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Radian Corp., Research Triangle Park, NC

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LITERATURE REVIEW AND SURVEY OF EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION AND THEIR IMPACT

by

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16. ABSTRACT The report gives results of a literature search of 53 reports covering woodstove design, operating conditions, emissions, testing methods, and ambient air impacts. The woodstoves studied, both controlled (catalytic) and uncontrolled, varied in design from simple to complex. The primary considerations in operating conditions were that the stoves burned primarily cord wood. Test results were segregated by the type of wood utilized, the percent moisture in the tested wood, the burn rate of the wood, the stage of burning that was tested, and the length of the test. In addition to the operating conditions, the emissions were qualified by the test method that was performed, the firebox temperature, and the stack temperature. Emission parameters studied included particulate matter (PM), carbon monoxide, nitrogen oxides, hydrocarbons (HC), and polycyclic organic material, especially benzo-a-pyrene. This report includes ambient air impact surveys at various locations in the U.S. Most ambient studies were concerned with the PM and HC impacts, but a few looked at relating these impacts back to their sources.

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Combustion	Stationary Sources	21B
Wood	Residential Wood Combustion	11L
Reviews		05B
Stoves	Woodstoves	13A

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ABSTRACT

This report resulted from a literature search of 53 reports covering woodstove design, operating conditions, emissions, testing methods, and ambient air impacts. The woodstoves studied varied in design from simple to complex and included controlled (catalytic) and uncontrolled woodstoves. The primary considerations in operating conditions were that the stoves studied burned primarily cord wood. The results of the tests were segregated according to the type of wood utilized, the percent moisture in the wood as tested, the burn rate of the wood in kg/hr, the stage of burning which was tested, and the length of the test. In addition to the operating conditions, the emissions were qualified by the test method which was performed, the firebox temperature, and the stack temperature. Emission parameters studied included particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC), and polycyclic organic material (POM), especially benzo-a-pyrene (BAP). This report includes ambient air impact surveys at various locations in the United States. Most ambient studies were concerned with the particulate matter and hydrocarbon impacts but a few looked at relating these impacts back to the sources.

TABLE OF CONTENTS

Preceding page blank

LIST OF FIGURES

(continued)

LIST OF FIGURES (Concluded)

LIST OF TABLES

1. INTRODUCTION

Radian Corporation has concluded a literature search of available data on woodstove emissions. In the computer search of various libraries of information, 239 citations were identified through the use of a key word listing which was primarily for residential wood combustion emissions and their impact. Approximately half of these were unique citations and of that number, 53 were chosen as applicable to this study. A computerized abstract of the 53 citations are contained in the appendix. The key word listing is located in the Appendix. The citations and literature studies came from all sectors of industry and government. To date, there has been no one agency or association, which has coordinated all of the work which has preceded this study. The result was that the information was mostly piecemeal as to its content, purpose and methods utilized.

The report discusses the various aspects of Residential Wood Combustion (RWC). Section 2.0 presents the summary and conclusions of this literature review. Section 3.0 summarizes the various emission ranges for the pollutants. Since the methods, stoves, wood burned, and conditions vary from citation to citation, this section is only concerned with overall trends. Section 4.0 is a review of some of the literature derived from ambient air studies of various air sheds and also discusses the tracer compounds or methods that have been utilized to link ambient samples to woodstove emissions. Sampling and analytical methods employed in the testing of stoves and ambient studies are discussed in Section 5.0. Section 6.0 is titled Alternative Design Approaches to Residential Wood Burning Appliances.

1.1 BACKGROUND

The use of wood for residential heating, while aesthetically pleasing and economically attractive, may carry a potential for adverse health effects to large segments of the population. The impact of RWC on ambient particulate emissions is especially noticeable because the plume impacts the ground very near the source. In addition, the areas of highest RWC emission density often coincide with the areas of maximum population density and the majority of the RWC particulate emissions are within the size range deposited within the lungs. RWC emissions are relatively rich in carcinogenic organics, toxic pollutants and respiratory irritants. For all of these reasons, wood smoke represents a problem that is of growing public concern.

The chemical products formed during wood combustion have recently been shown to contain 17 priority pollutants, 14 carcinogenic compounds and 6 toxic or mucus coagulating agents which, when considered in addition to toxic gaseous emissions and respiratory irritants, collectively represent a potential health risk.

RWC emissions are becoming increasingly important as a major contributor to violations of current particulate air quality standards and are implicated in issues related to visibility reduction, odors and public health. New attention being focused on the adoption of an Inhalable Particulate National Ambient Air Quality Standard has also caused concern about the RWC impact on 24-hour particulate standard attainment. The continuing economic pressures to expand the use of wood and coal for residential heating, and the limited regulatory pressures restricting the use of wood, may cause additional concern about the impact of RWC emissions on public health, aesthetics and the future "livability" of many communities.[1]

2. SUMMARY

This report resulted from a literature search of 53 reports covering woodstove design, operating conditions, emissions, testing methods, and ambient air impacts. The woodstoves studied varied in design from simple to complex and included both controlled (catalytic) and uncontrolled woodstoves. The stoves studied burned primarily cord wood. The results of the tests were segregated according to the type of wood utilized, the percent moisture in the wood as tested, the burn rate of the wood in kg/hr, the stage of burning which was tested, and the length of the test. In addition to the operating conditions, the emissions were qualified by the test method which was performed, the firebox temperature, and the stack temperature. Emission parameters studied included particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC), and polycyclic organic material (POM), especially benzo-a-pyrene (BAP). This report includes ambient air impact surveys at various locations in the United States. Most ambient studies were concerned with the particulate matter and hydrocarbon impacts but a few looked at relating these impacts back to the sources.

The test methodologies used for both the source testing of woodstoves and for the ambient impact varied from study to study. As a result, few conclusions or trends could be drawn from the combined studies. Conclusions and trends are seen within each study although the reader must exercise caution as to the test method and the test conditions utilized to achieve these conclusions. An overview of the testing methods and analytical techniques is presented in this report with no conclusions or recommendations made. The individual studies selected a test method which best suited their needs for the data. There is no standard method of sampling and analysis for woodstove emissions. ASTM

is working on a standard for sampling and analysis. Also, there is no standard set of conditions for the operation of the woodstoves, although guidelines are available.

Since the widespread use of woodstoves is a recent reoccurrence, the use of controls on them is still somewhat rare. The studies that evaluated control devices (i.e., catalytic, secondary combustion, or modified combustion) all reported variable decreases in emissions relative to standard stoves. No control devices appeared to dramatically reduce emissions under all conditions.

3. CHARACTERIZATION OF EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION

Numerous studies have been conducted which characterize emissions from residential wood combustion appliances. The goals and objectives of these investigations vary considerably and consequently the resulting emission characterizations also show considerable variation. For example, different emission test methods have been used to develop emission factors for a number of stove types using wide ranges of operating conditions and a diversity of fuel types. Test conditions have not been well defined and consequently, reproducible and comparable data have not been produced.

3.1 DATA BANK COMPILATION ANALYSIS

Emission measurements and test conditions reported in 13 studies were compiled into a data bank and used as the basis for the data analyses performed (see Table 3-1). The 13 studies selected were those that reported detailed information about test conditions, emission measurements, and stove operating parameters. From each of the chosen studies, measurements conducted during individual test runs were included in the data bank rather than overall summaries or averages (for the purpose of identifying overall emission trends.) A listing of each data source along with an assigned study code is presented in Table 3-2. The assigned study code provides a quick reference back to the original source of the data and identifies the test run.

The data retrieved from each of the studies may be categorized as either "Emission Measurement data" or "Test Condition data." All of the data is presented on a wet basis. Emission measurement data include particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC), and polycyclic organic matter (POM). Except for POM, all emission parameter values are expressed as grams of pollutant per kilogram of wood burned. In the case of POM, the emission value is

Table 3-1. WOODSTOVE DATA (AIRTIGHT STOVES)

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
M1-80-1	B	MM5	O	5	8.4		307	A	83	3.00	110	0.40		0.21
M1-80-1	B	MM5	O	28	6.6		300	A	83	2.50	120	0.70		
M1-80-3	B	MM5	P	28	7.2		247	A	83	7.00	220	0.80		
M1-80-4	B	MM5	P	5	7.8		378	A	83	3.90	270	0.50		
M1-80-5	NB	MM5	O	5	6.0		384	A	83	2.50	370	0.40		0.19
M1-80-6	NB	MM5	O	28	6.6		240	A	83	1.80	91	0.50		
M1-80-7	NB	MM5	P	5	7.2		304	A	83	2.00	150	0.20		
M1-80-8	NB	MM5	P	28	7.8		305	A	83	6.30	97	0.40		0.32
RTI-83-1	NB	MM5	O	11	4.5	515	286	C		0.50	29	0.69	4.9	
RTI-83-2	NB	MM5	O	11	4.0	537	248	C		0.80	44	0.82	6.5	
DG-82-1	NB	M7	DF	21	2.4	267	129	A	275	22.00	190		13.8	
DG-82-2	NB	M7	DF	12	2.7	283	158	A	250	54.00	189		16.9	
DG-82-3	NB	M7	DF	56	4.7	346	172	A	181	34.00	160		10.5	
DG-82-4	NB	M7	DF	12	9.2	357	284	B	35	40.00	210		11.9	
DG-82-5	NB	M7	DF	12	3.0	298	148	A	208	62.00	220		12.1	
DG-82-6	NB	M7	DF	19	7.2	314	205	B	46	42.00	170		9.2	
DG-82-7	NB	M7	DF	20	3.6	322	189	A	198	19.00	160		8.8	
DG-82-8	NB	M7	DF	56	4.5	243	146	B	155	24.00	190		11.1	
DG-82-9	NB	M7	DF	56	3.8	315	183	A	189	22.00	110		6.6	
DG-82-10	C-R	M7	DF	19	2.6	317	143	A	299	22.00	110		8.0	
DG-82-11	C-R	M7	DF	19	3.2	315	178	A	223	17.00	90		6.2	
DG-82-12	O	M7	DF	19	3.0	301	129	A	255	38.00	200		11.8	
DG-82-13	O	M7	DF	19	2.7	289	122	A	270	35.00	160		9.3	
DG-82-14	CAT	M7	DF	17	2.1	320	118	A	209	38.00	120		10.7	
DG-82-15	CAT	M7	DF	20	2.8	435	162	A	150	23.00	50		7.3	
DG-82-16	O	M7	DF	19	3.7	331	191	A	120	14.00	80		3.9	
DG-82-17	O	M7	DF	20	2.6	255	110	A	175	30.00	150		5.8	
DG-82-18	CER	M7	DF	16	7.7	826	415	A	61	1.00	20		0.4	
DG-82-19	CER	M7	DF	20	4.9	646	318	A	99	2.00	50		0.6	
CCRL-81-1	B		SM	16	1.2		44	B			165		39.0	
CCRL-81-2	B		SM	16	1.8		67	B			140		33.0	
CCRL-81-3	B		SM	16	3.7		150	B			108		25.0	
CCRL-81-4	NB		SM	16	2.4		122	B			184		43.0	
CCRL-81-5	NB		SM	16	2.5		124	B			129		30.0	
CCRL-81-6	B		SM	16	1.5		122	B			87		20.0	
CCRL-81-7	NB		SM	16	4.0		223	B			116		27.0	
CCRL-81-8	NB		SM	16	4.1		139	B			153		36.0	
CCRL-81-9	B		SM	16	4.5		117	B			169		40.0	
M2-81-1	NB	MM5	O	5	6.8		269	A		8.70	273			
M2-81-2	NB	MM5	O	5	7.4		249	A		8.10	270			
B1-81-1	B	MM5	O					A			420		112	
B1-81-2	B	MM5	O					A			63		12.0	
B1-81-3	B	MM5	O				360	A			100		15.0	
B1-81-4	B	MM5	O					A			190		28.0	0.03
B1-81-5	B	MM5	P					A			40		9.0	0.04
B1-81-6	B	MM5	O					A			67		56.0	
B1-81-7	B	MM5	O					A			67		56.0	

Table 3-1. Continued

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
B1-81-8	B	MM5	O					A			59		5.0	
B1-81-9	B	MM5	O					A			61		7.0	0.05
B1-81-10	NB	MM5	O					A						
B1-81-11	NB	MM5	O					A						
B1-81-12	NB	MM5	O					A						
B1-81-13	NB	MM5	O		6.5			A			220		34.0	
B1-81-14	NB	MM5	O		7.5			A			280		32.0	0.01
B1-81-15	NB	MM5	O		9.5			A			170		34.0	
B1-81-16	NB	MM5	O		12.3			A			400		42.0	
B1-81-17	NB	MM5	O		14.4			A			200		33.0	
B1-81-18	O	MM5	O		10.9			A			25		5.0	0.01
B1-81-19	O	MM5	O		9.9			A			30		2.0	
O-81-1	O	M7	DF	32	16.4		54	A		3.90				
O-81-2	O	M7	DF	33	10.5		90	A		3.40				
O-81-3	B	M7	DF	36	4.7		129	A		18.80				
O-81-4	B	M7	DF	36	5.8		127	A		10.00				
O-81-5	CAT	M7	DF	16	2.6		155	A		21.40				
O-81-6	CAT	M7	DF	18	1.8		125	A		29.30				
O-81-7	B	M7	DF	19	4.5		177	A		31.00				
O-81-8	B	M7	DF	17	4.5		157	A		20.00				
O-81-9	NB/O	M7	DF	14	3.8	379	254	A		23.90				
O-81-10	NB/O	M7	DF	14	1.6	243	124	A		50.60				
O-81-11	NB/O	M7	DF	15	4.2	159	257	A		9.60				
O-81-12	NB/O	M7	DF	14	1.5	229	104	A		74.30				
O-81-13	NB/O	M7	DF	14	3.6	404	232	A		23.30				
OM1-83-1	NB	M7	DF	16	3.3		123	A		14.20				
OM1-83-2	NB	M7	DF	16	3.4		128	A		15.50				
OM1-83-3	C-R	M7	DF	16	3.4		135	A		8.00				
OM1-83-4	C-R	M7	DF	16	3.4		134	A		6.00				
OM2-84-1	J	M7	DF	16	1.2		111	A	115	17.10	157		35.2	
OM2-84-2	J	M7	DF	19	1.0		90	A	130	24.40	153		20.2	
OM2-84-3	J	M7	DF	29	0.7		68	A	205	22.00	174		52.3	
OM2-84-4	J	M7	DF	19	2.5		243	A	55	1.40	21		61.3	
OM2-84-5	J	M7	DF	20	1.5		182	A	90	4.50	40		59.5	
OM2-84-6	J	M7	DF	18	1.4		132	A	100	12.60	130		84.8	
OM2-84-7	J	M7	DF	19	0.7		88	A	170	3.90	194		45.9	
OM2-84-8	O	DIL	DF	16	1.2		111	A	115	13.30	157		35.2	
OM2-84-9	O	DIL	DF	19	1.0		90	A	130	21.90	153		20.2	
OM2-84-10	O	DIL	DF	19	0.7		68	A	205	14.40	174		52.3	
OM2-84-11	O	DIL	DF	19	2.5		243	A	55	0.50	21		61.3	
OM2-84-12	O	DIL	DF	20	1.5		182	A	90	0.90	40		59.5	
OM2-84-13	O	DIL	DF	18	1.4		132	A	100	10.40	130		84.8	
OM2-84-14	NB	M7	DF	17	1.7		118	A	285	22.40	216		63.4	
OM2-84-15	NB	M7	DF	17	0.8		68	A	615	28.20	298		85.1	
OM2-84-16	NB	M7	DF	19	1.1		81	A	455	29.40	281		72.2	
OM2-84-17	NB	M7	DF	19	2.8		221	A	165	7.20	118		62.6	
OM2-84-18	NB	DIL	DF	17	1.7		118	A	285	37.00	216		63.4	
OM2-84-19	NB	DIL	DF	17	0.8		68	A	615	32.40	298		85.1	
OM2-84-20	NB	DIL	DF	19	1.1		81	A	455	44.40	281		72.2	
OM2-84-21	NB	DIL	DF	19	2.8		221	A	165	3.20	118		62.6	
OM2-84-22	CAT	M7	DF	19	0.8		73	A	610	5.00	134		55.3	
OM2-84-23	CAT	M7	DF	19	1.4		104	A	145	7.50	59		77.7	
OM2-84-24	CAT	M7	DF	17	1.6		111	A	295	6.10	101		73.0	
OM2-84-25	CAT	M7	DF	19	0.6		54	A	840	3.50	43		44.6	
OM2-84-26	CAT	DIL	DF	19	0.8		73	A	610	3.60	134		55.3	
OM2-84-27	CAT	DIL	DF	19	1.4		104	A	145	4.20	59		77.7	

Table 3-1. Continued

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (^oC)	Stove Temp. (^oC)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
OM2-84-28	CAT	DIL	DF	17	1.6		111	A	295	4.10	101		73.0	
OM2-84-29	CAT	DIL	DF	19	0.6		54	A	840	6.90	43		44.6	
OM2-84-30	CAT	M7	DF	18	1.2		74	A	325	1.50	25		53.8	
OM2-84-31	CAT	M7	DF	18	1.0		61	A	430	0.90	42		56.9	
OM2-84-32	CAT	M7	DF	18	0.8		58	A	485	1.10	12		54.9	
OM2-84-33	CAT	M7	DF	19	1.5		98	A	290	1.50	48		65.7	
OM2-84-34	NB	M7	DF	19	1.6		119	A	215	18.30	175		71.6	
OM2-84-35	NB	M7	DF	19	0.9		76	A	395	26.80	299		54.2	
OM2-84-36	NB	M7	DF	18	1.0		86	A	345	23.20	238		80.3	
OM2-84-37	NB	M7	DF	19	4.3		303	A	85	10.20	115		71.3	
OM2-84-38	NB	DIL	DF	19	1.6		119	A	215	20.60	175		71.6	
OM2-84-39	NB	DIL	DF	19	0.9		76	A	395	34.80	299		54.2	
OM2-84-40	NB	DIL	DF	18	1.0		86	A	345	30.70	238		80.3	
OM2-84-41	NB	DIL	DF	19	4.3		303	A	85	13.20	115		71.3	
OM2-84-42	NB	M7	DF	19	1.1		85	A	105	10.60	150		30.2	
OM2-84-43	NB	M7	DF	19	0.7		81	A	160	16.90	192		17.8	
OM2-84-44	NB	M7	DF	19	1.5		166	A	72	9.70	88		40.4	
OM2-84-45	NB	M7	DF	19	1.7		226	A	63	3.40	66		43.9	
OM2-84-46	NB	DIL	DF	19	1.1		85	A	105	14.20	150		30.2	
OM2-84-47	NB	DIL	DF	19	0.7		81	A	160	10.00	192		17.8	
OM2-84-48	NB	DIL	DF	19	1.5		166	A	72	6.90	88		40.4	
OM2-84-49	NB	DIL	DF	19	1.7		226	A	63	0.60	66		43.9	
BE-81-1	NB	DIL	O	18	3.0			A	61	3.90	106			
BE-81-2	NB	DIL	O	18	1.7			A	108	4.30	63			
BE-81-3	NB	DIL	O	18	2.0			A	123	6.40	106			
BE-81-4	NB	DIL	O	18	2.2			A	74	3.20	158			
BE-81-5	NB	DIL	O	16	2.9			A	60	2.60	67			
BE-81-6	NB	DIL	O	16	1.7			A	114	3.80				
BE-81-7	NB	DIL	O	16	2.2			A	24	1.60				
BE-81-8	NB	DIL	O	13	2.3			A	67	4.20				
BE-81-8	NB	DIL	H	16	3.4			A	45	2.40	98			
BE-81-8	NB	DIL	H	16	3.1			A	56	2.10				
TVA-83-1	NB	MM5	O	10	2.2			A		80.80	102	0.13	1.9	
TVA-83-2	NB	MM5	O	10	2.2			A		97.30	98	0.10	1.6	
TVA-83-3	NB	MM5	O	10	5.8			A		13.60	125	0.18	0.8	
TVA-83-4	NB	MM5	O	10	5.8			A		3.80	43	0.00	0.2	
TVA-83-5	NB	MM5	O	10	8.5			A		1.30	44	0.77	0.1	
TVA-83-6	NB	MM5	O	10	8.5			A		1.00	8	0.57	0.1	
TVA-83-7	CAT	MM5	O	10	1.3			A		16.80	28	0.03		
TVA-83-8	CAT	MM5	O	10	1.3			A		5.10	26	0.85		
TVA-83-9	CAT	MM5	O	10	2.0			A		6.40	50	0.88	0.2	
TVA-83-10	CAT	MM5	O	10	2.0			A		2.20	6	2.00	0.1	
TVA-83-11	CAT	MM5	O	10	2.9			A		2.60	23	0.81	0.1	
TVA-83-12	CAT	MM5	O	10	2.9			A		1.40	6	0.76		
TVA-83-13	C-R	MM5	O	10				A		16.80	95	1.01		0.19
TVA-83-14	CAT	MM5	O	10				A		6.90	139	0.82	0.2	0.16
TVA-83-15	O	MM5	O	10				A		1.80	80	1.14	0.1	0.08
B2-81-1A	B	MM5	O	12			370	A			190		28.0	0.04
B2-81-2A	B	MM5	P	42			310	A			40		9.0	0.05
B2-81-3A	NB	MM5	O	12			510	A			280		32.0	0.02
B2-81-4A	B	MM5	O	12			380	A			59		5.0	0.05
B2-81-5A	O	MM5	O	21			170	A			25		5.0	0.01
BS-81-1	NB	DIL	O/SM	23	2.0	158	137	D	300	8.50				
BS-81-2	NB	DIL	O/SM	23	1.7	154	149	D	300	7.80				
BS-81-3	NB	DIL	O/SM	23	2.0	160	132	D	300	9.80				
BS-81-4	NB	DIL	O/SM	23	1.7	148	133	D	300	11.00				

Table 3-1. Continued

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
BS-81-14	NB	DIL	O/SM	23	1.3	96	104	D	300	10.10				
BS-81-15	NB	DIL	O/SM	23	1.9	97	112	D	300	14.00				
BS-81-16	NB	DIL	O/SM	23	1.4	123	102	D	300	11.10				
BS-81-17	NB	DIL	O/SM	23	3.2	211	209	D	300	3.20				
BS-81-18	NB	DIL	O/SM	23	2.3	163	145	D	300	10.30				
BS-81-19	NB	DIL	O/SM	23	1.8	154	135	D	300	10.70				
BS-81-20	NB	DIL	O/SM	23	1.6	156	137	D	300	6.10				
BS-81-21	NB	DIL	O/SM	19	1.5	145	118	D	300	14.50				
BS-81-22	NB	DIL	O/SM	3	2.3	163	143	D	300	15.00				
BS-81-23	NB	DIL	O/SM	23	1.9	154	147	D	300	25.20				
BS-81-24	NB	DIL	O/SM	23	1.4	144	136	D	300	5.80				
BS-81-25	NB	DIL	O/SM	23	1.8	154	198	D	300	9.90				
BS-81-26	NB	DIL	O/SM	23	1.8	152	148	D	300	5.30				
BS-81-27	NB	DIL	O/SM	23	1.0	99	86	D	300	12.30				
BS-81-28	NB	DIL	O/SM	23	2.8	203	198	D	300	2.10				
BS-81-29	NB	DIL	O/SM	23	1.6	156	138	D	300	12.20				
BS-81-30	NB	DIL	O/SM	23	1.9	165	142	D	300	7.60				
BS-81-37	NB	DIL	O/SM	23	1.7	172	136	D	300	9.20				
BS-81-32	NB	DIL	O/SM	23	1.1	92	117	D	300	11.80				
BS-81-33	NB	DIL	O/SM	23	2.3	146	193	D	300	10.60				
BS-81-34	NB	DIL	O/SM	23	3.4	194	267	D	300	2.20				
BS-81-35	NB	DIL	O/SM	23	1.5	97	126	D	300	10.10				
BS-81-36	NB	DIL	O/SM	23	2.1	143	214	D	300	7.30				
BS-81-37	NB	DIL	O/SM	23	2.8	174	238	D	300	3.10				
BS-81-38	NB	DIL	O/SM	23	2.3	133	188	D	300	5.10				
BS-81-39	NB	DIL	O/SM	23	2.3	153	223	D	300	5.80				
BS-81-40	NB	DIL	O/SM	23	3.2	203	297	D	300	1.90				
BS-81-41	NB	DIL	O/SM	23	1.8	119	144	D	300	10.10				
BS-81-42	NB	DIL	O/SM	23	2.6	158	233	D	300	3.70				
BS-81-43	NB	DIL	O/SM	23	3.2	202	258	D	300	2.40				
BS-81-44	NB	DIL	O/SM	23	1.6	96	134	D	300	7.70				
BS-81-45	NB	DIL	O/SM	23	2.7	150	205	D	300	3.70				
BS-81-46	NB	DIL	O/SM	23	2.3	208	242	D	300	2.50				
BS-81-47	NB	DIL	O/SM	23	2.4	147	162	D	300	4.00				
BS-81-48	NB	DIL	O/SM	23	2.0	94	148	D	300	8.50				
BS-81-49	NB	DIL	O/SM	23	2.9	196	256	D	300	2.10				
BS-81-50	NB	DIL	O/SM	23	2.4	153	176	D	300	3.40				
BS-81-51	NB	DIL	O/SM	23	1.7	150	179	D	300	3.20				
BS-81-52	NB	DIL	O/SM	23	1.3	161	192	D	300	8.00				
BS-81-53	NB	DIL	O/SM	23	2.8	139		D	300	4.00				
BS-81-54	B	DIL	O/SM	23	2.3	147	138	D	300	4.30				
BS-81-55	B	DIL	O/SM	23	1.9	148	200	D	300	4.70				
BS-81-56	B	DIL	O/SM	23	2.4	153	155	D	300	3.90				
BS-81-57	NB	DIL	O/SM	23	1.5	158	163	D	300	3.20				
BS-81-58	NB	DIL	O/SM	23	1.4	96	116	D	300	3.60				
BS-81-59	CER	DIL	O/SM	23	1.7	143	160	D	300	2.40				
BS-81-60	NB	DIL	O/SM	23	3.2	196	210	D	300	1.10				
BS-81-61	NB	DIL	O/SM	23	2.9	144	224	D	300	3.60				

Table 3-1. Concluded

Stove Type

B - Baffled

CAT - Catalytic

C-R - Catalytic Retrofit

CER - Ceramic

NB - Nonbaffled

O - Other (includes modified combustion stoves and/or stoves that could not be classified into one of the other categories due to insufficient description)

J - Jotul 201

Test Method

MM5 - Modified Method 5

M7 - Oregon Method 7

DIL - Dilution Method

Wood Type

O - Oak

P - Pine

DF - Douglas Fir

SM - Sugar Maple

Burn Stage

A - Testing took place over an entire burn cycle with the fire being started from hot coals

B - Testing took place over an entire burn cycle beginning with a cold start

C - Testing only took place during the constant burn (steady-state) stage of the burn cycle

D - Testing took place over several burn cycles (additional fuel charges) with the fire being started from hot coals

Table 3-2. LISTING OF WOODSTOVE/EMISSION STUDIES USED AS THE BASIS FOR TREND ANALYSIS

Study Code	Reference
MI-80	"Preliminary Characterization of Emissions from Wood-Fired Residential Combustion Equipment," March 1980, Monsanto Corporation, DeAngelis, Ruffin, and Reznik.[11]
RTI-83	"Characterization of Emissions from the Combustion of Wood and Alternative Fuels in a Residential Woodstove," March 1983, Research Triangle Institute, Truesdale, Mack, White, Leese, and Cleland.[30]
DG-82	"Residential Wood Combustion Study; Task 5, Emissions Testing of Wood Stoves - Volumes 1&2," November 1982, Del Green Associates, Grotheer.[25]
CCRL-81	"Performance of Domestic Wood-Fired Appliances," 1981 Canadian Combustion Research Laboratory, Hayden and Braaten.[23]
M2-81	"Wood Combustion Emissions at Elevated Altitudes," 1981, Monsanto Corporation, Peters, Hughes, and DeAngelis.[17]
B1-81	"Control of Emissions from Residential Wood Burning by Combustion Modification," 1981, Battelle and Allen.[13]
O-81	"Particulate Emissions from New Low Emission Woodstove Designs Measured by EPA Method V," 1981, Oregon Department of Environmental Quality, Kowalczyk, Bosserman, and Tombleson.[21]
OM1-83	"Test Report prepared for Catalytic Damper Corporation," May 1983, Omni.[31]
OM2-84	"Test Report Woodstove Emissions and Efficiency," February 1984, Omni.[1]
BE-81	"Particulate Emission Factors for Small Wood and Coal Stoves," 1981, Butcher and Ellenbecker.[32]
TVA-83	"Efficiency and Emission Performance of Residential Wood Heaters With Advanced Designs," 1983, TVA, Knight and Knight.[20]
B2-81	"Characterization of Emissions from Residential Wood Combustion Sources," 1981, Battelle, Cooke, Allen, and Hall.[19]
BS-81	"Effects of Woodstove Design and Operation on Condensible Particulate Emissions," 1981, Barnett and Shea.[24]

expressed as milligrams of pollutant per kilogram of wood burned. Test condition information collected from each of the studies includes: the type of stove tested, method used for measuring particulate, moisture content of the fuel (expressed as wet basis), type of fuel, burn rate, firebox and stack temperatures, stage of the burn cycle during sample collection, and the length of the sampling period. Abbreviations or qualifiers were used to describe parameters such as stove type, test method, wood type, and burn stage and are defined at the end of Table 3-1.

In several studies, test conditions were not reported in detail. In such cases, the data incorporated into the data bank were somewhat subjective based solely on inferences or indirect evidence presented in the original study. For example, if a study did not document the burn rate, but did provide the initial charge loading and the total sampling time, burn rate was calculated based on the assumption that all of the fuel was burned during the reported sampling period. Other cases in which approximate values were included in the data set include instances when the value of a parameter was reported as a range (e.g., fuel moisture = 20-25 percent). In such cases, the average of the reported range was used. If sufficient information was not provided in the text to allow these values to be determined or approximated, the entry was left blank. When approximations were used, every attempt was made to represent the conditions of the study as accurately as possible.

3.1.1 Data Analysis

As mentioned before, the number of variables and the uncertainty of the validity of each variable has made this study one of general trends. These trends can be best pointed out by comparing a dependent and independent variable graphically. Burn rate was selected as the independent variable. When this is done and certain outlying points are discarded, some trends become noticeable. The largest problem encountered with this type of analysis was the uncertainty which results from analyzing a data set consisting of measurements collected by different test methods and using different stove types and operating parameters. An example of this can be seen when evaluating the effect of burn rate on particulate emissions. Individual studies demonstrate that particulate emissions decrease with increasing burn rate. However, when particulate measurements from all studies are reviewed and analyzed against burn rate, the trend is much weaker. The reason for this is that each testing group defined particulate with a different set of parameters. Some investigators defined particulate as front filter catch at 250°F, whereas others included various combinations of filter catch and condensed organics.

In addition to the problems of definition are the problems of plotting the graphs by overall studies. One study included 61 test runs, while others had as few as two test runs. This problem is accentuated if the author did not report measurements for the parameters of interest. The NO_x results are a good example of this. Only 25 individual tests from two studies measured NO_x. The results were similar. However, it is difficult to indicate a trend for 16 studies and 217 tests with this limited data. The same is true for POM measurements.

As noted previously, burn rate was selected as the independent variable. The data in the data bank were arranged so that the tests were ranked in order of increasing burn rate (see Table 3-3).

3.1.2 CO Analysis

The results of the CO analysis for the tests provided unexpected results. Except for the catalytic type, it appears to make no difference which stove is used. When presented on an emission factor (g/kg wood burned) basis, the CO emissions remain fairly constant as the burn rate increases (see Figure 3-1). However, when these results are plotted on an emission rate basis vs. burn rate, the CO emissions appear to increase as the amount of wood burned per hour is increased (see Figure 3-2). This latter result would tend to indicate that fireplaces yield a much higher CO emission rate than do woodstoves which generally are run at lower burn rates. The highest CO emissions rate noted in the literature was 5,000 grams/hour.[13] The observed CO trends run counter to some studies' results[23] which showed a decrease as the burn rate was increased. The methods by which the results were obtained were unclear in some cases; and the level of quality control exercised was in most cases, not addressed. Thus, the trends noted here must be interpreted with caution.

Table 3-3. WOODSTOVE DATA (BURN RATE RANKING)

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
B1-81-1	B	MM5	O					A			420		112	
B1-81-2	B	MM5	O					A			63		12.0	
B1-81-3	B	MM5	O				360	A			100		15.0	
B1-81-4	B	MM5	O					A			190		28.0	0.03
B1-81-5	B	MM5	P					A			40		9.0	0.04
B1-81-6	B	MM5	O					A			67		56.0	
B1-81-7	B	MM5	O					A			67		56.0	
B1-81-8	B	MM5	O					A			59		5.0	
B1-81-9	B	MM5	O					A			61		7.0	0.05
B2-81-1A	B	MM5	O	12			370	A			190		28.0	0.04
B2-81-2A	B	MM5	P	42			310	A			40		9.0	0.05
B2-81-4A	B	MM5	O	12			380	A			59		5.0	0.05
TVA-83-13	CAT-RET	MM5	O	10				A		16.80	95	1.01		0.19
TVA-83-14	CAT/B	MM5	O	10				A		6.90	139	0.82	0.2	0.16
B1-81-10	NB	MM5	O					A						
B1-81-11	NB	MM5	O					A						
B1-81-12	NB	MM5	O					A						
B2-81-3A	NB	MM5	O	12			510	A			280		32.0	0.02
B2-81-5A	O	MM5	O	21			170	A			25		5.0	0.01
TVA-83-15	O	MM5	O	10				A		1.80	80	1.14	0.1	0.08
OM2-84-25	CAT	M7	DF	19	0.6		54	A	840	3.50	43		44.6	
OM2-84-29	CAT	DIL	DF	19	0.6		54	A	840	6.90	43		44.6	
OM2-84-3	J	M7	DF	29	0.7		68	A	205	22.00	174		52.3	
OM2-84-7	J	M7	DF	19	0.7		88	A	170	3.90	194		45.9	
OM2-84-43	NB	M7	DF	19	0.7		81	A	160	16.90	192		17.8	
OM2-84-47	NB	DIL	DF	19	0.7		81	A	160	10.00	192		17.8	
OM2-84-10	O	DIL	DF	19	0.7		68	A	205	14.40	174		52.3	
OM2-84-22	CAT	M7	DF	19	0.8		73	A	610	5.00	134		55.3	
OM2-84-26	CAT	DIL	DF	19	0.8		73	A	610	3.60	134		55.3	
OM2-84-32	CAT	M7	DF	18	0.8		58	A	485	1.10	12		54.9	
OM2-84-15	NB	M7	DF	17	0.8		68	A	615	28.20	298		85.1	
OM2-84-19	NB	DIL	DF	17	0.8		68	A	615	32.40	298		85.1	
OM2-84-35	NB	M7	DF	19	0.9		76	A	395	26.80	299		54.2	
OM2-84-39	NB	DIL	DF	19	0.9		76	A	395	34.80	299		54.2	
OM2-84-31	CAT	M7	DF	18	1.0		61	A	430	0.90	42		56.9	
OM2-84-2	J	M7	DF	19	1.0		90	A	130	24.40	153		20.2	
BS-81-27	NB	DIL	O/SM	23	1.0	99	86	D	300	12.30				
OM2-84-36	NB	M7	DF	18	1.0		86	A	345	23.20	238		80.3	
OM2-84-40	NB	DIL	DF	18	1.0		86	A	345	30.70	238		80.3	
OM2-84-9	O	DIL	DF	19	1.0		90	A	130	21.90	153		20.2	
BS-81-32	NB	DIL	O/SM	23	1.1	92	117	D	300	11.80				
OM2-84-16	NB	M7	DF	19	1.1		81	A	455	29.40	281		72.2	
OM2-84-20	NB	DIL	DF	19	1.1		81	A	455	44.40	281		72.2	
OM2-84-42	NB	M7	DF	19	1.1		85	A	105	10.60	150		30.2	
OM2-84-46	NB	DIL	DF	19	1.1		85	A	105	14.20	150		30.2	
CCRL-81-1	B		SM	16	1.2		44	B			165		39.0	

Table 3-3. Continued

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
OM2-84-30	CAT	M7	DF	18	1.2		74	A	325	1.50	25		53.8	
OM2-84-1	J	M7	DF	16	1.2		111	A	115	17.10	157		35.2	
OM2-84-8	O	DIL	DF	16	1.2		111	A	115	13.30	157		35.2	
TVA-83-7	CAT	MM5	O	10	1.3			A		16.80	28	0.03		
TVA-83-8	CAT	MM5	O	10	1.3			A		5.10	26	0.85		
BS-81-14	NB	DIL	O/SM	23	1.3	96	104	D	300	10.10				
BS-81-52	NB	DIL	O/SM	23	1.3	161	192	D	300	8.00				
OM2-84-23	CAT	M7	DF	19	1.4		104	A	145	7.50	59		77.7	
OM2-84-27	CAT	DIL	DF	19	1.4		104	A	145	4.20	59		77.7	
OM2-84-6	J	M7	DF	18	1.4		132	A	100	12.60	130		84.8	
BS-81-16	NB	DIL	O/SM	23	1.4	123	102	D	300	11.10				
BS-81-24	NB	DIL	O/SM	23	1.4	144	136	D	300	5.80				
BS-81-58	NB	DIL	O/SM	23	1.4	96	116	D	300	3.60				
OM2-84-13	O	DIL	DF	18	1.4		132	A	100	10.40	130		84.8	
CCRL-81-6	B		SM	16	1.5		122	B			87		20.0	
OM2-84-33	CAT	M7	DF	19	1.5		98	A	290	1.50	48		65.7	
OM2-84-5	J	M7	DF	20	1.5		182	A	90	4.50	40		59.5	
BS-81-21	NB	DIL	O/SM	19	1.5	145	118	D	300	14.50				
BS-81-35	NB	DIL	O/SM	23	1.5	97	126	D	300	10.10				
BS-81-57	NB	DIL	O/SM	23	1.5	158	163	D	300	3.20				
BS-81-6	NB	DIL	O/SM	23	1.5	153	142	D	300	9.90				
OM2-84-44	NB	M7	DF	19	1.5		166	A	72	9.70	88		40.4	
OM2-84-48	NB	DIL	DF	19	1.5		166	A	72	6.90	88		40.4	
O-81-12	NB/O	M7	DF	14	1.5	229	104	A		74.30				
OM2-84-12	O	DIL	DF	20	1.5		182	A	90	0.90	40		59.5	
OM2-84-24	CAT	M7	DF	17	1.6		111	A	295	6.10	101		73.0	
OM2-84-28	CAT	DIL	DF	17	1.6		111	A	295	4.10	101		73.0	
BS-81-12	NB	DIL	O/SM	23	1.6	150	161	D	300	8.70				
BS-81-20	NB	DIL	O/SM	23	1.6	156	137	D	300	6.10				
BS-81-29	NB	DIL	O/SM	23	1.6	156	138	D	300	12.20				
BS-81-44	NB	DIL	O/SM	23	1.6	96	134	D	300	7.70				
BS-81-7	NB	DIL	O/SM	23	1.6	149	137	D	300	9.10				
OM2-84-34	NB	M7	DF	19	1.6		119	A	215	18.30	175		71.6	
OM2-84-38	NB	DIL	DF	19	1.6		119	A	215	20.60	175		71.6	
O-81-10	NB/O	M7	DF	14	1.6	243	124	A		50.60				
BS-81-59	CER	DIL	O/SM	23	1.7	143	160	D	300	2.40				
BE-81-2	NB	DIL	O	18	1.7			A	108	4.30	63			
BE-81-6	NB	DIL	O	16	1.7			A	114	3.80				
BS-81-11	NB	DIL	O/SM	23	1.7	150	183	D	300	12.90				
BS-81-2	NB	DIL	O/SM	23	1.7	154	149	D	300	7.80				
BS-81-37	NB	DIL	O/SM	23	1.7	172	136	D	300	9.20				
BS-81-4	NB	DIL	O/SM	23	1.7	148	133	D	300	11.00				
BS-81-51	NB	DIL	O/SM	23	1.7	150	179	D	300	3.20				
OM2-84-14	NB	M7	DF	17	1.7		118	A	285	22.40	216		63.4	
OM2-84-18	NB	DIL	DF	17	1.7		118	A	285	37.00	216		63.4	
OM2-84-45	NB	M7	DF	19	1.7		226	A	63	3.40	66		43.9	
OM2-84-49	NB	DIL	DF	19	1.7		226	A	63	0.60	66		43.9	
CCRL-81-2	B		SM	16	1.8		67	B			140		33.0	
O-81-6	CAT	M7	DF	18	1.8		125	A		29.30				

Table 3-3. Continued

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
BS-81-10	NB	DIL	O/SM	23	1.8		161	D	300	7.60				
BS-81-19	NB	DIL	O/SM	23	1.8	154	135	D	300	10.70				
BS-81-25	NB	DIL	O/SM	23	1.8	154	198	D	300	9.90				
BS-81-26	NB	DIL	O/SM	23	1.8	152	148	D	300	5.30				
BS-81-41	NB	DIL	O/SM	23	1.8	119	144	D	300	10.10				
BS-81-5	NB	DIL	O/SM	23	1.8	157	153	D	300	10.70				
BS-81-8	NB	DIL	O/SM	23	1.8	150	140	D	300	10.50				
BS-81-9	NB	DIL	O/SM	23	1.8	150	156	D	300	7.90				
BS-81-55	B	DIL	O/SM	23	1.9	148	200	D	300	4.70				
BS-81-15	NB	DIL	O/SM	23	1.9	97	112	D	300	14.00				
BS-81-23	NB	DIL	O/SM	23	1.9	154	147	D	300	25.20				
BS-81-30	NB	DIL	O/SM	23	1.9	165	142	D	300	7.60				
TVA-83-10	CAT	MM5	O	10	2.0			A		2.20	6	2.00		0.1
TVA-83-9	CAT	MM5	O	10	2.0			A		6.40	50	0.88		0.2
BE-81-3	NB	DIL	O	18	2.0			A	123	6.40	106			
BS-81-1	NB	DIL	O/SM	23	2.0	158	137	D	300	8.50				
BS-81-3	NB	DIL	O/SM	23	2.0	160	132	D	300	9.80				
BS-81-48	NB	DIL	O/SM	23	2.0	94	148	D	300	8.50				
DG-82-14	CAT	M7	DF	17	2.1	320	118	A	209	38.00	120			10.7
BS-81-36	NB	DIL	O/SM	23	2.1	143	214	D	300	7.30				
BE-81-4	NB	DIL	O	18	2.2			A	74	3.20	158			
BE-81-7	NB	DIL	O	16	2.2			A	24	1.60				
TVA-83-1	NB	MM5	O	10	2.2			A		80.80	102	0.13		1.9
TVA-83-2	NB	MM5	O	10	2.2			A		97.30	98	0.10		1.6
BS-81-54	B	DIL	O/SM	23	2.3	147	138	D	300	4.30				
BE-81-8	NB	DIL	O	13	2.3			A	67	4.20				
BS-81-18	NB	DIL	O/SM	23	2.3	163	145	D	300	10.30				
BS-81-22	NB	DIL	O/SM	3	2.3	163	143	D	300	15.00				
BS-81-33	NB	DIL	O/SM	23	2.3	146	193	D	300	10.60				
BS-81-38	NB	DIL	O/SM	23	2.3	133	188	D	300	5.10				
BS-81-39	NB	DIL	O/SM	23	2.3	153	223	D	300	5.80				
BS-81-46	NB	DIL	O/SM	23	2.3	208	242	D	300	2.50				
BS-81-56	B	DIL	O/SM	23	2.4	153	155	D	300	3.90				
BS-81-13	NB	DIL	O/SM	23	2.4	207	233	D	300	2.90				
BS-81-47	NB	DIL	O/SM	23	2.4	147	162	D	300	4.00				
BS-81-50	NB	DIL	O/SM	23	2.4	153	176	D	300	3.40				
CCRL-81-4	NB		SM	16	2.4		122	B			184			43.0
DG-82-1	NB	M7	DF	21	2.4	267	129	A	275	22.00	190			13.8
OM2-84-4	J	M7	DF	19	2.5		243	A	55	1.40	21			61.3
CCRL-81-5	NB		SM	16	2.5		124	B			129			30.0
OM2-84-11	O	DIL	DF	19	2.5		243	A	55	0.50	21			61.3
O-81-5	CAT	M7	DF	16	2.6		155	A		21.40				
DG-82-10	CAT-RET	M7	DF	19	2.6	317	143	A	299	22.00	110			8.0
BS-81-42	NB	DIL	O/SM	23	2.6	158	233	D	300	3.70				

Table 3-3. Continued

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
DG-82-17	O	M7	DF	20	2.6	255	110	A	175	30.00	150		5.8	
BS-81-45	NB	DIL	O/SM	23	2.7	150	205	D	300	3.70				
DG-82-2	NB	M7	DF	12	2.7	283	158	A	250	54.00	189		16.9	
DG-82-13	O	M7	DF	19	2.7	289	122	A	270	35.00	160		9.3	
DG-82-15	CAT	M7	DF	20	2.8	435	162	A	150	23.00	50		7.3	
BS-81-28	NB	DIL	O/SM	23	2.8	203	198	D	300	2.10				
BS-81-37	NB	DIL	O/SM	23	2.8	174	238	D	300	3.10				
BS-81-53	NB	DIL	O/SM	23	2.8	139		D	300	4.00				
OM2-84-17	NB	M7	DF	19	2.8		221	A	165	7.20	118		62.6	
OM2-84-21	NB	DIL	DF	19	2.8		221	A	165	3.20	118		62.6	
TVA-83-11	CAT	MM5	O	10	2.9			A		2.60	23	0.81	0.1	
TVA-83-12	CAT	MM5	O	10	2.9			A		1.40	6	0.76		
BE-81-5	NB	DIL	O	16	2.9			A	60	2.60	67			
BS-81-49	NB	DIL	O/SM	23	2.9	196	256	D	300	2.10				
BS-81-61	NB	DIL	O/SM	23	2.9	144	224	D	300	3.60				
BE-81-1	NB	DIL	O	18	3.0			A	61	3.90	106			
DG-82-5	NB	M7	DF	12	3.0	298	148	A	208	62.00	220		12.1	
DG-82-12	O	M7	DF	19	3.0	301	129	A	255	38.00	200		11.8	
BE-81-8	NB	DIL	H	16	3.1			A	56	2.10				
DG-82-11	CAT-RET	M7	DF	19	3.2	315	178	A	223	17.00	90		6.2	
BS-81-17	NB	DIL	O/SM	23	3.2	211	209	D	300	3.20				
BS-81-40	NB	DIL	O/SM	23	3.2	203	297	D	300	1.90				
BS-81-43	NB	DIL	O/SM	23	3.2	202	258	D	300	2.40				
BS-81-60	NB	DIL	O/SM	23	3.2	196	210	D	300	1.10				
OM1-83-1	NB	M7	DF	16	3.3		123	A		14.20				
OM1-83-3	CAT-RET	M7	DF	16	3.4		135	A		8.00				
OM1-83-4	CAT-RET	M7	DF	16	3.4		134	A		6.00				
BE-81-8	NB	DIL	H	16	3.4			A	45	2.40	98			
BS-81-34	NB	DIL	O/SM	23	3.4	194	267	D	300	2.20				
OM1-83-2	NB	M7	DF	16	3.4		128	A		15.50				
DG-82-7	NB	M7	DF	20	3.6	322	189	A	198	19.00	160		8.8	
O-81-13	NB/O	M7	DF	14	3.6	404	232	A		23.30				
CCRL-81-3	B		SM	16	3.7		150	B			108		25.0	
DG-82-16	O	M7	DF	19	3.7	331	191	A	120	14.00	80		3.9	
DG-82-9	NB	M7	DF	56	3.8	315	183	A	189	22.00	110		6.6	
O-81-9	NB/O	M7	DF	14	3.8	379	254	A		23.90				
CCRL-81-7	NB		SM	16	4.0		223	B			116		27.0	
RTI-83-2	NB	MM5	O	11	4.0	537	248	C		0.80	44	0.82	6.5	
CCRL-81-8	NB		SM	16	4.1		139	B			153		36.0	
O-81-11	NB/O	M7	DF	15	4.2	159	257	A		9.60				
OM2-84-41	NB	DIL	DF	19	4.3		303	A	85	13.20	115		71.3	
OM2-84-37	NB	M7	DF	19	4.3		303	A	85	10.20	115		71.3	
CCRL-81-9	B		SM	16	4.5		117	B			169		40.0	
O-81-7	B	M7	DF	19	4.5		177	A		31.00				
O-81-8	B	M7	DF	17	4.5		157	A		20.00				
DG-82-8	NB	M7	DF	56	4.5	243	146	B	155	24.00	190		11.1	
RTI-83-1	NB	MM5	O	11	4.5	515	286	C		0.50	29	0.69	4.9	
O-81-3	B	M7	DF	36	4.7		129	A		18.80				
DG-82-3	NB	M7	DF	56	4.7	346	172	A	181	34.00	160		10.5	
DG-82-19	CER	M7	DF	20	4.9	646	318	A	99	2.00	50		0.6	
O-81-4	B	M7	DF	36	5.8		127	A		10.00				

Table 3-3. Concluded

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (°C)	Stove Temp. (°C)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
TVA-83-3	NB	MM5	O	10	5.8			A		13.60	125	0.18	0.8	
TVA-83-4	NB	MM5	O	10	5.8			A		3.80	43		0.2	
M1-80-5	NB	MM5	O	5	6.0		384	A	83	2.50	370	0.40		0.19
B1-81-13	NB	MM5	O		6.5			A			220		34.0	
M1-80-1	B	MM5	O	28	6.6		300	A	83	2.50	120	0.70		
M1-80-6	NB	MM5	O	28	6.6		240	A	83	1.80	91	0.50		
M2-81-1	NB	MM5	O	5	6.8		269	A		8.70	273			
M1-80-3	B	MM5	P	28	7.2		247	A	83	7.00	220	0.80		
DG-82-6	NB	M7	DF	19	7.2	314	205	B	46	42.00	170		9.2	
M1-80-7	NB	MM5	P	5	7.2		304	A	83	2.00	150	0.20		
M2-81-2	NB	MM5	O	5	7.4		249	A		8.10	270			
B1-81-14	NB	MM5	O		7.5			A			280		32.0	0.01
DG-82-18	CER	M7	DF	16	7.7	826	415	A	61	1.00	20		0.4	
M1-80-4	B	MM5	P	5	7.8		378	A	83	3.90	270	0.50		
M1-80-8	NB	MM5	P	28	7.8		305	A	83	6.30	97	0.40		0.32
M1-80-1	B	MM5	O	5	8.4		307	A	83	3.00	110	0.40		0.21
TVA-83-5	NB	MM5	O	10	8.5			A		1.30	44	0.77	0.1	
TVA-83-6	NB	MM5	O	10	8.5			A		1.00	8	0.57	0.1	
DG-82-4	NB	M7	DF	12	9.2	357	284	B	35	40.00	210		11.9	
B1-81-15	NB	MM5	O		9.5			A			170		34.0	
B1-81-19	O	MM5	O		9.9			A			30		2.0	
O-81-2	O	M7	DF	33	10.5		90	A		3.40				
B1-81-18	O	MM5	O		10.9			A			25		5.0	0.01
B1-81-16	NB	MM5	O		12.3			A			400		42.0	
B1-81-17	NB	MM5	O		14.4			A			200		33.0	
O-81-1	O	M7	DF	32	16.4		54	A		3.90				

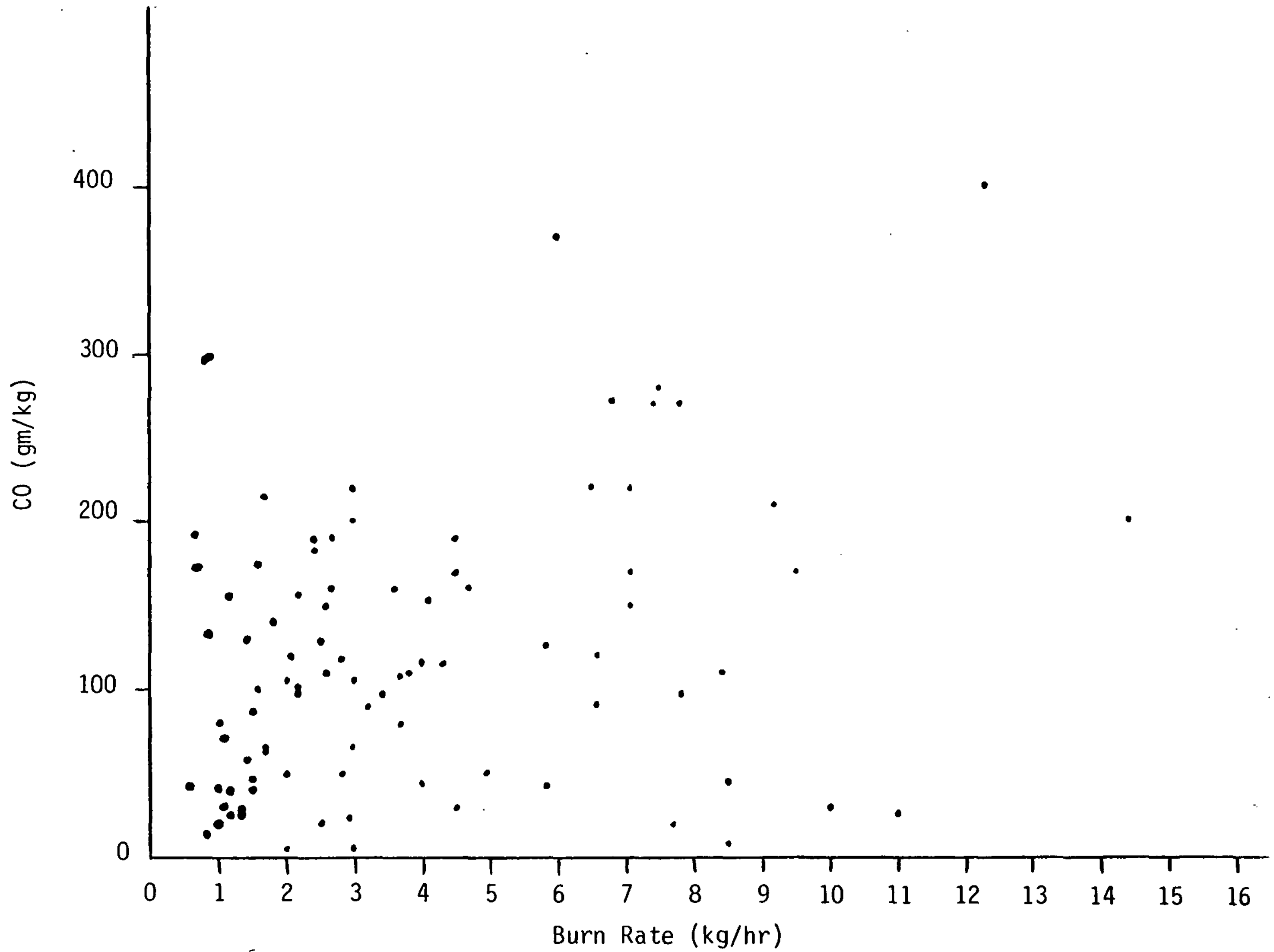


Figure 3-1. CO vs. burn rate.

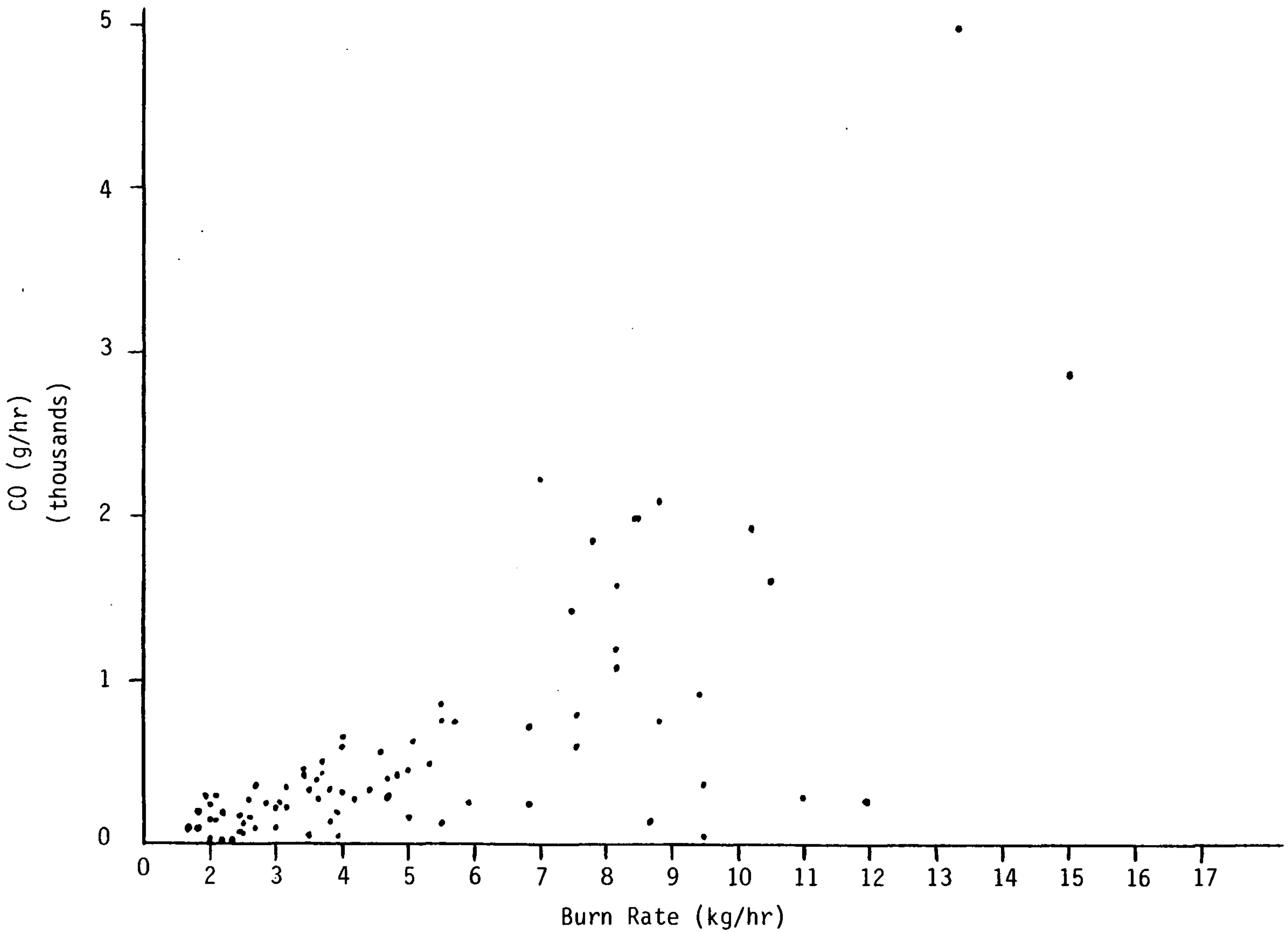


Figure 3-2. CO (g/hr) vs. burn rate (kg/hr).

A possible explanation for the CO results could be the size of the wood being burned. Since wood is loaded into fireplaces and woodstoves by the log, it is intuitive that, regardless of burn rate, CO would be produced in the inner portion of the log, while combustion occurred at the outer portion. This should hold somewhat true for HC emissions also. Almost all tests studied showed a fairly high CO value (1 to 4 percent), indicative of poor air mixing during the combustion process. Stoves equipped with oxidation catalysts did reduce the CO emissions approximately 40 percent on the average. Ceramic stoves were tested and ranked by burn rate and had the lowest CO emissions.

3.1.3 Catalytic Analysis

The results obtained on catalytic stoves were extracted from the data bank ranked by burn rate (Table 3-4). The only general conclusions which can be drawn are that the CO and particulate emissions averaged the same or lower than the noncatalytic average, while HC emissions average about the same. The high HC average comes primarily from one series of OMNI runs,[1] which may have been a result of differences in measurement methods. The OMNI results were measured on a NDIR instrument whereas TVA used a GC/FID which measures only the low molecular weight (C_1-C_7) hydrocarbons. Another possibility is that, in the OMNI tests, temperature of the gases was too low to achieve catalytic action. It is unclear from the test reports if this condition was achieved since the majority of investigators failed to report the operating temperature of the catalyst. Light-off temperature is about 400°F (205°C). In general, the removal efficiency of CO, HC, and particulate increases with an increase in temperature of the gases entering the catalyst.

3.1.4 Particulate and HC Results

The emissions from a woodstove contain flyash, condensed organics either adsorbed on the flyash or as liquid droplets, semi-volatile (boiling point >100°C) organics, and volatile (boiling point <100°C) organics. The method of testing and the care taken during the test can have a strong effect on whether a species is reported as a particulate or hydrocarbon. In viewing the data it was noted that very few tests had both high particulate and high hydrocarbon values. In most cases those tests which had high particulate values had low HC results and

Table 3-4. WOODSTOVE DATA (CATALYTIC STOVES)

Study Code	Stove Type	Test Method	Wood Type	% Moisture	Burn Rate (kg/hr)	Fire Temp. (^oC)	Stove Temp. (^oC)	Burn Stage	Sample Time	PM (g/kg)	CO (g/kg)	NO_x (g/kg)	HC (g/kg)	POM (mg/kg)
TVA-83-13	CAT-RET	MM5	O	10				A		16.80	95	1.01		0.19
TVA-83-14	CAT/B	MM5	O	10				A		6.90	139	0.82	0.2	0.16
OM2-84-25	CAT	M7	DF	19	0.6		54	A	840	3.50	43		44.6	
OM2-84-29	CAT	DIL	DF	19	0.6		54	A	840	6.90	43		44.6	
OM2-84-22	CAT	M7	DF	19	0.8		73	A	610	5.00	134		55.3	
OM2-84-26	CAT	DIL	DF	19	0.8		73	A	610	3.60	134		55.3	
OM2-84-32	CAT	M7	DF	18	0.8		58	A	485	1.10	12		54.9	
OM2-84-31	CAT	M7	DF	18	1.0		61	A	430	0.90	42		56.9	
OM2-84-30	CAT	M7	DF	18	1.2		74	A	325	1.50	25		53.8	
TVA-83-7	CAT	MM5	O	10	1.3			A		16.80	28	0.03		
TVA-83-8	CAT	MM5	O	10	1.3			A		5.10	26	0.85		
OM2-84-23	CAT	M7	DF	19	1.4		104	A	145	7.50	59		77.7	
OM2-84-27	CAT	DIL	DF	19	1.4		104	A	145	4.20	59		77.7	
OM2-84-33	CAT	M7	DF	19	1.5		98	A	290	1.50	48		65.7	
OM2-84-24	CAT	M7	DF	17	1.6		111	A	295	6.10	101		73.0	
OM2-84-28	CAT	DIL	DF	17	1.6		111	A	295	4.10	101		73.0	
O-81-6	CAT	M7	DF	18	1.8		125	A		29.30				
TVA-83-10	CAT	MM5	O	10	2.0			A		2.20	6	2.00	0.1	
TVA-83-9	CAT	MM5	O	10	2.0			A		6.40	50	0.88	0.2	
DG-82-14	CAT	M7	DF	17	2.1	320	118	A	209	38.00	120		10.7	
O-81-5	CAT	M7	DF	16	2.6		155	A		21.40				
DG-82-10	CAT-RET	M7	DF	19	2.6	317	143	A	299	22.00	110		8.0	
DG-82-15	CAT	M7	DF	20	2.8	435	162	A	150	23.00	50		7.3	
TVA-83-11	CAT	MM5	O	10	2.9			A		2.60	23	0.81	0.1	
TVA-83-12	CAT	MM5	O	10	2.9			A		1.40	6	0.76		
DG-82-11	CAT-RET	M7	DF	19	3.2	315	178	A	223	17.00	90		6.2	
OM1-83-3	CAT-RET	M7	DF	16	3.4		135	A		8.00				
OM1-83-4	CAT-RET	M7	DF	16	3.4		134	A		6.00				

vice versa. As noted previously, the tests with high HC results used an NDIR which includes all species in the absorbtive range. This would include methane which could account for as much as 50 percent of the total HC value. The particulate value is also uncertain since this measurement is dependent upon filter temperature, particle size, and pre-conditioning; variables which were not documented in the references. With all these undefined variables, it is difficult to draw conclusions from the testing done on an overall basis. Conclusions are probably more valid within each test as some of these variables are controlled.

3.1.5 NO_x Analysis

Only 25 of the 217 tests reported NO_x values which ranged from .03 to 2.0 gr/kg of wood fired, with an average value of .75 gr/kg. The higher values were all associated with tests done on catalytic stoves, while the lower values were associated mainly with non-catalytic stoves. While this is a significant trend, the level of NO_x emissions from woodstoves is lower than for other residential heating equipment.

3.2 INDIVIDUAL STUDY ANALYSIS

As noted above, looking for trends in the whole data bank is clouded by the wide, often undocumented, variations in the test procedures. Analyzing the trends in a single study might prove to be more fruitful since many of these variables were controlled within individual studies by the investigator.

The reported particulate emission factors for RWC range from 0.5 g/kg to as high as 62 g/kg of wood. Several studies have reported typical factors ranging from 0.5-25.0 g/kg. Table 3-5 illustrates particulate emission ranges reported in four different studies.

Carbon monoxide emission factors measured from RWC range from 4 to 400 g/kg of wood. In general, emission factors for stoves and other air-tight appliances have been in the 100 to 200 g/kg range. Fireplaces have demonstrated lower CO emissions (15 to 30 g/kg range).[11] Table 3-6 illustrates carbon monoxide emission ranges reported in four different studies.

The reported HC emission factors range from 2 to 113 g/kg. In the majority of the tests, HC emission factors have been in the 20-60 g/kg range. Table 3-7 illustrates HC emission factor ranges reported in three different studies.

Table 3-5. PARTICULATE EMISSION FACTORS

Study	Emission factor range (g/kg)	Reference
Butcher and Buckley	0.7 - 25	9
Butcher and Sorenson	1.3 - 24	10
Monsanto	5.1 - 19	11
Argonne	0.8 - 22	12

Table 3-6. CARBON MONOXIDE EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION

Study	Emission factor range (g/kg)	Reference
Argonne Lab	92 - 196	12
Monsanto	15 - 370	11
Battelle	33 - 400	13
California Air Resources Board	4 - 147	14

Table 3-7. TOTAL HYDROCARBON EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION

Study	Emission factor range (g/kg)	Reference
Battelle	2.0 - 113	13
Canadian Combustion Research Laboratory	20.4 - 43.4	15
Acurex	2.0 - 110	16

Table 3-8. POLYCYCLIC ORGANIC MATTER EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION

Study	Emission factor range (g/Kg)	Reference
Argonne	.004 - .040	12
Monsanto	.025 - .370	11
Battelle	.011 - .050	16

When airtight combustion units are operated under oxygen starved conditions low combustion efficiencies result. Incomplete combustion results in the formation of a complex mixture of products. These combustion products, a mixture of hydrocarbons, olefinic and polycyclic organic matter, condense as the stack emissions cool. In general, the term POM is used to describe all multi-ring organic compounds. POMs are of special concern in wood smoke since several of these compounds have been identified as potential carcinogens.[5] A well studied example is Benzo(a) pyrene (BaP).

Because of their high melting points the bulk of POM is believed to be linked with particulate matter.[17] It is uncertain whether POM condenses out as discrete particles after cooling or condenses on surfaces of existing particles after formation during combustion. It is clear, however, that POM tends to concentrate on the particle surfaces. It has been demonstrated that most of the mass of POM is associated with particles of aerodynamic diameters in the respirable size range.[17] It is estimated that RWC accounts for as much as 80 percent of the national POM emissions from stationary sources.[18]

Similar to other emission factors developed for RWC, factors reported for POM range over several orders of magnitude. Examples of POM emission factors developed in three studies are shown in Table 3-8. An overall range of 0.004-0.37 g/kg of wood is reported.

3.3 VARIABLES AFFECTING EMISSIONS

Several factors can significantly affect the emissions from wood burning appliances. In general, these factors can be grouped into one of three categories. These are: 1) equipment type, 2) operating conditions, and 3) fuel characteristics. Each of these categories and their role in affecting emissions will be discussed briefly.

3.3.1 Equipment Type

Several studies have demonstrated different emission rates for different combustion appliances. Initially, these studies compared emissions measured from fireplaces to those measured from stoves. One of the first such studies was conducted by Monsanto.[11] The Monsanto study compared emissions from a fireplace, a baffled stove and a nonbaffled stove. The results of this study have been included in Table 3-9. In summary, Monsanto demonstrated that the air-tight stoves have significantly higher emission rates for CO and POM, while NO_x emissions were greater from fireplaces.

More recently, studies have been conducted which compare emission performance of conventional air tight wood heaters with performance of advanced design heaters.[19,20] TVA has conducted such studies using carbon monoxide, particulate, and polycyclic aromatic hydrocarbon (PAH) measurements from various stove types to assess emission performance. Figure 3-3 summarizes the results of one comparison study.[20] In general, TVA found that the advanced design sytems tested generated much lower emission factors. The catalytic wood heater (#2) gave the lowest CO and PAH emission factors. The retrofit catalytic system (#3) tested on the conventional wood heater and the catalytic wood heater with a metal combustor (#4) had lower PAHs, total particulates, and volatile hydrocarbons than the conventional wood heater. Although emissions for the prototype secondary combustion wood heater (#5) were far reduced in comparison to the conventional wood heater, TVA noted that this system required frequent operator attention to sustain such reduced emissions. Referring back to the TVA-83 test series in Table 3-1, it can be seen that the conventional wood heater (tests 1-6) had emissions that increased dramatically with decreased burn rate. Generally, emissions from the catalytic wood heater (tests 7-12) showed less dependence upon wood load size than the conventional wood heater.

3.3.2 Operating Conditions that Affect Emissions

Several stove operating conditions have been identified as affecting emission rates. Three of these variables will be briefly discussed. These are: 1) burn rate, 2) stage of the burn cycle, and 3) charge loading.

3.3.2.1 Burn Rate. Several investigators have looked at the effect of burn rate on emission performance. In general, these studies have demonstrated that an increased burn rate will result in various emission reductions. These reductions include:

Table 3-9. SUMMARY OF EMISSION RESULTS FOR CRITERIA POLLUTANTS AND POMs FROM WOOD FIRED RESIDENTIAL COMBUSTION EQUIPMENT[a]

Wood burning device	Burn rate kg/hr	Particulate matter[b] g/kg	Condensible organics[c] g/kg	NO_x[d]	CO[e]	POM[f]
Fireplace	10.8	2.3	6.3	2.4	30	0.025
Baffled stove	8.4	3.0	4.0	0.4	110	0.21
Nonbaffled stove	7.8	2.5	6.0	0.4	370	0.19

Source: DeAngelis, et al.[11]

[a]Wood type - seasoned oak.

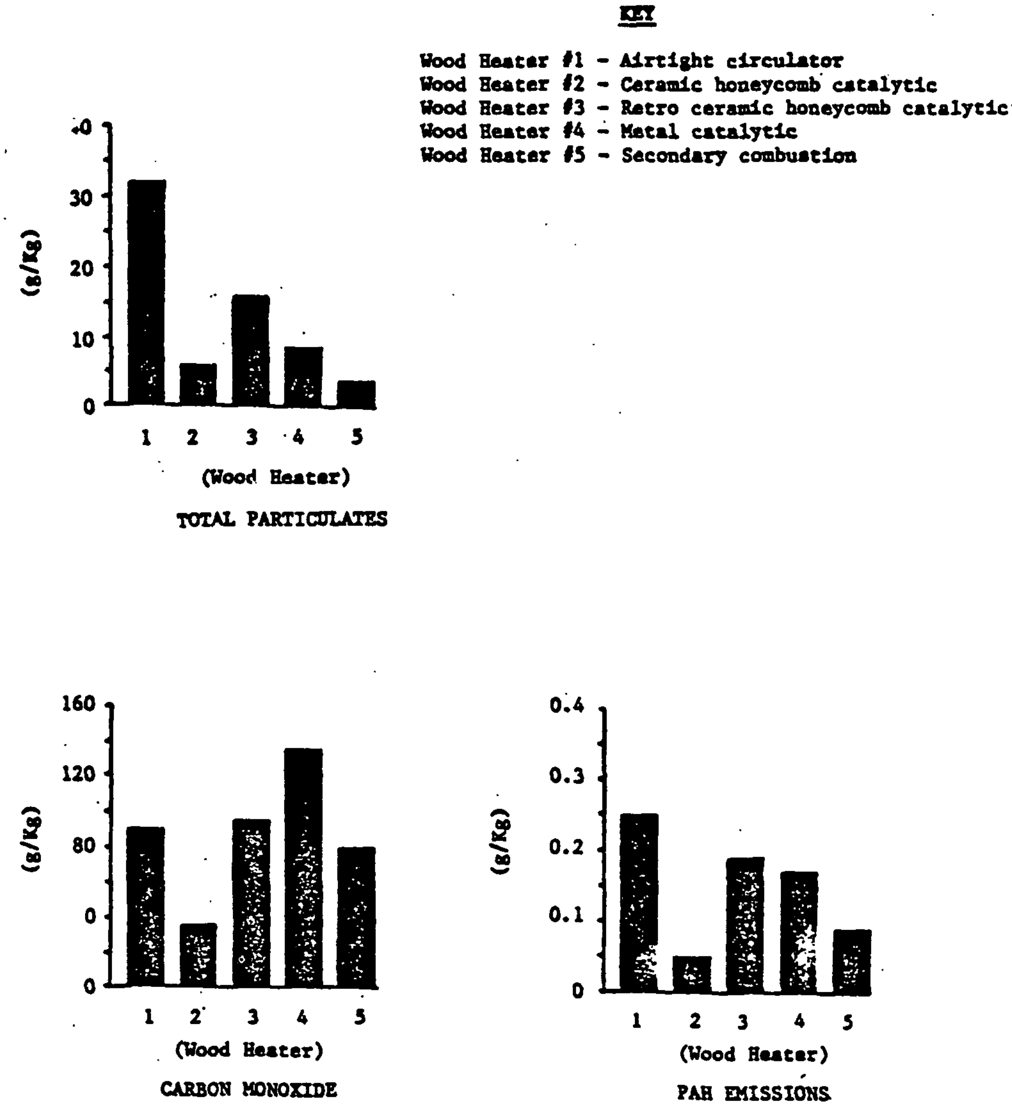
[b]Front half of EPA Method 5 and POM train. Averaged when two values are available.

[c]Back half of EPA Method 5. Averaged when two values are available.

[d]EPA Method 7. Average of six grab samples.

[e]EPA Method 3 (Orsat) for stoves; average of 10 samples. Dräger tube for fireplace; 15-30 minute composite.

[f]POM train (EPA Method 5 modified with XAD resin trap).



Footnotes:
a. Fuel sample was red oak, split cordwood, 10.4% moisture (wet).
b. Wood heater #1 data was taken from 8 samples at low, medium, and high burn rates.
c. Wood heater #2 and #3 data was taken from 6 samples at low, medium, and high burn rates.
d. Wood heater #4 data was taken from 2 samples at a medium burn rate.
e. Wood heater #5 data was taken from 2 samples at medium and high burn rates.

Figure 3-3. Comparison of emissions from several wood heaters.[20] (Reproduced with permission of APCA.)

1) particulate,[21,22]
2) condensible organics,[22]
3) carbon monoxide,[19,23]
4) total hydrocarbons,[19,23]
5) aliphatic compounds,[12] and
6) total organics.[12]

These burn rate emission reduction relationships are illustrated in Figures 3-4 through 3-8.

The effect that burn rate has on POM emissions is less certain. Studies[23] conducted at the Canadian Combustion Research Laboratory indicate a decrease in POM emissions with increasing burn rates (Figure 3-9). On the other hand, studies[12] conducted at the Argonne National Laboratory (ANL) strongly suggest that POM emissions increase with increasing burn rates. ANL's suggestions are supported by the apparent shift to higher molecular weight organics observed when the burn rate is increased.

Peters[17] suggests that high temperature combustion favors POM formation from the alkyl benzene fragments pyrolyzed during wood combustion. He makes the following statement concerning burn rate and POM emission rate: "The very limited data on POM emissions from residential wood-fired equipment and deductive reasoning suggest that, within the operating temperature range of residential equipment, the burning rate - POM emission rate relationship is exactly opposite that of other pollutants. Because temperatures of 500-800°C are needed for POM formation, a very cool fire similar to overnight use conditions should, at some point, result in zero POM emissions, although large amounts of other unburned organics and CO will be emitted."[17]

3.3.2.2 Stage of the Burn Cycle. Several investigators have determined that emission rates for various pollutants are dependent upon the stage of the burn cycle. DeAngelis, et al. observed this dependency when monitoring CO over an entire burn cycle.[11] Figure 3-10 illustrates the carbon monoxide concentration in the flue gas as a function of time. It has also been reported that particulate emission rates are dependent upon the stage of the burn.[21,10] These studies have shown that approximately one-half of the mass of particulates are emitted in the first 17 percent of the burn.

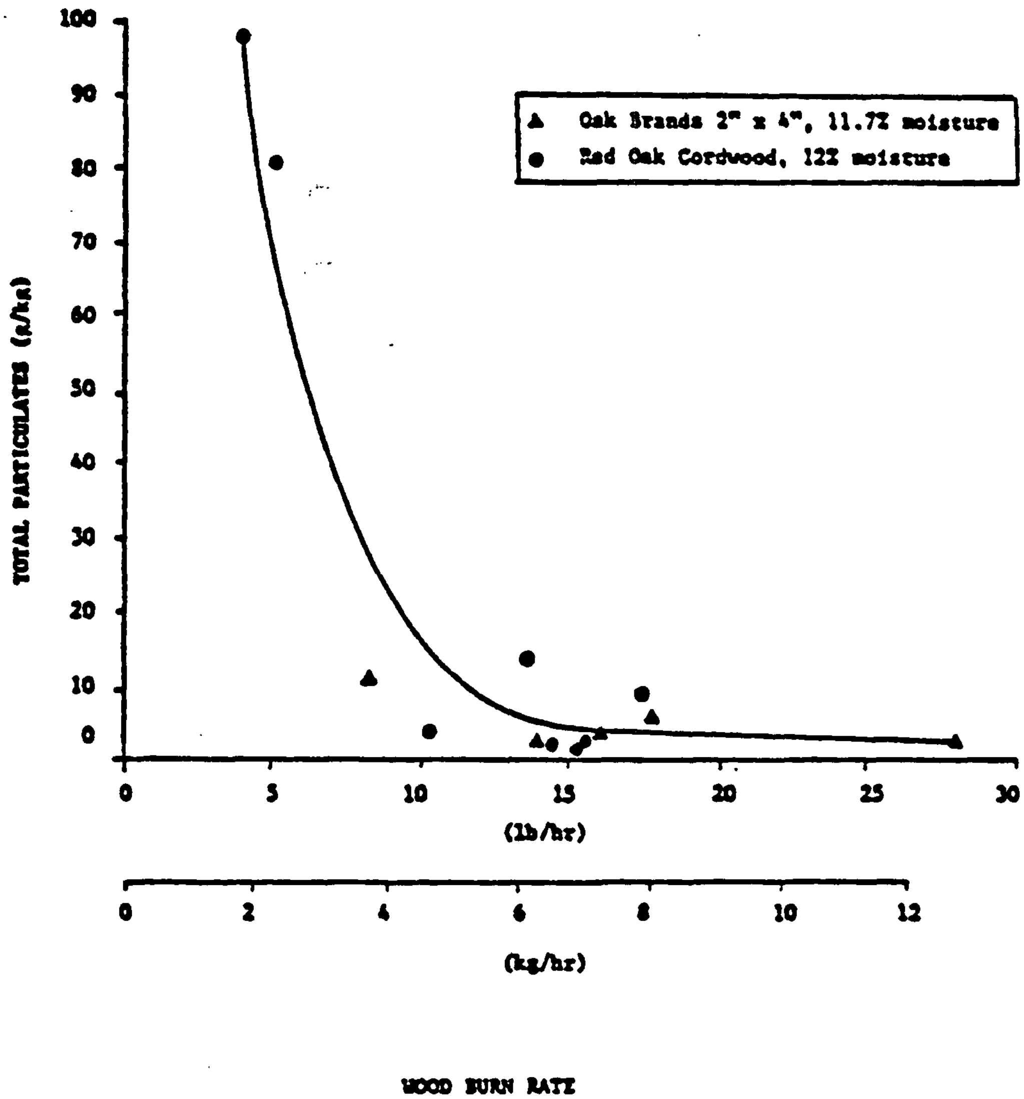


Figure 3-4. Summary of total particulate emission factors versus wood burn rate.[22]
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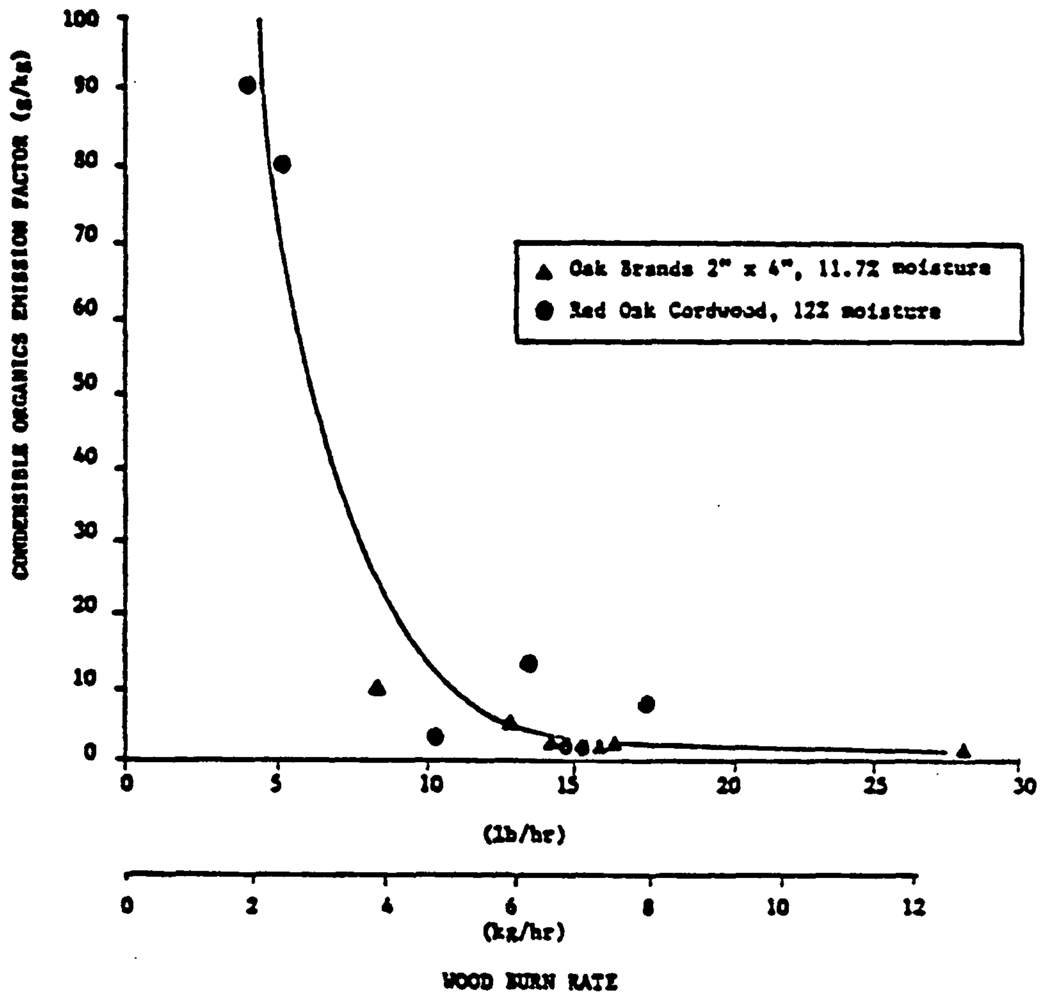

Figure 3-5. Summary of condensible organic emissions factor versus wood burn rate.[22]
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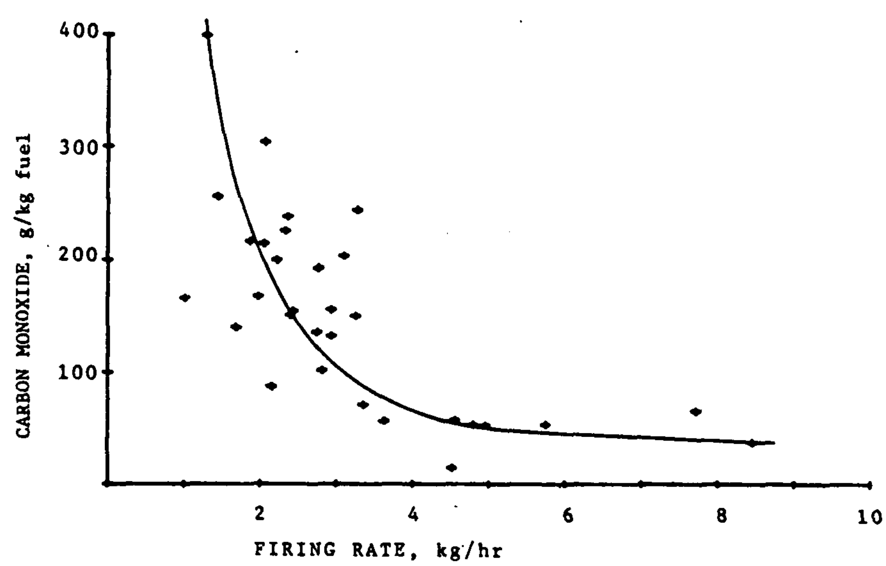

Figure 3-6. Variation of carbon monoxide with firing rate, conventional stoves.[23]
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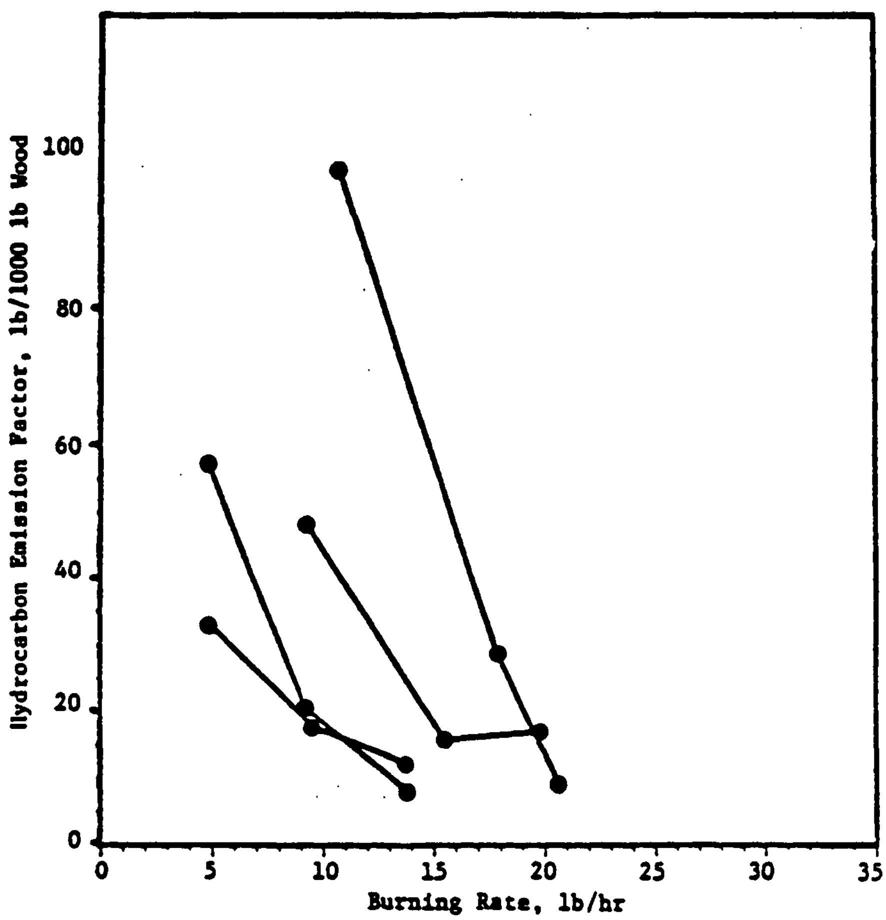

Figure 3-7. HC emissions for several stoves as a function of burn rate.[19]
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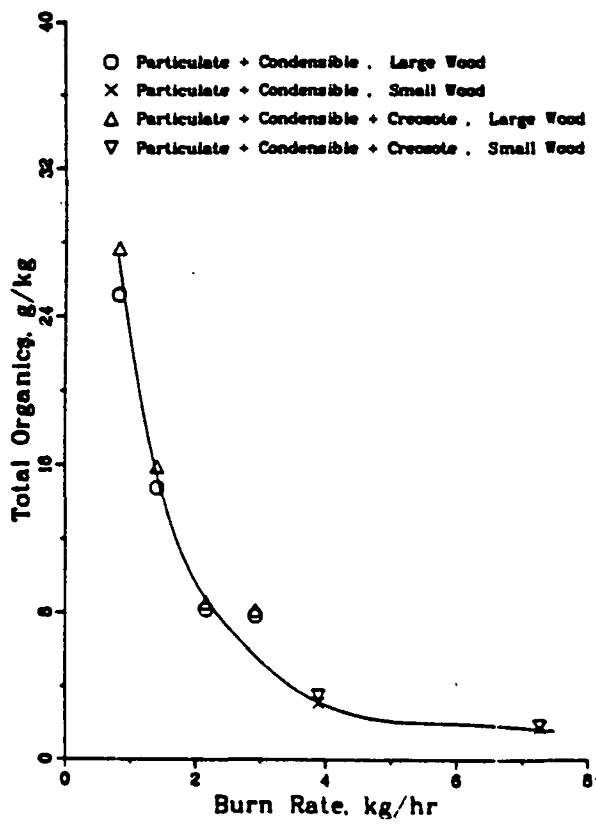

Figure 3-8. Summary of total organic emission factors (g/kg) as a function of burn rate (kg/hr) from combustion of 0.12M and 0.06M diameter oak logs.[12] (Reproduced with permission of the Oregon Graduate Center.)

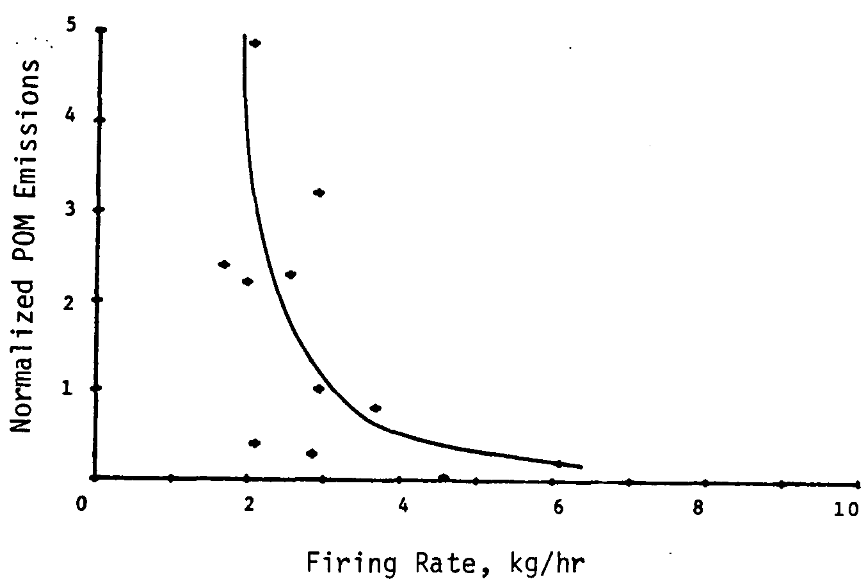

Figure 3-9. Variation in POM emissions with firing rate, conventional stoves.[23]
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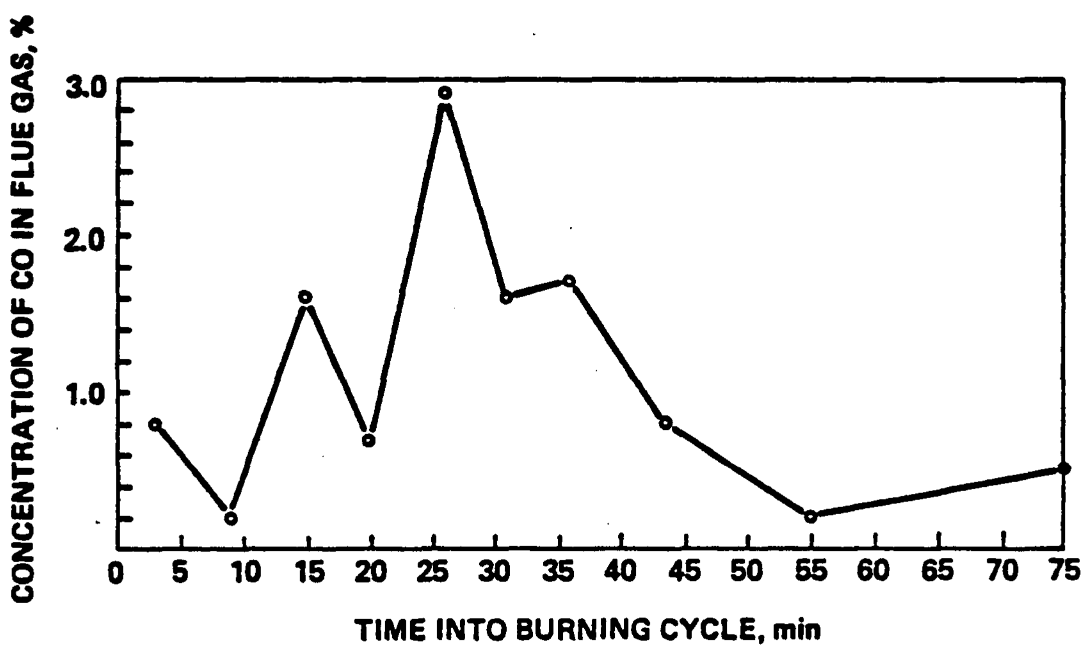

Figure 3-10. Concentration of CO in flue gas as a function of time.[11]

3.3.2.3 Charge Loading. Cooke, et al.[19] concluded from their emission studies that the amount of wood loaded into the stove will have a large influence on the amount of pyrolysis products leaving the stove. The emissions increase with the increase in wood inventory due to the increased quantity of wood exposed to the heat and thereby subject to preburning pyrolysis. As seen from these data (Table 3-10), both the HC and CO emissions increased when the charge mass increased.

3.3.3 Fuel Characteristics

The combustion properties of wood are influenced by several fuel characteristics. As a result the types and magnitudes of emissions generated by wood combustion are also governed by these characteristics. It has been reported that wood type, moisture content, size and shape of the fuel may all affect emissions. Each of these factors and their influence on emission performance will be briefly discussed.

3.3.3.1 Wood Type. To date, one of the most comprehensive studies that specifically investigates the relationship between emissions and wood type was conducted by Muhlbaier.[6] This study reported particulate emission rates from a free standing fireplace for seven different wood types. In addition to particulate emissions, gaseous emissions were measured during combustion of select woods. No significant trends are available in the data. A summary of these results is presented in Table 3-11.

3.3.3.2 Moisture Content. Considering the error factors involved with emission testing, many investigators have concluded that fuel moisture has little or no significant effect on emissions. Some have added that dry wood (less than 25 percent moisture) may produce slightly higher emissions than wood with more typical moisture contents of 30-40 percent.[24] In contrast, Del Green Associates concluded that fuel moisture does significantly affect emissions.[25] Figure 3-11 illustrates measured particulate emission rates for various fuel moisture contents. This figure illustrates that the low moisture fuel resulted in significantly higher emission levels than the medium moisture fuel. The high moisture fuel also resulted in higher particulate emissions, but the increase was not as great as with the dry fuel.

Table 3-10. EFFECTS OF SIZE OF CHARGE ON EMISSIONS, SIDE DRAFT BURNING OF OAK 4x4s[19]

Test run number	34	35
Mass of charge, lb	12.9	41.9
Burning rate, lb/hr	17.4	19.2
Excess air, percent	62.9	58.1
Stack temperature, °F (°C)	680 (360)	660 (350)
Gas composition, as measured		
CO, percent	1.2	2.5
HC, ppm	2800	5300
Emissions, lb/1,000 lb wood		
CO	100	220
HC	15	26

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Table 3-11. PARTICULATE EMISSION RATES FROM WOOD BURNING (g/kg)[6]

Test	Wood	Front Catch	Filter Catch	Impinger Catch	Total
Softwood					
25	Eastern Spruce	6.0 (47)*	2.1 (17)	4.6 (36)	13
26	"	2.9 (30)	1.2 (13)	5.5 (57)	9.6
27	"	1.8 (12)	1.9 (13)	11 (75)	15
32	"	-	1.4	-	
33	"	-	1.6	-	
31	Jack Pine	-	3.7	-	
34	"	1.7 (17)	1.7 (17)	6.7 (66)	10
36	"	4.0 (28)	7.6 (53)	2.6 (18)	14
40	"	4.2 (40)	2.9 (28)	3.3 (32)	10
Hardwood					
23	Soft Maple	2.6 (11)	3.9 (17)	17 (72)	24
24	"	1.9 (21)	1.4 (16)	5.7 (63)	9.0
35	"	2.2 (23)	1.6 (17)	5.8 (60)	9.6
42	Birch	5.9 (40)	4.2 (29)	4.5 (31)	15
43	"	2.2 (23)	1.7 (18)	5.7 (59)	9.6
20	Hard Maple	1.2 (12)	1.2 (12)	7.9 (77)	10
21	"	4.2 (38)	1.9 (17)	5.1 (46)	11
19	White Ash	1.5 (11)	1.0 (7.4)	11 (81)	14
22	"	1.1 (12)	1.5 (16)	6.5 (71)	9.1
28	Red Oak	3.4 (43)	2.0 (25)	2.6 (33)	8.0
29	"	2.5 (30)	3.4 (41)	2.3 (28)	8.2
30	"	2.8 (24)	6.2 (53)	2.8 (24)	12
37	"	2.6 (29)	1.2 (13)	5.1 (57)	8.9
38	"	2.2 (20)	1.8 (17)	6.9 (63)	11
39	"	3.3 (11)	3.6 (12)	22 (76)	29
Synthetic Logs					
41	Sternolog	1.5 (8)	8.4 (45)	8.8 (47)	19
44	Northland II	2.3 (11)	14 (71)	3.6 (18)	20

*Numbers in the ( ) are the percent of the total.
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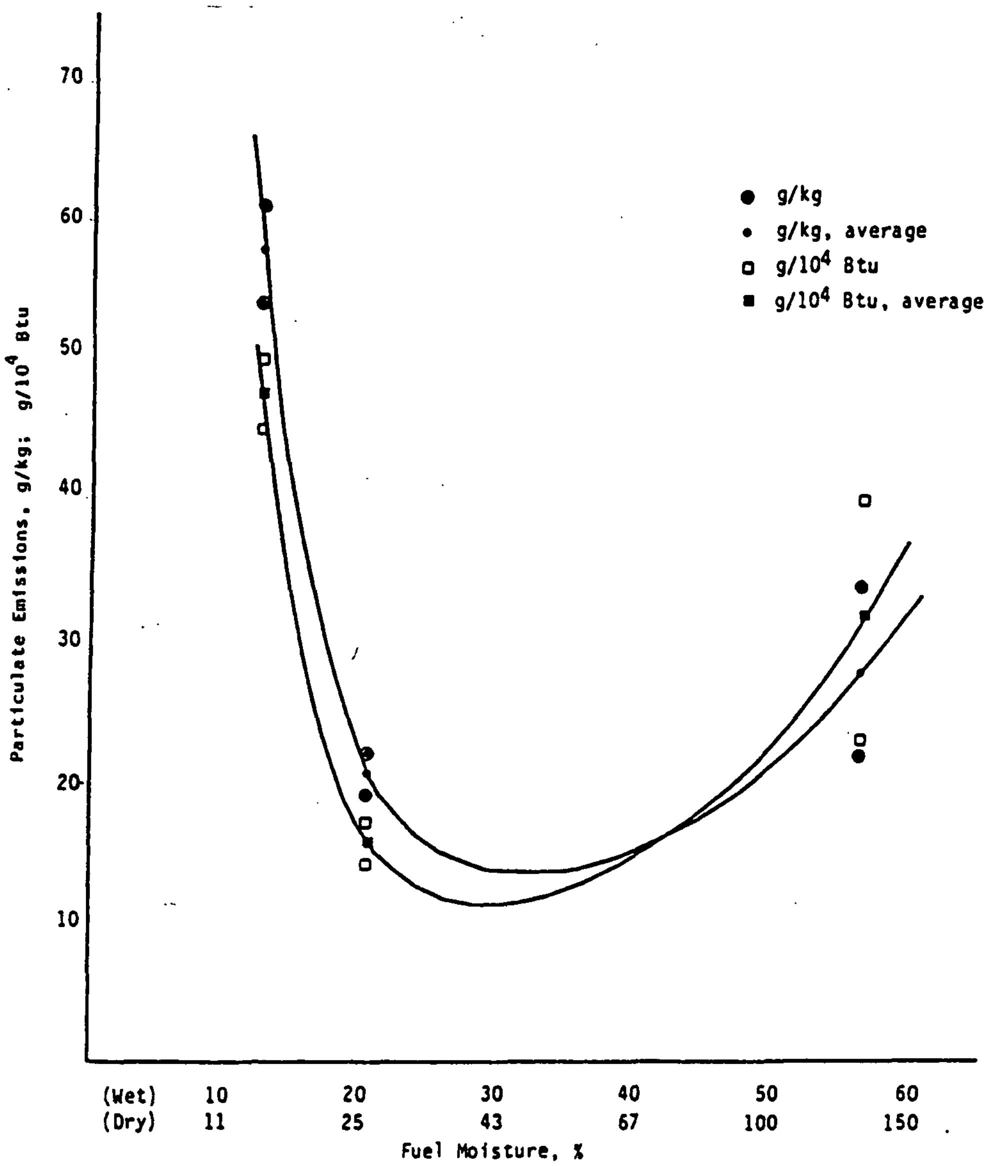

Figure 3-11. Particulate emissions (normalized to burn rate) as a function of fuel moisture.[25]

3.3.3.3 Fuel Size. The log size/emission relationship has been studied by several investigators. The size of the pieces of wood has a large effect on the rate of pyrolysis. The smaller pieces result in a shorter distance for the pyrolysis products to diffuse, a larger surface area to mass ratio, and a reduction in the time required to heat the entire piece of wood.

Investigators have shown that as the ratio of surface area to mass increased (i.e., smaller log sizes) the emission factors are markedly increased. Cooke, et al.[19] demonstrated this with CO emissions (Figure 3-12) while Barnett[24] demonstrated the same relationship with particulates (Figure 3-13). Hubble[12] concluded that total organics do not exhibit a log-size effect but the forms of the organics (particulate matter, creosotes, and condensibles) do exhibit such an effect (Figure 3-8).

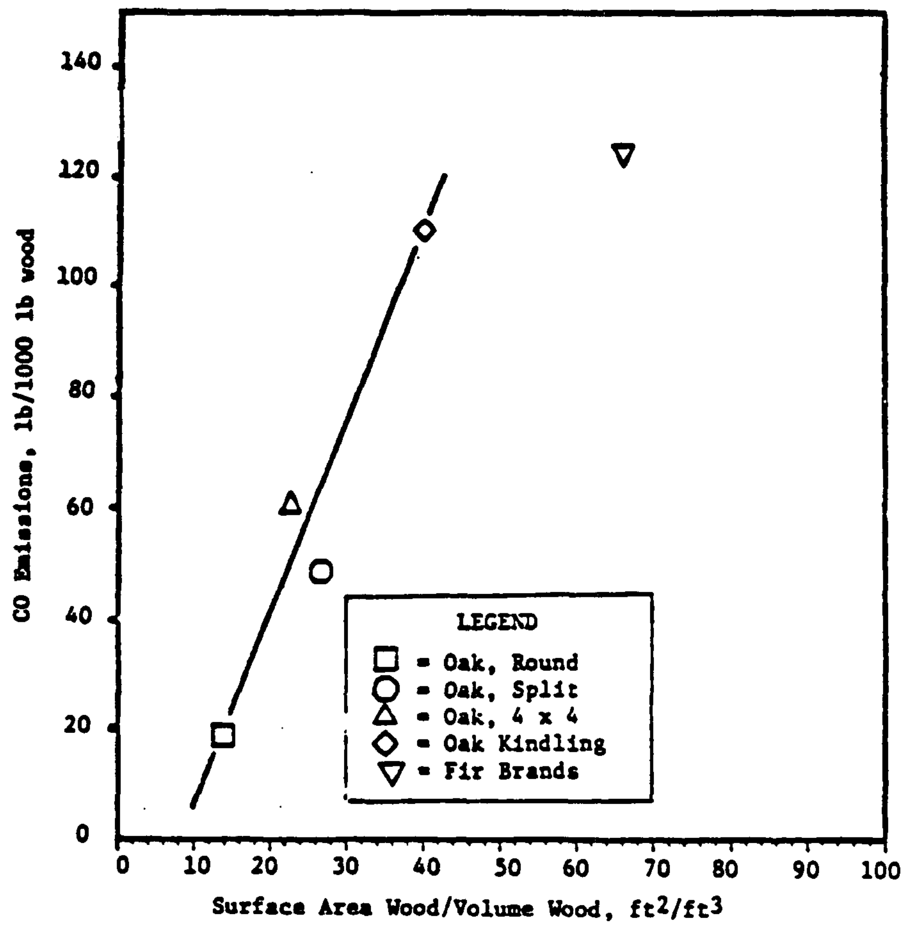

Figure 3-12. Effect of wood size on CO emission factors.[19] (Reproduced with permission of the Oregon Graduate Center.)

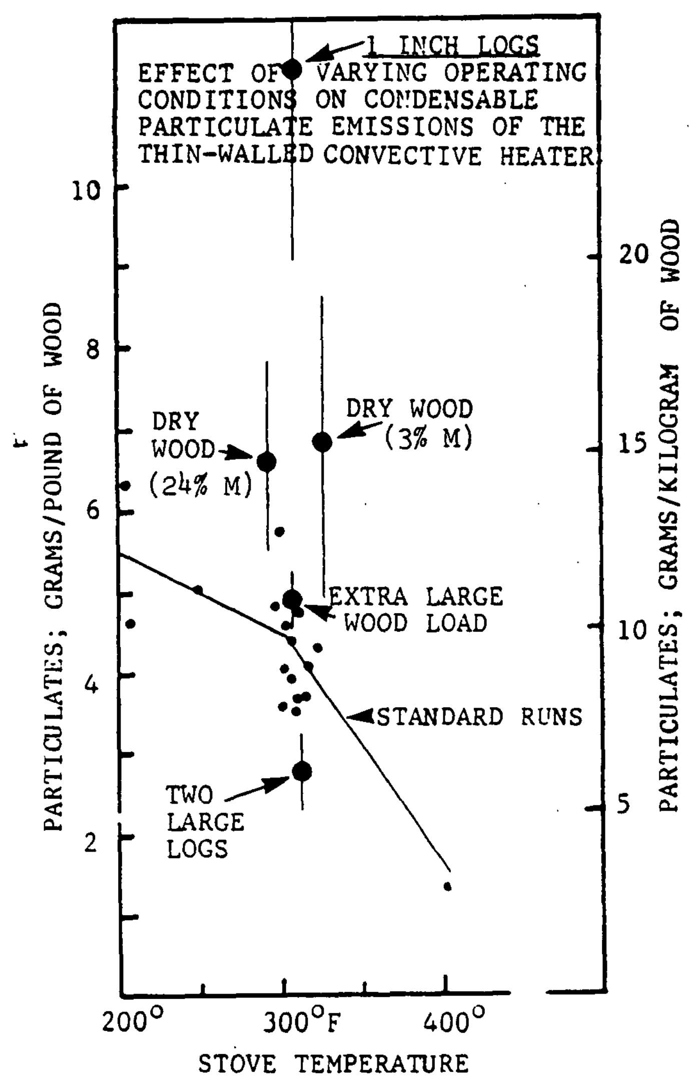

Figure 3-13. (The effect of varying operating conditions on condensible particulate emissions of the thin-walled convective heater.) Compare standard runs (small dots) with emission factors (large dots) produced by varying wood size and moisture. Note extreme effects caused by burning 1 inch logs. Dots represent sample means and vertical bars represent 97 percent confidence limits.[24] (Reproduced with permission of the Oregon Graduate Center.)

4. AIR SHED STUDIES AND IMPACT ASSESSMENT METHODS

Several air shed studies have indicated that RWC is a major air pollution source in regard to the current total suspended particulate (TSP) standards.[2,3,4] Additional concern is warranted due to the respirable nature of the particulate. Muhlbaier has reported RWC particulate to have a mass median diameter of 0.17 μm.[6] Other studies have measured similar sizes and have generally concluded that the majority of particulate emitted from RWC is less than 2.5 μm.[7,8] Based on these studies, if an inhalable particulate standard was implemented, RWC would be a much greater contributor to nonattainment than under the current TSP regulations.

During studies conducted in 1978 on the Denver "Brown Cloud," it was noted that wood burning sources contributed 12 percent of the fine particulate mass (<2.5μm) and 18 percent of the visual range reduction (0.1-1.0 μm) in that city.[26] These estimates were based on the high potassium to iron ratio noted for wood smoke that did not appear for other sources. Other studies have shown up to 84 percent of the fine particulate fraction to be attributed to RWC.[1] All studies predict an increase in this percentage as other sources are controlled and wood use increases. Table 4-1 displays six ambient air surveys, their measurement techniques, and the constituents measured.

The assessment of these reports was based upon:

(1) Size of the community and the ability to obtain a good indication of wood usage from home surveys. Example, the home survey was not obtained for Denver "Brown Cloud." However, a detailed survey was obtained for Waterbury, Vermont along with actual testing of 14 woodstoves.

(2) The placement of ambient air monitors. Good upwind and downwind monitors are needed to account for ambient background concentrations. These are easy to obtain for wood smoke as very few sources are greater than 15 meters high at the point of emission. The sampling and/or monitoring intervals are critical.

Table 4-1. AIR SHED STUDIES AND IMPACT ASSESSMENT METHODS

	TSP	<2.5μm	POM	Upwind/ downwind	Teflon® filter	Glass fiber filter	Backup trap XAD-2	Other filter	C^{14}	CMB	K:Fe	Survey	Stove test	TSP average μg/m^3
Colorado,[26] Denver "Brown Cloud"	X	X		X	X	X					X			89.6
Colorado,[28] Telluride	X		X	X		X								61
New Hampshire,[29] Lyme Center	X		X	X		X						X		52
Alabama,[2] Petersville	X	X	X	X		X	X		X	X				N/A
Montana,[4] Missoula	X	X			X	X				X	X		X	81
Oregon,[3] Medford	X	X	X			X		X	X	X	X		X	100

(3) The type of ambient monitor utilized. Generally wood smoke is found in the 0.1-1.0 μm size range. Analytical methodology can be improved by the use of a sampler which fractionates the size to less than 2.5 μm or "respirable" particulate matter.

(4) The filtration method or collection substrate. Both Teflon® and glass fiber filters are utilized for these studies, but new data shows that some of the hydrocarbons are passing through the filter material. This material, in the semi -volatile range, must be collected on an organic adsorbant such as XAD-2.

The key to obtaining a credible ambient air survey of RWC emissions appears to be the method utilized to correlate the ambient sample to the source emission. There are currently three main methods to separate the total particulate catch to a fraction which is wood smoke. They are listed below with their comments.

- Particulate sizing on the Hi-Vol Sampler. Wood smoke is known to be 80 percent in the 0.1-1 μm size range, so fractionating this size eliminates other interferences but does not necessarily preclude other condensibles or other fine particles.[27]

- Chemical Mass Balance (CMB). This method utilizes a detailed analysis of the filter samples to identify compounds or elements which are predominantly attributed to wood smoke emissions. Examples of these chemicals are the potassium to iron ratio, Levo glucosan and retene.

- Carbon^{14} identification. This method utilizes the fact that all vegetative and vegetatively derived material contains C^{14}. A known fraction of atmospheric CO_2 contains the C^{14} isotope formed in the upper atmosphere by cosmic ray bombardment of C^{12}. Plants incorporate the C^{14} isotope through photosyntheses. When the plant dies, incorporation of new C^{14} stops; the existing C^{14} in the plant starts to decrease decaying to C^{12}. C^{14} half life is $\sim$5,730 years. Over the hundreds of millions of years since the vegetation died, which now appears as coal, oil, or natural gas, virtually all of the C^{14} has decayed to C^{12}. The C^{12}/C^{14} ratio in ambient particulate matter is a measure of the fraction contributed by wood combustion. For best results, the analysis is performed on the <2.5 μm particulate fraction to separate the smaller combustion derived particles from the larger vegetative particles such as soil and bits of leaves entrained in wind blown dust.

5. SAMPLING AND ANALYTICAL METHODS

There has been considerable controversey surrounding the use of sampling methods both for source evaluation and ambient monitoring of woodstove emissions. As noted earlier in the discussion of emissions, very few people use the same method and little work has been done to evaluate the accuracy and precision of each method. A brief description of each method is provided below.

5.1 SAMPLING, SOURCE

5.1.1 Semi-VOST (Modified Method 5) Sampling and Analysis Procedures for the Determination of Semi-Volatile Compounds from Combustion Sources

Gaseous and particulate pollutants are withdrawn from an emission source at an isokinetic sampling rate and are collected in a multicomponent sampling train. Principle components of the train include a high efficiency glass or quartz fiber filter and a packed bed of porous polymeric adsorbent resin. The filter is used to collect organic laden particulate materials, and the porous polymeric resin to adsorb semi-volatile organic species. Semi-volatile species are defined as compounds with boiling points greater than 100°C.

This method is currently being studied in an EPA/IERL project. The purpose of the project is to validate the semi-VOST procedures and determine the Method Detection Limit, Method Accuracy and Precision, and Interferences.

A schematic of the sampling train used in this method is shown in Figure 5-1. This sampling train configuration is adapted from EPA Method 5 procedures and as such, the majority of the equipment required is identical to that used in EPA Method 5 determinations. The new components required are a condensor coil and a sorbent module, which is used to collect semi-volatile organic materials that pass through the glass or quartz fiber filter in the gas phase.

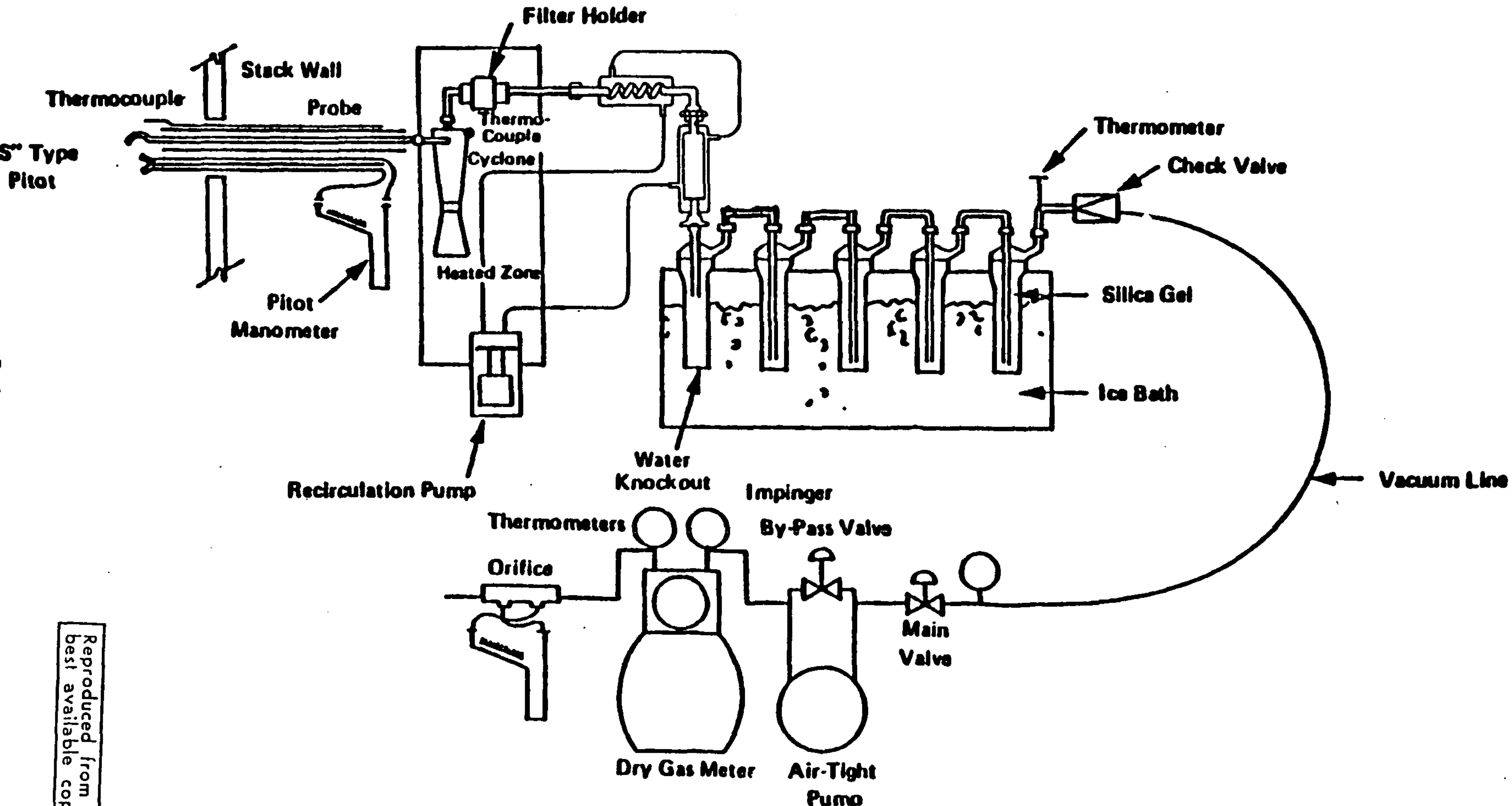

Figure 5-1. Semi-VOST train schematic diagram.

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5.1.2 Oregon Source Sampling Method 7

Particulate matter including condensible vapors are withdrawn isokinetically from a flowing gas stream. The particulate matter is determined gravimetrically after extraction with organic solvents and evaporation.

This method is applicable to stationary sources whose primary emissions are condensible gases. It should be considered a modification of Source Sampling Method 5 as shown in Figure 5-2.

The probe, sampling train, and metering system are the same as outlined in Source Sampling Method 5 with the following exceptions:

- The heated filter and cyclone are optional, but should be used if significant quantities of solid particulate are present.
- An unheated glass fiber filter is placed between the third and fourth impingers.

5.1.3 The Source Signature (S^2) Sampler (Dilution Sampler)

Figure 5-3 is a diagram of the principal components of the S^2 sampler. The S^2 sample train is made up of an isokinetic sampling probe, a dilution system, the two parallel filter trains, and the necessary flow control systems. The raw wood smoke is sampled from the stack at approximately 20 lpm and diluted to approximately 200 lpm with clean air. This dilution takes place in a dilution tube, 25 cm long and 2 cm in diameter.

Equal portions of the diluted aerosols are pumped through the two filter trains. The particles larger than 2.5 μm in aerodynamic diameter are cut from the stream in cyclones. The remaining fine particles are collected simultaneously on a Teflon® and a quartz filter. Both filters have a 1-μm pore size and are 37 mm in diameter. The Teflon® filter is used in the X-ray analysis procedure. The quartz filter is used in the carbon analysis procedures. In addition to the S^2 sampler, this method requires measurement of the chimney or stack flow rate. Measuring this flow rate can be difficult, given the low velocity in natural draft chimneys, but a standard "J" type Pitot tube with an electronic manometer sensitive to 0.001 mmHg provided suitable flow measurements in the laboratory.

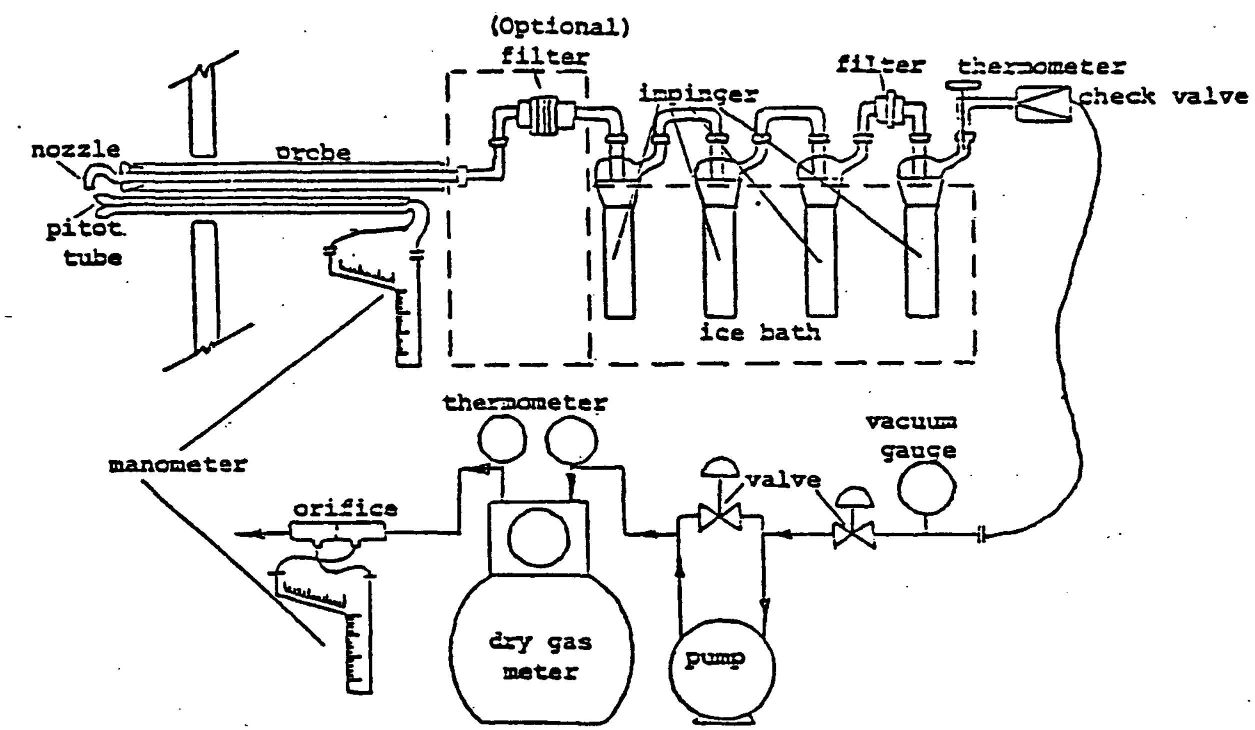

Figure 5-2. State of Oregon Source Sampling Method 7.

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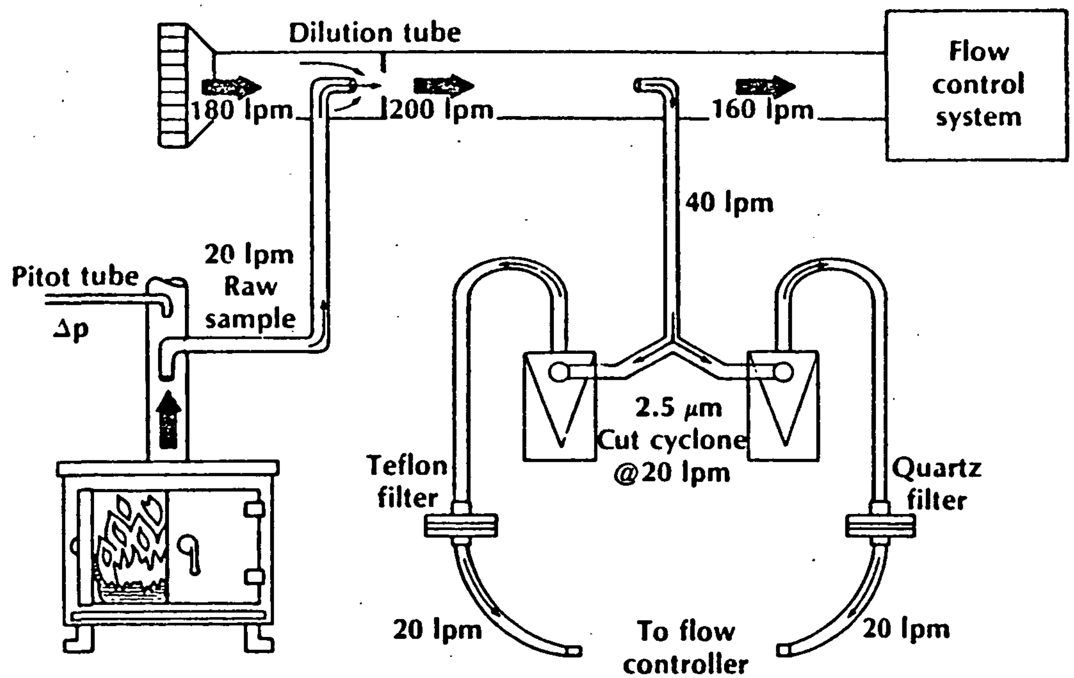

Figure 5-3. S^2 dilution sampling system.

5.1.4 Dilution Sampler (Condar)

Particulate emissions can be sampled by pumping a portion of the flue gases through a filter. Two versions are detailed in Figure 5-4. The unit consists of a sampling pipe that is inserted into the stack about two feet above the stove. The sampling pipe has numerous small holes that allow room air to dilute and condense the flue gases. This mixture then passes into the filter housing where the particulates are collected on filter paper. A vacuum motor is used to pump the flue gases through the system. This procedure samples 10 to 17 percent of the total stack exhaust flow.

5.1.5 Source Assessment Sampling System (SASS)

Particulate and semi-volatile organic materials are withdrawn from a source at constant rate near isokinetic conditions and are collected in a multi-component sampling train.

Three heated cyclones and a heated high-efficiency glass or quartz fiber filter remove and collect the particulate material from the sample, and a packed bed of porous polymeric resin adsorbs the semivolatile organic species.

Chemical analyses of the sample are conducted to determine the concentration and identity of the semi-volatile organic species and gravimetric determinations are performed to approximate particulate emissions.

A schematic of the sampling train used in this method is given in Figure 5-5. This sampling train configuration is that of the Source Assessment Sampling System (SASS) as supplied by Anderson Samplers, Inc., Atlanta, Georgia.

5.1.6 EPA Method 5--Determination of Particulate Emissions from Stationary Sources with Condensate Collection Analysis for Gaseous Emissions

Particulate matter and gaseous emissions are withdrawn isokinetically from the source and collected on a glass fiber filter maintained at a temperature in the range of 120 ± 14°C (248 ± 25°F) and in water collection impingers. The particulate mass, which includes any material that condenses at or above the filtration temperature, is determined gravimetrically after removal of uncombined water. The collected gaseous emissions are analyzed by ether chloroform extracts of the impinger solutions.

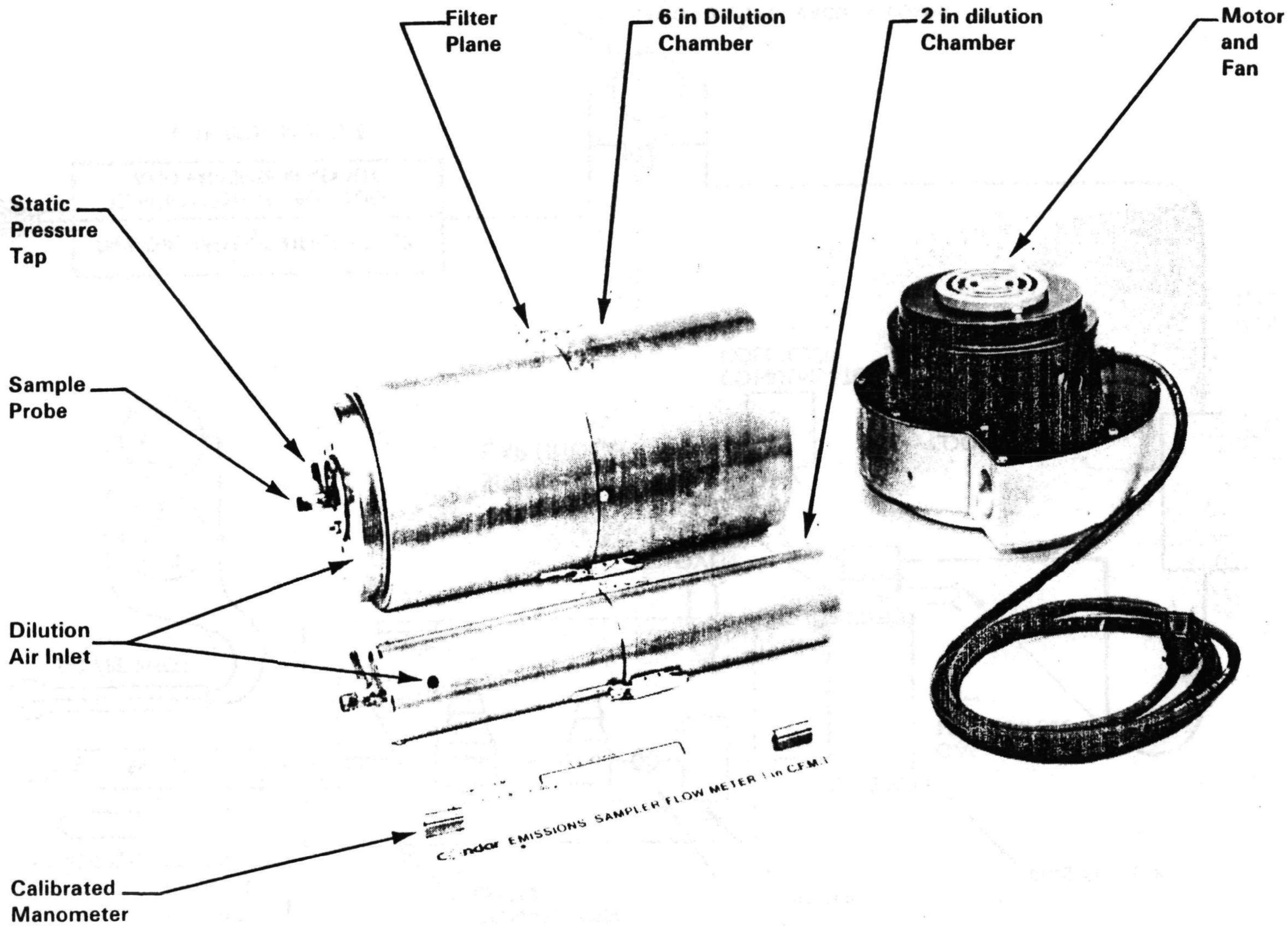

Figure 5-4. Condar Company sampling system.

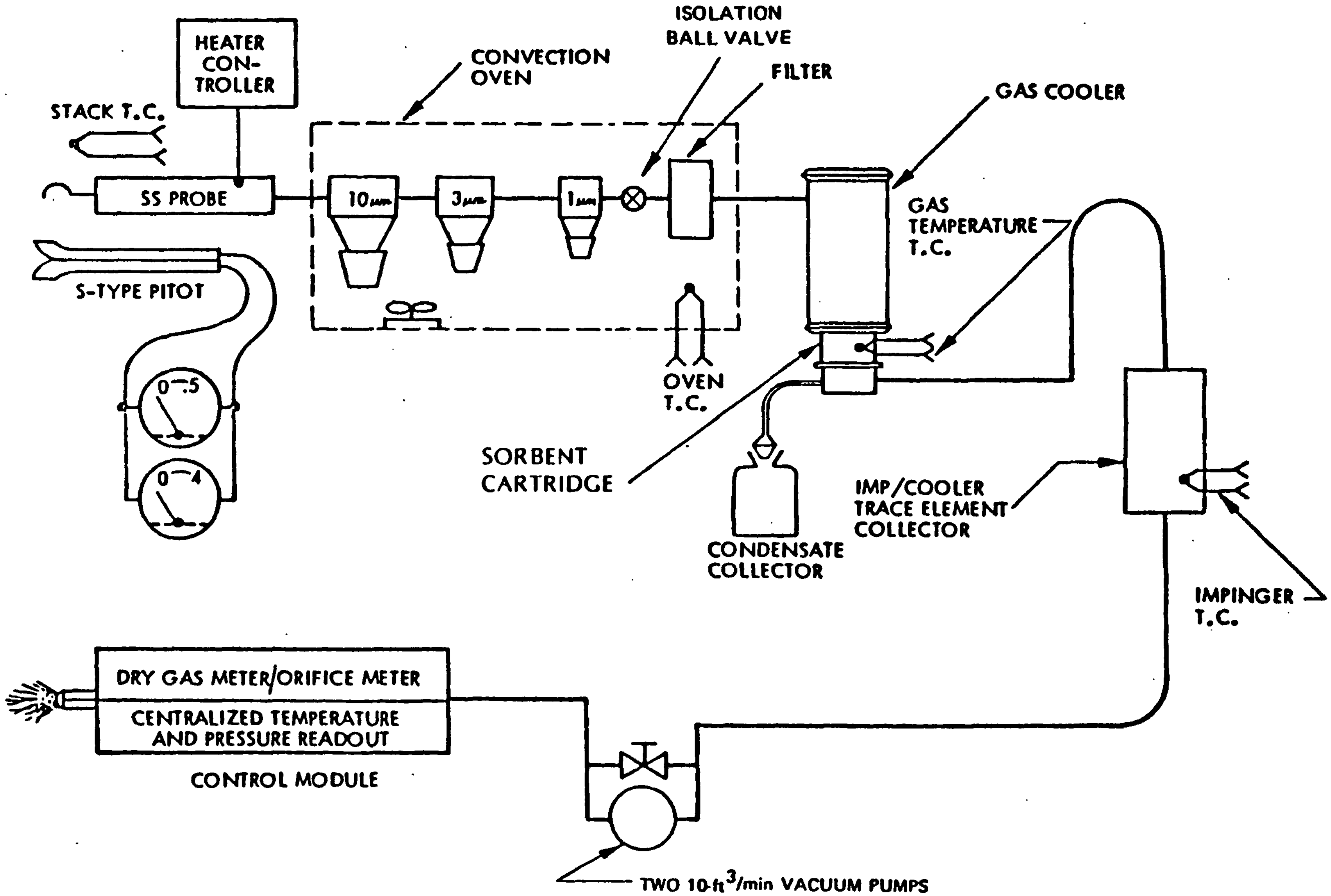

Figure 5-5. SASS schematic diagram.

This method is applicable for the determination of particulate emissions from stationary sources. Chemical analyses of the condensate sample are conducted to determine the concentration and identity of hydrocarbon emissions.

A schematic of the sampling train used in this method is shown in Figure 5-6. Complete construction details are given in APTD-0581 (Citation 2 in Section 7).

5.1.7 Cryogenic Trapping

Cryogenic trapping is routinely used to concentrate organics in air samples for injection into gas chromatographs. This preconcentration affords detection limits in the sub-parts-per-billion range with adequate reproducibility. Cryogenic traps are usually constructed of capillary-bore chromatographic grade stainless steel tubing formed into a loop. The loop is immersed in a cryogenic bath for trapping. Liquid nitrogen is most often used as the cryogenic fluid (boiling point - 195°C). Typically, an evacuated reservoir of precisely known volume is used to pull sample gas through the cryogenic trap. The volume of the gas sample is calculated from the pressure change in this reservoir. The concentrated organic sample is released into the GC by removal of the capillary tube from the cryogenic bath followed by heating. Figure 5-7 presents an example of a typical thermal desorption device with cryogenic trapping.

5.2 SAMPLING, AMBIENT

5.2.1 Ambient Sampling With Hi-VOL Sampler

Air is drawn into a covered housing and through a filter by a high-flow-rate blower at 1.13 to 1.70 m^3/min (40 to 60 ft^3/min) that allows total suspended particulates (TSP) with diameters of <100 μm (Stokes equivalent diameter) to collect on the filter surface. Particles with diameters of 0.1 to 100 μm are ordinarily collected on glass fiber filters. When a sampler is operated at an average flow rate of 1.70 m^3/min (60 ft^3/min) for 24 h, an adequate sample can be obtained even in an atmosphere having TSP concentrations as low as 2 μg/m^3.

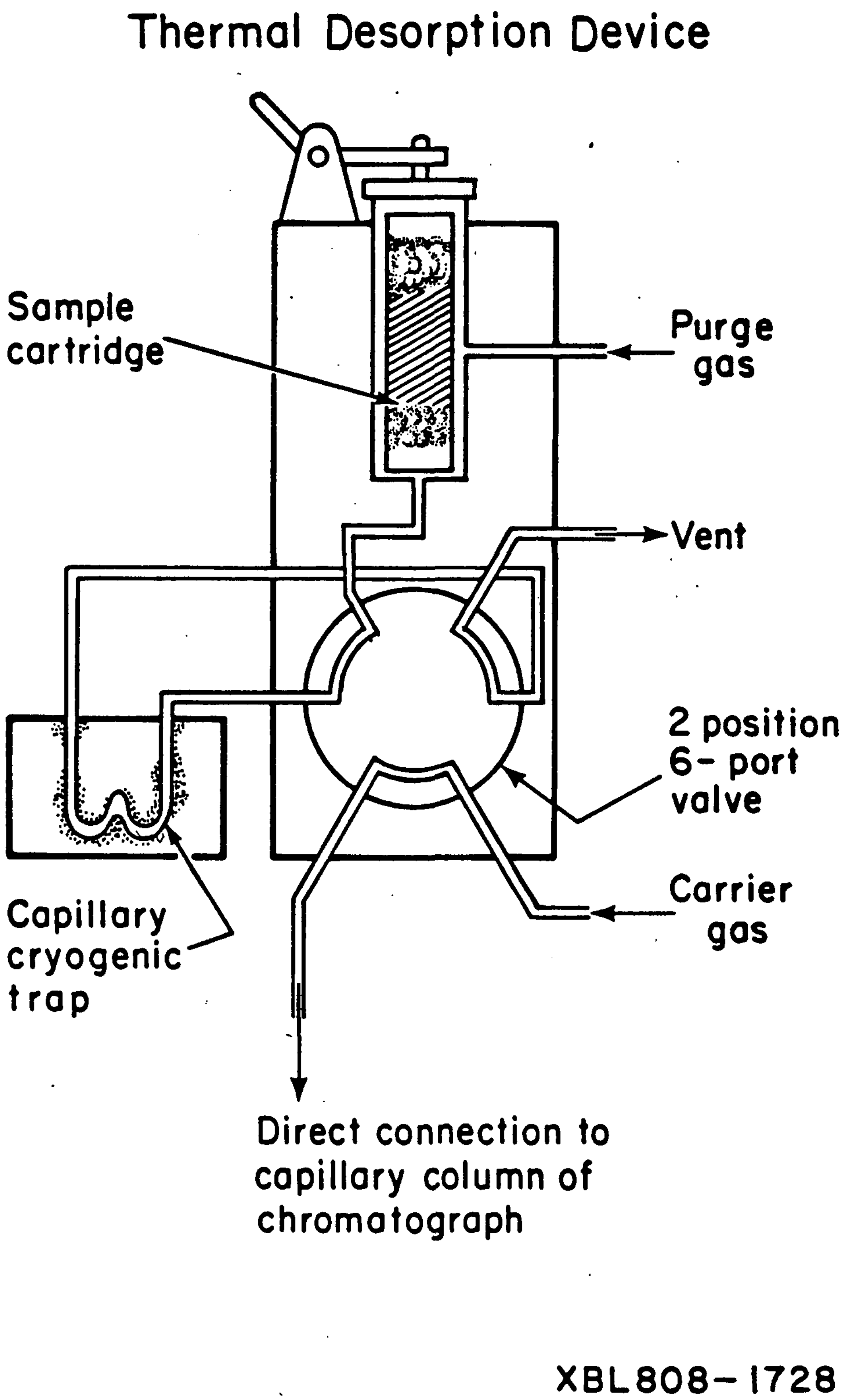

Figure 5-6. Schematic of NuTech thermal desorption device.

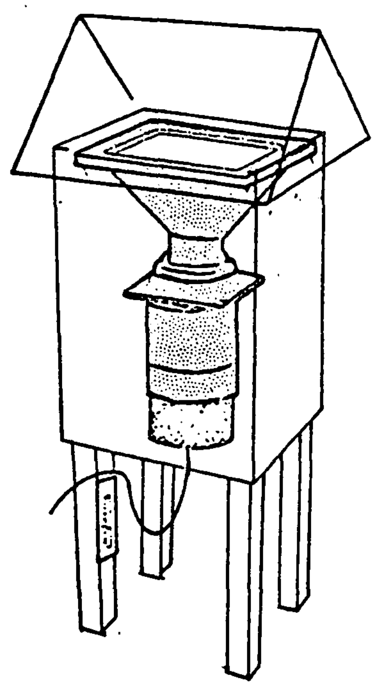

Figure 5-7. Assembled Hi-Vol sampler with shelter housing.

The mass concentration ($\mu g/m^3$) in ambient air is computed by measuring the mass of TSP collected and the volume of air sampled. Thus, this method is applicable to measurement of the mass concentration of TSP in ambient air. The size of the sample collected is usually adequate for other analyses.

5.2.2 Dichotomous Hi-Vol Sampler

Air is drawn through a mechanical separator enclosed in a covered housing and through a filter by a high-flow-rate blower. Particles with diameters greater than 2.5 μm are deposited in the mechanical separation chamber while particles less than 2.5 μm are captured on the glass fiber filter. The smaller size fraction can be separated for analysis either by gravimetric means or by specific compound or element identification.

5.2.3 Hi-Vol Sampler With Adsorbent

A high volume sample can be operated in either of the above modes of operation with an adsorbent placed after the glass fiber filter. The purpose of the adsorbent is to trap (adsorb) any condensible organic material which can be extracted or disorbed later. Recent studies have shown this to be a measurable fraction (>10 percent of the total catch).

5.3 LAB

5.3.1 Gas Chromatograph/Mass Spectrometer (GC/MS)

The Gas Chromatograph/Mass Spectrometer (GC/MS) is an ultra high sensitive analytical instrument. The instrument produces mass spectra of volatile and semi-volatile samples separated by the gas chromatograph or of samples introduced via a solid probe inlet.

The sample introduced via the GC is separated by the column and introduced into the source of the MS. The sample is ionized in the source and sent through a mass filter where a range of masses is scanned over a period of seconds. The output is a chromatogram which is characterized by the masses present and the elution time.

The sample introduced by solid probe is volatilized directly in the source and is characterized by the mass spectrum.

Data collection and manipulation are controlled by a dedicated computer system which minimizes operator time and report writing.

5.3.2 Ion Chromatography (IC)

Ion chromatography is used to identify and quantitate organic and inorganic ions in solution. IC combines the separation capabilities of ion exchange resins with conductivity detection. Small sample amounts are loaded onto ion exchange columns which separate the ions by their charge and size. The separated ions are detected by an increase in conductivity as they elute off the columns. The order of elution and the increase in conductivity determine the identity and quantity of the ion. To prevent background conductivity interference, a second exchange column converts the background ions to a common ionic form. Minimum detectable limits are often as low as 10 parts per billion or less.

5.3.3 HPLC/UV - Fluorescence

HPLC is a high pressure, highly efficient, high speed chromatographic technique. Variations of the experimental conditions and use of different detectors provides an immense work scope, and separations that are difficult or impossible by other means such as gas chromatography. Particular advantages of HPLC over gas chromatography are its ability to cope with polar, high molecular weight, thermally labile or relatively non-volatile compounds, and the ease with which fractions can be collected for further analyses.

The combination of a UV and a dedicated fluorescence detector allows the analyst to be specific and very sensitive (sub-nanogram) in the quantitation of fluorescent compounds such as polynuclear aromatic hydrocarbons (PNA).

5.3.4 Gas Chromatograph (GC)

The Gas Chromatograph is a sensitive analytical instrument which may identify any volatile or semi-volatile sample by means of separation, temperature and retention time. The unknown sample is introduced into a heated injector where it is volatilized and passed through a column by an inert carrier gas. The column is selected based on either the physical characteristics of the unknown or of the expected compounds.

The detector is selected based on the expected compounds.

The Electron Capture (EC) Detector is a radioactive source and is extremely sensitive to chlorinated hydrocarbons. This makes it especially suitable for analysis of volatile pesticides and most chlorinated compounds.

The Flame Ionization (FI) Detector is based on an oxidative hydrogen flame that ionizes molecular fragments which are collected at an electrode. The FID is less sensitive than the EC but is nearly uniform to all organics containing only carbon and hydrogen. Certain gases give little or no signal, i.e., H_2S, CS_2, CO, which makes them excellent solvents or media for analysis.

5.3.5 Metals

5.3.5.1 Inductively Coupled Plasma (ICAP). ICAP identifies and quantitates metals in solution. Atomic and ionic emission are measured at variable wavelengths of light. The sample is aspirated into an argon plasma flame. The energy of the flame excites either the atomic or ionic electrons. As the electrons fall back to their unexcited states, light is emitted. The intensity of this emission is measured by a photomultiplier tube. A double monochromator is used to observe many different wavelengths of light per analysis. The wavelength of emission and the intensity identify and quantitate the metal.

Determination of most metals is possible with minimum detectable limits as low as 5 parts per billion. Each analysis run can usually check for 30 to 40 elements. Generally, the amount of spectral overlap and interference is the main limiting factor on the number of elements checked for per analysis.

5.3.5.2 Atomic Absorption (AA). Atomic absorption identifies and quantitates metals in solution. A sample is aspirated into a flame and atomized. A light beam is directed through the flame into a monochromator, and onto a detector. The detector then measures the amount of light absorbed. The amount absorbed in the flame is proportional to the concentration of the element in the sample.

Absorption depends on the amount of free unexcited atoms. Usually, the ratio of unexcited to excited atoms is very high, which increases the sensitivity. Since each metal has its own absorption wavelength, a source lamp made up of that element is used. This makes the method relatively free of spectral interferences. However, each lamp can check for only one metal per analysis. The detection limits are often as low as 5 parts per billion.

6. ALTERNATIVE DESIGN APPROACHES TO RESIDENTIAL WOOD BURNING APPLIANCES

Several alternative residential woodstove designs have been or are being developed with the goals of improved overall efficiency and lower emission generation. Some of these designs are new, while others are old ideas which are being re-evaluated. These old ideas were initially designed for better fuel efficiency but are now being re-evaluated from an emission standpoint. Most of these alternative approaches fall into two main categories: those which utilize cord wood and those which use wood in other forms such as pellets or chips.

6.1 CORD WOOD DESIGNS

Most of the alternative cord wood burning stoves are designed to increase both the combustion efficiency and the subsequent transfer of the energy released into the room. These designs have been developed primarily to increase the overall thermal efficiency. Usually, increasing thermal and combustion efficiency results in lowered emissions.

The combustion of cord wood is inherently inefficient. In the localized combustion areas within the individual pieces of wood, there is insufficient oxygen present to fully combust the volatile organic compounds and CO driven out of the unburnt wood adjacent to the burning wood. In ordinary air tight stoves (and even in open fireplaces with high excess air), these combustible compounds are subject to rapid cooling once they are driven out of the wood and start to flow toward the flue. As soon as the temperature drops below the ignition point, no further burning will occur, no matter whether oxygen is present or not. Most secondary combustion stoves attempt to maintain these unburnt fuel components produced in the primary combustion zone (grate area) at a sufficiently high temperature and to provide sufficient oxygen so they will burn more completely. The two principal secondary combustion variants are defined by the absence or presence of a catalyst.

Noncatalyst secondary combustion stoves must maintain gas temperatures above 1,100°F to achieve ignition of the CO while providing sufficient oxygen. This appears to work well at high burn rates but is difficult to maintain at low burn rates. This trend can be seen by comparing tests OM2-84-1 through 7, Table 3-1. Note the low PM values at the higher burn rates. Several sources reported high operator attention was needed to maintain secondary combustion at low burn rates.

Placing a catalyst in the flue gas stream lowers the ignition temperature to about 400°F, thus greatly improving the changes for successful secondary combustion. Evidence for this can be seen by looking at tests OM2-84-30 through 33, Table 3-1. Note the low PM factor (1.1 g/kg) at a burn rate of 0.8 kg/hr. Catalysts, however, are not panaceas. Excessive temperature will cause melting and agglomeration of the precious metal greatly reducing the available contact area. Sulfur in coal and heavy metals in colored inks may poison the catalyst reducing its effectiveness. Even under normal homeowner use, effectiveness will decline, requiring periodic replacement of the catalyst cartridge to maintain good emission control.

6.2 NONCORD WOOD DESIGNS

Most noncord wood stoves utilize wood in the form of chips or compressed pellets. This form of wood fuel has commonly been burned in industrial wood boilers, but has seen very limited application to residential heating either in central systems or parlor stoves. The principal advantage of burrning wood in this form lies in the fact that each piece of fuel can be burned quickly in a nearly ideal temperature-oxygen environment which ensures virtually complete combustion.
Three residential-use stoves now entering the marketplace all employ a hopper to store 1 or 2 days fuel in pellet form. The fuel is automatically fed by an auger or similar device into the combustion zone at a variable rate dependent on home heating demand. Obviously there is a minimum rate required to maintain a continuous fire. Two drawbacks to widespread use of pellet- or chip-fueled residential stoves are (1) limited availability of fuel, and (2) loss of asthetics associated with gathering wood and tending the fire. Currently, pellets and chips are generally available only in those areas of the country where logging for construction and pulpwood are common. Certainly, if demand arose in

other parts of the country, suppliers would move into the market. The problem may be that homeowners will not buy a stove unless the fuel is readily available.

The fluidized bed optimizes the three "Ts" of combustion (Time, Temperature, and Turbulence). There was only one test citation available for this search, but it appeared to have promising results - lower emissions with increased efficiency.

The tunnel burner mentioned in one citation claimed to have a 99.999 percent reduction in POM emissions. Both of these burner modifications were used with wood chips or pellets to provide continuous feed to the systems.

Loss of the alsthetic appeal would be more difficult to counter. Convenience is certainly a positive selling point. At least a segment of the public would also react positively to the greatly reduced environmental impact of a clean burning stove.

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8.0 APPENDIX

18/5/6
81-00135
Air pollution emissions and control techniques: Residential heating units.
Robert, J.; Dibartolo, A. B.; Pinault, P. H.
Environment Canada, Environmental Protection Service, Air Pollution Control Directorate, Abatement and Compliance Branch, Combustion Sources Div., Fontaine Bldg., Ottawa, Ontario K1A 0H3, Canada
CANADA. ENVIRONMENTAL PROTECTION SERVICE REPORT SERIES. ECONOMIC AND TECHNICAL REVIEW REPORT Coden: ETRRDC Publ.Yr: Aug 1979
illus. 15 refs.
Eng., Fr. abs.
Languages: ENGLISH
Doc Type: REPORT
The principal air contaminant emissions attributable to fuel-fired residential heating units are particulates, SOx, unburnt hydrocarbons, NOx, and CO. Although domestic heating units account for only 11% of emissions from stationary sources, seasonal variations, geomorphology, and meteorology can combine to intensify greatly the adverse effects of these emissions. The reduction of emissions from heating systems is compatible with the present goal of energy conservation in that the best conservation strategies can reduce overall emissions. One strategy is burner modifications such as the addition of retention heads and the reduction of nozzle sizes. Another strategy is adjustments to furnaces and their controls to decrease cycle frequency and reduce flue gas losses. Further emission reductions could be effected by better quality control of fuel oil. Control over fuel oil S content and the nature of the hydrocarbon constituents would ensure better combustion and a reduction of overall emission levels. Recent substantial increases in fuel costs and concern about future supply have placed new pressures on the heating industry and precipitated the development of new, more efficient burners and furnaces. Another response to this situation has been a resurgence in the popularity of wood-fired heating. (AM)
Descriptors: Air pollution control; Emissions; Particulates; Sulfur oxides; Hydrocarbons; Nitrogen oxides; Carbon monoxide; Fuels; Fuel oils
Identifiers: residential heating units; control techniques

24/5/3
134724 *82-022144
THE ''BURNING HOT'' QUESTION: CAN WOOD STOVES MAKE IT IN THE STORAGE WORLD?,
TALBOT MICHAEL
ALTERNATIVE SOURCES OF ENERGY, SEP-OCT 81, V51, P6 (6)
FEATURE ARTICLE: CONVENTIONAL AIR-TIGHT WOOD-BURNING STOVES AND FURNACES ARE AN INEFFECTIVE WAY OF BURNING WOOD. TARS, PITCHES, RESINS, AND DANGEROUS GASES ARE FORMED AND CAN BE RELEASED TO THE ATMOSPHERE. IN 1974, THE MAINE AUDUBON SOCIETY BEGAN WORK OF A SOLAR HEATING SYSTEM. THE FURNACE WAS DESIGNED TO BURN WOOD MORE EFFICIENTLY WHILE STORING THE LARGE AMOUNT OF HEAT RELEASED FOR FUTURE USE. A SECOND VERSION OF THE FURNACE WAS DEVELOPED AND OPERATED AT 80% EFFICIENCY. THREE VERSIONS ARE ON THE MARKET AND ARE DESCRIBED. (3 DRAWINGS, 4 PHOTOS, 1 TABLE)
DESCRIPTORS: *WOOD ENERGY ; *THERMAL STORAGE ; *FURNACES, DOMESTIC ; *EMISSION CONTROL EQUIPMENT ; COAL IMPURITIES ; BOILERS, DOMESTIC
REVIEW CLASSIFICATION: 09

20/5/3
1013766 PB83-250720
Compilation of Air Pollutant Emission Factors, Third Edition, Supplement No. 14 (Including Supplements 1-7)
Environmental Protection Agency, Research Triangle Park, NC. Office of Air Quality Planning and Standards.
Corp. Source Codes: 034680059
Report No.: AP-42-SUPPL-14
May 83 172p
See also PB83-126557.
Languages: English
NTIS Prices: PC A08/MF A01 Journal Announcement: GRAI8326
Country of Publication: United States
In this Supplement for AP-42, new or revised emissions data are presented for Anthracite Coal Combustion; Wood Waste Combustion in Boilers; Residential Fireplaces; Wood Stoves; Open Burning; Large Appliance Surface Coating; Metal Furniture Surface Coating; Adipic Acid; Synthetic Ammonia; Carbon Black; Charcoal; Explosives; Paint and Varnish; Phthalic Anhydride; Printing Ink; Soap and Detergents; Terephthalic Acid; Maleic Anhydride; Primary Aluminum Production; Iron and Steel Production; Gypsum Manufacturing; Construction Aggregate Processing; Sand and Gravel Processing; Taconite Ore Processing; Western Surface Coal Mining; Fugitive Dust Sources; Unpaved Roads; Agricultural Tilling; Aggregate Handling and Storage Piles; and Industrial Paved Roads.
Descriptors: *Air pollution; Anthracite; Wood wastes; Coatings; Appliances; Furniture; Carbon black; Explosives; Detergents; Soaps; Paints; Maleic anhdride; Phthalic anhydride; Gypsum; Aluminum industry; Iron and steel industry; Pavement; Roads; Surface mining
Identifiers: *Emission factors; *Stationary sources; Wood stoves; Refuse derived fuels; Fugitive emissions; Unpaved roads; NTISEPAAQP
Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 68A (Environmental Pollution and Control--Air Pollution and Control)

23/5/5
0147919 EIM8304027919
CHARACTERIZATION OF EMISSIONS FROM RESIDENTIAL COAL STOVES.
Sanborn, Cedric R.
Vt Dep of Water Resour & Environ Eng, Montpelier, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 151-160 1982
Languages: English Conf. No.: 01854
Descriptors: STOVES-Environmetal Impact
Identifiers: RESIDENTIAL COAL EMISSION TESTING STUDY; PARTICULATE EMISSIONS; SULFUR DIOXIDE EMISSIONS; THREE COAL STOVE TYPES; RANGE OF BURNING RATES; TESTING WITH ANTHRACITE AND BITUMINOUS COAL; PRELIMINARY TEST PROGRAM RESULTS; SIGNIFICANTLY HIGHER PARTICULATE EMSSION RATE FOR BITUMINOUS COAL; EFFECT OF BURN RATE ON SULFUR DIOXIDE EMISSIONS; EFFECT OF FIREBOX TEMPERATURE ON SULFUR DIOXIDE EMISSIONS
Classification Codes: 643; 524; 451

? T 23/5/6-37

3/10

1157591 ERA-08:042212, INS-83:017234, NTS-83:018281, EDB-83:152419
Computing transient exposure to indoor pollutants
Owczarski, P.C.; Parker, G.B.
Pacific Northwest Lab., Richland, WA (USA)
13 P. Mar 1983
TIC Accession No.: DE83014500
76. annual meeting of the Air Pollution Control Association Atlanta, GA, USA 19 Jun 1983
Country of Publication: United States
Journal Announcement: EDB8307
Availability: NTIS, PC A02/MF A01; 1.
Report No.: PNL-SA-10838; CONF-830617-12
Note: Portions are illegible in microfiche products
Document Type: Report; Conference literature; Numerical data
Language: English
Subfile: NTS .(NTIS); INS .(US Atomindex input); ERA .(Energy Research Abstracts)
Work Location: United States
Contract No.: AC06-76RL01830
A computer code, CORRAL, is used to compute the transient levels of gases and respirable particulates in a residence. Predictions of time-varying exposure to radon (from the outside air, soil and well water) and respirable particulates (from outside air, wood stove operation and cigarette smoke) for a mother and child over 24 hours are made. Average 24-hour radon exposures are 13 times background (0.75 pCi/l) for the child and 4.5 times background for the mother. Average 24-hour respirable particulate exposures are 5.6 times background (100 ..mu..g/m/sup 3/) for the mother and 4.2 times background for the child. The controlling parameters examined are source location, flow rates between rooms, air infiltration rate and lifestyle. The first three are shown to influence the formation of local pockets of high concentration of radon and particulates, and the last parameter shows that lifestyle patterns ultimately govern individual exposure to these pockets of high concentrations. The code is useful for examination of mitigation measures to reduce exposure and examination of the effects that the controlling parameters have on exposure to indoor pollutants.
Descriptors: *INDOOR AIR POLLUTION----COMPUTER CALCULATIONS; *PARTICULATES----ECOLOGICAL CONCENTRATION; *RADON----RADIOECOLOGICAL CONCENTRATION; *RESIDENTIAL BUILDINGS----INDOOR AIR POLLUTION ; CHILDREN; COMPUTER CODES; EXPERIMENTAL DATA; TOBACCO SMOKES; VARIATIONS; WOMEN; WOOD BURNING APPLIANCES
Special Terms: AEROSOLS; AGE GROUPS; AIR POLLUTION; ANIMALS; APPLIANCES; BUILDINGS; COLLOIDS; DATA; DISPERSIONS; ECOLOGICAL CONCENTRATION; ELEMENTS; FEMALES; FLUIDS; GASES; INFORMATION; MAMMALS; MAN; NONMETALS; NUMERICAL DATA; PARTICLES; POLLUTION; PRIMATES; RARE GASES; RESIDUES; SMOKES; SOLS; VERTEBRATES
Class Codes: 500300*; 500200 ; B33*; C52

20/5/15
856614 PB81-217655
Control of Emissions from Residential Wood Burning by Combustion Modification
(Final rept. Jun 79-Nov 80)
Allen, John M. ; Cooke, W. Marcus
Battelle Columbus Labs., OH.
Corp. Source Codes: 038006000
Sponsor: Industrial Environmental Research Lab., Research Triangle Park, NC.
Report No.: EPA-600/7-81-091
May 81 100p
Languages: English
NTIS Prices: PC A05/MF A01 Journal Announcement: GRAI8121
Country of Publication: United States
Contract No.: EPA-68-02-2686
The report describes an exploratory study of factors contributing to atmospheric emissions from residential wood-fired combustion equipment. Three commercial appliances were operated with both normal and modified designs, providing different burning modes: updraft with a grate, updraft with a hearth, crossdraft, downdraft, and a high-turbulence mode utilizing a forced-draft blower. Fuels were naturally dried commercial oak cordwood, commercial green pine cordwood, oven-dried fir brands, and naturally dried oak cut into reproducible triangles. Continuous measurements of stack gases included O2, CO2, CO, NO, SO2, and total hydrocarbons (FID) as an indication of the total organic species in the stack gases during batch type operation. Several combustion modification techniques were identified which have an appreciable effect on emission factors and, therefore, can be developed and applied to reduce emissions in consumer use. The more promising design modifications include: prevention of heating the inventory of wood within the stove but not yet actively burning, focusing the air supply into the primary burning area with high turbulence, and increasing the temperatures in the secondary burning regions of the appliances.
Descriptors: *Air pollution control; *Wood; Stoves; Combustion products; Revisions; Residential buildings; Equipment; Oxygen; Carbon dioxide; Carbon monoxide; Nitrogen oxide(NO); Sulfur dioxide; Hydrocarbons; Design criteria ; Performance evaluation
Identifiers: NTISEPAORD; NTISEPAORD
Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 68A (Environmental Pollution and Control--Air Pollution and Control)

20/5/18
780215 COO-4559-1
Design, Construction and Performance of Stick-Wood Fired Furnace for Residential and Small Commercial Application, September 1, 1977-August 31, 1979
Hill, R. C.
Maine Univ. at Orono.
Corp. Source Codes: 050804000; 3877000
Sponsor: Department of Energy, Washington, DC.
Oct 79 28p
Languages: English
NTIS Prices: PC A03/MF A01 Journal Announcement: GRAI8019; NSA0500
Country of Publication: United States
Contract No.: EC-77-S-02-4559
An experimental program was conducted at the University of Maine at Orono to develop a combustion system for residential furnaces that solves the traditional problem of wood burning: inefficiency, air pollution, and fire hazard. The program led to the designs that are now covered by a patent application and are being manufactured by Dumont Industries, Madawaska Wood Furnace Company, and Hampton Technologies Corporation Ltd. The history, design, performance, and the construction of prototype production units are presented. (ERA citation 05:018993)
Descriptors: *Commercial buildings; *Residential buildings; *Wood; *Wood burning furnaces; Air pollution; Calorific value; Chemical composition; Combustion products; Concretes; Construction; Design; Experimental data; Fire hazards; Graphs; Maine; Manufacturing; Performance; Tables
Identifiers: ERDA/320101; ERDA/320104; NTISDE
Section Headings: 13A (Mechanical, Industrial, Civil, and Marine Engineering--Air Conditioning, Heating, Lighting, and Ventilating); 97J (Energy--Heating and Cooling Systems)

18/5/2
82-04512
Control of Emissions From Residential Wood Burning by Combustion Modification
Allen, J.M.; Cooke, W.M.
Battelle Columbus Lab., OH
Publ.Yr: 1981
NTIS, SPRINGFIELD, VA
SUMMARY LANGUAGE - ENGLISH; PB81-217655
Languages: ENGLISH
The report describes an exploratory study of factors contributing to atmospheric emissions from residential wood-fired combustion equipment. Three commercial appliances were operated with both normal and modified design, providing different burning modes: updraft with a grate, updraft with a hearth, crossdraft, downdraft, and a high-turbulence mode utilizing a forced-draft blower. Fuels were naturally dried commercial oak cordwood, commercial green pine cordword, oven-dried fir brands, and naturally dried oak cut into reproducible triangles. Continuous measurements of stack gases included O2, CO2, CO, NO, SO2, and total hydrocarbons (FID) as an indication of the total organic species in the stack gases during batch type operation.
Descriptors: combustion; wood; emissions; hydrocarbons; stacks; gases; turbulence; furnaces; air pollution control

1196909   EDB-83:191742
Development and testing of an automated wood-burning heating system. Final report
Martin (Werner), Chapel Hill, NC (USA)
48 P.   May 1981
TIC Accession No.: DE84000383
Country of Publication: United States
Journal Announcement: ERA8311
Availability: NTIS, PC A03/MF A01; 1.
Report No.: DOE/R4/10156-T1
Note: Portions are illegible in microfiche products
Document Type: Report
Languages: English
Subfile: ERA .(Energy Research Abstracts); NTS .(NTIS)
Work Location: United States
Contract No.: FG44-80R410156

An improved wood continuous, automated combustion system has been developed using a tunnel burner. The tunnel burner implemented into a boiler heating system has proven to be very efficient. The prototype was tested and evaluated. A second generation tunnel system was designed and fabricated. Work performed between April 1980 and April 1981 is summarized. The most important results of the project are: the finalized tunnel burner design; high combustion efficiency; and low air pollution emissions. 3 tables. (DMC)

Descriptors: *BURNERS----DESIGN; *FUEL FEEDING SYSTEMS----DESIGN; *WOOD----COMBUSTION; *WOOD BURNING APPLIANCES----DESIGN ; AIR POLLUTION ABATEMENT; AUTOMATION; EFFICIENCY; EMISSION; ENERGY SYSTEMS
Special Terms: APPLIANCES; CHEMICAL REACTIONS; FUEL SYSTEMS; OXIDATION; POLLUTION ABATEMENT; THERMOCHEMICAL PROCESSES
Class Codes: 090400*; 140504; 421000

23/5/20
0039963   EIM8210039963
EFFECT OF CATALYTIC COMBUSTION OF CREOSOTE REDUCTION, COMBUSTION EFFICIENCY, AND POLLUTION ABATEMENT FOR RESIDENTIAL WOOD HEATERS.
Zimar, Frank; VanDewoestine, Robert V.; Allaire, Roger A.
Corning Glass Works, NY, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 924-940 1982
Languages: English   Conf. No.: 00722
Descriptors: WOOD-Heating
Identifiers: CATALYTIC COMBUSTION; CREOSOTE REDUCTION; AIR POLLUTION ABATEMENT; NATURAL GAS; FLUE PIPES; CHIMNEYS; COMBUSTOR DESIGN; ORGANIC CHEMICALS
Classification Codes: 811; 643; 521; 451; 532

1196909   EDB-83:191742
Development and testing of an automated wood-burning heating system. Final report
Descriptors: *BURNERS----DESIGN; *FUEL FEEDING SYSTEMS----DESIGN; *WOOD----COMBUSTION; *WOOD BURNING APPLIANCES----DESIGN ; AIR POLLUTION ABATEMENT; AUTOMATION; EFFICIENCY; EMISSION; ENERGY SYSTEMS
Special Terms: APPLIANCES; CHEMICAL REACTIONS; FUEL SYSTEMS; OXIDATION; POLLUTION ABATEMENT; THERMOCHEMICAL PROCESSES
Class Codes: 090400*; 140504; 421000

✓ 1175232 EDB-83:170062

The effects of stove design and control mode on condensable particulate emissions, flue pipe creosote accumulation and the efficiency of woodstoves in homes

Symposium papers: energy from biomass and wastes VI

Barnett, S.G.; Feingold, B.W.; Courtney, L. (eds.)

Condar Co., NY

283-322 P. Jun 1982

6. annual conference on energy from biomass wastes VI Lake Buena Vista, FL, USA 25 Jan 1982

Country of Publication: United States

Publ: Institute of Gas Technology, Chicago, IL,

Journal Announcement: EDB8306

Report No.: CONF-820127-

Document Type: Analytic of a Book; Conference literature

Languages: English

Work Location: United States

Four years of woodstove research utilizing a mixture of laboratory and in-home investigations has lead to both the development at Condar Co. of a new extremely clean burning and efficient, commercially viable, catalytic woodstove as well as a new stove control system. Results are presented in four research areas: characterization of home burning rates, particulate emissions, in-home creosote accumulation rates, and in-home efficiency evaluations.

Descriptors: *CREOSOTE----BUILDUP; *STOVES----COMBUSTION PRODUCTS; *STOVES----DESIGN; *WOOD BURNING APPLIANCES----COMBUSTION PRODUCTS; *WOOD BURNING APPLIANCES----ENERGY EFFICIENCY ; AIR QUALITY; CATALYTIC COMBUSTORS ; COMBUSTION CONTROL; COMPARATIVE EVALUATIONS; CONTROL SYSTEMS; FLUE GAS; INDOOR AIR POLLUTION; PARTICULATES

Special Terms: AIR POLLUTION; APPLIANCES; COMBUSTORS; CONTROL; EFFICIENCY ; ENVIRONMENTAL QUALITY; GASEOUS WASTES; PARTICLES; POLLUTION; WASTES

Class Codes: 421000*; 320101; 090400; 500200

23/5/9

0147914 EIM8304027914

EFFECTS OF FIRING RATE AND DESIGN ON DOMESTIC WOOD STOVE PERFORMANCE.

Hayden, A. C. S.; Braaten, R. W.

Dep of Energy, Mines & Resour, Ottawa, Ont, Can

Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982

Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA

Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 56-69 1982

Languages: English Conf. No.: 01854

Descriptors: STOVES-Performance

Identifiers: CONTROLLED COMBUSTION WOOD STOVES; INCOMPLETE COMBUSTION; CORRESPONDING HIGH EMISSIONS; CLOSE RELATION OF EMISSION LEVELS OF CARBON MONOXIDE, UNBURNT; SENSITIVITY TO FIRING RATE BELOW CRITICAL RATE; CRITICAL RATE STOVE DEPENDENT; TWO TECHNICAL STRATEGIES FOR REDUCING EMISSION LEVELS ; SHIFTING OF CRITICAL BURN RATE TO LOWER LEVELS; LITTLE EFFECT ON EMISSIONS AT HIGHER BURN RATES; IMPORTANCE OF DETERMINATION OF CRITICAL RATE; EVALUATION OF WOOD FIRED APPLIANCES

Classification Codes: 643; 811; 521; 451

✓1110395 EDB-83:105268
Effects of woodburning on indoor pollutant concentrations
74. annual meeting of the Air Pollution Control Association. Session 22. Energy conservation effects on indoor air pollution (TT-7)
Moschandreas, D.J. (GEOMET Technologies Inc., Rockville, MD); Pelton, D.J.; Berg, D.R.
14 p, Paper 2 P. 1981
74. annual meeting of the Air Pollution Control Association Philadelphia, PA, USA 21 Jun 1981
Country of Publication: United States
Publ: Air Pollution Control Association, Pittsburgh, PA,
Journal Announcement: EDB8306
Report No.: CONF-810631-
Document Type: Analytic of a Book; Conference literature
Languages: English

Elevations in the concentrations of carbon monoxide, total suspended particulates, and benzo-a-pyrene are associated with fugitive indoor emissions from indoor woodburning activity in fireplaces and woodstoves. While indoor woodburning activity can not be statistically associated with elevated indoor concentrations of total aldehydes and formaldehyde, the existence of indoor sources of these pollutants has emerged from the collected data base. The operation of fireplaces leads to a marked increase of the infiltration rate of the room with the fireplace. This leads to waste rather than saving of energy. This is a pilot study and its conclusions must not be generalized to the American housing stock. It is apparent, however, that woodburning is an indoor activity that leads to an increase of human exposures to TSP and BaP, and it may contribute a significant portion of an individual's total exposure to those pollutants and their associated health effects.

Descriptors: *BENZOPYRENE----ECOLOGICAL CONCENTRATION; *CARBON MONOXIDE----ECOLOGICAL CONCENTRATION; *FORMALDEHYDE----ECOLOGICAL CONCENTR-ATION; *HUMAN POPULATIONS----HEALTH HAZARDS; *PARTICULATES----ECOLOGICAL CONCENTRATION; *WOOD FUELS----COMBUSTION PRODUCTS; *WOOD FUELS----ENVIRONM-ENTAL EFFECTS ; CARCINOGENS; ENERGY CONSERVATION; FIREPLACES; HOUSES; INDOOR AIR POLLUTION; SPACE HEATING
Special Terms: AIR POLLUTION; ALDEHYDES; AROMATICS; BUILDINGS; CARBON COMPOUNDS; CARBON OXIDES; CHALCOGENIDES; CONDENSED AROMATICS; ENERGY SOURCES; FUELS; HAZARDS; HEATING; HYDROCARBONS; ORGANIC COMPOUNDS; OXIDES; OXYGEN COMPOUNDS; PARTICLES; POLLUTION; POPULATIONS; RESIDENTIAL BUILDINGS
Class Codes: 500200*

23/5/27
0039925 EIM8210039925
EFFECTS OF WOODSTOVE DESIGN AND OPERATION ON CONDENSABLE PARTICULATE EMISSIONS.
Barnett, Stockton G.; Shea, Damian
State Univ of NY, Plattsburgh, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 227-266 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: FLUE GASES; WOOD STOVE DESIGN; FILTERS; FLOWMETERS; THERMOSTATS; AIR POLLUTION; CRITICAL STACK TEMPERATURE; CONVECTIVE HEATER
Classification Codes: 811; 521; 802; 451; 643; 732

18/5/5
81-00172

Environmental impact of residential wood combustion emissions and its implications.

Cooper, J. A.
Oregon Graduate Center, Dept. of Environmental Science, 19600 NW Walker Rd., Beaverton, OR 97005

Air Pollution Control Association. Journal 30(8), 855-861, Coden: JPCAAC Publ.Yr: Aug 1980
illus. 55 refs.
No abs.
Languages: ENGLISH
Doc Type: JOURNAL PAPER

A direct measurement of the impact of residential wood combustion (RWC) sources on ambient air particles showed that on a moderately cold day in Jan. 1978, 51% of the respirable particulates in a Portland, Oregon, residential area were from RWC sources. The results of a Vail, Colorado, survey showed that emissions from RWC could contribute <=0.64 T of particulates/d to the valley's air pollution levels. Health concerns relate to particulates and chemicals formed due to incomplete combustion. Two recent studies measured >100 chemicals and compound groups in emissions from burning wood and wood-burning stoves (WBS). The results are shown. Emissions from RWC sources must be considered a potential major threat to public health. There are currently 7 national ambient air quality standards and others are being considered. The major emissions and their emission factors for WBS and fireplaces are listed. These emissions normalized to a hypothetical WBS particulate level in the ambient environment are compared with ambient standards for an acute impact where WBS emissions are postulated to account for 260 mug/m3 of particulates. Emissions from RWC sources appear more significant when compared to other fuels for residential space heating and transportation sources. (FT)

Descriptors: Environmental impact; Combustion; Emissions; Particulates; Woods; Air pollution
Identifiers: residential wood combustion

✓212998 EDB-84:005496
Environmental impact of residential wood combustion emissions and its implications
Cooper, J.A.
J. Air Pollut. Control Assoc. (United States) 30:8 855-861 P. 1980
Coden: JPCAA
Journal Announcement: EDB8308
Document Type: Journal Article
Languages: English
Work Location: United States
Currently available information suggests a substantial environmental impact from residential wood combustion emissions. Air pollution from this source is widespread and increasing. Current ambient measurements, surveys, and model predictions indicate winter respirable (<2 micrometers) emissions from residential wood combustion can easily exceed all other sources. Both the chemical potency and deliverability of the emissions from this source are of concern. The emissions are almost entirely in the inhalable size range and contain toxic and priority pollutants, carcinogens, co-carcinogens, cilia toxic, mucus coagulating agents, and other respiratory irritants such as phenols, aldehydes, etc. This source is contributing substantially to the nonattainment of current particulate, carbon monoxide, and hydrocarbon ambient air quality standards and will almost certainly have a significant impact on potential future standards such as inhalable particulates, visibility, and other chemically specific standards. Emission from this growing source is likely to require additional expenditures by industry for air pollution control equipment in nonattainment areas.
Descriptors: *WOOD----COMBUSTION PRODUCTS; *WOOD BURNING APPLIANCES----ENVIRONMENTAL IMPACTS ; AIR POLLUTION; AIR POLLUTION ABATEMENT; ALDEHYDES; CARBON MONOXIDE; CARCINOGENS; COMBUSTION; ENVIRONMENTAL EFFECTS; HOUSES; PARTICULATES; PHENOLS; POLLUTANTS; RESIDENTIAL SECTOR; RISK ASSESSMENT
Special Terms: APPLIANCES; AROMATICS; BUILDINGS; CARBON COMPOUNDS; CARBON OXIDES; CHALCOGENIDES; CHEMICAL REACTIONS; HYDROXY COMPOUNDS; ORGANIC COMPOUNDS; OXIDATION; OXIDES; OXYGEN COMPOUNDS; PARTICLES; POLLUTION; POLLUTION ABATEMENT; RESIDENTIAL BUILDINGS; THERMOCHEMICAL PROCESSES

23/5/10
0147913 EIM8304027913
EMISSIONS AND THERMAL PERFORMANCE MAPPING FOR AN UNBAFFLED, AIRTIGHT WOOD APPLIANCE AND A BOX TYPE CATALYTIC APPLIANCE.
Knight, C. V.; Graham, M. S.
TVA, Chattanooga, Tenn, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 25-55 1982
Languages: English Conf. No.: 01854
Descriptors: STOVES
Identifiers: TENNESSEE VALLEY AUTHORITY TESTING OF RESIDENTIAL WOOD HEATING; ENERGY USE TEST FACILITY; EMISSION FACTORS; EFFICIENCIES; GAS CONCENTRATION MONITORING; TEMPERATURE AND WEIGHT DATA MONITORING; THERMODYNAMIC COMPUTER MODEL FOR CALCULATING EMISSION FACTORS AND; INDIRECT STACK LOSS METHOD; COMPARISON OF RESULTS WITH OTHER TEST DATA; DATA FOR LOWER BURN RATES; OPTIMUM OPERATING CONDITIONS
Classification Codes: 643; 811; 521; 451

20/5/4
1011629 PB83-247395

Evaluation of an S2 Sampler for Receptor Modeling of Woodsmoke Emissions

Northrop Services, Inc., Research Triangle Park, NC.

Corp. Source Codes: 058582000

Sponsor: Environmental Sciences Research Lab., Research Triangle Park, NC.

Report No.: EPA-600/D-83-099

Aug 83 20p

Languages: English

NTIS Prices: PC A02/MF A01 Journal Announcement: GRAI8325

Country of Publication: United States

The Source Signature (squared S) sampler was developed to characterize the carbon (C) and elemental components in fine particulate emissions from a residential wood burner. The hot exhaust is sampled and diluted with filtered air to simulate normal diffusion. The resulting aerosol is passed through a 2.5-mu m cyclone and the remaining particles collected on two parallel 1-mu m filers, one quartz and one Teflon. The quartz filter allows analysis of carbon content and the Teflon filter allows elemental analysis by x-ray fluorescence. Both filters are also weighed to determine the mass-emission rate. The test program's main objectives were (1) to test and improve the performance of the method, and (2) to make a laboratory measurement of the elemental composition including the carbon component to establish a source signature for use in receptor modeling.

Descriptors: *Mass; *Fines; *Air pollution; *X-ray fluorescence; *Samplers; *Chemical analysis; Mathematical models; Particles; Design criteria; Performance evaluation; Comparison

Identifiers: *Wood stoves; *Air quality; *Source signature samplers; *Air pollution sampling; Air pollution detection; NTISEPAORD

Section Headings: 14B (Methods and Equipment--Laboratories, Test Facilities, and Test Equipment); 7D (Chemistry--Physical Chemistry); 68A (Environmental Pollution and Control--Air Pollution and Control); 99A (Chemistry--Analytical Chemistry)

23/5/32
0039919 EIM8210039919
EXPERIMENTAL MEASUREMENTS OF EMISSIONS FROM RESIDENTIAL WOOD-BURNING STOVES.
Hubble, B. R.; Stetter, J. R.; Gebert, E.; Harkness, J. B. L.; Flotard, R. D.
Argonne Natl Lab, Ill, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA, Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 79-138 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: ORGANIC EMISSIONS; STACK GAS TEMPERATURES; HEATING REQUIREMENTS; LOGS; CREOSOTE; ENVIRONMENTAL ASSESSMENT; CHROMATOGRAPHY; DATA SYSTEM; ASH HANDLING
Classification Codes: 811; 521; 643; 901; 723; 802

21/5/7
146303 *80-006112
EPA'S RESEARCH PROGRAM FOR CONTROLLING RESIDENTIAL WOOD COMBUSTION EMISSIONS,
HALL ROBERT E. ; DEANGELIS DARYL G.
(EPA) AND; (MONSANTO RESEARCH CORP, OHIO)
APCA J, AUG 80, V30, N8, P862 (6)
RESEARCH REPORT: AN EPA-FUNDED STUDY BY THE MONSANTO CORP. OF OHIO, WAS CONDUCTED TO QUANTIFY CRITERIA POLLUTANTS AND TO CHARACTERIZE OTHER ATMOSPHERIC EMISSIONS FROM WOOD-FIRED RESIDENTIAL COMBUSTION EQUIPMENT. MAJOR FINDINGS OF THE MONSANTO CHARACTERIZATION STUDY ARE DISCUSSED. EQUIPMENT TESTED INCLUDED A ZERO CLEARANCE FIREPLACE AND TWO AIR TIGHT CAST IRON STOVES. WOOD TESTED INCLUDED SEASONED AND GREEN RED OAK AND YELLOW [illegible] SULFUR OXIDES, ORGANIC SPECIES, CONDENSABLE ORGANICS, PARTICULATES, AND TRACE ELEMENTS. BIOASSAY ANALYSES OF THE STACK EMISSIONS AND BOTTOM ASH WERE PERFORMED. (2 GRAPHS, 10 REFERENCES, 6 TABLES)
DESCRIPTORS: *EMISSION CONTROL PROGRAMS ; *EPA, FEDERAL ; *SPACE HEATING, DOMESTIC ; *WOOD ENERGY ; *PARTICULATES ; *AIR SAMPLING ; BIOASSAY ; CHROMATOGRAPHY, GAS ; NITROGEN OXIDES ; SULFUR OXIDES
REVIEW CLASSIFICATION: 01

23/5/14
0056062 EIM8211056062
FACTORS AFFECTING WOOD HEATER EMISSIONS AND THERMAL PERFORMANCE.
Harper, J. P.; Knight, C. V.
TVA, USA
Environmental and Economic Considerations in Energy Utilization, Proceedings of the 7th National Conference on Energy and the Environment. Phoenix, Ariz, USA Nov 30-Dec 3 1980
Sponsor: DOE, Washington, DC, USA; EPA, Washington, DC, USA
Source: Publ by Ann Arbor Sci Publ Inc, Mich, USA p 556-564 1981
ISBN: 0-250-40468-0
Languages: English Conf. No.: 00534
Descriptors: STOVES-Wood
Identifiers: RESIDENTIAL HEATING; TENNESSEE VALLEY AUTHORITY; ENVIRONMENTAL IMPACTS; CARBON MONOXIDE; HYDROCARBONS; COMPARATIVE EVALUATIONS; EMISSIONS DATA; EFFECTIVE FUEL SIZE; COMBUSTION EFFICIENCY; HEAT TRANSFER EFFICIENCY
Classification Codes: 811; 643; 902; 451; 641; 521

20/5/16
828563 DOE/EV-0114
Health Effects of Residential Wood Combustion: Survey of Knowledge and Research
Department of Energy, Washington, DC. Office of Environmental Assessments.
Corp. Source Codes: 052661219; 9511689
Sep 80 34p
Languages: English
NTIS Prices: PC A03/MF A01 Journal Announcement: GRAI8111; NSA0600
Country of Publication: United States
Health and safety issues related to residential wood burning are examined. Current research and findings are also described, and research status is assessed in terms of future health and safety requirements. (ERA citation 06:002170)
Descriptors: *Combustion; *Wood; Air pollution; Efficiency; Health hazards; Residential sector; Safety; Stoves
Identifiers: ERDA/140504; NTISDE
Section Headings: 6F (Biological and Medical Sciences--Environmental Biology); 68G (Environmental Pollution and Control--Environmental Health and Safety); 68A (Environmental Pollution and Control--Air Pollution and Control); 97J (Energy--Heating and Cooling Systems)

18/5/3
82-03065
Factors Affecting Wood Heater Emissions and Thermal Performance
Harper, J.P.; Knight, C.V.
TVA
Seventh Nat. Conf. Energy & Environ. Phoenix, AZ 30 Nov.-3 Dec. 1980
IN 'ENVIRON. & ECON. CONSIDERATIONS IN ENERGY UTILIZ. pp. 556-564, Publ.Yr: 1981
ANN ARBOR SCI. PUBL. INC., 230 COLLINGWOOD, P.O. BOX 1425, ANN ARBOR, MI 48106
SUMMARY LANGUAGE - ENGLISH
Languages: ENGLISH
The primary conclusion of this report from the environmental viewpoint, is by reducing emissions from wood heaters it is also possible to improve the efficiency of these devices. Therefore, the need exists to do both simultaneous emissions and efficiency testing. Secondly, fuel wood size may be a major operating variable governing the efficiency and emission of residential wood heaters.Thirdly, design considerations, primarily those affecting air flow into the combustion zone and flue gas resonance time in the wood heater, tend to be present in the more efficient stoves.Fourth, a comparative basis for evaluating different wood heaters, a performance index, was proposed. This performance index equalled the ratio of the efficiency to the source severity. This performance index could provide a basis for rank ordering those wood heaters which are the most highly efficient and least polluting devices.
Descriptors: heating systems; emissions; thermodynamics; wood processing; combustion; environmental impact

20/5/14
864227 PB81-226151
High Altitude Testing of Residential Wood-Fired Combustion Equipment (Final rept.)
Peters, J. A. ; DeAngelis, D. G.
Monsanto Research Corp., Dayton, OH. Dayton Lab.
Corp. Source Codes: 018509001
Sponsor: Industrial Environmental Research Lab., Cincinnati, OH.
Report No.: EPA-600/2-81-127
Jan 81 48p
See also rept. dated Mar 80, PB80-182066.
Languages: English
NTIS Prices: PC A03/MF A01 Journal Announcement: GRAI8124
Country of Publication: United States
Contract No.: EPA-68-03-2550

To determine whether emissions from operating a wood stove at high altitude differ from those at low altitude, a high altitude sampling program was conducted which was compared to previously collected low altitude data. Emission tests were conducted in the identical model stove using the same type of wood with the same moisture content, amount of wood charged, burning rate, air flow rate, and identical sampling intervals and port locations. Particulate emissions, carbon monoxide, and polycyclic organic matter were analyzed.

Descriptors: *Stoves; *Air pollution; *Oak wood; Combustion; Flue gases; Organic compounds; Carbon monoxide; Residential buildings; Performance tests
Identifiers: *Wood burning appliances; Particulates; NTISEPAORD
Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 68A (Environmental Pollution and Control--Air Pollution and Control); 97R (Energy--Environmental Studies)

23/5/2
0147927 EIM8304027927
INDOOR EXPOSURE TO CARBON CONTAINING PARTICULATES AND VAPORS IN HOMES WHICH USE WOOD FOR HEATING.
McGill, K. C.; Miller, D. P.
Washburn Univ, Topeka, Kans, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 281-295 1982
Languages: English Conf. No.: 01854
Descriptors: HOUSES-Fuels
Identifiers: PRELIMINARY RESULTS OF TESTING METHOD; THERMOGRPHIC METHOD; AMOUNT OF CARBON-CONTAINING SUBSTANCES IN AIR; RESULTS FOR EIGHT HOMES WITH DIFFERENT WOOD BURNING DEVICES; DIFFERENT DEVICES GIVING RECOGNIZABLE THERMOGRAMS; COLD METAL STOVES GIVING DETECTABLE EMISSIONS; FIREPLACES; CENTRAL FURNACE; METAL STOVES; EXPOSURE LEVELS
Classification Codes: 402; 811; 451

25/5/5
1162685 EI810862685
IMPACT OF RESIDENTIAL WOOD COMBUSTION ON URBAN AIR QUALITY: FIRST AMBIENT MEASUREMENTS.
Cooper, John A.; Currie, Lloyd A.; Klouda, George A.
Oreg Grad Cent, Beaverton
Proc Annu Meet Air Pollut Control Assoc 73rd, v 1, Montreal, Que, Jun 22-27 1980. Publ by APCA, Pittsburgh, Pa, 1980 Pap n 80-7. 1, 13 p CODEN: PRAPAP ISSN: 0099-4081
The impact of wood burning stoves and fireplaces on urban air quality has been measured and determined to be a significant source of respirable air particulates. One half of the respirable air particulates in a residential area of Portland, Oregon were found to have originated from wood combustion sources. The impact was determined using new low-level counting methods to measure biogenic carbon-14 and recently improved chemical mass balance methods. The methods and results of this study are discussed as well as their implications. 34 refs.
Descriptors: *AIR POLLUTION-*Air Quality; WOOD-Combustion; COMBUSTION; FURNACES, SPACE HEATING-Combustion
Classification Codes: 451; 811; 521; 643

23/5/28
0039924 EIM8210039924
MEASUREMENT OF WOOD HEATER THERMAL AND EMISSIONS PERFORMANCE.
Harper, Jerome P.; Harper, Jerome P.; Knight, C. V.
TVA, Chattanooga, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 210-226 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Heat Transfer
Identifiers: COMBUSTION; EMISSIONS PERFORMANCE; WOOD HEATER TESTING; HYDROCARBONS; CARBON MONOXIDE; ELECTRONIC SCALE; ELECTROCHEMISTRY
Classification Codes: 811; 641; 804; 803; 521; 801

23/5/6
0147918 EIM8304027918
MEASUREMENT TECHNIQUES AND EMISSION FACTORS FOR HAND-FIRED COALSTOVES.
Jaasma, Dennis R.; Macumber, Dale W.
Va Polytech Inst & State Univ, Blacksburg, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 129-150 1982
Languages: English Conf. No.: 01854
Descriptors: STOVES
Identifiers: RADIANT AND CONVECTIVE COAL STOVES; STUDY USING DILUTION TUNNEL TECHNIQUES; REAL-TIME MEASUREMENTS OF GAS-PHASE SPECIES EMISSIONS; TIME-AVERAGED TOTAL PARTICULATE AND CONDENSABLE ORGANICS EMISSIONS; AVERAGE HEAT RELEASE RATE; AVERAGE EFFICIENCIES FOR TWO STOVES STUDIED; SENSIBLE ENERGY LOSS MAJOR FACTOR IN DECREASING EFFICIENCY; MEASUREMENT TECHNIQUES FOR SMOKE EMISSIONS; ESTIMATE OF SAMPLING INTERVAL FOR ACCURATE EMISSIONS AND EFFICIENCY
Classification Codes: 643; 524; 451

1204489 NOR-83:05093, EDB-83:199324
Meeting on solid fuel room heaters. Testing for efficiency and safety
Soenju, O.K.; Klausen, T.
SINTEF, Trondheim (Norway)
186 P. Jun 1981
TIC Accession No.: DE83751460
Country of Publication: Norway
Journal Announcement: ERA8309
Availability: NTIS (US Sales Only), PC A09/MF A01; 1.
Report No.: STF-15A81020
Note: Portions are illegible in microfiche products
Document Type: Report; Numerical data
Languages: English
Subfile: ERA .(Energy Research Abstracts); NTS .(NTIS)
Work Location: Norway

The main goal of the meeting was to discuss testing procedures, standards, and trends of the future for solid fuel room heaters. The production and use of solid fuel room heaters are increasing at a rapid rate on a world wide scale, and it was felt that it would be very beneficial for experts on this subject from various countries to meet and exchange information and experience. A further goal of the meeting was to start some cooperative work on an international basis in this area. Senior staff members from research testing laboratories and governmental institutions in U.S., U.K., West-Germany, Denmark, Sweden, Finland and Norway perticipated. The report includes: A list of attendees, minutes of the meeting, notes taken during the meeting, correspondence, and papers/notes presented at the meeting. The technical papers/notes include the following topics: testing of solid fuel room heaters, measuring techniques and testing methods, safety testing, use of biomass, cooperative programs, and a paper on energy conservation in U.K. in relation to solid fuel room heaters. 37 drawings, 11 tables.

Descriptors: *SPACE HEATERS----THERMAL EFFICIENCY; *WOOD BURNING APPLIANCES----MEETINGS; *WOOD BURNING APPLIANCES----PERFORMANCE TESTING; *WOOD BURNING APPLIANCES----SAFETY ; AIR POLLUTION; CERTIFICATION; FIRE HAZARDS; FIREPLACES; SOLID FUELS; STANDARDS; STOVES; WOOD BURNING FURNACES

Special Terms: APPLIANCES; DOCUMENT TYPES; EFFICIENCY; FUELS; FURNACES; HAZARDS; HEATERS; POLLUTION; TESTING; WOOD BURNING APPLIANCES

Class Codes: 090400*; 140504; 299003 ; Z99*

20/5/9
945006 DE82005501

National Estimates of Residential Firewood and Air Pollution Emissions

Lipfert, F. W. ; Dungan, J. L.
Brookhaven National Lab., Upton, NY.

Corp. Source Codes: 004545000; 0936000
Sponsor: Department of Energy, Washington, DC.
Report No.: BNL-30367; CONF-811212-9
1981 10p
International conference on alternative energy sources, Miami Beach, FL, USA, 14 Dec 1981.
Languages: English Document Type: Conference proceeding
NTIS Prices: PC A02/MF A01 Journal Announcement: GRAI8304; NSA0700
Country of Publication: United States
Contract No.: AC02-76CH00016

Estimates are presented for the distribution and quantity of recent (1978-1979) use of residential firewood in the United States, based on a correlation of survey data from 64 New England counties. The available survey data from other states are in agreement with the relationship derived from New England; no constraints due to wood supply are apparent. This relationship indicates that the highest density of wood usage (Kg/ha) occurs in urban areas; thus exacerbation of urban air quality problems is a matter of some concern. The data presentation used here gives an upper limit to this density of firewood usage which will allow realistic estimates of air quality impact to be made. (ERA citation 07:044632)

Descriptors: *Wood; *Wood burning furnaces; *Fireplaces; Distribution; Fuels; Usa; Correlations; North atlantic region; Resources; Combustion; Air pollution; Environmental impacts
Identifiers: ERDA/500200; NTISDE
Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 68A (Environmental Pollution and Control--Air Pollution and Control)

1083656 EDB-83:078526
Factors affecting wood heater emissions and thermal performance
Environment and economical considerations in energy utilities
Harper, J.P.; Knight, C.V.
TVA, USA
556-564 P. 1980
7. national conference on energy and the environment Phoenix, AZ, USA 30 Nov 1980
Country of Publication: United States
Publ: Ann Arbor Sci Publ Inc.,Ann Arbor, MI,
Journal Announcement: EDB8302
Report No.: CONF-801171-
Document Type: Analytic of a Book; Conference literature; Numerical data
Languages: English
Work Location: United States
The objective is to identify those factors related to stove operation and design which may significantly affect the emissions and the efficiency of some residential wood heaters commonly used in TVA Region. The analysis presented shows that emissions and efficiency are interrelated factors governing the overall performance of wood heaters; such that reductions in emissions, for example carbon monoxide and total hydrocarbons, typically result in an increase in the efficiency of eight wood heaters tested. The paper not only presents the data obtained from the testing, but also proposes a performance index for the comparison of different wood heaters on the basis of both efficiency and emissions considerations. 7 refs.

1070992 ERA-08:019958, EDB-83:065861
Overview of R and D programs being coordinated by the inter-governmental wood combustion research group. Paper 81.8.3
Osborne, M.C.
US EPA, Research Triangle Park, NC, USA
Proc., Annu. Meet., Air Pollut. Control Assoc. (United States) vp P. 1981 Coden: PRAPA
74. annual meeting of the Air Pollution Control Association Philadelphia, PA, USA 21 Jun 1981
Journal Announcement: EDB8302
Report No.: CONF-810631-
Document Type: Journal Article; Conference literature
Languages: English
Work Location: United States
A study on the emissions from residential wood combustion was conducted. It was found that high concentrations of carbon monoxide and particulate are found in wood smoke but also concluded that socalled polycyclic organic matter (POM) is a more hazardous pollutant which is released from airtight wood stoves. A survey of programs for research of the hazards from air pollutants is given. 6 refs.
Descriptors: *COMBUSTION----RESEARCH PROGRAMS; *WOOD----COMBUSTION; *WOOD BURNING APPLIANCES----AIR POLLUTION ; AIR QUALITY; CATALYTIC CONVERTERS; POLYCYCLIC AROMATIC HYDROCARBONS; RESIDENTIAL SECTOR
Special Terms: APPLIANCES; AROMATICS; CHEMICAL REACTIONS; ENVIRONMENTAL QUALITY; EQUIPMENT; HYDROCARBONS; ORGANIC COMPOUNDS; OXIDATION; POLLUTION; POLLUTION CONTROL EQUIPMENT; THERMOCHEMICAL PROCESSES
Class Codes: 090400*; 500200; 140504

29/5/30

1020244 EDB-83:015107

Overview of emissions from wood combustion

Wood: an alternate energy resource for application industry and institutions. Conference proceedings and manual

Lim, K.J.; Lips, H.I.; Kohl, J.; Pulaski, E.; Rao, D.P.; Triplett, B. (eds.)

Acurex Corp., Mountain View, CA

61-74 P. 1981

industry and institutions Winston-Salem, NC, USA 7 Apr 1981

Country of Publication: United States

Publ: North Carolina State University,Raleigh, North Carolina,

Journal Announcement: EDB8301

Report No.: CONF-8104173-

Document Type: Analytic of a Book; Conference literature

Languages: English

Work Location: United States

Increasing combustion of wood for residential and industrial purposes has raised many environmental concerns. This paper attempts to assess and correlate scattered research results on the emissions from wood combustion. The major emissions are particulate matter, CO, and hydrocarbons, some of which are potentially carcinogenic. Research results show negligible amounts of SO/sub 2/ and low amounts of NO/sub x/ emissions. Parameters affecting emissions appear to be combustion design, firing rate, and excess air level. In general industrial users have lower emissions than residential users because of better combustion conditions. The problems of the residential emissions are aggravated by the localized and seasonal concentration of emissions. Significant data gaps exist, but the most urgent area needing investigation is the amount and kinds of potentially carcinogenic matter being emitted. (CKK)

Descriptors: *WOOD FUELS----COMBUSTION; *WOOD FUELS----POLLUTANTS ; AIR POLLUTION; CARBON MONOXIDE; CARCINOGENS; HYDROCARBONS; INDUSTRIAL PLANTS; PARTICLES; RESIDENTIAL BUILDINGS; WOOD BURNING FURNACES

Special Terms: APPLIANCES; BUILDINGS; CARBON COMPOUNDS; CARBON OXIDES; CHALCOGENIDES; CHEMICAL REACTIONS; ENERGY SOURCES; FUELS; FURNACES; ORGANIC COMPOUNDS; OXIDATION; OXIDES; OXYGEN COMPOUNDS; POLLUTION; THERMOCHEMICAL PROCESSES; WOOD BURNING APPLIANCES

Class Codes: 140504*; 090400; 500100

20/5/19
774547 PB80-182066
Preliminary Characterization of Emissions from Wood-fired Residential Combustion Equipment
DeAngelis, D. G. ; Ruffin, D. S. ; Reznik, R. B.
Monsanto Research Corp., Dayton, OH.
Corp. Source Codes: 018509000
Sponsor: Industrial Environmental Research Lab., Research Triangle Park, NC.
Report No.: EPA-600/7-80-040
Mar 80 159p
Languages: English
NTIS Prices: PC A08/MF A01 [illegible]
Country of Publication: United States
Contract No.: EPA-68-02-1874; EPA-ROAP-21AXM-071
This report describes a study conducted to quantify criteria pollutants and characterize other atmospheric emissions from wood-fired residential combustion equipment. Flue gases were sampled from a zero clearance fireplace and two air-tight cast iron stoves (baffled and nonbaffled design). Four wood types were tested, oak-seasoned and green- and pine-seasoned and green. Samples were analyzed for particulates, condensable organics, nitrogen oxides, carbon monoxide, sulfur oxides, organic species, and individual elements.
Descriptors: *Fireplaces; *Stoves; *Air pollution; *Oak wood; *Pine wood; Combustion; Nitrogen oxides; Carbon monoxide; Sulfur oxides; Flue gases; Organic compounds; Performance tests; Residential buildings
Identifiers: *Wood burning appliances; Particulates; NTISEPAORD
Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 68A (Environmental Pollution and Control--Air Pollution and Control); 97R (Energy--Environmental Studies)

23/5/13
0147910 EIM8304027910
PROCEEDINGS - RESIDENTIAL WOOD & COAL COMBUSTION SPECIALTY CONFERENCE.
Frederick, Edward R. (Ed.)
APCA, Pittsburgh, Pa, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference, Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA 300p 1982
Languages: English Conf. No.: 01854
Descriptors: HOUSES-Fuels
Identifiers: WOOD BURNING STOVES; COAL BURNING STOVES; DOMESTIC STOVE PERFORMANCE FACTORS AND ANALYSES; OUTDOOR AIR POLLUTION; INDOOR AIR POLLUTION; EUROPEAN ACTIVITES IN SOLID FUEL FIRED HEATING; EMISSIONS FROM RESIDENTIAL COAL STOVES; PREDICTION OF PULMONARY TOXICITY OF RESPIRABLE COMBUSTION PRODUCTS; SPACE HEATING
Classification Codes: 402; 811; 524; 521; 451; 461

25/5/2
1366960 EI8304026960
PROCEEDINGS - RESIDENTIAL WOOD & COAL COMBUSTION SPECIALTY CONFERENCE, 1982.
Frederick, Edward R. (Ed.)
APCA, Pittsburgh, Pa, USA
Proc - Resid Wood & Coal Combust Spec Conf, Louisville, Ky, USA, Mar 1-2 1982 Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA, 1982 300p
Languages: ENGLISH
The volume contains 18 papers and one abstract of a paper presented at the meeting. Subjects covered include techniques for achieving more complete combustion in wood stoves, emission and thermal performance mapping, effects of firing rate and design on domestic wood stove performance, European activities in solid fuel fired heating, measurement techniques, characterization of emissions from residential coal stoves, ambient impact of residential wood combustion, national assessment of air quality impacts, impact of residential wood combustion appliances on indoor air quality, prediction of pulmonary toxicity of respirable combustion products from residential wood and coal stoves, and others. Technical and professional papers from this conference are indexed with the conference code no. 01854 in the Ei Engineering Meetings (TM) database produced by Engineering Information, Inc.
Descriptors: *HOUSES-*Fuels; WOOD-Fuels; COAL; AIR POLLUTION-Analysis; STOVES; HEATING
Identifiers: WOOD BURNING STOVES; COAL BURNING STOVES; INDOOR AIR POLLUTION; HEALTH EFFECTS; EIREV
Classification Codes: 402; 811; 524; 521; 451; 461

23/5/33
0039918 EIM8210039918
PARTICULATE EMISSIONS FROM NEW LOW EMISSION WOOD STOVE DESIGNS MEASURED BY EPA METHOD V.
Kowalczyk, John F.; Bosserman, Peter B.; Tombleson, Barbara J.
Oreg Dep of Environ Qual, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 54 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: WOOD STOVE DESIGN; PARTICULATE EMISSIONS; STACK FILTER; AIR POLLUTION; FOSSIL FUELS; THERMOSTATS; DAMPER CONTROL; MOISTURE DETERMINATION; CREOSOTE
Classification Codes: 811; 521; 451; 532; 944; 732

20/5/13
867297 PB81-248155

Proceedings of the Conference on Wood Combustion Environmental Assessment Held at New Orleans in February 1981
(Rept. for Oct 80-Jun 81)
Ayer, Franklin A.
Research Triangle Inst., Research Triangle Park, NC.
Corp. Source Codes: 045968000
Sponsor: Industrial Environmental Research Lab., Research Triangle Park, NC.
Report No.: EPA-600/9-81/029; IERL-RTP-1235
1981 330p
Languages: English Document Type: Conference proceeding
NTIS Prices: PC A15/MF A01 Journal Announcement: GRAI8125
Country of Publication: United States
Contract No.: EPA-68-02-3170

These proceedings document presentations at the conference. The objective of the conference was to disseminate recent research and development findings on the subject of residential wood combustion. The conference sessions dealt with: (1) and overviw of environmental assessment activities, (2) specific emissions and heating efficiency assessments, (3) emissions control techniques, (4) [illegible] and (5) residential wood combustion issues and their resolution. In summary, the previously reported high concentrations of polycyclic organic matter (POM) in residential wood stove emissions were verified by several papers. One paper even reported high POM concentrations in the indoor environment of homes with wood stoves. High ambient values were not attributed to residential wood combustion, but many of the ambient impact studies were just beginning. Emission control techniques which were considered for controlling organic emissions included secondary combustion and the introduction of a combustion catalyst. These two control techniques were already being marketed; however, their reliability and structural stability were questioned by several researchers. Future regulation of wood stove emissions was considered unlikely due to problems relating to enforcing a residential emission standard.

Descriptors: *Air pollution control; *Wood; *Meetings; Residental buildings; Combustion products; Stoves; Assessments; Catalysts; Standards; Polycyclic compounds
Identifiers: NTISEPAORD
Section Headings: 13B (Mechanical, Industrial, Civil, and Marine Engineering--Civil Engineering); 68A* (Environmental Pollution and Control--Air Pollution and Control)

23/5/26
0039926 EIM8210039926

POM EMISSIONS FROM RESIDENTIAL WOODBURNING: AN ENVIRONMENTAL ASSESSMENT.
Peters, James A.
Monsanto Res Corp, Dayton, Ohio, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 267-288 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: HOME HEATING; ORGANIC SPECIES; EMISSION INVENTORY; FIREPLACE; COAL SMOKE; CARCINOGENS; PARTICULATE MATTER
Classification Codes: 811; 521; 643; 804; 461

20/5/8
0983614 DE83007784
Results of Laboratory Tests on Wood-Stove Emissions and Efficiency
Hubble, B. R. ; Harkness, J. B. L.
Argonne National Lab., IL.
Corp. Source Codes: 001960000; 0448000
Sponsor: Department of Energy, Washington, DC.
Report No.: CONF-810295-1
1981 19p
International trade show and wood heating seminar, New Orleans, LA, USA, 21 Feb 1981, Portions are illegible in microfiche products.
Languages: English Document Type: Conference proceeding
NTIS Prices: PC A02/MF A01 Journal Announcement: GRAI8316; NSA0800
Country of Publication: United States
Contract No.: W-31-109-ENG-38
Air-tight, wood-burning stoves were operated in a manner consistent with typical residential heating requirements in order to determine particulate and carbon monoxide emissions and creosote build-up. Test data are presented as functions of burn-rates and stove efficiencies. The principal conclusions are that emissions from the stove used in this study are related to log-size and wood burn-rate and that CO and particulate emissions and creosote build-up increased with increasing efficiency of operation. Therefore, future environmental testing should be conducted at typical stove operating conditions, low burn-rates with large logs. In addition, heat-loss calculations show a trade-off between sensible heat loss and CO-fuel heat loss over the range of burn-rates studied. This indicates that, if further improvements in stove efficiencies are desired, improvements in stove combustion efficiency are needed. This also decreases stove emissions. (ERA citation 08:020895)
Descriptors: *Wood burning furnaces; Particulates; Carbon monoxide; Creosote; Flue gas; Efficiency; Heat losses; Combustion; Carbon dioxide; Temperature distribution; Experimental data
Identifiers: ERDA/320101; ERDA/299003; ERDA/140504; NTISDE
Section Headings: 21D (Propulsion and Fuels--Fuels); 97K (Energy--Fuels); 68A (Environmental Pollution and Control--Air Pollution and Control)

23/5/16
0039978 EIM8210039978
REGULATORY OPTIONS FOR CONTROLLING EMISSIONS FROM COMBUSTION OF WOOD IN RESIDENTIAL APPLICATIONS.
Mors, Terry A.; Blair, Terrence T.; Cole, Robert H.
Dalton Dalton Newport, Cleveland, Ohio, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 1253-1271 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: PARTICULATE EMISSIONS; SPACE HEATING; AIR QUALITY; STOVE WASTE; CHIMNEY CLEANER; POLLUTION CONTROL; REGULATIONS; COMMON LAW DOCTRINES
Classification Codes: 811; 521; 451; 902

167471 83-006131
RESIDENTIAL WOOD & COAL COMBUSTION ,
APCA RESIDENTIAL WOOD & COAL COMBUSTION SYM PROCEEDINGS, LOUISVILLE, KY, MAR 1-2, 82, (308)

CONFERENCE PROCEEDINGS ON METHODS OF WOOD AND COAL COMBUSTION IN HOUSEHOLDS AND EMISSION MONITORING ARE PRESENTED. TOPICS DISCUSSED INCLUDE: IMPROVED COMBUSTION IN WOOD STOVES; EMISSION AND THERMAL PERFORMANCE MAPPING FOR AN UNBAFFLED, AIRTIGHT WOOD APPLIANCE AND A BOX-TYPE CATALYTIC APPLIANCE; EFFECTS OF FIRING RATE AND DESIGN ON DOMESTIC WOOD STOVE PERFORMANCE; SOLID FUEL-FIRED HEATING; RESIDENTIAL STOVE EMISSIONS FROM COAL AND OTHER ALTERNATIVE FUEL COMBUSTION; MEASUREMENT TECHNIQUES AND EMISSION FACTORS FOR HAND-FIRED STOVES; AN OUTDOOR EXPOSURE CHAMBER TO STUDY WOOD COMBUSTION EMISSIONS UNDER NATURAL CONDITIONS; IMPACT OF RESIDENTIAL WOOD COMBUSTION APPLIANCES ON INDOOR AIR QUALITY; AND INDOOR EXPOSURE TO CARBON-CONTAINING PARTICULATES AND VAPORS IN HOMES THAT BURN WOOD FOR HEATING. (NUMEROUS DIAGRAMS, GRAPHS, REFERENCES, TABLES)

DESCRIPTORS: *CONF PROCEEDINGS ; *WOOD ENERGY ; *COAL USAGE, DOMESTIC ; *MONITORING, ENV-AIR ; *AIR POLLUTION, INDOOR ; *HEATING SYSTEMS, DOMESTIC ; *MATHEMATIC MODELS-AIR ; *SPACE HEATING, DOMESTIC ; COMBUSTION ; PARTICULATES ; FIREWOOD ; PATHOLOGY, HUMAN ; AMBIENT AIR ; KEROSENE

REVIEW CLASSIFICATION: 01

21/5/2
165475 *83-004207
INDOOR AIR POLLUTION AND SOME SOLUTIONS,
MORRILL ELIZABETH
WOOD N ENERGY, DEC 82, V2, N12, P30 (4)

INSULATING THEIR HOUSES, RESEARCHERS HAVE DISCOVERED THAT SUCH ACTIVITIES SERVE TO SEAL IN POTENTIALLY DANGEROUS POLLUTANTS THAT NORMALLY ESCAPE THROUGH WINDOW AND DOOR CRACKS. ONE FREQUENT SOURCE OF INDOOR AIR POLLUTION IS THE FIREPLACE, ALONG WITH WOOD AND COAL-BURNING HEATERS. PARTICULATES AND CARBON MONOXIDE ARE EMITTED BY THESE SYSTEMS. KEROSENE HEATERS, GAS APPLIANCES, AND INSULATING MATERIALS ARE ALSO CULPRITS OF INDOOR AIR POLLUTION. AIR CLEANING APPLIANCES, INCREASED VENTILATION, AND THE USE OF AIR-TO-AIR HEAT EXCHANGERS CAN HELP PURIFY INDOOR AIR. (2 DIAGRAMS, 1 TABLE)

DESCRIPTORS: *AIR POLLUTION, INDOOR ; *HEATING SYSTEMS, DOMESTIC ; *INSULATION, COLD ; *RADON ; *RESPIRABLE DUST ; *FORMALDEHYDE ; *VENTILATION ; *HEAT EXCHANGERS ; WEATHERSTRIPPING ; GAS APPLIANCES ; KEROSENE

REVIEW CLASSIFICATION: 01

1130258 EDB-83:125133

Results of a forty-home indoor-air-pollutant monitoring study

Hawthorne, A.R.; Gammage, R.B.; Dudney, C.S.; Womack, D.R.; Morris, S.A.; Westley, R.R.; White, D.A.; Gupta, K.C.
Oak Ridge National Lab., TN (USA)

14 P. 1983
TIC Accession No.: DE83014138
76. annual meeting of the Air Pollution Control Association Atlanta, GA, USA 19 Jun 1983
Country of Publication: United States
Journal Announcement: ERA8307
Availability: NTIS, PC A02/MF A01; 1.
Report No.: CONF-830617-8
Note: Portions are illegible in microfiche products
Document Type: Report; Conference literature
Languages: English
Subfile: ERA .(Energy Research Abstracts); NTS .(NTIS)
Work Location: United States
Contract No.: W-7405-ENG-26

A study was conducted in 40 homes in the areas of Oak Ridge and west Knoxville, Tennessee. Concentrations of CO/sub x/, NO/sub x/, particulates, formaldehyde, and radon, as well as selected volatile organic compounds, were quantified. In addition, information was collected on air exchange rates, meteorological conditions, and structural and consumer products. This paper summarizes some of the results and provides specific examples of increased indoor concentrations of pollutants due to the operation of a kerosene space heater, a gas range, and a wood/coal stove. Results showed formaldehyde levels frequently exceeded 0.1 ppm; were highest in newer homes; and fluctuate diurnally and seasonally. Radon levels frequently exceeded 3 pCi/L and correlated strongly with house location. Organic pollutant levels were at least an order of magnitude higher indoors than outdoors. Combustion sources (especially unvented) significantly increased levels of CO/sub x/, NO/sub x/, and particulates. Air exchange rates were increased nearly two-fold by operation of the HVAC central air circulation fan.

Descriptors: *CARBON MONOXIDE----ECOLOGICAL CONCENTRATION; *FORMALDEHYDE----ECOLOGICAL CONCENTRATION; *HOUSES----AIR QUALITY; *NITROGEN OXIDES----ECOLOGICAL CONCENTRATION; *ORGANIC COMPOUNDS----ECOLOGICAL CONCENTRATION; *PARTICULATES----ECOLOGICAL CONCENTRATION; *RADON----ECOLOGICAL CONCENTRATION ; COAL; CONSUMER PRODUCTS; ELECTRIC APPLIANCES; ENERGY CONSERVATION; GAS APPLIANCES; INDOOR AIR POLLUTION; KEROSENE; METEOROLOGY; NATURAL GAS; SPACE HEATERS; TENNESSEE; VENTILATION; VOLATILE MATTER; WOOD; WOOD BURNING APPLIANCES

Special Terms: AIR POLLUTION; ALDEHYDES; APPLIANCES; BUILDINGS; CARBON COMPOUNDS; CARBON OXIDES; CARBONACEOUS MATERIALS; CHALCOGENIDES; ELEMENTS; ENERGY SOURCES; ENVIRONMENTAL QUALITY; FEDERAL REGION IV; FLUIDS; FOSSIL FUELS; FUEL GAS; FUELS; GAS FUELS; GASES; HEATERS; LIQUID FUELS; MATERIALS; MATTER; NITROGEN COMPOUNDS; NONMETALS; NORTH AMERICA; ORGANIC COMPOUNDS; OXIDES; OXYGEN COMPOUNDS; PARTICLES; PETROLEUM PRODUCTS; POLLUTION; RARE GASES; RESIDENTIAL BUILDINGS; USA

1137429 EDB-83:132305
A simple and effective technique for testing wood stove performance
Barnett, S.
Wood Energy (United States) II:12 54-57 P. Dec 1982 Coden: WOEND
Journal Announcement: EDB8307
Document Type: Journal Article
Languages: English
Work Location: United States
Simple and effective techniques for testing the performance of wood stoves is discussed. The two major sampling techniques are particulate emissions measurement and gas measurements.
Descriptors: *STOVES----PERFORMANCE TESTING; *WOOD BURNING APPLIANCES----PERFORMANCE TESTING ; EFFICIENCY; GAS ANALYSIS; HEAT TRANSFER ; MEASURING METHODS; PARTICULATES
Special Terms: APPLIANCES; ENERGY TRANSFER; PARTICLES; TESTING
Class Codes: 320100*

1020317 EDB-83:015180
Retrospective search on wood and wood waste burning equipment
144 P. 1980
Country of Publication: Ireland
Publ: Biomass Conversion Technical Information Service, Dublin, Ireland,
Journal Announcement: EDB8301
Document Type: Book; Bibliography/review article
Languages: English
Work Location: Ireland
This literature survey covers the period 1963 to date including residential and commercial wood stoves, fuels, mixed fuel combustion, emissions, wood waste combustion, general equipment, and miscellaneous.
Descriptors: *STOVES----BIBLIOGRAPHIES; *WOOD BURNING APPLIANCES----BIBLIOGRAPHIES; *WOOD BURNING FURNACES----BIBLIOGRAPHIES; *WOOD FUELS----BIBLIOGRAPHIES ; COMBUSTION; COMMERCIAL SECTOR; EQUIPMENT; RESIDENTIAL SECTOR; WOOD WASTES
Special Terms: APPLIANCES; CHEMICAL REACTIONS; DOCUMENT TYPES; ENERGY SOURCES; FUELS; FURNACES; OXIDATION; SOLID WASTES; THERMOCHEMICAL PROCESSES ; WASTES; WOOD BURNING APPLIANCES
Class Codes: 140504*; 090400; 299003

23/5/37
0013534 EIM8207013534
RESIDENTIAL WOOD FIRED FURNACES: RESULTS FROM A DEMONSTRATION OF ADVANCED SYSTEMS.
Brandon, R. J.
Inst of Man & Resour, Charlottetown, Prince Edward Isl, Can
Symposium Papers - Energy from Biomass and Wastes 5. Lake Buena Vista, Fla, USA Jan 26-30 1981
Sponsor: Inst of Gas Technol, Chicago, Ill, USA
Source: Symposium Papers - Energy from Biomass and Wastes 5. Publ by Inst of Gas Technol, Chicago, Ill, USA p 175-202 1981
CODEN: EBWADU
Languages: English Conf. No.: 00130
Descriptors: FURNACES, SPACE HEATING-Fuels
Identifiers: THERMAL PERFORMANCE; COMBUSTION SYSTEMS; EMISSIONS; WOOD WASTE UTILIZATION; BIOMASS COMBUSTION; ENERGY DENSITY; CREOSOTE FORMATION
Classification Codes: 643; 811; 524; 521; 901

18/5/3
99125287 CA: 99(16)125287z CONFERENCE PROCEEDING
Thermal performance testing of residential solid fuel heaters
AUTHOR(S): Shelton, Jay W.
LOCATION: Shelton Energy Res., Santa Fe, NM, 87502, USA
[illegible]
Solutions EDITOR: Cooper, John A. (Ed)^ Malek, Dorothy (Ed)^ DATE: 1982
PAGES: 1117-59 CODEN: 5OEHA6 LANGUAGE: English MEETING DATE: 810000
PUBLISHER: Oreg. Grad. Cent., Beaverton, Oreg
SECTION:
CA151018 Fossil Fuels, Derivatives, and Related Products
CA152XXX Electrochemical, Radiational, and Thermal Energy Technology
IDENTIFIERS: standardization evaluation residential heater, solid fuel residential heater evaluation, wood coal residential heater evaluation, combustion residential wood coal evaluation
DESCRIPTORS:
Wood...
combustion of, evaluation of residential heaters for
Air pollution...
emissions, from residential wood or coal heaters, evaluation criteria including
Creosote...
emissions of, from wood or coal residential heaters, evaluation criteria including
Heat transfer...
in residual wood or coal heaters, evaluation criteria including
Combustion...
of coal and wood, evaluation of residential heaters for
Standardization...
of residential wood or coal heaters, criteria for
Heating systems and Heaters...
residential, for wood and coal, evaluation of

23/5/11
0147912 EIM8304027912
TECHNIQUES FOR ACHIEVING MORE COMPLETE COMBUSTION IN WOOD STOVES.
Allen, John M.; Piispanen, William H.
Battelle, Columbus Lab, Ohio, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA; Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 2-24 1982
Languages: English Conf. No.: 01854
Descriptors: STOVES
Identifiers: SECONDARY COMBUSTION; REDUCTION OF AIR POLLUTION EMISSIONS; HIGH BURNING RATES; SMALL AIR-TIGHT BOX STOVE OPERATING AT LOW BURNING RATES; EXPERIMENTAL STUDY; DESIGN OF SECONARY AIR INLET SYSTEM; QUALITY OF SECONDARY AIR ADMITTED; THERMAL INSULATION OF STOVE; SIMULTANEOUS MONITORING OF CARBON MONOXIDE AND TOTAL HYDROCARBON; AIR IN-LEAKAGE THROUGH JOINTS
Classification Codes: 643; 811; 521

23/5/8
0147915 EIM8304027915
WOODSTOVE DESIGN AND CONTROL MODE AS DETERMINANTS OF EFFICIENCY, CREOSOTE ACCUMULATION, AND CONDENSABLE PARTICULATE EMISSIONS.
Barnett, Stockton G.
Condar Co, Hiram, Ohio, USA
Proceedings - Residential Wood & Coal Combustion Specialty Conference. Louisville, Ky, USA Mar 1-2 1982
Sponsor: APCA, Resid Fuel Combust Comm, Pittsburgh, Pa, USA; APCA, Indoor Air Qual Comm, Pittsburgh, Pa, USA
Source: Publ by APCA (Spec Conf Proc SP-45), Pittsburgh, Pa, USA p 70-88 1982
Languages: English Conf. No.: 01854
Descriptors: STOVES-Performance
Identifiers: THERMOSTATIC CONTROL; CATALYTIC WOOD STOVE; HOME BURN RATES CAUSING EXTENSIVE CREOSOTE FORMATION AND HIGH; EMISSION FACTORS DECREASING AS BURN RATE INCREASES; EFFECT OF WOOD PIECE SIZE; BURN RATE; EXTREMES OF WOOD MOISTURE; CREOSOTE ACCUMULATION IN FLUEPIPES; TEST HOUSES IN NEW YORK AND OHIO; EXPERIMENTAL STUDY OF WOOD STOVE EFFICIENCY
Classification Codes: 643; 811; 521; 451

23/5/29
0039923 EIM8210039923
WOOD COMBUSTION EMISSIONS AT ELEVATED ALTITUDES.
Peters, J. A.; Hughes, T. W.; DeAngelis, D. G.
Monsanto Res Corp, Dayton, Ohio, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
Sponsor: Oreg Grad Cent, Beaverton, USA; Northwest Environ Res Cent, USA; Omark Ind, Oreg Saw Chain Div, USA
Source: Publ by Oreg Grad Cent, Beaverton, USA p 199-209 1982
Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: ELEVATED ALTITUDES; HOME HEATING; POLLUTANT EMISSIONS; DATA COLLECTION; AIRTIGHT STOVE; BOILER PLATE; FILTERS; SEASONED OAK; SOLVENT EXTRACTION
Classification Codes: 811; 521; 641; 723; 614; 451

23/5/21
0039960 EIM8210039960
WOOD HEATING SYSTEM DESIGN CONFLICTS AND POSSIBLE RESOLUTIONS.
Shelton, Jay
Shelton Energy Res, Santa Fe, NM, USA
Proceedings - 1981 International Conference on Residential Solid Fuels, Environmental Impacts and Solutions. Portland, Oreg, USA Jun 1-4 1981
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Languages: English Conf. No.: 00722
Descriptors: WOOD-Combustion
Identifiers: HEATING SYSTEM; SOLID FUELS; WOOD STOVES; HEAT TRANSFER EFFICIENCY; CHIMNEYS; CREOSOTE; AIR POLLUTION
Classification Codes: 811; 521; 643; 641; 451

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Woodburning stove (Patent)
Jarboe, J.E.
Patent No.: US 4,335,702 Filed date 22 Aug 1979
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Country of Publication: United States
Note: PAT-APPL-068622
Document Type: Patent
Languages: English
Work Location: United States

An efficient, clean burning, woodburning stove in which super heated fresh air and exhaust gases from the primary combustion of the wood fire are introduced into a secondary combustion chamber wherein these gases are mixed to recombust remaining fuel particles. Exhaust from the secondary combustion chamber enters a heat exchange chamber wherein the heat content of the exhaust gas is transferred to the cooking surface of the stove. The burning rate of both the primary and secondary combustion can be independently controlled by individually selecting the air supplies to the combustion areas. An inclined grate, in combination with the direction of the exhaust gases, provides a self feeding feature in which an even burning rate of the fire is insured.

Descriptors: *STOVES----DESIGN; *WOOD BURNING APPLIANCES----AIR POLLUTION CONTROL; *WOOD BURNING APPLIANCES----FUEL ECONOMY ; AIR FLOW; COMBUSTION CHAMBERS; COMBUSTION CONTROL; EXHAUST GASES; FOOD PROCESSING; HEAT EXCHANGERS; HEAT TRANSFER

Special Terms: APPLIANCES; CONTROL; ENERGY TRANSFER; FLUID FLOW; FLUIDS; GAS FLOW; GASEOUS WASTES; GASES; POLLUTION CONTROL; PROCESSING; WASTES

Class Codes: 320100*

KEY WORDS

Sources

- Wood Stoves
- Wood Combustion
- Wood Heating
- Wood Furnaces
- Wood Heaters
- Wood Pyrolysis
- Wood Stokers
- Wood Pellets
- Wood Burning
- Woodstove Efficiency
- Residential Heating
- Residential Combustion
- Home Heating
- Fireplaces
- Residential Solid Fuels
- Biomass Combustion
- Biomass Energy

Emissions

- Wood Smoke
- Wood Volatiles
- POM Emissions
- PAH Emissions
- PNA Emissions
- BAP Emissions
- Pyrene Emissions
- Polar Fraction
- Acid Fraction
- Organic Fraction
- Inorganic Fraction
- Particle Bound Organics
- Condensible Organics
- Condensible Particulates
- Organic Emissions
- Inorganic Emissions
- Air Emissions
- Emission Factors
- Particulate Emissions
- Gaseous Emissions
- Chemical Emissions
- Carbonaceous Pollutants
- Toxic Air Emissions
- Hazardous Air Pollutants
- Genotoxic Pollutants
- Emission Characteristics
- Air Pollutants
- Indoor Air Pollution

KEY WORDS (Concluded)

<u>Effects</u>

- Carcinogenicity
- Mutagenicity
- Carcinogens
- Mutagens
- Cancer
- Health Effects
- Biological Effects
- Ecological Effects
- Bioassay
- Ames Test
- Salmonella Bioassay
- Tradescantia Bioassay

<u>Miscellaneous</u>

- Atmospheric Transforms
- Source Apportionment
- Source-Receptor Models
- Receptor Models
- Personal Monitoring
- Occupant Exposure
- Human Exposure
- Risk Assessment
- Particulate Sampling
- High Volume Sampling
- Organic Analysis
- Organic Fractionation