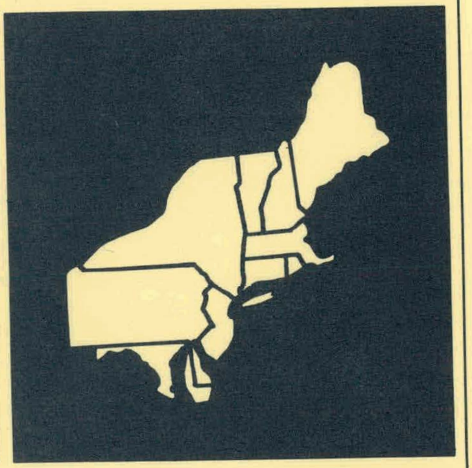

NORTHEAST REGIONAL BIOMASS PROGRAM

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PARTICULATE EMISSIONS
FROM
RESIDENTIAL WOOD COMBUSTION

FINAL REPORT PREPARED BY
ROY F. WESTON CO.
West Chester, PA

PREPARED FOR:

Northeast Regional Biomass Program
CONEG Policy Research Center, Inc.

Technical Coordinator:
The Technical Development Corporation

MASTER

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EXECUTIVE SUMMARY

Roy F. Weston, Inc. (WESTON), under a subcontract to the Coalition of Northeast Governors (CONEG) Policy Research Center, Inc. was retained to analyze the impact of residential wood combustion on ambient air quality and public health. Strategies to control the impact of residential wood combustion on air quality have recently been implemented in Oregon and other western states. The primary objective of this study was to determine if similar strategies need be implemented in Northeastern states. The secondary objective of this study was to provide a resource document for the states when pursuing the analysis of localized problems resulting from residential wood combustion.

Specific tasks performed under the contract include assigning emission rates for total suspended particulates (TSP) and benzo(a)pyrene (BaP) from wood burning stoves, estimating the impact on ambient air quality from residential wood combustion and elucidating the policy options available to Northeastern states in their effort to limit any detrimental effects resulting from residential wood combustion. Ancillary tasks included providing a comprehensive review on the relevant health effects, indoor air pollution and toxic air pollutant studies.

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INTRODUCTION

Roy F. Weston, Inc. (WESTON), under a subcontract to the Coalition of Northeast Governors (CONEG) Policy Research Center, Inc., was retained to analyze the impact of residential wood combustion on ambient air quality and public health. The analysis was performed under a grant from the U.S. Department of Energy (DOE) No. DE-FG05-830R21389. The analysis proceeded under the advisement of a group consisting of representatives from Northeast States Coordinated Air Use Management (NESCAUM), the U.S. Environmental Protection Agency (U.S. EPA), state air quality offices in the eleven state region, and the wood stove industry.

The specific tasks completed by WESTON relating to residential wood combustion under this subcontract were as follows:

1. Compiling studies relevant to residential wood combustion in the topical areas of emission characteristics, ambient air quality, health effects and policy options.

2. Reporting the nature and extent of the impacts on public health and ambient air quality caused by residential wood combustion.

3. Examining the growth of residential wood combustion within the eleven (11) state region.

SECTION 1

COMPILATION OF RELEVANT STUDIES

The objective of this section is to compile air quality studies used to determine wood stove emissions. An extensive bibliography has been compiled and placed in Section 9.0 of this document. Wood stove emission studies are divided into two categories:

- Emission Characterization

- Impact Analysis.

Table 1-1 contains a detailed chart of the critical parameters studied in emission characterization projects. Total suspended particulates (TSP) was found to be the most well studied pollutant, followed by carbon monoxide (CO). Both benzene extractables and benzo(a)pyrene were characterized in seven studies. Other polynuclear aromatic compounds were included in six projects.

A variety of short-term biological model systems are available for assessing the effects of wood smoke exposure. These systems are characterized by the use of end points to measure genotoxicity. In general, a battery of tests are conducted which allow evaluation of toxic effects, mutagenesis, DNA damage and repair, chromosomal alteration and neoplastic transformation. One such test, the Ames assay, utilizes bacterial systems to get a measure of the mutgenic potential

TABLE 1-1

CRITICAL PARAMETERS CONTAINED IN EMISSION CHARACTERIZATION STUDIES

REF.	STOVES	EMISSION FACTORS							FUEL						COMBUSTION PARAMETERS					
NO.	TESTED	POM	TSP	BE	BAP	PNA	CO	HC	M	OK	PN	FR	OT	CE	HT	OE	CT	FR	EA
1	5		o	o	o	3	o	o	o				o						o
2	2		o	o		16	o											o	
3	3				o		o		o	o	o							o	o
4	14		o	o														o	
5	1		o	o	o	27	o			o	o							o	o
8	1		o															o	
9			o				o												
11	2		o							o	o		o						
12	2		o	o					o	o	o								
14	-		o		o		o	o		o	o		o						
16	6		o				o	o	o			o					o	o	o
17			o	o	o	12	o	o	o					o	o	o	o	o	o
18	5		o						o			o						o	
19					o	9				o	o		o						
20	4		o				o		o			o						o	
21	2		o				o	o						o	o	o	o	o	o
22	5	o	o	o			o	o	o	o		o		o	o	o	o	o	o
23	4		o		o	25	o								o			o	o

KEY TO ABBREVIATIONS USED IN TABLE 1-1

EMISSION FACTORS

TSP = Total Suspended Particulate
BE = Benzene extractable organic matter
BAP = Benzo (a) pyrene
PNA = Other polynuclear aromatic compounds
AM = Ames testing
CO = Carbon monoxide
HC = Unburned hydrocarbons

FUEL CHARACTERISTICS

M = % moisture
OK = Oak
PN = Pine
FR = Fir
OT = Other wood fired

COMBUSTION PARAMETERS

CE = Combustion efficiency
HT = Heat transfer
OE = Overall efficiency
CT = Combustion chamber temperature
FR = Firing Rate
EA = Excess air

of organic compounds or compound mixtures. Ames assays were conducted in three characterization studies.

Several experiments have been conducted on animal exposure to wood smoke. One research group conducted animal tests on exposure to smoke from finished home products. Other groups performed studies which use products of combustion from fire wood. A list of reference numbers and study categories for health effect studies are shown in Table 1-2.

There are two methods which exist to conduct source impact analysis studies. The classical method is source-dispersion modeling. This modeling method combines information about emission factors and meteorological dispersion parameters to predict the impact at a receptor. The EPA has many approved models to determine the impact of point, line and area sources. The more recently developed method employs receptor modeling to apportion the contribution of particulate matter to each source category. Mathematical methods employed in receptor modeling include chemical mass balance, factor analysis and multiple regression. Physical and chemical measurements are required as a precursor to performing receptor analysis.

Impact Analysis studies most often couple a measurement program with a modeling study. The Tennessee Valley Authority used measurements to calibrate and validate dispersion modeling results. The "Portland Aerosol Characterization Study" employed chemical mass balance methods in a receptor modeling study to determine the contribution of vegatative burning to the total ambient particulate mass. Table 1-3 com-

TABLE 1-2

HEALTH EFFECTS STUDIES

REFERENCE NUMBERS	DESCRIPTION
1, 14, 23	Ames assay conducted on wood stove emissions
53-56	Animal exposure tests on combusted finished wood products
59, 60, 63	Epidemiological survey
61	Indoor air pollution and prevalence of lung disease
62	Patheological research
64	Annual inhalation studies on wood smoke

TABLE 1-3
CRITICAL PARAMETERS CONTAINED IN IMPACT ANALYSIS STUDIES

REF.	MEASUREMENTS	MODELING
24	CH_3Cl, FP	CEB
25	TSP, BaP	N.P.
26	TSP, FP, C14	CMB
29	C14	CMB
31	NAA	EI (TSP, FP)
32	NAA	EI DM (TSP)
33	TSP, SO_4, RP, NO_2, NAA	ANOVA
34	TSP, PAH	N.P.
35	TSP, PAH, SEM	DM
36	TSP, PAH, SEM	DM, CMB
37	NAA	DM

KEY to TABLE 1-3:

MODELING
CEB = Chemical Element Balance
CMB = Chemical Mass Balance
E.I. = Emissions Inventory
DM = Dispersion Modeling
ANOVA = Analysis of Variance (across sites)
N.P. = None performed

Measurements
CH_3Cl = Methylene Chloride
FP = Fine Particulate Matter
TSP = Total Suspended Particulate
C14 = Carbon 14
BaP = Benzo (a) pyrene
RP = Respirable Particulate Matter
SO_4 = Sulfates
NO_2 = Nitrogen Dioxide
NAA = Neutron Activation Analysis (metals)
PAH = Polycyclic Aromatic Hydrocarbons
SEM = Scanning Electron Microscope (particle differentiation)

piles the parameters examined in these and other impact analysis studies.

As shown in Table 1-3, TSP is the most frequently measured parameter of impact studies. Other common pollutants measured include PAH, carbon monoxide and fine particles (FP). Physical characterization techniques such as neutron activation analysis (NAA) and scanning electron microscopy (SEM) are employed to measure many parameters simultaneously. X-ray fluorescence, an important physical technique is used frequently. Of the impact analysis studies reviewed, about half use dispersion modeling techniques while the other half selected receptor modeling to characterize the ambient aerosol.

In summary, 42 studies were compiled and analyzed in Section 1. TSP was found to be the most well studied pollutant both in the emission characterization studies and the impact assessment studies. Other important pollutants, such as Benzo(a)pyrene were studied to a lesser extent. Health effect studies were conducted on three levels: human pathological and epidemiological surveys, animal respiratory system and bacterial cell line mutation. Finally, both dispersion and receptor modeling studies have been performed by research scientists to assess the impact of residential wood combustion on ambient air quality.

SECTION 2

ANALYSIS OF IMPACTS ON PUBLIC HEALTH AND AMBIENT AIR QUALITY FROM RESIDENTIAL WOOD COMBUSTION

2.1 ASSESSMENT OF THE CURRENT STATUS OF AIRSHEDS IN THE NORTHEAST

The existing primary standards for Total Suspended Particulates (TSP) are 260 ug/m^3 averaged over a 24-hour period and 75 ug/m^3 annual geometric mean. The secondary standard for TSP is 150 ug/m^3 averaged over a period of 24 hours. The value of 60 ug/m^3 annual geometric mean is used for the secondary standard by regulatory agencies for planning purposes.

WESTON's National Air Quality Data System was used to determine which counties in the study area have had exceedences of the primary or secondary standards in the years 1980-1982. A data base from the 11 states is created by extracting annual frequency distributions and means from the National Air Quality Data System. Next, the 11 state data base was examined to determine which counties could experience the greatest impact on ambient air quality from increased residential wood combustion. The following criteria were used:

- Sites with annual average means, based on three years of data, in exceedence of the secondary standard were defined for use in subsequent impact analyses.

- Sites with 24-hour values greater than the secondary standard were defined for use in subsequent case studies.

The results are shown in Table 2-1 and Table 2-2. Table 2-1 lists the states and counties where exceedences of the annual secondary standard occur. A total of 30 counties in the 11 state study are listed in this category. A subset of this listing contains six sites which have annual geometric means greater than 75 ug/m^3, the primary standard. Many of the counties shown in this table have multiple monitoring locations.

Data from all the monitoring locations in a county were grouped together to arrive at the annual mean concentration. Therefore, counties which contain individual sites showing exceedences of the secondary standard but did not average greater than the secondary standard across all sites were not included in Table 2-1. An example of this phenomenon is found in Penobscot, Maine. There are seven monitoring locations in Penobscot. Three sites show annual averages greater than 60 ug/m^3, while four sites are below that value. The county-wide average for the seven sites during the study years is 55.2 ug/m^3. While county-wide averaging is not used by regulatory agencies, it is used in this study for two reasons. First, the TSP problem in the Northeast is pervasive, and therefore this technique is used to limit the size

TABLE 2-1

COUNTIES WITH EXCEEDANCES OF THE ANNUAL PRIMARY (75 ug/m^3) OR SECONDARY (60 ug/m^3) STANDARD FOR TSP

STUDY YEARS (1980, 1981, 1982)

STATE	COUNTY	NO. SITES	ANNUAL MEAN CONCENTRATION (ug/m^3)
ME	Oxford	2	60.3
MD	Baltimore	3	69.5
	Anne Arundel	1	62.9
NJ	Essex	1	65.3
	Hudson	4	72.9
	Middlesex	1	68.0
	Union	2	63.1
NY	Erie	4	72.4
	Niagara	5	63.6
	Onondaga	4	62.8
PA	Allegheny	7	73.4
	Beaver	5	64.7
	Berks	1	67.2
	Blair	2	65.5
	Bradford	1	60.0
	Cambria	2	76.0
	Carbon	1	61.6
	Chester	1	65.6
	Cumberland	1	64.2
	Dauphin	1	68.0
	Erie	1	60.7
	Lancaster	1	76.1
	Lawrence	2	81.6
	Mercer	2	75.9
	Northampton	3	68.8
	Philadelphia	5	63.3
	Washington	2	64.3
	Westmoreland	1	85.9
VT	Washington	1	61.5

TABLE 2-2

COUNTIES WITH EXCEEDANCES OF THE ANNUAL PRIMARY (75 ug/m^3) OR SECONDARY (150 ug/m^3) STANDARD FOR TSP

STUDY YEARS (1980, 1981, 1982)

STATE	COUNTY	NO. SITES	NO. YEARS	NO. 150 ug/m^3	NO. 260 ug/m^3
CT	Fairfield	1	1	1	0
	Hartford	1	1	1	0
	New Haven	3	2	8	0
DE	New Castle	2	1	9	0
ME	Aroostook	2	3	31	11
	Cumberland	1	1	4	0
	Franklin	1	2	3	0
	Kennebec	1	3	13	0
	Knox	1	3	5	0
	Oxford	2	3	8	0
	Penobscot	7	3	81	11
	Washington	2	2	5	0
MD	Baltimore	10	3	62	3
	Allegany	1	1	3	0
	Wicomico	1	1	1	0
MA	Berkshire	1	2	2	0
	Central	2	2	5	1
	Pioneer Valley	1	1	1	0
NH	Belknap	1	2	2	0
	Coos	4	3	52	9
	Hillsborough	4	2	6	0
	Straford	1	1	4	0
NJ	Essex	1	2	3	0
	Hudson	4	3	22	0
	Middlesex	3	3	6	0
	Union	1	1	5	0

TABLE 2-2 (CONT'D)

STATE	COUNTY	NO. SITES	NO. YEARS	NO. 150 ug/m^3	NO. 260 ug/m^3
NY	Albany	3	3	8	0
	Chautaugqua	1	2	2	0
	Dutchess	1	3	5	0
	Erie	7	3	163	10
	Nassau	1	2	4	0
	Niagara	5	3	27	0
	Onondaga	4	3	17	2
	Schenectady	1	3	4	0
	Ulster	1	2	3	0
PA	Allegheny	7	3	87	2
	Beaver	6	2	25	2
	Berks	1	2	2	0
	Blair	2	3	13	1
	Bradford	1	1	1	0
	Cambria	3	3	21	0
	Carbon	1	2	12	2
	Chester	1	2	15	3
	Cumberland	1	3	4	0
	Dauphin	1	2	3	0
	Erie	1	1	1	0
	Lackawanna	1	2	4	1
	Lancaster	1	3	5	0
	Lawrence	2	3	20	0
	Mercer	2	3	10	1
	Northampton	2	3	15	0
	Philadelphia	6	3	17	3
	Schuylkill	1	1	1	0
	Washington	2	3	5	0
	Westmoreland	1	3	18	2
	York	2	1	30	2
RI	Providence	1	1	3	0
VT	Chittenden	1	1	4	0
	Washington	1	3	9	0
	Windham	1	1	1	0

of the study to the counties with the highest TSP levels. Second, it eliminates using counties where the TPS problem is highly localized or only marginal.

Table 2-2 lists the state and counties where exceedences of the 24-hour secondary standard occur. Exceedences are shown to occur in each of the 11 states in the study. Fifty-nine (59) counties show exceedences of the 150 ug/m^3 value within the study years. The second numerical column in Table 2-2 indicates the number of years during the three year study period which exceedences of the primary or secondary standard occurred. The majority of the counties listed have had violations in all three of the study years. The third and fourth numerical columns indicate the total number of violations of the secondary or primary standard, respectively, in the county at all sites. It is possible, then, that counties with multiple sites will show violations at more than one site on a violation day. This would be counted, then, as multiple occurrences in the county.

In summary, seven states contain counties which have exceedences of the annual secondary standard. All 11 states contain counties which have exceedences of the secondary 24-hour standard. The counties listed in Tables 2-1 and 2-2 are those exhibiting problems meeting the current ambient air quality standards for TSP. The counties listed in these tables define the data base which will be used in subsequent data analysis.

2.2 ESTIMATION OF IMPACT ON AMBIENT AIR QUALITY FROM RESIDENTIAL WOOD COMBUSTION

2.2.1 Determination of Emission Factors for Wood Burning Stoves

2.2.1.1 TSP Emissions

Fourteen emission characterization studies were analyzed to determine the mean emission factor for TSP. The mean and standard deviation for each study are shown in Figure 2-1. The results of Study 1 show that the mean emission rate from the stoves tested in extremely low, therefore, the results of Study 1 were treated as an outlier in the calculations for this study. The mean emission rate from RWC stoves calculated across the thirteen studies with a total of 198 observations is 12.8 g/kg. The standard deviation for these studies is 8.3 g/kg and the 95% confidence interval about the mean is 12.8 $^{+}$ 1.2 g/kg. As shown in Figure 2-1, the calculated mean emission rate for this study is below both the EPA and Oregon DEQ assumed values. The EPA emission value is one standard deviation away from the calculated mean. The EPA emission rate is a highly conservative value, i.e. a high emission rate is used when compared to the mean emission rate. This emission rate of TSP will be used to perform the impact assessment because it is the emission factor presented by EPA. However, for comparative purposes, the mean emission plus the upper 95% confidence interval calculated in this study will also be shown.

2.2.1.2 BaP Emissions

Five emission studies were analyzed to determine the mean emission factor for BaP. The mean and standard deviation for each study are shown in Figure 2-2. The mean emission

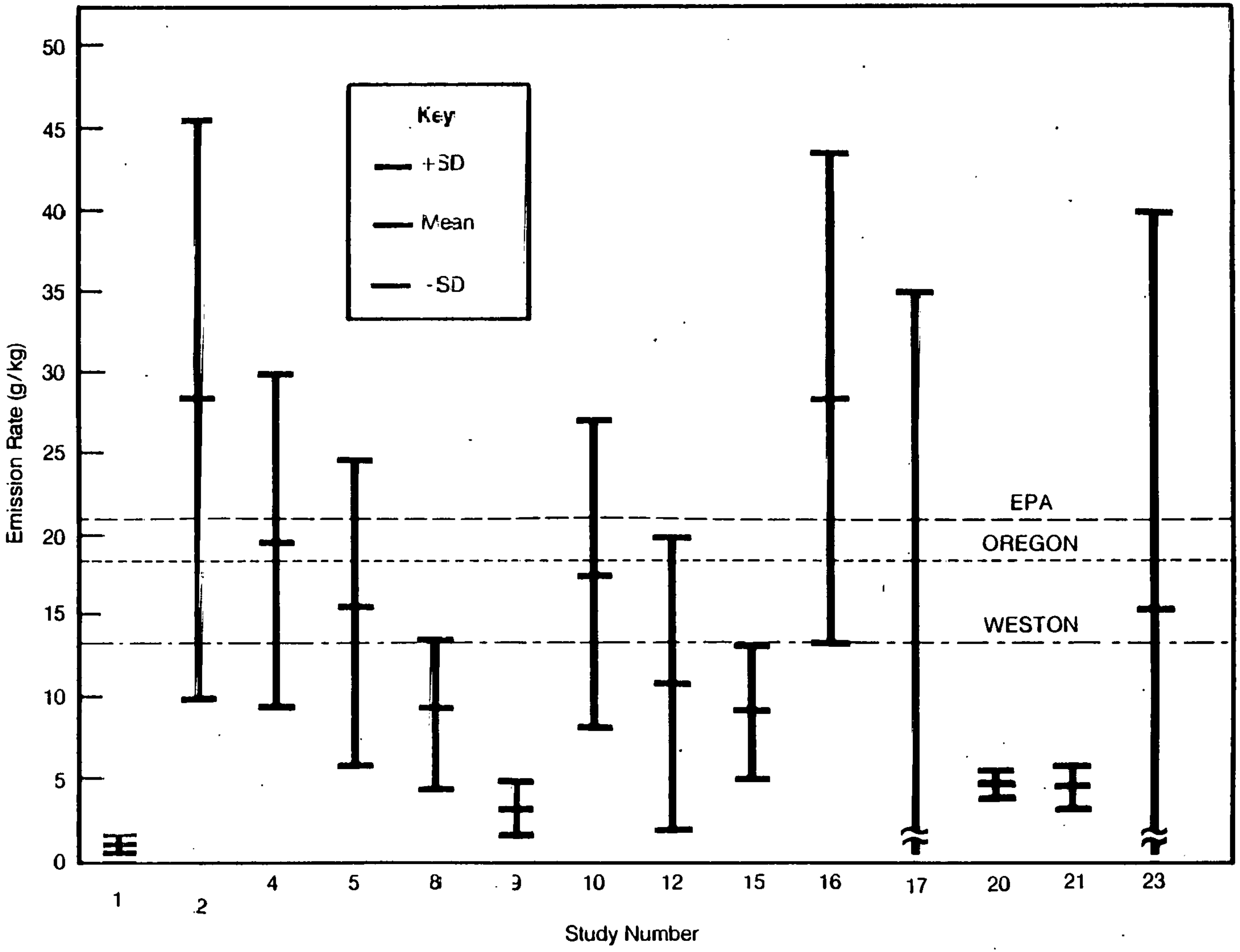


FIGURE 2-1 TSP EMISSION RATES FROM WOODBURNING STOVES

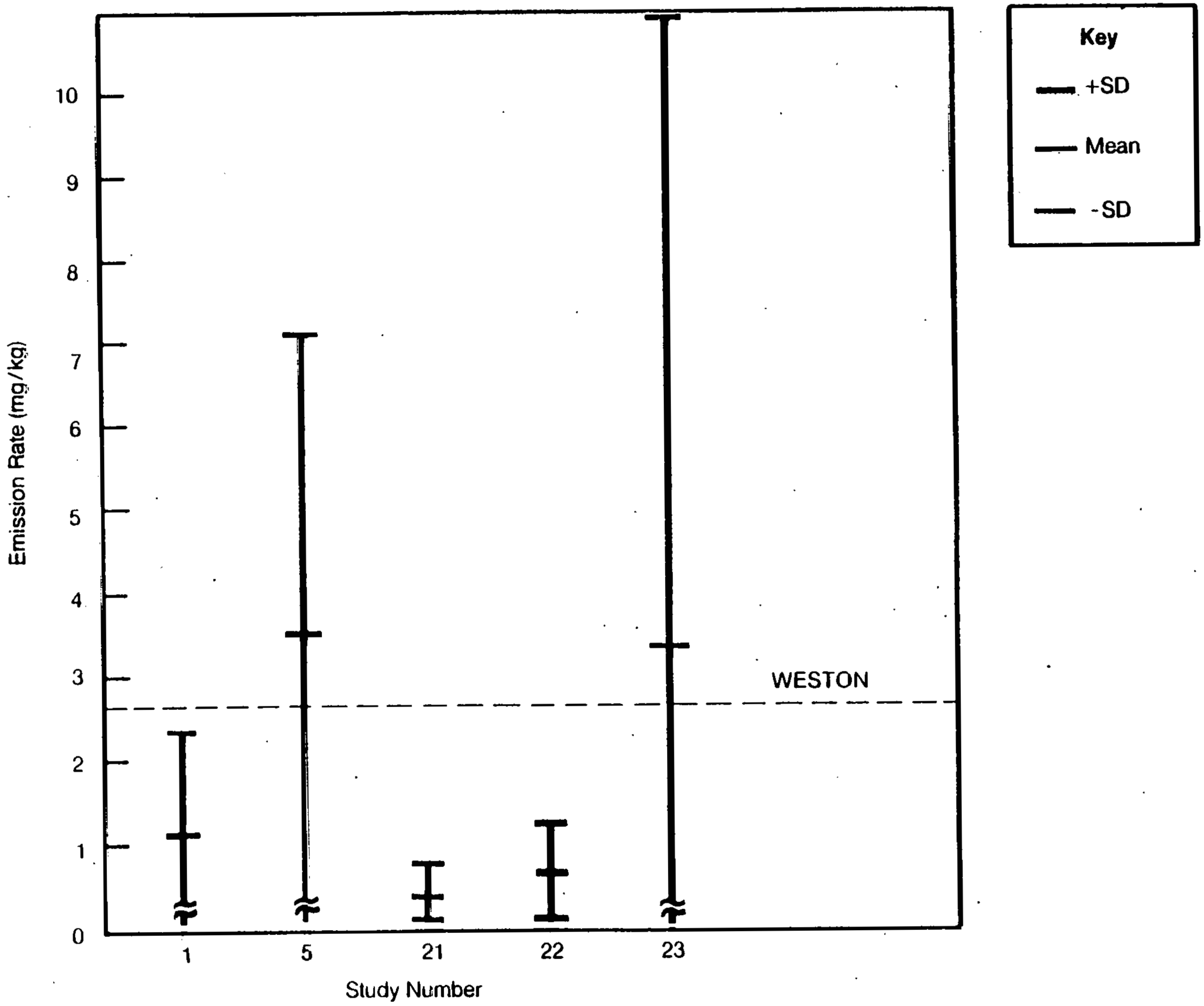


FIGURE 2-2 BaP EMISSION RATES FROM WOODBURNING STOVES

rate calculated across these studies with 40 observations is 0.56 mg/kg. The standard deviation for this study is 1.2 mg/kg and the 95% confidence interval about the mean is 0.56 ± 0.37 mg/kg. Too few observations were available for other POM to meaningfully calculate mean and standard deviations for emission rates. Since the EPA estimated the TSP emission rate to be equal to the mean emission rate plus one standard deviation, that criterion will be applied to estimate a BaP emission rate. Therefore, an emission rate of 1.76 mg/kg of BaP is used to perform the impact assessment. Again, for comparative purposes the result of using the mean emission rate plus the upper 95% confidence interval will be shown.

In addition to POM, dioxins have been found in wood smoke studies. Dioxins in samples from wood-fueled stoves and from the chimneys of wood-fueled furnaces have been reported in the literature.[76] The samples were collected from rural areas of the United States where fuel wood was expected to have had minimal exposure to pesticides and herbicides and where no industrial or municipal incinerators were located nearby. The wood was not treated or processed. The concentration of dioxin in the samples from the stoves was 170 ppt tetrochloro-dibenzodioxin (TCDD). Samples of chimney particulates around the region contained dioxin concentrations as high as 4,925 ppt for TCDD. Additional data suggest that the production of dioxins from the combustion of natural wood may be a general phenomenon.[77] Too few data are available to generate an emission rate value.

2.2.2 Estimated Contribution of RWC to Annual Ambient Air Quality

2.2.2.1 TSP

The TSP emission factor given in EPA, AP42 is 21 g/kg wood. This emission factor is combined with annual meteorological factors, county-wide areas and estimated wood burning rates to estimate the impact of residential wood burning on ambient TSP levels. The procedure is described below.

Counties which showed a violation of the annual secondary standard for TSP, listed in Table 2-1 were used for this aspect of the study. An annual residential wood fuel consumption rate developed for the New England states was based on a series of studies conducted by the United Stated Department of Agriculture[38-42]. For other states in the study, the empirically derived formula: [37]

$$\text{Cords used per household} = 3.087 - 0.322 \log (\text{population per } 10^4 \text{ Degree Days density})$$

was used to determine wood fuel usage. The determination of wood fuel usage for the subject counties is shown in Table 2-3. Also shown in Table 2-3 are population and area data. Wood usage is shown to vary greatly over the counties studied, from a low value of 9,200 cords per year for Hudson, New Jersey to a high value of 192,441 cords per year for Allegheny, Pennsylvania. Figure 2-3 shows the empirically derived relationship between population density and wood fuel usage.[37] Also shown in Figure 2-3b is a correlation study on observed and estimated wood burning using this relationship. According to this study, states surveyed use firewood in the same manner as New England, where detailed sur-

TABLE 2-3

ESTIMATED ANNUAL WOOD FUEL USE (1978-1979)

STATE	COUNTY	POPULATION	AREA (sq.mi.)	USAGE (cords)
CT	Hartford	807,766	739	121,193
	New Haven	761,337	610	149,715
DE	New Castle	399,002	396	62,894
ME	Aroostook	91,331	6,721	64,282
933,722	Cumberland	215,789	876	104,565
	Kennebec	109,889	876	71,427
	Oxford	48,968	2,053	38,815
	Penobscot	137,015	3,430	76,615
MD	Allegany	80,548	421	18,574
3,923,897	Ann Arundel	370,775	418	66,380
	Baltimore	655,615	598	112,565
	Wicomico	64,540	379	15,606
MA	Hampden	443,018	618	64,731
	Worcester	646,352	1,513	152,970
NH	Cheshire	62,115	711	35,242
737,681	Coos	35,147	1,804	20,401
NJ	Essex	850,451	127	43,329
7,171,112	Hudson	556,972	46	9,200
	Middlesex	595,893	316	76,212
	Union	504,094	103	36,352

TABLE 2-3
(continued)

STATE	COUNTY	POPULATION	AREA (sq.mi.)	USAGE (cords)
NY	Albany	285,909	524	58,565
18,241,584	Erie	1,015,472	1,046	172,282
	Niagara	227,101	526	49,506
	Onondaga	463,324	206	30,294
	Schenectady	149,946	206,	30,294
PA	Alleghany	1,450,085	727	192,441
11,800,766	Beaver	204,441	436	41,035
	Berks	312,509	861	65,841
	Blair	136,621	527	27,900
	Bradford	62,919	1,152	33,882
	Cambria	183,263	691	40,647
	Carbon	53,285	384	13,553
	Chester	316,660	758	71,341
	Cumberland	178,037	547	38,612
	Dauphin	232,317	528	49,694
	Erie	279,780	804	61,482
	Lackawanna	227,908	461	48,812
	Lancaster	362,346	952	72,800
	Lawrence	107,150	363	23,488
	Lycoming	118,416	1,237	36,382
	Mercer	128,299	672	31,624
	Northampton	225,418	376	46,447
	Philadelphia	1,688,210	136	27,200
	Schuylkill	160,630	782	36,800
	Washington	217,074	958	50,718
	Westmoreland	392,294	1,033	78,994
	York	312,963	906	63,953
RI	Providence	571,349	416	51,852
VT	Chittenden	115,534	540	25,412
	Washington	52,393	787	23,147
	Windham	36,933	787	23,147

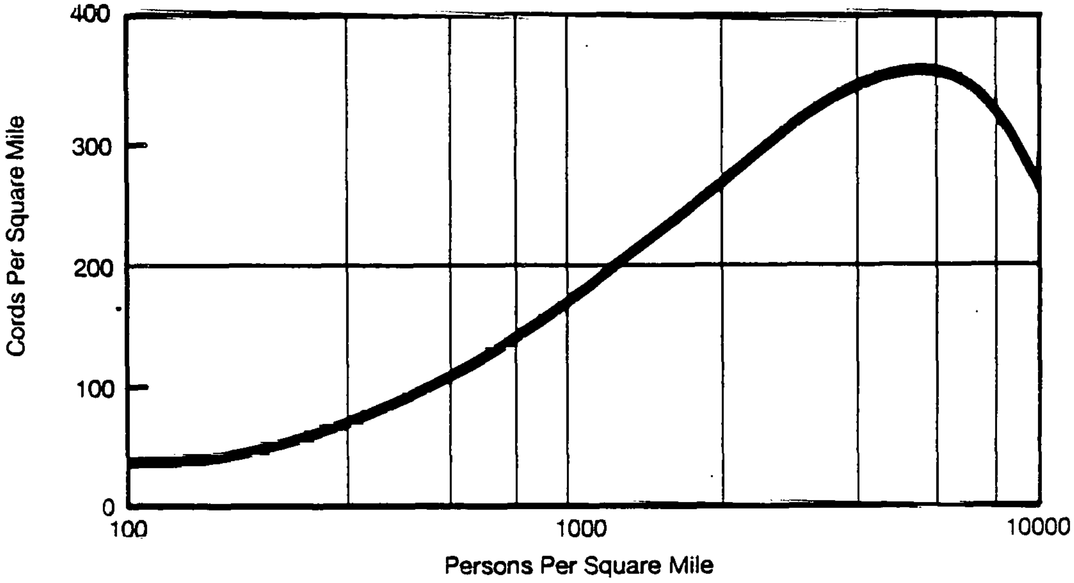


FIGURE 2-3 ANNUAL WOOD FUEL USE IN THE NORTHEAST (1978-1979)

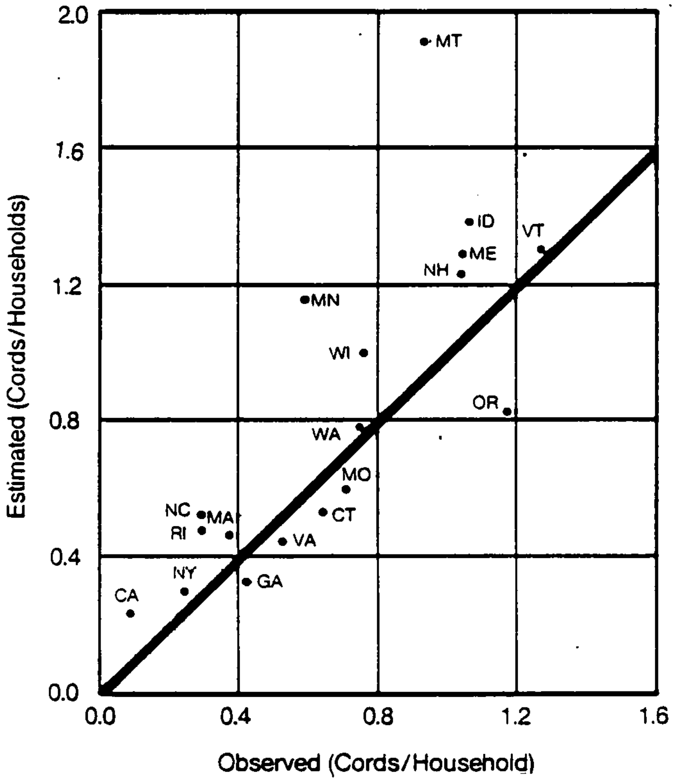


FIGURE 2-3b STATE LEVEL WOOD USE CORRELATION

veys were conducted, and no supply constraints are apparent. Note that the curve reaches a maximum at 6,000 persons per square mile indicating that wood consumption peaks in moderately dense cities. Wood fuel usage in very dense cities is shown to be equivalent to consumption in more sparsely populated regions.

Using the annual wood fuel usage, it is possible to calculate the source strength, Q, for each county. Source strength is a parameter used in dispersion meteorology which is in units of mass per area times time. The source strength and annual average wind speed were then input to a box model to the estimate the impact of wood burning on ambient air quality.

A simple but physically realistic model is adequate for estimating pollutant concentrations due to area sources. Area source emissions can be regarded as the sum of numerous small point sources across a broad area. In the context of this report, space heating units will make up the area source. In urban areas, box models have been shown to perform nearly as well as more complex models.[75] No comparisons have been performed in rural areas because, until recently, there has been little concern over exceedences of ambient air quality standards outside of metropolitan areas. There are several limitations to using this approach. First, terraine factors are not accounted for in the model. Second, it is only possible to calculate values based on long averaging times and large surface areas. An annual averaging time and county-wide area are selected for this estimation procedure. While it might be desirable to model shorter averaging times (probably 24-hours) and small areas (such as one neighborhood), it is not possible to perform this modeling within the confines of this project.

The results of the dispersion modeling are shown in Tables 2-4A and 2-4B. The assumptions used in the calculations are as follows:

1. The emission factor is 21 grams TSP per kilogram of wood burned in Table 2-4A and 14 grams TSP per kilogram of wood burned in Table 2-4B.
2. Particulates are dispersed uniformly over the county.
3. Pollutant is released at a uniform rate.
4. A cord weighs 5000 pounds (this corresponds to the density of ash, birch, hickory, and maple).

Using the EPA AP42 emission factor, Coos, New Hampshire shows the minimum estimated annual impact value of 0.7 ug/m^3 or 0.8% of the annual mean concentration. The maximum estimated impact is 10.9 ug/m^3 in Alleghany, Pennsylvania or 14.9% of the measured annual mean TSP concentration. Using the alternative emission factor, the estimated annual impact on ambient air quality ranges from a low of 0.5 ug/m^3 in Coos, NH to a high value of 7.3 ug/m^3 in Alleghany, PA.

These results seem quite reasonable in light of a recently published article[26]. Utilizing receptor modeling techniques, that study found that residential wood combustion contributed between 7% (in industrial areas) to nearly 44% (in residential areas) of the TSP fraction in Portland, Oregon. In Washington state, residential wood combustion was found

TABLE 2-4A

ANNUAL ESTIMATED TSP IMPACT FROM RESIDENTIAL WOOD COMBUSTION EPA EMISSION FACTOR

State	County	Annual Mean Concentration (ng/m^3)	Estimated Impact (ng/m^3)	Relative Impact (percent)
ME	Oxford	60.3	0.9	1.5
MD	Ann Arundel	62.9	6.0	9.5
	Baltimore	69.5	7.5	10.8
NH	Coos	97.7	0.7	0.8
NJ	Essex	65.3	10.1	15.5
	Hudson	72.9	5.2	7.1
	Middlesex	68.0	8.0	11.8
	Union	63.1	10.1	16.0
NY	Erie	72.4	5.4	7.5
	Niagara	63.6	2.8	4.4
	Onondaga	62.8	3.9	6.2
PA	Alleghany	73.4	10.9	14.9
	Beaver	64.7	3.6	5.6
	Berks	67.2	3.9	5.8
	Blair	65.5	2.1	3.2
	Bradford	60.0	1.1	1.8
	Cambria	76.0	2.4	3.2
	Carbon	61.6	1.5	2.4
	Chester	65.6	3.8	5.8
	Cumberland	64.2	2.8	4.4
	Dauphin	68.0	4.5	6.6
	Erie	60.7	2.6	4.3
	Lancaster	76.7	4.0	5.3
	Lawrence	81.6	2.4	2.9
	Mercer	75.9	1.6	2.1
	Northampton	68.8	5.7	8.3
	Philadelphia	63.3	6.5	10.3
	Washington	64.3	2.2	3.4
	Westmoreland	85.9	3.3	3.8
VT	Washington	61.5	1.3	2.1

TABLE 2-4B

ANNUAL ESTIMATED TSP IMPACT FROM RESIDENTIAL WOOD COMBUSTION
MEAN EMISSION RATE PLUS UPPER 95% CONFIDENCE INTERVAL

State	County	Annual Mean Concentration (ng/m^3)	Estimated Impact (ng/m^3)	Relative Impact (percent)
ME	Oxford	60.3	0.1	1.0
MD	Ann Arundel	62.9	4.0	6.4
	Baltimore	69.5	5.0	7.2
NH	Coos	97.7	0.5	0.5
NJ	Essex	65.3	6.8	10.4
	Hudson	72.9	5.5	4.8
	Middlesex	68.0	5.4	7.9
	Union	63.1	6.8	10.7
NY	Erie	72.4	3.6	5.0
	Niagara	63.6	1.9	2.9
	Onondaga	62.8	2.6	4.2
PA	Alleghany	73.4	7.3	10.0
	Beaver	64.7	2.4	3.8
	Berks	67.2	2.6	3.9
	Blair	65.5	1.4	2.1
	Bradford	60.0	.7	1.2
	Cambria	76.0	1.6	2.0
	Carbon	61.6	1.0	1.6
	Chester	65.6	2.5	3.4
	Cumberland	64.2	1.9	2.9
	Dauphin	68.0	3.0	4.4
	Erie	60.7	1.7	2.9
	Lancaster	76.7	2.7	3.2
	Lawrence	81.6	1.6	1.9
	Mercer	75.9	1.0	1.4
	Northampton	68.8	3.8	5.6
	Philadelphia	63.3	4.4	16.9
	Washington	64.3	1.5	2.0
	Westmoreland	85.9	2.2	2.5
VT	Washington	61.5	.9	2.1

to contribute between 61% and 93% of the fine fraction (2.5 um) in a 24-hour period.

2.2.2.2 BaP

The estimated impact of benzo(a)pyrene (BaP) emission from residential wood combustion is calculated in the same manner as for TSP. The results of these calculations are shown in Table 2-5A and 2-5B. The estimated annual BaP impact is shown to range from a low value of 0.08 ng/m^3 in Oxford, Maine to high value of 0.98 ng/m^3 in Alleghany; Pennsylvania. Only four annual measurements were available for comparison from literature sources. The alternative projections provide estimates of 0.04 ng/m^3 BaP in Oxford, ME and 0.52 ng/m^3 Bap in Alleghany, PA.

Table 2-6 is included for comparative purposes.[43] The authors of that study estimate that wood fired appliances contribute 34.8% of all polycyclic organic material (POM) to the ambient environment in the U.S.A. This would make such appliances by far the largest single source in the United States. However, in high density urban areas there is little wood burning and therefore it is more likely that mobile sources are the primary contributors to ambient air POM in densely populated urban areas.

2.2.3 Review of Short-Term Monitoring Studies

Three short-term studies have been conducted recently to examine the contribution of RWC to ambient air pollution.[48-50]

TABLE 2-5A

ESTIMATED ANNUAL BaP IMPACT FROM RESIDENTIAL WOOD COMBUSTION
MEAN EMISSION RATE PLUS ONE STANDARD DEVIATION

State	County	Annual Mean Concentration (ug/m^3)	Estimated Impact (ug/m^3)
ME	Oxford	NA	0.08
MD	Ann Arundel	NA	0.5
	Baltimore	0.6	0.6
NH	Coos	NA	0.06
NJ	Essex		0.8
	Hudson	1.0	0.4
	Middlesex	(Newark)	0.7
	Union		0.8
NY	Erie	NA	0.5
	Niagara	NA	0.2
	Onondage	NA	0.3
PA	Alleghany	NA	0.98
	Beaver	NA	0.3
	Berks	NA	0.3
	Blair	NA	0.2
	Bradford	NA	0.09
	Cambria	NA	0.2
	Carbon	NA	0.1
	Chester	NA	0.3
	Cumberland	NA	0.2
	Dauphin	NA	0.4
	Erie	0.30	0.2
	Lancaster	NA	0.3
	Lawrence	NA	0.2
	Mercer	NA	0.1
	Northampton	NA	0.5
	Philadelphia	0.7	0.5
	Washington	NA	0.2
	Westmoreland	NA	0.3
VT	Washington	NA	0.1

TABLE 2-5B

ESTIMATED ANNUAL BaP IMPACT FROM RESIDENTIAL WOOD COMBUSTION MEAN EMISSION RATE PLUS UPPER 95% CONFIDENCE INTERVAL

State	County	Annual Mean Concentration (ug/m^3)	Estimated Impact (ug/m^3)
ME	Oxford	NA	0.04
MD	Ann Arundel	NA	0.26
	Baltimore	0.6	0.32
NH	Coos	NA	0.03
NJ	Essex	1.0 (Newark)	0.42
	Hudson		0.21
	Middlesex		0.57
	Union		0.42
NY	Erie	NA	0.26
	Niagara	NA	0.11
	Onondage	NA	0.16
PA	Alleghany	NA	0.52
	Beaver	NA	0.16
	Berks	NA	0.16
	Blair	NA	0.11
	Bradford	NA	0.05
	Cambria	NA	0.11
	Carbon	NA	0.05
	Chester	NA	0.16
	Cumberland	NA	0.11
	Dauphin	NA	0.21
	Erie	0.30	0.11
	Lancaster	NA	0.16
	Lawrence	NA	0.11
	Mercer	NA	0.05
	Northampton	NA	0.26
	Philadelphia	0.7	0.26
	Washington	NA	0.11
	Westmoreland	NA	0.16
VT	Washington	NA	0.05

TABLE 2-6

ESTIMATES OF ANNUAL POM EMISSION BY SOURCE TYPE ON A NATIONAL BASIS

Source type	Estimated annual POM emissions, metric tons	Percent of total POM emissions from all sources
Residential heating		
o Wood-fired total	3,837	34.8
o primary heating	1,383	
o auxiliary heating	2,376	
o fireplaces	78	
o Coal-fired	102	0.9
o Oil-fired	7.4	<0.1
o Gas-fired	9.8	<0.1
Open burning sources		
o Agricultural open burning	1,190	10.8
o Prescribed burning	1,071	9.7
o Forest wildfires	1,478	13.4
o Coal refuse piles	28.5	0.3
o Land clearing waste burning	171	1.6
o Structural fires	86	0.8
Mobile sources		
o Autos-gasoline	2,160.8	19.6
o Autos-diesel	1.2	<0.1
o Trucks-diesel	103.5	0.9
Coke production	632	5.7
Industrial boilers		
o Coal	69.0	6.3
o Oil	1.3	<0.1
o Gas	2.1	<0.1
o Wood/bark	1.2	<0.1
o Begasse	0.3	<0.1
Incinerators		
o Municipal	0.3	<0.1
o Commercial	55.8	0.5
Utility boilers		
o Coal	12.9	0.1
o Oil	0.3	<0.1
o Gas	0.3	<0.1

TABLE 2-6
(continued)

Source type	Estimated annual POM emissions, metric tons	Percent of total POM emissions from all sources
Carbon Black	3.1	<0.1
Charcoal manufacturing		
o uncontrolled batch kilns	0.8	<0.1
o continuous furnace production	0.7	<0.1
Asphalt production		
o Saturators	0.2	<0.1
o Air blowing	0.2	<0.1
o Hot road mix	3.9	<0.1
Barium chemicals (Black ash rotary kiln)	0.3	<0.1
TOTAL	11,031	

Adapted from Reference 43.

A study was conducted in two New Hampshire towns during the 1979-1980 heating season.[48,49] Concentrations of POMs were determined in ambient air samples in the small community of Lyme Center, NH, where wood was the dominant heating source. Although occasional atmospheric conditions led to POM concentrations comparable to those reported in large urban areas (BaP = 1 ng/m^3), the ambient air quality most commonly reflected the lower POM values associated with the surrounding rural area. By contrast, POM measurements in the larger town of Hanover, New Hampshire, regularly approached the typical urban values. The Hanover samples were also surprising in that the fingerprint given by relative concentrations of various POMs did not differ appreciably from the Lyme Center pattern, despite the fact that oil is the dominant domestic and commercial heating fuel in Hanover.

Another study was conducted during the winter of 1981-1982 in Western Massachusetts.[50] This receptor modeling study was designed to allocate the fraction of TSP attributable to RWC. The results indicated that in suburban areas of Western Massachusetts residential woodburning accounts for about 36 percent of the TSP and in urban areas about 15 percent of the TSP.

Exceedances of the 24-hour TSP standards were not observed in either study. In only one of the five locations monitored in these studies did the highest observed TSP value approach 60 percent of the secondary standard. There are no ambient standards for POM or BaP. The highest BaP values observed were close to the levels measured in major metropolitan areas.

2.3 ESTIMATION OF IMPACT ON PUBLIC HEALTH FROM RESIDENTIAL WOOD COMBUSTION

2.3.1 Review of Pertinent Health Effects Studies

The environment is a major contributor to the development of a variety of pathological conditions in humans. It has been estimated that as much as 13 percent of all human deaths from cancer may be attributed to exposure to polluting substances in the environment.[66] This section describes the biological activity of wood smoke and several of its POM components. The review includes tests conducted on cell lines (Ames assay), whole animals (respiratory physiology) and human populations (pathology and epidemiology).

2.3.1.1 Cell-line Tests

Products of incomplete combustion contain POM, many of which are suspected human carcinogens. A relatively inexpensive short-term biological model used to assess mutagenic potential of wood exhaust and its components is the Ames assay. Ames tests use bacterial systems to measure parameters indicating DNA damage. Three Ames assay laboratory studies have been conducted on wood smoke.

Table 2-7 is presented in order to compare the mutagenic potential of wood stove emissions to other sources of residential heat. Although residential oil furnace organics are 1.5 to 6 times more mutagenic than wood stoves, the wood stove tested emitted 400 times more particulate organic mat-

TABLE 2-7

A COMPARISON OF MUTAGENICITY FOR RESIDENTIAL HOME HEATING DEVICES

SOURCE	FUEL	*REVERTANT per ug Organic	Ng ORGANIC per Joule	*REV. x 10^{-3} per Joule
Woodstove	Pine	1.3	508	900
Woodstove	Oak	0.9	187	169
Residential Furnace	No. 2 Fuel	2.0	0.5	1.0
Residential Furnace	No. 2 Fuel	5.1	1.5	7.6

*Revertants in Ames assay using bacterial strain T98 with 69 activation.

Adapted from Reference 73.

ter per kilogram of fuel burned. Therefore, when the sources are compared on a fuel heating value basis, wood stove emissions contribute significantly more potentially hazardous organic material into ambient air than the residential use of No. 2 fuel oil.

2.3.1.2 Animal Studies

Hilado and colleagues[53-56] have reported considerable morbidity in experimental animals that were exposed to the products of combustion of hard woods, such as birch and oak, or soft woods, such as fir and pine; they noted no difference in toxicity between the products of these hard and soft woods. The problem of interpreting these results is compounded by the presence of preservatives and other additives in the wood. It is often difficult to establish whether any observed toxicity is caused by the combustion products of the wood itself or of a contaminating additive. And it has not been established whether the particle-bound POM generated during combustion contribute more to the observed toxicity than the gaseous products. Considerable additional work with subacute and chronic exposure is required to characterize toxicity.

A study commissioned by the Northeast States for Coordinated Air Use Management (NESCAUM) was conducted to examine increased potential for respiratory disease from inhalation of wood smoke.[64] Respirable particles generated from a wood stove were implanted in the trachea of hamsters. The results showed that the response to wood combustion products was less than the response to coal products, but elevated over inhalation of a nontoxic dust. No unique, discernable pathological effects were noted, i.e., the response resembled inhalation of other smokes.

2.3.1.3 Epidemiological and Pathological Studies

Numerous epidemiological and pathological studies have been conducted over the past 20 years to examine the incidence of lung disease in New Guinea natives.[59-63] The disease observed resembles chronic bronchitis and emphysema common in Western nations. It is possible that environmental factors, such as exposure to domestic wood smoke, or acute repeated infection of lungs in infancy causes the disease.[60] As indicated in Section 2.4, the level of air pollution in native huts is extremely high due to wood fire. Observation of pathological samples supports epidemiological evidence that environmental pollution plays a minor role in the pathogenesis, while repeated lower respiratory tract infection is a major contributor to lung disease.[62] While the studies are inconclusive to date, ongoing investigations should provide insights into the emphysemic effect of chronic exposure to high concentrations of wood smoke.

2.3.2 Quantitative Risk Assessment

Quantitative risk assessment is a developing, rather than a precise science. The use of different assumptions or extrapolations could lead to very different conclusions. The calculated risk at ambient concentration is not an absolute indicator of risk, but is intended to represent a best estimate between the upper and lower bounds of risk.

At present, there are only two sources of human exposure to POM on which data are reliable. These sources are occupational exposure to coke ovens and cigarette smoking. The major known human cancer associated with exposure to chemical mixtures containing POM is lung cancer. While much is known about the quantitative relationship between cigarette smoking and lung cancer, far less is known about exposure to other PAH containing mixtures and lung cancer.

Studies of the effects of exposure to general air pollution have uncovered a consistently higher lung cancer rate in urban areas than rural areas. Interpretation of this observation has been confounded by the lack of detailed information on smoking history. Urban-rural comparisons have only provided a very weak basis for evaluating the effect of general air pollution on lung cancer rates.

The EPA has not assigned a unit risk value for exposure to wood smoke. Furthermore, there have been neither guidance documents nor criteria set to perform a risk assessment. Studies are presently being conducted by EPA to determine if emissions from wood combustion are similar to those from other combustion sources. Assuming that there are no unique harmful effects attributable to wood smoke, the following procedure is adopted in this study to estimate cumulative risk.

There is considerable animal and occupational data indicating that POM, or some of the prevalent compounds in a POM mixture, is carcinogenic. Estimate of cancer rates per unit exposure can only be made through the use of crude indices. BaP is a commonly used index for this purpose.

There are difficulties with the use of such an index: (1) BaP may be a minor constituent compared to other POM compounds, (2) the biological activity of a POM mix may be primarily in other fractions, (3) the fraction of BaP in the POM mix varies from one situation to another, and (4) BaP may be less chemically stable than other POM compounds. The use of BaP as an index may stem more from familiarity than sound reasoning.[68] BSF, another POM compound, has also been used as an indicator but it has not demonstrated consistent results with bacteriological mutation tests. A complete list of organic compounds measured in one RWC test series is enclosed in Appendix A.

There is little alternative for quantitative estimates at this point. Use of a range of estimates overcomes some problems; Meyers et. al. suggests an annual rate of 10-40 fatal cancers per 10^6 person-ng/m^3 BaP, assuming exposure to the entire mix of combustion products indexed by BaP.[69]

Lung cancer rates in nonsmokers have been found to fit an empirically derived equation relating air pollution to cigarette smoking.[44] If the observed lung cancers were due totally to BaP pollution, the estimate is:

$$42 \text{ ng/m}^3 \text{ BaP-U.S.} = 1 \text{ U.K. cigarette}$$

This may be considered an <u>upper</u> <u>limit</u> of the potency of BaP - U.S. pollution in nonsmokers. U.K. cigarettes were used because the study was conducted in Wales and extrapolated lung cancer risk to U.S. air pollution levels. The cumulative incidence of lung cancer for a lifetime exposure, taken as 70 years, was estimated to be 2,524 per 100,000 or 2.52% for inhalation of one U.K. cigarette per day.

In Section 2.2, it was estimated that residential wood combustion, contributed 34.8 percent of the POM to ambient air on a nationwide, annual average basis.

In the four urban areas where annual mean BaP concentrations are available, the level ranges from 0.3 ng/m^3 to 1.0 ng/m^3. Assuming that 34.8 percent is contributed by RWC then the effective levels for this analysis ranges from 0.1 ng/m^3 to 0.35 ng/m^3 BaP. According to the above equation, this would be equivalent to a burden of smoking 0.002 to 0.008 U.K. cigarettes per day, or 0.7 to 2.8 cigarettes per year. For a lifetime exposure, this translates to a cumulative incidence of 5 to 20 lung cancers per population of 100,000 or 0.005 percent to 0.020 percent. Due to the uncertainties associated with using BaP as an index, the level of uncertainty with the measurement technique and with the population distribution, the estimate provided is only good within a factor of 10.[/1]

The above analysis is given to present an order of magnitude for the RWC problem. A more rigorous analysis of cancer risk from wood smoke requires far more data than are available to date. Other weaknesses in the approach taken include a lack of supporting bioassay studies by which comparisons can be made, a true estimate of wood smoke contribution to ambient air pollution levels and an estimate of uncertainty in the equation used to perform the risk assessment. In addition, the areas of concern are the rural or semi-rural valley areas where pollutant trapping occurs, not

TABLE 2-8

COMPARISON OF MEAN INDOOR POLLUTANT LEVELS

Pollutant	Units	GROUP Summer	 Winter Control	 Winter Combustion
Formaldehyde	ppb	75	34	31
NO	ppb	5	6	30
NO_x	ppb	13	9.5	40
CO	ppm	1.7	1.8	2.7
CO_2	ppm	-	600	1000
TSP	ug/m^3	32	30	40
RSP	ug/m^3	24	21	33
Volatile Organics	ug/m^3	260	136	125

Source: Reference 58.

TABLE 2-9

INDOOR-OUTDOOR RESPIRABLE SUSPENDED PARTICULATE CONCENTRATIONS

STUDY NO.	WOODBURNER IN HOME[a]	NUMBER OF DAYS SAMPLED	OUTDOOR CONCENTRATION[b] (ug/m^3)	INDOOR CONCENTRATION[b] (ug/m^3)
Spengler(33)	No	24	11.5(2.4-22.7)	15.2(8.4-23.0)
	No	30	10.9(2.4-18.3)	29.9(7.6-72.4)
	Yes (W)	30	12.5(4.8-24.0)	27.5(8.4-60.3)
	Yes (F)	30	10.3(3.7-21.6)	17.9(6.6-61.8)
Moschandreas(74)	Yes (W)	14	34.2(22.6-57.6)	49.0(14.3-72.5)
	No	14	27.4(13.9-53.7)	28.0(23.9-31.6)
	Yes (F)	1	30.3	159.9
	No	14	14.0(7.3-21.8)	40.9(21.7-66.9)
	Yes (F)	1	6.0	67.6
	No	14	17.9(7.7-30.5)	18.8(6.3-39.0)

a - (W) woodstove, (F) fireplace.
b - The concentration range is in parentheses.
ND - not determined.

ulate matter is measured indoors when compared to outdoor concentration.

A study of indoor air pollution levels was conducted in Native Huts in the highlands of New Guinea.[61] Native populations in New Guinea have a high prevalence of chronic non-tuberculoan lung disease which could be caused by exposure to wood smoke. In huts with open, uncontrolled fires, the average concentrations of wood smoke, aldehydes and carbon monoxide are 666 ug/m^3, 1.08 ppm and 21.3 ppm, respectively. Peak concentrations of these substances, generally occurring soon after fire start-up, are 4862 ug/m^3, 3.8 ppm and 150 ppm, respectively. A discussion of health effects relavent to this study is provided in Section 2.3.1.

2.5 REGULATORY ALERT: A NEW PARTICULATE STANDARD AND PROMULGATION OF A POM STANDARD

2.5.1 Particulate Standard

The existing primary standard for TSP are 260 ug/m^3 averaged over a 24-hour period and 75 ug/m^3 annual geometric mean. The secondary standard is 150 ug/m^3 averaged over a period of 24 hours.

The proposed primary standards are based on particles in the 0-10 micron diameter range (PM_{10}).[67] The concentration will be in the range of 150-250 ug/m^3 averaged over a 24-hour period and 50-65 ug/m^3 annual arithmetic mean. The secondary standard will be an annual TSP value in the range of 70-90 ug/m^3 arithmetic mean.

the urban areas where annual average BaP concentrations are known. No long-term monitoring has been conducted to determine ambient air levels of PAH in rural or semi-rural areas.

The significance of exposure to this level of BaP or the assessment of cumulative incidence for a 70 year exposure cannot be determined. It can, however, be unequivocally stated that the ambient concentration of BaP has decreased steadily and consistently in urban areas since 1966. This observation, shown in a recent journal article,[57] was attributed to the decrease in residential coal combustion. **Therefore, while we have determined that residential wood combustion contributes significantly to existing levels of ambient BaP, it cannot be concluded that these levels are cause for concern.**

2.4 INDOOR AIR QUALITY

Indoor pollutant concentration may be significantly different from outdoor levels. The Oak Ridge National Laboratory took measurements in 40 homes during the period April 1982 through February 1983.[58] One objective of the study was to determine if RWC contributed significantly to the level of indoor air pollution. Results from the monitoring program are shown in Table 2-8. The authors conclude that combustion sources, especially unvented sources, significantly increase levels of indoor CO, NO_x and particulates. Very high concentrations of TSP (200-400 ug/m^3) are observed in houses where incorrectly operated wood stoves are located. Table 2-9 shows the results of several indoor-outdoor studies. In general, a 1.5-5 fold increase in respirable partic-

PM_{10} measurements in ambient air are usually 0.35 to 0.65, the concentration of TSP in any given location. The average conversion factor of calculating PM_{10} from TSP measurements is based on studies in U.S. cities. The values commonly cited are 0.5 and 0.6. The current annual TSP standard (75 ug/m^3 geometric mean) is roughly equivalent to an arithmetic mean of 50 ug/m^3 of PM_{10}. Note that the Administrator is requesting a range of 50-65 ug/m^3 be considered adequate, hence, a slackening of the standard. The value of the 24-hour TSP standard, 260 ug/m^3 is roughly equivalent to 140 ug/m^3 PM_{10}. The Administrator has recommended a value in the range of 150-250 ug/m^3 be considered. Again, unless the lowest recommended value is selected, more ambient particulate matter will be allowed.

2.5.2 Promulgation of a POM Standard

The attached brief from Inside EPA, August 10, 1984 summarizes the EPA's position on a POM standard. In brief, while the EPA believes "POM compounds pose a significant risk at ambient concentration levels" and that residential wood and coal combustion contribute significantly to this risk, the agency is unlikely to regulate wood and coal burning in the near-future.

Saying POM poses significant risk

CANNON: WOODBURNING STOVES MAJOR POM SOURCE, BUT REGULATION UNCERTAIN

EPA Air chief Joseph Cannon this week said the agency's decision against regulating polycyclic organic matter (POM) under the Clean Air Act is not based, as was an earlier proposal, on an inability to conclude that "POM compounds pose a significant risk at ambient concentration levels." In a briefing with reporters explaining the POM decision, Cannon said he had become convinced in recent months that residential wood and coal burning (which produce 44% of POM emissions) present a major health problem, but would not commit to a specific date for an agency decision on whether and how woodburning stoves should be regulated. Cannon stressed that the agency decision against regulating POM, which EPA admits is a carcinogen, was in large part an effort to avoid having the agency placed on an overly strict timeframe to reach tough regulatory decisions. As EPA ponders whether and how it should regulate woodburning stoves, Cannon added, POM emissions from mobile sources (40% of total emissions) and stationary sources are expected to decrease as a result of current regulations.

POM is one of a few selected pollutants for which the 1977 CAA amendments required EPA to within one year assess all relevant information and determine whether the emissions into ambient air "will cause, or contribute to, air pollution which may reasonably be anticipated to endanger public health." The amendments further directed EPA, if an endangerment determination were made, to regulate POM under either section 109 (by setting a national ambient air quality standard), section 111 (by setting new source performance standards), under section 112 (by setting national emissions standards for hazardous air pollutants), or under a combination of these authorities. EPA's recent decision against regulating POM responds to a U.S. District Court order that a final decision be reached Aug. 2.

Cannon said that draft results of an EPA-staff six-month study on the toxics problem (summary reprinted below) "leads us to believe that POM is a significant carcinogen." But Cannon said that the study was not prepared "to a level of scientific credibility" necessary to support a regulatory decision. The staff study, Cannon said, was compiled to assess "the dimensions of the toxics problem in the United States" and was not meant to be used "as a regulatory tool." The controversial study found that POM emissions account for 61% (around 800 cancer cases) of total toxic air pollutant-related cancers. EPA, in a press release announcing its decision, said that because POM "is a large class of chemicals composed of hundreds of compounds, the release of POM, for the most part, has not been measured, and attempts to estimate the amount of POM compounds generated nationally are unreliable."

Cannon said that preliminary studies show it is cost-effective to control new wood burning stoves to address the POM problem, and that he "is not horrified at the prospect of" developing new source performance standards regulating woodburning stoves. But Cannon stressed that he doesn't know how long it will be before the agency decides whether an NSPS should be developed, and that once that determination is made it would still take the agency "at least" three additional years, with a significant resource commitment on the order of $500,000 per year, to propose an NSPS.

Despite strong agency interest in regulating new woodburning stoves, Cannon indicated it is very unlikely the agency will move to regulate existing residential wood and coal burning. Following is the text of the summary of FPA staff's six months toxic study draft:

Executive Summary

This report summarizes the results of a project which was designed to define the dimensions of the air toxics problem in the United States. The analyses that make up this study examined four basic questions concerning the magnitude and nature of the air toxics problem:

(1) What is the approximate magnitude of the air toxics problem, as represented by numerical estimates of cancer incidence associated with air pollution?

(2) What is the nature of the air toxics problem in terms of major pollutants and major sources, and what is their relative importance?

(3) Does the air toxics problem vary geographically, and if so, in what ways?

(4) Are current air toxics data bases adequate, and what are the significant data gaps?

We limited the study to cancer caused by direct inhalation, since other health effects and pathways could not be adequately quantified. Cancer unit risk factors were obtained from EPA's Carcinogen Assessment Group (CAG) and Clement Associates.

Four major analyses formed the quantitative core of the study. The Ambient Air Monitoring Study used air toxics ambient data for five metals, 11 organic compounds, and benzo(a)pyrene (B(a)P) to estimate excess cancer incidence and individual risks. Ambient data were available for approximately 170 sites for the metals and for about 50 sites for BaP, whereas fewer data were available for volatile organic compounds.

A second study reviewed epidemiological studies that evaluated the association between air pollution and lung cancer using health statistics. In this analysis, ambient and occupational B(a)P data were used as an indicator for pollutants associated with incomplete combustion (PIC). A dose-response coefficient relating lung cancer and B(a)P concentrations was generated from these studies. Cancer incidence associated with exposure to PIC was estimated by applying this dose-response coefficient to current ambient B(a)P concentrations.

The two other core analyses (the NESHAPS study and the 35 County Study) used exposure models to estimate incidence and maximum risks. Exposure modeling combines emissions estimates, metrological dispersion models, population distribution data, and cancer potency numbers to estimate annual cancer incidence and maximum lifetime individual risks. The NESHAPS Study provides national estimates for about 40

SECTION 3

PROJECTED GROWTH OF RESIDENTIAL WOOD COMBUSTION

The use of wood for primary and auxiliary heating has grown at a steady rate over the past few years. Wood use surveys were conducted by the U.S. Department of Agriculture in New England over the years 1976 through 1980. A plot of the residential wood use in five states is shown in Figure 3-1. As can be seen, a steady rate of wood growth is exhibited in all states surveyed.

A description of the best fit line for each state is provided in Table 3-1. The correlation coefficient for each state is shown to be quite strong, in each case greater than or equal to 0.97. This, however, is an artifact due to the low number of years sampled in each state. The mean value of the slope, excluding Rhode Island is 87.8 thousand cords per year. The 95 percent (95%) confidence interval constructed about this mean is 87.8 ± 20.5. In other words, the lowest expected growth rate in New England is 67.3 thousand cords per year and the highest expected growth rate is 108.3 thousand cords per year. As indicated in Section 2.2, wood use in other parts of the country during the late 1970's appear to be similar to New England,[37] therefore, this extrapolation will be applied to the projected emission impact analysis.

WESTON requested CONEG member states to submit data on wood

TABLE 3-1

DESCRIPTIVE STATISTICS FOR GROWTH OF WOOD USE IN NEW ENGLAND STATES

STATE	BEST FIT LINE	CORRELATION COEFFICIENT
ME	$y = 93.9x + 334$	$r = 0.97$
MA	$y = 102x + 505$	$r = 0.998$
NH	$y = 82.7x + 165$	$r = 0.99$
RI	$y = 12x + 72$	$r = 1$
CT	$y = 72.5x + 457$	$r = 0.987$

mean slope = 87.8
standard deviation = 12.9
95% C.I. about mean = 87.8 $^{+}$ 20.5

use for the previous four (4) winters. New Hampshire replied with data indicating that wood use had increased by an average of eight percent (8%) per year from the winter of 1980-1981. This wood-use estimate will also be applied to calculate a projected TSP emission impact.

Table 3-2 shows the projected linear annual increase of residential wood use. The minimum annual increase is based on 67.3 thousand cords per state per year as discussed above. Similarly, the maximum projected increase uses the 108.3 thousand cords per state per year value. The numbers are calculated by assuming that wood use is proportional to population. As shown in Figure 2-3, this assumption is appropriate except for very densely populated cities.

The average annual increase across the five New England states surveyed is 19.5 percent (19.5%). Using either the box modeling approach adopted for Task 2 or a linear rollback scheme results in the same conclusion, that is, 19.5 percent (19.5%) more ambient TSP. The alternate projection estimates an increase of eight percent (8%) per year if all other Northeastern states follow the New Hampshire pattern. **Given the fact that all of the assumptions used in the modeling and projections are fairly conservative, it is estimated that many counties presently in violation of the secondary standard will be in violation of the primary standard within five years. This statement is only valid if the very high growth rate in wood use persists.** If the states follow the growth pattern of New Hampshire, then, the primary standard will not be exceeded due to RWC within the next decade.

TABLE 3-2

PROJECTED ANNUAL INCREASE OF RESIDENTIAL WOOD USE

STATE	COUNTY	USAGE 1978-79 (CORDS)	MINIMUM ANNUAL INCREASE (CORDS)	MAXIMUM ANNUAL INCREASE (CORDS)
ME	Oxford	38,815	3,529	5,680
MD	Baltimore	112,565	11,245	18,095
	Anne Arundel	66,380	6,359	10,233
NH	Coos	20,401	3,207	5,160
NJ	Essex	43,329	7,981	12,843
	Hudson	9,200	5,227	8,412
	Middlesex	76,212	5,592	8,999
	Union	36,352	4,731	7,613
NY	Erie	172,282	3,746	6,029
	Niagara	49,506	840	1,348
	Onondaga	96,847	1,709	2,751
PA	Allegheny	192,441	8,270	13,308
	Beaver	41,035	1,166	1,876
	Berks	65,841	1,782	2,868
	Blair	27,900	779	1,254
	Bradford	33,882	359	577
	Cambria	40,647	1,045	1,682
	Carbon	13,553	304	439
	Chester	71,341	1,806	2,906
	Cumberland	38,612	1,015	1,634
	Dauphin	49,649	1,325	2,132
	Erie	61,482	1,596	2,568
	Lancaster	72,800	2,066	3,325
	Lawrence	23,488	611	983
	Mercer	31,624	732	1,177
	Northampton	46,497	1,457	2,069
	Philadelphia	27,200	9,628	15,493
	Washington	50,718	1,238	1,992
	Westmoreland	78,994	2,237	3,600
VT	Washington	20,294	7,928	12,758

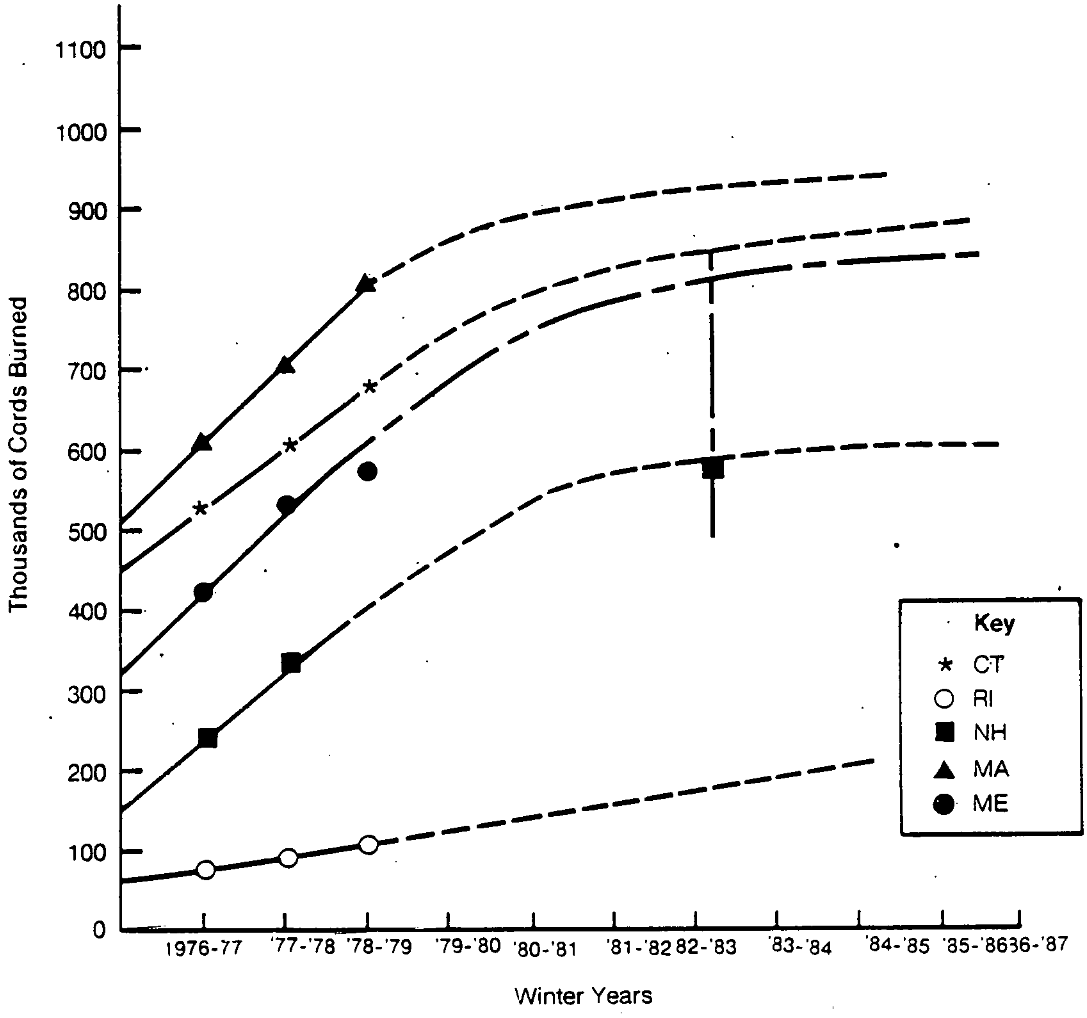


FIGURE 3-1 TRENDS IN RESIDENTIAL WOOD USE FOR THE NEW ENGLAND STATES

SECTION 4

TOPICS IN RESIDENTIAL WOOD COMBUSTION REQUIRING FURTHER RESEARCH

Throughout the course of this project, deficiencies in data have been noted in many topical areas. Further, research is needed in topics ranging form wood use patterns to sampling and emission characterization. The data needed to further the analysis WESTON has started in this project are listed in this chapter.

Wood Use Patterns

- Follow-up surveys on wood use in New England are needed to determine if the trends detected in the late 1970's have continued.
- Surveys need to be initiated in study states other than New England to determine if the empirical correlation is a good fit for these areas.
- A statistical study needs to be conducted on these wood burning data to determine if the projections of future wood use are valid and within what bounds.

Source Contribution to Ambient Air Quality

- Receptor modeling studies need to be conducted in the Northeast to determine if the aerosol composition is similar to areas where studies have been conducted, i.e., Portland, Oregon and Denver, Colorado. These studies should examine TSP, FP and targeted organic compounds.

- An expanded database is needed on ambient BaP and other organic compounds if meaningful risk analyses are to be conducted.

Sampling Methodology and Characterization of Emissions

- Standard sampling and analysis methods need to be developed for emission characterization. There are many methods which have been reported in the technical literature. Comparability of results between methods is questionable.

- The sampling method for ambient PAH needs to include a resin trap to capture volatile and semi-volatile compounds. There is a lack of consistency in the sampling methods reviewed for this study.

- A careful look should be taken at all of the engineering and emissions data on residential wood combustion. A statistical study could determine underlying relationships between TSP and other pollutants, such as CO, BaP and benzene extractables. Understanding these relationships would be useful for impact analysis, for planning purposes and for developing low-cost sampling methods.

Risk Analysis

- A unit risk value for wood stove PAH is required before the concern risk associated with high density wood stoves can properly be assessed. A formal risk analysis should be prepared to understand the impact of wood smoke on public health.

SECTION 5

CONTROL STRATEGIES

Potential control strategies to reduce wood burning particulate emissions include the following:

1. Woodstove education.
2. Firewood seasoning.
3. Home weatherization programs.
4. Pollution control devices.
5. Energy subsidies.
6. Woodstove certification/standardization program.
7. Restricted use.

5.1 WOODSTOVE EDUCATION

Woodstove education has been recognized in Oregon as an important element of air pollution control. Several woodstove publications specific to Oregon have been widely distributed. A series of video public service announcements were produced. Numerous presentations have been made to interested groups. Newspapers, television stations and radio stations have provided extensive coverage. Many state and local agencies, especially the Oregon Department of Energy (ODOE), ODEQ, and the Oregon State University Extension Service, have been involved in this woodstove education effort.

Table 5-1 contains a list of woodstove publications available from the Oregon DEQ.

5.2 FIREWOOD SEASONING

There are two effects of burning wet wood as compared to dry wood:

1. The heating value of the wet wood is less and thus more wood must be burned to achieve the same heating.

2. More particulates per pound of wood burned are emitted from the unseasoned wood.[72]

The heating value of unseasoned or wet wood is less because more energy must be used to vaporize the water out of the wood. More particulates per pound burned are emitted because the additional steam in the combustion area reduces the firebox temperature, resulting in less complete combustion of the wood tars and hydrocarbons given off as the wood breaks down in the combustion process. Table 5-2 illustrates these two effects.

Well-seasoned wood stored in a very dry location will have a moisture content of 15 percent to 20 percent. Conversly fresh cut wood will typically have a moisture content in the 40 to 50 percent range. Wood seasoned for only 6 months will have a moisture content in excess of 50 percent. Douglas fir slash in the forest exposed to heavy moisture during the rainy winter season, even if downed for six months and

TABLE 5-1

OREGON WOODSTOVE PUBLICATIONS AVAILABLE FROM OREGON DEQ

Woodstoves: Energy Solution or Air Pollution?

Woodstove Bibliography

Interpretation of Woodstove Emission Testing Results

Oregon Woodheat Handbook

Burn Wood Better

DEQ Views on Woodheating

TABLE 5-2

IMPACT OF MOISTURE ON WOOD NET HEAT CONTENT AND PARTICULATE EMISSIONS

Wood Moisture* Content (%)	Relative Energy Content	Relative Particulate Emissions Per Pound Wood Burned	Relative Particulate Emissions Per Net BTU Content of Wood Burned
10%	1.00	1.0	1.00
20%	.88	1.2	1.36
30%	.67	1.5	2.25
40%	.59	1.9	3.22
50%	.47	2.4	5.10

* Wet basis, i.e. 10% moisture content = $\frac{\text{10 lb. water}}{\text{10 lb. water + 90 lb. water}}$

partially cutup, would typically have a moisture content of about 35 percent or greater.

A sample comparison from Table 5-2 shows the impact of moisture content. Wood with 40 percent moisture content has only 67 percent of the heating value of an equal amount of wood with 20 percent moisture content wood. Thus, about 1-1/2 times as much of the 40 percent moisture wood must be burned to produce equivalent heat. In addition, the particulate emissions per unit of heat output are 2.4 times as high, because the gases and tars are burned less completely. Hence, overall emissions are higher than dry wood. The difference is solely due to higher creosote and hydrocarbon particulate emissions. Individuals should seek to burn drier wood for three reasons:

1. The heat content is higher;

2. The creosote emissions would be cut in half, resulting in safer stove operation and reduced cleaning requirements; and

3. Air pollution emissions are less.

Although information is not available to know precisely the average moisture content of wood burned in the Northeast, it is probably in the 25 percent to 30 percent range. Assuming an average moisture content of 28 percent, significant reductions in particulate emissions could be obtained if the average moisture content were reduced to 20 percent. The heat output from burning 20 percent moisture wood would be 22 percent higher. Assuming that all stove owners and one-fourth of the fireplace owners would burn less wood with higher heat content, particulate emissions would be reduced by 26 percent, given an eight percent (8%) reduction in fuel moisture, because of more efficient and complete combustion.

Regulations to reduce the average moisture content of wood burned could include:

1. Requiring commercial wood suppliers to specify the average moisture content of the wood they sell;

2. Requiring suppliers to specify the time elapsed since the wood has been cut and split and where it was stored;

3. Cooperating with the Forest Service to allow National Forest wood cutting only under drier summer-type conditions,

4. Prohibiting the sale of inadequately seasoned wood or wood with a moisture content above a certain level, say 30 percent.

5.3 HOME WEATHERIZATION PROGRAMS

Improved residential insulation and weatherization could reduce particulate emissions by reducing the amount of space heating needed to maintain comfortable temperatures. A typical home requires about 121 million BTU's per year for space heating. If each home were weatherized the amount of energy required could drop as low as 49 million BTU's, a reduction of 60 percent. The effect of this program might be to increase indoor air pollution while reducing outdoor pollution. A second point to note is that weatherization programs can cost the government a considerable amount of resources. Energy subsidies are discussed more fully in Section 7.2. Finally, indoor air pollution could increase as a result of weatherization due to a reduction in the exchange rate between indoor and outdoor air.

5.4 POLLUTION CONTROL DEVICES

Three devices are in production and undergoing evaluation which reduce emission and conserve fuel:

1. Catalytic afterburners.

2. Air supply controls.

3. Stack gas temperature gauge.

Catalytic Afterburners

Catalytic afterburners are available on some new wood stove models as well as separately for retrofit to some previously purchased stoves. Stoves with built-in catalysts reduce emissions by about 80 to 90 percent. Retrofit devices have somewhat lower reduction efficiencies (40-60%). Catalysts can have net fuel savings of up to 20%.[72]

Air Supply Control Device

One variable which can play a key role in determining the amount of emissions produced by wood burning is the rate of air supply. If the air supply is excessively restricted on an airtight wood stove, the particulate emission rate can rise significantly because not enough oxygen is supplied for complete fuel mixing and combustion to occur. Under such conditions, more unburned hydrocarbons and wood tars are produced, either to condense in the stack as creosote or to exit as particulate air pollution.

EPA has funded a two-phase research contract to:

1. Determine more precisely the relationship between creosote formation or particulate emissions air supply rates; and

2. Develop an inexpensive electronic feedback devise to regulate the air supply rate based on certain combustion process measurements.

This work should help clarify the effect of air supply on particulate emissions and provide an indication of the effectiveness and feasibility of reducing emissions and creosote formation in this manner. In addition, stove manufacturers are redesigning fireboxes for more efficient combustion.

Stack Temperature Gauge

Temperature gauges are currently available at a cost of about $10. Such gauges can help reduce emissions because they provide feedback to the stove owner on the approximate temperature of the existing stack gases. If the owner is so motivated, he can then regulate the amount of wood and air supplied to the stove such that reasonably good air-fuel ratios are maintained. Such devices are commonly marked to indicate that creosote forms at a very rapid rate at low temperatures and that the stove is operating inefficiently (due to excess heat loss) if stack temperatures are too high. An owner can reduce the amount of creosote emissions and stove deposits by determining what temperature his stove operates at when smoke density from the stack is minimal (by visual observation), and then by generally trying to maintain normal stove operation near that temperature level.

5.5 ENERGY SUBSIDIES

The State of Oregon has authorized the expenditure of $14 million to provide relief for low income or elderly residents who cannot afford to pay their space heating bills and have not received assistance from any other programs. These are direct energy subsidies rather than loans or grants for home weatherization. While the effects of this program are not quantifiable, it may help to lessen the rush of lower income homeowners to utilize wood space heating as a means for reducing their space heating costs.

The primary disadvantages of such a program would be: (1) its high cost, and (2) the fact that it would tend to support high levels of energy consumption rather than conservation.

5.6 WOODSTOVE CERTIFICATION

Woodstove manufacturers have claimed overall efficiencies of 70% or more in recent designs which include modified combustion chambers and catalysts. Independent testing has verified some of these claims. A high efficiency woodstove (70% efficient) is expected to burn about 25% less wood than the average woodstove (50-55% efficient) to produce the same heat output. In addition, the emission rates (lb/ton) from some new woodstove designs are 70-80% lower than from the average woodstove. The combined effect of increased efficiency and lower emission rate is a 50-55% reduction in emissions per unit of heat output.

The 1983 Oregon Legislature authorized the Oregon Department of Environmental Quality to implement a woodstove certification program. The test method and performance standard were adopted in July 1984. The test methods which are acceptable are the EPA Modified Methods and Oregon Method 7. A voluntary labeling program also begun in July 1984. Another key aspect to this legislature mandates that only low emission woodstoves be sold in Oregon after July 1986.

5.7 RESTRICTED USE

Prohibition of More than One Stove or Fireplace Per Residence

Vail, Colorado recently adopted an ordinance to prohibit more than one stove or fireplace being installed in any new residential construction. Regulation assumed to slow the rate of growth of wood combustion by 10 percent in Colorado, would also have the value of getting the message to homeowners that wood burning is significant and increasing air pollution problem.

Prohibition of Future Stove and Fireplace Installations

A decision could be made that wood burning emissions are increasing at too rapid a rate for particulate air quality to be protected, and new stove installations could theoretically be prohibited. Such a policy would have significant public opposition, and would probably require extensive documentation of a very severe health problem before the necessary support could be obtained from the legislature.

Table 5-3 lists control strategies presently in use or proposed in various parts of the country.

TABLE 5-3

CONTROL STRATEGY ELEMENTS IN USE/PROPOSED

Element	Areas in Use/Proposed
Public Education	Alaska; Oregon; Missoula, Mt; Colorado (ski communities & elsewhere); Reno, NV
Visible emission limits	Juneau, AK; Missoula, MT
Mandatory curtailment of use during high pollution episodes	Medford, OR; Missoula, MT; Beavercreek, CO; Reno, NV; Juneau, AK
Voluntary curtailment of use during high pollution episodes	Reno, NV; Albuquerque, NM; Vail, CO; Juneau, AK
Reduce wet wood burning	Juneau, AK; Medford, OR
Weatherization requirements for stove use	Medford, OR; Crested Butte, CO
Restriction on wood burning appliances:	
• Number of appliances	Telluride, Aspen, Vail, Crested Butte, CO
• Design standards	Aspen, Vail, Beavercreek, CO
• Emission standards (stove certification)	Oregon; Missoula, MT
• Residential permitting requirements	Missoula, MT; Beavercreek, CO
• Require alternate heating in new homes	Medford, OR

SECTION 6

EVALUATION OF CONTROL OPTIONS

The expected outcome of various residential wood combustion (RWC) control strategies vary with specific programs, their goals, and assumptions made regarding future events. The effectiveness of the control strategies outlined in Section 5 is discussed in this section. First, a general discussion is presented on developing cost-effective control strategies. Next, these principles are illustrated by presenting the Portland Aerosol Characterization Study. The following two sections present control strategy elements relevant to RWC devices, and application of these control elements in two urban areas. Finally, these strategies are discussed in light of the air quality problems in the Northeastern states.

6.1 DEVELOPING A COST-EFFECTIVE CONTROL STRATEGY

Over the past several years techniques have been developed that assist planners devise cost-effective control strategies. In particular, the use of source apportionment models in combination with economic data enhance the development of air pollution control strategies.

Figure 6-1 illustrates the relationship between various elements in the air pollution control process. In the first step, a question must be posed. Is the air quality satisfactory? If so, than a monitoring program is adequate to ensure continuing quality. If not, than the goal of the control program must be defined. The most likely goal as applied to this program will be to meet, primary or secondary NAAQS for TSP or CO. Next, a detailed emission control plan is devised. The plan might include some of the elements discussed in Section 6.2 for limiting TSP emissions from RWC devices. At this step in the process, the information obtained in a receptor modeling program is essential for developing the most effective air pollution control strategy. Finally, the control program is implemented and the effects noted, returning the planner to the beginning of the cycle.

Figure 6-2 shows the steps involved in developing a costeffective air pollution control strategy. In the data gathering step, information regarding emissions, air quality, meteorology and control technology are assembled. In the process steps, verifiable air quality models are used in conjunction with the air quality objective to arrive at the least-cost optimization.

Using spatially resolved air quality models, it is possible to identify control strategies that selectively abate those sources responsible for hot spots in an air basin. Early control strategy studies that attempted to account for atmospheric pollutant transport employed Gaussian dispersion models. More recently, control strategies have been developed for particulate matter using source apportionment methods.

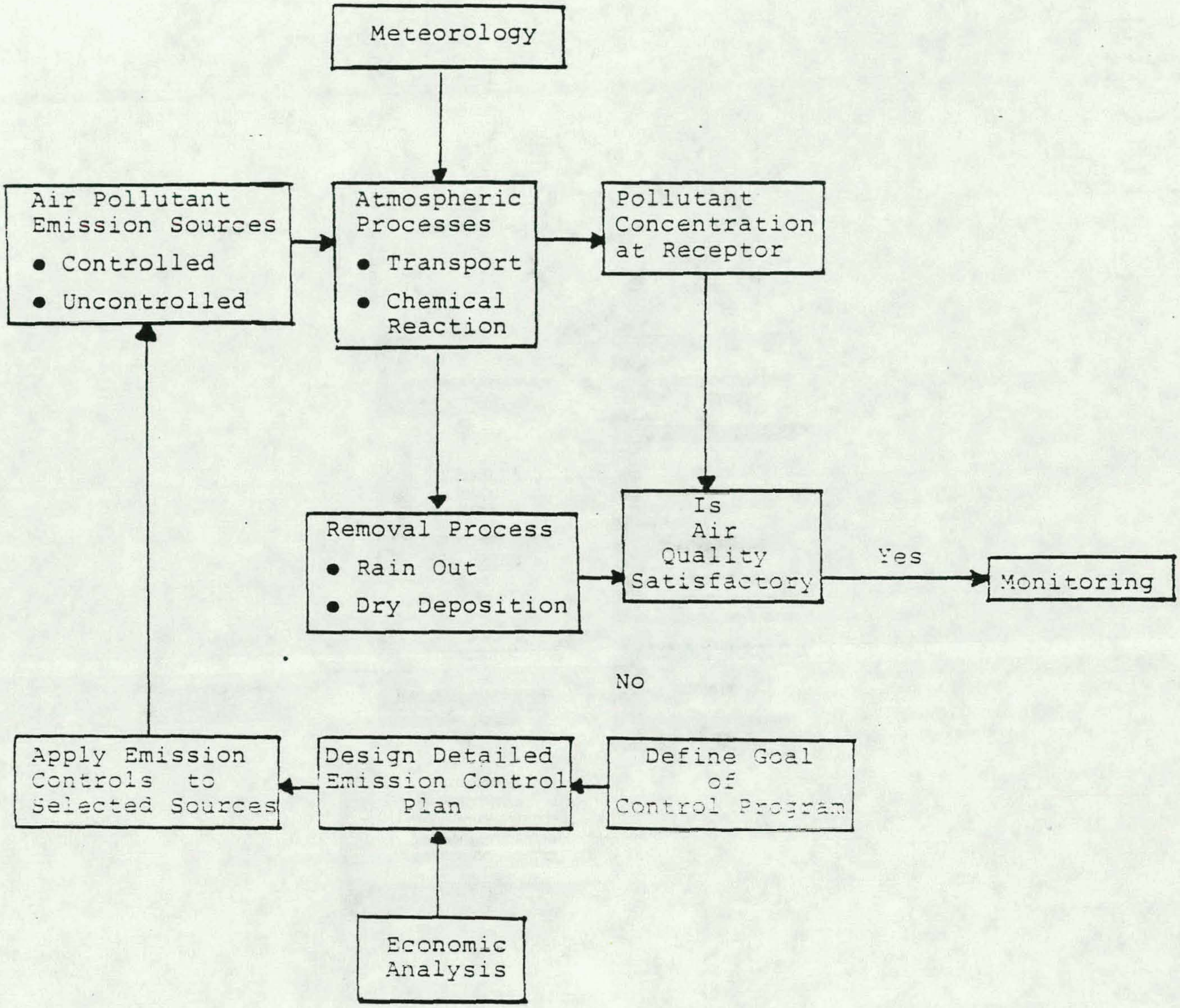


Figure 6-1 -- Relationship between various elements in the Air Pollution Control Process.

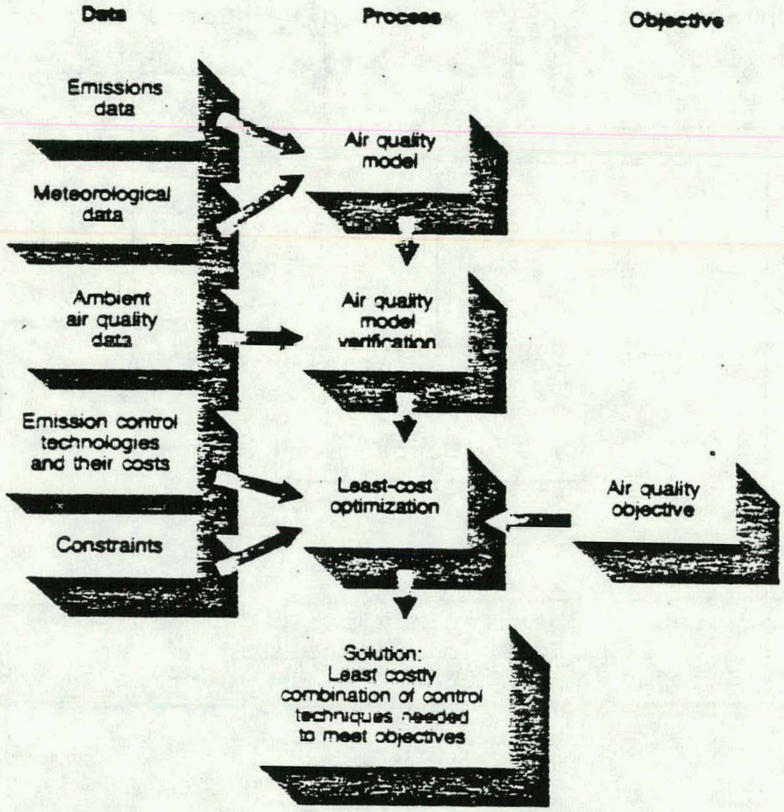


FIGURE 6-2 Steps involved in developing a cost-effective air pollution control strategy.

The Portland Aerosol Characterization Study[27] (PACS) employed chemical element balance techniques, a source apportionment method, to identify the actual source classes contributing to local particulate air quality. The air quality model was combined with data on the cost of available abatement techniques. A strategy was identified that emphasized traffic control and road cleaning in selected areas of the city to suppress fugitive road dust. The other major element of the program involved phased-in control on residential wood combustion.

The PACS represents a new, advanced method to devise a cost-effective control strategy. The objective of the control strategy is to limit the control elements to only the major sources. In the case of Portland, Oregon, the control strategy is designed to meet compliance with the primary NAAQS for TSP. By directing the control effort toward reducing fugitive road dusts and RWC emissions, the Oregon DEQ has eased their enforcement activities, while ensuring that their goal will be met.

WESTON emphasizes that the PACS analytical methodology, but not the study itself is recommended as an approach in developing control strategies. The study has been criticized on several counts, most noteably the timing of the sampling period. Care must be taken to devise a study that accurately reflects the air quality in the study area.

The methodology followed by the Oregon DEQ in devising a cost-effective particulate control strategy is germane to the project undertaken by CONEG. **Understanding the source of TSP problem in the Northeastern states is essential for** the development of an effective control strategy. The next several sections will discuss elements of a control strategy oriented toward RWC devices. In the final section, application of these control elements to the TSP problem in the Northeast will be discussed.

6.2 CONTROL STRATEGY ELEMENTS

Actual air quality benefits of RWC control elements depend on site-specific factors such as quantity of wood burned, availability and cost of alternative fuels, growth rates, population density and meteorology. This section presents a range of costs and benefits estimated by application to designated urban areas.

6.2.1 Public Education

Public education is recognized as an essential component of RWC control strategies. Public education programs are proposed or implemented in Oregon, Colorado, Alaska, Montana and Nevada. The benefits from this strategy are difficult to quantify and in general, it is unlikely that a significant fraction of the public alter their behavior as a result of an education program.

Oregon DEQ estimates that public education programs have reduced emissions by 13 percent. Survey data indicate that more than 75 percent of the residents follow the ODEQ's suggestions on wood seasoning (6-9 months of air drying) and cutting practices.(45) Firewood seasoning is estimated to reduce emissions by 6.2 percent. Proper sizing of stoves, i.e., the use of the correct size stoves to prevent over or under charging, reduces emission proportioned to wood charge size.

One other operator controlled variable is the size of the firewood. Smaller pieces of firewood have more surface area and therefore release volatile components at a faster rate than large pieces of firewood. The result of this volatilization is incomplete combustion due to an oxygen deficiency. Increasing average wood size from the 2-6 inch diameter range to the 4-6 inch range can reduce emissions by 33 percent.(45) It is estimated that this control element can be 50 percent effective through public education. Both distributors and wood fuel users need to be educated on optional fuel dimensions.

Retrofitting RWC devices with temperature gauges and catalysts could be encouraged through a public education program. Temperature gauges are inexpensive and provide useful information regarding stove operating conditions. Maintaining optimum operating temperature is advantageous to the operator since it reduces used consumption and creosote formation. Some retrofitted catalysts are effective for reducing creosote. Catalysts cost \$50-\$70 for replacement elements and temperature gauges cost approximately \$10.

6.2.2 Mandatory Emissions Labeling

Similar to EPA's gas mileage rating of automobiles, new stoves could be required to have labels affixed indicating the results of emission tests and energy rating. This strategy was estimated to reduce emissions by 25 percent in Oregon.(45) The program was estimated to reduce emissions by 11 percent in 20 years, with additional reductions taken when combined with the energy subsidy program for low TSP emitting RWC devices. Examples of labels for the proposed Oregon program are shown in Figure 6-3.

6.2.3 Restricted Use

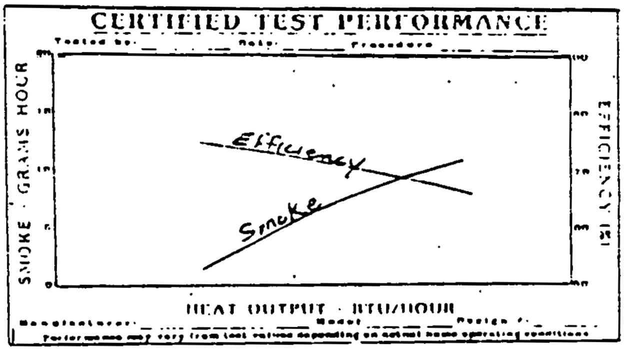
The implementation of restricted use ordinances falls in two categories. The first category is exemplified by the air pollution strategy used in Colorado: Vail, Aspen and other ski communities throughout Colorado have adopted ordinances to prohibit the use of more than one stove from being installed in a new residence. This strategy is designed to slow the growth rate of RWC but has no effect on reducing immediate TSP problems.

FIGURE 6-3 EXAMPLES OF RWC DEVICE LABELS

Labels

- TWO LABELS are required, a permanent one and a removable one.
- The REMOVABLE LABEL must be ATTACHED TO THE FRONT of all woodheaters being sold.
- The PERMANENT LABEL (at least 3½" by 2") must be "VISIBLE AFTER INSTALLATION", similar to detailed safety labels (not CPSC warnings).

Permanent label (actual size)



Removable label

EMISSIONS AND EFFICIENCY PERFORMANCE

Smoke __________ grams/hour (DEQ Standard: 9)

Efficiency __________ % (No DEQ Standard)

HEAT OUTPUT RANGE

__________ to __________ BTU's/hour

Manufacturer: __________ Model: __________ Design #: __________
Name Name Number

(Performance may vary from test values depending on actual home operating conditions)

Pursuant to OAR __________, this unit has been certified as meeting Oregon Department of Environmental Quality emission standards and has been approved for sale in the State of Oregon.

The second category of restricted use is exemplified by programs in Missoula, Montana and Medford, Oregon. In this air pollution control strategy, the use of RWC devices is restricted or curtailed during pollution episodes. Compliance based on a voluntary program is expected to be in the 25-50 percent range, while a mandatory program with fines levied for non-compliance is expected to make the program 75-100 percent effective.(46) In Medford, Oregon curtailment during air pollution episodes is expected to result in a 5-15% reduction in TSP while in Missoula, Montana curtailment is expected to reduce TSP by 23-44% if 100 percent effective. The difference between these two estimates of TSP reduction in primarily due to differences in the particulate emission inventory. Medford is both more urbanized and industrialized than Missoula, therefore, a smaller part of its inventory is attributable to RWC.

6.2.4 Certification

Programs which allow only clean burning residential woodheating appliances to be sold are an integral element of the TSP air pollution control strategy in Oregon and Colorado. The objectives of the certification program are to lower emissions, conserve resources and promote safety. Resources will be conserved by burning fuel more efficiently in the certified stoves. Fire safety will be promoted by requiring inspections during the time of installation of a new stove. The Oregon DEQ estimates that a certification program will become fully effective after 15-20 years and will reduce emissions by 68-75%. In Missoula, Montana the proposed certification program is expected to take 15 years before it is fully implemented and is expected to reduce emissions by 92 percent.

Colorado has not issued numbers on the projected effectiveness of its program. However, since the TSP problem in Colorado is located in ski communities, an 85-95 percent reduction in TSP emissions could be expected. This range is based on an emission inventory that is dominated by RWC emissions. Mobile source and industrial point source are expected to constitute minor elements of the emissions particulate inventory.

6.3 PROJECTED BENEFITS OF URBAN-WIDE CONTROL STRATEGIES IN USE

6.3.1 Medford, Oregon

The wood stove and fireplace control strategy adopted for the Medford, Oregon area is part of the Oregon DEQ's overall strategy to achieve the primary NAAQS for TSP. The portion of the overall strategy pertaining to RWC is projected to reduce the annual ambient TSP concentration by 16 ug/m^3 in 1985.(47) Specific elements of the RWC strategy are outlined in Table 6-1. Weatherization of homes with stoves is projected to be a more effective air pollution control element than weatherization of homes prior to installation of stoves because many stoves were installed in the 1970's prior to the onset of the weatherization program. The firewood seasoning control element will increase spring cutting by 40 percent, thereby increasing the amount of time to dry the fuel. On a tonnage basis, the Medford strategy is projected

Table 6-1

Projected Effect of RWC Control Strategy on TSP Air Quality in Medford, Oregon

Control Element	TSP Reduction (tons/year)	Implementation Time (years)	Effect on Air Quality (ug/m^3)
Weatherization prior to new stove installation	133	3-10	3.2
Weatherization of homes with stoves	289	3-10	5.5
Firewood seasoning	147	2-3	4.2
Episode Curtailment	117	1	2.6
Certification*	505	15-20	9.6

Source: Reference 47.

to reduce RWC emissions by 40 percent from the 1979-1980 baseline of 1557 tons of TSP.

The time for these control strategies to become fully effective ranges from 2-10 years. Curtailment during episodes would have an immediate effect on air quality. Improved stove operation and spring cutting, both public education programs, would not become fully effective for 2-3 years. The weatherization program is expected to require 3-10 years before it is completely effective.

The Medford strategy to attain the secondary NAAQS for TSP by the year 2000 is based on the continuation of the aforementioned control elements and the implementation of the wood stove certification program. The Oregon DEP estimates the expected change in emission is a reduction of approximately 70 percent by the year 2000.

6.3.2 Missoula, Montana

Missoula, Montana presently has an episode curtailment program. This voluntary program is believed to reduce emissions by 6-12 percent, based on an estimated compliance rate of 30 percent. A mandatory curtailment program with 100 percent compliance is projected to reduce emissions by 23-44 percent.

6.4 POLYNUCLEAR ORGANIC MATERIAL

Although POMs are the product of every combustion process, developing a cost effective pollution control strategy requires focusing on the quantitatively important sources. As is shown in Table 2-6, the important sources on a nationwide basis are the following (in descending order):

- Residential wood combustion
- Mobile sources
- Open burning
- Coal-fired industrial boilers
- Coke production
- Incinerators
- Other combustion sources

Light duty gas vehicles and residential wood combustion contribute approximately 50 percent of the annual POM on the national level. It is estimated that open burning, which includes agricultural burning, prescribed burning and forest fires contributes another 30 percent to the national POM budget. Coke production and coal-fired industrial boilers contribute another 12 percent. The remaining 8 percent are contributed by other mobile and stationary sources.

In April, 1984, the Administrator of the U.S. EPA announced that he would not be seeking regulatory control of POM emissions. One local authority, Philadelphia AMS has an ambient standard for BaP (0.7 ng/m^3). Several states are considering implementation of BaP or POM standards.

As shown in several recent research papers (48,49,50), when ambient levels of TSP are high in rural areas, the POM level approaches or exceeds that observed in many urban areas. It should be noted, though, that ambient levels of POM in all urban areas monitored have decreased several-fold over the past 20 years. Background levels of TSP, except in areas with significant fugitive dust sources, as well as POMs are usually well below that of urban areas. Recall that POM health problems relate to long term exposure only. In general, control strategies which limit emissions of TSP also limit emissions of POMs.

Public education, a control strategy designed to enhance the use of well seasoned firewood, proper stove size and fuel wood size, effect TSP emissions and POM emissions by improving combustion characteristics. Energy subsidies and curtailment strategies effect both TSP and POM ambient air levels by reducing the amount of wood combusted. Catalytic devices are designed to oxidize flue components with more complex structures to CO_2 and water. This is true of both TSP and POM. Finally, certification programs, when fully enacted, will improve both emission and combustion characteristics which effect TSP and POMs.

There are presently no control strategies designed to specifically address the reduction of ambient levels of POMs. Developing a cost-effective control strategy for POMs, requires the following elements: Emission inventories on the local level, control technologies, modeling methods and air quality objectives. A comprehensive control strategy would include limiting emissions from mobile sources, RWC devices and other important local sources. Until ambient air quality goals are defined for POMs, and data gathering and processing techniques are improved, an effective POM control strategy cannot be developed.

6.5 COST

The cost of implementing a comprehensive RWC air control strategy is distributed between individual RWC device users, regulatory agencies and stove manufacturers. Strategies which rely on reduced use of wood for home heating are only effective through a weatherization program. While tax incentive can be provided, the homeowner must co-pay for the cost of the insulation. Also, less wood use results from burning fuel more efficiently. Burning fuel more efficiently can result from public education campaign, a cost incurred by the regulatory agency, and using new, more efficient stoves. The cost of developing more efficient stoves is burdened by the manufacturer.

Control strategies using curtailment during high pollution episode, have significant costs to both individual homeowners and regulatory agencies. In Oregon, where a voluntary program was adopted, curtailment is expected to increase average home heating costs by \$50/year.(51) The regulatory agency costs include real-time ambient air monitoring, data processing, public announcements and enforcement. Establishing a real-time ambient air monitoring station including professional time could cost as much as \$50,000, and an additional \$10,000 annually for manning and maintenance.

A strategy based on new installations of low emitting RWC devices will have costs to regulatory agencies, the wood stove industry and the stove purchasing individual. The Oregon DEQ estimates its costs for the stove certification program to be \$6,000 per stove.(52) The additional cost to the purchasing individual could be \$300-\$500 over the cost of a standard model. However, since the stove is more efficient than the standard model, the operating cost will offset the purchase cost over a 10-year period. If a catalytic converter is included, an additional cost of $50-$70 is incurred by the homeowner for replacement every two years. Estimating the cost for redesigning RWC devices is complex and no costs were cited in the technical literature. To encourage the purchase of new, low polluting RWC devices, a tax credit could be offered in the $300-$500 range.

Weatherization is another RWC control measure with high initial cost. Weatherization is estimated to cost $1400-$1500 per household in the Portland, Oregon area.(45) These costs will eventually be offset by reduced fuel usage.

The direct costs of the wood stove certification program was estimated to be $500/ton of TSP, while the cost of the voluntary pollution episode curtailment program was estimated at $1900/ton of TSP.(47) These costs compare favorably against those incurred by industry for particulate control. Table 6-2 shows the comparative energy and economic impact of control measures implemented in Medford, Oregon. Table 6-3 shows the economic analysis for the cost of new RWC device technology. Table 6-4 shows which party would incur costs for the implementation of each control element.

6.6 DEVELOPING A RWC CONTROL STRATEGY IN THE NORTHEAST

The promulgated list of TSP non-attaining counties for 1983 is shown in Table 6-5. Several trends are evident upon examining this table. First, outside of Connecticut, only 2 whole counties, New York, New York and Hudson, New Jersey, are not in attainment for TSP. Second, only 6 counties are not in attainment with the primary standard. Only 1 of these

TABLE 6-2

ENERGY, ECONOMIC AND EMISSION IMPACTS OF MEDFORD CONTROL MEASURES

MEASURE	ENERGY REQUIREMENT	ANNUAL COST PER TSP REDUCTION per ton	ANNUAL COST PER TSP REDUCTION per ug/m^3
Residential			
Weatherization	Net Savings	Net Savings	Net Savings
Firewood seasoning	Net Savings	Net Savings	Net Savings
Woodstove curtailment	No change	$1,850	$48,000
Woodstove certification	Net Savings	350	18,000
Industrial			
Cyclone controls	350 $hp/ug/m^3$	1,000	130,000
Veneer dryer controls	450 $hp/ug/m^3$	4,500	500,000
Small boiler controls	350 $hp/ug/m^3$	17,000	130,000
Large boiler controls	No change	3,400	120,000

PARTICULATE EMISSION REDUCTION POTENTIAL

CONTROL	TIME TO IMPLEMENT (YR)	TIME TO ACHIEVE SIGNIFICANT BENEFIT (YR)	PARTICULAT EMISSION REDUCTION POTENTIAL (%)
Curtailment during pollution episodes	1/2	1-2	5-15
Improved operation and firewood seasoning	1	2-3	10-20
Weatherization and proper stove sizing	2	3-10	30-50
Certification program (for high efficiency/low emissions designs)	3	10-20	75-85
Overall	3	1-20	80-95

SOURCE: Reference 51

TABLE 6-3

ECONOMIC CONSIDERATIONS IN RWC DEVICE TECHNOLOGY

CASE	MARGINAL COST[a]	COST PER YR. CATALYST REPLACEMENT	SAVINGS PER YR. CHIMNEY CLEANING[b]	FUEL SAVINGS PER YEAR[c]	PAYBACK TIME FOR INCREMENTAL INVESTMENT IN NEW TECHNOLOGY[d]
Trade in existing stove for catalytic stove	$500 $900	$50	$50	$206	2.4- 4.4 years
Trade in existing stove for improved non-catalytic stove	$800	0	$50	$116	4.8 years
Buy catalytic stove instead of conventional stove	$200	$50	$50	$206	1- 2.9 years
Buy improved non-catalytic stove instead of conventional stove	$500	0	$50	$116	3 years
Buy catalytic add-on for existing stove	$140 $200	$50	$50	$124	1- 1.6 years

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a. Assumptions: Cost of catalytic stove $700-$1100; cost of non-catalytic stove $1,000; trade-in-value of existing conventional stove $200; cost of add-on devices $140-$200; conventional stove cost $500.

b. Assumptions: Only one cleaning per year instead of two will be necessary, and the cost per cleaning is $50. (Actual need for cleaning can only be determined by inspecting the flu; whenever the creosote deposit is 1/4 inch thick or more, cleaning is advisable.)

c. Assumptions: 6 cords per year burned in conventional stoves; wood costs of $100 per cord; Average Efficiencies: Catalytic stove - 70%, Improved Non-catalytic Stove - 57%, Catalytic add-ons - 58%, Conventional stove - 46%.

d. Assumptions: Interest, inflation, etc. not included.

SOURCE: Reference 52

TABLE 6-4

CONTROL ELEMENT	PARTY INCURRING COST
Public Education	State government for planning, implementation and maintenance
Control Devices	Consumer
Energy Subsidies	Cost usually shared between consumer and state government
Episode Curtailment	State and/or local government for planning, operation, enforcement, and maintenance
Certification	State government to accredit test laboratories, reviewing test results, enforcement. Industry incurs the cost of performing the tests. Industry might pass the costs of these tests on the consumer.

TABLE 6-5

COUNTIES NOT MEETING THE NAAQS FOR TSP IN 1983

CONNECTICUT

COUNTY	POPULATION	T S P PRIM	 SEC
Fairfield Co.	807,143		W
Hartford Co.	807,766		W
Litchfield Co.	156,769		W
Middlesex Co.	129,0917		W
New London Co.	238,409		W
Tolland Co.	114,823		W
Windham Co.	92,312		W

MAINE

COUNTY	POPULATION	PRIM	SEC
Kennebec Co.	109,889		P
Knox Co.	32,941		P
Penobscot Co.	137,015		P
Washington Co.	34,963		P

MASSACHUSETTS

COUNTY	POPULATION	PRIM	SEC
Berkshire	145,110		P
Bristol	474,641		P
Essex	633,632		P
Hampden	443,018		P
Middlesex	1,367,034		P
Norfolk	606,587		P
Suffolk	650,142		P
Worcester	646,354	P	P

P = Part of the county

W = The whole county

TABLE 6-5 (Cont'd)

NEW HAMPSHIRE

		TSP	
COUNTY	POPULATION	PRIM	SEC
Coos Co.	35,147	P	
Hillsborough Co.	276,608		P

RHODE ISLAND

Providence Co.	571,349		P

VERMONT

Chittenden Co.	115,534		P
Rutland Co.	58,347		P

NEW JERSEY

Camden Co.	471,650		P
Essex Co.	851,116		P
Hudson Co.	556,972		W
Middlesex Co.	595,893		P
Cumberland Co.	132,866		P
Union Co.	504,094		P

NEW YORK

Albany Co.	285,909		P
Bronx Co.	1,168,972		P
Chautauqua Co.	146,925		P
Erie Co.	1,015,472	P	P
Greene Co.	40,861		P
Kings Co.	2,230,936		P
New York Co.	1,428,285		W
Niagara Co.	227,354	P	P
Onondaga Co.	463,920		P
Queens Co.	1,891,325		P
Richmond Co.	352,121		P

TABLE 6-5 (Cont'd)

MARYLAND

		T S P	
COUNTY	POPULATION	PRIM	SEC
Anne Arundel Co.	370,775		P
Baltimore Co.	655,615	P	P
Baltimore	786,775	P	P
PENNSYLVANIA			
Allegheny	1,450,085	P	
Beaver Co.	204,441	P	
Berks Co.	312,509		P
Blair Co.	136,721		P
Cambria Co.	183,263	P	
Chester Co.	316,660		P
Erie Co.	279,780		P
Fayette Co.	159,417		P
Lackawanna Co.	227,908		P
Lancaster Co.	362,346	P	
Lawrence Co.	107,150	P	
Lehigh Co.	272,349	P	
Luzerne Co.	343,079		P
Lycoming Co.	118,416		P
Mercer Co.	128,299	P	
Montgomery Co.	643,621		P
Northampton Co.	225,418	P	
Philadelphia Co.	1,688,210		P
Washington Co.	217,074	P	
Westmoreland Co.	392,294	P	
York Co.	312,963	P	

P = Part of the County

W = The whole county

SOURCE: EPA-450/2-83-004 MAPS DEPICTING NON-ATTAINMENT AREAS PURSUANT TO SECTION 107 OF THE CLEAN AIR ACT - 1983 counties, Coos, New Hampshire is located in a rural, non-industrial area. Third, in most Northeastern states, less than 25 percent of the counties exceed the secondary NAAQS for TSP. Finally, of the counties listed as not meeting the NAAQS for TSP, almost all are in highly industrialized areas. In summation, Table 6-5 shows the following:

- TSP problems in the Northeast are local in nature.
- Only 6 counties in 11 states do not meet the primary NAAQS standard.
- Fewer than 25 percent of the counties in the northeast exceed the secondary NAAQS standard.
- Most of these counties are highly industrialized.

The analysis of Table 6-5 presented above, begs the question to be asked: Are we missing local hot spots in rural or mountain towns due to a lack of monitoring? While there are few data available, three studies have been conducted in the northeast.(48-50) These studies were designed to demonstrate the contribution of RWC to the ambient level of TSP. The results are shown in Table 6-6. In only one of the five locations monitored did the highest observed TSP value approach 40 percent of the secondary standard. The one outstanding location is Springfield, an industrialized city in Western Massachusetts. The highest value in this city neared 60 percent of the secondary NAAQS.

At the onset of Section 6, the relationship between elements in the air pollution control strategy are outlined. The

TABLE 6-6

MEASUREMENTS OF TSP AND BaP
IN RURAL AND SEMI-RURAL NEW ENGLAND TOWNS

LOCATION	REF	MAXIMUM 24-HOUR TSP CONCENTRATION (ug/m^3)	MAXIMUM 24-HOUR BaP CONCENTRATION (ug/m^3)
Lyne, NH	49	52	3.8
Brigham Hill, NH	49	48	3.7
Hanover, NH	49	61	6.2
Easthampton, MA	50	48	---
Springfield, MA	50	94	---

Primary 24-Hour TSP Standard: 260 ug/m^3
Secondary 24-Hour TSP Standard: 150 ug/m^3

first steps involve determining if the air quality is acceptable and defining the air quality objective. In the counties where the primary NAAQS for TSP is not being met than the objective is to reach attainment. Since these counties are highly industrialized, except Coos, NH, than probably the large stationary and mobile sources are the major source categories. In the many counties where the secondary NAAQS for TSP is not being met, source inventories must be established to determine which souce categories contribute significantly to the ambient level of TSP.

Developing a control strategy which includes residential wood stoves will most likely result from concern over fine particulate matter or toxic air pollutants. Some local agencies, such as the Philadelphia AMS have air toxic regulations which include ambient levels for BaP. Several state agencies, for example Massachusetts, are in the process of promulgating air toxic regulations which will include POM and other pollutants emitted from wood burning stoves. As these regulations are established, control strategies will be implemented which reduce the levels of these toxic air pollutants. Controlling emissions from wood burning stoves could become an important element of these programs.

In conclusion, the Portland Aerosol Characterization Study,(28) which utilized source receptor modeling, demonstrated how to unravel source contribution to ambient TSP levels. No study to date in the Northeast demonstrates with any degree of confidence that controlling RWC on a region-wide scale would significantly reduce ambient TSP levels. Furthermore, although elevated TSP levels have been demonstrated to exist in mountainous areas, these levels never approach the secondary NAAQS. Finally, most counties which exceed the secondary NAAQS are in urban, industrialized areas.

The only significant change in regulatory structure over the near future is altering the primary particulate standard from TSP to PM_{10}. It is not possible at this time to evaluate the full effect of the standard shift since neither the primary nor secondary concentration levels have been set. Comprehensive studies will have to be conducted to determine if areas meet the new NAAQS for particulate matter prior to devising an inhalable particulate control strategy.

SECTION 7

RESIDENTIAL WOOD STOVE CERTIFICATION

Certification programs have been enacted in two states, Oregon and Colorado. In both states evidence indicates that RWC devices are primary contributors to high ambient levels of TSP. Certifying stoves to meet defined emission criteria will help alleviate a significant portion of the TSP problem in those two states. The Oregon DEP estimates that the ambient TSP level will be reduced by 70 percent over present day levels within 15-20 years. This section analyzes the attempts by the Oregon DEP and the Wood Heating Alliance (WHA) to establish an equitable certification program.

7.1 OREGON CERTIFICATION PROCEDURE

The Oregon certification procedure is the result of over 2 years of work by members of the wood heating industry, represented by the WHA, and members of the Oregon DEQ. The test procedure consists of four tests over various burn rates, starting from a hot start, using dimensional lumber and using the calorimetry room or stack loss method to determine efficiency. The WHA lobbied for use of the hot start and the room calorimetry method. Both of these methods are incorporated into the final test procedure. More precise results from the certification procedure result from the use of dimensional lumber instead of cord wood, as well as starting with a hot stove. Precision, or reproduceability,is essential to provide an equitable basis for comparison between stoves.

Support for the RWC control strategy came from the Portland and Medord Air Quality Advisory Committees composed of numerous representatives of public, industrial, government organizations and elected officials. The Environmental Quality Commission unanimously supports implementation of a woodstove certification program. The Associated Oregon Industries Board of Directors has passed a unanimous resolution in support of such a program and other agencies such as the Oregon Department of Energy and Bonneville Power Administration favor implementation of a woodstove certification program.

In addition, safety testing labs and fire insurance companies should support an emission certification program as it would be the only type of a program that would have a significant effect on creosote formation in flues which is a significant cause of chimney fires.

7.2 WOOD HEATING ALLIANCE (WHA) DEVELOPMENT OF A LOW COST TEST METHOD

A study commissioned by the Oregon DEQ showed that there is little correlation between particulate emissions and emissions of hydrocarbons or carbon monoxide. The correlation study was performed because it is less costly to monitor carbon monoxide or total hydrocarbons. Both total hydrocarbon and carbon monoxide analyzers are real-time monitors and could be used as an inexpensive method to estimate the emission rate of particulate matter. Unfortunately, no statistically valid studies have been conducted which shows a strong correlation coefficient for these (and probably other simple measurements) parameters. These inexpensive methods could be used in the future if such studies were conducted and were shown to be valid.

The Condar sampler is another inexpensive method which is used to measure particulate emissions. The Condar sampler did not meet the equivalency criteria established by the WHA and the ODEQ. The Condar sampler, however, can be used as an inexpensive, pre-certification screening tool. Results of the equivalency tests indicate that the Condar sampler provides results within ± 25 percent of the U. S. EPA Modified Method 5.

Most recently, the WHA has decided to support the efforts of the American Society of Testing and Materials (ASTM) to establish a consistant, accurate national test method. The purposes of the ASTM standard are to, "establish a uniform procedure for appliance operation which can be used in conjunction with a standardized test method for obtaining thermodynamic performance and emissions data, specify the types of test equipment and establish standard performance requirements for test equipment, specify data required and calculations to be used; define terms used in testing; establish guidelines for certifying and labeling appliances." ASTM procedures are designed to assure full participation in the standard-making process by all interested parties. The ASTM process avoids domination or distortion by special interest groups because it operates on a democratic principle. The result of such procedures is the establishment of credible standards. U.S. EPA, as well as the WHA supports the ASTM effort to develop a testing and certification standard.

An ASTM test protocol for testing RWC devices will not become available until late in 1985. Other than the Condar sampler, the Oregon Method 7 and the EPA Modified Method 5, the ASTM will consider the use of a non-condensing dilution tunnel as an alternative measurement technique. The ASTM test protocol will become available long before the Oregon 1988 limits for RWC device emissions become enforced.

SECTION 8

CONCLUSIONS

- An analysis of the technical literature on emissions from residential wood combustion (RWC) devices indicates that total suspended particulates (TSP) and fine respirable particulates (FP) are adequately characterized. The benzo(a)pyrene (BaP) emission rate, a component of polycyclic organic material (POM), was determined in several studies. Other components of POM do not have well characterized emission rates.

- Similar conclusions are drawn from an examination of the literature regarding impacts of RWC devices on ambient air quality, i.e., TSP and FP are adequately characterized, BaP to a lesser extent is characterized and other POM components are not well characterized.

- The emission rate of TSP for RWC devices published in the U.S. EPA document AP-42 is equal to the mean emission rate plus one standard deviation. This conservative emission value, when utilized in dispersion modeling exercises, results in an overestimate of the impact of RWC. RWC contributes 1 to 15 percent of the existing annual TSP levels in the Northeast, but as much as 50 percent of the annual BaP levels, in the counties studied. These impact estimates are similar to those found in Northwestern

U.S. communities. The two primary contributors to ambient air POM are mobile sources and RWC devices. While RWC contributes significantly to the ambient level of BaP, it cannot be concluded that the observed levels are cause for concern.

- Health effects of RWC products have been studied on three levels: cell-line mutagenesis, animal pulmonary disfunction, and human pathology and epidemiology. On the cell-line level, wood smoke was compared to smoke from a No. 2 oil-fired furnace and found less mutagenic. However, since wood stoves have a far higher emission rate for TSP and POM than No. 2 oil-fired furnaces, the overall effect is to burden the environmental with more pollutant per unit of energy consumed by using RWC devices.

  Animal studies are less conclusive. An examination of hamster lungs after tracheal instillation of wood smoke indicates that there is no specific pathological effects due to exposure. The pathological effects are less than than that exhibited by coal smoke but above those shown for exposure to non-toxic dust.

  Finally, epidemiological and pathological studies have been conducted in New Guinea where natives are exposed to extremely high concentrations of wood smoke. Researchers found that the turbercular type disease found in New Guinea is most probably caused by childhood infection with wood smoke as only a minor contributor to the manifestation of the disease.

- Indoor air pollution levels are most often higher than outdoor levels when RWC devices are located in the home.

- Several short-term monitoring studies in New England were examined in an effort to determine if pollutant levels were elevated on a 24-hour basis due to RWC. None of the studies showed TSP levels approaching the 24-hour secondary standard. Rural BaP levels were shown to approach levels typically found in large urban areas. Since BaP, and more generally POM, is neither regulated nor its health effects understood, it is not clear what the significance is of the observed levels.

- Seven (7) control elements which pertain to RWC devices are discussed in detail. These control elements are public education, mandatory firewood seasoning, implementing home weatherization programs, installing pollution control devices, providing energy subsidies, restricting wood stove use during pollution episodes and certifying consumption rate and wood stove emissions. Those programs requiring government intervention are expensive to initiate and maintain.

- The Northeastern states are urged to pursue further studies, in particular, source-receptor studies to delineate the contribution of RWC on ambient air quality. To date, inadequate data exist to determine if implementing any of the seven (7) control strategies will substantially reduce ambient TSP levels in urban areas. Inadequate data exist to determine if a particulate or air toxic problem exists in rural, or semi-rural valley areas.

- The primary impetus to implementing a control program on RWC devices is not air pollution, but fire hazard. Many fires are caused by RWC devices because of creosote build-up or improper installation.

- If the Northeastern states determine that a certification program should be implemented, then WESTON recommends that the states wait for the organization of a national program. There are three reasons for this advise. First, the ambient pollution problem needs further characterization and the threat to public health is not imminent. Several states already have regulatory authority over residential wood burning by enforcing odor and nuisance statutes. Second, most RWC control strategies are costly and difficult to enforce. Finally, uneven emission limits will curtail further expansion of the cottage, wood stove industry.

SECTION 9

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APPENDIX A

COMPREHENSIVE LIST OF ORGANIC EMISSIONS FROM RESIDENTIAL WOOD COMBUSTION

Source: Reference Number 70

Appendix A. Emission Factors, mg/kg

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_5H_{10}O$ C_5-ketones	86						0.0157
$C_5H_{12}O$ C_5-alcohol	88						0.0137
$C_6H_{12}O$ C_6-ketones	100			0.2960		0.2960	6.350
$C_6H_{12}O$ C_6-ketones	100			0.3462		0.3462	11.4648
$C_6H_{12}O$ C_6-ketones	100			0.4994		0.4994	1.9451
$C_6H_{14}O$ (3-hexanol)	102			1.0732		1.0732	4.9438
Not Identified	82	18.01	0.00180	1.2708		1.2726	4.9403
Methylester/C_4-acid[b]	104			0.0815	0.5118	0.5933	13.5107
$C_7H_{17}N$ amine	115	18.91			1.4038	1.4038	
$C_5H_4O_2$ furfural	96	19.43		0.1886	8.7185	8.9071	2.7846
$C_4H_8O_2$ 2-methyl propionic acid	88						not computed
C_4H_8O butanoic acid	88						not computed
$C_7H_{16}O$ structure[b]	116	21.88			0.7897	0.7897	0.1363
Not Identified	94						0.0543
C_6H_8O cyclic ketone	96						0.1065

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.32 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_7H_{16}O$ C_7-alcohol	116						0.2448
C_6H_8O 2-methyl-2-cyclopenten-1-one	96	24.18		0.0538	1.1607	1.2145	2.4255
Pyrrolidone[b]	86	24.57		0.5154	2.1293	2.6447	
$C_5H_{10}O_2$ 2-methyl butanoic acid	92						not computed
$C_5H_6O_2$ 2-furanmethanol	98	24.57					
$C_6H_6O_2$ methy furyl[b]	110	25.37			1.1600	1.1600	0.1065
$C_7H_{14}O$ C_7-ketone	114	25.90		0.0422	0.2692	0.3114	
Not Identified	110	23.97					0.0992
$C_6H_6O_2$ C_1-furfural	110 }	27.19			0.2489	0.2489	
$C_6H_{10}O$ C_1-cyclopentanone	98 }						
C_6H_8O 3-methyl-2-cyclopenten-1-one	96	29.01 }		0.0492	1.1661	1.2153	
C_7H_6O benzaldehyde	106	29.01 }			1.1661	1.1661	
$C_7H_8O_2$[b]	124	29.01 }			1.1661	1.1661	11.3817

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_6H_6O_2$ C_1-furfural	110	29.64		0.1588	1.8986	2.0574	1.0725
$C_8H_{18}O$ C_8-ether	130	29.64			1.8986	1.8986	0.5385
C_6H_8O cyclic ketone	96						0.3386
C_6H_5CN benzonitrile	103	30.50			2.3717	2.3717	0.3885
$C_6H_6O_3$methylfuryl carboxylate	126	30.97					0.0728
$C_7H_{16}O$ C_7-alcohol	(130)	31.62			0.2573	0.2573	
$C_6H_6O_2$[b]	110	31.62					
$C_6H_8O_2$ C_1-cyclopentanone[b]	112	32.12			0.6844	0.6844	0.1725
$C_5H_{10}O_2$ tetrahydrofurfuryl alcohol[b]	102	33.15		0.4018	0.8566	1.2584	0.2785
$C_6H_6O_2$[b]	110						0.0493
$C_7H_8O_2$ C_2-furfural	124	33.58			0.2035	0.2035	
Not Identified	100 ?	34.00			0.4105	0.4105	
Not Identified	115 ?	35.00			0.2765	0.2765	
$C_6H_6O_2$ methylfurfural[b]	110	35.51			0.6231	0.6231	0.1754
$C_7H_8O_2$ C_1-methylfurylketone	124	35.68			0.4053	0.4053	

Appendix A (Cont'd)

Compound	M.W.	Time (min)[a]	Polar Fraction 0.12 m Logs, 0.82 kg/hr Burn Rate Particulate	 Creosote	 Condensible	 Total	 0.06 m Logs, 7.73 kg/hr Burn Rate Condensible
$C_7H_6O_2$ 2-hydroxybenzaldehyde	122						0.0938
C_8 or C_9-ketone	130						0.7339
$C_5H_8O_2$ 2-hydroxy-3-methyl-2-cyclopenten-1-one	112	36.82			4.5189	4.5189	
C_6H_6O phenol	94	37.88		6.3003	6.0372	12.3375	21.4295
C_8H_8O C_1-benzaldehyde	120						1.5289
C_8H_8O C_1-benzaldehyde	120						0.7686
Cyclic Ketone[b]	110						0.1588
Not Identified	--						0.1378
C_8H_8O C_1 benzaldehyde	120						0.2947
Mixture[b]	126	39.88			0.1482	0.1482	
	126	40.14			0.9189	0.9189	
$C_7H_8O_2$ methoxyphenol	124	40.84			0.1574	0.1574	0.0797
Not Identified	--						1.0134
Not Identified	136	40.84					
$C_7H_8O_2$ methoxyphenol	124	41.55		0.2562	8.0003	8.2565	0.0777

Appendix A (Cont'd)

Compound	M.W.	Time (min)[a]	Polar Fraction: 0.12 m Logs, 0.82 kg/hr Burn Rate: Particulate	Creosote	Condensible	Total	0.06 m Logs, 7.73 kg/hr Burn Rate: Condensible
C_7H_8O o-cresol	108	41.79			0.8758	0.8758	0.6069
Not Identified	126						0.2135
$C_7H_8O_2$ methoxyphenol	124	43.48			0.2961	0.2961	
Not Identified	138	43.48			0.2961	0.2961	
$C_8H_{10}O_2$ C_2-phenol	122	43.61			0.3632	0.3632	
$C_7H_{10}O_2$, Not Identified	126	43.61			0.3632	0.3632	
C_7H_8O m-cresol	108	44.02		0.0792	2.4084	2.4876	0.4364
C_7H_8O p-cresol	108	44.15		0.2292	3.2295	3.4587	1.1375
C_9H_8O phenylpropenal	132						0.1969
C_9H_8O 3-phenylpropenal	132						0.4666
$C_8H_{10}O$ C_2-phenol/ C_3-phenyl Ketone	122/134						0.5849
$C_8H_{10}O_2$ dimethoxybenzene	138	47.99			1.5354	1.5354	
$C_8H_{10}O$ dimethylphenol	122	48.21		0.1264	1.8886	2.0150	0.6396

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_9H_8O phenyl propenal	132						0.2721
$C_8H_{10}O_2$ dimethoxybenzene	138	48.73			0.1602	0.1602	
$C_8H_{10}O_2$ dimethoxybenzene	138	49.38		0.2414	4.2423	4.4837	
C_9H_8O vinyl benzaldehyde	132						1.9188
$C_8H_{10}O$ dimethylphenol	122	50.18		0.2442	1.5718	1.8160	1.2811
$C_9H_{12}O$ C_2-methoxybenzene	136	50.18			1.5718	1.5718	
$C_9H_{12}O_2$ C_1-dimethoxybenzene	152	51.47		0.1042	0.1407	0.2449	
Not Identified							0.8370
Ethyl benzaldehyde	132						0.5423
$C_8H_{10}O$ C_2-phenol	122						0.1867
$C_8H_{10}O$ dimethylphenol	122	51.62			0.1958	0.1958	0.0718
C_9H_8O 1-indanone	132	51.36			1.1069	1.1069	1.8113
$C_9H_{12}O$ C_3-phenol	135	53.58			0.0731	0.0731	
$C_9H_{12}O_2$ C_1-dimethoxybenzene	152	54.43		0.3296	3.4820	3.8116	
C_8H_8O aromatic ketone[b]	120						0.5219

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
Not Identified	146						0.4053
Not Identified	110						0.0571
Aliphatic oxygen compd.[b]							16.6675
$C_9H_{10}O_2$ C_2-methoxyphenol	150	56.34		0.0904	1.2381	1.3285	
$C_{10}H_{10}O$ C_4-alkenyl phenyl ketone/ C_2-benzopyran[b]	146						0.0603
$C_{10}H_{10}O$ C_4-alkenyl phenyl ketone C_2-benzopyran[b]	146						0.0503
$C_{10}H_{10}O$ C_4-alkenyl phenyl ketone C_2-benzopyran[b]	146						0.2795
$C_{10}H_{10}O$ C_4-alkenyl phenyl ketone C_2-benzopyran[b]	146						0.4197

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{10}H_{10}O$ C_4-alkenyl phenyl ketone C_5-benzopyran[b]	145						0.5175
$C_{10}H_8O$ naphthenol	144						0.5551
$C_{10}H_{14}O$ C_4-phenol	150						0.2653
$C_{10}H_8O$[b]	-						0.1583
$C_9H_{10}O$ aromatic ketone[b]	134						0.1095
$C_{10}H_{10}O$[b]	146						0.1549
$C_8H_{10}O_3$ dimethoxyphenol	154	58.02		8.5960	11.2409	19.8369	
$C_{10}H_{12}O_2$ propenylguaiacol[b]	164	58.30			0.4299	0.4299	
$C_{10}H_{12}O_2$ dimethoxybenzaldehyde	166	58.69	0.00479	0.2206	.0731	1.2985	
$C_{10}H_{10}O$[b]	146						0.0621

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_9H_6O_2$[b]	146						0.3205
Aliphatic oxygen compd.[b]							0.5057
$C_9H_6O_2$ 4H-1-benzopyran-2-one	146						0.6000
Not identified	158						0.3772
$C_{10}H_{14}O_3$ C_1-trimethoxybenzene	182	59.68		0.2404	0.3539	0.5943	
$C_{10}H_{10}O$, structure uncertain	146						0.0713
C_9H_8O C_1-benzofuran[b]	132						0.0973
Alkylated phenol[b]	150						0.3064
$C_8H_8O_3$ vanillin (4-hydroxy-3-methoxy-benzaldehyde)	152	60.40		0.5960	0.4239	1.0199	0.2653
$C_{10}H_{12}O_2$ propenylmethoxyphenol	164	60.40			0.2028	0.2028	

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_9H_6O_2$ 4H-1-benzopyran-4-one	146						0.6489
$C_{11}H_{12}O$ C_3-benzofuran	160						0.0826
$C_{11}H_{12}O$[b]	160						0.1349
$C_9H_{12}O_3$ trimethoxybenzene	168	61.96		5.9694	5.1656	11.1350	
$C_{10}H_{12}O_2$ propenylguaiacol	164	62.20		0.3952	0.4709	0.8661	
$C_6H_6O_2$ benzenediol[b]	110						0.0577
C_3-phenol	136						0.5669
$C_{11}H_8O$ naphthaldehyde	156						0.7364
$C_9H_{10}O_3$ 4-hydroxy-3-methoxybenzophenone	166	63.76		0.4137	0.1833	0.5970	
$C_{11}H_8O$ naphthaldehyde	156						1.0594

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{11}H_7N$ cyanonaphthalene	153						0.1051
$C_{10}H_{14}O_3$ C_4-pyrogallol	182	64.83		4.5440	3.9583	8.5023	
$C_{11}H_{16}O_2$ C_3-dimethoxybenzene	180	65.17		0.6196	0.6597	1.2793	
$C_{11}H_{14}O_2$ propenyl dimethoxyphenol	194	67.38		0.6140	0.7341	1.3481	
$C_{11}H_{16}O_3$ C_2-trimethoxyphenol	196	67.64	0.00840	2.1430	1.4851	3.6367	
$C_{10}H_{10}O$ 1-(1-naphthenyl) ethanone	170						0.2429
$C_{11}H_{10}O$ or $C_{10}H_8O_2$	168						0.3924
$C_{10}H_{12}O_3$ C_2-substituted vanillin	182	69.55		0.1844	0.7447	0.9291	
Not Identified	186	70.46		0.3018	0.8966	1.1984	
$C_{11}H_{16}O_3$ C_5-pyrogallol	196	71.68		0.0612	0.5999	0.6611	

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, [illegible] kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{13}H_8O$ 9H-fluorene-9-one	180						2.3221
$C_{12}H_{18}O_3$ C_6-pyrogallol	210	72.67		0.2372	0.1152	0.3524	
$C_{12}H_{18}O_3$ C_6-pyrogallol (methoxy subst.)	210	74.19			0.1839	0.1839	
Not Identified	196						0.2756
Not Identified	180						1.4826
Phthalate ester		77.65			0.0767	0.0767	
$C_{13}H_8O_2$ 9H-xanthen-9-one	196						0.5581
Phthalate ester							2.4658
$C_{14}H_8O_2$ anthracene-9, 10-dione	208						0.4349
Not Identified		78.93	0.0493		0.1957	0.2450	

Appendix A (Cont'd)

			Polar Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
Not Identified	204						0.2790
High-molecular-weight aliphatic oxygen compound							0.0562

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[a] GC retention time for low-burn-rate condensible sample.

[b] Tentative assignment when no standard, no chromatographic data, or ambiguous mass spectral data exist.

Appendix B. Emission Factors, mg/kg

			H_2 (Aliphatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
Toluene	92	12.81	0.0435	0.2847	1.4134	1.7416	Concentration Below GC/MS Limit of detection
Not Identified					0.2032	0.2032	
C_8-alkane	114	13.81	0.00186	0.0412	0.0726	0.1157	
C_8-alkane	114	14.30	0.00352	0.0294	0.2159	0.2488	
Not Identified	100						
C_8-alkene	112	15.49	0.00924	0.0675	0.0369	0.1136	
C_8-alkane	114						
Tetrachloromethane	154			0.1586		0.1586	
C_6-alkene/cyclohexane	84	16.19	0.00551	0.1166	0.2765	0.3986	
C_7-alkene	100	18.09	0.00227	0.0485	0.1236	0.1744	
C_9-alkane & alkene	128				0.0293	0.0293	
	126	18.48	0.00207	0.0296	0.1015	0.1332	
C_9-alkane & alkene	128	18.94		0.0280	0.0720	0.1000	
	126						
Ethyl benzene	106	19.53	0.0123	0.0564	0.2544	0.3231	
m/p-xylene	106	20.30	0.0230	0.0964	0.4309		
C_9-alkane & alkene	128			0.0580		0.0580	

Appendix B (Cont'd)

			H_2 (Aliphatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
	126	20.49		0.0543	0.0259	0.0802	Concentration Below GC/MS Limit of detection
o-xylene	106	21.28	0.00271	0.0471	0.1390	0.1888	
C_9-alkene	126	21.80		0.0203	0.1008	0.1212	
Not Identified	85	21.96		0.00972	0.2203	0.2300	
C_9-alkene & alkane	126	22.52	0.0127	0.0112	0.0695	0.0934	
	128						
n-propyl benzene	120	24.13	0.00540	0.0238	0.3430	0.3722	
Not Identified		24.72	0.00547		0.1210	0.1265	
C_9-alkene	126	25.98		0.0109	0.0259	0.0368	
Isopropyl benzene	120	27.34	0.00750	0.0320	0.1721	0.2116	
C_3-benzene	120	27.83	0.0186	0.0563	0.2944	0.3693	
C_3-benzene	120	27.97	0.00877	0.0272	0.1644	0.2004	
C_3-benzene	120	28.49	0.00684	0.0218	0.0966	0.1252	
C_3-benzene	120	29.19			0.0268	0.0268	
C_3-benzene	120	29.34	0.00702	0.0247	0.0850	0.1167	
C_3-benzene	120	30.46	0.00667	0.0182	0.0924	0.1173	

Appendix B (Cont'd)

B: (Aliphatic) Fraction,

Compound	M.W.	Time (min)[a]	0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
			Particulate	Creosote	Condensible	Total	Condensible
C_{10}-alkene	140	32.52	0.00218		0.0556	0.0578	Concentration Below GC/MS Limit of detection
C_{10}-alkane	142			0.0116	0.0242	0.0358	
C_{11}-alkene	154	39.78			0.0340	0.0340	
C_{11}-alkane	156	40.71	0.00545	0.0426	0.0660	0.[illegible]14[illegible]	
C_{12}-alkene	168	47.62			0.0836	0.0836	
C_{12}-alkane	170	48.44			0.1231	0.1231	
C_{13}-alkene	182	53.80			0.1318	0.1318	
C_{13}-alkane	184	54.39	0.00130	0.00712	0.2067	0.215[illegible]	
C_{14}-alkene	196	58.57			0.2432	0.2432	
C_{14}-alkane	198	59.04	0.00519	0.0122	0.3729	0.3903	
C_{15}-alkene	210	62.57			0.3688	0.3688	
C_{15}-alkane	212	62.96	0.0132	0.0574	0.5604	0.6310	
C_{16}-alkene	224	66.09	0.014[illegible]	0.0564	0.4063	0.4771	
C_{16}-alkane	226	66.43			0.5180	0.5180	
C_{17}-alkene	238	68.68		0.0126	0.0546	0.0672	
C_{17}-alkene	238	68.98			0.0784	0.0784	

Appendix B (Cont'd)

			H_2 (Aliphatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_{17}-alkene	238	69.29	0.0129	0.0460	0.3730	0.4319	Concentration Below GC/MS Limit of Detection
C_{17}-alkane	240	69.60	0.00114	0.0395	0.9126	0.9532	
C_{17}-phytane	240	70.54			0.5367	0.5367	
C_{18}-alkene	254	72.75	0.00787	0.0336	0.2709	0.3124	
C_{18}-alkane	256	72.54	0.0100	0.0410	1.0813	1.1323	
C_{19}-alkene	268	75.04	0.00789	0.00940	0.3168	0.3341	
C_{19}-alkane	270	75.30		0.1199	0.9524	1.0723	
C_{20}-alkene	280	77.69	0.00454	0.0289	0.4302	0.4636	
C_{20}-alkane	282	77.93		0.1307	1.0269	1.1576	
C_{21}-alkene	294	80.21	0.00259	0.0365	0.4077	0.4468	
C_{21}-alkane	296	80.44		0.1616	1.1759	1.3375	
C_{22}-alkene	308	82.62		0.0527	0.4911	0.5438	
C_{22}-alkane	310	82.82	0.00386	0.1534	0.9799	1.1371	
C_{23}-alkene	322	84.93		0.0412	0.4650	0.5062	
C_{23}-alkane	324	85.12		0.1676	1.3399	1.5075	
C_{24}-alkene	336	87.14		0.0373	0.4384	0.4757	
C_{24}-alkane	338	87.30	0.00514	0.0643	0.4704	0.5398	

Appendix B (Cont'd)

			H_2 (Aliphatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_{25}-alkene	350	89.43		0.00438	0.0720	0.0764	Concentration Below GC/MS Limit of Detection
C_{25}-alkane	352	89.62	0.00557	0.0351	0.2547	0.2954	
C_{26}-alkene	364	92.02			0.1105	0.1105	
C_{26}-alkane	366	92.23	0.00557		0.1054	0.1110	
C_{27}-alkene	378						
C_{27}-alkane	380		0.00429			0.00429	

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[a] GC retention time for low-burn-rate condensible sample

			HB (Aromatic) Fraction				
			0.12 m logs, 0.82 kg/hr Burn Rate				0.06 m logs, 7.75 kg/hr Burn Rate
Compound	M.W.	Time (min)^a	Particulate	Creosote	Condensible	Total	Condensible
C_7-alkene or cycloalkane	98	12.76			0.5360	0.5360	
Not identified	-	13.39			0.2012	0.2012	
Toluene	92	14.82	0.2267	1.810	6.8474	8.8841	0.5968
C_8-alkane	114	15.68		0.00735	0.1172	0.1246	0.00515
C_8-alkane	114	15.78			0.0755	0.0755	0.00475
C_8-alkene	112	16.17			0.2385	0.2385	
Cyclohexane	84				0.0246	0.0246	
C_8-alkene	112				0.0310	0.0310	
C_8-alkene	112				0.0134	0.0134	
C_2Cl_4	166	17.40		0.0136	0.0535	0.0671	0.0106
C_8-alkane	114	18.07	0.00780		0.3658	0.3736	0.00660
C_8-alkene	112				0.0168	0.0168	
C_8-alkene	112	20.05		0.0370	0.1699	0.2069	
C_9-alkane	128	20.36		0.0230	0.0886	0.1116	
C_9-alkane	128				0.0790	0.0790	

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_4-benzene	134				0.0168	0.0168	
C_4-benzene	134	39.62			0.0323	0.0323	
C_4-benzene	134				0.0180	0.0180	
C_4-benzene	134	40.71			0.0191	0.0191	
C_1-benzofuran	132	41.09			0.0479	0.0479	0.0110
C_1-benzofuran	132						0.00572
C_1-benzofuran	132	41.51			0.0811	0.0811	0.00772
C_4-benzene	134	41.86			0.0143	0.0143	
C_1-indan	132				0.0149	0.0149	
C_1-indene	130	44.77			0.0581	0.0581	
C_1-indan	132				0.0311	0.0311	
C_1-indene	130	45.19			0.1375	0.1375	0.0668
C_4-benzene	148				0.0573	0.0573	
C_4-benzene	148				0.0180	0.0180	
Naphthalene	128	47.22			1.0927	1.0927	14.1665

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_2-indan	146				0.0135	0.0135	0.0232
C_2-indan	146	48.64			0.0350	0.0350	0.0248
C_2-benzofuran	146	48.98			0.0539	0.0539	
C_2-benzofuran	146	49.28			0.1659	0.1659	0.0309
C_2-benzofuran	146	49.64			0.0879	0.0879	0.0163
C_2-benzofuran	146	49.83			0.1885	0.1885	0.1091
Not identified	-	50.16			0.0363	0.0363	0.0220
Not identified	-	50.63			0.0218	0.0218	0.0289
$C_{11}H_{12}$ C_2-indene / C_1-dihydronaphthalene[b]	144	52.34			0.0456	0.0456	0.0330
$C_{11}H_{12}$ C_2-indene / C_1-dihydronaphthalene[b]	144	52.61			0.0608	0.0608	0.0167
$C_{11}H_{12}$ C_2-indene / C_1-dihydronaphthalene[b]	144	52.83			0.1498	0.1498	
$C_{12}H_{14}$ C_2-indan / C_5-alkenyl substituted benzene[b]	146	53.17			0.0799	0.0799	
[illegible]-benzene	162	53.37			[illegible]	[illegible]	

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{12}H_{16}C_3$-indan / C_6-alkenyl substituted benzene[b]	160	53.92			0.0235	0.0235	
2-methylnaphthalene	142	54.39			0.4936	0.4936	0.7169
$C_{12}H_{16}$ C_3-indan	160	54.82			0.0916	0.0916	
1-methylnaphthalene	142	55.19			0.2749	0.2749	0.3510
Benzofuran	160	55.47			0.1949	0.1949	0.0159
1,2,3,4-tetrahydronaphthalene	160	55.81			0.0446	0.0446	
1,2,3,4-tetrahydronaphthalene	160	56.40			0.0862	0.0862	0.1181
C_7 alkenyl benzene[b]	174	56.75			0.0838	0.0838	?Rt
C_7-benzene[b]	176	57.00			0.0143	0.0143	0.0196
C_7-alkenyl benzene[b]	174	57.33			0.0772	0.0772	0.0159

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_7-benzene[b]	176	57.48			0.0209	0.0209	0.0199
Not identified	–	57.99			0.0208	0.0208	
C_7-alkenyl benzene[b]	174				0.3324	0.3324	
Biphenyl	154	58.53			0.3504	0.3504	0.6301
Not identified	–	58.87			0.0156	0.0156	
C_7-alkenyl benzene[b]	174	59.03			0.5261	0.5261	
C_2-naphthalene	156	59.31			0.1915	0.1915	0.2555
$C_{13}H_{18}$	174	59.47			0.0684	0.0684	0.0134
C_2-naphthalene	156	59.84			0.2809	0.2809	0.0919
C_2-naphthalene	156				0.0768	0.0768	0.0610
$C_{13}H_{18}C_4$-indan[b]	174				0.0444	0.0444	
Not identified	–	60.15					0.0680
C_2-naphthalene	156	60.43			0.0216	0.0216	0.0692
C_2-naphthalene	156	60.57			0.1649	0.1649	0.0531
$C_{12}H_{10}$[b]	154	60.74			0.1622	0.1622	

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{13}H_{18}$	174						
C_8-benzene	190						
C_2-naphthalene	156	61.33			0.2861	0.2861	0.0388
Acenaphthalene	152	61.49			0.4994	0.4994	1.9159
C_2-naphthalene	156	61.83			0.1654	0.1654	0.3909
$C_{13}H_{18}$	174						
$C_{14}H_{20}$	188						
C_8-benzene	190						
$C_{13}H_{18}$	174	62.14			0.0234	0.0234	0.0225
$C_{14}H_{20}$	188	62.25			0.0172	0.0172	0.0513
$C_{15}H_{24}$ (a terpene)[b]	204	62.59			0.5325	0.5325	0.0176
$C_{12}H_{10}$ acenaphthalene	154	62.85			0.1462	0.1462	0.0822
C_8-benzene	190	63.00			0.0881	0.0881	0.1114
C_8-benzene	190	63.36			0.2073	0.2073	0.0317
C_1-biphenyl	168	63.36					
C_3-naphthalene	170				0.0346	0.0346	0.0186

Compound	M.W.	Time (min)[a]	HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
			Particulate	Creosote	Condensible	Total	Condensible
C_1-biphenyl	168						
$C_{15}H_{24}$ C_9-benzene/terpene[b]	204	63.71			0.1087	0.1087	
$C_{14}H_{20}$	188	63.71					
C_3-naphthalene	170	63.97			0.0967	0.0967	0.0364
Dibenzofuran	168	64.28		0.0108	0.9385	0.9493	1.5185
$C_{15}H_{24}$ C_9-benzene/terpene[b]	204	64.52			0.1354	0.1354	0.0171
$C_{15}H_{24}$ C_9-benzene/terpene[b]	204	64.74			0.0478	0.0478	
C_3-naphthalene	170	64.74					
C_3-naphthalene	170	64.96			0.1696	0.1696	0.2084
C_1-acenaphthene	168	64.96			0.0431	0.0431	
$C_{15}H_{24}$ C_9-benzene/terpene[b]	204						
C_1-acenaphthene	168						
$C_{15}H_{24}$ C_9-benzene/terpene[b]	204						
C_3-naphthalene	170	65.23			0.1092	0.1092	0.1094

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{15}H_{20}$[b]	200	65.48			0.1181	0.1181	0.0229
C_3-naphthalene	170						
$C_{15}H_{24}$ (a terpene)[b]	204						
C_3-naphthalene	170	65.62			0.0578	0.0578	0.0119
C_3-naphthalene	170	65.82			0.0640	0.0640	
C_3-naphthalene	170	66.01			0.1215	0.1215	0.0943
Not identified	-	66.14			0.0813	0.0813	0.1007
$C_{15}H_{22}$	202				0.0274	0.0274	
Fluorene	166	66.43			0.1139	0.1139	0.0733
$C_{15}H_{24}$	204						
C_3-naphthalene	170	66.63			0.2949	0.2949	0.1240
$C_{15}H_{24}$	204						
C_1-dibenzofuran or C_1-fluorene	168	66.90			0.1570	0.1570	0.0371
$C_{14}H_{12}$	180	67.25			0.0763	0.0763	0.0156
Not identified	-	67.36			0.0655	0.0655	0.0205
$C_{14}H_{16}$[b]	184	67.50			0.1301	0.1301	0.0327

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
Not identified	-				0.0497	0.0497	
C_1-dibenzofuran	182	68.01			0.1867	0.1867	0.1334
C_1-dibenzofuran	182	68.49			0.1292	0.1292	0.1324
C_4-naphthalene	184	68.78			0.0533	0.0533	0.0308
$C_{15}H_{20}$[b]	200						
$C_{16}H_{26}$	218	69.13			0.1363	0.1363	0.0298
C_1-dibenzofuran	182	69.29			0.0350	0.0350	0.00927
C_4-naphthalene	184	69.44			0.0457	0.0457	0.0127
Not identified	--	69.56			0.0224	0.0224	
Not identified		69.80			0.0633	0.0633	
$C_{15}H_{20}$	200	70.74			0.0152	0.0152	
C_1-dibenzofuran	182	70.85			0.0255	0.0255	
$C_{16}H_{24}$[b]	216	69.93			0.1247	0.1247	
C_5-naphthalene	198	70.17			0.1520	0.1520	
Not identified	-	70.28		0.0114	0.0957	0.1071	
Not identified	-	68.56			0.0371	0.0371	
C_{10}-benzene $C_{16}H_{26}$	218	70.44		0.0246	0.2176	0.2422	0.0215
$C_{15}H_{20}$[b]	200	70.74		0.0120	0.2419	0.2539	0.0459

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
$C_{14}H_{30}$[b]	198	71.07		0.0146	0.2275	0.2421	0.0195
$C_{14}H_{12}$ C_1-fluorene	180						
C_4-naphthalene	184	71.43			0.0468	0.0468	0.0225
$C_{17}H_{28}$ C_{11}-benzene[b]	232	71.72		0.0114	0.1464	0.1578	0.0161
C_4-naphthalene	184	71.86			0.0321	0.0321	0.0371
$C_{15}H_{16}$ C_3-acenaphthene[b]	196	72.17			0.1463	0.1463	0.0127
$C_{17}H_{26}$	234	72.33			0.0365	0.0365	0.0151
$C_{17}H_{28}$ C_{11}-benzene	232	72.52			0.0248	0.0248	0.0156
Phenanthrene	178	73.03		0.0596	0.8203	0.8799	2.2974
Anthracene	178						
C_{11}-benzene	232	73.31			0.2467	0.2467	0.2560
Not identified	196,212						
C_2-fluorene	194	73.62			0.1015	0.1015	
$C_{11}H_{26}$	242						
Not identified	194	73.84			0.0833	0.0833	
$C_{14}H_{24}$	192	74.09			0.0682	0.0682	
Not identified	-	73.40			0.0423	0.0423	

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
Not identified	-	74.48			0.0251	0.0251	
Not identified	-	74.88			0.0162	0.0162	
1-phenyl naphthalene	204	75.06			0.0433	0.0433	0.1867
C_1-anthracene/phenanthrene	192	75.37			0.0325	0.0325	
Not identified	-	75.61			0.0250	0.0250	
Not identified	-	75.92			0.00900	0.00900	
$C_{18}H_{30}$	246	76.19			0.0487	0.0487	
2-methyl phenanthrene	192 }	76.35		0.0156	0.0949	0.1105	
$C_{14}H_{22}$	190 }						
Not identified	264	76.50		0.0202	0.1326	0.1528	0.1350
2-methyl anthracene	192	76.78			0.0949	0.0949	0.0142
$C_{15}H_{10}$ POM	190	76.99		0.0170	0.0833	0.1003	0.0595
1 methyl phenanthrene	192	77.15		0.0180	0.0655	0.0845	0.1162
[illegible] acenaphthalene	210	77.47			0.0138	0.0138	
Not identified		77.63			0.0120	[illegible]	
[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	

			HB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_2-anthracene/C_2-phenanthrene	206	80.43			0.0298	0.0298	
Not identified	–	80.64			0.0237	0.0237	
Pyrene	202	80.83		0.0261	0.2850	0.3111	1.3947
C_6H_{10} POM	202	81.45		0.0138	0.1633	0.1771	0.4742
Not identified	–	81.91			0.0683	0.0683	0.0227
$C_{16}H_{10}$ fluoranthene	202	82.16		0.0354	0.2146	0.2500	0.1004
POM Structure[b]	218	82.34			0.0908	0.0908	0.3980
Not identified	–	82.74		0.0228	0.1948	0.2176	0.1422
Not identified	–	83.17			0.0455	0.0455	0.1268
Not identified	–	83.71			0.1031	0.1031	0.1459
Benz(a)fluorene	216	83.97			0.1259	0.1259	0.0881
Not identified	–	84.53			0.1345	0.1345	0.1693
C_3-anthracene/C_3-phenanthrene	220	85.17		0.0333	0.1624	0.1957	0.0330
Methyl-pyrene	216	85.78			0.0537	0.0537	
C_1-pyrene	216	85.94			0.0525	0.0525	

			BB (Aromatic) Fraction				
			0.12 m Logs, 0.82 kg/hr Burn Rate				0.06 m Logs, 7.73 kg/hr Burn Rate
Compound	M.W.	Time (min)[a]	Particulate	Creosote	Condensible	Total	Condensible
C_2-pyrene	230	87.45			0.0781	0.0781	
Benz(ghi)fluorene	226	88.76			0.0444	0.0444	0.0972
9-phenylanthracene	226	88.94			0.0444	0.0444	0.1979
Benz(a)anthracene		90.35			0.1508	0.1508	0.4769
Chrysene	228	90.59			0.2929	0.2929	0.8729
Not identified	-	91.21			0.0626	0.0626	0.0381
Not identified	-	92.24			0.0671	0.0671	0.2565
Not identified	-	93.78					0.0198
Not identified	-	97.93					0.0190
Not identified	-	100.50			0.0839	0.0839	0.1634
Not identified	-	101.46					0.0418
Not identified	-	103.26					0.5057
Not identified	-	103.49			0.0321	0.0321	0.2191

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[a] GC retention time for low-burn-rate condensible sample

[b] Tentative assignment when no standard, no chromatographic data, or ambiguous mass spectral data exist.

APPENDIX B

STUDY DATABASE - EMISSIONS CHARACTERIZATION

		TSP (g/kg)	CO (g/kg)	POM (mg/kg)	HC (g/kg)	BE (mg/kg)	BAP (mg/kg)	AMES ($\times 10^5$)	BENZ (mg/kg)	FORM. (mg/kg)	FUEL MOIST (%)		FLUE TEMP (°F)	FEED RATE	EXCESS AIR
00001	1 A	0.7	0.0	5.20	0.0	0.340	0.100	3.3	0.630	0.190	16.0		842	4.2	3.5
00002	1 B	0.3	0.0	5.10	0.0	0.540	0.027	3.6	0.000	0.000	16.0		932	7.0	3.4
00003	1 C	0.6	0.0	6.00	0.0	0.320	0.190	5.2	0.000	0.063	16.0		842	7.0	3.3
00004	1 D	1.5	0.0	63.00	0.0	7.000	1.900	15.0	0.000	0.030	41.0		572	7.0	5.8
00005	1 E	0.8	0.0	140.00	0.0	6.300	3.300	25.0	0.000	0.110	16.0		842	7.0	2.8
00006	2 A	18.8	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	35.9		264	13.0	4.6
00007	2 B	10.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	35.6		222	5.0	4.1
00008	2 C	21.4	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	16.3		311	4.0	2.5
00009	2 D	29.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	17.6		257	4.0	2.0
00010	2 E	31.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	19.4		350	4.0	5.0
00011	2 F	20.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	17.1		314	4.0	2.5
00012	2 G	23.9	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	14.0		490	4.0	2.6
00013	2 H	50.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	14.0		256	4.0	2.8
00014	2 I	9.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	15.0		494	4.0	3.4
00015	2 J	74.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	14.0		219	2.0	2.7
00016	2 K	23.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	14.0		450	0.0	0.0
00017	3 A	13.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	EASTERN SPRUCE	0	0.0	0.0
00018	3 B	9.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	EASTERN SPRUCE	0	0.0	0.0
00019	3 C	15.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	EASTERN SPRUCE	0	0.0	0.0
00020	3 D	0.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	EASTERN SPRUCE	0	0.0	0.0
00021	3 E	0.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	EASTERN SPRUCE	0	0.0	0.0
00022	3 F	0.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	JACK PINE	0	0.0	0.0
00023	3 G	10.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	JACK PINE	0	0.0	0.0
00024	3 H	14.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	JACK PINE	0	0.0	0.0
00025	3 I	10.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	JACK PINE	0	0.0	0.0
00026	3 J	24.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	SOFT MAPLE	0	0.0	0.0
00027	3 K	9.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	SOFT MAPLE	0	0.0	0.0
00028	3 L	9.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	SOFT MAPLE	0	0.0	0.0
00029	3 M	15.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	BIRCH	0	0.0	0.0
00030	3 N	9.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	BIRCH	0	0.0	0.0
00031	3 O	10.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	HARD MAPLE	0	0.0	0.0
00032	3 P	11.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	HARD MAPLE	0	0.0	0.0
00033	3 Q	14.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	WHITE ASH	0	0.0	0.0
00034	3 R	9.1	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	WHITE ASH	0	0.0	0.0
00035	3 S	8.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	RED OAK	0	0.0	0.0
00036	3 T	8.2	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	RED OAK	0	0.0	0.0
00037	3 U	12.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	RED OAK	0	0.0	0.0
00038	3 V	8.9	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	RED OAK	0	0.0	0.0
00039	3 W	11.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	RED OAK	0	0.0	0.0
00040	3 X	29.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	RED OAK	0	0.0	0.0
00041	3 Y	19.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	STERNOLOG	0	0.0	0.0
00042	3 Z	20.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	NORTHLAND II	0	0.0	0.0
00043	4 A	21.1	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		394	2.0	0.0
00044	4 B	12.4	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		450	4.7	0.0
00045	4 C	10.5	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		410	3.3	0.0
00046	4 D	35.5	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		330	1.8	0.0
00047	4 E	7.8	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		270	4.5	0.0
00048	4 F	14.5	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		490	10.3	0.0
00049	4 G	6.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		425	6.4	0.0
00050	4 H	19.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		344	4.5	0.0
00051	4 I	42.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		245	2.7	0.0
00052	4 J	30.4	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		352	3.0	0.0
00053	4 K	17.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		358	3.3	0.0
00054	4 L	13.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		302	3.1	0.0
00055	4 M	20.0	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		299	2.7	0.0
00056	4 N	23.9	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		282	2.2	0.0
00057	4 O	15.2	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		338	2.7	0.0
00058	5 A	9.0	181.0	50.90	0.0	0.000	2.000	0.0	0.000	0.000	0.0	SEASONED OAK	493	6.9	1.4
00059	[illegible]	[illegible]	230.8	[illegible]	0.0	0.000	8.400	0.0	0.000	0.000	0.0	SEASONED OAK	718	7.1	1.2
00060	[illegible]	[illegible]	219.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	SEASONED PINE	415	6.2	1.5
00061	[illegible]	[illegible]	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0		278	2.0	0.0

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00063    8 C    9.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  270   2.0  0.0
00064    8 D   11.0   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  272   1.7  0.0
00065    8 E   10.7   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  308   1.8  0.0
00066    8 F    9.9   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  287   1.5  0.0
00067    8 G    9.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  278   1.6  0.0
00068    8 H   10.5   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  284   1.8  0.0
00069    8 I    7.9   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  313   1.8  0.0
00070    8 J    7.6   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  321   1.8  0.0
00071    8 K   12.9   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  361   1.7  0.0
00072    8 L    8.7   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  321   1.6  0.0
00073    8 M   15.0   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  290   2.3  0.0
00074    8 N   25.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  297   1.9  0.0
00075    8 O    5.8   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  277   1.4  0.0
00076    8 P    9.9   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  388   1.8  0.0
00077    8 Q    5.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  298   1.8  0.0
00078    8 R   12.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  186   1.0  0.0
00079    8 S    2.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  388   2.8  0.0
00080    8 T   12.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  280   1.6  0.0
00081    8 U    7.6   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  287   1.9  0.0
00082    8 V    9.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  287   1.9  0.0
00083    8 W   11.8   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  276   1.7  0.0
00084    8 X   10.6   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  243   1.1  0.0
00085    8 Y    2.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  380   2.3  0.0
00086    8 Z   10.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  512   3.4  0.0
00087    8 AA   7.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  258   1.5  0.0
00088    8 AB   3.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  417   2.1  0.0
00089    8 AC   5.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  460   2.8  0.0
00090    8 AD   5.8   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  371   2.3  0.0
00091    8 AE   1.9   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  433   2.3  0.0
00092    8 AF  10.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  567   3.2  0.0
00093    8 AG   3.7   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  292   1.8  0.0
00094    8 AH   2.4   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  252   2.6  0.0
00095    8 AI   7.7   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  497   3.2  0.0
00096    9 A    3.9 106.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   18.4 OAK                                0   0.0  0.0
00097    9 B    4.3  63.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   18.4 OAK                                0   0.0  0.0
00098    9 C    6.4 106.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   18.4 OAK                                0   0.0  0.0
00099    9 D    3.2 158.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   18.4 OAK                                0   0.0  0.0
00100    9 E    2.6  67.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   16.4 OAK                                0   0.0  0.0
00101    9 F    3.8   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   16.4 OAK                                0   0.0  0.0
00102    9 G    1.6   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   16.4 OAK                                0   0.0  0.0
00103    9 H    4.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   12.7 OAK                                0   0.0  0.0
00104    9 I    2.4  98.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   15.9 HEMLOCK                            0   0.0  0.0
00105    9 J    2.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   15.9 HEMLOCK                            0   0.0  0.0
00106   10 A    3.9   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  130   0.0  0.0
00107   10 B    3.4   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  194   0.0  0.0
00108   10 C   10.8   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  264   0.0  0.0
00109   10 D   10.0   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  222   0.0  0.0
00110   10 E   31.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  351   0.0  0.0
00111   10 F   20.0   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  314   0.0  0.0
00112   10 G   21.4   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  311   0.0  0.0
00113   10 H   29.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000    0.0                                  257   0.0  0.0
00114   12 A   13.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00115   12 B    2.3   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00116   12 C    9.4   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00117   12 D    5.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00118   12 E   10.4   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00119   12 F   10.1   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00120   12 G    8.2   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00121   12 H    6.8   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   23.8 OAK                                0   0.0  0.0
00122   12 I    2.5   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   22.8 OAK                                0   0.0  0.0
00123   12 J    3.4   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   22.8 OAK                                0   0.0  0.0
00124   12 K    2.5   0.0    0.00   0.0   0.000    0.000   0.0  0.000  0.000   22.8 OAK                                0   0.0  0.0
00125   12 [illegible] [illegible] 0.0 0.00 0.0 0.000 0.000  0.0  0.000  0.000   19.8 OAK                                0   0.0  0.0
00126   [illegible] [illegible] 0.0 0.00 0.0 0.000 0.000     0.0  0.000  0.000    8.7 OAK                                0   0.0  0.0
00127   [illegible] [illegible] 0.0 0.00 0.0 0.000 0.000     0.0  0.000  0.000    8.7 OAK                                0   0.0  0.0
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00129	12	P	15.7	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	[illegible]	[illegible]			
00130	12	Q	24.4	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	23.8	OAK	0	0.0	0.0
00131	12	R	12.8	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	23.8	OAK	0	0.0	0.0
00132	12	S	10.4	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	23.8	PINE	0	0.0	0.0
00133	12	T	10.8	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	42.4	PINE	0	0.0	0.0
00134	12	U	18.5	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	42.4	PINE	0	0.0	0.0
00135	12	V	15.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	42.4	PINE	0	0.0	0.0
00136	12	W	9.6	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	42.4	PINE	0	0.0	0.0
00137	12	X	11.9	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	22.8	OAK	0	0.0	0.0
00138	12	Y	13.3	0.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	42.4	PINE	0	0.0	0.0
00139	12	Z	6.2	0.0	0.00	0.0	2.900	0.000	0.0	0.000	0.000	0.0		0	0.0	0.0
00140	12	AA	16.5	0.0	0.00	0.0	9.300	0.000	0.0	0.000	0.000	0.0		0	0.0	0.0
00141	12	AB	6.0	0.0	0.00	0.0	2.500	0.000	0.0	0.000	0.000	0.0		0	0.0	0.0
00142	12	AC	49.0	0.0	0.00	0.0	32.600	0.000	0.0	0.000	0.000	0.0		0	0.0	0.0
00143	12	AD	22.2	0.0	0.00	0.0	12.800	0.000	0.0	0.000	0.000	0.0		0	0.0	0.0
00144	14	A	4.9	160.0	0.00	1.1	0.000	0.050	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00145	14	B	17.0	0.0	0.00	0.0	0.000	1.300	0.0	0.000	0.000	0.0	WILLOW	0	0.0	0.0
00146	14	C	7.0	0.0	0.00	0.0	0.000	0.011	0.0	0.000	0.000	0.0	ASH	0	0.0	0.0
00147	14	D	17.0	120.0	0.00	2.7	0.000	0.045	0.0	0.000	0.000	0.0	MAPLE	0	0.0	0.0
00148	14	E	2.9	0.0	0.00	0.0	0.000	0.130	0.0	0.000	0.000	0.0	HICKORY	0	0.0	0.0
00149	14	F	16.0	160.0	0.00	7.4	0.000	0.230	0.0	0.000	0.000	0.0	SYNTHETIC	0	0.0	0.0
00150	15	A	7.0	110.0	210.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	0.0	0.0
00151	15	B	6.3	120.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	0.0	0.0
00152	15	C	8.0	270.0	370.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00153	15	D	19.0	220.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00154	15	E	8.5	370.0	190.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	0.0	0.0
00155	15	F	5.1	91.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	0.0	0.0
00156	15	G	7.6	150.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00157	15	H	16.3	0.0	97.00	0.3	0.000	0.000	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00158	15	BA	8.6	30.0	25.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	0.0	0.0
00159	15	BB	7.9	22.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	0.0	0.0
00160	15	BC	7.7	21.0	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00161	15	BD	12.0	15.0	36.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	PINE	0	0.0	0.0
00162	16	A	22.0	190.0	0.00	13.0	0.000	0.000	0.0	0.000	0.000	26.0		265	1.9	0.0
00163	16	B	54.0	189.0	0.00	16.9	0.000	0.000	0.0	0.000	0.000	14.0		316	2.4	0.0
00164	16	C	34.0	160.0	0.00	10.5	0.000	0.000	0.0	0.000	0.000	126.0		342	2.1	0.0
00165	16	D	40.0	210.0	0.00	11.9	0.000	0.000	0.0	0.000	0.000	14.0		544	8.1	0.0
00166	16	E	62.0	220.0	0.00	12.1	0.000	0.000	0.0	0.000	0.000	14.0		299	2.7	0.0
00167	16	F	42.0	170.0	0.00	9.2	0.000	0.000	0.0	0.000	0.000	24.0		401	5.8	0.0
00168	16	G	19.0	160.0	0.00	8.8	0.000	0.000	0.0	0.000	0.000	25.0		372	2.9	0.0
00169	16	H	24.0	190.0	0.00	11.1	0.000	0.000	0.0	0.000	0.000	126.0		295	2.0	0.0
00170	16	I	22.0	110.0	0.00	6.6	0.000	0.000	0.0	0.000	0.000	126.0		361	1.7	0.0
00171	16	J	22.0	110.0	0.00	8.0	0.000	0.000	0.0	0.000	0.000	22.0		290	2.1	0.0
00172	16	K	17.0	90.0	0.00	6.2	0.000	0.000	0.0	0.000	0.000	23.0		353	2.6	0.0
00173	16	L	38.0	200.0	0.00	11.8	0.000	0.000	0.0	0.000	0.000	23.0		244	1.7	0.0
00174	16	M	35.0	160.0	0.00	9.3	0.000	0.000	0.0	0.000	0.000	42.0		251	2.2	0.0
00175	16	N	38.0	120.0	0.00	10.7	0.000	0.000	0.0	0.000	0.000	23.0		244	1.7	0.0
00176	16	O	23.0	50.0	0.00	7.3	0.000	0.000	0.0	0.000	0.000	21.0		323	2.2	0.0
00177	16	P	14.0	80.0	0.00	3.9	0.000	0.000	0.0	0.000	0.000	25.0		375	3.0	0.0
00178	16	Q	30.0	150.0	0.00	5.8	0.000	0.000	0.0	0.000	0.000	24.0		230	2.1	0.0
00179	16	R	1.0	20.0	0.00	0.4	0.000	0.000	0.0	0.000	0.000	21.0		779	6.4	0.0
00180	16	S	2.0	50.0	0.00	0.6	0.000	0.000	0.0	0.000	0.000	25.0		604	3.9	0.0
00181	17	A	2.0	0.0	45.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	14.1	1.0
00182	17	B	1.3	0.0	15.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	7.1	1.4
00183	17	C	2.3	0.0	305.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	8.1	0.1
00184	17	D	10.8	0.0	9.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	4.2	1.4
00185	17	E	5.4	0.0	119.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	6.3	1.8
00186	17	F	2.8	0.0	13.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	4.2	1.7
00187	17	G	30.1	0.0	15.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	7.1	2.3
00188	17	H	8.6	0.0	1562.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	14.0	0.3
00189	17	I	1.0	0.0	11.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	7	0.0	0.8
00190	17	J	1.0	0.0	7.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	7.9	1.1
00191	17	K	1.3	0.0	21.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	7.7	0.6
[illegible]	[illegible]	[illegible]	3.0	0.0	51.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	5.2	0.5
[illegible]	[illegible]	[illegible]	[illegible]	0.0	421.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	OAK	0	6.8	0.2

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00195   17 O    80.9    0.0   448.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   2.5  2.0
00196   17 P     1.2    0.0    33.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   2.9  0.8
00197   17 Q     2.2    0.0    58.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   3.3  0.6
00198   17 R     1.7    0.0     6.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   2.1  0.1
00199   17 S     6.5    0.0   134.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   2.4  0.6
00200   17 T     5.0    0.0    22.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   1.3  0.9
00201   17 U     7.2    0.0   234.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   1.5  0.9
00202   17 V     2.2    0.0    19.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   3.4  1.7
00203   17 W     4.0    0.0    84.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   4.4  1.1
00204   17 X     4.2    0.0   129.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   6.0  1.6
00205   17 Y    28.3    0.0   737.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0 OAK                  0   5.0  0.7
00206   17 Z    13.6    0.0   141.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0                      0   1.2  4.4
00207   17 AA   48.8    0.0    88.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0                      0   1.3  2.6
00208   17 AB    5.1    0.0    93.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0                      0   2.6  2.5
00209   17 AC    8.1    0.0   232.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0                      0   4.6  0.6
00210   17 AD    0.9    0.0   430.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0                      0   3.3  0.5
00211   17 AE    2.5    0.0   108.00    0.0   0.000     0.000  0.0  0.000  0.000    0.0                      0   2.3  1.0
00212   20 A     4.6   26.0     0.00    2.6   0.000     0.000  0.0  0.000  0.000    0.0                    175   1.9  1.9
00213   20 B     4.5   62.9     0.00    1.1   0.000     0.000  0.0  0.000  0.000    0.0                    363   2.1  1.3
00214   21 A     6.4    0.0    20.90    0.0   0.000     0.560  0.0  0.068  0.058    0.0 BIRCH              626   3.5  1.9
00215   21 B     3.3    0.0     2.60    0.0   0.000     0.050  0.0  0.000  0.041    0.0 SPRUCE             662   3.1  1.8
00216   22 A     0.0  190.0    35.00   28.0   0.000     0.500  0.0  0.000  0.000    0.0 OAK                700   8.5  0.4
00217   22 B     0.0   40.0    45.00    9.0   0.000     1.200  0.0  0.000  0.000    0.0 PINE               590   8.4  1.3
00218   22 C     0.0  280.0    18.00   32.0   0.000     1.400  0.0  0.000  0.000    0.0 OAK                950   7.5  0.4
00219   22 D     0.0   59.0    50.00    6.0   0.000     0.040  0.0  0.000  0.000    0.0 OAK                710   6.2  0.8
00220   22 E     0.0   25.0    11.00    5.0   0.000     0.050  0.0  0.000  0.000    0.0 OAK                340  11.0  9.2
00221   23 A     5.7   49.0   120.10   14.0   4.900     0.700  0.0  0.000  0.000    0.0                      0   0.0  0.0
00222   23 B     2.8  139.0   300.00   26.0   2.200    10.500  0.0  0.000  0.000    0.0                      0   0.0  0.0
00223   23 C     8.6  113.0  1570.00   35.0   7.900    34.600  0.0  0.000  0.000    0.0                      0   0.0  0.0
00224   23 D     1.3   44.0    20.00   14.0   1.200     0.300  0.0  0.000  0.000    0.0                      0   0.0  0.0
00225   23 E     3.8   43.0    50.00   19.0   3.400     0.400  0.0  0.000  0.000    0.0                      0   0.0  0.0
00226   23 F    13.6  125.0   420.00   35.0  13.500     5.000  0.0  0.000  0.000    0.0                      0   0.0  0.0
00227   23 G    97.3   98.0   580.00  105.0  92.100     3.700  0.0  0.000  0.000    0.0                      0   0.0  0.0
00228   23 H    80.8  102.0   450.00   95.0  80.500     3.100  0.0  0.000  0.000    0.0                      0   0.0  0.0
00229   23 I     1.0   37.0    10.00    8.0   0.840     0.000  0.0  0.000  0.000    0.0                      0   0.0  0.0
00230   23 J     1.2    6.0    30.00    8.0   0.730     0.600  0.0  0.000  0.000    0.0                      0   0.0  0.0
00231   23 K     2.2   23.0    60.00   23.0   1.110     0.800  0.0  0.000  0.000    0.0                      0   0.0  0.0
00232   23 L     6.5   50.0   110.00   94.0   6.060     1.600  0.0  0.000  0.000    0.0                      0   0.0  0.0
00233   23 M     5.0   26.0   230.00   30.0   4.600     0.600  0.0  0.000  0.000    0.0                      0   0.0  0.0
00234   23 N     7.2   27.0    20.00   41.0   6.900     0.300  0.0  0.000  0.000    0.0                      0   0.0  0.0
00235   23 O     1.7    3.0    10.00   10.0   1.210     0.000  0.0  0.000  0.000    0.0                      0   0.0  0.0
00236   23 P     4.0   32.0    84.20   11.0   3.500     0.700  0.0  0.000  0.000    0.0                      0   0.0  0.0
00237   23 Q     4.2   55.0   129.30   33.0   3.400     1.500  0.0  0.000  0.000    0.0                      0   0.0  0.0
00238   23 R    28.3   98.0   737.00   36.0  26.900    12.000  0.0  0.000  0.000    0.0                      0   0.0  0.0
00239   23 S    13.6  137.0   140.50   44.0  12.810     1.500  0.0  0.000  0.000    0.0                      0   0.0  0.0
00240   23 T    48.8  193.0    88.00  116.0  47.600     0.003  0.0  0.000  0.000    0.0                      0   0.0  0.0
00241   23 U     2.2   32.0    19.30    8.0   1.440     0.000  0.0  0.000  0.000    0.0                      0   0.0  0.0
00242   23 V     5.1   90.0    93.10   26.0   4.010     1.500  0.0  0.000  0.000    0.0                      0   0.0  0.0
00243   23 W     8.1  119.0   232.30   26.0   7.380     1.700  0.0  0.000  0.000    0.0                      0   0.0  0.0
00244   23 X     0.9   79.0   430.00   19.0   0.690     0.000  0.0  0.000  0.000    0.0                      0   0.0  0.0
00245   23 Y     2.5   47.0   110.00    6.0   2.230     1.700  0.0  0.000  0.000    0.0                      0   0.0  0.0
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