.5	28.3	204.9	306.3	170.6	649.1		92.8	23.5	
154	acenaphthene	10.2		9.3	13.6	Trace	22.0		22.4	6.8	
166	fluorene	77.6	Trace	47.0	72.8	44.3	145.7		36.9	8.5	
173	nitronaphthalene										
178	phenanthrene	258.1	41.1	135.8	194.0	128.5	494.4		117.2	29.4	
178	anthracene	37.7	Trace	24.2	30.1	17.8	75.7		Trace		
174	acridine										
167	carbazole										
202	fluoranthene	103.6	12.8	67.4	75.9	36.1	175.5		34.2	7.7	
194	phenanthrol										
202	pyrene	83.9	Trace	52.2	59.0	29.6	132.1		29.3	6.9	
228	benzo(a)anthracene	17.4		13.6	17.4	Trace	47.7		6.2		
228	chrysene	16.2		12.3	19.0	Trace	42.8		7.8		
252	benzo(b)fluoranthene	20.0		17.4		Trace	79.7				
252	benzo(k)fluoranthene										
252	benzo(a)pyrene	11.5				Trace	46.5				
263	3-methylcholanthrene										
276	benzo(g,h,i)perylene										
278	dibenzo(a,h)anthracene										
276	indeno(1,2,3cd)pyrene										

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE HS-1	HS-2	HS-3	HSQC-3	HS-4	HS-5	HS-B
94	phenol	1726.0	6763.5	9759.7	1674.1	9446.4	11194.2	26.4
128	naphthalene	2273.6	1659.0	6910.4	1638.6	6133.7	11378.1	
152	acenaphthylene	808.3	494.7	1777.2	457.6	1588.6	3457.3	
154	acenaphthene	31.1		101.2	25.3	89.1	150.9	
166	fluorene	191.6	169.2	464.0	110.1	365.4	815.5	
173	nitronaphthalene							
178	phenanthrene	505.3	462.6	1086.2	232.9	982.6	2414.1	
178	anthracene	96.6	91.7	208.9	45.3	176.0	446.1	
174	acridino							
167	carbazole							
202	fluoranthene	183.8	179.4	370.9	90.4	342.1	1016.6	
194	phenanthrol							
202	pyrene	153.6	161.5	275.9	66.8	265.1	862.5	
228	benzo(a)anthracene			87.8	19.9	110.2		
228	chrysene	44.2		96.5	21.3	116.5	219.5	
252	benzo(b)fluoranthene	64.8		137.3	33.0	244.3	378.3	
252	benzo(k)fluoranthene							
252	benzo(a)pyrene	40.4		81.6		135.8	244.8	
263	3-methylcholanthrene							
276	benzo(g,h,i)perylene					81.0	128.8	
278	dibenzo(a,h)anthracene							
276	indeno(1,2,3cd)pyrene						136.9	

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE TS-1	TS-2	TS-3	BLANK
94	phenol	1283.5	1368.1	1946.7	9.4
128	naphthalene	737.9	572.4	482.9	
152	acenaphthylene	164.6	112.7	84.5	
154	acenaphthene	38.7	37.6	Trace	
166	fluorene	56.4	45.0	Trace	
173	nitronaphthalene				
178	phenanthrene	117.8	106.4		
178	anthracene	14.7	17.6	77.2	
174	acridine				
167	carbazole		3.1		
202	fluoranthene	40.9	33.7	Trace	
194	phenanthrol				
202	pyrene	37.3	32.9		
228	benzo(a)anthracene				
228	chrysene	9.2	15.6		
252	benzo(b)fluoranthene		22.8		
252	benzo(k)fluoranthene		,		
252	benzo(a)pyrene				
263	3-methylcholanthrene				
276	benzo(g,h,i)perylene				
278	dibenzo(a,h)anthracene				
276	indeno(1,2,3cd)pyrene				

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE FD-1	FDQC-2	FD-2	FD-3	Duplicate FD-3	FD-4	FDQC-4	SOLVENT BLANK +
94	phenol	1181.6	608.4	683.9	794.5	788.2	486.5	604.4	NO TARGETS DETECTED
128	naphthalene	258.6	158.1	133.0	274.9	252.1	114.4	135.6	
152	acenaphthylene	40.7	24.8	27.4	50.0	46.2	19.2	21.8	
154	acenaphthene				Trace	Trace			
166	fluorene	15.6	Trace	15.1	17.4	16.6	Trace	Trace	
173	nitronaphthalene								
178	phenanthrene	52.0	26.5	61.7	40.5	39.6	26.1	21.4	
178	anthracene	Trace	Trace	11.2	Trace	Trace	Trace	Trace	
174	acridine	15.8							
167	carbazole								
202	fluoranthene	17.9	Trace	33.4	14.0	13.8	Trace	Trace	
194	phenanthro!								
202	pyrene	15.8	Trace	29.1	13.9	13.0	Trace	Trace	
228	benzo(a)anthracene	Trace		Trace	Trace	Trace			
228	chrysene	Trace	Trace	Trace	Trace	Trace	Trace	Trace	
252	benzo(b)fluoranthene								
252	benzo(k)fluoranthene								
252	benzo(a)pyrene								
263	3-methylcholanthrene								
276	benzo(g,h,i)perylene								
278	dibenzo(a,h)anthracene								
276	indeno(1,2,3cd)pyrene								

continued

Table 4-3. AMOUNT OF TARGET COMPOUNDS IN SAMPLE, MICROGRAMS

ION	COMPOUND	SAMPLE FS-1	FS-2	FS-3	FS-4	Duplicate FS-4	ANALYT. BLANK +	BLANK XAD*
94	phenol	4572.6	3087.4	3125.7	2500.4	2357.2	NO TARGETS DETECTED	
128	naphthalene	995.2	607.4	978.8	554.8	524.0		614.3
152	acenaphthylene	166.0	94.0	126.1	70.3	73.2		
154	acenaphthone	15.9	11.2	14.2				321.2
166	fluorene	72.3	51.6	58.3	38.9	36.4		
173	nitronaphthalene							
170	phenanthrene	215.6	108.1	127.5	75.0	76.4		402.8
178	anthracene	42.4	18.8	27.4	17.0	18.2		
174	acridine							
167	carbazole							
202	fluoranthene	71.8	35.9	38.1	27.1	27.9		
194	phenanthrol							
202	pyrene	24.2	32.8	33.4	26.0	23.5		
228	benzo(a)anthracene	15.7	10.8	10.1	Trace	Trace		
228	chrysene	16.2	9.9	9.4	Trace	Trace		406.1
252	benzo(b)fluoranthene							
252	benzo(k)fluoranthene							
252	benzo(a)pyrene							65.1
263	3-methylcholanthrene							
276	benzo(g,h,i)perylene							
278	dibenzo(a,h)anthracene							
276	indeno(1,2,3cd)pyrene							

concluded

* Significant quantities of targets detected in Blank 11002
+ Solvent and Analytical Blanks are Solvent Lot #AN319

5.0 QUALITY ASSURANCE AND QUALITY CONTROL

Supporting quality control and quality assurance data for the analytical determinations are reported in this section.

5.1 GRAVIMETRIC ANALYSIS

As requested in the QA/QC protocol the accuracy of the gravimetric (GRAV) analysis must be $\pm 20\%$ of the actual value. Proficiency tests were administered to the analyst using prepared standards containing known amounts of stearic acid, eicosane, and triphenylmethane in a total volume of 100 mL of methylene chloride. The results for the GRAV tests are as follows:

	<u>Actual</u>	<u>Experimental</u>	<u>Accuracy</u>	<u>% CV</u>
GRAV Test 1	1.21 mg/mL	1.20 mg/mL	-0.8%	2.4%
GRAV Test 2	1.21 mg/mL	1.16 mg/mL	-4.1%	
GRAV Test 3	1.04 mg/mL	1.05 mg/mL	1.0%	
GRAV Test 3	1.04 mg/mL	1.10 mg/mL	5.8%	

The results of the GRAV Audit were within the precision and accuracy specification outlined in the SOP. It should be noted that the same analyst performed all GRAV analyses.

A GRAV value for duplicate method blanks was determined for each new lot of solvent and/or set of samples. Also, a reagent blank was analyzed for GRAV every ten samples (listed in Table 4-1). These reagent (solvent) blanks consisted of the same volume of solvent used in analyzing the samples. Any unusually high reagent blanks were noted and the blanks reanalyzed. The reported GRAV values were determined by subtracting the values of the solvent blanks from the samples, including the method blanks.

5.2 TOTAL CHROMATOGRAPHABLE ORGANICS (TCO)

The gas chromatograph (GC) was calibrated using solutions prepared by diluting a stock solution of C_7 to C_{17} hydrocarbons. The stock solution contained approximately 37 mg (C_7 to C_{17})/mL. Linear regression analysis of the calibration curve resulted in a correlation coefficient of 0.9999. C_7 and C_{19} peaks were not included in the regression analysis. One calibration standard in the middle of the linear working range was used as the daily QC standard.

Duplicate injections of the QC standard were performed daily prior to sample analysis. If the QC standard duplicates differed by more than 15% the injections were repeated. If the mean QC standard response differed by more than 15% from the original value obtained, a new standard was prepared and then analyzed. If the new standard failed to meet the criteria, the instrument was recalibrated. A plot of the QC standard results is shown in Figure 5-1.

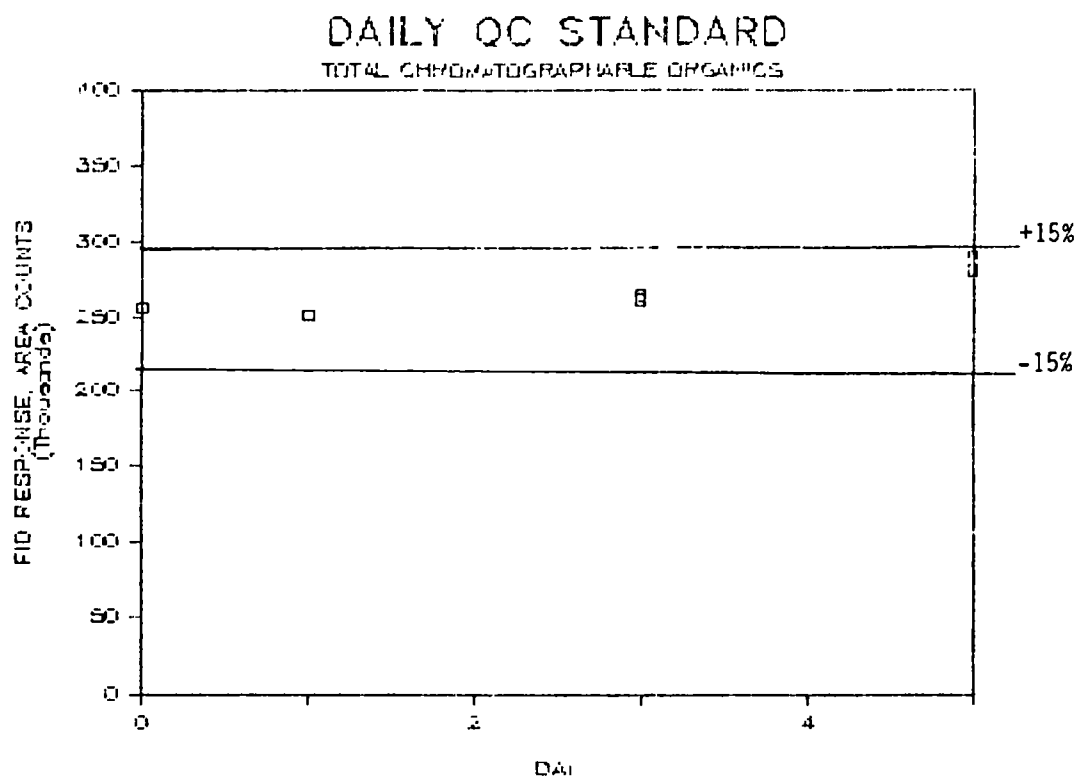
The GC injector septum was changed daily, along with a column bake-out at 300°C for twenty minutes. If the detector response was not stable after column bake-out, this procedure was repeated until stability was obtained.

Duplicate injections were performed for all samples analyzed. The TCO results from both injections could not differ by more than 15%. The TCO values were calculated by subtracting the appropriate field blanks from the total values.

5.3 GC/MS CALIBRATION AND TUNING DATA

The gas chromatograph/mass spectrometer system was tuned to meet DFTPP criteria every day prior to analysis. Daily analysis was initiated by a check of DFTPP to verify that the instrumental tune was acceptable prior to the analysis of samples. Tuning data are included as Appendix J.

The instrument was calibrated by analysis of five calibration samples at a concentration of 5, 10, 50, 100, and 200 ng/uL. These points were incorporated into a database and the mean, standard deviation, and per cent coefficient of variation calculated. The database is shown in Table 5-1. A linear regression was performed for each of the ions for each compound in the calibration standard, with the



Day	FID Response	Relative % Difference
0	256020.5	-----
1	251064.5	1.954702
3	261676.0	2.184871
3	264540.5	3.273392
5	290394.5	12.58164
5	280126.0	8.992132

Figure 5-1. TCO QC standard analysis.

Table 5-1 WOODSTOVES RESPONSE FACTOR DATABASE

<u>Compound</u>	<u>Ion</u>	<u>Mean</u>	<u>SD</u>	<u>% CV</u>	<u>+2SD</u>	<u>-2SD</u>
d ₁₀ -phenanthrene	188	1.000	0	0	---	---
phenol	94	1.203	0.081	6.7	1.041	1.365
naphthalene	128	1.786	0.238	13.3	1.310	2.262
acenaphthylene	152	1.548	0.198	12.8	1.152	1.944
acenaphthene	154	0.940	0.116	12.3	0.708	1.172
fluorene	166	1.010	0.122	12.1	0.766	1.254
nitronaphthalene	127	0.311	0.025	8.0	0.261	0.361
	173	0.210	0.022	10.4	0.166	0.254
phenanthrene	178	1.273	0.160	12.6	0.953	1.593
anthracene	178	1.537	0.182	11.8	1.173	1.901
acridine	179	1.227	0.075	6.1	1.077	1.377
carbazole	167	1.260	0.080	6.3	1.100	1.420
DFTPP	127	0.080	0.004	5.0	0.072	0.088
	198	0.161	0.009	5.4	0.143	0.179
fluoranthene	202	1.134	0.147	13.0	0.084	1.428
phenanthrol	194	0.177	0.033	18.4	0.111	0.243
pyrene	202	1.167	0.163	14.0	0.841	1.493
d ₁₂ -chrysene	240	1.000	0	0	---	---
benzo(a)anthracene	228	2.054	0.213	10.4	1.628	2.480
chrysene	228	1.816	0.192	10.6	1.432	2.200
benzo(b)fluoranthene	252	1.687	0.185	11.0	1.317	2.057
benzo(k)fluoranthene	252	1.591	0.185	11.6	1.221	1.961
benzo(a)pyrene	252	1.394	0.148	10.6	1.098	1.690
3-methylcholanthrene	268	0.694	0.092	13.3	0.51	0.878
benzo(g,h,i)perylene	276	1.502	0.167	11.1	1.168	1.836
dibenzo(a,h)anthracene	278	1.192	0.129	10.8	0.934	1.450
indeno(1,2,3,c,d)pyrene	276	1.209	0.151	12.5	0.907	1.511

exception of pyrenequinone, which could not be chromatographed under the analytical conditions used. Correlation coefficients are shown in Table 5-2. The linear plots are included as Appendix K. Calibration checks were performed daily prior to sample analysis. Values for the response factors obtained in the daily calibration checks are shown in Table 5-3, and compared to the database values. The precision of the analysis is illustrated by the eight daily analyses of the same standard (100 mg/uL), with only phenol exhibiting % CV above 20 and all of the rest of the compounds showing % CV less than 15 (Table 5-3).

A check sample containing naphthalene, phenanthrene, fluoranthene, pyrene, and chrysene was analyzed daily. The results of the first two analyses, with relative percent difference, are shown in Table 5-4. Results for the subsequent days are shown in Table 5-5. Duplicate analyses were performed for four samples. These samples were injection duplicates, not process duplicates, since an entire sample (e.g., the entire XAD-2 module) was extracted to prepare the sample. Results are shown in Table 5-6. The GC/MS values for all Blank Runs (field and solvent) were reported separately. All reported GC/MS sample values were reported independently of the blank values.

A peak is observed at approximately 1500 scans in the sample chromatograms. The mass spectrum, shown in Figure 5-2, is characteristic of an unsaturated aldehyde. This compound is not observed in the solvent blanks (Appendix I, Figures I1 and I2) but appears to be an artifact associated with the extraction of XAD-2. Field exposure of the XAD-2 is not essential, since the compound appears also in the chromatograms of the internal audit samples consisting of spiked XAD-2 which was not sent to the field.

5.4 SYSTEMS AND PERFORMANCE AUDIT

A systems and performance audit of the Woodstove Project was performed by Donna Holder as part of the internal Radian quality assurance program. Joann Rice, Nancy Cole and Melinda Dilda provided input for the systems audit. Denny Wagoner, Joan Bursey, Ed Messer and Joann Rice were responsible for coordinating the performance audit analysis.

Table 5-2. LINEAR REGRESSION, WOODSTOVE DATABASE

<u>Compound</u>	<u>Ion</u>	<u>Correlation Coefficient</u>
phenol ^a	94	0.964
naphthalene ^a	128	0.936
acenaphthylene ^a	152	0.930
acenaphthene ^a	154	0.922
fluorene ^a	166	0.923
nitronaphthalene ^a	127	0.928
	173	0.928
phenanthrene ^a	178	0.911
anthracene	178	0.903
acridine ^a	179	0.886
carbazole ^a	167	0.907
fluoranthene ^a	202	0.891
phenanthrol ^a	194	0.924
pyrene ^a	202	0.884
benzo(a)anthracene ^b	228	0.883
chrysene ^b	228	0.875
benzo(b)fluoranthene ^b	252	0.847
benzo(k)fluoranthene ^b	252	0.901
benzo(a)pyrene ^b	252	0.886
3-methylcholanthrene ^b	268	0.874
benzo(g,h,i)perylene ^b	276	0.856
bibenzo(a,h)anthracene ^b	278	0.862
indeno(1,2,3-c,d)pyrene ^b	276	0.853

^aRelative to d₁₀-phenanthrene.

^bRelative to d₁₂-chrysene.

Table 5-3. DAILY CALIBRATION CHECKS

Compound	Ion	Database	11/12	11/13	11/14	11/15	11/18	11/19	11/20	11/21	Mean	SD	%CV
phenol	94	1.203	1.092	1.258	1.247	1.214	1.139	1.000	0.673	0.607	1.029	0.255	24.8
naphthalene	128	1.786	1.529	1.677	1.657	1.663	1.681	1.544	1.142	1.118	1.501	0.237	15.8
acenaphthylene	152	1.548	1.395	1.422	1.445	1.411	1.445	1.335	1.158	1.041	1.332	0.151	11.3
acenaphthene	154	0.940	0.849	0.872	0.880	0.881	0.884	0.844	0.747	0.667	0.828	0.079	9.5
fluorene	166	1.010	0.927	0.911	0.943	0.932	0.907	0.889	0.823	0.772	0.888	0.060	6.7
nitronaphthalene	173	0.210	0.227	0.231	0.226	0.230	0.223	0.216	0.198	0.180	0.216	0.018	8.4
phenanthrene	178	1.273	1.178	1.196	1.208	1.221	1.207	1.207	1.189	1.166	1.197	0.018	1.5
anthracene	178	1.537	1.453	1.498	1.478	1.504	1.521	1.529	1.507	1.518	1.501	0.025	1.7
acridine	179	1.227	1.288	1.331	1.302	1.329	1.315	1.346	1.337	1.315	1.320	0.019	1.4
carbazole	167	1.260	1.306	1.374	1.289	1.304	1.346	1.277	1.181	1.171	1.281	0.071	5.6
fluoranthene	202	1.134	1.116	1.150	1.071	1.098	1.174	1.154	1.260	1.261	1.161	0.070	6.0
phenanthrol	194	0.177	0.216	0.262	0.215	0.211	0.205	0.194	0.201	0.210	0.214	0.021	9.6
pyrene	202	1.167	1.118	1.195	1.104	1.128	1.213	1.223	1.341	1.368	1.211	0.099	8.2
benzo(a)anthracene	228	2.054	1.888	1.917	1.883	1.862	1.947	1.844	1.744	1.722	1.851	0.079	4.3
chrysene	228	1.816	1.684	1.683	1.699	1.723	1.670	1.631	1.630	1.639	1.670	0.034	2.0
benzo(b)fluoranthene	252	1.687	1.576	1.557	1.659	1.741	1.645	1.386	1.635	1.830	1.628	0.132	8.1
benzo(k)fluoranthene	252	1.591	1.527	1.411	1.453	1.538	1.355	1.358	1.444	1.703	1.474	0.115	7.8
benzo(a)pyrene	252	1.394	1.381	1.271	1.357	1.411	1.252	1.160	1.307	1.492	1.329	0.104	7.8
3-methylcholanthrene	268	0.694	0.872	0.756	0.802	0.863	0.618	0.616	0.641	0.839	0.751	0.111	14.7
benzo(g,h,i)perylene	276	1.502	1.599	1.353	1.451	1.572	1.208	1.241	1.416	1.696	1.442	0.173	12.0
di benzo(a,h)anthracene	278	1.192	1.314	1.096	1.170	1.297	0.891	1.007	1.199	1.411	1.173	0.171	14.6
indeno(1,2,3-c,d)pyrene	276	1.209	1.283	1.175	1.186	1.330	1.049	1.006	1.217	1.424	1.209	0.139	11.5

Table 5-4. ANALYSES OF CHECK SAMPLE

<u>Compound</u>	<u>Mean Response Factor</u>	<u>F850540 Q.C. Sample Run #1</u>	<u>F850533 Q.C. Sample Run #2</u>	<u>*RPD</u>
naphthalene	1.786	1.803 (101)	1.752 (98)	2.9
phenanthrene	1.273	1.320 (104)	1.300 (102)	1.5
fluoranthene	1.134	1.065 (94)	1.027 (91)	3.6
pyrene	1.167	1.176 (101)	1.134 (97)	3.6
chrysene	1.816	1.514 (83)	1.426 (79)	6.7

() = % Recovery.

*RPD = Relative % difference between QC Sample Run #1 and Run #2.

$$RPD = \left[\frac{(QC_1 - QC_2)}{\frac{QC_1 + QC_2}{2}} \right] \times 100$$

Table 5-5. DAILY PERCENT RECOVERIES (CHECK SAMPLE)

Compound	11/13	11/14	11/15	11/18	11/19	11/20	11/21	Mean	SD	% CV
naphthalene	98	101	100	99	98	73	68	91	14.1	15.5
phenanthrene	102	104	103	103	105	102	102	103	1.2	1.1
fluoranthene	91	94	92	99	98	106	107	98	6.4	6.5
pyrene	97	101	99	107	107	122	122	108	10.4	9.6
chrysene	79	83	83	80	82	79	79	81	1.9	2.3

Table 5-6. WOODSTOVE DUPLICATES

<u>BS-2</u>	<u>Total ng F850530</u>	<u>Total ng F850606</u>	<u>RPD</u>
phenol	2249	1339	50.7
naphthalene	872	654	28.6
acenaphthylene	132	91	36.8
fluorene	36	19	61.8
phenanthrene	165	140	16.4
anthracene	15	---	---
fluoranthene	57	43	28.0
pyrene	41	32	24.7
<u>GS-2</u>	<u>F850541</u>	<u>F850607</u>	
phenol	15,329	6,692	75.1
naphthalene	4,391	2,610	50.9
acenaphthylene	713	390	58.5
acenaphthene	77	---	---
fluorene	244	95	87.9
phenanthrene	669	508	27.4
anthracene	102	---	---
fluoranthene	219	---	---
pyrene	175	---	---
chrysene	92	---	---

(continued)

TUNNEL DUPLICATES

<u>BD-4</u>	<u>F850581</u>	<u>F850570</u>	<u>RPD</u>
phenol	1568	1452	7.7
naphthalene	490	461	6.1
acenaphthylene	101	101	0
acenaphthene	10	10	0
fluorene	38	39	2.6
phenanthrene	105	108	2.8
anthracene	17	18	5.7
fluoranthene	35	38	8.2
pyrene	32	33	3.1
<u>HD-1</u>	<u>F850594</u>	<u>F850560</u>	
phenol	853	506	51.1
naphthalene	911	872	4.4
acenaphthylene	335	293	13.4
acenaphthene	13	10	26.1
fluorene	92	78	16.5
phenanthrene	282	258	8.9
anthracene	40	38	5.1
fluoranthene	99	104	4.9
pyrene	75	84	11.3
benzo(a)anthracene	21	17	21.1
chrysene	19	16	17.1
benzo(b)fluoranthene	25	20	22.2
benzo(a)pyrene	13	12	8.0

MASS SPECTRUM
11/14/85 10:49:00 + 25:02
SAMPLE: WOODSTOVE GS-2 1:10 DILUTION
CONDS.: -
ENHANCED (S 158 2N 0T)

DATA: F850541 #1502
CALI: FC43RP #7

BASE M/Z: 55
RIC: 145664.

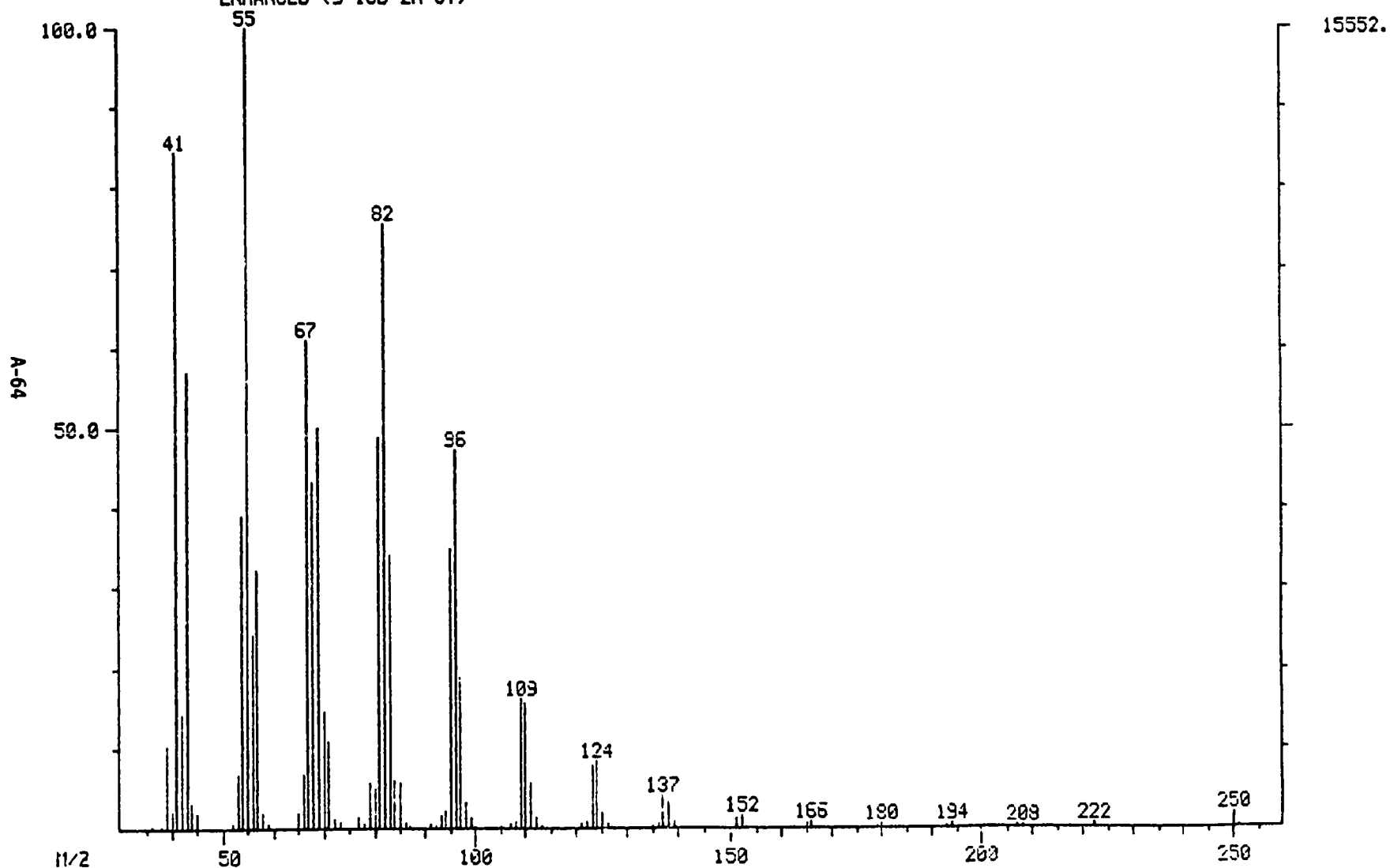


Figure 5-2. Artifact peak of GC/MS analysis.

The systems audit focused on observing the procedures and techniques used by the laboratory team, a check of documentation completeness and a review of team adherence to the QC protocol prescribed by the Quality Assurance Project Plan (QAPP). Several modifications to the analytical procedures were made (based on EPA approval). The memoranda documenting these changes are included in this section as Figures 5-3, 5-4 and 5-5. No other significant procedural problems were noted. Upon thorough examination of the original and revised Draft Woodstoves Report several modifications were made in the previously reported data. The documentation of these changes are addressed via Corrective Action Memoranda that are included in this section as Figures 5-6 and 5-7. The systems audit checklist is presented as Figure 5-8.

The performance audit for TCO and GC/MS consisted of six audit samples submitted blindly to the laboratory for analysis. The first set of three audit samples were submitted and analyzed simultaneously with the first set of woodstove burns. The second set of three audit samples were submitted at a later date and analyzed along with the last set of woodstove burns. The samples were prepared by spiking approximately 25 grams of XAD-2 packed in resin tubes with a known amount of POMs and PNAs. Two additional blind samples were prepared by Candace Blackley according to the QAPP for Gravimetric analysis. The overall results of the performance audit are presented in Tables 5-7 and 5-8. The average recovery for target compounds (PNAs and POMs) was 85 percent for the initial set of three audit samples. The final set of three audit samples showed an average recovery (target compounds) of 89 percent for both low and high spiked concentrations.

In summary, the performance audit showed that the accuracy targets were met well within the acceptance range. The systems audit confirmed the laboratory team to be competent and knowledgeable in their tasks, documentation to be completed and current, chain-of-custody procedures satisfactory and the prescribed QC protocol to be met to satisfy the program objectives.

MEMORANDUM

DATE: November 7, 1985

TO: Robert McCrillis (EPA-ERC), Raymond Merrill (EPA-ERC),
Richard Cruze (RTI)

FROM: Donna Holder *DH*

SUBJECT: Gravimetric Analysis (GRAV) Modifications for Analysis of Wood
Stove Emission Samples

Per a phone conversation between Ed Messer (Radian) and Ray Merrill (EPA) on November 1, 1985, the Gravimetric (GRAV) analysis for the Wood Stove Emission Samples will be modified as follows:

The Soxhlet methylene chloride and the contents of the separatory funnel (condensate, Me Cl₂ Rinse Condensate Impinger, Impinger H₂O, and Me Cl₂ Rinse Impinger) will be combined and adjusted to 10.0 mL total volume, instead of the original 250.0 mL total volume. The minimum requirement for total mass of sample was also been changed from 10.0 mg to 1.0 mg total weight. This procedure is depicted in the attached figure.

This modification was a result of analyzing three Radian Audit Samples and screening several woodstove extracts at the original 250 mL volume. The Audit Samples were submitted to the laboratory to evaluate the method performance. These were prepared and analyzed upfront prior to actual sample analyses. Preliminary GRAV and TCO (Total Chromatographable Organics) analyses were unable to detect the spiked concentrations within the linear working range of the standard curves, indicating the need for further concentration of the samples.

Figure 5-3. Gravimetric analysis (GRAV) modifications

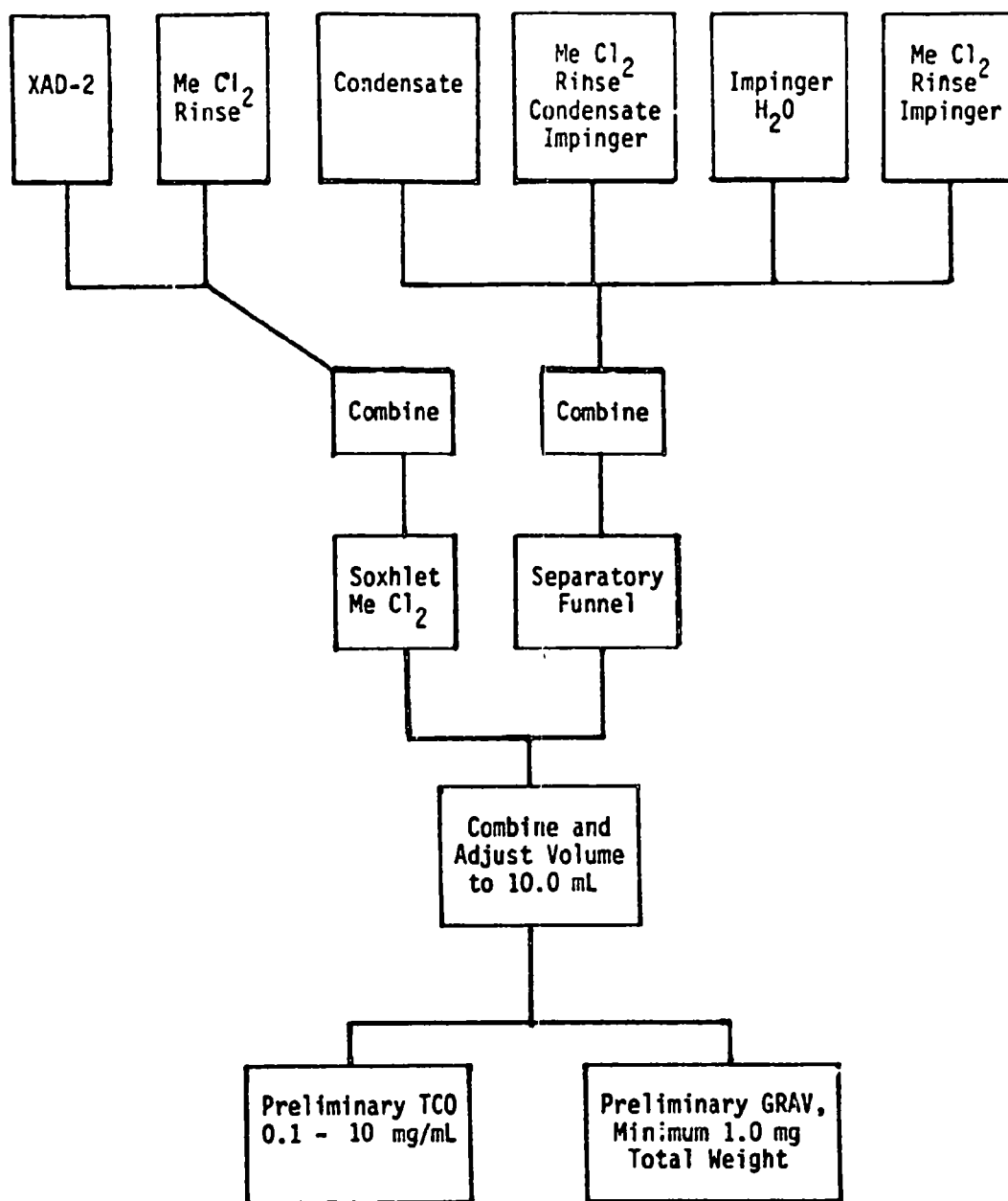


Figure 5-3. Continued

MEMORANDUM

DATE: November 19, 1985
TO: Ray Merrill (EPA), Robert McCrillis (EPA), and Richard Crum (RTI)
FROM: Donna J. Holder
SUBJECT: Modification to Woodstoves QAPP

The procedure for the calibration of the gas chromatograph/mass spectrometer should be amended to read as follows:

A five-point calibration, with a single value at each concentration level, will be used to calibrate the gas chromatograph/mass spectrometer system. Triplicate values for one of the calibration points (one analysis on each of three successive days) will be used to assess analytical precision: mean, standard deviation, and percent coefficient of variation will be calculated. A linear regression will be performed for each of the points of the original calibration curve and the value of the correlation coefficient will be reported.

If you have any questions please call J. Bursey or E. Messer at 481-0212.

Figure 5-4. Modification to woodstove QAPP.

TO: Dr. Ray Merrill (EPA), Dr. Robert McCrillis (EPA),
Richard Crume (RTI)

FROM: Donna Holder (Radian)

DATE: December 2, 1985

SUBJECT: Gas chromatograph Calibration for Total Chromatographable Organics
(TCO) Analysis (Modification to Calibration Curve).

As per the standard operating procedure for TCO analysis, a multi-point calibration curve was performed that covered the range from 0.37 mg/mL to 37.04 mg/mL total chromatographable organics. A five point calibration curve was used. A linear regression calculation was performed using the five GC responses obtained for the five concentrations on the curve. The results are given below:

Slope	156960.1
Intercept	153969.9
Corr. Coefficient	0.9949

The intercept generated from the regression calculation was relatively large (153969.9). The intercept is used to calculate TCO amounts by subtracting it from the GC response for a particular sample. TCO analysis of sample blanks resulted in small GC response values. Therefore, when the intercept was subtracted from blank values to determine TCO amounts, negative values were obtained.

The TCO linear regression line was plotted to determine if any of the points were significantly skewed. The highest concentration point were significantly skewed. The highest concentration point analyzed deviated noticeably from the regression line and was causing the intercept of this line to be large. Since few samples had TCO values in this range, the highest point was dropped and the linear regression was repeated. The values are given below:

Slope	187284.5
Intercept	20327.5
Corr. Coefficient	0.9999

All TCO values were calculated and reported using the slope and intercept of the four point calibration. The sample blank values obtained were approximately zero mg/mL.

Figure 5-5. Modification to TCO analysis.

MEMORANDUM

DATE: December 13, 1985
TO: Dr. Ray Merrill (EPA), Dr. Robert McCrillis (EPA), and Joe Evans (RTI)
FROM: Donna Holder *DH*
SUBJECT: Gravimetric (GRAV) Analysis Corrections

In reviewing the GRAV filter data, two changes were made that resulted in new values for several samples. The changes are as follows:

- 1) Due to a number of blank samples with unusually high values, the GRAV filters were reweighed. It was noticed that labels with the Radian number and sample ID were placed on the petri dish bottom. This resulted in the dish weights approximately 100 mg higher. All petri dishes with labels on the bottom were reweighed three times (without the filters)--first with the labels on them; second, after the labels were removed and the petri dish bottom was cleaned with acetone (NOTE: The filter number from Engineering Science was NOT removed.); and third, after two hours to reach constant weight (within 0.5 mg). The second and third weights were averaged and then subtracted from the first weight to get the label's weight. The label weight was then subtracted from the GRAV value to get the correct filter weight.
- 2) Upon examination of filter tare weights provided by Engineering Science, Radian found several tare weights that had been miscalculated. As a result, all filter tare weights were checked and any necessary corrections made.

If you have any questions, please call Melinda Dilda or Ed Messer at (919) 481-0212.

Figure 5-6. GRAV analysis corrections.

MEMORANDUM

To: Donna Holder (Radian QA/QL)
From: Joan Bursey (PPK GC/MS) *Joan I. Bursey*
Subject: GC/MS Unit Correction Involving Woodstoves Program
Date: January 10, 1986

For the first series of analyses of POM and phenol, an error was made in the calculations. The value as originally obtained from the GC/MS determination is expressed as ng/uL, which is equivalent to ug/mL. This value is then multiplied by the total number of mL in the sample to obtain a value of micrograms per total sample. In order to perform a calculation involving the number of mL of sample to obtain the total weight of material per sample, a conversion of units must take place. Otherwise, the multiplication should be by a factor of 10,000, for example, for a 10 mL sample. However, the multiplication was performed but the units written after the multiplication were consistently nanograms rather than micrograms. The result is that the digits as reported in the data tables are correct but the units are incorrect; the units should be reported as micrograms per total sample, not nanograms.

cc: Ed Messer
Denny Wagoner

Figure 5-7. GC/MS Unit Correction.

ANALYSIS OF WOOD STOVE EMISSION SAMPLES
TECHNICAL SYSTEMS AUDIT
CHECKLIST

Site: PPK Laboratory Date: December 2, 1985
Contract: 203-023-38-01 Auditor: D. J. Holder

YES	NO	COMMENTS	ITEM
<u>ORGANIZATION AND PERSONNEL</u>			
<u>X</u>	<u> </u>		1. Project Manager: <u>Susan Fernandes</u> Project Director: <u>Ed Messer</u>
<u>X</u>	<u> </u>		2. Task Leaders: Sample Preparation: <u>J. McGaughey</u> GC/TCO: <u>J. Rice</u> GC/MS: <u>J. Bursey</u> GRAV: <u>M. Dilda</u>
<u>SAMPLE HANDLING/STORAGE</u>			
<u>X</u>	<u> </u>		1. Are SOPS available for sample custody? - logging samples - storing samples - dispersement
<u>X</u>	<u> </u>		2. All samples logged in manually and through SAM?
<u>X</u>	<u> </u>		3. All samples labelled appropriately (log-in date, disposal date, client, etc.) before refrigeration?
<u>X</u>	<u> </u>	Bottles are marked with an "x" to indicate that they have been analyzed.	4. All completely analyzed samples stored separately in the refrigerator with holding time requirements?
<u>X</u>	<u> </u>	Stored in the freezer.	5. Are all TCO samples stored in refrigerator at or below 4°C?
<u>X</u>	<u> </u>	All GRAV samples are stored in a dessicator until weighed.	6. Are all dry GRAV samples stored in a dessicator?

Figure 5-6. Systems audit checklist.

YES	NO	COMMENTS	ITEM
<u> X </u>	<u> </u>		7. Are all GC/MS samples stored in a refrigerator or freezer?
<u> X </u>	<u> </u>		8. Are all diluted samples labelled with diluted sample container label containing the appropriate information (date, solvent, Radian ID number, dilution factor, new concentration, analyst's initials)?
<u> X </u>	<u> </u>		9. Are standards stored separately in the refrigerator?
<u> X </u>	<u> </u>		10. Is the refrigerator checked monthly for expired sample dates?
<u>CALIBRATION PROCEDURES</u>			
<u>ICQ</u>			
<u> X </u>	<u> </u>	C ₇ - C ₁₇	1. Quantitative calibration using stock solution of decane, dodecane, and tetradecane?
<u> X </u>	<u> </u>	≥ 0.99 usually the standard.	2. Calibration curve linear with correlation coefficient ≥ 0.97 for acceptance?
<u> X </u>	<u> </u>	Daily QC standard calibration records.	3. Calibration frequency documented?
<u> X </u>	<u> </u>		4. Calibrations recorded in a permanent record?
<u>GRAV</u>			
<u> X </u>	<u> </u>		1. Analytical balance calibrated to ±0.1 mg accuracy against a certified standard?
<u> X </u>	<u> </u>		2. Frequency of calibration well documented?
<u> X </u>	<u> </u>		3. Balance calibrations recorded in a permanent record?

Figure 5-8. Continued

YES	NO	COMMENTS	ITEM
<u>X</u>	_____		4. Is all apparatus that contacts a concentrated or evaporated residue sample glass, teflon, aluminum, or steel?
			<u>GC/MS</u>
<u>X</u>	_____		1. Is calibration curve verified daily by measuring one or more calibration standards ($\pm 15\%$ of true value as acceptable)?
<u>X</u>	_____		2. Frequency of calibration well documented?
<u>X</u>	_____		3. Are calibration data kept in a permanent record?
			<u>QUALITY CONTROL PROCEDURES</u>
			<u>TCO QC Checks</u>
<u>X</u>	_____		1. Is a daily bakeout done and a QC sample analyzed to test for contamination?
<u>X</u>	_____		2. If contamination is suspected, or duplicates of a sample show increasing concentration $\geq 15\%$, is a reagent blank analyzed?
<u>X</u>	_____		3. If contamination is found, is the column baked out at 270°C for 20 minutes and is a blank check repeated?
<u>X</u>	_____		4. Is a QC sample run daily (to check $\text{C}_7\text{-C}_{17}$ window)?
<u>X</u>	_____		5. Is a reagent sample run for each new reagent batch?
<u>X</u>	_____	Auto-sampler used. Place a flush vial between samples but not between duplicates.	6. Is the needle flushed with solvent (Dichloromethane) between injections?

Figure 5-3. Continued

YES	NO	COMMENTS	ITEM
<u> X </u>	<u> </u>		7. Is the GC inlet septum changed daily?
<u>GRAV QC Checks</u>			
<u> X </u>	<u> </u>		1. Is analyst proficiency demonstrated prior to testing (following SOP guidelines)?
<u> X </u>	<u> </u>	Opens from the top. Sealing around it.	2. Is the dessicating cabinet have a sealtight door with gum rubber (no silicon sealant)?
<u> X </u>	<u> </u>	Done in the hood.	3. Is the evaporation of samples carried out in an area clean of airborne dust and organic vapors?
<u> X </u>	<u> </u>	Entire sample is used much of the time.	4. Are all samples analyzed in duplicate by the same analyst?
<u> X </u>	<u> </u>		5. Is a method blank analyzed in duplicate for each new solvent lot or sample set?
<u> X </u>	<u> </u>		6. Are 2 reagent blanks analyzed each day samples are run?
<u> X </u>	<u> </u>		7. If a sample needs to be re-analyzed but insufficient sample remains, is the initial result reported with a qualifying statement?
<u>GC/MS QC Checks</u>			
<u> X </u>	<u> </u>		1. Does each sample set (≤10 samples) include a method blank and sample duplicate?
<u> X </u>	<u> </u>		2. Are the following QC samples analyzed: -surrogates -internal standards -duplicates -glassware blank -matrix spike -system performance standard (MS)

Figure 5.8. Continued

YES	NO	COMMENTS	ITEM
<u> x </u>	<u> </u>		3. Is the GC column and sample inlet system evaluated using the appropriate standards?
<u> x </u>	<u> </u>		4. Is the MS performance evaluated using the following: -standards -daily response factors (using standards) -Peak width evaluation (≤5 scans wide at a concentration of 50 ug/mL)
<u> x </u>	<u> </u>		5. Are at least 10% of all samples spiked and analyzed to monitor data quality?
<u> x </u>	<u> </u>		6. Are at least 10% of all samples analyzed QC checks?
<u> x </u>	<u> </u>		7. Are all QC data accessible for all GC/MS analytical results?
<u> x </u>	<u> </u>		8. Are QC results kept in a permanent record?
<u>GENERAL QC Checks</u>			
<u> x </u>	<u> </u>		1. Have standards been analyzed periodically to verify that each analytical method is in control?
<u> x </u>	<u> </u>		2. Do QC records indicate corrective action taken on data that has been rejected?
<u> x </u>	<u> </u>		3. Are questionable results considered acceptable by authorized persons (chemist, engineer, etc.)?
<u> x </u>	<u> </u>		4. Are all QC data accessible for all analytical results?

Figure 5.8. Continued

YES	NO	COMMENTS	ITEM
<u>PREVENTIVE MAINTENANCE</u>			
<u>GENERAL PROCEDURES</u>			
<u>X</u>	_____		1. Are system operating (manufacturer's) manuals available?
<u>X</u>	_____	Maintenance logbook for each instrument.	2. Are preventive maintenance activities (service calls) documented in standard forms?
<u>X</u>	_____	Maintained by the Task Leader.	3. Are permanent service records for all instruments available and maintained (logbooks)?
<u>X</u>	_____	Project Director and Task Leader.	4. Does the laboratory supervisor monitor supplies and maintain a purchase order file?
_____	<u>X</u>		5. Is a storeroom available for inventory of spare parts?
<u>X</u>	_____		6. Are the following general on-hand laboratory supplies maintained? -printer paper -printer/plotter supplies -magnetic tapes -ultrasonic bath -centrifuge -digital voltmeter -electrical connectors and supplies
<u>X</u>	_____		7. Are the following GC supplies inventoried: -fused silica capillary columns -glass packed columns -carrier gas -secondary gases -glassware

Figure 5.8. Continued

YES	NO	COMMENTS	ITEM
			-dilution glassware -drummond pipettes -syringes with replacement parts.
<u>X</u>	_____		8. Are the following MS maintenance procedures performed: -Evaluation of ion source performance (history profile, routine cleaning) -quadruple performance (mass peak shape, isotope abundance and ratios) -Electron Multiplier Performance (history profile, replacement) -Overall performance (repeller voltage, high mass peak shape, operating vacuum, ultimate sensitivity, background noise, signal-to-noise ratio, etc.)
<u>DOCUMENTATION PROCEDURES</u>			
<u>GENERAL</u>			
<u>X</u>	_____		1. Are all samples accompanied by sample tracking form and appropriate signatures?
_____	_____	N/A	2. Do sample worksheets contain all pertinent information, including methods of dilution or concentration?
<u>X</u>	_____		3. Do all instruments have documented troubleshooting procedures?
<u>X</u>	_____		4. Are instrument modifications well-documented?

Figure 5.8. Continued

YES	NO	COMMENTS	ITEM
<u>LABORATORY NOTEBOOKS</u>			
<u> X </u>	<u> </u>		1. Is permanent ink used for all entries and sample worksheets?
<u> X </u>	<u> </u>		2. Are changes in entries made by a single line drawn through the incorrect information, dated and initialized?
<u> X </u>	<u> </u>		3. Are reporting units for data specified where appropriate?
<u> X </u>	<u> </u>		4. Are repeat analyses recorded properly?
<u> X </u>	<u> </u>	Maintained in a general project file.	5. Do lab notebooks contain all pertinent information such as: -chromatograms -spectra information -instrument parameters -copies of sample log-in sheet -calculations -dilution factors -instrument problems -maintenance measures -hardware changes
<u> </u>	<u> X </u>		6. Is electronic data storage available?
<u> </u>	<u> </u>	N/A	7. Are all internal standards and surrogate spikes documented on sample worksheet forms?
<u> </u>	<u> </u>	N/A	8. Are all sample worksheets reviewed, signed, and dated by appropriate member of the GC/MS group?
<u> </u>	<u> X </u>		9. Are all notebooks for the project maintained in one central file?

Figure 5.8. Continued

YES	NO	COMMENTS	ITEM
_____	<u> X </u>	Information is recorded in appropriate logbook.	10. Are all problems encountered documented on standard forms?
_____	<u> X </u>		11. Is a corrective action file maintained?

Figure 5.8. Concluded

Table 5-7. QA/QC AUDIT GC/MS SAMPLES

TARGET COMPOUND	Audit 1 (9872)			Audit 2 (9873)			Audit 3 (9874)		
	True Conc. (ng/uL)	Measured Conc. (ng/uL)	Percent Recovery (%)	True Conc. (ng/uL)	Measured Conc. (ng/uL)	Percent Recovery (%)	True Conc. (ng/uL)	Measured Conc. (ng/uL)	Percent Recovery (%)
Phenol	0	Trace	-	200	132.0	66	1,000	725.9	73
Napthalene	0	Trace	-	200	142.1	71	1,000	721.0	72
Acenaphylene	0	0	-	200	161.3	81	1,000	811.9	81
Acenaphthene	0	0	-	200	163.6	82	1,000	821.9	82
Fluorene	0	0	-	200	171.0	86	1,000	824.5	82
Nitronaphthalene	0	0	-	-	-	-	-	-	-
Phenanthrene	0	0	-	200	187.8	94	1,000	861.9	86
Anthracene	0	0	-	200	120.7	60	1,000	714.6	71
Acridine	0	0	-	-	-	-	-	-	-
Carbazole	0	0	-	-	-	-	-	-	-
Fluoranthene	0	0	-	200	130.3	65	1,000	870.8	87
Phenanthrol	0	0	-	-	-	-	-	-	-
Pyrene	0	0	-	200	123.7	62	1,000	854.5	85
Benzo(a)anthracene	0	0	-	200	182.0	91	1,000	869.5	87
Chrysene	0	0	-	200	157.6	79	1,000	824.1	82
Benzo(b)fluoranthene	0	0	-	200	198.3	99	1,000	863.8	86
Benzo(k)fluoranthene	0	0	-	200	185.4	93	1,000	911.0	91
Benzo(a)pyrene	0	0	-	200	208.5	104	1,000	927.3	93
3-methylcholanthrene	0	0	-	-	-	-	-	-	-
Benzo(g,h,i)perylene	0	0	-	200	211.6	106	1,000	921.1	92
Dibenzo(a,h)anthracene	0	0	-	200	222.2	111	1,000	992.7	99
Indeno(1,2,3-cd)pyrene	0	0	-	200	227.3	114	1,000	946.9	95

continued

Table 5-7. QA/QC AUDIT GC/MS SAMPLES

TARGET COMPOUND	Audit 4 (11165)			Audit 5 (11166) *			Audit 6 (11167) +		
	True Conc. (ng/uL)	Measured Conc. (ng/uL)	Percent Recovery (%)	True Conc. (ng/uL)	Measured Conc. (ng/uL)	Percent Recovery (%)	True Conc. (ng/uL)	Measured Conc. (ng/uL)	Percent Recovery (%)
Phenol	0	0	-	201.3	127.2	63.2	2013	1378	68.4
Napthalene	0	0	-	300.0	336.0	112	1000	1054	105
Acenaphylene	0	0	-	300.0	266.3	88.8	1000	970.0	97.0
Acenaphthene	0	0	-	300.0	262.1	87.4	1000	787.8	78.8
Fluorene	0	0	-	300.0	287.7	95.9	1000	1065	107
Nitronaphthaleno	0	0	-	201.4	262.1	130	2014	1574	78.2
Phenanthrene	0	0	-	300.0	292.9	97.6	1000	1079	108
Anthracene	0	0	-	300.0	245.5	81.8	1000	861.2	86.1
Acridine	0	0	-	402.0	406.5	101	1500	1732	115
Carbazole	0	0	-	404.8	389.7	96.3	1518	1491	98.2
Fluoranthene	0	0	-	300.0	278.0	92.7	1000	1029	103
Phenanthrol	0	0	-	400.2	-	0.0	1501	47.6	3.2
Pyrene	0	0	-	300.0	301.1	100	1000	1062	106
Benzo(a)anthracene	0	0	-	300.0	290.0	96.7	1000	988.0	98.8
Chrysene	0	0	-	300.0	293.0	97.7	1000	1008	101
Benzo(b)fluoranthene	0	0	-	300.0	275.5	91.8	1000	1026	103
Benzo(k)fluoranthene	0	0	-	300.0	254.6	84.9	1000	945.3	94.5
Benzo(a)pyrene	0	0	-	300.0	234.2	78.1	1000	811.5	81.2
3-methylcholanthrene	0	0	-	200.8	85.2	42.4	2006	449.1	22.4
Benzo(g,h,i)perylene	0	0	-	300.0	287.0	95.7	1000	1095	110
Dibenzo(a,h)anthracene	0	0	-	300.0	310.2	103	1000	1131	113
Indeno(1,2,3-cd)pyrene	0	0	-	300.0	284.2	94.7	1000	1108	111

concluded

* All PAH's @ 300
+ All PAH's @ 1000

Table 5-8. QA/QC AUDIT TCO AND GRAY

SAMPLE I.D.#	AREA COUNTS	AREA COUNTS	PERCENT DIFF.	MEAN AREA CTS.	Mg/mL	SAMPLE VOL (mL)	TOTAL mg
10251-B	14000	12124	14.362	13062	+	1	+
Audit 1 (9872)	6222	5800	7.020	6011	0.03 *	1	0.03 *
Audit 2 (9873)	118196	115812	2.038	117004	0.62 *	1	0.62 *
Audit 3 (9874)	499979	454941	9.433	477460	2.54 *	1	2.54 *
Audit 4 (11165)	50314	55860	10.447	53087	0.08 *	5	0.04 *
Audit 5 (11166)	109225	105423	3.543	107324	0.37 *	5	1.85 *
Audit 6 (11167)	311201	322811	3.662	317006	1.50 *	5	7.50 *

+ Solvent Blank

* Total mg/mL calculated using daily response factor.

GRAY TEST	THEORETICAL mg/mL	EXPERIMENTAL mg/mL	ACCURACY %
1	1.21	1.20	-0.83
2	1.21	1.16	-4.13
3	1.04	1.05	0.96
4	1.04	1.10	5.77