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Technical Support Document For Residential Wood Combustion

By
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Portland, Oregon

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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ABSTRACT

This Technical Support Document is prepared to assist state and local air pollution control agencies in assessing and controlling Residential Wood Combustion (RWC) air pollution impacts. It provides an overview, description and leading references to many technical topics related to characterization of wood usage, pollutant emissions and resulting ambient concentrations attributable to RWC.

RWC emissions relative to other emissions sources, and various methods for estimating RWC wood usage and resulting emissions are described and quantified. Factors affecting the magnitude of RWC emissions from woodstoves and fireplaces are analyzed. Past and future trends are examined.

The magnitude of RWC ambient impacts is summarized based on available data from localities around the nation, for total and fine particulates, carbon monoxide and benzo(a)pyrene. Methods for measuring or estimating RWC air quality impacts are described, including field monitoring, sample analyses, source apportionment analysis, dispersion modeling, and other specialized analysis. A stepwise approach to estimating RWC ambient impacts is outlined, with options based on available study resources.

Leading examples of RWC emissions control strategies are described, based on programs implemented in Oregon, Montana, Colorado, Alaska, and Nevada. Example laws, regulations, local ordinances and informational materials related to these cases are included in an Appendix. Methods for estimating the potential effectiveness of RWC emission measures are described and illustrated, including the use of receptor and dispersion models.

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EXECUTIVE SUMMARY

Characterizing RWC Emissions

Residential Wood Combustion (RWC) accounts for only 3% of Total Suspended Particulate (TSP) emissions, and about 7% of Carbon Monoxide (CO) emissions nationally. However, emissions of these pollutants are dominated by transportation sources, such as resuspended road dust and vehicle exhaust. Among all wood burning sources including industrial, agricultural, forest management, forest wildfires, and residential open (backyard) burning, RWC accounts for almost half of all TSP, Inhalable Particulate (IP), and CO emissions.

The significance of RWC particulate emissions is substantially enhanced for the following reasons. Virtually all of the RWC emission is inhalable particulate. RWC emissions occur predominately in residential areas. Poor meteorological conditions for dispersion (winter/evening), coupled with low plume rise, tend to increase human exposure. RWC is the single largest source in the nation of emissions of benzo(a)pyrene B(a)P - a proven carcinogen, and prime example of the important class of toxic air contaminants referred to as Polycyclic Organic Material (POM).

The large and steady decline in RWC since the 1940's, when eight million households used wood as their primary heating fuel, was reversed in 1973-74 as prices for oil, natural gas and electricity began to increase sharply. The strong resurgence in RWC has continued for the last decade, with about 10 million new residential burning devices sold in the U.S. during that period. Where wood is reasonably available, it is not unusual to find half or more of all households using wood as a primary or secondary heating fuel, or for aesthetic burning.

During this resurgence of RWC, its air pollution impacts have been exacerbated by several factors. The woodstoves and fireplaces have generally not been developed and engineered to minimize emissions. Their combustion efficiencies are further reduced (and emission increased) when they are operated in a starved air ("airtight") mode, to prolong fuel burning time. A shift from

fireplace to woodstove use, which generally increases emissions per unit of wood burned, is also common, because woodstoves heat houses much more efficiently. Eighty percent of all RWC emissions in the U.S. are from woodstoves, including fireplace inserts.

Rising concerns about the air pollution effects of RWC have prompted study of factors which influence the magnitude of RWC emissions from stoves and fireplaces. The following factors are examined in this report: a) burn rate; b) appliance size; c) wood moisture content; d) wood charge size; e) appliance size; f) fuel type, and; g) wood piece size. Efforts to design and engineer cleaner burning woodstoves have also increased dramatically in recent years, including applications of catalyst technology. Based on the research reviewed, the following general conclusions are offered.

In general, higher woodstove burning rates (kg/hr) result in lower emissions factors (grams of pollutant per kg. of wood burned) for TSP, CO, hydrocarbons (HC), and POMs. The same is probably true for fireplaces, although little data on this exists.

Conventional woodstoves tend to have higher emission factors (g/kg) than fireplaces for TSP, CO, and HC. More complete combustion with lower resultant emission factors can be achieved by catalyst stoves, catalyst add-on devices, and an increasing array of improved design, non-catalyst combustion stoves. Although ranges can overlap, in general, catalyst equipped stoves result in lowest emissions, conventional airtight stoves produce the highest emissions, and improved design non-catalyst stoves perform in between.

Wood with moisture content in the range of 20% to 26% (wet basis) seems to produce the lowest particulate emission factors in stoves. Wood moisture contents above and below this range resulted in higher emission factors in limited testing. For fireplaces, a more linear relationship seems to exist, with higher wood moisture content generally resulting in higher emissions factors.

Larger "charge size" in stoves generally results in higher emission factors for TSP, CO and HC. However, charging larger pieces of wood in stoves generally results in lower emission factors for these pollutants.

Larger firebox size in stoves generally results in higher particulate emission factors. Information is inconclusive regarding whether hard or softwoods produce higher emissions, although softwoods have a higher content of volatiles.

The best, most direct method for quantifying RWC emissions in a local area is through household surveys conducted by telephone or mail. Wood supplier information, census data and related information are likely to be too incomplete or too indirect. They do not afford enough information on the number of households using wood, the amounts used per household, the mix of wood burning appliances in an area, household burning practices and other household characteristics. Such information is critical in understanding the dynamics of RWC for a given community, and thus in designing effective RWC control measures. Information on RWC household surveys is included in Appendix A.

One of the major sources of uncertainty in estimating RWC emissions for a local area involves selection of appropriate emission factors for woodstoves and fireplaces. Scarcity of emissions test data, lack of standardized test conditions, and lack of testing under "typical" household wood burning conditions, have all contributed to a wide range of RWC emissions factors in the current literature. Table ES-1 summarizes this variability, and compares it to EPA's current woodstove and fireplace emission factors for TSP and CO. More and better woodstove emissions testing, in conjunction with ongoing efforts at the federal and several state levels should improve estimation and selection of RWC emissions factors.

One of the best, most direct methods for quantifying RWC ambient impacts is Chemical Mass Balance (CMB) receptor modeling source apportionment analysis. Using detailed chemical composition of particulate emissions from various airshed sources, CMB determines the relative contributions of individual sources which best explains both the mass and chemical composition of particulate samples collected at monitoring sites (receptors). CMB methods thus directly attribute a specific amount of measured ambient particulate concentrations to RWC, and to any other sources for which emissions chemical composition can be established.

TABLE ES-1. Comparison of EPA Emission Factors With Range of Literature Values

RWC Appliance, Pollutant	EPA Emission Factor[a] (g/kg)	Range of State/Local[b] Emis. Factors (g/kg)
Woodstove, TSP	21	5-62.5
Fireplace, TSP	14	2-25
Woodstove, CO	130	50-180
Fireplace, CO	85	9-150

a. AP-42 (U.S EPA, 1983b)
b. Gay, et al., (1985)

The strength of CMB source apportionment analysis is its ability to determine relative source contributions from a single monitoring sample - e.g., one collected under worst case meteorological conditions. A principal drawback is the inability to distinquish impacts from chemically similar sources - e.g., woodstoves, fireplaces and forest burning. Other receptor modeling techniques, such as multivariate analyses, require many more samples to obtain statistically valid results.

Field monitoring and sample analysis are discussed in this report, primarily in terms of supporting receptor modeling studies. A stepwise approach to estimating RWC ambient impacts is outlined, with options based on available study resources.

A recent national RWC assessment document (Nero and Associates, Inc., 1984) compiled the best available data on RWC ambient impacts for twenty localities around the country (Table ES-2). Fine particulate masss (< 2.5 um) attributable to RWC (mostly using CMB methods) ranged from: a) 6 to 93 ug/m^3 as a study period or seasonal average, and; b) 24 to 234 ug/m^3 as a 24-hour maximum average. The small size of this data base, and other limitations discussed in this report, provide only a preliminary view of the potential significance of RWC ambient impacts. It seems clear, however, that RWC could be a very significant fine particulate source, relative to EPA's proposed national (PM_{10}) standard, for any locality with substantial wood burning and restrictive wintertime meteorology.

Dispersion modeling is also useful in estimating RWC impacts - especially: a) in areas where no monitoring sites exist; b) for future years, using projections of future RWC emissions; and, c) to compare potential air quality improvements from alternative RWC emission control strategies. Various dispersion models developed by EPA and others, which are applicable to RWC analysis, are reviewed in this report. The use of receptor modeling to calibrate dispersion models for RWC applications is also discussed.

Other special methods to RWC impact assessment, discussed in this document, include: a) radiocarbon analysis (carbon-14) of particulate and carbon monoxide field samples, b) modeling RWC contributios to visibility impairment; and c) monitoring for CH_3Cl as an RWC tracer.

TABLE ES-2. Summary of RWC Impact on Fine Mass and Measured Benzo(a)pyrene Levels at Selected Locations

No.	Location	Study Year	RWC Impact on Fine Mass $\mu g/m^3$			Measured Benzo(a)pyrene ng/m^3		
			No. of Samples	Avg.	Max.	No. of Samples	Avg.	Max.
1	Waterbury, VT	81-82	33	19	30	16	0.8[a]	2.4[a]
2	Western MA	81-82	13	15	25	--	--	--
3	Nashville, TN	83	24	9-20	51	21	2.3[a]	11.4[a]
4	Petersville, AL	81	8	33	65	4	41[c]	110.0[c]
5	Albuquerque, NM	82-83	56	25	59	--	--	--
6	Missoula, MT	83	12	37	48	--	--	--
7	Denver, CO	78	16	6-18	29	--	--	--
8	Telluride, CO	80	13	10-30[a]	59[a]	13	7.4[a]	14.8[a]
9	Reno, NV	83-84	8	13[a]	23[a]	--	--	--
10	Las Vegas, NV	83	4	--	41	--	--	--
11	Boise, ID	80-81	9	85[b]	128[b]	2	1.5	2.3
12	Portland, OR	77-78	32	4-10[e]	50	3	3.2	5.4
13	Medford, OR	79-80	40	9-30[e]	126[d]	2	8.4	8.5
14	Yakima, WA	80-81	4	50	55	--	--	--
15	Spokane, WA	80-81	15	17-45	68	3	6.1	11.0
16	Seattle, WA	81	9	29	49	3	2.1	4.2
17	Tacoma, WA	81	4	35	44	--	--	--
18	Longview, WA	80-81	4	42	26	--	--	--
19	Anchorage, AK	81-84	8	18[a]	45[a]	--	--	--
20	Juneau, AK	81-82	11	48-93[a]	234[a]	1	--	11.0

ABBREVIATIONS:

RWC - Residential Wood Combustion
Fine Mass - $\leq 2.5\mu m$ unless otherwise specified
$\mu g/m^3$ - microgram per cubic meter
ng/m^3 - nanogram per cubic meter
Avg. - 24-hour average for the study period at one or more sites
Max. - 24-hour maximum for the study period
PM_{10} or PM_{15} - Particulate matter ≤ 10 or ≤ 15 μm.

FOOTNOTES:

a - Analysis of TSP samples
b - Analysis of PM_{10} or PM_{15} samples
c - Gaseous and particulate benzo(a)pyrene - 4-hour sample
d - 8-hour or 12-hour maximum
e - Annual average

RWC Control Measures

Leading examples of RWC particulates emission control measures are described for the following states and localities: a) Medford, Oregon; b) Oregon's statewide woodstove certification program; c) several Colorado ski communities, including Aspen (Pitken County), Vale, Beavercreek and Telluride; d) Colorado's statewide woodstove and fireplace control program; e) Missoula, Montana; f) Juneau, Alaska; and, g) Reno, Nevada. Illustrative laws, regulations, ordinances, and information materials developed in these programs are included in Appendix B.

The major types of RWC emission control measures discussed in the document include: a) emission standards for new woodstoves; b) home weatherization; c) wood moisture controls; d) episode controls, and, e) public education. The most effective of these measures for reducing RWC emissions appears clearly to be woodstove emission standards for woodstoves. However, its full benefits take many years to accrue, as cleaner burning devices replace existing stoves. For example, the Oregon Department of Environmental Quality attributes an estimated 75% reduction in existing RWC emissions over a 10-20 year period to its new mandatory woodstove certification program.

Key elements of RWC emission control strategies are discussed for all of the states and localities listed above. However, the only State Implementation Plans (SIPs) to date which have addressed RWC comprehensively are for particulates for three Oregon airsheds (Medford, Portland and Eugene). A package of RWC control measures implemented for the Medford area is the best documented example of applying all types of RWC control measures mentioned above in a local area.

In Medford, an ambitious home weatherization program was predicted to reduce RWC particulate emissions by up to 30-50% over a 3-10 year period. Wood moisture controls (improved firewood seasoning) were estimated to achieve about a 10% reduction. Episode controls (curtailment of burning during certain air stagnations) were estimated to afford a 6-7% reduction. Public education was not assigned an emission reduction benefit, but was deemed essential to the success of the other measures. Overall, including statewide

mandatory woodstove certification, an 80-95% reduction in RWC particulate emissions was predicted from the combined control measures, but fully realizable only in 10-20 years.

Both generic and site-specific methods are discussed for estimating the potential effectiveness of RWC control measures, including the use of receptor and dispersion modeling. Major uncertainties and assumptions are identified and discussed. The important role of a citizens advisory process in developing and selecting control measures is stressed.

I. INTRODUCTION

A. Background/Introduction to Residential Wood Combustion

In response to sharply increasing energy prices (since the early 1970s), many households have turned to woodburning as a primary or supplementary source of space heating. This led to sharp increases in the sales of wood stoves and fireplace inserts (as described in Section III.C), which were more efficient for space heating purposes than fireplaces. Another factor contributing to increased fuelwood usage was governmental promotion of renewable energy resources to reduce dependence on fossil fuels, exemplified by programs to encourage biomass utilization sponsored by the U.S. Department of Energy (Pacific, 1984).

The air pollution impacts associated with Residential Wood Combustion (RWC) can be significant. They also represent an impediment to desirable exploitation of wood as a renewable energy resource. Various studies have shown that RWC can be one of the largest sources of emissions of fine particulate and Total Suspended Particulate (TSP), in an airshed (Cooper and Watson, 1979). RWC can contribute significantly to exceedances of national ambient air quality standards for both TSP and Carbon Monoxide (CO), especially in residential neighborhoods (Nero and Associates, Inc. 1984).

Among the most troubling characteristics of RWC particulate emissions are their small particle size (respirability) (Rau and Huntzicker, 1984), and potential toxicity (Alfheim et al, 1983; Hytonen et al, 1983). Toxicity concerns are based on their relatively high mutagenic activity, and relative abundance of Polycyclic Organic Matter (POM), including known carcinogens such as benzo(a)pyrene (B(a)P) (Cannon, 1984). RWC has been identified as the largest single source nationally of emissions of POMs, which are one of the toxic air pollutants of most concern to the Environmental Protection Agency (EPA) (Radian, 1983).

RWC has also been shown to be a major contributor to visibility impairment and urban haze, due to its aerosol character and light scattering capability (Wolff et al, 1980; Dennis, 1983).

For air pollution control agencies seeking to attain and maintain ambient air quality standards, RWC is a prime example of the growing importance of areawide emissions sources in airshed management. As stationary, largely industrial point sources have been controlled, residual exceedances of ambient standards are increasingly due to areawide sources, such as RWC, road dust, and vehicle exhaust. These numerous, small, people-oriented emissions sources present special challenges in pollution assessment and control strategy development.

B. Purposes and Limitations of This Document

The primary purpose of this document is to provide information which can help state and local air pollution control agencies in their efforts to assess and control emissions from Residential Wood Combustion (RWC). This goal is approached through discussions of RWC emissions (Section III), description of leading methods for characterizing ambient impacts attributable to RWC (Section IV), and a review of RWC control measures (Section V).

In general, the technical discussions herein provide an overview of the topics addressed, and leading references to more detailed studies. Illustrative examples are included to help clarify or demonstrate technical points. More extensive technical details - e.g., to help plan quantitative studies of RWC emissions or ambient impacts - may be found in the leading example studies referenced.

Approaches and methods for characterizing ambient particulate concentrations directly attributable to RWC are addressed in Section IV. Primary emphasis is given to Chemical Mass Balance (CMB) receptor modeling and source apportionment analysis, but dispersion modeling and other approaches are also discussed. CMB analysis is one of the most direct and accurate method for quantifying RWC ambient impacts. Field monitoring requirements to support CMB analysis, and the use of receptor modeling in conjunction with dispersion modeling to estimate RWC impacts, are also discussed.

RWC control strategies are discussed first in general terms in Section V. Then leading examples of actual control measures adopted or proposed by state or local agencies are described. Available approaches for projecting RWC control strategy effectiveness, including using receptor and dispersion modeling and other analyses, are also discussed. Recommendations or preferences among various RWC control measures are not presented, although their relative ability to reduce RWC particulate emissions is discussed briefly.

While the information presented herein is intended to help state and local agencies assess and control RWC impacts, it is not referenced in terms of State Implementation Plan (SIP) requirements or procedures. Detailed SIP requirements and procedures are described in other EPA documents and regulations.

Also, estimates of RWC wood usage, emissions and ambient impacts reported herein for specific localities, should not be extrapolated to other localities without considerable caution. RWC characteristics and impacts can vary widely from one locality to another. A better use of this document is to review and select appropriate methods for analyzing local RWC parameters.

II. OVERVIEW OF DOCUMENT CONTENTS

This section provides an overview of the contents of this document, in terms of the primary topics covered in each of the remaining sections.

A. Residential Wood Combustion (RWC) Emissions Characterization

RWC emissions are characterized in Section III.A in terms of their nature and magnitude relative to all other emissions sources. Particular emphasis is placed on other wood combustion sources, such as industrial wood boilers, agricultural and forest managed burning, forest wildfires, and residential open ("backyard") burning.

Pollutant emissions addressed include the following criteria pollutants: Total Suspended Particulate (TSP), Carbon Monoxide (CO), Nitrogen Oxides (NO_x), Sulfur Oxides (SO_x), and Volatile Organic Compounds (VOC). Total and Inhalable Particulate, CO, and Polycyclic Organic Matter (POM) emissions from RWC and other wood combustion sources are also summarized on a national basis. The nature of emissions from the various wood burning sources is compared in terms of particle size, carbon content, plume rise, and the predominant locations and timing of their emissions.

Factors which influence the magnitude of RWC emissions are described and discussed in Section III.B, including the effects of: a) appliance type (woodstoves vs fireplaces); b) appliance size and design (existing vs emerging or advanced technology); c) firing practices - e.g., burn rate, wood charge size, and piece size; and, d) fuel type and condition - e.g., moisture content.

Trends in RWC appliance and fuel use are addressed in Section III.C, including the residential use of wood and coal.

Section III.D reviews and discusses several aspects of estimating air pollutant emissions from RWC. Approaches and methods for estimating RWC wood usage, and translating this into RWC emissions estimates are discussed, including the use of household surveys, data available from wood suppliers, and census and related information. Selection and use of

appropriate RWC emission factors is discussed. Projection of RWC emissions for future years is discussed, including trend factors and a wood use forecasting model.

B. Characterizing RWC Ambient Impacts

A summary of documented ambient impacts attributable to RWC is presented for fine particulate (< 2.5 um), based upon a recently completed national assessment of RWC impacts (Nero and Associates, Inc., 1984.) The representativeness and limitations of these field measurements of RWC impacts is discussed.

The primary tools for assessing ambient particulate impacts attributable to RWC - receptor modeling source apportionment analysis, and dispersion modeling analysis - are both described and discussed in Section IV. Chemical Mass Balance (CMB) receptor modeling is emphasized, because it is the most direct and accurate method available for quantifying RWC ambient impacts. The theoretical basis for receptor modeling is described in some detail, because it is a relatively new approach - e.g., compared to dispersion modeling with which users of this document will probably be more familiar.

Field monitoring for RWC applications is discussed in Section IV.B in terms of desirable features for network design, instrumentation, sampling and analysis. Receptor modeling requirements are stressed, including chemical and physical analyses required to establish source composition profiles.

Receptor modeling input data requirements are described, including both chemical composition information and measures of its uncertainties.

Various receptor modeling techniques applicable to RWC assessment are described in Section IV.C, and categorized as to whether their results are quantitative, semi-quantitative, or qualitative. Examples of quantitative techniques include CMB analysis of RWC particulate impacts, and radiocarbon (carbon-14) isotope analysis of particulate and/or carbon monoxide impacts from RWC. Multivariate models are also discussed.

Enrichment factor models are discussed as an example of a semi-quantitative receptor modeling technique applicable to RWC assessment. Qualitative approaches discussed include carbon thermograms, and analysis of temporal patterns (diurnal and seasonal variations) of light scattering (nephelometer) and chemical composition data.

Dispersion modeling as an RWC assessment tool is discussed in Section IV.D, first in general terms, and then by reviewing the characteristics of ten dispersion models applicable to RWC analysis. These include five models from EPA's UNAMAP series (PAL, RAM, ISCST, ISCLT, and CDMQC). Other models considered include: GRID; box model; proportional rollback; Holzworth urban model; and AREAS.

Dispersion modeling applications to RWC assessment are discussed in terms of: input data requirements; model selection and validation; data analysis and interpretation; and intercomparison of the advantages and disadvantages of various dispersion models for RWC assessment.

The joint application of receptor and dispersion models is discussed, because it offers particular strengths for RWC assessment and State Implementation Plan (SIP) control strategy development. The use of models to evaluate control strategies is further discussed in Section V.D. Receptor modeling of visibility impacts is discussed, as is the use of atmospheric tracers (e.g., SF_6) to estimate RWC ambient impacts.

Section IV.E briefly describes three levels of field monitoring and sample analysis that could be undertaken to quantify ambient impacts attributable to RWC. Approximate costs for levels I, II, and III are estimated at $6,000, $25,000 and $75,000 respectively, exclusive of equipment costs. The intent is to illustrate the types of measurements and analyses that could be conducted with very modest study resources (Level I), and the additional information that could be obtained with additional funds.

C. RWC Control Strategies

A brief overview of several factors which can govern selection and design of RWC control strategies is provided as introduction in Section V.A. The

following five types of RWC control measures are then discussed and illustrated: a) emissions standards for new woodstoves; b) weatherization of houses; c) wood moisture controls; d) episode controls; and e) public education. The important role of a citizen advisory process in developing and selecting RWC control measures is then briefly discussed.

III. RWC EMISSIONS CHARACTERIZATION

This chapter addresses four main topics: (a) how Residential Wood Combustion (RWC) emissions compare in magnitude and nature to other wood-burning sources; (b) seven different factors which can influence emission rates; (c) trends in wood burning in terms of appliance sales and in the use of wood and coal as residential fuels; and, d) approaches and methods for quantifying RWC emissions.

A. Emissions from RWC vs Other Wood Burning Sources

Emissions of Total Suspended Particulates (TSP), inhalable particulates (IP) and Carbon Monoxide (CO) from Residential Wood Combustion (RWC) in the U.S. are large in magnitude compared to those from other wood burning sources (Table III-1). When emissions of Polycyclic Organic Matter (POM) are considered, the relative contribution from RWC is much larger. RWC emissions account for about eight times as much POM emissions as all other wood burning sources and about 58% of total U.S. emissions of POM (See Table III-2). The relative magnitude of RWC emissions compared to other wood burning sources is discussed first, followed by a discussion of the nature of emissions from various wood burning sources.

1. Total Emission Estimates

One primary source of information which estimates air pollution emissions for the entire U.S. for major pollutant categories is the EPA's National Emission Data System (NEDS) (U.S. EPA, 1984a). Table III-1 shows the latest (1981) NEDS emission estimates for: a) Residential Wood Combustion; b) industrial wood combustion; c) forest managed burning; d) agricultural burning; e) residential open burning; and, f) forest wildfires. To provide perspective, information is also presented on point sources vs area sources and transportation vs non-transportation sources. Pollutants addressed by NEDS include: Total Suspended Particulates (TSP), Carbon Monoxide (CO), Sulfur Oxides (SO_x), Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOC).

TABLE III-1. 1981 Total U.S. Emissions Estimates for Wood Burning Sources and Other Sources From EPA's National Emissions Data System (NEDS)[a]

	Thousand Tons Per Year				
	TSP	CO	NO_x	SO_x	VOC
Source - Category					
Residential Wood Combustion [b,c]					
- Stoves	722	4,471	49	7	1,718
- Fireplaces	191	1,160	23	3	174
Industrial Wood Combustion	76	121	88	14	71
Forest Managed Burning	431	2,412	86	3	308
Agricultural Burning	72	476	10	0	66
Residential Open Burning	239	1,022	61	9	322
Forest Wildfires	483	3,982	114	4	546
Total of "Wood Burning" Sources	2,214	13,644	432	40	3,206
All "Transportation"	34,754[d]	77,832	9,518	927	8,146
All "Non-Transportation	7,353	23,616	14,994	26,586	13,514
All "Area Sources"	37,270	93,115	12,898	2,246	16,896
All "Point Sources"	4,837	8,333	11,614	25,267	4,764
All Sources	42,107	101,448	24,512	27,514	21,661

a. (US EPA, 1984a)
b. These NEDS values should be increased by 25% as shown in Table III-2 and explained in the Table III-2 footnote.
c. NEDS data actually shows stoves and fireplaces combined. Data was disaggregated to show the greater contribution by stoves. NEDS assumes 71.6% of wood consumption in each state was in stoves; 28.4% in fireplaces. NEDS uses emission factors for TSP, CO, NO_x, SO_x, and VOC of 21, 130, 1.4, .2, and 51 g/kg for stoves and 14, 85, 1.7, .2, and 13 g/kg for fireplaces (U.S.EPA, 1983b). Split was back-calculated using these values.
d. TSP emissions of 34,753,991 T/yr includes 28,225,321 T/yr from unpaved road dust which thus accounts for 67% of total TSP emissions from transportation related sources.

TABLE III-2. Emissions of Various Pollutants in 1981 from Wood Burning Source Categories

(Thousand tons/Year)

Source Category	Total Suspended Particulates (TSP)[h]	Inhalable Particulates (10 um) (IP)	Carbon Monoxide (CO)[h]	Polycyclic Organic Matter (POM)[i]
Residential Wood Combustion[a]				
- Stoves	903	812[b]	5,589	9.655
- Fireplaces	239	215[b]	1,450	0.690
Ind. Wood Com.	76	53[c]	121	0.066
Forest Managed Burning	431	410[d]	2,412	0.330
Agricultural Burning	72	68[e]	476	N/A
Res. Open Burning	239	215[f]	1,022	N/A
Forest Wildfires	438	459[d]	3,982	0.906
Total of "Wood-Burning" Sources	2,442	2,232	15,052	11.647
Transportation	34,754[j]	N/A	77,832	7.04
Total of Inventoried Sources	42,335[g]	N/A	102,856[g]	19.817[g]

a. Residential wood combustion emissions estimates have been increased by 25% over the NEDS values used in Table III-1, as explained in the text.
b. Inhalable particulate fraction estimated at 90% of TSP based on Rau, 1984.
c. Inhalable particulate fraction estimated at 70% of TSP based on PEDCo, 1984.
d. Inhalable particulate fraction estimated at 95% of TSP based on data by Sandberg and Martin, 1975 which found 92% of slash burning emissions mass to be associated with particles of 5 um diameter and smaller.
e. Sandberg and Martin data (1975) assumed to apply (see d. above).
f. Rau (1984) data assumed to apply (see b. above).
g. Totals include RWC emissions correct as explained in a. above.
h. Data from NEDS (U.S. EPA, 1984a).
i. Data is for 1980 and from Radian (1983).
j. Includes 28,225,321 T/yr from unpaved road dust.

The NEDS estimates indicate that for these wood-burning sources about 41% of the TSP and CO is contributed by Residential Wood Combustion. The NEDS data shows that woodstoves alone are estimated to account for over 80% of the TSP and CO emissions from RWC, and about 32% of the emissions from all the wood burning sources shown in Table III-1. Table III-2 compares the relative emissions from various wood burning sources of Total Suspended Particulates (TSP), Inhalable Particulates (IP), Carbon Monoxide (CO) and Polycyclic Organic Matter (POM).

A recent study concluded that all of the RWC emissions estimates from NEDS were approximately 25% low because underlying wood usage estimates were calculated in dry tons (Nero and Associates, Inc., 1984b). These had not been increased to account for normal firewood moisture contents, which typically range from 20%-30% by weight. Uncorrected NEDS estimates are shown in Table III-1, with corrected estimates used in Table III-2.

Any estimate of wood burning emissions must rely on some method of averaging or selecting from the wide range of reported emission factor data. Thus, the values shown in Table III-2 should be considered as best estimates. The uncertainty in the emission estimates in Table III-2 is probably the highest for POM's, and for the outdoor burning sources. For example, available POM emission factors can vary by several orders of magnitude (Harkov, 1984). Estimates of the emission factors for open burning, wild fires, managed forest burning, and agricultural burning are more uncertain, because it is more difficult to measure both the amount of material burned and the total emissions produced.

A review of Table III-2 shows that wood-related sources in 1981 accounted for 5.8% of all inventoried TSP source emissions and 14.6% of all inventoried CO source emissions. However, the total TSP emissions are dominated by the transportation categories (82% of the total). For example, the source category unpaved road dust, accounts for 67% of the total estimated TSP source emissions. Transportation emissions also account for about 76% total U.S. CO emissions. On the order of 90% of the transportation TSP emissions are from unpaved and

paved road dust. When the transportation category emissions are excluded, wood-related TSP emissions accounted for 2.44 million tons per year or 32% of the non-transportation TSP emissions of 7.6 million tons per year.

A comparison of emissions in Table III-2 from wood burning sources shows their relative magnitude. For each of the pollutants TSP, IP, and CO, Residential Wood Combustion in stoves and fireplaces contributes about 37% and 10%, respectively, to the totals from all wood-burning sources. Forest managed burning contributes about 16% to 18% of total wood-burning emissions for TSP, IP, and CO, and forest wild fires contribute about 20%-27% of the total for those three pollutants. The contribution from industrial wood combustion and agricultural burning is much smaller, with each at about 3% or less for those three pollutants. Residential open burning is estimated to contribute about 10% of the TSP and IP and about 7% of the CO. It is noteworthy that the emissions from agricultural and forestry burning are released, on average, much further from populated areas than the other sources. Thus, while these source categories contribute about 40% of the TSP, IP, and CO emissions from wood-burning sources, their percentage contribution to measured air quality impacts is on average much lower in populated areas.

The relative contribution by various wood-related sources to POM emissions is much different. However, results should be viewed in the context that POM emission estimates for some of the source categories shown in Table III-2 are not available. The others have relatively high uncertainty due to the uncertainty in POM emission factors (Harkov, 1984). POM emissions from stove wood burning and fireplace wood burning account for 83% and 6%, of the total POM emissions from the wood burning sources shown in Table III-2. This is consistent with a recent study for EPA (Radian, 1983) which estimated that RWC was the single largest source nationally of POM emissions.

2. Nature of Emissions From Various Wood Burning Sources

Emissions from various wood burning sources can be characterized in

terms of the size of the particulates, the particulate carbon content, the plume rise, where the emissions are emitted, and when they are emitted, as summarized in Table III-3.

The nature of the particulate emissions from these various sources is generally similar with the exception of industrial wood burning. For most of the source categories, 90% to 95% of the emissions are expected to be in the inhalable size range (< 10 um). Carbon dominates the particulate mass emissions for all the sources except industrial wood combustion. The difference is primarily associated with the degree to which complete combustion is achieved. For all these sources except stove wood burning and industrial wood burning, combustion conditions are not controlled. The highest degree of complete combustion is generally achieved in industrial wood burning, due to more expensive equipment and greater operator attention to achieving complete combustion. In contrast, poor combustion conditions are sometimes selected for woodstoves in order to lengthen the time between stove reloadings.

RWC emissions have an enhanced ambient air quality impact, because the emissions are released in residential areas with minimum plume rise. Agricultural burning emissions occur in more rural areas and forest burning emissions tend to be released even further from populated areas. Such release conditions do not, of course, preclude impact on populated areas. Industrial wood burning emissions are released in industrial rather than residential areas, generally in hot buoyant plumes with relatively high plume rise.

RWC emissions tend to be released at times which can produce relatively greater impacts than comparable amounts of emissions from other wood burning sources. RWC emissions are concentrated during the winter evening hours when atmospheric mixing height can be limited (due to residual solar heating effects and associated inversions). RWC emissions are also concentrated during the winter months. For many parts of the U.S., worst ventilation conditions occur during the winter period.

TABLE III-3. Characterization of Emissions from Various Wood Burning Sources

	Fraction of Particulate Mass In Inhalable Size Range (< 10 um)	Fraction Carbon Content	Plume Rise	Where Emitted	When Emitted
Residential Wood Combustion					
- Stoves	0.9[a]	.7[f]	Lowest	Neighborhoods above homes	Winters: concentrated in evenings
-Fireplaces	0.9[a]	.7[f]	Low	Neighborhoods above homes	Winters: Almost exclusively in evening
Industrial Wood Combustion	0.7[b]	.2-.55[g]	High	Industrial land use	Year Round: throughout day
Forest Burning Emissions	0.95[c]	.9[g]	Low to high	Generally in remote areas	Spring and Fall: Most during daytime hours
Agricultural Burning	0.95[d]	.7[g]	Low to high	More rural farming areas	Summer and Fall: Most during daytime hours
Residential Open Burning	0.9[e]	NA	Low	Neighborhoods	Year round; more in Spring and Fall; daytime hours

a. Inhalable particulate fraction estimated at 90% of TSP (Rau and Huntzicker 1985).
b. Inhalable particulate fraction estimated at 70% of TSP based on PEDCo, (1984).
c. Inhalable particulate fraction estimated at 95% of TSP based on data by Sandberg and Martin, 1975 which found 92% of slash burning emissions mass to be associated with particles of 5 um diameter and smaller.
d. Sandberg and Martin data (1975) assumed to apply (see c. above).
e. Rau and Huntzicker (1985) data assumed to apply (see a. above).
f. Rau and Huntzicker (1985).
g. Nero and Associates, Inc., (1984).

B. Factors Influencing RWC Emissions

The amount of emissions produced by households burning the same amount of wood can vary significantly. Knowledge of how RWC emissions can change with different factors is essential both to estimate the amount of emissions, and to develop successful RWC control strategies. This section focuses on the following seven factors that influence RWC emissions:

- burning rate
- appliance design
- wood moisture content
- wood charge size
- appliance size
- fuel type
- wood piece size

Table III-4 summarizes the effects of these factors on RWC emissions. Detailed discussion is presented in the text below. In this discussion a greater emphasis is placed on stoves than fireplaces, and on particulate emissions. This is because stoves often account for more RWC particulate and CO emissions than fireplaces, and because there is more research information on stove particulate emissions.

1. Burning Rate Effects on Emissions

Wood burning rates can affect both the amount of wood burned, and the TSP, HC, and CO emission factors (g/kg) for that wood burning. Burn rate effects are discussed in this section both on a grams per kilogram basis and a grams per hour basis.

The traditional way to express emissions effects is in grams of pollutant emitted per kilogram of fuel(wood) burned, or g/kg. This is how RWC emission factors are expressed in EPA's compilation of emissions factors, referred to as "AP-42" (U.S. EPA, 1983b). Woodstove and fireplace emission factors from AP-42 are summarized in Table III-5. However, expression of RWC emissions in grams of emissions per hour (g/hr) has also become useful - e.g., in identifying burn rate effects and in comparing different RWC appliances.

Table III-4. Summary of How Various Factors Can Influence RWC Emissions

Factor	Effects	References
Burning Rate	• Higher burning rates result generally in lower emission factors (g/kg) for TSP, CO, HC and POM.	Hayden and Braaten, 1982; Allen et al, 1981; Hubble et al, 1981; Butcher and Sorenson, 1979; Knight and Graham, 1982; U.S. EPA 1984b/gh
Appliance Design	• Conventional wood stoves have higher emission factors than fireplaces, for CO, TSP, and HC.	U.S. EPA, 1983 (AP-42)
	• Among stoves, more complete combustion with lower resultant emission factors can be achieved by catalyst stoves, catalyst add-on devices, and improved design non-catalyst combustion units.	Tiegs et al, 1984; Allen and Cooke, 1983; Hayden and Braaten, 1982
	• Although ranges can overlap, in general, catalyst stoves result in lowest emissions, conventional airtight stoves produce the greatest emissions, and improved design non-catalyst stoves perform in between.	Tiegs et al, 1984
Wood Moisture Content	• For stoves, the wood moisture content which produces the lowest particulate emission factors is 20% to 26% (wet basis). Wood moisture contents above and below this range result in higher emission factors.	U.S. EPA, 1984 b/gh
	• For fireplaces, higher wood moisture content levels result in higher amounts of unburned material. Specific effects on CO, HC, or TSP cannot be generalized from literature to date.	Shelton, 1981.

Table III-4 Continued (Page 2)

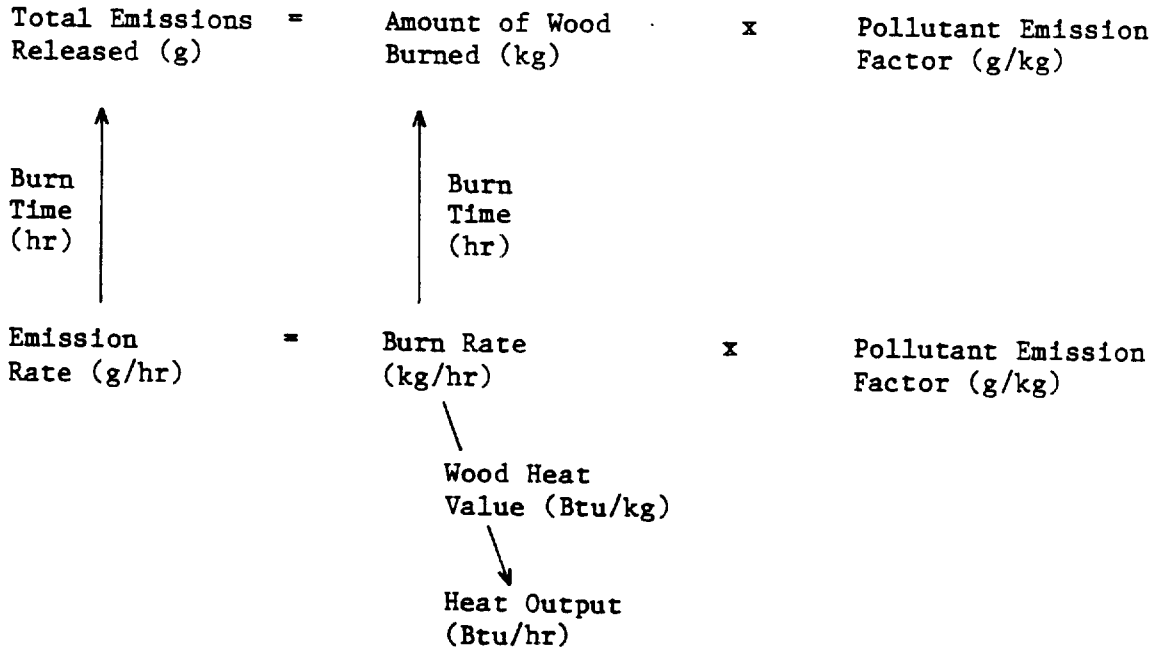
Factor	Effects	References
Wood Charge Size	• Larger "charge size" in stoves generally results in higher emission factors for TSP, CO, and HC.	Butcher and Sorenson, 1979
Appliance Size	• Larger fireboxes in stoves generally result in higher particulate emission factors.	Burnet and Tiegs, 1984
Fuel Type	• Softwoods have a higher volatile content. Information is inconclusive regarding whether hard or softwoods produce more emissions.	DeAngelis et al, 1980.
Wood Piece Size	• For stoves, larger wood pieces generally result in lower emission factors for CO, HC and TSP.	Barnett and Shea, 1981; Allen and Cooke, 1981.

TABLE III-5. EPA Emission Factors For Stoves And Fireplaces[a]

Pollutant	Stove Emission Factor (g/kg)	Stove Emission Factor (lb/ton)	Fireplace Emission Factor (g/kg)	Fireplace Emission Factor (lb/ton)
Particulate	21	42	14	28
Sulfur Oxides	0.2	0.4	0.2	0.4
Nitrogen Oxides	1.4	2.8	1.7	3.4
Carbon Monoxide	130	260	85	170
Volatile Organic Compounds				
- Methane	0.5	1.0	-	
- Non-methane	51	100	13	26

[a] Source: U.S. EPA (1983b)

As the following general relationships illustrate, the total RWC emissions released are a function of both the amount of wood burned (kg), and the associated pollutant emission factor (g/kg) achieved under the combustion conditions at which the wood is burned.



Burn rate changes can simultaneously affect both the amount of wood burned and the associated emission factor. Thus pollutant emission factors should be referenced to the burn rates at which they were determined, for they may not be as representative of RWC emissions at higher or lower burn rates. In AP-42, EPA notes that its current woodstove emission factors were based on tests conducted at burn rates of 3 kg/hr or less (U.S. EPA, 1983b).

When estimating RWC emissions for an airshed, multiplying the amount of wood burned by a pollutant emission factor (g/kg) which is representative of areawide average or predominant burning practices is the typical approach. AP-42 emission factors are commonly used, unless better local estimates are available.

However, in testing woodstove emissions, it is desirable to test over a full range of heat outputs (Btu/hr), which is also a function of

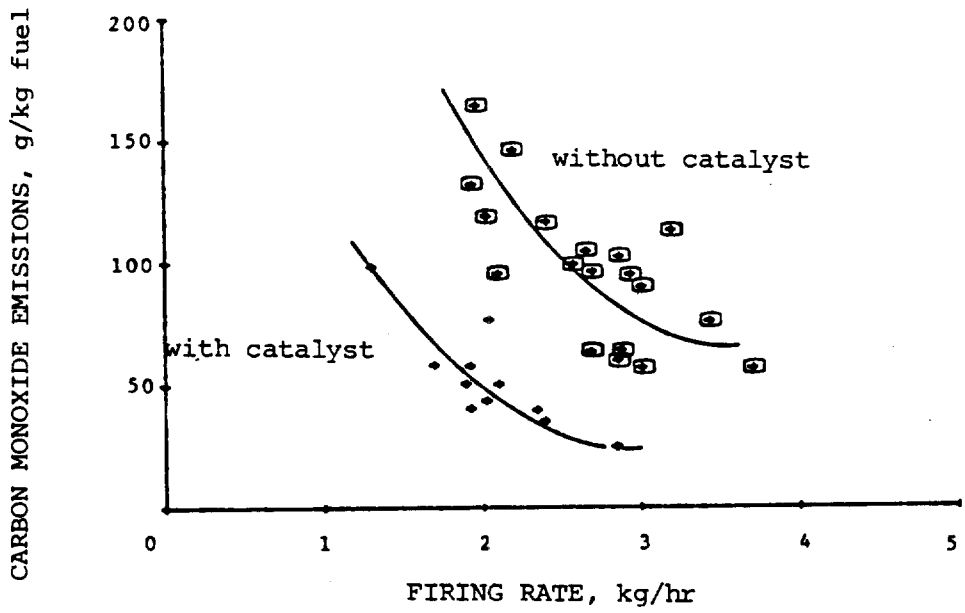
burn rate, as illustrated above. Since pollutant emission factors (g/kg) will also be varying over this range of burn rates, it is more meaningful to express stove emissions test results as an emission rate (g/hr) over the entire range of heat outputs tested. This accounts for burn rate effects on emissions performance in a more accurate way than could be done using a single or average emission factor. This also allows the stove's emission performance over its heat output range to be simply and clearly represented in a label (e.g. see Figure V-2).

The emissions rate (g/hr) parameter thus enables appliances operating over a range of heat outputs to be compared on a consistent basis. The Oregon wood stove certification program describes stove emissions performance on a grams per hour basis, based on a series of tests conducted over the stove's entire heat output range.

Thus, emission factors (g/kg) and emission rates (g/hr) are useful in different ways in analyzing and expressing RWC emissions. The influence of burn rate on both emission factors and emission rates is further discussed in the next two sections.

a. Influence of Burn Rate on Emission Factors (g/kg).

For the pollutants TSP, CO, and HC, a decrease in wood stove burning rate generally results in an emission factor (g/kg) increase. This has been confirmed by many researchers in recent years, including: Butcher and Sorenson (1979); Allen and Cooke (1981); Hubble et al, (1981); Knight and Graham (1982); Hayden and Braaten (1982), and; Del Green Associates (U.S. EPA, 1984b/g). Although the burning conditions and other parameters have often been different, the general shape of the burn rate vs emission factor curve has been consistent. For example, Figure III-1 shows CO emission factors vs wood burning rate for a conventional stove (with and without catalyst) as measured by Hayden and Braaten (1981). This example is illustrative of similarly shaped emission factor vs burn rate curves identified by the researchers cited above.



[a]Source: Hayden, 1982

Figure III-1. Variation of CO Emissions Factor with Firing Rate for A Catalyst-Equipped Horizontal Baffle Stove[a]

ORDINANCE 24

Series of 1983

AN ORDINANCE REPEALING AND REENACTING CHAPTER 28 OF THE VAIL MUNICIPAL CODE RELATING TO SOLID FUEL BURNING DEVICES; PROVIDING CERTAIN DEFINITIONS; REGULATING THE NUMBER AND CONSTRUCTION OF SOLID FUEL BURNERS; REQUIRING HEAT EFFICIENT UNITS; PROHIBITING COAL USAGE.

WHEREAS, the setting of the Town of Vail in a valley between two mountains restricts air movement through the valley;

WHEREAS; the movement of air through the Gore Valley is further restricted in cold times of the year;

WHEREAS, the pollutants in the air caused by solid fuel burning devices have become increasingly worse;

WHEREAS, the Town Council finds that the pollution caused by solid fuel burning devices is exacerbated by the altitude, topography, climate and meteorology of the Town of Vail; and

WHEREAS, the Town Council finds that these sources of air pollution may be minimized by presently-existing, practical and economical technologies.

NOW, THEREFORE, BE IT ORDAINED BY THE TOWN COUNCIL OF THE TOWN OF VAIL, COLORADO, THAT:

Section 1. The Vail Municipal Code is amended by the addition of a new Chapter 8.28 "Air Pollution Control" which reads as follows:

8.28.010 Purpose and Applicability

These regulations are enacted for the purpose of promoting the health, safety, and general welfare of the residents and visitors in the Town of Vail. These regulations are intended to achieve the following more specific purposes:

(1) To protect the air quality in the Town of Vail;

(2) To reverse the trend towards increased air degradation in the Town of Vail;

(3) To provide heat sources that are efficient and have a reduced polluting effect;

(4) And to generally protect the air for the purpose of the public's health, safety and welfare.

The provisions of this Chapter shall apply to all areas of the Town of Vail.

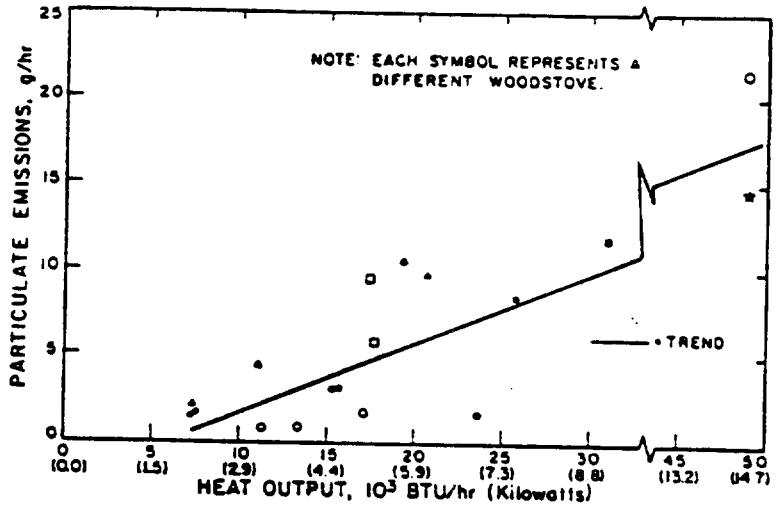
tests in which the lowest emission factors for naphthalene and phenanthrene were measured at the lowest burn rate tested. This phenomenon is not completely understood.

Regarding fireplaces, Muhlbaier (1981) reported that as fireplace burn rate decreases particulate emissions tend to increase. An inverse relationship between burn rates and emissions (correlation coefficient of -.44) was identified. However, the degree to which burn rate determines fireplace emissions factors cannot be determined due to various limitations of Muhlbaier's research. For example, the reported correlation was for burn rate vs particulate emissions rather than particulate emission factors (g/kg). Also, most of the tests involved burning of kindling size wood (100 gram pieces) which were placed on hot coals, which is not typical of normal fireplace burning practices.

b. Influence of Burn Rate on Emission Rates (g/hr)

For catalyst stoves, lower burn rates generally result in a lower gram per hour (g/hr) particulate emission rate. Figure III-2 shows the findings of Tiegs et al, (1984), which illustrate this relationship. Although the data are presented on a heat output basis, the curve would be very similarly shaped if converted to a wood burning rate basis, because those researchers found overall catalyst appliance efficiency to vary by less than 10% over the range in wood burn rates tested..

The ability of catalytic stoves to emit at lower rates (g/hr) at lower burn rates (kg/hr) is apparently attributable to more complete combustion efficiency. This occurs because the exhaust gas flow rate is lower and exhaust gas "residence time" near the catalyst is increased. In low burn rate situations where combustion of exhaust gases is no longer occuring in the catalyst region, emission factors could be expected to be somewhat higher. This situation could occur either because of poor design, or at low burn rates where the exhaust gas temperatures were too low to



Source: Tiegs et al, 1984

Figure III-2. Particulate Emission Rate vs Heat Output for Catalytic Woodstoves

allow combustion even in the presence of a catalyst. Allen et al, (1983) have reported that secondary combustion of wood combustion products begins to occur at temperatures above 260°C (500°F).

Regarding conventional stoves, available data show that burn rate increases can result in an increase or a decrease in particulate emission rates (g/hr) depending on the appliances and burn rates compared. Data illustrating how emissions in g/hr vary with burn rates show differing behavior for different conventional stoves. Such behavior is demonstrated by Tiegs et al, (1984) in reports for the Oregon Department of Environmental Quality (1983). Accordingly, no general conclusions can be drawn regarding how emissions in g/hr for non-catalyst appliances tend to vary with burn rates. Further research may result in the detection of some consistent relationship.

2. Emissions Effects of Appliance Design

A wide range of emissions findings have been reported for various designs of wood burning appliances by numerous investigators. Findings discussed in this section include the following:

- EPA emission factors (g/kg) for stoves vs fireplaces;
- Design factors which can minimize emissions; and,
- Emission performance of different stove designs.

a. EPA Emission Factors

EPA emission factors are shown in Table III-5 for residential stoves and fireplaces. Emission factors presented for both CO and TSP are about 50% higher for stoves than fireplaces.

EPA revised its emission factors to the levels shown in Table III-5 in 1983. The wood stove emission factors may be conservative, since some investigators have conducted their stove emissions testing at burn rates higher than typical. As discussed above, testing at a higher burn rate often yields a lower emission

factor (g/kg). For example, EPA based its estimates of stove emission factors on various stove tests in which wood was burned at a rate of 3 kg/hour or less. However, Hayden (1981), the Oregon DEQ (1984), and Barnett (1981) have reported average stove burn rates for Ottawa, Canada, Oregon, and northern New York to be 3, 3.7, and 3.5 pounds per hour (1.36, 1,68, and 1.59 kg/hour).

b. Design Factors Which Can Minimize Emissions

Aside from add-on pollution control equipment where emissions would be filtered or otherwise "captured", the reduction in emissions of pollutants such as carbon monoxide, unburned hydrocarbons, tars and other carbonaceous particulate matter hinges on the achievement of more complete combustion. Various woodburning appliance designs can be selected, but any design approach must optimize the following three factors in order to approach complete combustion:

- Time: There must be sufficient residence time in the area where combustion occurs for unburned hydrocarbons and carbonaceous material to be combusted.

- Temperature: Sufficiently high temperatures must be maintained in the combustion zone(s) to support combustion.

- Oxygen Availability: Oxygen must be available in the combustion zone(s) in sufficient quantity and distribution to enable combustion of previously unburned materials.

EPA has previously commissioned research which reported on design factors which can reduce RWC emissions by achieving more complete combustion. Research by Allen and Cooke (1981) constitutes one of the best summaries of such design considerations. The design considerations presented below, are from Allen and Cooke (1981), unless otherwise noted:

- Designs which limit the amount of wood exposed to heat (but not yet burning) can avoid excessive pre-burning pyrolysis. This can help avoid situations where insufficient combustion air is available to allow complete combustion.

- Smaller firebox sizes tend to result in hotter burning and therefore more complete combustion (Burnett and Tiegs, 1984).

- Primary air inlets can be oriented to better channel combustion air so as to optimize combustion conditions.

- Turbulent air introduction can promote better air-fuel mixing and thereby more complete combustion.

- Higher combustion zone temperatures result in more complete combustion. Insulation of the combustion zone can promote such higher temperatures.

- Thermostatic control devices used should not allow such severe air-supply cycling that sufficient oxygen is often unavailable.

- Channeling of gaseous pyrolysis products to a well-controlled combustion zone can result in more complete combustion.

- A secondary combustion zone can be provided. To enable secondary combustion to occur, air pre-heating and other measures to increase temperatures in that zone can help.

- An auxilliary ignition source can be used to combust exhaust products more completely.

- Catalytic afterburners can be used to achieve more complete combustion.

- Heat storage capacity can enable burning to occur at a faster rate (lower emission factors) while still maintaining a relatively uniform rate of heat output.

Any of the above design considerations can be used to achieve more complete combustion. Different options can be selected to achieve the same result. For example, if an effective secondary combustion chamber or catalyst is integrated into a design, the completeness of combustion in the primary burning chamber is less critical. Regardless of design, in order to achieve complete combustion in the unit as a whole, the elements of residence-time, temperature, and oxygen availability must be optimized in one of the primary, secondary or after burning combustion areas.

c. Emissions Performance For Different Stove Designs

Although there is much emissions testing information available for different stove designs, one major obstacle to comparing the emissions performance of different stove designs is that different test methods and burning conditions have often been used. This section reports on emissions testing work by several leading test facilities (Tiegs et al, 1984; TVA, 1983; NYSERDA, 1984).

The largest available data base on emissions from different stoves (at consistent burn rates) is the testing work which has been reported by Tiegs et al, (1984). Reports on that work enable the comparison of the emissions performance for conventional wood stoves, catalytic wood stoves, catalytic add-on devices and "new technology" woodstoves. Little or no data are available in the literature on how emissions vary with different fireplace designs.

Table III-6 shows the range in emission rates (g/hr) identified for these appliance classes. The data presented represent about one-hundred tests of thirty different models. This testing showed that catalytic woodstoves generally operated at the lowest emission rates, with new-technology non-catalytic devices higher,

TABLE III-6. Summary of Woodstove Test Results

	Woodstove Type			
	Convention	Add-on Devices	Catalytic New Technology	Non-Catalytic New Technology
Particulate Emissions, g/hour	10-44	10-30	1-21	3-42
Overall Efficiency, %	53-60	55-71	66-85	54-73
Heat Output, Btu/hour (kilowatts)	9.000-45,000 (13.6-3.2)	7,000-29,000 (2.0-8.5)	7,000-50,000 (2.0-14.7)	7,000-32,000 (2.0-9.4)

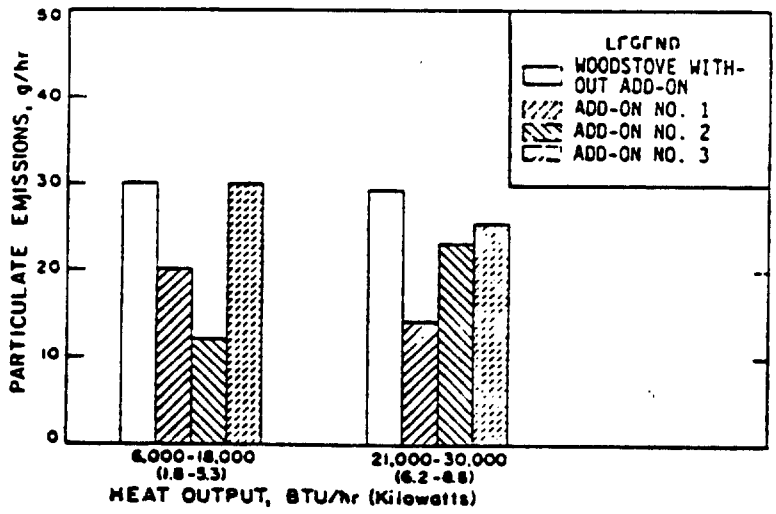
Source: Tiegs et al, (1984).

and conventional devices having the highest emission rates. In this research effort, two baffled airtight stoves, considered typical of the majority of wood stoves on the market, were selected to represent conventional wood stoves. Five "new technology, non-catalytic" wood stoves were selected to represent this category. These devices employed design modifications such as secondary combustion chambers, preheated secondary air, and/or distribution optimizers.

While the catalytic woodstoves generally had the lowest emission rates, and conventional stoves generally had the highest emission rates, the range of performance does overlap to a certain extent. Thus, catalytic stoves produced more emissions than conventional or new technology non-catalytic stoves in some of the tests reported by Tiegs et al, (1984).

The catalytic add-on devices tested were inserted on top of a conventional wood stove, between the flue collar and stove pipe. This arrangement reduced the particulate emission rate from fourteen to forty-four percent, over the range of heat output conditions tested, according to Tiegs et al (1984). The authors noted: "the add-on catalysts displayed erratic characteristics in ignition temperatures, making performance inconsistent and unpredictable". At least one of the add-on devices worked more efficiently on a different airtight stove than on the stove used most for these tests. This indicates that performance of add-on devices can vary significantly for different stoves. The add-on catalytic devices tested do not represent the maximum reductions achievable by this technology. They only represent three units out of the population developed to date.

Figure III-3 shows the difference in particulate emission rates achieved by the three catalytic add-on devices tested. Add-on unit 1 was most effective at lower heat output rates. Add-on unit 2 most effective at higher heat output rates. Add-on unit 3 performed worst, at both low and high heat output rates, and achieved no emission reduction at all during the low heat output



NOTE: Each bar represents the average of two tests.

Figure III-3. Particulate Emissions From a Conventional Woodstove with Catalytic Add-on Devices

Source: Tiegs et al, (1984).

test. This further illustrates that catalyst add-ons can vary substantially in their effectiveness, depending upon operating conditions.

The Tennessee Valley Authority has conducted 132 woodstove appliance tests addressing emissions and efficiency (TVA, 1983). An evaluation of this work illustrates the difficulty which is often encountered in applying the findings from emissions testing research to evaluate the emissions performance of household wood burning appliances as they are commonly used.

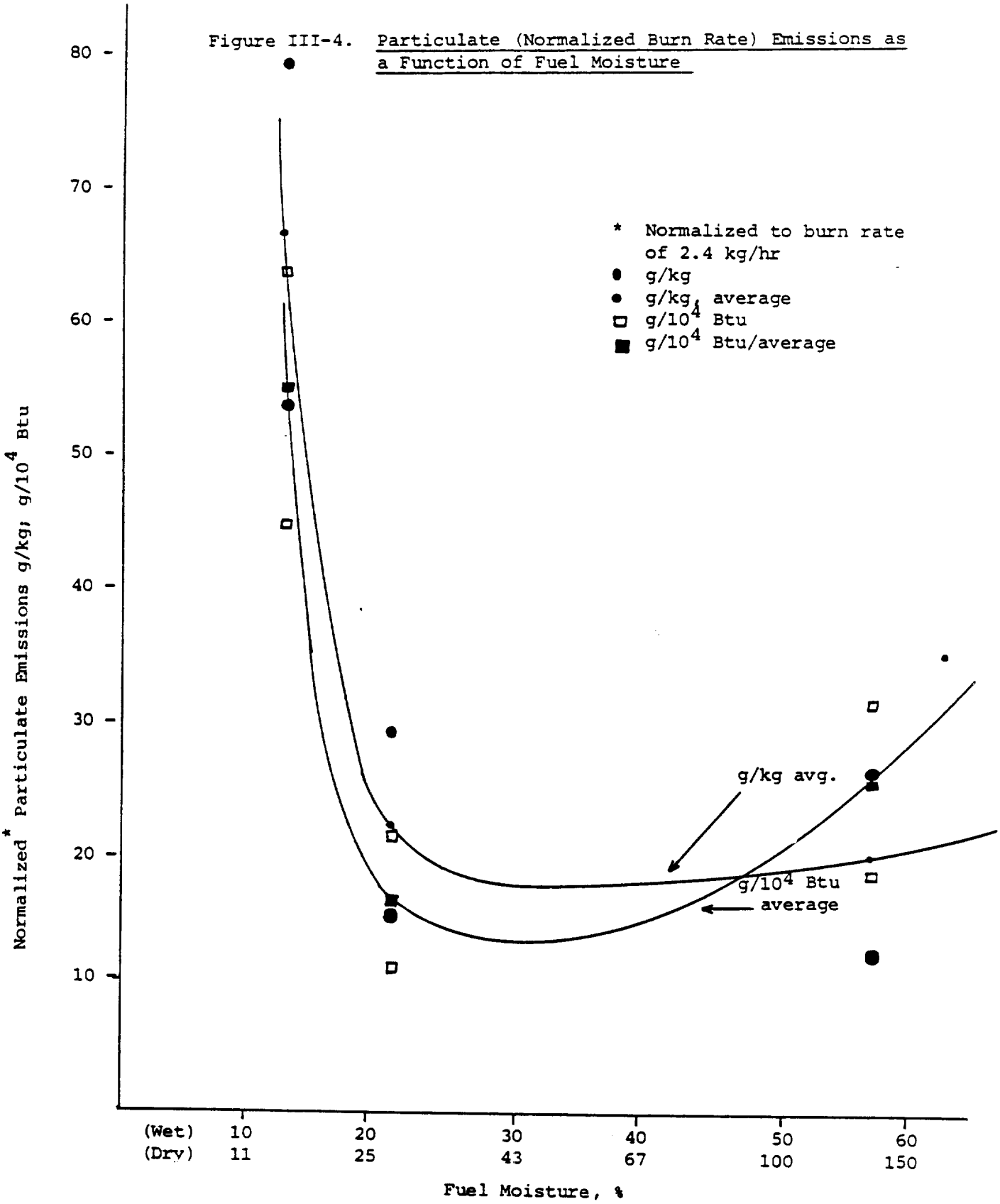
Out of the total of 132 tests, none of the tests represent common household burning conditions. Twenty-nine (29) of the tests used "brands" (small pieces of wood comparable to garden stakes) which are "not typical of the fuel used by the average homeowner" (TVA, 1983).

Of the 103 tests which used oak cordwood as fuel, the moisture content of the wood used was atypically low (10.4%), achieved by oven drying of the wood. Available sources indicate that residential cordwood typically has a moisture content of more than 20% (Tombleson, 1984). This discrepancy means that the TVA data base has limited value for characterizing typical household wood burning emissions.

For example, research reported in EPA (1984b/h), which is shown graphically in Figure III-4, indicates that emission testing with 10% moisture content wood can produce emissions at a substantially higher rate (factor of 3 or more) than when normal moisture content wood is used.

The New York State Energy Research and Development Authority also conducted emissions and efficiency testing of eight different stoves (NYSERDA, 1984). That study examined particulate emissions from several types of new technology stoves including: a) catalyst-equipped stoves; b) a secondary-combustion stove, and; c) conventional stoves with add-on catalytic inserts. All exhibited

Figure III-4. Particulate (Normalized Burn Rate) Emissions as a Function of Fuel Moisture



Source: U.S. EPA (1984b; Task 5)

particulate emission rates where were 50% to 80% lower than those of conventional airtight stove. Carbon monoxide rates were also generally reduced, although to a lesser extent.

3. Emissions Effects from Wood Moisture Content

The most comprehensive treatment of the issue of how stove emission factors vary with wood moisture content is reported in research in EPA (1984b), which is the basis for the conclusions presented below. Other research which reports some emission factor information for wood at different moisture contents (Barnett and Shea, 1981; Rudling et al, 1981) offers too few data points, or involves testing at different burn rates, so that general conclusions are difficult. Information is available from Shelton (1981) on how combustion efficiency varies with wood moisture content, but it is not possible to determine from those results how specific emission factors (e.g., for TSP, or CO, or HC) vary with wood moisture content.

Figure III-4 shows the Del Green Associates findings (U.S. EPA, 1984b; Task 5) on how particulate emission factors vary with wood moisture content. Data are shown for wood moisture content on both a wet and dry basis. Emission factors are shown in units of g/kg and $g/10^4$ Btu. The data have also been "normalized" in an attempt to factor out the differences in emission factors associated with burn rate differences rather than wood moisture content. Based on this data, and data from Shelton on how combustion efficiency varies with wood moisture content, Del Green Associates concluded that lowest particulate emission factors probably occur in the 25% to 35% moisture content range on a "dry basis" (which is 20% to 26% on a "wet basis").

Del Green Associates also measured how carbon monoxide, hydrocarbons, and creosote emissions varied with different moisture contents. Interestingly, their results for CO and HC showed that emission factors for those pollutants were lowest for the highest moisture content wood tested. Thus, woodstove emission factors for carbon monoxide and hydocarbons appear to have a different relationship to moisture content than that discussed above for particulates.

Regarding how fireplace emission factors (g/kg) vary with wood moisture content, the data are even more limited than for stoves. Rudling and Ahling (1981) report four test results, but the reported units (ppm CO, and ppm HC) do not enable conversion to g/kg figures.

Shelton (1981) reported combustion efficiency research which provides some insight on how much "unburned material" is emitted for wood burned in fireplaces at different moisture contents. Based on Shelton's combustion efficiency vs wood moisture content relationship (Figure III-5), it is apparent that the total amount of unburned material (predominately HC, CO, TSP, and deposited creosote) increases with increasing wood moisture content. However, no direct conclusions can be drawn regarding how fireplace emission factors in (g/kg) for specific pollutants (i.e. TSP or CO or HC) would vary with moisture content.

In summary, particulate emissions factors for stoves vary with wood moisture content. Lowest emission factors appear to occur in or near the 20% to 26% moisture content range, on a wet basis. Higher particulate emission factors appear to result when wood with moisture content above or below that range is burned. However, since data on this subject are limited, the moisture content range which produces lowest emissions may lie slightly above or below the 20%-26% range cited.

4. Effects Of The Amount of Wood "Charged"

Butcher and Sorenson (1979) postulated and demonstrated a positive relationship between the amount of wood charged in a stove and the resulting particulate emission factors. Allen and Cooke (1981) found that stove CO and HC emission factors (g/kg) increase with increasing charge size. No information is available from the literature which determines whether or to what extent this relationship applies to fireplace combustion.

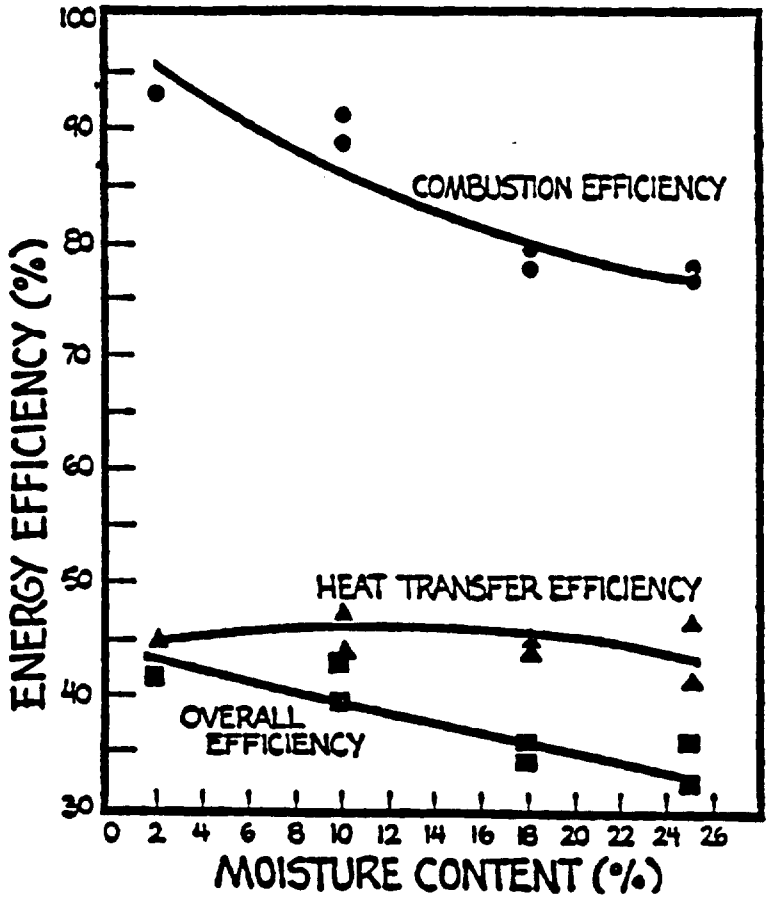


Figure III-5. Effect of Wood Moisture Content on Fireplace Combustion Efficiency

Source: Shelton (1981).

The Butcher and Sorenson (1979) research indicated that stove particulate emission factor is directly proportional to the amount of wood charged and inversely proportional to the wood burning rate. The equation developed by them to describe this relationship is shown below:

$$y = 10.34\ m/q - 1.18$$

where:

y = emission factor in g/kg
m = fuel charge in kg of wood
q = combustion rate in 10,000 Btu's output/hour

and:

$$q = \frac{[17{,}970-(203 * p)]}{10{,}000 * h}$$

where:

p = percentage of wood moisture content (wet basis)
h = length of burn in hours

Figure III-6 shows a plot of the data collected in the Butcher and Sorenson (1979) research, and a superimposed line calculated using this data and his equation above.

The physical explanation which underlies the identified relationship appears to be related to the intensity of the fire. Intensity of a fire can be thought of as the heat release rate from ongoing combustion divided by the amount of wood charged. For the same wood charge ("m"), burning with a greater heat release results in a more intense fire and less emissions. For the same heat release rate ("q"), a smaller wood charge ("m") results in a more intense fire and less emissions.

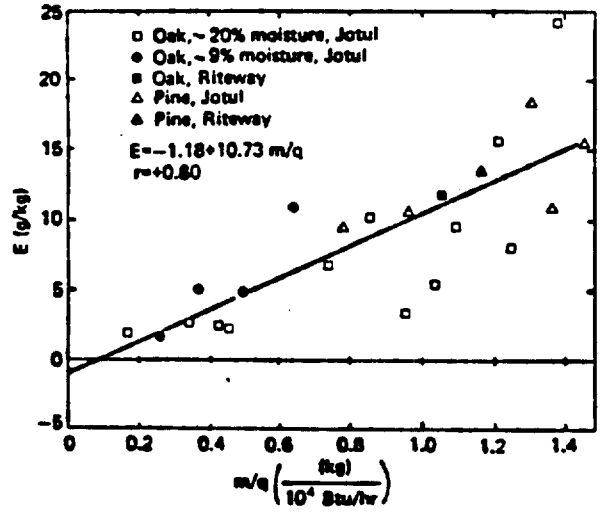


Figure III-6. Emission Factor as a Function of m/q

Source: Butcher (1979)

Testing conducted by Allen and Cooke (1981), which focused on carbon monoxide and hydrocarbons, also found that larger charge sizes produce higher emission factors. Their explanation of the underlying physical phenomenon was as follows:

> "The amount of wood loaded into the stove will have a large influence on the amount of pyrolysis products leaving the stove. The emissions increase with the increase in wood inventory at the same burning rate, due to the increased quantity of wood exposed to heat and thereby subject to preburning pyrolysis."

No information was identified which addresses whether this relationship applies for fireplaces.

5. Emission Effects From Burning Unit Size

Research by Burnet and Tiegs (1984) indicates that particulate emission factors increase with increasing firebox size. They evaluated five different conventional stoves with different firebox sizes. The particulate emission factors (g/kg) was found to decrease with decreasing firebox size for comparable burn rates. They explained this phenomena as follows: "temperatures will generally be higher, and combustion more intense, if a smaller firebox stove is used than a larger firebox stove, burn rates being equal".

Research by Butcher and Sorenson (1979), discussed in the previous section indicated that stove particulate emission factors are proportional to the amount of wood charged. This also supports the hypothesis that smaller sized stoves will tend to produce emissions at a lower emission factor (g/kg), since charge size should typically be smaller in a smaller stove.

Burnett and Tiegs (1984) addressed firebox size, but did not address how charge size varied as they tested stoves with different fireboxes. Butcher and Sorenson (1979) addressed charge size but did

not address firebox size. Thus, it is not possible to demonstrate from the work by these researchers how these two obviously related factors interact in influencing emissions. No information was identified which addresses whether this relationship applies to fireplace size.

6. Effects of Fuel Type

The available data are too limited to draw general conclusions about emission factor differences for different types of wood. Although emissions have been measured when many different types of wood were burned, too few of the tests were conducted under comparable operating conditions. Among emissions investigators such as Allen and Cooke, DeAngelis, Knight, Butcher, Tiegs, Del Green Associates, and Barnett, none have reported to date that soft or hard wood generally produces greater or lesser emissions.

DeAngelis et al, (1980) noted that yellow pine in the "green state" did produce higher emission factors (g/kg) than green oak, seasoned oak, or seasoned pine, but such a finding does not provide a basis for generalization. The researchers postulated that the emissions differences might have been associated with the characteristics of the volatile carbon portion of the green pine wood. They reported that softwoods contain 0.8% to 25% resinous material while hardwoods contain only 0.7% to 3% (Wise and Jahn, 1974) and concluded that the higher resin content of the green pine could have been responsible for the higher emission factor produced. Leading experts on RWC at the Oregon Department of Environmental Quality (Tombleson, 1984) agree that no firm conclusions can be drawn from current data regarding whether softwoods or hardwoods have higher emission factors.

7. Emission Effects of Wood Piece Size

Both Barnett and Shea (1981) and Allen and Cooke (1981) have noted that smaller sized logs burn with higher emission rates than larger logs when burn rates are held constant. Results of Allen and Cooke

are based on CO and total hydrocarbon emissions. Both of these research teams concluded that small wood pieces can result in the generation of more pyrolyzed wood gases than sufficient oxygen is available to combust:

> "The size of wood has a large effect on the rate of pyrolysis. The smaller pieces of wood result in a shorter distance for the pyrolysis products to diffuse, a larger surface area to loss ratio, and a reduction in time required to heat the entire piece of wood" (Allen and Cooke, 1981).

Barnett and Shea (1981) similarly postulated that the "surface area to wood volume" is the key parameter:

> "... results indicate that log diameter has a large effect on emissions. Undoubtedly, the surface area to wood volume relationship is a key factor. Thin logs have a large surface area to volume ratio. Therefore, these logs heat up relatively fast and then release their volatiles at a fast rate. This process is further aided by the large surface area of the logs through which volatiles are released."

Barnett and Shea (1981) developed a best fit equation for a thin-walled convective heater operated with a stove surface temperature of 500° F:

$$y = 11.3 - 9.9\ [\log (\log \text{size})]$$

where:

y = TSP emissions factor in grams per pound
log size = log diameter in inches

If the emission factor (y) is expressed in g/kg, the equation converts to:

$$y = 24.9 - 21.8\ [\log (\log \text{size})]$$

Table III-7 shows (Column 2) how emission factors vary with log diameters ranging from 1/2 to 6 inches. Column 4 shows the % emission factor reduction which results from increasing log diameter in several 2 inch increments, based on the equation above. As can be seen, each increase in log size by 2" is predicted to decrease the emission factor by about 33%, within a range of common log sizes.

Such a relationship holds promise as a simple and unrestrictive control strategy. People could be encouraged to burn larger wood pieces in stoves. Since less wood splitting work would be involved, this idea might be readily accepted and adopted.

Available information on how wood piece size affects fireplace emission factors is limited. Although Muhlbaier (1981) reported fireplace testing results in which larger wood pieces produced a higher particulate emission factor, several factors preclude generalizing her findings to the population of fireplaces. For example, her tests involved atypically small wood charges (most less than 2.1 kilograms). Also, the large pieces stopped burning, and thus burned in the smoldering phase for at least some time period. Lastly, since the large pieces were not completely burned, their emission factors do not include the cleaner burning charcoal phase of combustion. Thus no conclusions can be drawn at this time regarding how wood piece size effects fireplace particulate emission factors.

C. Trends In Wood Burning Appliance and Wood Fuel Use

The most readily available information on trends in the U.S. on wood burning appliances is U.S data on sales of Residential Wood Burning devices. This information, for 1972 to 1982, is presented in Table III-8 and plotted in Figure III-7. Figure III-7 shows annual sales and cumulative sales for the 1972 to 1982 period.

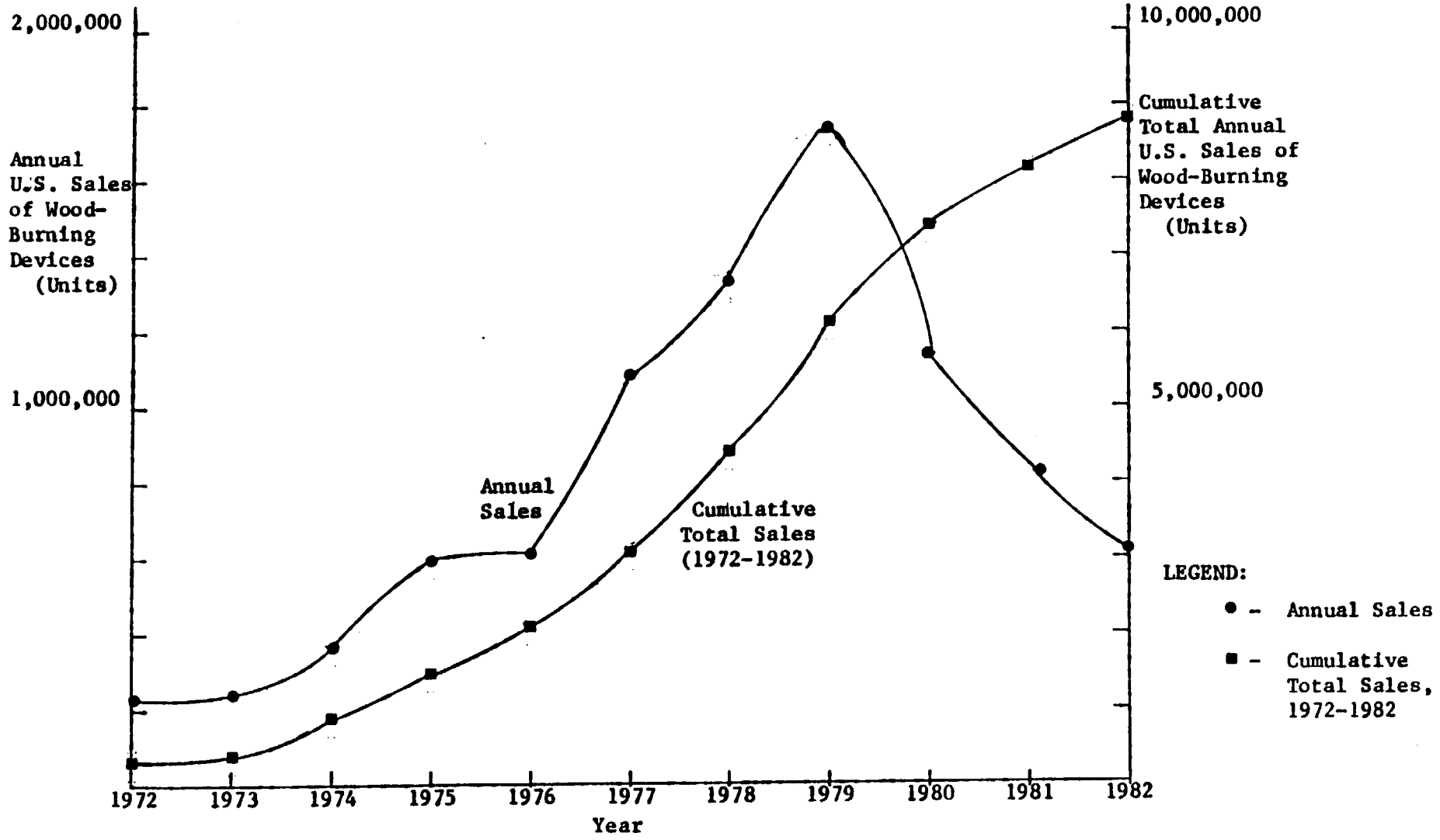
The annual sales graph illustrates the "boom" in wood stove sales spawned by the increase in conventional energy prices subsequent to the Arab Oil Embargo of 1973. Stove sales apparently peaked in 1979. Despite this "peaking", a plot of cumulative sales between 1972 and 1982 suggests that

TABLE III-7. Effect of Log Size on Particulate Emission Factor[a]

Log Size (inches)	Predicted Emission Factor[a] (g/kg)	Example Log Size Change From	Resultant % Emission Factor Decrease[b]
0.5	31.5		
1	24.9		
2	18.3	2" to 4"	36%
3	14.5	3" to 5"	33%
4	11.7	4" to 6"	32%
5	9.7		
6	7.9		

a. From an equation reported by Barnett and Shea, 1981.

b. Based on estimated emission factors in Column 2.



Source: U.S. Census (1972-82)

Figure III-7. Annual and Cumulative U.S. Sales of Residential Wood-Burning Devices, 1972-82

the number of units in operation has continued to increase, at least through the period for which data are available. Figure III-7 shows both annual sales and cumulative sales for the 1972 to 1982 period.

Strictly speaking, sales of replacement units should be subtracted from cumulative sales to estimate total additional units operating. However, assuming a 10-15 year stove life, this correction should not be large, over the decade shown in Figure III-7.

The total number of wood burning units in operation is a major determinant of total national RWC emissions. This has dramatically increased in the last decade, and is probably still increasing (depending upon the rate of retirement and/or replacement of burning units).

Accompanying the growth in RWC in the last decade has been a shift from fireplace to woodstove use in some areas (Nero and Associates, Inc., 1984). This is probably because stoves are generally more efficient for space heating. However, more pollutant emissions generally result from this shift, especially where stoves are operated in an airtight mode. Typical stoves produce about 50% more TSP and CO emissions per unit of wood burned than fireplaces (Table III-5), so a shift in woodburning activity from fireplaces to stoves results in an emissions increase greater than that from the growth in wood usage alone. For example, based on current EPA emission factors (see Table III-5; U.S. EPA, 1983b), if an area burns 70% of its wood in stoves instead of in fireplaces, the resultant TSP and CO emissions are about 17% higher.

Several other sources of information provide insight into residential wood usage trends. U.S. Census data (DeAngelis et al, 1980; Skog and Watterson, 1983) on the number of U.S. households which use wood as their "primary heating fuel" show that this number decreased from about 8,000,000 households in 1940 to about 660,000 households in 1974. Households using wood as the primary heat source began to increase at that point, rising to an estimate 2,600,000 households in 1980. This information is shown in Table III-9.

TABLE III-9. Trends in Residential Wood Usage

Year	Number of U.S. Households Using Wood As Their Primary Heat Source	Annual U.S. Residential Wood Usage (Dry Tons/Yr)
1940	8,000,000[a]	NA
1950	4,200,000[a]	NA
1960	2,100,000[a]	36,432,000[c]
1970	800,000[a]	23,301,000[c]
1974	660,000[a]	21,567,000[c]
1976	912,000[a]	28,002,000[c]
1980	2,600,000[b]	47,543,000[c]
1981	NA	48,215,000[c]

[a] DeAngelis et al, 1980.

[b] Skog and Watterson, 1983.

[c] U.S. Doe /EIA, 1982b.

NA=Not available

Another study, commmissioned by the U.S. Department of Energy (U.S. DOE/EIA, 1982), estimated that total annual U.S. residential wood usage dropped from 36.4 million tons (dry basis) in 1961 to 20.6 million dry tons in 1974, and rose thereafter to 48.2 million dry tons in 1981.

Residential Coal Usage Trends

Residential coal usage accounted for less than 3% of all U.S. coal usage and less than 1% of all residential energy usage in 1980 (U.S. EPA, 1984b). No historical data base was identified in this study which estimated annual residential coal usage over the last 20 years. A 1980 U.S. Department of Energy Survey (U.S. D.O.E., 1982) estimated that total 1980 U.S. residential coal usage was about 4.5 million tons, which compares to the 47.5 million dry tons of wood burned in the U.S. in 1980 (U.S. DOE/EIA, 1982).

Appliance sales data from the U.S. Department of Census (see Table III-8) also indicated that residential coal usage is small compared to residential wood usage. For the year 1980, the only year in which separate estimates are available for coal vs wood stove appliance sales, coal burning appliance sales only amounted to about 5% of woodburning stove sales.

Although there is no direct measure available of historical residential coal usage by year, some trend information is available on shipments of Pennsylvania anthracite between 1955 and 1980. While these estimates include anthracite used in sectors other than the residential sector, they do include the type and size of coal most commonly used for residential heating. This data are shown in Figure III-8. This information shows that annual anthracite shipments decreased until 1975, then stayed about the same through 1978 and began to increase thereafter.

Since information on past trends in residential coal usage is limited, studies which project future usage of coal can be used as an indication of whether residential coal usage is likely to increase substantially. Three such studies reported by EPA (1984b) do not project major expansion in residential coal usage. The first, a U.S. DOE report entitled Energy Projections to the Year 2000, projected residential coal usage to remain

TABLE III-8. Annual and Cumulative U.S. Sales of National Wood Burning Devices (1972-82)

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Wood (burning Sheet Metal Airtight Stoves	86,319	88,161	123,798	118,853	118,058	291,239	427,783	517,244	420,076		
Other Coal and Wood Burning Stoves and Fireplace Inserts	141,882	151,111	240,926	484,269	470,019	785,293	894,660	1,299,266			
Other Wood Stoves									297,030	239,931	202,253
Fireplace Inserts									416,456	223,348	158,944
Coal Stoves									52,698		
Freestanding Fireplaces										244,673	142,104
Heat Exchangers and Zero Clearance Fireplace										103,281	83,864
WOOD BURNING UNITS	228,201	239,273	364,724	603,122	588,077	1,076,532	1,322,443	1,746,510	1,133,582	811,233	587,172
Cumulative Total Wood Burning Units	228,201	467,473	832,197	1,435,319	2,023,396	3,099,928	4,422,372	6,168,881	7,302,463	8,113,696	8,700,868

Source: U.S. Census (1972-82)

Note: The 1972-1979 appliance sales estimates available are for coal and wood burning stoves together However, for the year 1980 coal stove sales were reported separately, and amounted to only 52,698 units sold, or less than 5% of the total of 1,133,582 wood and coal burning units sold that year. This suggests that coal burning device sales also represent only a small fraction of the other sales total in this table.

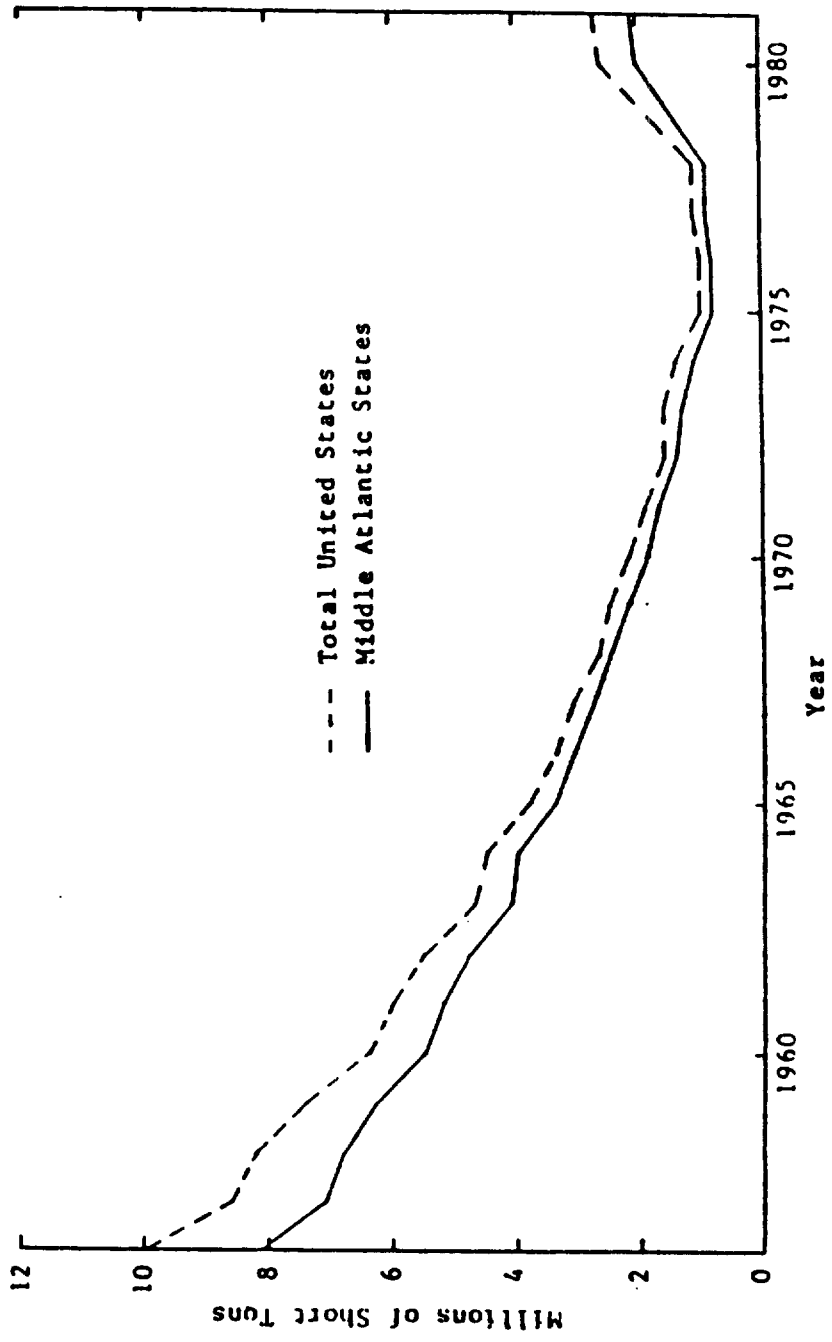


Figure III-8. Distribution of Pennsylvania Anthracite, Sizes Pea and Larger, to the Middle Atlantic States (NJ, NY, PA) and Total U.S.

Source: Pell (1982)

constant between 1980 and 2000 at about 4.5 million tons per year. A second U.S. DOE report, 1981 Annual Report to Congress, projected residential coal usage to decrease by about 30% between 1980 and 2000. The third study by the Office of Technology Assessment (1980) projected residential coal usage to double between 1985 and 2000.

D. Approaches and Methods for Estimating RWC Emissions

The following aspects of estimating air pollutant emissions from Residential Wood Combustion (RWC) discussed in this section are:

- Approaches available for quantifying RWC wood usage, based on household surveys, wood supplier data, and census and related information;

- Translation of RWC wood usage estimates into emissions estimates, including selection and use of RWC emission factors, and discussion of the wide range of such factors in the current literature; and,

- Projection of future RWC emission levels, including discussion of various trend factors and a model to project wood usage.

1. Quantifying RWC Wood Usage

The strengths and limitations of three approaches to quantify RWC wood usage discussed here are: a) direct surveys of households; b) wood supplier information, from commercial and other wood supply sources; and, c) use of census data and related information about the use of wood for space heat in residences, and about the prevalence of wood burning heating equipment in houses.

a. Household Surveys

Traditionally, survey methods are used to measure any phenomena or attitudes within an areawide population. Carefully designed questionnaires are typically administered to a judiciously selected, random sample of the population. Sample size and degree of randomness determine the accuracy and representativeness of survey results.

RWC emission sources are households scattered throughout an area. The density and distribution of RWC households can vary widely, both within a particular local area and among different localities. Wood usage per household, areawide RWC appliance mix, and other factors can also vary considerably among different localities (Nero and Associates, Inc., 1984). This indicates the risk of assuming that: a) RWC wood usage estimates from one locality will be representative of another locality, even within the same state or region; and, b) that neighborhood scale survey results are representative of the larger metropolitan area. RWC wood use surveys are only representative of the population sampled.

RWC household survey questionnaires should be designed to determine as many of the following types of information as practicable:

- The fraction of area households which burn wood, preferably categorized by type - e.g., single family, owner vs renter occupied etc.;

- Amount of wood used per household during a heating season (cords), for major types of RWC appliance - e.g., fireplaces, woodstove, fireplace insert, furnace, etc.;

- Number and type of RWC appliances in use;

- Type and source of wood used;

- Wood storage method, and time seasoned before use;

- Degree of home weatherization;

- Whether RWC is a primary or secondary means of space heating, or only used for aesthetic purposes, and whether such usage patterns will continue or change;

- Burning practices - e.g., time of day when wood burning occurs, typical wood charge size and/or piece size, and whether airtight operation occurs and when; and,

- Demographic information (optional) - e.g., household size, income level, age, location, etc.

The first three items above provide the main information needed to quantify RWC wood usage. Characterizing the amounts of wood burned for major RWC appliance categories, and types of RWC appliances in use, is important, because some appliances burn wood more cleanly.

The next two items (source and storage of wood) provide valuable indicators of wood moisture content, and the origins and costs of wood fuel relative to other heating fuels. The next two items help characterize whether RWC is a primary or supplemental heating fuel, and how its use varies with home weatherization. Characterization of the degree to which local homes are already weatherized, local firewood moisture content, and primary wood supply sources, not only helps understand local RWC, but also may help design RWC emission control strategies.

The information on burning practices can indicate how RWC emission densities are likely to vary during a day or week. It can also afford useful information on other factors which influence emissions - e.g., wood charge size and piece size, and how often burning devices are operated in a damped down or "airtight" mode. Such information is useful in many ways, including: a) selection of appropriate emission factors; b) identification of practices that could be targeted for attention in emission control strategies; and, c) identification of "typical" burning practices to be simulated in laboratory emissions testing of RWC appliances.

Determining whether RWC is a major household heating method or an aesthetic amenity, and whether households anticipate increased or decreased RWC activity, also helps understand present RWC impacts and future trends. Cross tabulation of survey responses with demographic information can indicate whether RWC activity is concentrated in particular population groups. This can help understand local wood burning activity, and target public information efforts and emission control strategies.

Household RWC surveys have been conducted by telephone, by mail, door-to-door, and using combinations of these methods. In general, telephone or other "in-person" approaches allow better probing for desired information, better control over sample selection (randomness), and better determination of respondent characteristics. Random sampling of the population being surveyed is important to assure that survey results are representative of that population as a whole.

Mailback questionnaires are significantly less costly, but the sample size and randomness is a function of who chooses to respond. Telephone follow-up to mailed questionnaires can improve sample size and probably randomness as well. To obtain optimal sample randomness requires telephone interviews, in order to assure that completed surveys represent a stratified random sample - i.e., that respondents exhibit the same basic characteristics (age, sex, income, etc.) as the population being sampled. Other useful quality controls include: provisions to assure access to unlisted phone numbers in the sample called, and the ability to determine the geographic distribution of respondents, e.g. through zip codes or other means.

Surveys are best conducted in the spring, when wood usage for the recent heating season is better known. In-person interviews should be done when heads of households are home -- i.e., mostly in the evenings. Training and supervision of interviewers is important to assure consistency of approach, deal with problems as

they arise, and determine invalid responses. Pretesting of survey questionnaires on a small sample, say 50 respondents, is the best way to identify and correct awkward survey questions or unforeseen problems, and to complete interviewer training.

Standard statistical or polling procedures can be used to preselect a sample size that is affordable and meets desired accuracy criteria. As a first approximation, a random sample of 400 valid responses should provide survey results at a 95% confidence level (See Appendix A). This size sample is a good goal, regardless of local population size, or survey method unless budget constraints dictate a smaller effort. In very small communities, a substantial fraction of the entire local population could be surveyed, if resources permit.

Analysis of survey results should provide at least the first three of the following types of wood usage estimates:

- Number of wood burning households;

- Cords used per household - e.g., per "average" household, and/or per wood burning household, or for any other household category (e.g., single vs multiple family dwellings) desired to help characterize aggregate areawide wood usage;

- Cords used per type of RWC appliance — i.e., fireplaces, inserts, woodstoves, etc. — including separate categories for advanced design units, or certified units in communities which require certification of wood burning devices;

- Cords obtained from each major supply source -- e.g., self-cut, commercial purchase, mill residues, etc; and,

- Cords of each predominant firewood species used.

This quantitative survey information on RWC wood usage provides a comprehensive basis for estimating RWC emissions, as discussed in subsection two of this section.

Household RWC surveys have been conducted since the mid to late 1970s in several Oregon communities and in Missoula, Montana. Recent surveys have also been conducted by the State of Colorado for seven communities (TRC, 1985), and by the State of Idaho for Boise (Edmundson, 1985). Appendix A contains information developed by the State of Oregon on: household survey design and cost; the use of household surveys to develop RWC wood usage estimates and emissions inventories; an example questionnaire and cover letter; information on sample size calculation and sampling error for mailback questionnaires; and, sample calculations of RWC wood usage and emissions from survey findings.

b. Firewood Supply Data

Common sources of household firewood include: self-cut wood from public or private lands; purchases from commercial suppliers; and, wood waste from wood processing facilities or construction sites. Information may exist to estimate the amounts of household firewood usage originating from one or more of these supply routes for a given locality. However, comprehensive estimation of total RWC wood usage from firewood supply data is usually not possible, due to difficulty and/or lack of various data in identifying all suppliers.

The percentage of firewood which is self-cut in an area is usually significant. Much of the self-cut wood usage may be estimated based on firewood cutting permit records from nearby public forests. However, such permits are usually not closely monitored. The best information available may be the number of permits issued, and a rough estimate by forest staff of the average number of cords removed per permit.

Commercial firewood sales from wood lots, or log truck loads purchased from truck owners, are typically not a matter of record. Private timber companies may also allow cutting on their land by permit, or be a source of wood wastes eventually burned in homes. Even wood theft from public or private forest land can be a significant, unquantified source of firewood.

In general, estimation of RWC wood usage from firewood supplier information is likely to be time consuming and would represent only an unknown fraction of areawide total usage. Where a few large suppliers account for most of the firewood usage in an area, and can provide data, such analysis could serve as a useful check on RWC wood usage estimates derived by using other methods.

c. Census and Related Data Sources

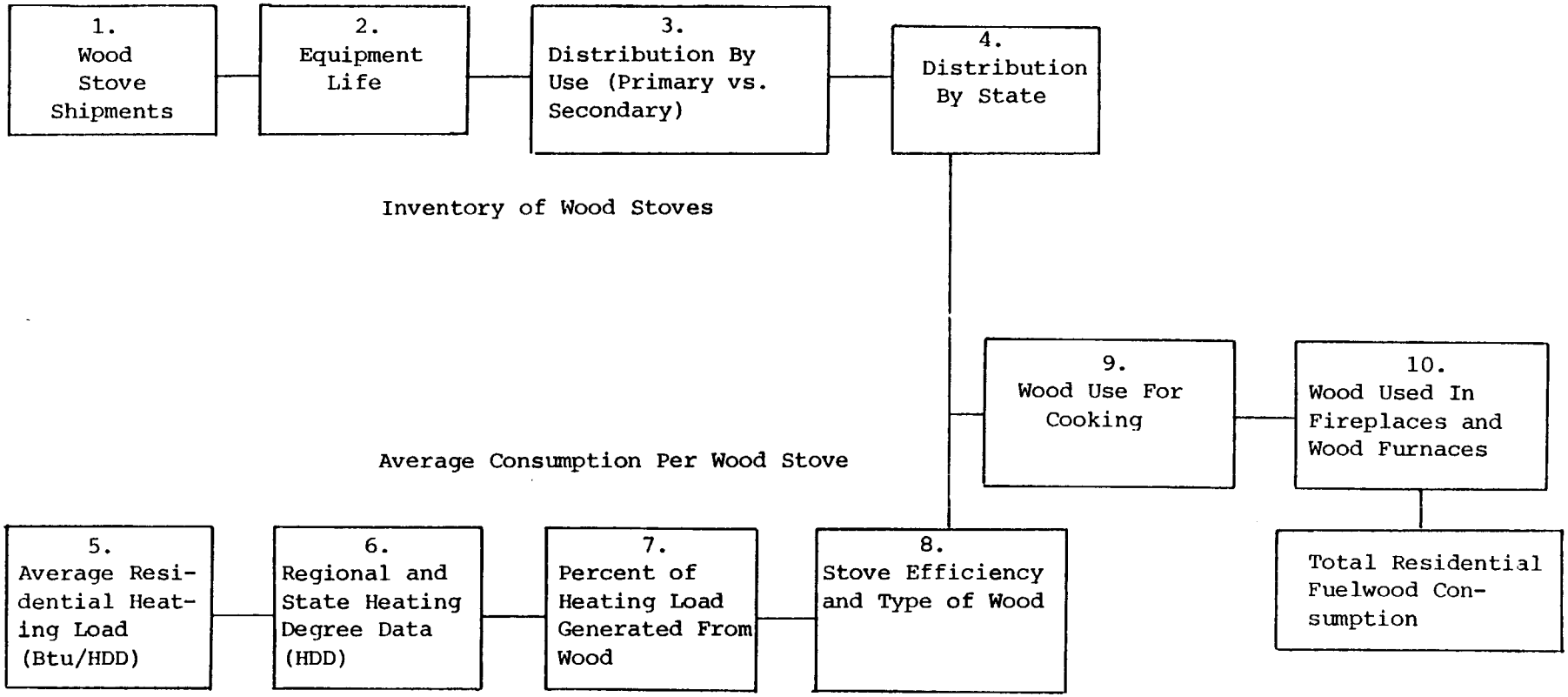
The U.S. Department of Commerce, Bureau of the Census, in its decennial national census estimates: a) how many housing units use wood as their primary house heating fuel; and, b) how many housing units use "fireplaces, stoves, or portable room heaters" as their primary house heating equipment (U.S. Department of Commerce, 1983). Another bureau of Census report cross-tabulates this information with other census information on housing characteristics, including: location of such housing units inside vs outside of central cities and standard metropolitan statistical areas (SMSAs); the number of housing units in a structure, and rooms per housing unit; household income, market value of housing units, rental payments, year built, and heating fuel costs (U.S. Department of Commerce, 1983).

Information is also available from several federal agencies which describes the number of fireplaces in new housing built during a given year or period (U.S. Department of Commerce and U.S. Department of Housing and Urban Development, 1981; U.S. Department of Labor, 1958). Annual shipments by manufacturers of various types of domestic heating stoves are also published by the Bureau of the Census (U.S. Department of Commerce, 1982). Sales and marketing data on residential wood burning devices may also be

available for an area of interest (e.g., U.S. Department of Energy, 1982a). A 1982 review of studies to estimate residential wood energy consumption discusses both direct survey information and indirect sources of information, such as the census reports mentioned above (U.S. Department of Energy, 1982b).

The use of census and other indirect information to estimate RWC wood use has several advantages and some distinct disadvantages. The major advantages are that the census and related information already exists, and is collected systematically, providing an inexpensive representative data base, often available on national, regional, state and local level. The major disadvantages are: such data bases do not include estimates of the amount of wood consumed; wood usage is not apportioned among categories or types of wood burning appliances (e.g., stoves, fireplaces, inserts, etc.); wood usage as a secondary or supplemental heating fuel is not addressed at all; and no information is provided on wood type, seasoning or other wood fuel characteristics.

Lack of information on actual wood consumption in census data is a major barrier to its use to estimate RWC wood usage, necessitating development of estimation models based on other parameters which can serve as proxies for wood usage. One of the leading examples of this approach is the U.S. Department of Energy (DOE) study referred to above (U.S. DOE, 1982b). Figure III-9 shows a schematic representation of the model developed in the DOE study to estimate RWC wood usage. It used existing census and other information to estimate household heating requirements (in Btus), and then how much firewood must be burned (in various RWC appliances) to satisfy these requirements. This model involved many steps and assumptions as it estimated internally such basic parameters as: the number of woodstoves in operation; distribution of woodstoves between primary and secondary use categories; and, the average wood consumption per stove.



Source: U.S. Department of Energy (1982)

Figure III-9. Flow Diagram for Residential Fuelwood Consumption Model

Alternative approaches or models for estimating RWC wood usage can be conceptualized to try to take advantage of the information base provided by census and other data sources. However, all would have to overcome key gaps in this information base with basic assumptions which answer the following types of questions:

- How many operating wood stoves and fireplaces exist in the study area?

- How many are actually used for primary heating, for secondary heating, and for aesthetics only?

- What is the average wood consumption for each of the above use categories and appliance types?

Estimating such basic parameters rather than directly measuring them using survey methods runs the risk of introducing potentially large uncertainties which can propagate throughout the analysis.

d. Comparison of RWC Wood Usage Estimation Approaches

The current state-of-the-art approach to estimating RWC wood usage is to conduct a telephone survey of a random sample of all households in the study area of interest. Surveys are the only direct measure of total RWC wood usage, since wood supplier data are likely to provide an incomplete picture. The major drawback to surveys are their potential costs. These can be mitigated somewhat through use of mailback questionnaires (instead of telephoning), although the accuracy of results may suffer. Where possible, readily available wood supplier data should also be compiled, to check the reasonableness of survey results.

The use of census and similar information sources to estimate RWC wood usage should be approached cautiously, unless or until some of the fundamental gaps in this data base are addressed. For example, census questions can be expanded to directly determine wood usage by type of wood burning device.

The uncertainties inherent in estimating RWC wood usage using census and other data bases may be less troublesome for larger (e.g., national or regional) study areas--e.g., if overestimates and underestimates for various sub areas compensate each other. Table III-10 compares two leading examples of national studies which estimated RWC wood usage at the state level. The study by the USDA Forest Service used telphone surveys (Skog and Watterson, 1983). The other study is the 1982 U.S. DOE Study referred to above, which used a model (Figure III-9) based on census and other data.

The latter study estimated RWC wood usage in dry tons. These are shown in the table and converted to cords of seasoned wood, by assuming 15% average moisture content and a cord weight of 2850 lbs. In both studies, statewide wood use estimates are divided by state total households (wood burning and non-woodburning households), to afford a RWC wood usage per "average" household (HH), in cords per HH. Both studies refer to 1980-81 RWC wood usage.

Among the more pertinent observations from Table III-10 are the following:

- After correction for moisture content, the national total RWC wood use estimates by U.S. DOE, and by the Forest Service are almost identical: 36.1 million and 36.3 million cords per year, respectively, for the 37 states for which both studies made estimates.

- Total estimated RWC wood usage, averaged over all households in the nation, is about one-half cord per year from both the U.S. DOE and Forest Service estimates.

TABLE III-10. Statewide RWC Wood Use Estimates from U.S. DOE and the USDA Forest Service (cords/year; 1980-81)

State	U.S. Department of Energy[a]			USDA Forest Service[b]	
	Dry Tons	Million Cords[c]	Cords Per HH[d]	Million Cords	Cords Per HH[d]
1. Alabama	0.712	0.59	0.45	0.76	0.56
2. Alaska	0.189	0.156	1.19	—	—
3. Arizona	0.272	0.225	0.23	—	—
4. Arkansas	0.566	0.47	0.57	0.85	1.03
5. California	2.473	2.04	0.24	1.84	0.21
6. Colorado	0.569	0.47	0.44	0.39	0.37
7. Connecticutt	0.792	0.65	0.59	0.44	0.40
8. Delaware	0.168	0.139	0.67	—	—
9. Washington, D.C.	0.015	0.012	0.05	—	—
10. Florida	0.795	0.66	0.18	0.62	0.17
11. Georgia	0.991	0.82	0.44	0.73	0.39
12. Idaho	0.399	0.33	1.02	0.39	1.21
13. Illinois	1.830	1.51	0.37	1.58	0.39
14. Indiana	1.615	1.33	0.69	0.86	0.44
15. Iowa	0.171	0.141	0.13	—	—
16. Kansas	0.154	0.127	0.15	—	—
17. Kentucky	1.473	1.216	0.96	—	—
18. Louisiana	0.382	0.315	0.22	—	—
19. Maine	0.762	0.63	1.59	0.84	2.13
20. Maryland	1.090	0.90	0.61	0.49	0.33
21. Massachusetts	1.085	0.90	0.44	1.07	0.52
22. Michigan	2.191	1.81	0.57	1.79	0.56
23. Minnesota	1.447	1.19	0.83	0.96	0.67
24. Mississippi	0.625	0.516	0.62	—	—
25. Missouri	1.777	1.47	0.82	1.23	0.69
26. Montana	0.401	0.33	1.15	0.26	0.91
27. Nebraska	0.091	0.075	0.13	—	—
28. Nevada	0.125	0.103	0.34	—	—
29. New Hampshire	0.430	0.36	1.11	0.46	1.42
30. New Jersey	1.112	0.92	0.36	0.41	0.16
31. New Mexico	0.473	0.39	0.88	0.23	0.51
32. New York	2.693	2.22	0.35	2.12	0.33
33. North Carolina	2.819	2.33	1.14	1.92	0.94
34. North Dakota	0.034	0.03	0.13	0.14	0.61
35. Ohio	2.536	2.09	0.54	2.09	0.54
36. Oklahoma	0.874	0.72	0.65	0.57	0.51
37. Oregon	0.947	0.78	0.79	1.55	1.56
38. Pennsylvania	3.054	2.52	0.60	2.20	0.52
39. Rhode Island	0.141	0.116	0.34	—	—
40. South Carolina	0.626	0.52	0.50	0.61	0.59
41. South Dakota	0.059	0.05	0.20	0.22	0.90
42. Tennessee	2.089	1.72	1.065	1.47	0.91
43. Texas	0.582	0.48	0.097	1.32	0.27
44. Utah	0.237	0.196	0.44	—	—
45. Vermont	0.347	0.29	1.63	0.41	2.28
46. Virginia	2.298	1.90	1.02	1.76	0.94
47. Washington	1.088	0.90	0.58	1.67	1.09
48. West Virginia	0.958	0.79	1.15	0.64	0.94
49. Wisconsin	1.509	1.25	0.76	1.28	0.77
50. Wyoming	0.149	0.12	0.72	0.14	0.87
TOTALS		39.818	0.50[d]	36.31	0.51[d]

Source: Nero and Associates, Inc. (1974)

a. From U.S. DOE 1982b
b. From Skog and Waterson, (1983)
c. From dry tons, assuming 15% moisture content, and 2,850 lbs. per cord
d. Total cords, divided by state total households

- However, for individual states, U.S. DOE estimates of total cords range from up to a factor of two or more higher than Forest Service estimates (New Jersey, Maryland, New Mexico), to a factor of three or more lower than Forest Service estimates (Oregon, Texas, Washington, and North and South Dakota).

- The magnitude and distribution of RWC wood use estimates is noticeably different between the U.S. DOE and the Forest Service surveys; for example:

  - In the higher usage states - e.g., in northernmost New England and Pacific Northwest - U.S. DOE estimates are consistently lower than those of the Forest Service.

  - However, in most of the Appalachian and Southeastern states which have relatively high usage - e.g., West Virginia, Virginia, North Carolina and Tennessee - U.S. DOE estimates are higher than those by the Forest Service.

  - Overall, U.S. DOE estimates, corrected for moisture content, in Table III-10 are generally "flatter" than those of the Forest Service - i.e., U.S. DOE estimates are lower for states where the Forest Service estimates were high and vice versa.

The Forest Service estimates are probably better, because they are direct estimates, based on a careful random sample telephone survey of actual wood usage by households. The U.S. DOE wood use estimates are derived indirectly from a variety of data and assumptions about how household heating requirements may be met with wood fuel. Assuming the survey results are more accurate, Table III-10 illustrates how indirect methods based on census and other data can produce estimates which are both significantly higher and/or lower than survey results, due to unintended bias or errors in the use of such indirect data bases.

Localities which cannot afford the cost of doing household surveys may have to use indirect information sources to estimate RWC wood usage. If so, every effort should be made to check resulting estimates against other pertinent information, including household survey results from other similar localities. A recent national study of RWC wood usage, emissions and ambient impacts investigated the extent of RWC information in all 50 states and profiled 20 localities in more depth (Nero and Associates, Inc., 1984). Table III-11 summarizes wood usage estimates from these twenty localities.

As explained in that report, RWC wood usage estimates, for some of these twenty localities, were considerably more uncertain than for others. Among the twelve best estimates, RWC wood usage ranged from 0.37 to 1.9 cords per "average" household. However, these per household wood usage estimates appear to be rather sensitive to the total number of households in the study areas, which ranged from small mountain communities to large cities, as well as to geographic and/or climatological factors. Thus, assuming that site-specific estimates could be representative of other localities should be done with great caution.

Accordingly, there is no substitute for local household (preferably telephone) surveys to determine actual local wood use, mix and distribution of wood burning devices, burning practices, and local trends. Such information is the best basis for developing reliable local RWC emission inventories, as discussed in the next section. These in turn are prerequisites for assessing RWC ambient impacts through receptor or dispersion modeling as discussed in Section IV of this document.

2. Translating Wood Usage Estimates into RWC Emissions Estimates

Translation of RWC wood usage estimates into corresponding estimates of air pollutant emissions is most commonly done as illustrated in the following equation.

TABLE III-11. RWC Wood Usage Estimates for Twenty Localities

Locality, State	Year or Heating Season	Total HHs 1000s	Annual RWC Wood Usage: Total Cords 1000s	Annual RWC Wood Usage: Cords Per "Average" HH[a]	Annual RWC Wood Usage: Stove Usage[b] (%)	Comments
1. Waterbury, VT[d]	80/81	0.647	0.929	1.44	90(est)	door-to-door HHSs
2. Western, MA	78/79[d]	283	164.4	.58	65-70%	Forest Service HHS
	83/84	281	60	.21	N/A	State Agency Estimate
3. Nashville, TN[d]	81/82	178	73.6	.41	71%	Davidson County HHS
4. Petersville, AL	80/81	1.2	1.45	1.21	N/A	Visual and aerial surveys
5. Minneapolis, MN[d]	79/80	721	265	.37	76%	From statewide HHS
6. Albuquerque, NM	1980	151	104.3	.69	59%	Questionable survey
7. Missoula, MT[d]	76/77	21.3	15	.70	N/A	Phone and in-person HHS
	79/80	22	32	1.45	60%	Phone and in-person HHS
	82/83	23	16-33	.71-1.43	83%	Telephone HHS
8. Denver, CO[d]	83/84	567	347.5	.61	30%	Mailback HHS
9. Telluride, CO[d]	83/84	0.671	.96	1.43	94%	100% HHS
10. Reno, NV[d]	83/84	67.5	38.6	.57	49%	Careful HHS
11. Las Vegas, NV	83/84	103	5.8	.06	few	Visual survey; assumptions
12. Fresno, CA[d]	81/82	96	42.5	.44	2%	Surveyed only SFDs
13. Boise, ID	83/84	60	N/A	N/A	N/A	Still reviewing HHS data
14. Portland, OR[d]	78/79	—	198.6	.46	N/A	Careful Phone HHS
	1980	383	262.1	.68	40%	Mailback HHS
	1981	387	272.7	.72	62%	RFP extrapolation
	1982	390	307	.79	63%	RFP extrapolation
	1983	386	280.2	.73	63%	RFP extrapolation
15. Medford, OR[d]	78/79	42.7	42.7	1.0	N/A	Careful phone HHS
	1981	42.1	62.7	1.49	71%	Mailback HHS; RFP
	1982	42.1	59.6	1.42	78%	RFP extrapolation
	1983	42	54.8	1.31	78%	Mailback HHS; RFP
16. Eugene, OR[d]	78/79	66.4	56.5	.85	20%	Careful phone HHS
	81/82	70	77.1	1.10	68%	Mailback HHS
17. Yakima, WN	82/83	21.4	21.4	1.0	N/A	Questionable HHS
18. Spokane, WN	80/81	70.9	1.5	1.58	23%	1 $mi.^2$ area HHS
19. Anchorage, AK	82/83	55.2	12.1	.22	N/A	Limited HHS (60 HHs)
20. Juneau, AK[d]	83/84	2.93	5.57	1.9	63%	Mendenhall Valley HHS

Source: Nero and Associates, Inc., 1984

a. Total cords divided by total households.
b. Percentage of total wood use in stoves, furnaces and inserts
c. Abbreviations: HHS = household survey by phone unless other stated
SFD = single family dwelling
RFP = reasonable further progress analysis
N/A = not available
d. Considered to be among the more reliable of the household surveys due to sample size, randomness or coverage of a high percentage of all households, etc.

RWC Wood Usage (kg/yr)	x	Emission Factor (g/kg)	x	Conversion Factor (Tons/g)	=	RWC Emissions (Tons/Yr)

Wood usage estimates are typically obtained in cords per year, or per heating season. This estimate of the volume of firewood used is converted to weight units (e.g., kg/yr) by multiplying by an assumed cord weight. Cord weights are discussed below. Selection and use of emission factors, usually expressed as grams of pollutant emitted per kilogram of wood burned (g/kg) is also discussed below.

a. Cord Weight

A cord of wood measures 4 ft. X 4 ft. X 8 ft. = 128 $ft.^3$ in volume. The weight of a cord of wood primarily depends upon its species (density), seasoning (weight of moisture and other volatiles), and the fraction of cord volume assumed to be air space vs wood. Table III-12 shows how wood density can vary with species.

A recent study (Nero and Associates, Inc., 1984) of twenty selected localities throughout the nation which had estimated RWC wood usage and emissions, found that their assumed cord weights ranged from 955 to 1,815 kg/cord (Table III-13). One of these local studies (for Reno; Pitter et al, 1984) based its relatively low cord weight assumption (1,011 kg/cord) on its conclusion that 45% of local cord stack volume was air space.

Selection of an appropriate areawide average cord weight assumption for a given locality can be made by considering the following factors:

- Areawide average mix of predominant firewood species used locally;
- Density of this mix (kg/ft^3), using data such as in Table III-12).

TABLE III-12. Wood Density and Heating Values for Selected Species

Species	Density (dry weight) (Pounds per cubic foot)	Higher heating values (dry weight) (Btu per pound)
Douglas-fir	28	9,050
Western hemlock	26	8,260
True firs	23	-
Western red cedar	19	9,700
Ponderosa pine	24	9,100
Lodgepole pine	24	8,730
Western larch	30	-
Spruces	22	-
Red alder	23	8,000
Bigleaf maple	27	8,000
Black cottonwood	19	8,510
Oregon white oak	37	8,170

Source: (Howard, 1981)

TABLE III-13. Cord Weights Used In RWC Studies in Various Localities

Locality/Region	Cord Weight Assumed (kg/cord)
1. Waterbury, VT.	1497
2. Western Massachusetts	955
3. Nashville, TN	1438
4. Petersville, AL	1438
5. Minneapolis, MN	1815
6. Albuquerque, NM	1100
7. Missoula, MT	1489
8. Denver, CO	1100
9. Telluride, CO	1100
10. Reno, NV	1011
11. Las Vegas, NV	1100
12. Fresno, CA	1815
13. Boise, ID	-
14. Portland, OR	1588
15. Medford, OR	1588
16. Eugene, OR	1800
17. Yakima, WA	-
18. Spokane, WA	1588
19. Anchorage, AK	1444
20. Juneau, AK	1466

Source: Nero and Associates, Inc., 1984

- Volume of wood in a typical local cord (ft^3 of wood per cord).

Alternatively, cord weights used by another similar locality can be assumed to be applicable.

b. Selection and Use of RWC EMission Factors

Measurement and interpretation of emission factors for woodstoves and fireplaces is undergoing development and change. Reasons for this include: a) the relatively recent (last 5-10 years) recognition of RWC as a potentially significant pollution source in many localities (Nero and Associates, Inc., 1984); and, b) subsequent efforts to develop new technology intended to reduce emissions from RWC appliances - e.g., catalytic combustors, and various advanced design woodstoves.

Table III-5 summarized woodstove and fireplace emission factors for six criteria pollutants, from EPA's Compilation of Air Pollutant Emission Factors (AP-42; U.S. EPA, 1983b). These were EPA's best estimates, based on test results available several years ago. EPA assigned these an emission factor rating of "C", indicating that the testing data base available was "average" at best, due to the limited number of tests and source types tested. The woodstove emission factors were futher qualified in AP-42 as being based on burn rates of 3 kg/hr or less. EPA noted that decreased emissions could occur at higher burn rates. EPA also noted that the available data referred to tests using primarily oak, fir and pine woods, with moisture contents ranging from 15%-35%.

The variety of conditions and emissions test procedures used in studies to date has been a major factor contributing to the wide range of woodstove and fireplace emission factors in the current literature. For example, Table III-14 compares current EPA woodstove and fireplace emission factors for two pollutants - particulates and carbon monoxide-with the range of comparable RWC emission factors used or cited in recent RWC studies conducted by twenty localities around the nation (Gay et al, 1985).

TABLE III-14. Comparison of EPA Emission Factors With Range of Literature Values

RWC Appliance, Pollutant	EPA Emission Factor[a] (g/kg)	Range of State/Local Emission Factors (g/kg)
Woodstove, TSP	21	5-62.5
Fireplace, TSP	14	2-25
Woodstove, CO	130	50-180
Fireplace, CO	85	9-150

a. AP-42 (U.S. EPA, 1983b)

Source: Gay et al, (1985)

For the most part, the range of emissions factors shown reflect substantial variation in published test results. This in turn reflects the lack of standardization of RWC emissions testing procedures. However, underlying uncertainty about "typical" household wood usage and burning practices hinders design of RWC emissions testing procedures which are representative of actual household practices.

Conversely, the emissions testing conditions employed in laboratory studies may or may not seem representative of actual household practices to agencies who need to select RWC emission factors appropriate for their locality. For example, in a study several years ago, Montana scientific and regulatory personnel reviewed the literature and selected TSP and CO emission factors for fireplaces, woodstoves and residential furnaces which they believed were "more generally representative of common burning practices in Missoula, Montana" (Steffel, 1983). These were slightly to substantially higher than the EPA emission factors in Table III-14, including a TSP emission factor of 62.5 g/kg for woodstoves operated in an "airtight" mode.

Development of RWC emissions inventories using the general equation above will become more complex, as the variety of RWC appliances in use increases. The ongoing development and sales of advanced design appliances should increase the difference in average emissions performance between newer and older appliances. Accordingly, wood usage estimates should be broken down by category of burning device, in order to select appropriate emission factors for each category. At a minimum, wood usage should be estimated separately for fireplace and woodstove categories. These could then be multiplied by EPA's fireplace and woodstove emission factors (Table III-5) to afford a basic RWC emissions inventory. Fireplace inserts would generally be included in the woodstove category.

As use of catalytic and advanced design non-catalytic RWC appliances becomes significant, their wood usage and emissions should be estimated separately, because their emissions factors will be substantially lower than the current EPA factors in Table III-5. Similarly, if stove wood usage in an "airtight" mode can be separately quantified, higher emissions factors may be appropriate for this category.

As indicated in the previous section, reliable estimation of local RWC wood usage by type of burning device, generally calls for household surveys in the community of interest. Today, such surveys should include questions to determine both the present and possible future mix of RWC appliances. This would help to determine the number and type of wood usage categories for which separate RWC emission factors are needed.

More test data and better RWC emissions factors should be available in the near future, as EPA develops a New Source Performance Standard (NSPS) for woodstoves, and updates its AP-42 RWC emission factors, and states or localities implement testing/certification programs for RWC and applicances. Meanwhile, state or local agencies may wish to better account for their changing RWC appliance mix in estimating both present and future RWC emissions. They, may be able to utilize the growing body of results from woodstove testing and certification programs operated in such states as Oregon or Colorado.

For example, Appendix B, Section 1b contains a summary sheet describing the first nine woodstoves certified under Oregon's program. However, Oregon's emissions testing results are expressed in grams/hour, and are weighted averages of several tests conducted over the full heat output range of each appliance, using Douglas Fir as fuel. Other localities which use similar wood fuels may be able to utilize some of the individual test results e.g., at heat outputs

consistent with their climate and space heating demands. From these results they could estimate RWC emission factors in grams/kilogram of wood burned, for appliances of special interest in their areas.

This level of effort in estimating RWC emission factors for different types of RWC devices is not warranted to obtain a first approximation of RWC emissions. However, it may be useful in projecting future RWC emissions levels, for areas in which a significant transition to much cleaner burning appliances is anticipated over time. Under such assumptions, AP-42 RWC emission factors could substantially overpredict future RWC emissions. The following section discusses projection of future RWC emissions in more detail.

Another factor that may have to be considered in selecting appropriate local RWC emission factors is altitude (elevation above sea level). Recent preliminary findings (Shelton, 1985) have been interpreted by others (Oregon DEQ, 1985) as indicating that particulate and carbon monoxide emissions from both catalytic and non-catalytic woodstoves tested in Sante Fe, New Mexico (elevation: 7,300 feet above sea level) average about twice

as high as emissions compared to the same woodstoves tested in Portland, Oregon (elevation: 75-100 feet above sea level). If these results are confirmed by more testing, they will represent a significant consideration for higher altitude communities in selecting appropriate RWC emission factors, as well as for EPA in revising AP-42. This development is consistent with EPA's development of different vehicle exhaust emission factors for use in higher altitude states, principally in the Rocky Mountains.

3. Projecting Future RWC Emissions

Projecting future RWC emissions levels typically begins by estimating RWC wood usage and corresponding emissions for some appropriate baseline year, using approaches such as those described in the previous two sections. Baseline emissions can now be extrapolated into the future using various trend factors - e.g.,

anticipated growth (or decline) in the population or the number of households in the area of interest. Alternatively, baseline RWC wood usage can be extrapolated to future years and converted into corresponding RWC emissions. Subsection (d) below describes a model used for this purpose.

A common approach is to first estimate areawide total RWC emissions in a baseline year, using the total number of occupied households multiplied by the average RWC emissions per household. Then, local planning agency projections of future changes in the number of areawide households can be used as a trend factor to extrapolate estimates of future RWC emissions, assuming that emissions per average household will remain constant. Important factors to consider in this basic approach include the following:

- If possible, the baseline year should be one for which RWC emissions are measured directly using a household survey.

- Emissions estimates for all years should be normalized to account for year-to-year changes in the severity of winter weather, using local heating degree day data. Future projections should assume a long term average weather severity, or heating demand. Significant changes in household weatherization levels overtime could also affect heating demand.

- Projected changes in the number of households should consider any local trends in average household size (persons per household). A decreasing trend in the number of persons per average household will mean the total number of households will increase somewhat faster than projected general population increases.

- RWC emissions per average household will tend to decrease, due to improvements in woodstove technology.

- RWC emissions per average household will increase if households in an area shift from fireplace to woodstove usage for home heating-e.g., through conversion of fireplaces with inserts.

- Increases in RWC activity in a community will tend to level off as the number of households willing to incur the inconvenience of heating with wood is approached.

- Future changes in the relative prices of wood versus alternative heating fuels (gas, oil, and electricity) should affect RWC wood usage trends.

a. Normalization Based on Heating Demand

A reasonable assumption is that the amount of wood burned for household heating in an area will vary from year to year with how cold the weather is, other things being equal. Seasonal total heating degree days (HDDs) are a common measure of the relative coldness of a heating season. HDDs are based on an assumption that household heating demand beings when the mean daily outdoor temperature drops below 65 degrees Fahrenheit. Thus, a day on which the mean temperature was 50 degrees Fahrenheit would contribute 15 degree days to the seasonal total.

The National Weather Service publishes Local Climatological Data Summaries for many localities, which include heating degree days. A long term (30-40 year) average of total annual heating degree days should be used to represent an average or "normal" heating season. RWC emissions estimates for the baseline year should be normalized prior to extrapolation to future years. For example, if the baseline year had 10% more heating degree days than the long term annual average, its RWC emissions estimate would be normalized by increasing it by 10%.

b. Factors Affecting Average Wood Usage And Emissions Per Household

Table III-11 in Section D.1.d above summarized estimates of RWC wood usage for twenty localities around the nation. Three of these localities had conducted several household surveys over a period of years. These all indicated a shift from fireplace to woodstove usage, with woodstoves eventually accounting for a large majority of total areawide wood usage. This is understandable, since stoves are generally more effective than fireplaces for

space heating. However, since woodstoves emit on average about 50% more particulates and carbon monoxide than fireplaces (per unit of wood burned; Table III-14), a shift from fireplace to stove usage increases total RWC emissions in an area, other factors remaining constant. This also illustrates why RWC wood usage and emissions should be estimated separately for woodstoves and fireplaces first and then combined to estimate total RWC emissions.

One factor that is changing, and which should decrease average RWC wood usage and emissions per household, is improvement in wood burning appliance technology. Cleaner burning woodstoves or fireplaces, which emit less pollutants per unit of wood burned, generally also consume less fuel (i.e., are more fuel efficient per unit of heat delivered. As discussed in Section III.B above, emissions testing has demonstrated that most catalyst equipped woodstoves, and some advanced design non-catalytic stoves, are capable of emissions rates anywhere from two to ten times lower than the average of stoves currently in use.

If and when the use of such cleaner burning RWC appliances becomes more commonplace, the effects on areawide RWC emissions can be estimated in several ways. If the changes over time in the fraction of total wood usage in such advanced design appliances can be estimated (e.g., based on household surveys, or installation permit trends), their future emissions can be separately projected, using appropriately lower emissions factors. A cruder approach would be to simply reduce estimated RWC emissions per household for future years, to represent increasing usage of cleaner burning appliances.

c. RWC Trend Factors - Short Term

As indicated in Section III.C, RWC wood usage on a national basis decreased substantially between 1940 and the early 1970's, then sharply increased as the oil prices escalated. It may be gradually plateauing in the 1980's as a national phenomenon, although for particular communities, the trend may be different.

Projecting future RWC emissions in view of changing RWC trends can be difficult, and large errors can be costly - e.g., in terms of inappropriately targeted emission control strategies. For example, Figure III-10 illustrates why RWC particulate emissions projections helped change the particulate control strategy for Portland, Oregon from primary emphasis on industrial sources to increased emphasis on residential woodstoves. Further industrial particulate controls were estimated to cost $10,000 per year per ton, by the State of Oregon. This was determined to be a much more costly and less effective means of attaining particulate standards in Portland (Seton, Johnson and Odell, 1980).

The basic approach described at the beginning of this section could utilize projected household or population growth as a trend factor to estimate future RWC emissions. However, RWC trends may not parallel population or household trends - especially if the community anticipates expanding RWC activity due to other factors, such as rising costs of competitive heating fuels. This calls for other (than population based) trend factors capable of representing whether the community is likely to experience increasing, level or declining RWC wood usage in the future, or possibly a combination of these phenomena.

A study conducted in 1981-82 for U.S. EPA, Region X, examined various trend factors for projecting wood fuel use for three cities in the Pacific Northwest - Portland, Oregon; Seattle and Spokane, Washington (U.S. EPA, 1984b, Task 3). Short-term (through 1985) and long-term (through 2000) trends in RWC wood usage were considered. Long-term trends were estimated using an economic model discussed at the end of this section. Short-term trend factors considered included the following:

- Direct data on firewood use, including:
  - Volumes of firewood removed from public and privatelands under firewood cutting permits
  - Household survey findings

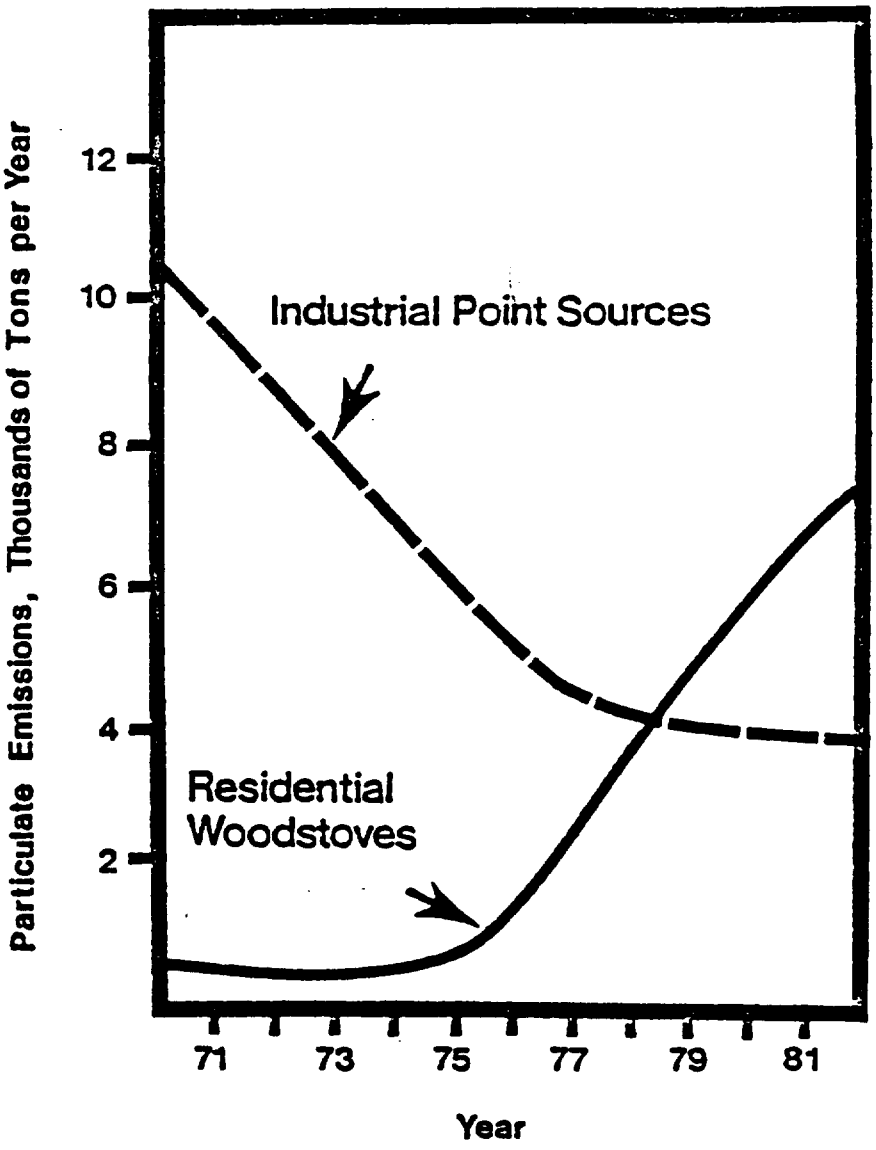


Figure III-10. Industrial and Residential Particulate Emissions Portland, Oregon

Source: Tombleson, B.J. (1984)

- Indirect data on firewood use, including:
  - Sales of wood burning appliances
  - Census data

- Direct measures of RWC ambient impacts, based on chemical tracers for RWC contributions to particulate levels

- Indirect measures of RWC ambient impacts, based on other air quality measurements including: nephelometer light scattering coefficient (b_{scat}); coefficient of haze; soiling index; benzene soluble particulate extractions; organic and total carbon measurements on particulate (Hi-vol) samples.

Most of these factors were not used due to an inadequate database - e.g., too few years of data for trend analysis, or data gaps-or too indirect a linkage to RWC wood usage. The following two short-term trend factors were used, primarily because there was more data available on them.

- Volumes of firewood (cords/year) removed from the nearest national forest(s); and

- Average heating season nephelometer light scattering coefficient (b_{scat}), normalized for temperature and meteorological effects.

Estimated volumes of firewood removed from the national forest(s) nearest to each city were based on the number of firewood cutting permits issued, and forest staff estimates of the average number of cords of wood taken by each permittee. This represented only an unknown fraction of the area's total RWC wood usage. However, few databases suitable for trend analysis were available. Accordingly, it was assumed that trends in this data would be representative of areawide RWC wood usage trends.

Light scattering data were plentiful, but also had some drawbacks as an RWC trend indicator. For example, while light scattering

measurements are used in RWC analysis because they are sensitive to fine particulate emissions, sources of fine particulate other than RWC may often be present - e.g., other combustion sources such as forest fires. To minimize such interference, only data collected during the "heating season" (October-March) were used, when RWC impacts would peak, and the influence of many potentially interfering sources would be absent or minimal. Monthly average b_{scat} data were also normalized for year-to-year variations in temperature (using heating degree days) and wind speed, since b_{scat} levels can be influenced by such meteorological factors. National Weather Service data were used to normalize b_{scat} data, as described previously.

Table III-15 summarizes the short term trend estimates calculated using the two trend factors. Overall, the recent annual average rate of increase in both factors had been between 6% and 8%. Accordingly, RWC wood usage was assumed to increase by 6-8% per year, as a short term trend.

Neither of these trend factors was ideal for projecting RWC wood usage. However, they illustrate how local data can be used to help gauge short term RWC trends. The next section discusses estimation of long term trends.

d. Long Term RWC Trends

Long term trends analysis is more uncertain than short-term projections, because more unforeseen events can occur which undermine key assumptions. For example, few could have predicted the Arab Oil Embargo of 1973, which triggered rising energy prices and associated increases in RWC wood use as an alternative means of household heating.

The simplest approach to long-term projections is to use anticipated population growth as the trend factor. This is not necessarily the best trend factor for projecting RWC wood use or emissions, as discussed above. However, it may be suitable for a first approximation, and population growth forecasts are generally more readily available than data for other RWC trend factors.

TABLE III-15. Summary of Short Term Trend Estimates

Short Term Trend Parameter; City	Heating Seasons Trended (No. of Seasons)	Estimated Annual Aver. Rate of Increase (%)
A. Firewood Volume Removed from Nearest National Forest(N.F.)		
1. Seattle, Washington Mt. Baker/Snoqualmie N.F.	1975-80 (5)	7.8-7.9
2. Portland, Oregon Mt. Hood N.F.	1976-81 (6)	6.5
3. Spokane, Washington Colville N.F.	1977-80 (4)	5.7
4. Spokane, Washington Idaho Panhandle N.F.	1977-81 (5)	7.2-7.3
B. Heating Season Average Light Scattering Coefficient (Bscat)		
1. Seattle, Washington	1978-81 (3)	7.9
2. Portland, Oregon		
a. CAMS Site	1988-81 (3)	5.7
b. Carus Site	1978-81 (3)	5.6

Source: U.S. EPA (1984b; Task 3)

Several published studies have projected long-term future RWC wood use through the year 2000 or beyond (OTA, 1980; USFS, 1980; SERI, 1981; Booz, Allen and Hamilton, 1979; Bradburd et al, 1979; Onisko, 1980; Marshall, 1981). Marshall's report includes a review of the other studies listed here. Another report prepared for the U.S. Department of Energy includes a literature review and critique of a number of studies of historical RWC wood use (U.S. DOE/EIA, 1982b). All of these studies estimated the amount of fuelwood consumed as a product of a number of households burning wood and the average fuelwood consumption per household.

A more sophisticated methodology is Marshall's development of a systems dynamics model to forecast RWC wood usage (Marshall, 1981). This model projects wood usage based on estimated cost differentials between heating with wood versus heating with alternative fuels. Model input requirements include local price forecasts for conventional fuels - usually from utilities or regulatory bodies - and for wood. The latter were estimated by extrapolating historical wood prices, in consultation with knowledgeable wood suppliers.

Marshall's model also takes into account several important factors, including: a) the effect of self-cut wood, and the inconvenience of heating with wood, on peoples' perceptions of their wood heating costs; b) the likelihood that, as market penetration by wood for space heating increases, further market penetration is more difficult, because the easiest wood installations will occur first; and, c) the likelihood that wood heating installation costs will increase, as the more convenient installations are completed, or that air pollution from RWC will result in new regulations which increase RWC costs. A shortcoming of this model is that competing demands for firewood supplies are not simulated - e.g., utilization of potential firewood supplies in wood-fired power plants or co-generation facilities. This will not be a problem unless firewood supplies are significantly limited.

Marshall's model was modified and used in the study referred to above to forecast RWC wood usage in three Pacific Northwest cities through the year 2000 (U.S. EPA, 1984b; Task 3). The model was calibrated using available information about actual wood use from household surveys, then used to predict future RWC wood usage at (five) 5 year intervals. Table III-16 summarizes the resulting wood usage estimates, and their conversion to corresponding particulate emissions.

Increases in RWC wood usage were projected for all three cities. Fireplace wood usage declined while stove wood usage essentially doubled in all cases. Future wood usage in stoves substantially exceeded fireplace usage in Portland, but fireplaces were projected to use more wood than stoves in the other two cities. However, this may have been due to the lack of areawide household survey data on actual wood usage in the latter two cities. The only survey in these cities at that time was of one residential neighborhood area of one square mile.

As expected, estimates generated by this model were sensitive to the changes in fuel price assumptions. The basic assumptions used included an approximate doubling of the real cost of oil, gas and electricity prices between 1980-2000. Based on utility forecasts, about a 50% increase in real cost was predicted for wood fuel. Changing the assumed wood price increase from 2% per year to 5% per year resulted in a net decrease in projected RWC wood usage, as expected.

Such a model was found to be the only tool currently available for assessing the effects of future fuel price changes on RWC wood usage and emissions. Calibrated models of this type could be used to test some of the RWC control strategies discussed in section V of this report; e.g., to estimate RWC wood use changes attributable to weatherization of houses to lower their heating requirements, or incentives for installing cleaner burning RWC appliances which would lower RWC costs.

TABLE III-16. Best Estimate Projections of Residential Wood Fuel Use (10^3 cords/year) for Portland, Seattle and Spokane (1980-2000) and Corresponding Particulate Emissions (10^3 tons TSP/yr)

Year	Stove/Furnace Wood Usage	Fireplace Wood Usage	Total Wood Usage	Total Particulate Emissions
	Portland Metropolitan Area			
1980	150	190	340	9.3
1985	240	190	430	12.8
1990	240	170	410	12.5
1995	300	150	450	14.5
2000	340	140	480	15.9
	City of Seattle			
1980	45	110	155	3.7
1985	85	100	195	5.1
1990	85	100	195	5.1
1995	90	100	200	5.3
2000	85	100	195	5.1
	City of Spokane			
1980	28	93	121	2.7
1985	42	84	126	3.1
1990	45	81	126	3.2
1995	51	78	129	3.4
2000	54	75	129	3.4

Source: U.S. EPA (1984b; Task 3)

IV. CHARACTERIZING RWC AMBIENT IMPACTS

In this section, steps essential in characterizing Residential Wood Combustion (RWC) ambient impacts are described and discussed. The best available quantitative estimates of fine particulate (< 2.5 um) matter ambient impacts attributable to RWC for twenty locations around the nation, are summarized in Section IV.A. The field monitoring considerations, necessary for evaluation RWC ambient impacts, are discussed in Section IV.B. The two major approaches to data interpretations, receptor modeling and dispersion modeling, are discussed in Sections IV.C. and IV.D., respectively. Their theoretical basis and example applications to RWC impact assessment are discussed briefly. For further explanation of methodology and example applications, readers should refer to references cited.

A. Summary of Ambient Impacts

1. Introduction

The use of wood for space heating has increased throughout the nation. The corresponding ambient impact due to this increase in RWC has been measured or estimated in a few metropolitan areas. This section summarizes the available data on such RWC ambient impacts for twenty localities.

Adverse air quality impacts are one of the major deterrents to expanding RWC as a biomass energy resource. RWC has been suspected of contributing significantly to ambient levels of fine mass, Carbon Monoxide (CO), and benzo(a)pyrene (B(a)P). Reasons for special concern with RWC emissions are their: 1) location; 2) size of particles being emitted; and, 3) chemical composition. Because RWC is a localized area source, with a low plume rise, it exposes residential populations to elevated concentrations of the above pollutants. Because most of the RWC emissions are in the fine size fraction, RWC also impairs visibility, is inhalable into the lungs (potentially affecting health), and contributes to the proposed size specific (PM_{10}) particulate standard (Federal Register, March 20, 1984). RWC emissions are also rich in many gaseous and particulate organics, some of which are known mutagens, carcinogens and irritants.

2. National Summary

Available information regarding RWC impact on air quality was gathered from literature, researchers, and state, local and federal agency personnel working in this field. The information was reviewed, synthesized and tabulated for this document.

Localities included in this section were selected based on availability of experimental quantitative ambient impact data. Localities where RWC was suspected to have large ambient impact without experimental data, are not included in this section. Table IV-1 summarizes the RWC ambient impact on fine particulates documentable for twenty localities. Tables IV-2 and IV-3 summarize the carbon monoxide and benzo(a)pyrene levels measured during the studies included in Table IV-1.

Detailed profiles of (17) of the localities included in Table IV-1, are given in a report entitled "A National Assessment of Residential Wood Combustion Air Quality Impacts", (Nero and Associates, Inc., 1984), recently prepared for EPA's Office of Policy Analysis in Washington, D.C. (EPA Contract No. 68-01-6543; Project Officer, Ms. Sidney Worthington).

Headings in the summary Table IV-1 are self explanatory for the most part. The second column lists the location of the air quality impact study while the third column includes both the number of field samples and sampling period for the study. The sampling site, and the surrounding land use classification are listed in column four. The average RWC impact on fine mass in percent and ug/m^3 is given in columns 5 and 7, respectively. The average fine mass measured in ug/m^3 for the study period is given in column 6. The 24-hour maximum RWC impact in ug/m^3 is included in column 8. The corresponding concentrations of particulates with 10 or 15 micron diameter (PM_{10} or PM_{15}), and total suspended particulates (TSP), are given in columns 9 and 10, respectively. The references for the study, from which the data were obtained are included in column 11.

TABLE IV-1. Summary of RWC Impact on Fine Particulates for Selected Locations

(1) No.[a]	(2) Location, State	(3) Samples No.	(3) Dates	(4) Site Name	(4) Type	(5) Avg RWC Impact on Fine Mass < 2.5 μm (%)	(6) Avg Fine Mass From all sources < 2.5 μm (μg/m³)	(7) Avg RWC Fine Mass Impact[b] < 2.5 μm (μg/m³)	(8) 24-hr Max RWC Fine Mass Impact[c] < 2.5 μm (μg/m³)	(9) Avg PM_{10} or PM_{15} Mass (μg/m³)	(10) Avg TSP Mass (μg/m³)	(11) Reference	(12) Comments
1	Waterbury, VT	33	1979/80	Eldredge	(R)	35.0[d]	—	27.0[d]	--	—	79	Sanborn et al, 1981	Seasonal average impact estimates based on dispersion model
		39	1980/81	Eldredge	(R)	35.0[d]	—	18.9[d]	--	--	54		
		33	1981/82	Eldredge	(R)	85.0[d]	22.0	18.7[d]	29.9[d]	26.0	35	Sexton et al, 1983,84	
2	Western, MA	13	12/81 -	Springfield	(C)	--	—	15.0[d,e]	25.0[d,e]	39.0	59	Howland and Kowalczyk, 1984	CMB analysis, seasonal impact
		13	4/5/82	East Hampton	(R)	--	—	15.0[d,e]	25.0[d,e]	30.0	32		
3	Nashville, TN	24	1-3/83	Center City	(C)	33.9	25.4	8.6	51.2	65.5	72	Imhoff et al, 1984	CMB analysis, seasonal impact
		8		Center City	(R)	22.7	22.5	5.1	—	47.3	57		
		7		Background	(B)	45.0	27.8	12.5	—	48.8	49		
		12		Center City	(R)	66.2	29.9	19.8	26.9	59.7	84		
4	Petersville, AL	8	2/2-2/14 1981	Downwind	(R)	73.7	45.3	33.4	65.1	--	--	Imhoff, 1982	CMB analysis, seasonal impact
5	Albuquerque, NM	56	12/28/82 to 2/23/83	Zuni Park	(R)	66.6	37.7	25.1	59.3	60.9	—	Zak et al, 1984	MLR results, seasonal study
6	Missoula, MT	12	2-3/83	Lyons Park	(R,C)	58.7	63.0	37.0	48.0	111.0	186	Cooper and DeCesar, 1980	CMB analysis, seasonal study
7	Denver, CO	16	12/7-19	Five Sites		14.0	39.5	5.5	—	—	90	Wolf et al, 1980	CMB ^{14}C results on composites
		5	1978	Composite		--	—	18.0[d]	29.0[d]	--	--		
8	Telluride, CO	13	1/7-1/9 1980	Site 1	(B)	—	—	5.2[d]	13.6[d]	—	20	Murphy et al, 1982	TSP samples, RWC impact estimated from B(a)P levels, seasonal study
				Site 2	(C)	--	—	29.6[d]	59.3[d]	--	61		
				Site 3	(R)	--	—	9.6[d]	20.4[d]	—	36		
				Site 4	(B)	--	--	--	--	--	8		
				Composite		--	—	35.6[d]	--	—	71	Wilson et al,1983	Based on SF_6 tracer study

TABLE IV-1 Continued (Page 2)

(1) No.[a]	(2) Location, State	(3) Samples No.	Dates	(4) Site Name	Type	(5) Avg RWC Impact on Fine Mass <2.5 μm (%)	(6) Avg Fine Mass From all sources <2.5 μm (μg/m³)	(7) Avg RWC Fine Mass Impact[b] <2.5 μm (μg/m³)	(8) 24-hr Max RWC Fine Mass Impact[c] <2.5 μm (μg/m³)	(9) Avg PM_{10} or PM_{15} Mass (μg/m³)	(10) Avg TSP Mass (μg/m³)	(11) Reference	(12) Comments
9	Reno, NV	8	2-3/84	Three Site	(RCR)	—	—	13.4[d]	23.0[d]	—	83	Bonderson, 1984	RWC impact estimated on TSP filters
10	Las Vegas, NV	4	12/83	E.Charleston	(C)	50.0[d]	—	--	41.1[d,h]	—	140	Naylor, 1984	Mass measurements estimated
11	Boise, ID	9	12/80-2/81	Fairview & Liberty St.	(C)	69.5	121.8[e]	84.7[e]	127.9[e,i]	122.0	149	Core et al, 1984	All analyses on PM_{15} samples
12	Portland, OR	32	1977-78	Flavel Park	(R)	18.6	19.9[j]	3.7[j]	47.4[i]	64.0	65	Cooper and Watson, 1979	Annual averages, seasonal averages are higher
		32		Indus. Air	(I)	9.9	27.3[j]	2.7[j]	49.5[i]	62.0	79	Watson, 1979	
		32		Downtown	(C)	16.4	23.8[j]	3.9[j]	31.8[h]	64.0	77		
		32		Carus	(B)	9.6	15.6[j]	1.5[j]	7.3	29.0	33		
		18	1977-78	Downtown	(C)	42.0	22.7	9.5	24.2	--	--	Shah,1981 Shah et al,1984	Reanalysis of above data
		8	1-3/81	Whitman Sch.	(R)	68.5	40.0	27.4	49.0	--	62	Core et al,1984	CMB analysis
13	Medford, OR	40	4/79 to 3/80	Justice Bldg	(RC)	65.7	46.0	30.2	126.0[i]	—	97	DeCesar and Cooper, 1981	Annual average impact from CMB analysis
		40		Dodge Rd.	(B)	58.7	15.0	8.8	33.0	--	26		
		40		White City	(I)	42.2	32.0	13.5	80.0	—	94		
14	Yakima, WA	4	11/17/80 2/21/81	Courthouse	(C)	93.1	53.8	50.0	55.1	--	222	Core et al, 1984	CMB analysis, seasonal average
15	Spokane, WA	15	1-3/81	CountryHomes	(R)	81.0	55.0	44.5	68.1	—	119	Core et al, 1984	CMB analysis, seasonal average
		1	10/31/80	CountryHealth	(C)	64.7	53.0	34.3	--	--	--		
		4	1-3/81	Crown Zellerbach	(I)	45.3	37.0	16.7	19.1	—	232		

TABLE IV-1 Continued (Page 3)

(1) No.[a]	(2) Location, State	(3) Samples No.	Dates	(4) Site Name	Type	(5) Avg RWC Impact on Fine Mass <2.5 μm (%)	(6) Avg Fine Mass From all sources <2.5 μm (μg/m³)	(7) Avg RWC Fine Mass Impact[b] <2.5 μm (μg/m³)	(8) 24-hr Max RWC Fine Mass Impact[c] <2.5 μm (μg/m³)	(9) Avg PM_{10} or PM_{15} Mass (μg/m³)	(10) Avg TSP Mass (μg/m³)	(11) Reference	(12) Comments
16	Seattle,Wa	9	2-3/81	Newport Bay	(R)	87.0	33.8	29.4	48.8	—	72	Core et al,1984	CMB analysis
		2		South Park	(R)	65.8	—	--	--	--	--		
		3		Georgetown	(I)	73.4	39.7	29.1	35.5	—	--		
17	Tacoma,Wa	4	1-2/81	Fire Station	(I)	74.9	47.0	35.2	44.3	--	159	Core et al, 1984	CMB analysis
18	Longview,Wa	4	12/80-1/81	City Shops	(C)	61.4	41.8	25.6	40.5	—	—	Core et al, 1984	CMB analysis
19	Anchorage, AK	8	12/81-1/84	Composite Samples		—	—	17.5[d]	45.0	—	45	Myers, 1984	TSP filter analysis
20	Juneau, AK	8	12/81	Floyd Dryden	(RI)	--	—	93.3	123.0[f]	—	104	Cooper and Frazier, 1983	High TSP days averages
		11	12/82	Floyd Dryden	(RI)	—	—	48.4	234.0[g]	--	56		CMB analysis, seasonal impact
		10	12/81	Super Bear	(R)	—	—	72.8	157.0[f]	—	87		
		9	12/82	Super Bear	(R)	—	—	56.1	168.0[g]	--	61		
		3	12/82	Municpl.Bldg	(B)	—	--	9.5	--	—	15		

Abbreviations
RWC - Residential Wood Combustion
μm - Micrometers (Particle Diameter)
TSP - Total Suspended Particulate
PM_{10} - Particulate Matter; particle diameter 10 um
PM_{15} - Particulate Matter; particle diameter 15 um
R - Residential land use predominates near site
C - Commercial land use predominates near site
I - Industrial land use predominates near site
B - Background site, remote from urbanized area
CMB - Chemical Mass Balance
MLR - Multiple Linear Regression

Footnotes
a. Numbers correspond to profiles in Section V of this report
b. Avgerage RWC impact % X Average Fine Mass
c. From Literature cited unless otherwise stated
d. Estimated as explained in text
e. Average impact measured on PM_{15} sample
f. Maximum impact on 11/19/82, not included in December average impact
g. Maximum impact on 11/22/82, not included in December average impact
h. 4-hour maximum impact
i. 8-hour impact
j. Annual impact

TABLE IV-2. Summary of RWC Carbon Monoxide Levels for Profiled Locations

(1) Location, State	(2) Sampling Period	(3) Monitoring Site & Type	(4) CO Levels in PPM 8hr avg	8hr max	1hr max	(5) Evidence of RWC Impact on CO	(6) Reference
Waterbury, VT	1/31/80 3/12/80	Eldredge (R)	<1	—	3.5	Minimum RWC impact on CO	Sanborn et al, 1980
	9 homes	Indoor (R)	<1	—	1.9		
Albuquerque, NM	12/28/82	Zuni Park (R)	2.0	—	--	Daily average values. RWC impact not quantified	Zak et al,1984
	2/23/83	Volandia (C)	2.3	—	--		
Missoula, MT	1982-84	Boyd Park (C)		13.3	16.5	CO maximum correlated with RWC activities	Carlson, 1984
Portland, OR	1982-84			10.4			Tombleson et al, 1983
Juneau, AK	1/20-3/14,'83	1 (R,C)	1.2	4.0		About 50% of CO was believed to be RWC related	Chapple, 1983
		2 (C)	2.3	5.5			
		3 (R)	0.8	2.0			
		4 (C)	2.1	4.5			
		5 (R)	0.9	2.0			
		6 (R)	1.0	3.0			
		7 (R,C)	2.7	6.5			
		8 (R)	1.8	5.5			
		9 (B)	0.5	1.5			

Source: Nero and Associates, Inc., (1984)

Abbreviations:
RWC = Residential Wood Combustion
R = Residential Site
C = Commercial Site
B = Background Site
avg = Average
max = Maximum
CO = Carbon Monoxide

TABLE IV-3. Summary of RWC Benzo(a)pyrene Levels for Profiled Locations

(1) Location, State	(2) Samples No.	Date	(3) Monitoring Site & Type	(4) B(a)P Levels in ng/m^3 avg	max	(5) Evidence of RWC Impact, other Organics Measured, and Comments	(6) Reference
Waterbury, VT	16	1/29/82-3/11/82	Eldredge (R)	0.8	2.4	Many organics measured	Sexten et al, 1984
Nashville, TN	21	1/24-	Metro.Autho.(C)	2.3	11.4	No other organics measured.	Imhoff et al, 1984
	4	3/31/83	E.Health Ctr(R)	0.7	1.6		
	1		Background (B)	1.5	--		
	9		McCann Sch. (R)	1.8	3.6		
Petersville, AL	2	2/81	Background (B)	21.0	34.0	Many other organics measured	Imhoff, 1982
	4	2/81	Downwind (R)	41.0	110.0		
Telluride, CO	13	1/80	1 (B)	1.3	3.4		Murphy et al, 1982
			2 (C)	7.4	14.8		
			3 (R)	2.4	7.4		
			4 (C)	--	--		
Boise, ID	2	12/80-1/81	Fairview& Liberty (C)	1.5	2.3	High RWC impact	U.S. EPA, 1984a
Portaland, OR	3	1-3/81	Marcus Wh.Sc(R)	3.2	5.4	High RWC impact	U.S. EPA, 1984a
Medford, OR	2	12/80-1/81	Courthouse (C)	8.4	8.5	High RWC impact	U.S. EPA, 1984a
Spokane, WA	3	2-3/81	Country Home(R)	6.1	11.0	High RWC impact	U.S. EPA, 1984a
Juneau, AK	1	11/19/82	Floyd Dryden(R)	--	11.0	All other priority pollutants were below detection	Cooper and Frazier, 1984

Abbreviations:
B(a)P = Benzo(a)pyrene
R = Residential site
B = Background site
C = Commercial site
Avg. = Average
Max. = Maximum

Footnotes:
a = Profile number in the text

Source: Nero and Associates, Inc. (1984)

Critical comments regarding the data set referenced are included in the last column. This column is especially important for understanding the data limitations. Abbrevations and footnotes, also essential in understanding values in the table, are given at the end of the Table.

Based on the critical evaluation of available information, the best available RWC ambient impact estimates on fine particulates and corresponding measured benzo(a)pyrene (B(a)P) concentrations are summarized in Table IV-4. This table shows a preliminary picture of RWC impact for the various geographic locations studied. The RWC impact on fine mass was calculated based on one of the many available techniques discussed in Section IV.C. The measured B(a)P concentration listed in Table IV-4 may not necessarily be from RWC activities alone.

Unless otherwise noted, fine mass results refer to analysis of samples of particulate smaller than 2.5 micro meters (um) in diameter. Where samples with other particle size ranges were analyzed (e.g., PM_{10}, PM_{15}, or TSP), the mass fraction attributed to RWC was assumed to be less than 2.5 um in size. This assumption is based on the Portland Aerosol Characterization Study findings by Cooper and Watson (1979) and similar findings from other studies (Muhlbaier, 1982; Rau and Huntzicker 1985; and, Core et al, 1984) which indicate that most of RWC emissions (over 80% to 90%) are less than 2.5 um in size.

Benzo(a)pyrene (B(a)P) measurements were available for less than half of the localities. No locality had collected carbon monoxide field samples for direct analysis for RWC impact -- e.g., using radiocarbon measurements -- although several were considering doing so. Several localities had indirectly analyzed CO data for RWC impacts, as discussed below.

TABLE IV-4. Summary of RWC Impact on Fine Mass and Measured Benzo(a)pyrene Levels at Selected Locations

No.	Location	Study Year	RWC Impact on Fine Mass $\mu g/m^3$			Measured Benzo(a)pyrene ng/m^3		
			No. of Samples[f]	Avg.	Max.	No. of Samples	Avg.	Max.
1	Waterbury, VT	81-82	33	19	30	16	0.8[a]	2.4[a]
2	Western MA	81-82	13	15	25	--	--	--
3	Nashville, TN	83	24	9-20	51	21	2.3[a]	11.4[a]
4	Petersville, AL	81	8	33	65	4	41[c]	110.0[c]
5	Albuquerque, NM	82-83	56	25	59	--	--	--
6	Missoula, MT	83	12	37	48	--	--	--
7	Denver, CO	78	16	6-18	29	--	--	--
8	Telluride, CO	80	13	10-30[a]	59[a]	13	7.4[a]	14.8[a]
9	Reno, NV	83-84	8	13[a]	23[a]	--	--	--
10	Las Vegas, NV	83	4	--	41	--	--	--
11	Boise, ID	80-81	9	85[b]	128[b]	2	1.5	2.3
12	Portland, OR	77-78	32	4-10[e]	50	3	3.2	5.4
13	Medford, OR	79-80	40	9-30[e]	126[d]	2	8.4	8.5
14	Yakima, WA	80-81	4	50	55	--	--	--
15	Spokane, WA	80-81	15	17-45	68	3	6.1	11.0
16	Seattle, WA	81	9	29	49	3	2.1	4.2
17	Tacoma, WA	81	4	35	44	--	--	--
18	Longview, WA	80-81	4	42	26	--	--	--
19	Anchorage, AK	81-84	8	18[a]	45[a]	--	--	--
20	Juneau, AK	81-82	11	48-93[a]	234[a]	1	--	11.0

ABBREVIATIONS:

RWC - Residential Wood Combustion
Fine Mass - $\leq 2.5\mu m$ unless otherwise specified
$\mu g/m^3$ - microgram per cubic meter
ng/m^3 - nanogram per cubic meter
Avg. - 24-hour average for the study period at one or more sites
Max. - 24-hour maximum for the study period
PM_{10} or PM_{15} - Particulate matter ≤ 10 or ≤ 15 μm.

FOOTNOTES:

a - Analysis of TSP samples
b - Analysis of PM_{10} or PM_{15} samples
c - Gaseous and particulate benzo(a)pyrene - 4-hour sample
d - 8-hour or 12-hour maximum
e - Annual average
f - Samples were taken during heating season, unless indicated otherwise

Table IV-4 indicates the sampling year(s) for RWC impact estimates. The number of samples analyzed (Column 4) and the resulting average and maximum mass values (ug/m^3) shown in Columns 5 and 6, are for 24-hour averaging times unless otherwise indicated. The average values shown represent averaging all of the field samples available for a given site, during the study period. A range of average value indicates sampling at more than one site. The measured B(a)P concentrations from all sources presented in Columns 7-9 were developed in the same manner.

The seasonal or study period average RWC impact on fine particulate matter was in the range of 6 to 93 ug/m^3. The 24-hour maximum RWC impact varied from 24 to 234 ug/m^3. Not all the values reported in Tables IV-1 and IV-3 were measured on the fine mass fraction. However since most of the RWC emissions is fine mass, the average and maximum RWC in ug/m^3 should remain relatively unchanged. The following caveats are important for evaluating this national survey.

3. Caveats and Conclusions

The average RWC impact on fine particulates are expressed as seasonal or study period averages. In many cases the sampling is conducted on adverse days or analysis is done on worst case days only. Thus the average impact is biased high. The average values reported for Portland and Medford in Tables IV-1 to IV-3, are the only stratified annual averages reported. The extent of bias to the average RWC impact cannot be determined, but the maximum and average RWC impacts in the table can be concluded to be significant and demand further investigation. This is partially expected because these studies were carried out in areas where RWC was thought to contribute significantly. Since most of the RWC impact is in the fine mass fraction, RWC will contribute significantly (and in many cases be the primary source of violations) to the proposed size specific particulate standard. Limitations of the inventory presented here are discussed below.

Many of the studies are seasonal and involve limited sampling over short durations. Systematic long-term measurements are lacking in general. Even though monitoring for particulate matter has been carried out in most parts of the U.S., chemical analysis followed by source apportionment has been done in a handful of locations only. In many cases, RWC impact was projected by Nero and Associates, Inc. based on limited data and involved many assumptions. The errors in input data need to be propagated and evaluated to establish the upper and lower limits to the RWC impacts. In some localities, the studies were conducted many years ago and may no longer be applicable in view of rapid changes observed in the RWC activities. Also some of the studies were based on TSP samples. RWC impact measured on the TSP samples should be viewed as upper limit.

The factors which would tend to make the RWC impacts reported in Table IV-4 biased low are discussed below. In some cases, study results date back five or more years, and cannot reflect the substantial growth in RWC activity since then. Factors which may have resulted in not measuring actual maximum impacts include: limited sampling especially in residential settings where maximum RWC impacts are not likely; failure to sample under worst case meterological conditions, and, "filter plugging" (causing loss) of some of the highest impact samples. Agency staff from several localities thought the data in Table IV-4 gave an unrealistically low estimate of their average or maximum RWC fine mass impact (e.g., Missoula; Portland) during the heating season.

The B(a)P data base in Table IV-3 and IV-4 is very limited and subject to the same caveats discussed above, plus others. The number of samples analyzed for B(a)P is small in most cases. The three cases with more than ten B(a)P estimates all involved TSP samples. B(a)P may be contributed from a larger range of source. A final limitation of the data is that many of the B(a)P measurements are based on B(a)P extraction from particulate samples, whereas Imhoff (1982) has reported significant B(a)P in the gaseous phase as well.

It is also important to note that the B(a)P ambient concentrations shown in Table IV-3 and IV-4 cannot be directly attributed to RWC emissions, in the same way that fine particulate contrations are attributed to RWC in Tables IV-1 and IV-4. This is because the latter are based on chemical tracers and mass balance analysis. However, RWC has been shown in recent studies (Radian, 1984) to be the largest national source of Polycyclic Organic Materials (POMs) such as B(a)P. Thus, there is likely to be a strong association between the B(a)P levels in Table IV-3 and IV-4 and RWC activities. B(a)P has commonly been used as an indicator of POM levels. The fact that B(a)P was found in significant ambient concentrations where RWC impacts were also measured is consistent with previous studies which strongly link RWC to POM emissions.

Preliminary indirect evidence shows that RWC contributes significantly to carbon monoxide (CO) impacts, but no field monitoring study has been completed to test the hypothesis. Several such studies are planned, generally built around radiocarbon ($^{14}C/^{12}C$) analysis to distinguish ambient CO from combustion of "contemporary" vs "fossil" fuels. Preliminary evidence of RWC CO impacts include: (1) elevated CO levels at residential monitoring sites which occur late at night on cold winter evenings where RWC can be assumed to be the dominant CO emissions source; and, (2) nephelometer data from residential areas which correlates better with ambient CO levels than it does with traffic counts.

Concern about the RWC CO impacts has been slower to develop because most CO monitoring is done at roadway oriented sites, where CO levels are dominated by vehicle exhaust. Siting more CO and fine particulate monitors in residential neighborhoods with RWC activity is needed to help calculate RWC impacts not only for CO, but also for particulate and B(a)P.

In Table IV-4 the highest RWC impacts measured are for localities where meteorology and/or terrain features greatly restrict pollutant dispersion, thereby encouraging higher ambient concentrations -- e.g.,

Medford, Juneau (Mendenhall Valley), Telluride and Missoula. For example, Table IV-4 indicates that Medford, Oregon had (annual) average and maximum fine particulate impacts from RWC that were two or three times higher than in Portland, Oregon -- despite the fact that total TSP emissions from RWC were four to five times higher in Portland. This is attributable to Medford's valley location and frequent inversions which trap pollutants. Medford's higher RWC TSP emission per household (90 vs 47 lb/HH/yr) may also indicate higher RWC emission density than in Portland (Nero and Associates, Inc., 1984).

Relatively high fine mass impacts are also noted in Table IV-4 for localities where pollutant trapping by terrain and/or meteorology is not a strong determinant of ambient concentrations -- e.g., Albuquerque, Petersville, Spokane, Boise, Yakima, Nashville, and Portland. The terrain and meteorological variables are significant in any attempt to determine the extent to which the RWC impacts shown in Table IV-4 may be representative of other localities throughout the nation.

In at least one locality (Missoula) the average and maximum RWC impacts were much lower than anticipated, based on its especially poor dispersion characteristics (Holzworth, 1972), high per household wood usage, and long standing concern about RWC impacts. Missoula agency staff can qualitatively attribute TSP impacts to RWC that are much higher than are shown in Table IV-4. On some worst case TSP days, HiVol TSP sampling has measured concentrations in the hundreds of ug/m^3, where RWC was thought to be the dominant source.

The main reason for this inability to document these higher levels is that receptor modeling/source apportionment analysis for Missoula RWC impacts is notably limited. The only completed study was conducted during a limited period (February - March) when maximum RWC impacts would not be likely (Cooper and DeCesar, 1983). Other Chemical Mass Balance (CMB) analysis of Missoula fine particulate samples was "in progress" and not available for inclusion in this report.

This is the most notable example of the following general conclusion. Despite the fact that the data assembled on RWC ambient impacts in this report addresses most of the major localities where RWC impacts have been documented to date, it is notably limited in supporting broad general conclusions about the national significance of RWC ambient impacts. Nevertheless, the available data base has strong features in terms of such a national assessment, which are:

- State-of-the-art (CMB) methods have documented significant RWC fine particulate impacts in localities in many regions of the country (albeit mostly in the western USA).

- While the highest impacts have predictably been found in localities where meteorology and/or terrain features severely restrict pollutant dispersion, other communities in which these factors are not dominant also experience relatively high average and maximum RWC impacts.

Limitations of the data base reported herein are:

- RWC impact data for localities are too limited in size and consistency (of methods, sample years, etc.) to support broader or more general conclusions about the geographic extent and severity of RWC ambient impacts. The extent to which RWC impacts documented to date, are or are not representative of RWC impacts in other localities where RWC is a significant means of home heating, is not clear.

- There is a lack of consistent methods of analysis in the present data base -- especially a lack of systematic application of CMB receptor modeling methods, which have proven most specific and defensible in quantifying RWC impacts.

In summary, the present data base presents a preliminary picture of RWC ambient impacts that suggests this source to be significant in localities with high wood usage and restricted pollutant dispersion. At a minimum, the data base also indicates that RWC impacts are potentially as significant in any other locality with similar amounts of wood usage and comparable meteorology and terrain features. Direct evidence of RWC impacts on fine particulate levels exists, from Chemical Mass Balance (CMB) receptor modeling analysis of particulate samples. The evidence linking RWC to carbon monoxide (CO) and benzo(a)pyrene (B(a)P) ambient impacts is more indirect, albeit very suggestive.

The national assessment study (Nero & Associates, Inc., 1984) which compiled the data discussed above also interviewed state and local air pollution control agency staff in all fifty states. Their overall perceptions of RWC impact in their jurisdictions, based on their available RWC information base, their field observations, and their best judgement were determined. Regarding the type, severity and frequency of RWC impacts, a majority of all respondents indicated the following:

- Severity: RWC impacts are definitely or potentially significant - i.e., a high priority for investigation and/or control;

- Type: RWC contributes to visiblity impairment, and to increased ambient concentrations of particulates or carbon monoxide. Thirty percent (30%) believed RWC contributed to standard violations for one or both of these pollutants; and,

- Frequency: RWC impacts occur on 4 to 25 days each heating season.

This study showed that most air pollution agencies do not have adequate technical information on RWC impacts. Eighty percent of the state agencies interviewed lacked quantitative estimates of wood usage, emissions or ambient impacts specifically attributable to RWC. Thirty eight percent had none of these.

There was a strong correlation between lack of such technical information and respondent's who rated RWC impacts as "marginal" or "insufficient" - including some states with relatively colder climates and higher wood usage. Such areas may have RWC impacts of greater significance than they recognize.

B. Field Monitoring for RWC Impact Estimation

1. Introduction

This section discusses the measurement of Residential Wood Combustion ambient air quality impacts through field measurements of particulate concentrations. The monitoring methods, instrument siting considerations and sample analysis techniques discussed in this section are directed primarily toward the application of receptor models as the principal tool in distinguishing RWC impacts from those of other sources.

A receptor model is a mathematical method for identifying and quantifying the sources of ambient air pollutants at a receptor, primarily on the basis of the physical and chemical characteristics of the aerosol. Because receptor model quantification of RWC impacts is based on data sets developed through sophisticated chemical analysis of ambient aerosols, it is extremely important that the instrument siting, monitoring methods and supporting measurements (i.e., meteorological, light scattering, gaseous pollutants, etc.) be carefully coordinated. The overall design of the field study, however, is largely dictated by the resources available and the level of confidence that the analyst must have in the results. Receptor modeling studies of particulate (including RWC) impacts can be designed and implemented at various levels of effort, including relatively simple and inexpensive studies (See section IV.E).

Receptor model estimation of RWC impacts has become the primary technique used by regulatory agencies because of its unique ability to quantify impacts during historical short-term periods (24 hour or less) of adverse air quality. Although dispersion modeling and emission inventory techniques have also been applied, receptor models

are unique in their ability to identify RWC impacts for any given sampling period, independent of emission inventory and meteorological assumptions. The complex terrain that typifies many of the airsheds subject to woodsmoke episodes further complicates dispersion modeling studies. Given the extreme difficulty of recreating an emission inventory that is representative of a specific day in history, receptor models are the best available method for directly and specifically measuring RWC ambient impacts.

Receptor models are also subject to distinct limitations that must be recognized and mitigated by the analyst during the experimental design phase of the study. The principal limitation of receptor models is the inability to identify specific sources of chemically and physically similar aerosols. These methods are not able to quantify impacts from specific sources within the same source group. This includes emissions originating from woodstoves, fireplaces, open burning of vegetative matter, smoke from prescribed burning of forest residues, structural fires and land clearing open burning. Fortunately, supplemental information on source emission activities can often narrow the list of potential contributing sources. Judicious placement of sampling sites with respect to the transport of smoke from interfering source locations can further minimize impacts from other sources.

The second limitation of receptor models, as they are applied to RWC impact assessment, centers on dependence of the method on a firm knowledge of the chemical composition of woodsmoke. Studies conducted by Stiles (1983), DeCesar and Cooper (1981) and Dasch (1982) have concluded that the composition of woodsmoke varies as a function of wood species and combustion conditions, resulting in relative impact estimates uncertainties that typically average $\pm$ 30%. To minimize the degree of uncertainty in the source assignments and maximize the credibility of study conclusions, several independent forms of receptor modeling are often applied. Since the greatest degree of

confidence in the program conclusions typically results from the application of several complimentary methods, each RWC assessment program should include two or more independent methods of impact analysis.

2. Network Design Considerations

a. Monitor Siting

In designing a monitoring network to evaluate RWC impacts, it is important to first determine the objective of the study. For purposes of this document, it will be assumed that the analyst is interested in evaluating the maximum 24 hour, seasonal and annual impact of RWC emissions within an airshed as well as the impact of these emissions at a TSP nonattainment site. These objectives are typical of most studies conducted within the past few years.

b. Sampling Locations and Periods

Most studies require at least three sampling sites - one site to monitor "background" RWC emissions transported into the airshed, one historical nonattainment site at which RWC impacts are of interest, and a third maximum impact (often residential) site. All sites should conform to EPA siting criteria (40 CFR Part 58 Appendix E) to insure that the program results are representative of the airshed. Neighborhood scale sites, representative of conditions throughout a homogenous urban subregion of a few kilometers in size, are usually selected for RWC monitoring. Such sites provide data that are representative of similar neighborhoods within the airshed and are suitable for determining trends in RWC impacts, compliance with air quality standards and population exposure.

Sampler inlet heights should vary from two meters above ground for sites greater than 25 meters from major roadways (Average Daily Traffic 3000) to 15 meters above ground for sites five meters from the roadway. The site should not be unduly impacted by any single source and should be unobstructed by surrounding objects, i.e., two meters from the nearest wall and at least 20 meters from the nearest tree. The distance between surrounding obstacles and the

sampler should be at least twice the height that the obstacle protrudes above the sampler. The site should also have unrestricted airflow in an arc of at least 270 degrees around the sampler.

Maximum RWC impact sites are usually located in high density residential areas that have been informally surveyed to identify the number of homes with winter wood supplies. Local topography that may restrict dispersion of emissions should be reviewed to find high impact sites. In addition, dispersion modeling results and winter wind direction frequency distributions (wind roses) for the airshed should be reviewed as an aide in identifying potential sampling locations.

Background sampling locations should be located in rural areas upwind of the airshed during the winter heating season. Data from such sites are important in distinguishing "local" emission impacts from those transported into the airshed. The impact of these "local" emission forms the basis for developing RWC emission control strategies for the airshed.

If the results of the program are to be used to evaluate the performance of a dispersion model, sampling locations should be selected based on a performance evaluation protocol designed in accordance with EPA's Interim Procedures for Evaluating Air Quality Models (Revised), (EPA-1984e). For example, at least one site should be located in a residential area of average population density and wood burning activity. A second site should be located within an area of commercial or industrial land use. Other choices include locations of modeled high concentrations. The diverse locations of monitored and modeled RWC impacts preclude setting a generalized minimum number of required samplers that might be acceptable in a given model performance evaluation study.

The ability of receptor models to isolate RWC impacts from other airshed sources is dependent, in part, on the ability of the analyst to minimize potential interfering sources within the same source group (see above) while measuring representative RWC emission impacts. Proper instrument siting, as mentioned above, is means of accomplishing this objective.

A second approach is to insure that the ambient samples are taken only during periods of maximum RWC emissions, i.e. during the evening hours of the winter heating season. Three eight-hour sampling periods (e.g. 6 pm to 2 am, 2 am to 10 am, and 10 am to 6 pm) can be used to isolate the peak emission period while providing a means of estimating 24 hour maximum impacts. As a less costly option, two 12 hour samples collected during the daytime hours (6 am to 6 pm) and evenings (6 pm to 6 am) can be taken. Under the latter option, however, care should be taken to avoid splitting the periods of maximum emission strength (6 pm to 2 am and 6 am to 10 am) between the two sampling periods.

It is important to note that the plugging of filters during periods of heavy RWC impacts is a common cause of sample loss. Filter plugging, with resultant failure to maintain required airflows, can thus void some of the most important ("worst case") 24-hour samples obtainable. This can generally be avoided by dividing the 24-hour sampling into two or more shorter sampling periods.

At a minimum, 24 hour samples should be taken each day. Daily, consecutive samples should be included in the experimental design to insure that samples are taken during periods of adverse air quality. Fine particle mass loading, the occurrence of cold weather periods coupled with poor dispersion and/or high light scattering can then be used as criteria for sample selection for chemical analysis.

Estimates of RWC impacts during the space heating season are usually obtained through receptor model analysis of samples collected during periods of low, moderate and high fine particle concentrations. An analysis of scattering coefficient measurements (b_{scat}) obtained with an integrating nephelometer can be used to estimate fine particle mass concentrations. Space heating degree day data can also be used as sample selection criteria. Estimates of annual average impacts are best obtained, resources permitting, through the analysis of samples taken throughout the year. Lower limit approximations, however, can be obtained by assuming that RWC impacts are limited to the winter months. Since the period of greatest concern relative to air quality standard attainment is usually limited to short-term (24 hour) episodes, estimates of seasonal and annual impacts may not be necessary.

c. Supportive Monitoring Data

In addition to fine particulate samples, several other supportive measurements are useful in interpreting RWC impacts. Meteorological measurements of wind speed, wind direction and temperature are required to evaluate transport conditions, space heating degree days, and dispersion characteristics of the atmosphere. An integrating nephelometer measuring light scattering in order to provide a continuous indication of fine particle concentrations, can be extremely helpful in identifying qualitative estimates of RWC impacts (see Section IV.C.4.c). Specialized sampling systems designed to measure woodsmoke organic tracers such as methylchloride (Khalil et al, 1983) have also been used as discussed below. Carbon monoxide (CO) measurements at residential sites have also recently been used as another possible indicator of woodsmoke concentrations within airsheds that have traditionally experienced low CO concentrations outside of their commercial/industrial landuse areas (Harris, 1982).

3. Air Monitoring Instrumentation

Table IV-5 lists air quality measurements that are needed to determine RWC impacts using receptor modeling methods. Two filter substrates must be used to satisfy the trace element and carbon analysis requirements. Two dichotomous (Olin, 1978) samplers or one fine particle sequential sampler (Camp et al, 1978) is required to collect concurrent samples on membrane and quartz filter substrates. The sequential filter samplers commonly used have been designed to simultaneously capture fine particle (<2.5 um) samples by using two sampling ports within a sampling plenum. The ports are also programmable to permit collection of 2,4,6,8 or 12 hour sample sets, thereby minimizing servicing requirements. If manual dichotomous samplers are used, one sampler is equipped with a membrane filter substrate (typically Teflon) while quartz filters are used with the second sampler. Data on mass concentrations, elemental and ionic composition, and light absorption coefficient are obtained from the membrane filters while organic and elemental carbon concentrtions are obtained from the quartz filters.

High volume air samplers used to capture total suspended particulate, and size selective inlet (SSI) samplers equipped with 10 or 15 um inlets and glass fiber filter, have been used in several studies where fine particle samples have not been available. It is difficult to obtain credible trace element concentration data from glass fiber filters. It is also important to isolate the fine particle fraction as the first level of RWC impact apportionment. Accordingly, results from these programs have been considered preliminary pending completion of studies using fine particulate samples designed as outlined above.

If agency resources clearly preclude fine particle sampling, or if historical TSP or SSI samples must be used as a basis for RWC impact assessment, semiquantitative impact estimates can be obtained by using atomic absorption measurements of a few key elements (Fe, Ca, K, Pb, Ni, V, etc.). Carbon-14 and organic/elemental carbon measurements can also be done, if the filter blank values are significantly lower than measured values on the sample itself. Sample analysis methods are discussed in Section IV.B.5.

TABLE IV-5. Air Quality Measurement Methods for RWC Assessment

Sampling Method	Parameter Measured	Sampling Frequency	Analysis Method
Dichotomous Sampler* (Membrane Filter) (2um pore size)	Fine Particle Mass Elements Ions Light Extinction	8, 12 or 24 hours	Gravimetric (Courtney et al, 1982) X-Ray Fluorescence (Wagman et al, 1977) Ion Chromotography (Stevens et al, 1978) Light Transmittance (Hasan and Dzubay, 1983)
Dichotomous Sampler* (Quartz Filter)	Elemental, Organic Carbon	8, 12 or 24 hours	Combustion (Stevens et al, 1982)
Integrating Nephelometer	Particle Light Scattering	1-hour Averages	Fine Particle Light Scattering (U.S. EPA, 1975)
Nondispersive Infrared	Carbon Monoxide	1-hour Averages	Infrared Energy Absorption (40 CFR Part 58)

* Collocated sampling. One sequential sampler can be used in the place of two dichotomous samplers.

Two additional instruments helpful in interpreting RWC impacts are nephelometers and CO monitors. Integrating nephelometers have been widely used to monitor hourly variations in light scattering, while nondispersive infrared instruments are used to continuously monitor CO concentrations.

4. Specialized Sampling Techniques

Recent research activities related to RWC impact assessment have resulted in the development of several extremely useful techniques of interest to regulatory agencies, since they provide additional independent approaches to RWC apportionment. Khalil et al, (1983) have recently described an RWC tracer method based on the measurement of methylchloride (CH_3Cl), a low temperature pyrolysis product of wood combustion. CH_3Cl is typically not found in higher temperature combustion processes - e.g., from wood-fired boilers and is thus a potentially unique tracer for RWC. The method can measure short-term variations in RWC concentrations based on the ratio of methylchloride to fine particle mass emission rates. Uncertainties in determining particulate mass concentrations by this method are largely due to the variability of the natural background of methylchloride and the emission rate ratio, limiting the accuracy of the method to about $\pm$ 30%. Sampling is conducted using evacuated cylinders into which air samples can be drawn over time periods ranging from two to eight hours.

Currie (1982) and Klouda et al, (1982) have developed radiocarbon analysis methods that can be used to distinguish fossil fuel carbon from contemporary (e.g., wood) carbon by means of carbon-14 measurement. The method provides an estimate of the portion of aerosol carbon associated with woodburning sources as distinguised from oil, coal, diesel and gasoline combustion. The method's ability to distinguish RWC carbon from fossil carbon is based on the natural decay rate of carbon-14 over time. If the ratio of carbon-14 (^{14}C) to carbon-12 (^{12}C) is known for wood burned within the airshed, and measurements of this ratio are made from fine particle aerosol samples, the proportion of contemporary carbon can be determined. Since the sample analysis method has commonly required at least 5 mg

of carbon, high volume particulate samplers equipped with multistage cascade impactors have been used to insure that sufficient sample is collected for analysis. More recent research indicates that analytical sensitivity levels approaching 10 ug of carbon will soon be possible, allowing the use of dichotomous fine particle filters and radiocarbon analysis of smaller samples.

Both ^{14}C and CH_3Cl methods are being used by regulatory agencies as independent methods to validate other receptor model estimates of woodsmoke impacts. Section IV.C.4.a. further discusses the advantages and limitations of ^{14}C analyses, including its application to source apportionment of ambient carbon monoxide levels.

5. Sample Analysis

The measurement of particulate mass and elemental concentrations represents the minimum level of sample analysis required for receptor modeling. Several additional measurements (see Table IV-5) should be performed, especially organic and elemental carbon, since RWC emissions are largely composed of these two components. While scanning electron microscopy and X-ray diffraction analysis may be helpful in identifying impacts from industrial sources and fugitive dust, they are not useful in quantifying RWC impacts because of the carbonaceous nature of RWC particles. Optical microscopy can be used effectively with TSP and SSI samples, however, to identify coarse particles such as burned wood fibers that may indicate RWC impacts. The final choice of analytical measurements should be based on the resources available and, if historical TSP or SSI samples must be used, on the nature of the samples available.

C. Receptor Modeling Assessment of RWC Impacts

1. Introduction

A discussion of field sampling and analytical methods that are used to support receptor modeling of RWC impacts is presented in Section IV.B. This section provides a brief review of the fundamentals of

TABLE IV-6. Analytical Methods for RWC Studies

Components Measured	Analytical Method	Cost Per Sample*	Compatible Filters	Notes	Reference
Mass	Gravimetric or Beta gauge	$ 10	Any	Cost includes filter, handling and mass analysis	Courtney et al, 1982
25 elements (Al to Pb)	X-Ray Fluorescence (XRF)	$ 35	Teflon, Nucleopore, Cellulose Acetate	Poor sensitivity for some elements (Se, As, Sb, etc.)	Wagman et al, 1977
40 Elements (Na to Pb)	Neutron Activation Analysis (NAA)	$ 250	Same as XRF	Complements XRF analysis, serves as intermethod QA check	Zoller and Gordon, 1970
Elements from Na to Pb	Atomic Absorption Spectrophotometry (AAS);	$ 15	Same as XRF; can also be applied to glass fiber	Requires sample extraction prior to analysis with loss of insoluble species	Gordon, 1979
	Inductively Coupled AAS (ICPS)	$ 25			Lynch et al, 1980
SO_4, NO_3, NH_{4+}, Cl^-, F^-, NA^+, K^+	Ion Chromatography (IC); Colorimetric	$ 25	Same as XRF; glass fiber	Requires sample extraction	Mulik et al, 1977
Elemental and Organic Carbon	Carbon combustion	$ 40	Glass fiber or quartz	Requires analysis at 350 and 600 C.	Johnson et al, 1981

* Approximate cost per sample. Actual costs depend on the number of samples to be analyzed, sensitivity requirements and filter blank variability.

Cost estimates are in 1984 dollars.

receptor modeling and its application to RWC assessment. Receptor model input requirements and sources of error are presented, as are model validation methods. This section also discusses a number of receptor model approaches that may be used by analysts.

2. Introduction to Receptor Modeling

Receptor models are mathematical and analytical techniques that examine the ambient sample and conditions of its collection to infer the types and relative mix of sources impacting a receptor. Receptor models may be thought of as a set of mathematical equations which relate one set of variables with unknown values to a set of variables with known values. A set of known particle characteristics (elemental composition, size, shape, crystalline pattern or isotope ratio) measured in the source emissions is related to similar characteristics measured for particulate samples collected at a receptor. The known chemical composition of all major local emissions sources is referred to as source chemical profiles, or as "finger prints" in vernacular terms. The receptor model develops a "best fit" of source contributions which best explains the chemical composition of particulate samples collected at the receptor.

While dispersion models estimate source impacts given known emission rates and pollutant transport conditions, receptor models "decode" the chemistry, variability and/or morphology of the particles to identify their origins. Both types of models assume that the mass of particles transported from the source are essentially unchanged, obeying the following "Conservation of Mass" law that is the foundation of both dispersion and receptor models:

Conservation of Mass Equation

$$M = \sum_{j=1}^{P} M_j \qquad (1)$$

Where:

M= Aerosol Mass (ug/m^3)
M_j= Mass Impact of Source "j" (ug/m^3)
P= Number of Contributing Sources.

For example, if three sources contributed all of the mass measured at the receptor (P=3), then the sum of the individual source impacts (M_j) would explain all of the measured mass. Receptor models expand this concept to individual characteristics or features, of the aerosol:

$$M_i = \sum_{j=1}^{P} M_{ij} \qquad (2)$$

Where:

M_i= Concentration of feature "i" at the receptor (ug/m^3)
P = Number of contributing sources
M_{ij}= Impact of feature "i" from source "j" emissions (ug/m^3)

In this example, M_i could be the concentration of lead measured on the filter. The concentration of lead at the receptor is then the sum of lead from each of the individual contributing sources. This relationship can be expressed in terms of the total source mass impact by substituting the M_{ij} term for the product of the source impact (S_j) and the fraction of feature "i" in the emissions from source "j" (F_{ij}). If equation (2) is rewritten in this form, and the M_i and Mij terms are redefined as concentrations normalized to mass, we obtain the receptor model equation commonly found in the literature:

Receptor Model Equation

$$C_i = \sum_{j=1}^{P} F_{ij} S_j \qquad (3)$$

Where:

C_i = Concentration of feature "i" normalized to mass
P = Number of contributing sources
F_{ij} = Fraction of feature "i" in source "j" emissions
S_j = Impact at the receptor of source "j" (ratio to mass)

A variety of receptor models have been applied to RWC impact assessment (Core et al, 1984; Watson et al, 1981; Gordon, 1980; Cooper and Watson, 1980). EPA's technical series documents on receptor models contain elaborate information on various models. The most useful of these methods are briefly described below.

a. Chemical Mass Balance (CMB)

This method compares the elemental composition of the particulate matter collected by an ambient sampler with similar information collected from woodstove and fireplace emissions to estimate the RWC contribution to the ambient particulate mass. CMB attempts to match the source "profile" or "fingerprint" to those measured at the receptor. By superimposing the appropriate source profiles one can generate a profile that resembles the ambient aerosol fingerprint, identifying the relative mix of sources. The method can be applied to a single sample collected over a 24 hour (or less) time period thereby providing an excellent method of assessing RWC impacts on actual worst case air pollution episodes.

b. Multivariate Techniques

These techniques include factor analysis, regression methods, cluster analysis and principal component analysis. The methods are based on the common variability of chemical elements as measured on a large number of ambient filters. The underlying assumption is that the temporal or spatial variability of the chemical species at the receptor and attributable to specific sources, will be similar. Source identity is determined by comparing species of similar variability to the chemical emission profile of the sources.

These methods can include ambient measurements of parameters other than elemental chemical composition in different size ranges. Examples of other measurements that may be included in the analysis include light scattering, carbon monoxide, and meterological parameters. Additional parameters increase the analyst's ability to resolve RWC impacts from other sources. At least 30 and preferably 50-100 samples should be analyzed to provide a sufficiently large database for multivariate analysis to obtain statistically valid results. This is in contrast to CMB analysis which achieves a separate, stand alone conclusion for each filter or sample analyzed.

c. Enrichment Factor Models

Enrichment factor models can be used to calculate the impact of a source based on the relative enrichment of a tracer element in an ambient sample. The method has been most widely used in RWC studies assessment by assuming that fine particle potassium (K) is solely associated with woodsmoke emissions. Iron (Fe) from soils has been used to normalize the potassium (K) concentrations to a crustal component. By examining the variations of the K/Fe ratio during impact peiods, a semi-quantitiative estimate of RWC impact can be made if the percent potassium (F_{ij}) in woodsmoke is known. Organic carbon can be used in much the same manner.

d. Pattern Recognition

Integrating nephelometer measurements of light scattering (b_{scat}) can also be used to obtain a qualitative estimate of woodsmoke impacts. Because most of the woodsmoke emissions are less than 2.5 um in size, they are effective light scattering aerosols. By subtracting "background" scattering levels measured during periods of minimal RWC emissions from those measured during impact periods, an estimate of mass concentration impact (ug/m^3) can be made given the knowledge of the b_{scat} to fine particle mass relationship.

3. Model Input Requirements

As noted above, many receptor models require a knowledge of the chemical composition of both the source emissions and ambient aerosol, and the number of sources impacting the receptor. Ideally this calls for chemical characterization of samples collected from source(s) as well as similar characterization of ambient monitoring samples. However, if source sampling and characterization cannot be done, published data on source chemical profiles can be used to construct the matrix of source composition information needed for CMB analysis, as described in the next subsection below. In the case of the least squares effective variance Chemical Mass Balance Model, estimates of the uncertainties associated with the source emission and ambient aerosol components are also needed in order to estimate confidence limits for resulting model estimates.

Although multivariate methods do not require direct input of source emission profile information, a knowledge of the likely emissions is necessary to interpret and apply the model outputs and/or to select the independent variables that are to be used as source tracers in the regression analysis. Target transformation factor analysis (TTFA) may be a potentially useful method of identifying the number and approximate composition of source emissions likely to be impacting the receptor (Hopke et al, 1982). Where TTFA analysis is not available, the number of sources impacting the sampler are commonly based on the analyst's knowledge of the airshed.

Major impacts from sources that may have been omitted from the analysis are usually apparent by the inability of the CMB model to account for all of the measured mass and aerosol components. For example, failure to include an RWC source in the CMB analysis will result in an inability to account for a major portion of the fine particle potassium and organic carbon.

Table IV-7 lists the ambient and source measurements commonly required for CMB and multivariate model analysis of RWC impacts.

TABLE IV-7. Receptor Model Input Requirements

Mass	Cl	Fe	Pb
Na*	K	Ni	SO_4
Mg*	Ca	Cu*	NO_3
Al	V	Se*	Organic Carbon
Si	Cr*	Br	Elemental Carbon
S	Mn	Ba*	
As*	Sr*	Cd*	
Sn*	Sb*		

* Desirable but not mandatory measurements

a. Development of CMB Source Profiles and a Source Matrix

A critical element of Chemical Mass Balance (CMB) receptor modeling is development of the source emission profile matrix-i.e., the F_{ij} values referred to in Equation 3 above for all emission sources to be considered. Although it is always preferable to develop source profiles for the specific airshed under study, data sets published in the U.S. EPA Source Library (U.S. EPA, 1984c) can provide such information for many types of emissions sources including RWC, based on previous studies. As this library of source chemical profiles is periodically updated using new research, it will become an essential reference document for CMB analysis. This section discusses example source chemical profiles from this library, and how such information is used to develop the basic source matrix used in any CMB analysis.

Of special interest in RWC studies is the chemical composition of woodstove and fireplace emissions. The current EPA Source Library (U.S. EPA, 1984c) contains a number of RWC source profiles, four of which are shown in Tables IV-8 through IV-11. Such profiles were based on available source characterization data through mid-1984. Recent increases in stove and fireplace testing, associated with federal and state regulatory program development, could expand the available source profile database significantly in the near future, if chemical characterization of emissions test samples is done.

Stiles (1983) has reported the results of an extensive study of woodstove emissions composition. Rau and Huntizcker (1985) have studied the size distribution and chemical composition of emissions from woodstove and fireplaces as a function of burning conditions and fuel type concluding that under hot burning conditions (damper fully open), 60% of the carbon emissions are in the form of elemental carbon while under cool burning (damper fully closed) the carbon emissions are primarily in the form of organic carbon. In both cases, 70 $\pm$ 10% of the aerosol mass was carbon. Muhlbaier (1981) has published results for fireplace emissions from soft and hardwood fuels.

TABLE IV-8. Example from EPA Source Library of Wood Stove Source Profile

SOURCE: WOOD STOVES-PINE FUEL
SCC: NONE
CONTROLS: NONE

PROFILE: 42101
RANKING: 3338
RATING : A

SPECIES NUMBER	SPECIES NAME	********* % BY WT	<2.5 UM + -	****** UNC	********* % BY WT	<2.5 UM +-	****** UNC	********* % BY WT	<2.5 UM +-	****** UNC
4	BE	NA	+ -	NR		+ -			+ -	
5	B	NA	+ -	NR		+ -			+ -	
9	F	NA	+ -	NR		+ -			+ -	
11	NA	NA	+ -	NR		+ -			+ -	
12	MG	NA	+ -	NR		+ -			+ -	
13	AL	NR	+ -	NR		+ -			+ -	
14	SI	NR	+ -	NR		+ -			+ -	
15	P	NR	+ -	NR		+ -			+ -	
16	S	0.100	+ -	NR		+ -			+ -	
17	CL	0.100	+ -	NR		+ -			+ -	
19	K	1.000	+ -	NR		+ -			+ -	
20	CA	<	+ -	NR		+ -			+ -	
21	SC	<	+ -	NR		+ -			+ -	
22	TI	<	+ -	NR		+ -			+ -	
23	V	<	+ -	NR		+ -			+ -	
24	CR	<	+ -	NR		+ -			+ -	
25	MN	<	+ -	NR		+ -			+ -	
26	FE	<	+ -	NR		+ -			+ -	
27	CO	<	+ -	NR		+ -			+ -	
28	NI	<	+ -	NR		+ -			+ -	
29	CU	<	+ -	NR		+ -			+ -	
30	ZN	<	+ -	NR		+ -			+ -	
31	GA	<	+ -	NR		+ -			+ -	
32	GE	<	+ -	NR		+ -			+ -	
33	AS	<	+ -	NR		+ -			+ -	
34	SE	<	+ -	NR		+ -			+ -	
35	BR	<	+ -	NR		+ -			+ -	
37	RB	<	+ -	NR		+ -			+ -	
38	SR	<	+ -	NR		+ -			+ -	
40	ZR	<	+ -	NR		+ -			+ -	
47	AG	<	+ -	NR		+ -			+ -	
48	CD	<	+ -	NR		+ -			+ -	
50	SN	<	+ -	NR		+ -			+ -	
51	SB	<	+ -	NR		+ -			+ -	
55	CS	<	+ -	NR		+ -			+ -	
56	BA	<	+ -	NR		+ -			+ -	
58	CE	<	+ -	NR		+ -			+ -	
80	HG	<	+ -	NR		+ -			+ -	
82	PB	<	+ -	NR		+ -			+ -	
201	OC	38.700	+ -	NR		+ -			+ -	
202	EC	4.500	+ -	NR		+ -			+ -	
203	SO4	NA	+ -	NR		+ -			+ -	
204	NO3	NA	+ -	NR		+ -			+ -	
SUM(%)		44.400			0.000			0.000		

NOTES: OC = ORGANIC CARBON : EC = ELEMENTAL CARBON : NA = NOT ANALYZED : NR = NOT REPORTED
< = LESS THAN DETECTION LIMIT
OTHER NOTES : VALUES REPORTED ARE EMISSION WEIGHTED VALUES CALCULATED FROM EARLY, MIDDLE AND LATE - STAGE EMISSION PROFILES. REF. 33.

Source: U.S. EPA, 1984c

TABLE IV-9. Example from EPA Source Library of Wood Stove Source Profile

SOURCE: WOOD STOVES-OAK FUEL
SCC: NONE
CONTROLS: NONE

PROFILE: 42103
RANKING: 3338
RATING : A

SPECIES NUMBER	SPECIES NAME	********* % BY WT	<2.5 UM + -	****** UNC	********* % BY WT	<2.5 UM +-	****** UNC	********* % BY WT	<2.5 UM +-	****** UNC
4	BE	NA	+ -	NR		+ -			+ -	
5	B	NA	+ -	NR		+ -			+ -	
9	F	NA	+ -	NR		+ -			+ -	
11	NA	NA	+ -	NR		+ -			+ -	
12	MG	NA	+ -	NR		+ -			+ -	
13	AL	NR	+ -	NR		+ -			+ -	
14	SI	NR	+ -	NR		+ -			+ -	
15	P	NR	+ -	NR		+ -			+ -	
16	S	1.600	+ -	NR		+ -			+ -	
17	CL	1.800	+ -	NR		+ -			+ -	
19	K	7.700	+ -	NR		+ -			+ -	
20	CA	<	+ -	NR		+ -			+ -	
21	SC	<	+ -	NR		+ -			+ -	
22	TI	<	+ -	NR		+ -			+ -	
23	V	<	+ -	NR		+ -			+ -	
24	CR	<	+ -	NR		+ -			+ -	
25	MN	<	+ -	NR		+ -			+ -	
26	FE	<	+ -	NR		+ -			+ -	
27	CO	<	+ -	NR		+ -			+ -	
28	NI	<	+ -	NR		+ -			+ -	
29	CU	<	+ -	NR		+ -			+ -	
30	ZN	<	+ -	NR		+ -			+ -	
31	GA	<	+ -	NR		+ -			+ -	
32	GE	<	+ -	NR		+ -			+ -	
33	AS	<	+ -	NR		+ -			+ -	
34	SE	<	+ -	NR		+ -			+ -	
35	BR	<	+ -	NR		+ -			+ -	
37	RB	<	+ -	NR		+ -			+ -	
38	SR	<	+ -	NR		+ -			+ -	
40	ZR	<	+ -	NR		+ -			+ -	
47	AG	<	+ -	NR		+ -			+ -	
48	CD	<	+ -	NR		+ -			+ -	
50	SN	<	+ -	NR		+ -			+ -	
51	SB	<	+ -	NR		+ -			+ -	
55	CS	<	+ -	NR		+ -			+ -	
56	BA	<	+ -	NR		+ -			+ -	
58	CE	<	+ -	NR		+ -			+ -	
80	HG	<	+ -	NR		+ -			+ -	
82	PB	<	+ -	NR		+ -			+ -	
201	OC	29.200	+ -	NR		+ -			+ -	
202	EC	7.200	+ -	NR		+ -			+ -	
203	SO4	NA	+ -	NR		+ -			+ -	
204	NO3	NA	+ -	NR		+ -			+ -	
SUM(%)		47.500			0.000			0.000		

NOTES: OC = ORGANIC CARBON : EC = ELEMENTAL CARBON : NA = NOT ANALYZED : NR = NOT REPORTED
< = LESS THAN DETECTION LIMIT
OTHER NOTES : VALUES REPORTED ARE EMISSION WEIGHTED VALUES CALCULATED FROM EARLY, MIDDLE AND LATE - STAGE EMISSION PROFILES. REF. 33.

Source: U.S. EPA, 1984c

TABLE IV-10. Example from EPA Source Library of Fireplace Source Profile

SOURCE: FIREPLACES -SOFTWOODS
SCC: NONE
CONTROLS: NONE

PROFILE: 42201
RANKING: 2224
RATING : C

SPECIES NUMBER	SPECIES NAME	FINE <2.5 UM % BY WT	FINE <2.5 UM +-	FINE <2.5 UM UNC	COARSE 2.5-10UM % BY WT	COARSE 2.5-10UM +-	COARSE 2.5-10UM UNC	TSP <30 UM % BY WT	TSP <30 UM +-	TSP <30 UM UNC
4	BE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
5	B	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
9	F	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
11	NA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
12	MG	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
13	AL	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
14	SI	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
15	P	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
16	S	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
17	CL	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
19	K	0.606	+ -	NR	0.606	+ -	NR	0.606	+ -	NR
20	CA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
21	SC	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
22	TI	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
23	V	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
24	CR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
25	MN	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
26	FE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
27	CO	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
28	NI	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
29	CU	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
30	ZN	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
31	GA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
32	GE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
33	AS	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
34	SE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
35	BR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
37	RB	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
38	SR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
40	ZR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
47	AG	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
48	CD	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
50	SN	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
51	SB	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
55	CS	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
56	BA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
58	CE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
80	HG	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
82	PB	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
201	OC	38.000	+ -	6.000	38.000	+ -	6.000	38.000	+ -	6.000
202	EC	33.000	+ -	13.00	33.000	+ -	13.00	33.000	+ -	13.00
203	SO4	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
204	NO3	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
SUM(%)		71.606			71.606			71.606		

NOTES: OC = ORGANIC CARBON : EC = ELEMENTAL CARBON : NA = NOT ANALYZED : NR = NOT REPORTED
< = LESS THAN DETECTION LIMIT
OTHER NOTES : EC, OC MEAN AND STD. DEV. VALUES FROM 7 SOURCE TESTS.K VALUES AVERAGE OF 3 TESTS. PROFILES ALL ASSUMED SIMILAR BASED ON SIZE DISTRIBUTION. REF. 34

Source: U.S. EPA, 1984c

TABLE IV-11. Example from EPA Source Library of Fireplace Source Profile

SOURCE: FIREPLACES - HARDWOODS
SCC: NONE
CONTROLS: NONE

PROFILE: 42202
RANKING: 2224
RATING : C

SPECIES NUMBER	SPECIES NAME	FINE <2.5 UM % BY WT	+-	UNC	COARSE 2.5-10UM % BY WT	+-	UNC	TSP <30 UM % BY WT	+-	UNC
4	BE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
5	B	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
9	F	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
11	NA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
12	MG	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
13	AL	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
14	SI	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
15	P	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
16	S	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
17	CL	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
19	K	1.030	+ -	NR	1.030	+ -	NR	1.030	+ -	NR
20	CA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
21	SC	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
22	TI	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
23	V	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
24	CR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
25	MN	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
26	FE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
27	CO	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
28	NI	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
29	CU	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
30	ZN	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
31	GA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
32	GE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
33	AS	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
34	SE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
35	BR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
37	RB	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
38	SR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
40	ZR	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
47	AG	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
48	CD	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
50	SN	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
51	SB	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
55	CS	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
56	BA	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
58	CE	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
80	HG	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
82	PB	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
201	OC	46.000	+ -	7.000	46.000	+ -	7.000	46.000	+ -	7.000
202	EC	8.000	+ -	7.000	8.000	+ -	7.000	8.000	+ -	7.000
203	SO4	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
204	NO3	NA	+ -	NR	NA	+ -	NR	NA	+ -	NR
SUM(%)		55.030			55.030			55.030		

NOTES: OC = ORGANIC CARBON : EC = ELEMENTAL CARBON : NA = NOT ANALYZED : NR = NOT REPORTED
< = LESS THAN DETECTION LIMIT
OTHER NOTES : EC AND OC VALUES AVERAGE AND STD. DEV. OF 14 TESTS. K VALUES MEAN OF THREE TESTS. ALL PROFILES ASSUMED SIMILAR BASED ON SIZE DISTRIBUTION. REF. 34.

Source: U.S. EPA, 1984c

The RWC source profiles for woodstoves and fireplaces shown in Tables IV-8 through IV-11 illustrate how key RWC tracers can vary with operating parameters such as fuel type. For example, woodstoves burning hardwoods such as oak fuel appear to emit signficantly more fine particulate potassium (7.7%K) than when a softwood fuel such as pine was used (1.0%K) - based on work by Stiles (1983). The variations in organic and elemental carbon shown in these four profiles - which could reflect differences in operating parameters such as combustion, temperature, excess air, etc. - further, illustrate the variability of wood smoke chemical composition.

Figure IV-1 illustrates the variability in RWC emission profiles by chemical species. The variability in the RWC emission profile is the single most important factor contributing to the relative uncertainties associated with RWC impact estimates obtained from receptor models.

To help insure that the RWC profile for the study area is representative of the actual mix of wood fuels and woodstove/fireplace emissions, it is advisable to calculate an emission inventory weighted composite for the airshed as explained below. The calculations require information detailing actual fireplace and woodstove emissions as well as the relative amounts of soft and hardwoods used. This information is often gathered through household surveys of wood use patterns. RWC source profiles (such as those in Tables IV-8 through IV-11, are then weighted in proportion to the percent of RWC emissions in each category (fireplace, hardwoods; fireplace, softwoods; stove, hardwoods; stove, softwoods) and averaged to produce a single composite profile to represent RWC in a CMB analysis.

Chemical composition profiles for all sources to be included in a CMB analysis are then combined into a Source Matrix and input into the CMB model to be used. Table IV-12 illustrates the type of information included in the Source Matrix.

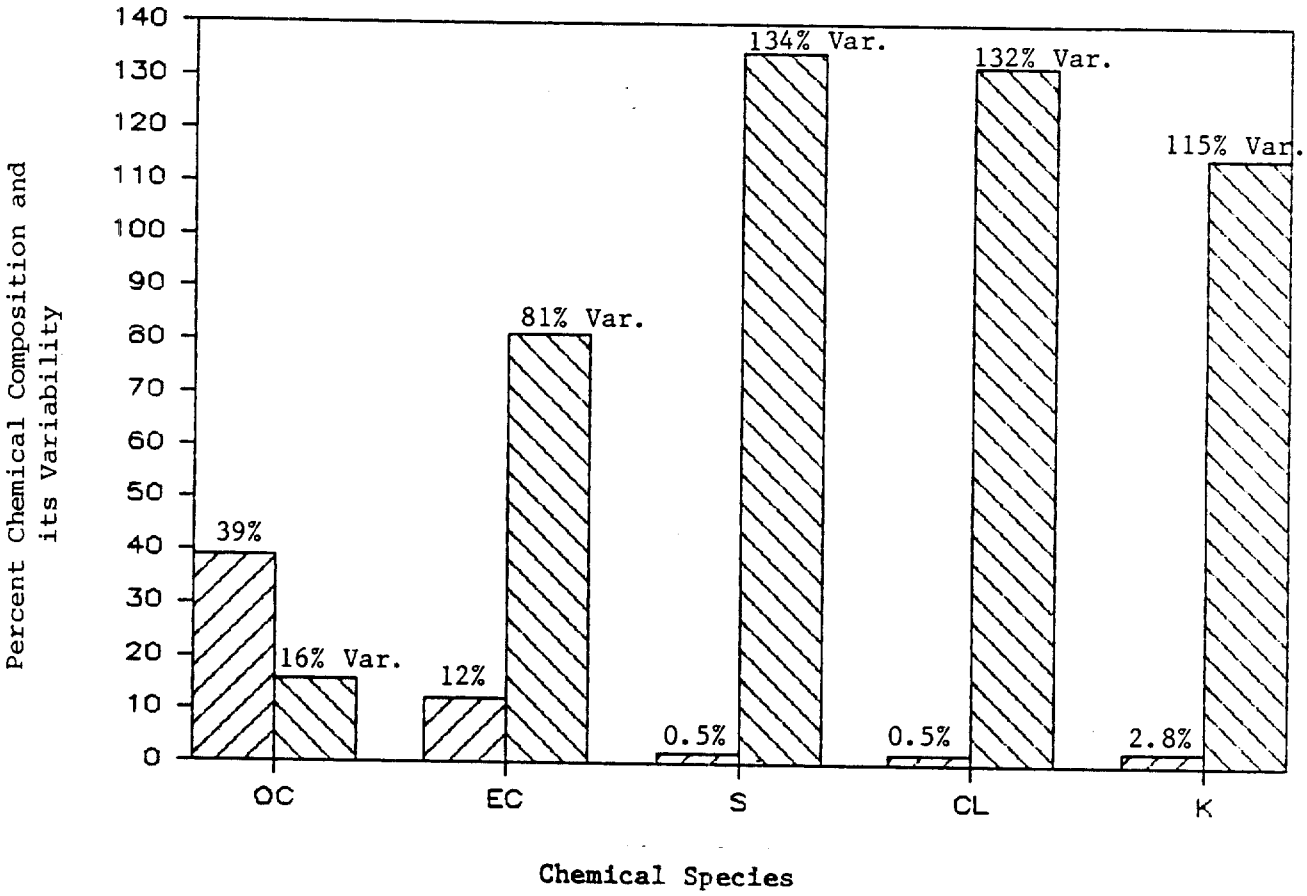


Figure IV-1. RWC Emission Profile Variability

TABLE IV-12. Source Matrix - Generic Example

Emission Source	Fine Particulate Chemical Composition (Weight%)							
	Silicon	Aluminum	Potassium	Organic Carbon	Elemental Carbon	Sulfate	Lead	Bromine
Soil Dust	26 ± 2	10 ± 1	1.0 ± 0.3	4.0 ± 1.5	.6 ± .4	—	.006 ± .001	—
Vehicle Exhaust	—	—	—	50 ± 5	—	—	21 ± 2	8 ± 2
Residential Wood Combustion	—	—	2 ± 1	38 ± 7	7 ± 4	—	—	—
Industrial Point Sources								
#1	5 ± 21	.7 ± .2	.9 ± .07	—	—	2.5 ± 1.3	.8 ± .07	—
#2	.3 ± .3	27 ± 8	.22 ± .06	4 ± 4	2.5 ± 1	4.4 ± 3.9	.01 ± .01	.04 ± .05

Each source profile should also have an associated uncertainty estimates. This is used by the CMB model in estimating variance for each source contribution. The analyst then operates the CMB model to find the mix of source contributions which best "explains" the total mass and chemical characteristics of an ambient monitoring sample(s).

Enrichment factor and multivariate models require that a single trace element (typically potassium) be identified as a tracer element for RWC emissions. While potassium may be a useful tracer for RWC emissions in isolated, rural areas, it is most helpful to assess the uniqueness of potassium (or other aerosol components) to determine the validity of the tracer assumption. One of the best means of evaluating this is to calculate a chemical element emission inventory for the study area based on: (a) the TSP point and area source emission inventory; (b) a knowledge of the percent of TSP emission < 2.5 um in size; and, (c) the chemical profiles for each of the area's fine particulate emissions sources. From this information, the total number of tons per year of potassium (or any other species included in the source matrix) can be estimated and the percent of potassium associated with RWC emissions can be obtained. If RWC emissions can reasonably be shown to contribute the majority of the potassium emissions during the space heating season, then potassium can be used as a valid tracer in enrichment factor and multivariate analysis.

4. Receptor Model Applications

The receptor model application described above can be catagorized as quantitative, semi-quantitative or qualitative based on the method's ability to resolve woodsmoke impacts from other sources. Only the quantitative methods provide a sufficient level of confidence to support regulatory action. Semi-quantitative and qualitative techniques, however, are highly useful in confirming the conclusions reached through the more accurate methods. Their parallel use is therefore encouraged.

a. Quantitative Methods of RWC Impact Assessment

Radiocarbon Techniques

The measurement of RWC particulate impacts through radiocarbon (carbon-14) isotope analysis pioneered by Currie (1982) can provide an accurate direct assessment of RWC impacts if: (a) fine particle samples are submitted for analysis; (b) it can be reasonably shown that other sources of "modern carbon" (e.g., structural fires, forest fires, landclearing burning, industrial combustion of woodfiber or other potential sources of vegetative burning emissions) are of minor importance at the time of sampling. Since the ratio of $^{14}C/^{12}C$ in the fuels burned in the airshed is required as an input to the interpretation of the data, radiocarbon measurements of sawdust obtained from cross sections of fuel wood used within the airshed should be concurrently analyzed with the ambient samples. If a mix of wood species are burned, a weighted average sawdust composite sample should be analyzed.

Since this method only provides an estimate of the percent of "modern" carbon exclusive of the oxygen, hydrogen, nitrogen and trace elements associated with RWC emissions, it is necessary to correct the radiocarbon estimates to include these components. Based on studies by Rau and Huntzicker (1985), 70 $\pm$ 10% of RWC emissions are carbon requiring that the "modern" carbon estimate be scaled up by a factor of 1.42 (1/0.70).

Although radiocarbon methods have been applied to TSP and SSI samples, results obtained from such samples should be considered semi-quantitative. They provide an upper-limit estimate of woodsmoke impacts, since interferences from coarse particle "modern" carbon sources (e.g., leaf fragments, insect parts, pollen, sander dust, etc.) can be incorrectly assigned to RWC sources.

Duker et al, (1984) have recently applied radiocarbon methods to the determination of ambient Carbon Monoxide (CO) impacts associated with wood burning sources. Figure IV-2 illustrates the ^{14}CO sampling train. Integrated four to 16 hour samples can be collected at flow rates of five liters per minute before the substrates in the train need to be changed. Ambient air is drawn through a rotometer to a series of soda lime and Drierite absorption columns to remove ambient carbon dioxide and water vapor. Activated charcoal is used to trap C_4 and higher hydrocarbons. CO is then oxidized in a Hopcalite column and the resultant CO_2 is trapped on a carbonate-free, sodium hydroxide impregnated firebrick substrate. The sealed CO_2 absorption column can be stored indefinitely prior to Tandem Accelerator Mass Spectrometer analysis for radiocarbon isotopes. The $^{14}C/^{12}C$ ratio measured in the desorbed CO_2 provides a direct measurement of the percent of ambient CO which originated from woodburning sources.

Chemical Mass Balance

CMB-derived estimates of short term RWC impacts offer the most cost-effective means of obtaining quantitative data. The analyst must be aware, however, that other emissions from vegetative burning sources may not be distinguished by the model if the source profiles of the two emissions sources are similar. An analysis of source emission activities can often be used to clarify such issues as described in the previous subsection. To provide additional verification of CMB-estimated impacts, many researchers have intercompared radiocarbon and CMB estimates. Such comparisons have typically found that the impact estimates from the two methods were comparable within the limits of experimental error ($\pm$ 30%). Again, the CMB ambient aerosol data sets must be obtained from fine particle samples to assure a high degree of confidence in the results.

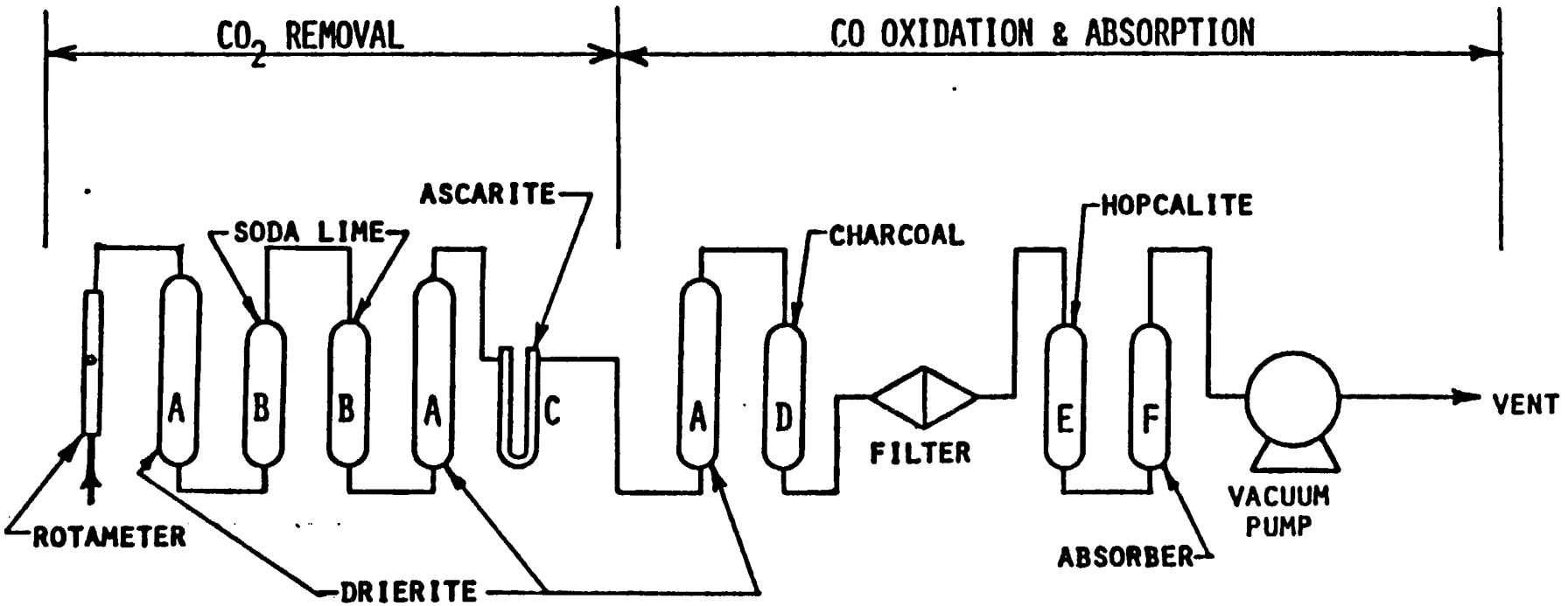


Figure IV-2. Radiocarbon CO Sampling Train

Source: Duker et al (1984).

Multivariate Models

Multiple regression analysis may be used as a quantitative analysis tool if the features (elements, ions or carbon species) selected for analysis as independent variables are known to be tracers for specific sources. The F_{ij} values used in the chemical emission inventory calculations may be utilized to determine the species that can serve as source tracers. The general multiple regression equation is shown in Equation 4.

Multiple Regression Equation

$$Y = a + b_1X_1 + b_2X_2 \ldots + b_nX_n \qquad (4)$$

Where:

Y = Dependent Variable (fine particle mass)
a = Intercept (Background fine particle mass)
b = Partial Regression Coefficient, variable i
X = Independent Variable (tracer elements)

The intercept represents the value of Y when all of the independent variables are zero. The partial regression coefficients are a measure of the change in the value of Y per unit change in X when all other independent variables are held constant. The value of the partial regression coefficients determined by multiple regression analysis are the reciprocal of F_{ij} which the tracer represents. The product (bX) of the partial regression coefficient and the concentration of the tracer element is the impact of the source which the tracer element represents.

b. Semi-quantitative Methods

Enrichment Factor Models

As noted above, this method uses ambient aerosol elemental composition data in association with a reference element to

provide an estimate of the degree to which the "natural concentration" of a given element has been "enriched" by a man-made emissions source. The generalized equation for this application is shown in Equation 5.

Enrichment Factor Equation

$$EF_i = \frac{(Ci/Cr)\ aerosol}{(Ci/Cr)\ reference} \qquad (5)$$

Where:

EF_i = Enrichment factor or tracer element "i"

C_i = Concentration of tracer element "i" in the ambient aerosol

C_r = Concentration of reference element "i" in soils

The reference element is usually a crustal element, commonly iron, aluminum, silicon, or calcium. Crustal elements are used because of their abundance in ambient samples. By normalizing the source tracer element to a crustal element, local meteorology that may affect the elemental concentrations can be factored out. Enrichment factors near 1.0 indicate that soil is the likely source of the tracer element. Values significantly greater than 1.0 indicate that the ambient aerosol has been enriched by another source. Potassium (K) is typically used as a tracer element for RWC emissions, while iron (Fe) has been widely used as a crustal reference element. Variation in the K/Fe enrichment factor have been found to closely correlate to known periods of RWC impact in several studies (Lyons et al, 1979).

This concept can be extended to provide a semi-quantitative estimate of woodsmoke impact, if the concentration of potassium in RWC emissions is known:

$$C_{RWC} = \left[\frac{(C_i/C_r \text{ Impact}) - (C_i/C_r \text{ No Impact})}{(C_i/C_r \text{ Impact})(F_{ij})}\right] * C_i \qquad (6)$$

Where:

C_{RWC} = Concentration of RWC (ug/m^3)
C_i = Concentration of tracer element "i" (ug/m^3)
C_r = Concentration of reference element "r" (ug/m^3)
F_{ij} = Fraction of tracer element "i" in source "j" emissions (weight percent)
C_i = Mean concentration of the tracer element "i"

Used in this form, the enrichment factor model is a form of Chemical Mass Balance in which the tracer element (typically potassium) is used to calculate woodsmoke impacts. For example, assume the average K/Fe ratio during woodsmoke impact periods is 2.0, compared to an average K/Fe ratio of 0.6 during non-impact periods and that the average ambient concentration of potassium is 0.2 ug/m^3. Then an estimated average impact of 5.0 ug/m^3 is obtained, given an average content of 2.8% potassium in the woodsmoke emissions:

$$C_{RWC} = \frac{2.0 - 0.6}{(2.0)\ (0.028)} * 0.2 \qquad (7)$$

$$C_{RWC} = 5.0\ ug/m^3 \qquad (8)$$

Such estimates are considered semi-quantitative because of their sensitivity to the variability of potassium in the source emissions (Figure IV-1). In addition, the model assumes that potassium is uniquely emitted by RWC sources, an assumption that may not be valid in some urban settings.

c. Qualitative Methods

Time series analysis of light scattering measurements, enrichment factors and fine particle mass can be effectively compared to RWC impacts estimated by CMB, radiocarbon and multivariate analysis methods to evaluate the credibility of RWC impact estimates. Temporal and spatial patterns of these parameters should be highly intercorrelated if woodsmoke impacts are the principal source impacting the receptor. These qualitative methods of RWC impact assessment are discussed below.

Carbon Thermograms

Stepwise temperature programming combustion of aerosol samples over a temperature range of 350^{o} to 700^{o} C can be used to detect changes in the boiling point distribution of organic and elemental carbon aerosols in the ambient air (Johnson and Huntzicker, 1978). Thermograms of woodstove and fireplace emissions, for example, are similar to ambient samples known to have been highly impacted by RWC emissions. These patterns are distinctly different from those obtained from other sources or from ambient samples taken in the same airshed during summer months in which little, if any RWC emissions are occuring. Figure IV-3 illustrates the differences in these patterns.

Temporal Patterns

Diurnal and seasonal variations in light scattering measurements made by integrating nephelometers can provide a qualitative indication of woodsmoke concentrations. Figure IV-4, for example, illustrates differences between typical hourly average scattering coefficients measured during summer and winter months in an airshed known to be impacted by woodsmoke. The winter pattern is typified by a late evening peak in fine particle concentrations that is not seen during the summer months. Diurnal patterns shown in Figure IV-4 indicate a peak during the winter months that may track the late evening peak in woodstove and fireplace use, which typically occurs between 8 and 11 pm local time.

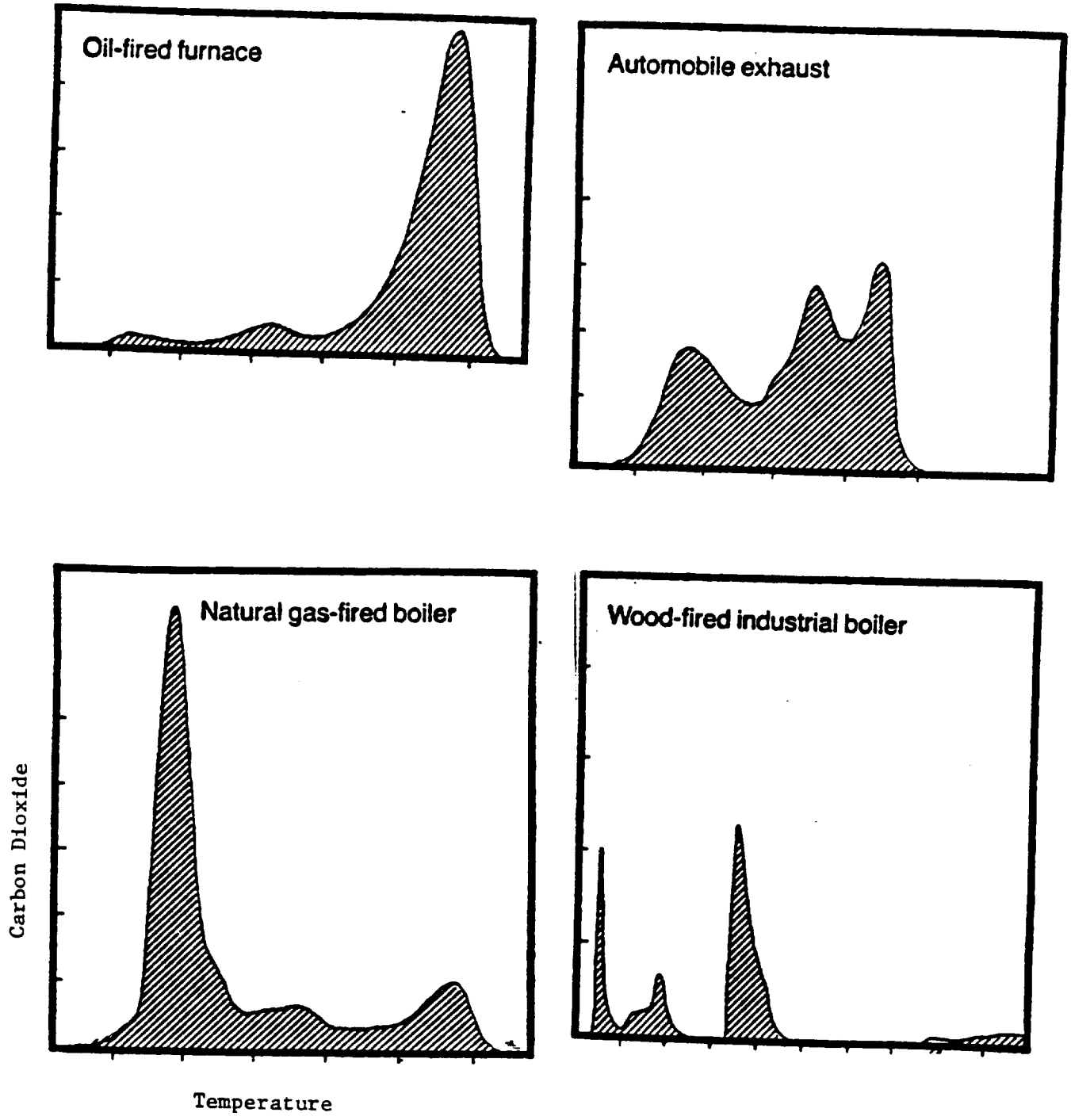


Figure IV-3. Carbon Thermograms of Source and Ambient Aerosols

Source: Kowalczyk and Greene (1982).

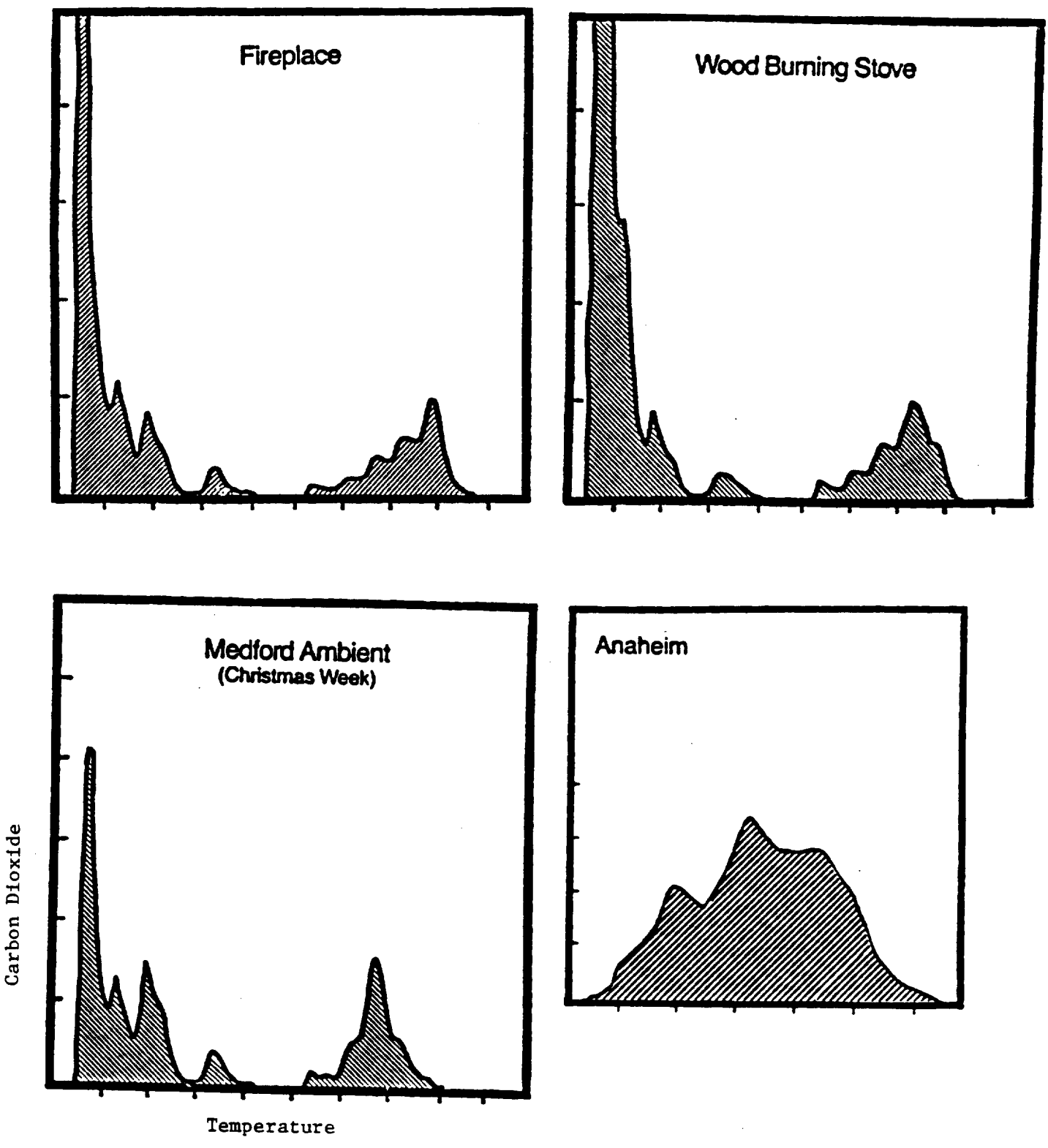
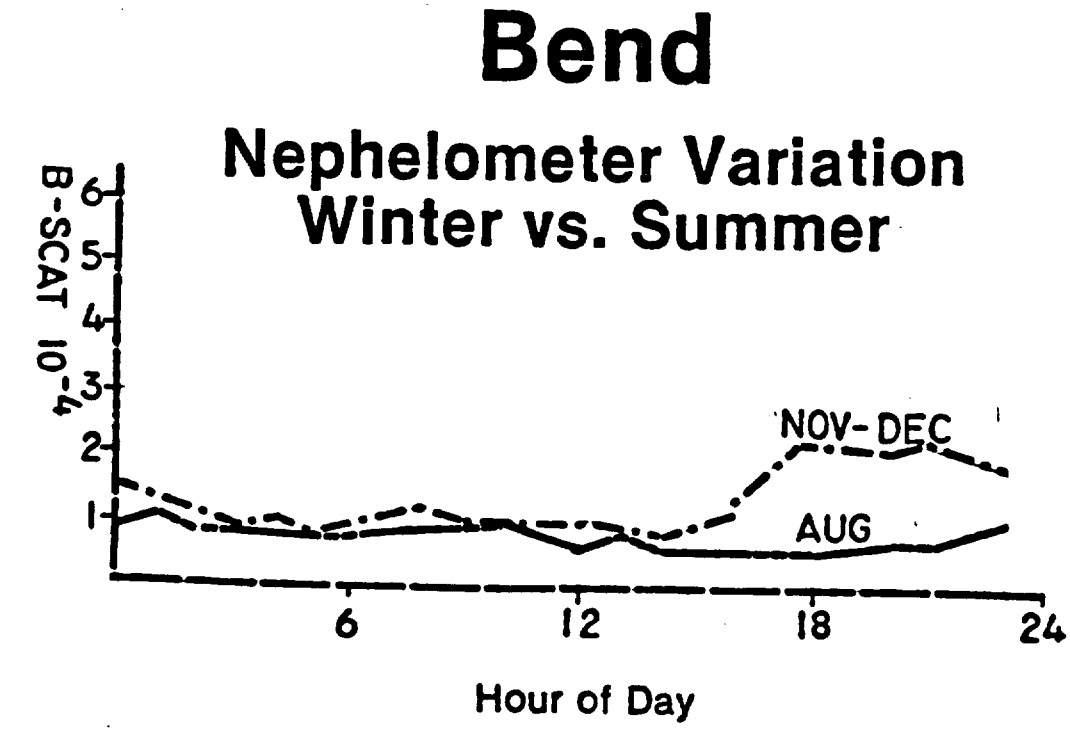


Figure IV-3. (Continued)



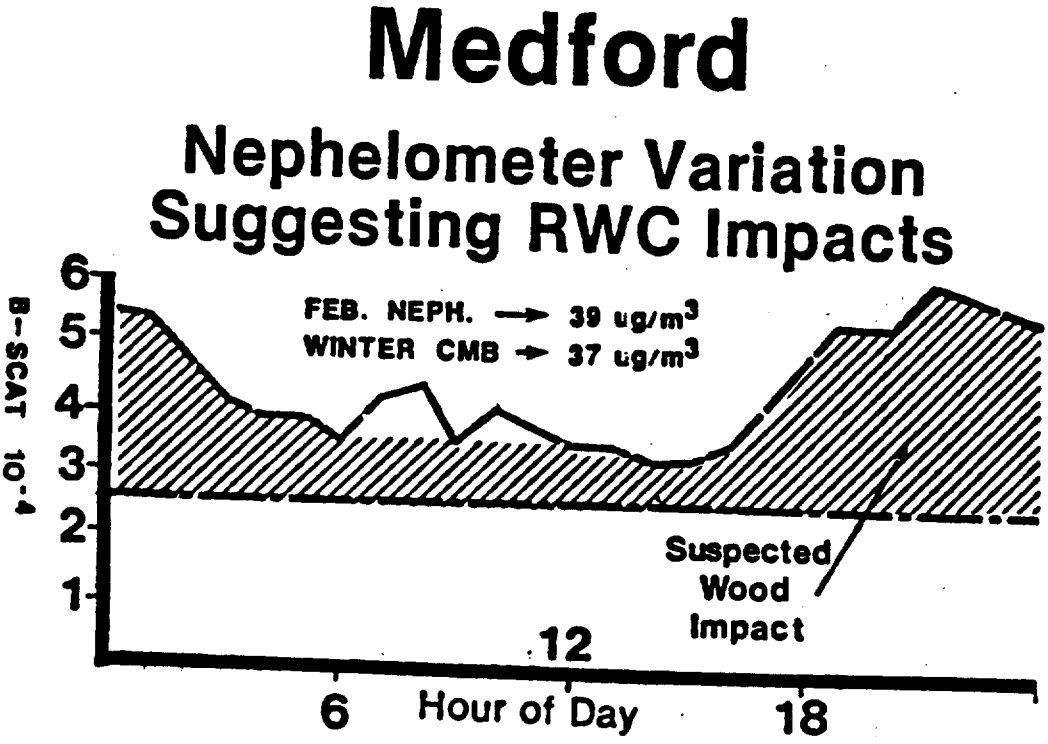


Figure IV-4. Seasonal and Diurnal Variations in RWC Pollutants

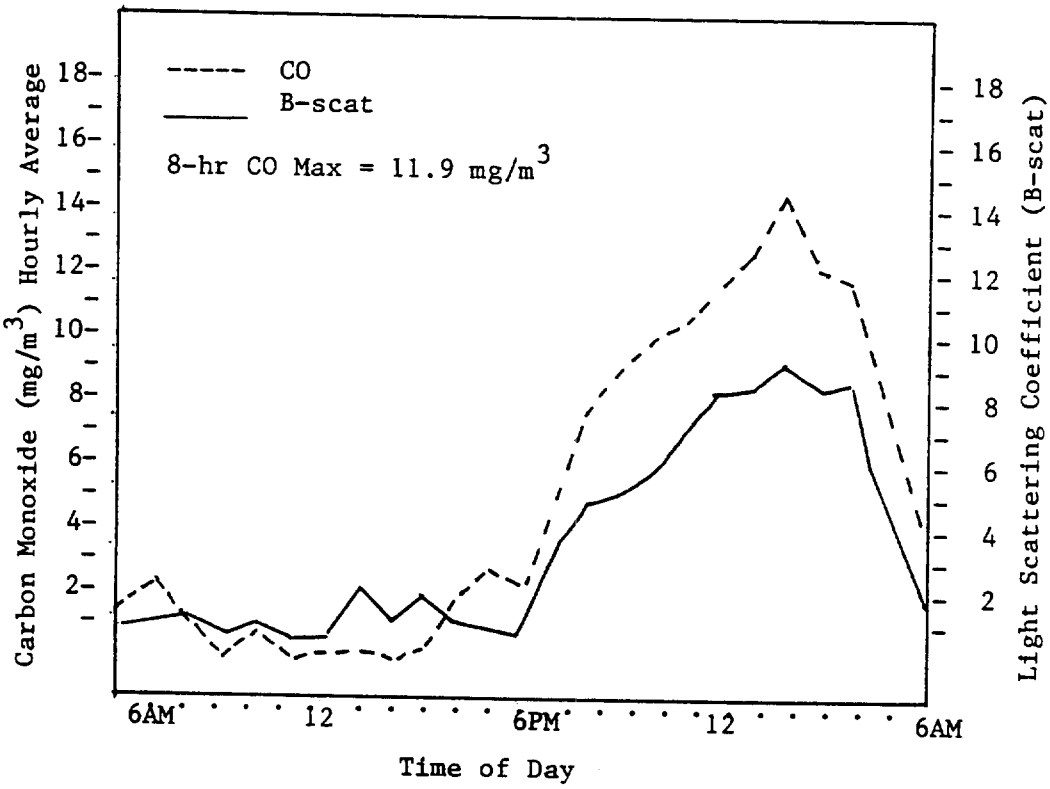
Source: Kowalczyk and Greene (1982).

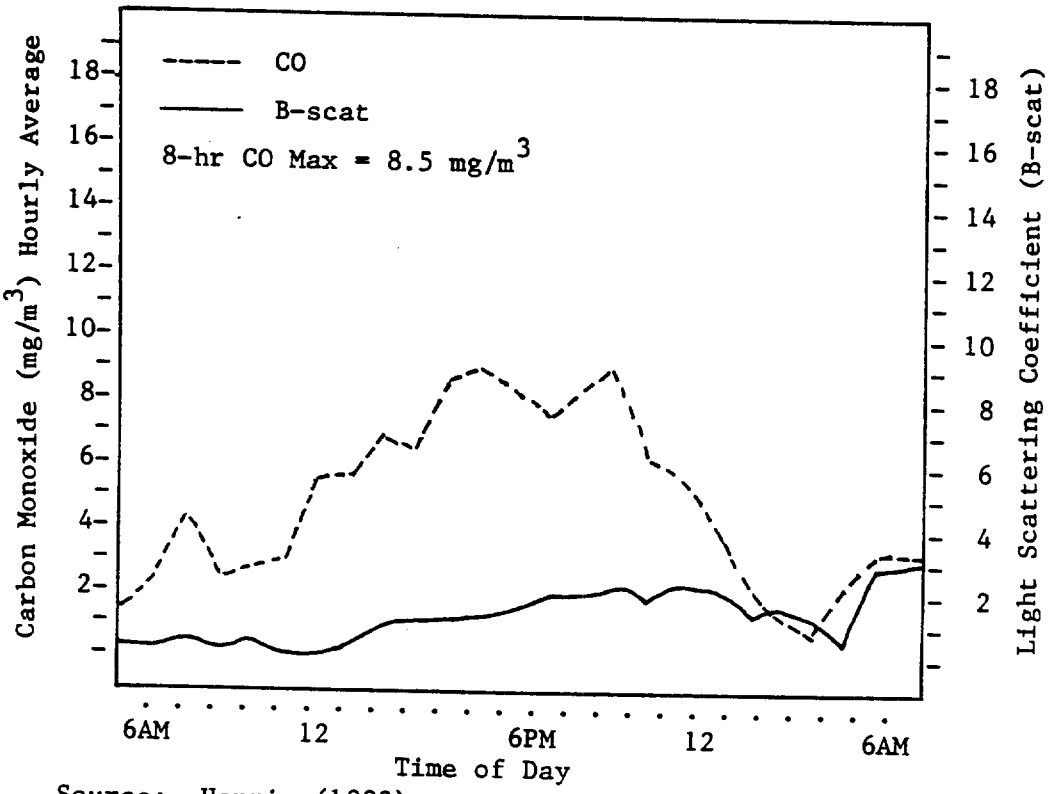
Since woodstoves emit, on the average 600 and 1,000 times more carbon monoxide than oil furnaces and natural gas furnaces, respectively, evening CO peaks in winter time at residential sites provide additional qualitative evidence linking RWC appliance use to air quality impacts. The value of the analysis is further enhanced if the CO diurnal variations at the residential site are compared to that measured at a central business district (CBD) monitoring site that is known to be principally impacted by transportation sources. Studies by Harris (1983) indicate that, while winter CO and scattering coefficient variations are highly correlated at a residential site (R^2 of 0.95), the correlation between these two parameters at a CBD site during the same time period were poor (R^2 of 0.2). As illustrated in Figure IV-5, the temporal variation patterns of CO and light scattering (b_{scat}) at the two sites are strikingly dissimilar, indicating the likely differences between the emission patterns of transportation and RWC sources.

In addition to analysis of light scattering, CO and fine particle mass variations, additional information can be gained by a diurnal and seasonal analysis of the organic carbon and/or fine particle potassium to mass ratios of the aerosol. Since RWC emissions are highly rich in these species, a high degree of correlation between these measurements would tend to provide confirming evidence that RWC emissions are the common source of the pollutants. While it is important to note that a high degree of correlation does not prove a causal relationship, the occurrence of the pollutant variability patterns and correlation during the winter season furthers the evidence that RWC emissions are likely sources impacting the site.

5. Joint Application of Dispersion and Receptor Models

Several researchers have demonstrated the value of the joint use of dispersion and receptor models in RWC impact studies. This approach is especially useful when the emission inventory and/or other data





Source: Harris (1983)

Figure IV-5. Diurnal Variations in CO and B-scat at Residential and CBD Monitoring Sites

bases used in dispersion modeling are of marginal adequacy (Core et al, 1980). The results of the receptor modeling can be used to critically evaluate the emission and meteorological assumptions used in dispersion modeling to deduce whether the emission and dispersion characteristics of the RWC sources have been adequately characterized. Imhoff et al, (1983) for example, applied Chemical Mass Balance receptor modeling results in an evaluation of the ability of several dispersion models to reasonably simulate RWC area source impacts within the Petersville, Alabama airshed. Core and Hanrahan (1983) were able to identify major deficiencies in the Portland, Oregon RWC emission inventory based on an intercomparison of woodsmoke impacts independently derived from each modeling approach. Since dispersion models must be used to estimate future source emission impacts, the validation of dispersion models against receptor modeling estimates of source impacts is an extremely useful tool for regulatory actions that must be based on future year projections of air quality.

6. Modeling RWC Visibility Impacts

During the past decade, numerous studies have been conducted to determine the relationship between urban haze and air pollution sources. Extinction budget analysis has been conducted in many airsheds including Denver (Dennis, 1983; Wolf et al, 1980), Detroit (Sloane and Wolf, 1984), Los Angeles (Cass, 1979), Portland (Shah, 1981 and Shah et al, 1984), and Oakland (Barone et al, 1979). These studies have clearly demonstrated the relationship between fine particle (< 2.5 um) size, mass and chemical composition and atmospheric light extinction through empirical models based on statistical associations. Empirical models fit the measured total light scattering and absorbance of airborne aerosols to the concentrations of chemical species by multivariate linear regression. Such models generally provide good fits in that the correlation coefficient for the fitted and measured light scattering measurements is usually high, providing valuable insights into the relative importance of each aerosol species to visibility impairment. Empirical regression models take the form of:

$$B_{sp} = \Sigma C_i M_i + B_{abs} \qquad (9)$$

In this relationship: B_{sp} represents the measured scattering coefficient; C_i is the partial regression coefficient which physically represents the scattering efficiency of the individual species; M_i is the measured mass concentration of the chemical species "i"; and B_{abs} is the light absorbance associated with the elemental carbon component of the aerosol.

The aerosol sampling and analytical requirements of extinction budget models are similar to those described for receptor modeling, but require concurrent B_{sp} data obtained from integrating nephelometer measurements of light scattering. As a prerequisite to model development, the analyst must select aerosol species that can serve as unique tracers for airshed sources while attempting to explain, through the multiple linear regression analysis, as much of the variability in the B_{sp} observations as possible. Chemical emission inventories, described in Section IV.C.3, are extremely useful in isolating those aerosol species that are useful source tracers. Typical regression models include organic carbon or potassium mass concentrations as tracers for RWC emissions, Pb as a transportion tracer and Si as a soil dust tracer. Nitrate and Sulfate measurements are usually included to account for scattering associated with secondary aerosol. The reciprocal of the relative humidity may also be added to the list of independent variables, to account for humidity effects on aerosol size, which effect the scattering efficiency of fine particles.

Once the regression models are developed, predicted changes in average visibility conditions under altered emission scenarios can be made by increasing or decreasing the M_i concentrations of one species, while holding the others constant. Future year concentrations of specific aerosol species (M_i) are obtained from proportional rollback modeling of RWC emissions changes, given a knowledge of current RWC emissions and ambient impacts. As an alternative, future year M_i concentrations can be obtained by dispersion modeling of likely emission increases and application of source profile information. If, for example, a 10 ug/m^3 increase in woodsmoke impact is predicted by

a proportional or dispersion modeling analysis, and RWC emissions are assumed to contain about 36% organic carbon (see Tables IV-8 through IV-11) then a 3.6 ug/m^3 increase in organic carbon would be predicted. Associated visibility impairment could be estimated using the regression model already established for the airshed. The validity of this approach, of course, is dependent upon the stability of the regression model. This can be tested by iterative modeling using subsets of the ambient aerosol database.

7. Estimating RWC Impacts Through Atmospheric Tracer Studies

a. Overview

Chemical tracers (e.g., sulfur hexafluoride, SF_6) can be released in precise quantities and then measured through field monitoring in order to determine the pollutant dispersion characteristics for an area. The relationship between emissions released and resultant measured concentrations can be used to predict short term (e.g. peak 24 hr.) impacts, based on an inventory of RWC emissions.

This section addresses the use of tracers selected because they are not normally found in ambient air in significant concentrations. The use and applicability of other trace chemicals or elements selected because they comprise a measurable fraction of RWC emissions (e.g. methyl chloride, or carbon-14) are addressed in Section IV.C.3 and IV.C.4.

Tracer studies are discussed below in terms of: how they work; strengths and limitations; and, an example RWC application.

b. How Tracer Studies Work

Pollutant emissions disperse and result in concentrations of varying magnitude throughout an airshed. Certain "tracer" chemicals exist which can facilitate the determination of this relationship between emissions released and resultant concentrations. Sulfur hexafluoride (SF_6) is one of the most

commonly used gaseous tracers. SF_6 is non-toxic, detectable in the parts-per-trillion range, not typically found in ambient air at those concentrations, chemically stable, easily dispersed at a measured rate, and has a fairly low molecular weight which results in rapid mixing with the air (Collins et al, 1965). These characteristics make it possible to use SF_6 to simulate pollutant dispersion processes with precise measurement of release rates and resultant concentrations. The results are valid only for specific locations, and for the meteorological conditions which exist during the test. The data can be used to verify and modify a dispersion model for the study area.

c. Strengths and Limitations of Tracer Studies

Predicting the ambient air impact of a source is likely to be more accurate with the use of a tracer study than using computer modeling alone. This is because pollutant dispersion is a complex physical process to simulate mathematically.

Most models require wind flow fields to be simulated, yet wind speed and direction information are not always available. Due to the response threshold of typical anemometers, wind speeds below about two miles per hour are reported as calm. Thus during periods of flow reversal, when winds are light and variable, the available meteorological data may even be misleading (Willson et al, 1983). Reviews of the accuracy of various dispersion models in predicting concentrations for complex terrain commonly report model prediction performances in the range of a factor of two or worse (American Meteorological Society, 1984). If worst case meteorology is the period of interest, and the tracer study is conducted under poor dispersion conditions, the actual relationship found between emissions released and resultant concentrations can be used. The tracer study findings can also be used to select and suggest modifications to an appropriate dispersion model. When vehicle traverses are used to sample SF_6, with samples taken at intervals one tenth of the mile apart, a wealth of data are available for analysis. Having

measurements from hundreds of different locations can enable a much better understanding and simulation of the mechanics of local dispersion processes.

The ability to measure SF_6 at concentrations in the parts per trillion range and the stability of SF_6 enable accurate calculation of the relationship between emissions released and resultant concentrations. The use of actual RWC tracers such as potassium (K), methylchloride (CH_3Cl), or carbon, does not have such a clear cut relationship, since the percentage of RWC emissions which those compounds comprise can vary with wood type, and other variables.

A tracer study can be uniquely beneficial when planners are attempting to predict the air impact of a source before it is constructed or in operation. In such a case, there is no way to estimate impacts by receptor modeling since the emissions do not yet exist. Such an example is discussed in the next subsection.

SF_6 tracer studies can be expensive, generally costing more than $25,000. Actual costs depend on: 1) the number of tests, 2) use of ground vehicle vs airplane traverses and; 3) complexity of data interpretation, e.g. whether computerized dispersion modeling is included.

Although the relationship between emissions released and resultant concentrations can be quantified accurately, there are two key obstacles to determining RWC impacts from such a tracer study. First, predicting RWC impacts based on tracer study findings requires the input of some assumed amount of RWC emissions. There is always some error in estimating the emissions from a source, and RWC emission factors often have relatively high uncertainty. This same obstacle is faced in computerized dispersion modeling.

Second, tracer studies are done during time periods with specific meteorology. Field monitoring tracer studies without subsequent computer modeling can only characterize dispersion conditions present during the field tests. Some tracer study experiences help minimize this concern. For example, when two tests were done in Telluride, Colorado several days apart under conditions with different meteorology, the ratios of emissions released to resultant concentrations at the key site of interest were within 28% of each other (Wilson et al, 1983).

It is also difficult to duplicate with tracers the manner in which emissions are released from area sources - e.g. RWC. For example, area sources in a small confined area may be adequately represented by a single release point, but multiple release points would be necessary to simulate area source emissions for a metropolitan area SF_6 tracer study. It can also be difficult to simulate the time variation of an emission source, such as RWC, especially if there is limited information on emission rates vs. time of day.

d. Example Tracer Study

An SF_6 tracer study was conducted in 1982 in Telluride, Colorado with the goal of characterizing current and future potential RWC air impacts. The primary motivation for the study was the need of a Colorado ski resort developer to determine likely air impacts from Residential Wood Combustion if a large ski area development were constructed in this mountain resort area. Since dispersion modeling alone was judged an inadequate prediction tool in such complex terrain, the tracer study approach was selected.

Three different tracer release tests were conducted. Two tests were set up with tracer releases from the proposed new development area, and monitoring was conducted in the surrounding territory via fixed sites and auto traverse sampling. The third test was set up to simulate RWC emissions within the Town of Telluride, in order to characterize the impact of existing sources at various locations.

The tests improved understanding of the dispersion mechanics in and near the San Miguel Valley near Telluride. Actual results and methods are discussed by Wilson et al, (1983). Among the findings was the conclusion that each ton of emissions released per day in the Town of Telluride would tend to result in 24-hour particulate impacts of 179 ug/m^3 under the meteorological conditions which prevailed at the time of the experiment.

D. Dispersion Modeling

1. Overview of Dispersion Modeling

The development of Residential Wood Combustion (RWC) control strategies requires the application of dispersion models capable of accurately estimating RWC impacts under a variety of emission control scenarios. This section discusses a variety of models, their data base requirements, model validation and specific model applications in actual airsheds. The following text is intended only to address the application of dispersion models to RWC assessment. Readers interested in more general applications of these models should also refer to appropriate EPA dispersion modeling guidance, including: Guideline on Air Quality Models (U.S. EPA, 1978, 1984d); Interim Procedures for Evaluating Air Quality Models (Revised) (U.S. EPA, 1984e, 1985); "Regional Workshops on Air Quality Modeling" (U.S. EPA, 1981c); and to users guides for specific dispersion models of interest (e.g., U.S. EPA, 1973, 1977a, 1978a, 1979a, 1979b) on EPA's UNAMAP system. The joint application of dispersion and receptor models was discussed briefly in Section IV.C.5.

a. Introduction to Dispersion Modeling

Air Quality dispersion models are a set of mathematical equations relating the release of air pollutants to resulting concentrations of pollutants in the ambient atmosphere. Thus, they provide a tool for predicting the consequences of changing pollutant emission rates, or assessing the impact of an emission source(s) on ambient air quality standards.

Dispersion models are useful in developing and evaluating RWC control strategies designed to attain acceptable air quality, in

evaluating likely consequences of expanding emission growth, and in projecting future air quality trends and patterns associated with community growth.

In addition, dispersion model-derived estimates of RWC impacts are highly useful for identifying areas of expected high impacts, and providing insights on locating additional monitoring sites. Effective use of dispersion models, however, requires the collection and analysis of both meteorological and air quality data to provide a basis for model evaluation and validation. Monitoring of background pollutant concentrations associated with distant, upwind RWC sources that are not included in the emission inventory data base is also required.

Generally accepted practice is to complete a two level modeling analysis. The first level provides a screening analysis of potential RWC source impacts through the use of a simplified model analysis designed to estimate RWC impact under worst case meteorological situations. The second step, employing any one of a number of more complex models, is initiated if potential problems are identified during the screening analysis.

The second phase of modeling incorporates a more detailed treatment of actual meteorological episodes, terrain influences and dispersion characteristics of the emissions sources. Both phases of modeling require data on source emissions, air quality and meteorology, including wind direction, wind speed, atmospheric stability and mixing height information.

The choice of a dispersion model to be applied during the refined modeling analysis is primarily dependent on the level of detail required to fulfill the objectives of the analysis, the availability of input data and the physical nature of the airshed. In RWC applications, the most critical factors in selecting a model are its ability to accurately simulate area source emissions for 24 hours, seasonal and annual time periods.

RWC emissions are relatively nonreactive during short transport periods. RWC particulate matter emissions are predominantly within the fine particle size range, so complex particle deposition, reactivity and secondary aerosol formation assessments are not essential.

b. Considerations in RWC Applications

Dispersion modeling of RWC emissions presents several difficulties not usually encountered with point source modeling. These include the complexity of simulating the dispersion of low level, low buoyancy area source plumes that are subject to plume downwash around buildings.

Also airsheds adversely impacted by RWC emissions are often located in mountainous areas typified by complex terrain, where low wind speeds and stable atmospheric conditions can effectively trap pollutants. The limited availability of onsite meteorological data in rural areas, and/or difficulties in preparing accurate emission inventories of RWC emissions can further complicate dispersion model applications. Because of the limited ability of dispersion models to address the extremely complex nature of dispersion under such conditions, the analyst must exercise caution in the application of dispersion models within such airsheds. Comparisons with some form of receptor-oriented RWC impact estimates is especially advisable in such cases.

2. Applicable Dispersion Models

Although a number of dispersion models have potential application to RWC impact assessment, relatively few papers have been published documenting model applications and intercomparisons of modeling results. The models described below, however, have been found to be useful in RWC studies. This section lists the characteristics of various models and their application to woodsmoke impact assessment.

This discussion includes some of the standard models from EPA's "Users Network for Applied Modeling of Air Pollution", or UNAMAP system (U.S. EPA, 1983e), as well as other specialized models that have been applied to RWC analysis. Table IV-13 summarizes the characteristics of those models which have been commonly used in RWC studies. Each of these models are discussed in greater detail below.

a. EPA UNAMAP Models

A number UNAMAP models have been used in RWC studies, including ISCLT, ISCST, CDMQC, RAM and PAL. Each of these models is described below. Since the model's treatment of area source emissions is especially critical in RWC studies, the description focuses on this aspect of the model. More detailed descriptions of each model can be found in the US EPA guidance documents and users guides cited above. Several of these models require that the analyst select either urban or rural dispersion coefficients as inputs to the model. EPA guidance on this issue specifies that the analyst determine the land use within a three km radius of the source. If more than 50% of the land use is of an industrial, commercial or multiple dwelling residential nature, urban dispersion coefficients should be used (Auer, 1978). In addition, the analyst can specify an effective stack height for area source emissions. Work by Imhoff et al, (1984) suggests that a source height of four meters is appropriate for RWC emissions based on calculated building downwash effects which can occur even at low wind speeds.

PAL Model

PAL is a point, area and line source model used to calculate short-term concentrations of stable pollutants (U.S. EPA, 1978a). The model can be used to estimate RWC impacts within portions of an urban area at a maximum of 30 receptors. Calculations are performed for each hour and require hourly meteorological data (wind speed, wind direction, stability class and mixing height). Level terrain, steady state conditions and Gaussian plume dispersion are assumed. Area source emissions can be gridded for modeling in either squares or rectangles. Emission rates can be

TABLE IV-13. Dispersion Model Characteristics

Model	Averaging Period Annual	Averaging Period 24 Hour	Plume Dispersion	Complex Terrain	Met Inputs	Gridded Emissions
PAL		X	Gaussian	No	Hourly	Yes
RAM		X	Gaussian	No	Hourly	Yes
ISC-ST		X	Gaussian	No	Hourly	Yes
ISC-LT	X		Guassian	No	STAR	Yes
CDMQC	X	X*	Gaussian	No	STAR	Yes
GRID	X	X	Eulerian	Yes	Hourly	Yes
AREAS	X	X*	Gaussian	No	AIRDOS II	Yes
Box		X	Advection	Yes	Hourly	No
Rollback	X		Implicit	—	None	No
Holzworth	X		Gaussian	—	Published	No

* Requires statistical time average conversion. See Text.

varied hourly by specifying the fractional amount of emissions to be applied, thereby enhancing the ability of the model to accurately simulate diurnal variations in RWC emissions. Since Gaussian models fail to account for the hour-to-hour buildup of pollutants during low wind speed conditions 1 m/sec. is the minimum wind speed sanction for use in PAL), worst case short-term estimates may be under predicted. PAL is, however, especially useful for carbon monoxide (CO) RWC impacts, because it is able to simulate both the RWC area source and line source emissions of CO from vehicle exhaust.

RAM Model

The RAM model is useful for calculating short-term concentrations during a one year period in flat urban areas with point and area sources in multiple locations (U.S. EPA, 1979a). Like PAL, RAM is a steady-state Gaussian model which employs a narrow plume simplification to calculate area source concentrations. This assumption is appropriate for cases in which area source emission densities are relatively uniform. RAM can also accept diurnal variations in RWC emissions. Locations, size, emission rates and the effective plume height of the emissions are required for each area source. Meteorological data are input to CRSMET or RAMMET, two meteorological preprocessor programs which can be effectively used to sequentially scan the data base for worst case, 24 hour dispersion conditions.

ISCST Model

The ISC model (U.S. EPA, 1979b) is another steady-state Gaussian model used to estimate pollutant concentrations from a variety of point, area, line and volume sources for both short-term (ISCST) and long-term (ISCLT) periods. Both forms of ISC can account for particle deposition. Point source building-induced plume downwash is handled by the Huber-Snyder method. The area source treatment is calculated as a finite crosswind line source, or as a volume source in which the area source emissions within each grid are mixed within their respective cells and then advected downwind. The volume of the cell is determined by the dimensions of the grid

consistent with their climate and space heating demands. From these results they could estimate RWC emission factors in grams/kilogram of wood burned, for appliances of special interest in their areas.

This level of effort in estimating RWC emission factors for different types of RWC devices is not warranted to obtain a first approximation of RWC emissions. However, it may be useful in projecting future RWC emissions levels, for areas in which a significant transition to much cleaner burning appliances is anticipated over time. Under such assumptions, AP-42 RWC emission factors could substantially overpredict future RWC emissions. The following section discusses projection of future RWC emissions in more detail.

Another factor that may have to be considered in selecting appropriate local RWC emission factors is altitude (elevation above sea level). Recent preliminary findings (Shelton, 1985) have been interpreted by others (Oregon DEQ, 1985) as indicating that particulate and carbon monoxide emissions from both catalytic and non-catalytic woodstoves tested in Sante Fe, New Mexico (elevation: 7,300 feet above sea level) average about twice as high as emissions compared to the same woodstoves tested in Portland, Oregon (elevation: 75-100 feet above sea level). If these results are confirmed by more testing, they will represent a significant consideration for higher altitude communities in selecting appropriate RWC emission factors, as well as for EPA in revising AP-42. This development is consistent with EPA's development of different vehicle exhaust emission factors for use in higher altitude states, principally in the Rocky Mountains.

3. Projecting Future RWC Emissions

Projecting future RWC emissions levels typically begins by estimating RWC wood usage and corresponding emissions for some appropriate baseline year, using approaches such as those described in the previous two sections. Baseline emissions can now be extrapolated into the future using various trend factors - e.g.

A useful feature of this model is the ability to adjust predicted concentrations based on a linear regression analysis against measured RWC impacts. Meteorological inputs are similar to ISCLT, in that STAR deck data are needed. CDM does not treat building plume downwash, or particle settling/deposition, nor does it calculate plume rise for area sources. Flat terrain is assumed.

b. GRID Model

One example of a model that may be considered on a case by case basis, after a performance evaluation and approval by EPA, is the GRID model.

GRID is a numerical conservation of mass, Eulerian model (Hanrahan 1981a) which has several major advantages over Gaussian models in estimating RWC impacts. Principal among these is the model's ability to use a unique wind speed, wind direction and stability class for each grid cell for each hour. This is supplied by key station meteorological data and coded inputs describing airshed topography. The GRID model wind fields are calculated using the WEST meteorological preprocessor (Hanrahan, 1981a).

GRID's DTBASE emission inventory preprocessor (Hanrahan, 1981a) produces separate point and area source emission files in an input format suitable for GRID. It also apportions point and area source emissions into day and night time periods, and provides initial calculations of plume rise during stable and unstable conditions.

The model's cell array accomodates a user-defined grid cell size (e.g., two km), each of which may be divided into up to five vertical cells of variable height. This vertical zoning provides an important advantage in simulating low level RWC emissions, while also accomodating the higher plume rise associated with higher energy emissions from point sources.

A Brigg's (1975) plume rise algorithm is used for point sources. Area source emissions are assigned to the lowest cell (50 meters) existing above the topography. Because of the computational requirements of the model, the airshed climatology is often categorized in terms of discrete meteorological "regimes". Each of these describes a wind field pattern and stability, with a known seasonal frequency of occurrence. The model can, however, use hourly data developed for specific days.

Simulations are then prepared for each regime, and the outputs weighted based on regime frequency of occurrence, to arrive at an annual or seasonal average pollutant concentration. Short-term impacts may also be estimated on the basis of a worst case 24 hour regime.

Once the model is validated using all airshed point and area source emissions, impacts associated with specific sources can be estimated, by limiting the emission database used to only the source(s) of interest. Specific control strategies can be simulated, using their estimated reduction in specific source emissions.

The GRID model has been applied to RWC modeling in Portland, Oregon. This experience demonstrated the importance of specifying the distribution of emissions during the day, and the value of comparison of the modeling results with those obtained from receptor (e.g., CMB) models. For example, the initial GRID model predictions underestimated CMB results by one-half (Hanrahan, 1981b).

This discrepancy led to a review of the EPA (AP-42) RWC emission factor used, which at the time was 22 pounds per ton of wood burned. This was based on the EPA Method 5 source testing method, which excluded the condensible organic fraction of the RWC emissions. Comparison of the Chemical Mass Balance/GRID impact

estimates, however, indicated that a 75% increase in the emission factor to 38.5 pounds per ton would yield comparable impact estimates.

Chemical Mass Balance/CDMQC results for the Medford, Oregon airshed were similar, so the higher emission rate was also used in the control strategy development modeling for this airshed. Subsequent to this work, the AP-42 woodstove emission factor has been changed to 40 pounds per ton of wood burned (U.S. EPA, 1983b). Following corrections to the emission inventory, the GRID model was used to predict future (1987) RWC impacts based on estimated emission growth and assuming typical worst case winter meteorological conditions. Results from the modeling with GRID in Portland, Oregon indicated RWC impacts ranging from 6.9 (industrial receptor) to 37 ug/m^3 (residential area), compared to impacts of 6.2 to 7.4 ug/m^3 for all point sources at the same receptors (Core et al, 1980).

c. Screening Models

Box Models

The simplest and most appropriate screening analysis for estimating worst case 24-hour impacts involves the use of the basic box model. In this model, the change in pollutant concentrations over time is directly proportional to the source emission strength, mixing height and wind speed through the mixing layer:

$$X = X_o e^{-nt} + \frac{Q}{Hn} (1 - e^{-nt}) \qquad (9)$$

Where:

X_o = Ambient Concentration entering the box (ug/m^3)
X = Ambient Concentration (ug/m^3)
Q = Emission Strength within the box ($ug/sec/m^2$)
U = Average Mixing Layer Wind Speed (m/sec)
H = Mixing Height (meters)
n = Loss factor (sec^{-1})
t = Time

When wind transport is the only loss mechanism and steady state conditions are assumed, equation 9 can be simplified to:

$$X = \frac{QL}{\bar{U}H} \qquad (10)$$

Where: L=Box Width (meters)

This model assumes that pollutants are well mixed instantly after release, and that the atmosphere is unstable, assuring good vertical mixing. Values for L, the box model width, are determined by the location of topographical features which limit pollutant dispersion.

Rau has applied the box model to the Medford, Oregon airshed to estimate RWC emission impacts over a series of 24 hour periods for which fine particle (< 2.5 um) carbon data were available (Rau, 1981). Earlier studies by DeCesar and Cooper have demonstrated that 60% of the airshed's carbon emissions originated from RWC sources (DeCesar and Cooper, 1981).

Comparisons of the variability of measured atmospheric fine carbon concentrations and those predicted by the box model showed that these were highly correlated ($r=0.87$). Figure IV-6 illustrates a comparison of measured fine particle carbon concentrations versus box model estimates.

Proportional Rollback Model

A rollback model is based on the simple assumption that source impacts are directly proportional to emissions. A source's contribution to measured ambient concentrations is calculated by multiplying the measured concentrations by the ratio of that source's emission rate to the total emissions rate of that pollutant from all other sources in the airshed. Thus, absolute pollutant concentrations are not predicted. Only the relative contribution of the sources in the emission inventory and the

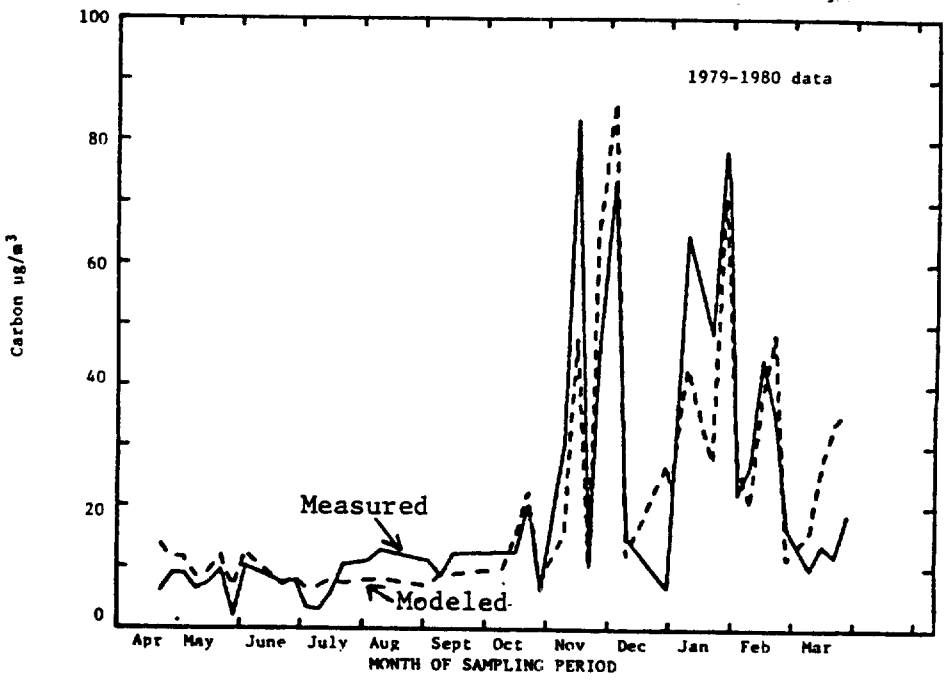


Figure IV-6. Modeled vs Estimated Atmospheric Carbon Medford, Oregon (1979-80)

Source: Rau (1981)

relative changes in concentrations over time are calculated. The relative changes can be used in association with receptor modeling results to estimate likely RWC impacts in future years.

Holzworth Urban Model

Historical meteorology and urban size are used in the Holzworth model to estimate the ratio of concentrations to emissions, expressed as X/Q, where: X = ground level concentration of a pollutant in air, and Q = the emissions rate of the pollutant from a source(s). This ratio can be used to calculate RWC impacts by multiplying the annual average normalized concentration (X/Q) by the RWC emission rate (Holzworth, 1972). The principal assumptions are that steady-state conditions prevail, emissions occur at ground level and are uniformly distributed over the city, emissions are non-reactive and emissions are uniformly distributed within the mixing layer. Sources are treated as a continuous series of infinitely long cross-wind line sources. Values for X/Q as a function of mixing height (H), wind speed (U) and along-wind distance across the airshed (S) have been published by Holzworth for cities 10 and 100 Km in size. Since the X/Q values are presented in terms of frequency of occurrence, results obtained with this model also represent the frequency of occurrence with which the source impacts can be expected to occur.

d. AREAS Model

AREAS is an area source model which estimates annual average pollutant concentrations at ground level in each of 400 grids within a 20 by 20 grid area (Moore, 1978). Particulate or carbon monoxide emissions from low level dispersed sources can be modeled.

Input data include the total emission rate within the study area (micrograms per second), the fraction of the total emissions within each of the 400 grids, and the grid size (meters). Two km grid sizes are commonly used.

The model allows point source model to be used in an area source mode. It does not employ meteorological data as inputs but instead uses an array of 400 X/Q values (pollutant concentration/emission rate from the source) to describe pollutant behavior. These X/Q values may be derived from any point source dispersion model to provide an output file (uu/m^3 estimates) for direct input to AREAS. For example, AIRDOS II - a Gaussian plume model which estimates pollutant concentrations based on annual average meteorological data has been used for this purpose (Moore, 1977).

Uniform annual-average meteorology across the grided area, and uniformly distributed area source emissions of similar magnitude, are assumed. Accordingly, results obtained from AREAS are only as valid as these assumptions.

3. Dispersion Modeling Analysis

The extent to which a specific model may be suitable for RWC impact assessment depends on the detail and accuracy of the database, the meteorological and topographical complexity of the area to be studied, the modeling resources available to the analyst, and the level of confidence needed in modeling results. Generally, the greater the degree of detail with which a model considers such factors as spatial and temporal variability in emission and meteorological conditions, the greater the ability of the model to evaluate source impacts under a number of control strategy scenarios. A complete analysis may require the application of a complex terrain model such as GRID. However, the cost associated with the development of an appropriate database may be difficult to justify, if a simple box model analysis provides the level of confidence required by decision makers.

The principal steps in the dispersion modeling process are discussed below:

a. Input Information

As a first step, the analyst should evaluate the availability, quantity and quality of meteorological data, air quality data, and emission inventory information within the airshed. If on-site

surface and upper air meteorological data are not available, an evaluation of the applicability of data from the nearest National Weather Service site should be made. The evaluation should consider topographical features which may alter on-site wind speeds and direction, the representativeness of upper level winds, and potential differences in atmospheric stability. If possible, a comparison of surface winds observed during a brief period in the winter months at both sites should be completed.

Models such as GRID which require a large amount of detailed input data cannot be applied to most airsheds without an intensive period of database development. Assuming that the available data are adequate to support models such as ISC, CDMQC, PAL or RAM, the second step is to evaluate each model's treatment of area source emissions, the importance of including point and line sources in the analysis, and the number of receptors to be modeled. Consideration of each of these elements will be important in selecting the appropriate model, should the screening model analysis indicate a need for additional work.

b. Model Comparisons with Measured RWC Impacts

A limited number of studies have been published which compare dispersion model predictions with direct measurements of RWC impacts. This section reviews five such studies which compared Chemical Mass Balance (CMB) measurements of RWC impacts with estimates from a variety of dispersion models, in locations in Alabama, Tennessee and Oregon. Table IV-14 summarizes dispersion model and CMB comparison data from these studies.

The Tennesee Valley Authority (TVA) conducted two studies of RWC impacts in Petersville, Alabama (Imhoff et al, 1982, 1983) and one in Nashville, Tennesee (Imhoff et al, 1984). The Petersville studies both covered 10-day periods in February of 1981 and 1982, respectively, and monitored at residential sites. CMB indicated RWC accounted for most (80-90%) of the ambient fine particulate levels, which TVA attributed mostly to woodstoves with only minor contributions from fireplace emissions.

TABLE IV-14. Comparison of Dispersion Model and CMB Estimates of RWC Impacts (ug/m^3)

Airshed	CMB (1) RWC Impact	Rollback Model	Holzworth Model(2)	CDMQC Model	ISCST Model	GRID Model	PAL Model
Petersville, AL	34.9 (3a)	-	-	-	-	-	45.8
" "	65.1 (3b)	-	-	-	-	-	88.0
" "	26.3 (4a)	-	-	-	23.7-28.9	-	-
	117.0 (4b)	-	-	-	65	-	117
Nashville, TN	8.7 (5)	14.2	2.5	7.8	-	-	-
Medford, OR	21.5 (6a)	-	-	19.4	-	-	-
	5.8 (6b)	-	-	6.5	-	-	-
Portland, OR	5.8 (7)	-	-	-	5.5-7.7	-	-

Table Notes:

(1) Estimates of RWC impacts from chemical mass balance (CMB) analysis of fine particulate (< 2.5-3.0 um) samples;

(2) 50th percentile values

(3) From Imhoff et al (1982): a) 24 hour study period average, based on seven days during February 2-14, 1981; b" highest 24 hour average RWC impact, February 6, 1981.

(4) From Imhoff et al (1983): a) 24 hour study period average during February 6-15, 1982, based on twenty consecutive 12 hour samples; b) maximum 12-hour average - recorded 6 PM, February 13th to 6 AM, February 14, 1982.

(5) From Imhoff et al (1984); 24 hour study period average for the first quarter of 1982, also averaged over three monitoring sites, affording a generalized impact for the metro area.

(6) From Core and Cox (1982) and Hanrahan 1981b); 24 hour average for winter heating season (1979-80) at two Medford area sites: a) Medford Central Business District; b) White City industrial area, eight miles from Medford.

(7) From Hanrahan (1981b); annual (1977) average RWC impacts at a residential site (Flavel School). Range of values reflects the reported range of uncertainty in CMB estimates. CMB versus GRID estimates at three other sites showed comparable agreement.

The first Petersville study used several mobile vans to collect air quality and meteorological data in and around a residential area where RWC occurred. The study then compared CMB estimates to PAL model estimates. PAL predicted higher 10-day average RWC impacts, and maximum 24-hour average RWC impacts about 30-35% higher than (CMB estimates (Table IV-14), and overpredicted total fine particulate impacts by a factor of two.

The second Petersville study was conducted at two fixed sites (residential neighborhood and rural background sites). This study compared CMB estimates primarily to ISCST model estimates, with comparison also to a PAL model estimate for the single 12-hour period of maximum measured RWC impact. For wind speeds 1 m/sec, 10-day average RWC impacts estimated by ISCST were within 10% of CMB estimates, although the model underpredicted the maximum (12-hour) RWC impact measured by a factor of two (Table IV-14).

Despite close agreement between CMB and PAL estimates for the maximum 12-hour RWC impact (Table IV-14), and greater ease in using PAL versus ISCST, the authors concluded that the ISCST model yielded more realistic X/Q values (concentration/emissions) than PAL for area sources like RWC. This was because PAL estimated X/Q values 2-3 times higher than did ISCST for stable, low wind speed conditions considered more representative of maximum RWC impact situations, based on work by TVA and others. For example, TVA cited a previous comparison of ISCST and PAL models, which found that at a distance of 250 meters, PAL estimates were a factor of three higher than ISCST estimates during D stability and 3.5 meter/second wind speed for surface emissions from an area source 50 meters on a side (Gschwandtner, et al, 1982).

Figures IV-7 and IV-8 illustrate CMB-estimates (o) versus maximum and minimum ISCST-calculated RWC impacts for the following two wind speed cases: a) measured wind speeds, except using 1 meter/second as a minimum wind speed value, consistent with user guidelines (Figure IV-7), and; b) measured wind speeds, with a 0.34 meter/second minimum wind speed, which was the minimum detectable by the meteorological equipment used. The modeled concentrations increased significantly for calm nights, when RWC

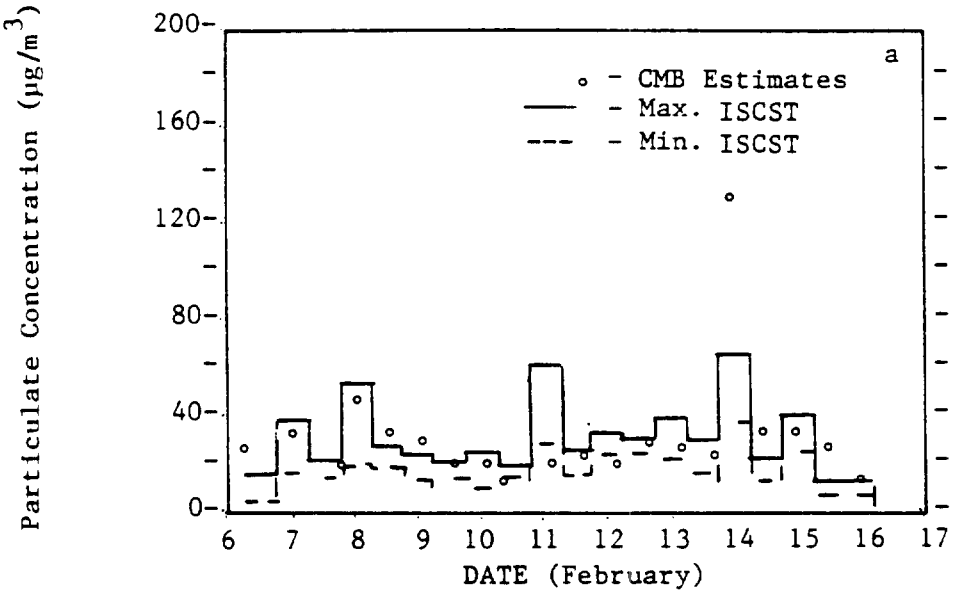


Figure IV-7. CMB-Estimated vs ISCST-Estimated RWC Impacts (1 m/s Minimum Wind Speed)

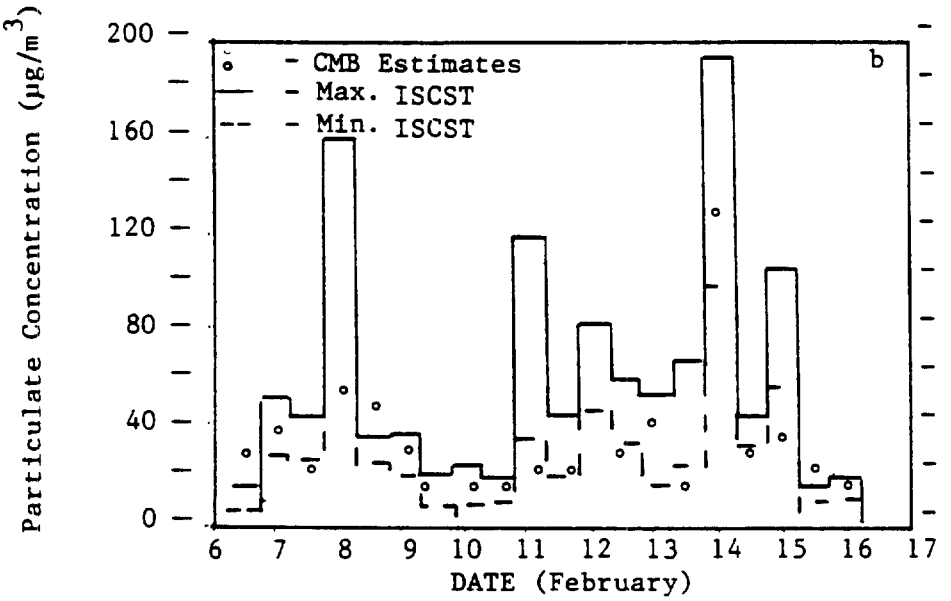


Figure IV-8. CMB-Estimated vs ISCST-Estimated RWC Impacts (0.34 m/s Minimum Wind Speed)

Source: Imhoff et al, 1983

impacts estimated by CMB were highest, resulting in ISCST estimates consistently higher than CMB estimates (Figure IV-8). TVA researchers noted that using Gaussian models with dispersion coefficients based on Pasquill's experiments, it is difficult to assess how representative calculated concentrations are at wind speeds less than one meter/second. Unfortunately, these are typically the conditions under which maximum CMB estimates of RWC impacts are observed (Imhoff et al, 1983).

Another TVA study compared CMB estimates of RWC impacts in the Nashville, Tenneseee metropolitan area during the first quarter of 1983 (Imhoff et al, 1984) with estimates from three dispersion models - CDMQC, rollback and Holzworth. RWC was estimated to account for 22-66% of fine particulate (< 3um) levels and 15-28%. The maximum 24-hour RWC impact measured was 51 ug/m^3.

CDMQC season average estimates were quite consistent with CMB estimates (7.8 versus 8.7 ug/m^3 respectively; Table IV-12). Rollback model estimates overestimated RWC impacts, while Holzworth model estimates underestimated RWC impcts by a factor of three to four. The latter are 50th percentile estimates, and hence not strictly comparable to the others.

CDMQC estimates of RWC impacts averaged over an entire heating season (1979-80) also agreed well with CMB estimates at several sites in the Medford, Oregon area (Core and Cox, 1982; Hanrahan (1981b). Annual (1977) average RWC impacts estimated by CMB methods at four sites in Portland, Oregon also agreed well with GRID-model estimates (Hanrahan, 1981b). In both Oregon studies however, the CMB estimates and other information were used to refine emission inventories for RWC and other particulate sources, in order to achieve as close agreement as possible between the CMB and dispersion modeling estimates. Accordingly, these comparisons represent optimized cases of of dispersion model versus CMB estimates of RWC impacts.

Overall, these studies suggest that dispersion modeling is capable of estimating RWC impacts in good agreement with CMB estimates. However, it is also clear that the selection of dispersion model(s) to be used, and the model's capability to similute stable meteorological conditions, can have a large effect on the RWC impacts calculated.

The limited studies cited above indicate that ISCST and CDMQC, GRID, and even PAL can estimate RWC impacts consistent with CMB estimates. Other models not tested in these studies may also yield close agreement for RWC analysis - e.g., RAM, box models, and others. Table IV-15 summarizes some of the principal advantages and disadvantages of several dispersion models that have been or could be used in RWC assessment studies.

EPA must approve any dispersion modeling of RWC impacts undertaken for regulatory application - e.g., SIP development. For models not already recommended for particular applications in EPA modeling guidance, this could require a site specific performance evaluation in accordance with EPA dispersion model evaluation procedures (U.S. EPA 1984e).

c. Analysis of Background Concentration

Development of RWC control strategies using dispersion models requires that background concentrations of woodsmoke transported into the airshed be considered. Such estimates are developed through an analysis of ambient air quality data obtained from an upwind remote (rural) site that is unaffected by emissions within the study area. Winter season particulate data obtained from the background site should be screened to identify days on which the site was upwind of the study area, and the wind persistence (ratio of vector averaged wind to average wind speed) was greater than 0.7 over a 24 hour period, corresponding to an hourly wind direction deviation of 45^{o}. CMB model-estimated RWC impact data are preferred but fine particle mass data (< 2.5 um) can also

TABLE IV-15. Dispersion Model Advantages and Disadvantages for Applications to RWC

Model	Advantages	Disadvantages
PAL	Treats point area and line sources in same simulation	Simulation area is relatively small - e.g. a portion of the metropolitan area. Assumes flat terrain.
	Relatively easy and to run. Not for seasonal/annual averages	Tends to overpredict RWC impacts under low wind speed, stable conditions in model intercomparison analysis (Imhoff, 1983)
RAM	Modeler can extract worst case meteorology from sequential data via RAMMET	Assumes flat terrain
ISCST	Best area area source treatment among Gaussian models. Area source may be treated as volume sources of specified height	No terrain allowed which is greater than stack weight
	Variable area source size.	
	Worst case meteorology can be extracted by modeler from sequential data via CRSMET	
CDMQC	Acceptable area source treatment has been achieved for airshed	Cannot simulate volume sources, assumes flat terrain.
	with heavy RWC impacts (Hanrahan, 1981b)	
	STAR meteorological data available for a wide number of locations.	Requires statistical inference to estimate worst case 24-hour impacts ,which is no longer recommended by EPA for regulatory applications.
GRID	Best meteorological treatment of area sources.	Simulation costs are high
	Wind flow fields can become curvilinear near terrain.	Large meteorological data base input required.
Box	Simple and inexpensive to use.	Size of the box is often difficult to determine and a critical parameter in
	Adaptability to simulate complex terrain may make box models more practicable for such cases than more complex models	Low level of credibility

be used. TSP mass concentrations should not be directly used. However, a useful estimate of woodsmoke background concentrations can be obtained from TSP filters, if they are analyzed for organic (preferred) or total carbon.

d. Model Evaluation

Dispersion model evaluation studies, such as those described above, can greatly increase the analyst's level of confidence in the model predictions. Model evaluation studies can be conducted using fine particle mass concentration, ambient aerosol organic carbon data, Chemical Mass Balance estimates or other indicators of RWC impacts described in Section IV.C.

Anderson et al, (1984), Core and Cox (1982), and Hanrahan (1981b) have each described similar protocols for evaluating dispersion models using receptor model estimates of source impacts. Briefly, the process requires comparison of same-day receptor and dispersion model RWC impacts for the same sampling site. Also required are identification of discrepancies, isolation of assumptions or database errors causing the descrepancy, error correction, and final modeling. The benefits derived from this procedure, in terms of increased confidence in the final RWC impact assessment, are invaluable during development of control strategy programs.

e. Analysis of Results

Upon completion of the model validation step, dispersion model predictions of 24 hour, seasonal or annual concentration can be conducted. Spatial distributions within the airshed can now be predicted, by running model simulations for different locations. Projection of future air quality impacts of RWC emissions can be simulated, and control strategy options can be evaluated, using the model.

f. Modeling Carbon Monoxide Concentrations

Upon completion of the particulate model validation step, RWC CO, B(a)P or oxides of nitrogen (NO_x) emission inventories can also be input to the model to estimate ambient impacts from these pollutants. Optionally, a model postprocessor program can be used to estimate contributions of these pollutants by multiplying the concentrations of RWC particulate impacts by the CO or NO_x relative emission strengths (e.g. Q_{CO}/Q_{PM}), assuming no atmospheric transformation. This requires that the initial model runs be made with unit emission rates. Since CO emissions may principally be transportation oriented, development of a suitable CO ambient air quality database for model validation may be difficult. Accordingly, validation of the model using particulate emission inventories is suggested as an initial step. ISCST modeling of CO and NO_x concentrations in Petersville, Alabama indicated that 3.6% and 21% of the NO_x and CO ambient concentrations were related to woodstove and fireplace emissions, respectively (Imhoff et al, 1983).

g. Other Airshed Applications

In addition to the Nashville, Petersville, Medford and Portland dispersion modeling studies noted above, CDMQC modeling of RWC particulate and CO emissions are being conducted by the State of Colorado for Denver, Fort Collins and Grand Junction. Simple Box models have been applied in Bangor, Maine (Anderson et al, 1984) and Vail, Colorado (Meyer, 1981).

The State of Vermont has used the Texas Climatological Model TACB (1980) to predict seasonal average RWC impacts in Waterbury, Vermont, using emission inventory data developed through household surveys and local meteorological data. Modeling results were not verified against ambient measurements. The relative results among source groups, however, were consistent with the emission inventory. They were not, however, considered conclusive because

of complex terrain and windfield limitations. Hourly impacts predicted by the Texas Episodic Model TACB (1979) indicated RWC impacts of 60-120 ug/m^3 under one meter per second winds speeds and 20 meter mixing heights that occur during calm, clear and cold winter mornings.

h. Use of Dispersion Modeling To Evaluate RWC Control Measures

A major application of dispersion modeling to RWC analysis is in simulation of the potential effectiveness of candidate RWC emissions control measures in reducing ambient pollutant levels attributable to RWC. This topic is discussed in section V.D.2 of this document.

E. Stepwise Approach to Characterizing RWC Ambient Impacts

This section describes three different hypothetical levels of effort that could be undertaken to estimate RWC ambient impacts, and their approximate costs. This is intended to illustrate the types of measurements and analyses that could be conducted with very modest study resources, and additional information that could be obtained with additional funds. The cost estimates are general approximations intended only as guidelines, to assist localities in considering site specific studies. Localities considering initiating a study to quantify RWC (or other particulate) impacts, should also consider EPA guidance on modeling and monitoring relative to national particulate standards, as well as the level of study effort needed to answer local questions, and achievable with available resources, as discussed in this section.

After EPA's proposed fine particulate (PM_{10}) National Ambient Air Quality Standard (U.S. EPA, 1984g) is promulgated in final form, the resulting development of particulate State Implementation Plans (SIPs) will provide an opportunity to use many of the monitoring and modeling methods described in this document. EPA's proposed PM_{10} SIP development guidance (U.S. EPA, 1984f) discusses recommended modeling approaches for demonstrating the adequacy of any control strategies proposed for attainment and maintenance of PM_{10} standards.

This PM_{10} modeling guidance indicates that model preferences depend upon such factors as the type of monitoring data available (TSP versus fine particulate data), and the time scale (annual or 24 hour) of the non-attainment problem. Both receptor and dispersion modeling are discussed, and their joint use is recommended for both annual and 24 hour PM_{10} source apportionment. Any RWC impact assessment study which is intended to support SIP development should be planned in light of the appropriate SIP guidance, so that field monitoring and sample analysis can support any subsequent modeling efforts cost-effectively. Also, since any dispersion or receptor modeling used to demonstrate the attainment/maintenance of ambient standards in SIPs must be approved by EPA, any models used for this purpose should either already be sanctioned by EPA in its SIP Guidance (e.g., see U.S. EPA, 1984f, for PM_{10} modeling guidance), or be evaluated in consultation with EPA using EPA's model evaluation procedures (U.S. EPA, 1984e).

Study resources available must be matched with the program objectives and the degree of confidence desired in the conclusions. In general, if a high level of confidence is required, more of the program resources must be directed toward the completion of several independent impact assessment methods, instead of reliance on any single source apportionment method. Regardless of the specific modeling approach adopted, several of the qualitative methods described above should be used and compared, to assure the reasonableness of results.

The three levels of effort described below emphasize the Chemical Mass Balance (CMB) receptor modeling approach for several reasons, but this does not imply that dispersion modeling is not advisable especially if a validated dispersion model is already available for the study area. CMB receptor modeling is emphasized here because of its strengths in diagnosing RWC impacts specifically, using a limited number of field monitoring samples, and especially in complex terrain situations where dispersion modeling uncertainties are greatest.

CMB methods lend themselves well to preliminary screening assessments as well as to sophisticated aerosol characterization studies. CMB findings can be used to improve dispersion models - e.g., by detecting deficiencies in their emissions data base for specific sources. Dispersion models may then be preferred tools for assessing RWC impacts in locations which have no monitoring data, or for estimating how emission control strategies might reduce future ambient pollutant levels. However, the costs to develop and apply dispersion models is not included in the three levels of effort described below, because CMB approaches alone can generally quantify RWC ambient impacts with less uncertainty and less initial cost than dispersion modeling approaches.

Three levels of RWC impact assessment, at increasing levels of sophistication, are proposed as follows:

- Level I: semiquantitative approach based on evaluation of existing data and analysis of hi-vol (TSP) samples.

- Level II: quantitative program employing at least three monitoring sites followed by data analysis.

- Level III: Intensive monitoring program involving at least five sites utilizing several independent monitoring and analysis approaches to RWC assessment.

Each level of analysis requires more resources than the preceeding one but provides results of greater reliability. In the following discussion, a four-month field program during the winter season is assumed in all cases. Analysts interested in the Level II and III programs should first complete an evaluation of existing air quality and emission inventory data, as outlined in the Level I program.

A single program protocol and cost estimate for each level of effort described here is not appropriate or possible. Analysts must use judgement and make appropriate changes for their locations, meteorological

conditions, and study objectives using the following information as guidelines. General field monitoring and design considerations for source apportionment studies are discussed in Section IV.B, Gordon et al, (1984), and the EPA Technical Series on Receptor Modeling Volumes I to V (EPA 1981a, 1981b, 1983a, 1983b, and 1984).

Table IV-16 summarizes the approximate resource requirements of each program design level for labor, sample analysis, data analysis and computer costs. The program cost estimates presented in this table assume that air monitoring technician labor and air sampling equipment are available during the field monitoring phase of the project. Estimates for technician and analyst labor are estimated at $7 and $13 per hour exclusive of overhead, administrative and profit costs. Adjustments to the estimates shown should be made, if needed, to reflect other labor or non-direct rates. If adequate monitoring equipment is not available, it can often be borrowed from other governmental agencies or leased from private sources. Since capital costs for equipment are a major expense in any field study — and considering the short term nature of most field programs -- purchase of the monitoring equipment is often difficult to justify unless a need for a continuous program can be argued.

Table IV-17 provides a listing of the air sampling equipment requirements of the Level I, II and III programs. In light of EPA's current proposals for a size specific particulate standard, dichotomus sampling with 2.5 and 10 micron (um) cut points is included for Levels II and III. Hivol TSP sampling at one or more of the Level II or III sites may be included if the analyst wishes to evaluate the impact of RWC emission to TSP.

1. Level I: Semi-quantitative Study Design

   Level I analysis is the first step towards estimating RWC ambient impact level for an airshed. It is recommended as a screening method where the extent of RWC impact is not known. The Level I program requires minimum resources while providing a first-cut approximation of RWC impacts. It utilizes existing ambient air quality data, source

TABLE IV-16. Approximate Program Costs

Program Level	Direct Labor Analyst	Direct Labor Technician	Analytical Costs (a)	Computer Costs	Total Program Costs (b)
Level I	$ 1,800	$ 200	$ 4,000	minimal	$ 6,000
Level II	$ 4,000	$ 5,500	$15,000	$1,500	$25,000
Level III	$10,000	$10,000	$50,000	$5,000	$75,000

(a) Unit costs noted in Table IV-6.
(b) Approximate costs in 1984 dollars, exclusive of air sampling instruments and some specialty analyses, e.g. for certain toxic air contaminants such as benzo(a)pyrene, B(a)P.

TABLE IV-17. Air Sampling Equipment Requirements

Program Level	HiVol TSP	Dichotomous Samplers(a)	Sequential Sampler(b)	Int(d) Neph.	Meterological(e)	Other(f)
I	1	none	none	1	1	^{14}C
II	none	6 (c)	0 to 3	1	1	^{14}C
III	none	5	5	1 (minimum)	1	CH_3Cl, ^{14}C, ^{14}CO

(a) Two samplers required per site; one with membrane and one with quartz/glassifier filter.
(b) Equipped with 2.5 um inlet; dual port configuration for simultaneous glass fiber/Membrane filter substrates for XRF and carbon analysis.
(c) Only 3 samplers required (1 per site) if sequential samplers are also used.
(d) Int. Neph = Integrating Nephlometer.
(e) temperature, wind speed; wind direction.
(f) Other sampling includes specialty sampling equipment discussed in Section IV-B.

profile information, planned and/or historical TSP hi-vol samples, and local emission inventory data. The design is based on samples taken on a sixth day sampling schedule at one or more monitoring sites over a four-month winter period. Samples selected for analysis should include those most likely to contain maximum RWC impacts, including samples from residential areas if possible. Archived filters from previous winter periods may be used for this evaluation.

The twenty-four TSP samples collected during this period should be analyzed by atomic absorption for Iron (Fe) and Potassium (K). Elemental and organic carbon may also be completed to provide a data set for enrichment factor analysis using Fe as a crustal reference element. Time series and RWC impact analysis using organic carbon as a tracer can also be completed (Section IV.C). To determine the validity of organic carbon as an RWC tracer, optical microscopy analysis of five selected worst case filters should be completed. The microscopy data can be used to determine the extent of coarse mode carbonaceous particles (leaf fragments, etc.) on the filters. The K concentrations can be used to estimate RWC impact using a simple linear regression model (Section IV.C).

If it can be shown through chemical emission inventory that RWC is the predominant source of organic carbon (OC), an upper-limit estimate of RWC impact can be obtained by subtracting from the measured OC the amount of coarse mode carbonaceous particles identified by microscopy. Radiocarbon analysis of the same five selected worst case filters can also be used as an independent measure of RWC impact, if non-RWC modern carbon sources are not present in the airshed (e.g. field residue burning, forest fires, etc.)

Integrating nephelometer measurements can be and have been, used to document RWC impacts. Since RWC emissions are primarily fine particulates, elevated nephelometer readings during typical heating periods (especially in residential neighborhoods) can often be attributed to RWC emissions for an RWC-dominated site. The organic

carbon to TSP ratio can be correlated with scattering coefficient (bscat) measurements to evaluate common variablility. The organic carbon measurements can be used to estimate the extent of RWC impact, which can also be tracked with bscat measurements on a real time basis (Harris 1983, Tombleson et al, 1983). Carbon thermogram analysis can also provide another qualitative indicator of the presence of woodsmoke aerosols. Example applications and explanations of these methods are covered in Section IV. C.4.

The principal limitation of the Level I approach is related to the use of hi-vol TSP filters as the sample collection medium. If RWC impacts are marginal, the organic carbon (OC) blank of the glass fiber filters may be significant. In addition, the presence of coarse mode carbonaceous particles from "modern carbon" sources (other than RWC) can cause the radiocarbon RWC estimates to be incorrect, overestimating woodsmoke impacts. As a result, the findings of a Level I analysis should be considered tentative pending completion of a field program in which fine particle samples can be obtained and a detailed data analysis can be conducted. Results of Level I analysis can be very useful in guiding Level II and III program designs.

2. Level II: Quantitative Study Design

The Level II design incorporates three monitoring sites operated daily (12 to 24 hour samples) over a four-month period. The analytical costs noted in Table IV-16 include gravimetric analysis for about 700 fine (<2.5 um) and coarse mode (<10 um) filters. From this set of samples, 20 to 30 days are selected for analysis by X-Ray fluroescence, and for elemental/organic carbon and ions. Resources for radiocarbon analysis of three to five worst case filters, and computer costs for completion of 60 Chemical Mass Balance (CMB) calculations, are also included. Although the coarse mode samples are not included in the analytical protocol, the gravimetric data from the

fine and coarse mode filters provide a basis for estimating RWC impacts on PM_{10} levels. Direct labor costs include two months of analyst time for data analysis and reporting tasks and over four months of technician's time to service the sampling sites.

Locations for sampling sites include: one upwind (background) and two downwind sites where maximum concentrations are anticipated on the basis of preliminary screening, modeling, or monitoring sites measuring TSP violations. Site location and field monitoring design considerations are covered in Section IV.B. Dichotomous samplers are recommended for Level II analysis to provide improved source resolution (EPA 1981a) and to assertain RWC impact on PM_{10}. Shorter sampling duration can provide better source resolution if adequate sample size for analytical accuracy can be assured. Some of the design parameters may be varied according to the results of Level I efforts, project objectives and resources (Table IV-17).

The principal receptor modeling method used in the Level II analysis is Chemical Mass Balance (CMB) or other multivariate analysis using source profile information from the literature. The CMB analysis can be validated against radiocarbon analysis of 5 samples and correlated to scattering coefficient measurements (for an RWC dominated site), carbon thermogram patterns and chemical emission inventory/enrichment factor analysis (Section IV.C.4).

In contrast to the Level I analysis, the Level II effort should provide a higher level of confidence in the conclusions, since state of-the-art monitoring, analytical and modeling methods are used. In addition, the measurements made at the background and downwind or nonattainment sites provide useful information for determining the amount of "local" versus "transported" RWC emission impacts, as well as a measure of the importance of RWC impacts to regulatory programs. For example, if RWC aerosols are measured in substantial concentration at the upwind site, they would need to be subtracted from the downwind

measurements to evaluate local RWC contribution. This background site measurements are required to estimate the extent and nature of air pollution transported into the airshed.

The principal limitation of Level II analysis, however, is the use of literature-derived source profile data sets. Inclusion of an additional $3000-$5000 in source testing and analytical testing would correct this deficiency. This is done in Level III analysis, as described below.

3. Level III: Optimum Program Design

The Level III program incorporates daily eight to 24 hour sampling at five monitoring sites with complete fine particle filter analysis (XRF, carbon and ions) for 20 selected days. An intensive 12 day sampling period in which short term samples are collected at each of the five sites should be incorporated, if only 24 hour samples are collected during the rest of the program. Since most of RWC contribution is in the fine mass fraction, filter analysis is generally restricted to this fraction. However, coarse particle mass data is obtained to provide an estimate of RWC impacts on PM_{10} concentrations. Specialized sampling and/or analyses which are described in Section IV.B and are recommended for Level III.

- Methyl chloride (CH_3Cl) measurements - Section IV.B.4
- Particulate radiocarbon measurements - Section IV.B.4
- Radiocarbon measurements on CO to assess RWC CO impacts - Section IV.B.4

Inclusion of these special purpose sampling methods would provide independent verification of RWC impact, and result in conclusions with a higher level of confidence.

The source composition profile for RWC is obtained for the airshed by stack sampling (preferably using dilution sampling methods). Dilution

sampling is source sampling with dilution air, to simulate the atmospheric history stack samples would face prior to reaching receptor sites and ambient sampling. This will assure a representative source profile for the airshed. Dilution sampling is recommended to simulate the real world situation and to collect condensable species. The stack samples should be collected in size fractions similar to those collected at ambient monitoring sites. Further details on stack sampling methods are found in Harris, (1985) and Gordon et al, (1984).

The importance of well thought out sampling procedures is shown by Rau and Huntzicker (1985). Rau and Huntzicker showed that RWC profiles are very dependent on the combustion temperature. A composite profile for the complete burn cycle of RWC appliances tested should be obtained for data analysis.

Radiocarbon analysis of five selected samples, 12 days of methylchloride tracer sampling, and computer resources to complete 200 CMB calculations are included in the estimated Level III costs in Table IV-16. The Level III direct labor estimate includes 230 hours of analyst time and 800 hours of technician's time to complete the project design, field sampling, quality assurance, sample selection, data analysis, reporting and administrative tasks required. Analytical costs include the development of RWC source profiles from woodstoves, and fireplaces, as well as several other major sources in the airshed. The data base developed by such a program can be used for enrichment factor, CMB, multivariate and time series analysis receptor modeling as discussed in section IV.C.4 of this document.

Inclusion of C^{14} monitoring along with methylchloride to supplement particulate measurements provides three independent methods of RWC impact assessment. The principal disadvantage of Level III analysis is its cost. The availability of dichotomous (or sequential) samplers, integrating nephlometer(s), a methylchloride sampling train(s), and a radiocarbon sampling train(s) (Lavaggi et al, 1984)

may also pose problems. Depending on the importance of RWC contribution to ambient air quality and knowing the importance of SIP development process, the cost of Level III analysis may be justified in many airsheds. The importance of precise RWC estimates is further justified by the presence of potentially carcinogenic compounds in the RWC emissions (Section IV.B.5.)

Since it is now recognized that RWC emissions are a major source of polycyclic matter (Radian, 1983), and contain toxic compounds including a variety of mutagenic compounds (Kamens et al, 1984; Lewtas, 1982), an intensive study at Level III could include: measurements of B(a)P and possibly other specific POMs.

EPA's integrated Air Cancer Project has conducted several field studies to evaluate the importance of RWC contributions to the mutagenic activity of particulate samples. The results of these studies should be considered in Level III RWC study designs.

V. RESIDENTIAL WOOD COMBUSTION CONTROL STRATEGIES

A. Introduction

In this section, we discuss strategies for reducing pollutant emissions from Residential Wood Combustion (RWC), in order to minimize its adverse impact on ambient air quality.

This discussion, as has most research to date on RWC, primarily addresses particulate impacts, and how these might be reduced by specific control measures. Other RWC emissions of concern include Polycyclic Organic Matter (POM), due to its potential toxicity, and Carbon Monoxide (CO). As a first approximation, it can generally be assumed that RWC control measures which reduce particulate emissions will also reduce CO and POM emissions, although not necessarily proportionately.

Section III.B of this report discussed factors which influence the magnitude of RWC emissions - e.g., burn rate, wood moisture content, and appliance design, etc. Improving the control of one or more of these types of factors is usually the technical basis for RWC control strategies. Another primary influence is public response. The degree of public understanding of, and cooperation with, RWC control measures can greatly influence their effectiveness. Another determinant of RWC control strategy design is the relative contribution of woodstoves vs fireplaces to local air pollution problems. Fireplace controls have received much less attention than stove measures, but fireplaces can account for a majority of local RWC emissions (e.g., in Colorado; see Section V.C.3 below).

Section V.B discusses potential RWC control strategies which states and localities could adopt. It does so in general terms, drawing upon available generic analyses of the benefits and costs of different types of approaches.

Section V.C describes the leading examples of RWC control strategies implemented or proposed to date. It focuses on the states and localities listed below, because they have adopted or proposed the most unique RWC control measures. They also have more information on the effectiveness of their RWC control measures, including air quality benefits in some cases:

- Oregon
  - Medford
  - Statewide Woodstove Certification Program
- Montana
  - Missoula
- Colorado
  - Ski Communities
  - State Level RWC Control Measures
- Alaska (Juneau)
- Nevada (Reno)

Example regulations for each of these states and localities are included in Appendix B.

B. Potential RWC Control Strategies

Possible RWC control measures, which state or local air pollution control agencies could use to minimize RWC emissions, are reviewed and discussed in this section. Strengths, weaknesses, costs and benefits, are discussed for a variety of possible measures in general terms. This provides a context for the subsequent discussion of actual control strategies adopted or proposed by specific states or localities, in Section V.C.

While many reports and papers have mentioned or discussed RWC control measures, few have focused primarily on this, and only one has attempted a comprehensive and quantitative comparison of a full range of control options. Greene and Tombleson (1981) reviewed potential approaches for RWC control measures, and their strengths and weaknesses. Mors et al, (1981) reviewed current federal laws to discuss legal bases (or lack thereof) for controlling RWC emissions.

Grotheer (1984) reviewed leading examples of actual RWC control measures adopted or proposed, and discussed their projected benefits and costs. He concluded that a variety of site-specific factors, including local public acceptance, often determine the choice and ultimate effectiveness of RWC control measures for any particular locality.

Only one published study to date has attempted a comprehensive and quantitative evaluation and ranking of a full range of RWC control options (U.S. EPA, 1984b, Task 6). The rest of this section draws primarily on this study's findings and conclusions.

Seventy-five different RWC control strategy elements were initially evaluated in this study. These were based on a literature review of control measures applied to RWC (or similar combustion sources) throughout the world, and any other potentially feasible control actions. A Keppner-Tregoe evaluation and ranking system was used to identify the most promising RWC control measures (Keppner and Tregoe, 1965). It utilized criteria designed to reflect attributes desired in an effective RWC control strategy.

The criteria used in the Keppner-Tregoe analysis for scoring and ranking strategy elements are summarized in Table V-1. Potential RWC control measures which did not meet one of the "MUST criteria" were not considered further. Those which passed this initial screening were scored from one to ten, based on how well they satisfied each of the twelve "WANT criteria". The twelve criteria were also weighted to indicate the relative importance assigned to them in this study. The resulting overall scores determined a ranking for all of the RWC controls initially considered.

The weight factors used in this study reflected the perception of the study authors about the relative effectiveness of actions or policies related to each criteria in reducing RWC particulate emissions. The authors point out that the weights assigned do not reflect public policy preferences of theirs or of any agency. They are an element called for in the Keppner-Tregoe analysis. The weights assigned could be changed by other analysts.

TABLE V-1. Criteria and Weight Factors Used in Keppner-Tregoe Analysis

CRITERIA	WEIGHT FACTOR*
MUST Criteria	
1. Reduce air pollution impacts from RWC	Mandatory
2. Meet legal requirements	Mandatory
3. Widely applicable to RWC equipment or operating practices	Mandatory
4. Must not increase safety hazard	Mandatory
5. Can be implemented within five years, unless long-term benefits great	Mandatory
WANT Criteria	
1. Reduce average RWC emissions/household	13
2. Reduce number of RWC households	13
3. Widely applicable	10
4. Maximum public acceptance	9
5. Discourage worst appliances/practices	9
6. Minimum consumer cost	6
7. Uses proven technology	5
8. Minimum circumvention of control measure possible	4
9. Maximum agency administrative feasibility	3
10. Encourages innovative technology	2
11. Minimum free market interference	2
12. Promotes conservation/use of renewable resources (except wood)	1

* These weight factors were calculated using an analytic tool called "paired comparison".

Source: U.S. EPA (1984b; Task 6)

Based on this initial evaluation, the most promising (highest ranked) measures were categorized into a list of generic approaches for reducing RWC emissions, which is shown in Table V-2. This list is comprehensive in several ways.

First, all of the major approaches available to reduce RWC emissions are represented - i.e., reducing wood usage, or improving new or existing wood burning devices, or improving the way people operate such devices. Table V-2 also covers the main types of RWC control measures actually adopted or proposed to date by states or localities. It also includes leading examples of the means by which RWC control strategies can be implemented - i.e., by imposing regulatory requirements, by offering economic incentives or subsidies, and by public education or technology transfer. The RWC control measures in Table V-2 cover both stoves and fireplaces. For each of the generic approaches in Table V-2, the authors estimated the potential reductions achievable (if any) in RWC particulate emissions. Their findings are summarized in Table V-3. To address strategies whose benefits accumulate over a period of years - e.g., weatherization, or woodstove testing/certification - emissions reductions estimates were projected through the year 2000. The estimates in Table V-3 required many assumptions and hypotheses, because sufficient experimental data or knowledge did not exist for many key variables. Extensive literature review and discussions with leading researchers were used to formulate these assumptions, which were documented in detail. Nevertheless, the emissions estimates in Table V-3 should be viewed as speculative.

For example, this study preceded the development of a statewide woodstove testing and certification program in Oregon. Oregon subsequently estimated that particulate emissions reductions attributable to a statewide, mandatory certification program would be 50-75% over a 10-20 year period (see section V.C.1.b), in contrast to the 30% shown in Table V-3. This is neither surprising nor inconsistent, given the differences in methods, assumptions and data available when each estimate was made. The generic analysis described in this section (U.S. EPA, 1984b; Task 6) rated woodstove certification as the most effective control measure in reducing particulate emissions, but only estimated a 30% reduction. This

TABLE V-2. Generic Approaches to Reducing RWC Particulate Emissions

A. Improving Burning Unit Design
   1. Improved design of new stoves
      a. Testing of wood stoves/furnaces, and certification of compliance with an established emission limit, as a prerequisite for allowed sales
      b. Testing/certification as a prerequisite of stove furnaces sales, plus a financial incentive (33% tax credit) to buy the cleaner (certified) stoves
      c. Testing/certification as a basis for mandatory labelling of all stoves/furnaces sold, which specifies their efficiency and emissions performance
      d. Testing/certification as a basis for mandatory labelling, plus the 33% tax credit for clean units

   2. Modification of installed stoves/furnaces, including:
      a. Air inlet modifications
      b. Insertion of firebrick in stove box
      c. Fans to improve heat transfer
      d. Add-on particulate control devices:
         1. Steel wool mesh filter
         2. Catalytic afterburner

   3. Improved design of add-on devices for fireplaces
      a. Underfire air
      b. Electrostatic precipitator
      c. Glass doors

B. Reducing Wood Usage
   1. Reducing home heating requirements
      a. Weatherization
      b. Reducing stove charge size
   2. Improving wood fuel quality
      a. Selection of wood with higher heating value
      b. Moisture control (seasoning)
   3. Direct restrictions of wood usage
      a. Episode controls
      b. Emission density zoning

C. Improving RWC Operating Practices
   1. Initial selection of burning units - sizing
   2. Operating technique modifications
      a. Discouraging airtight stove operation
      b. Charging larger pieces of wood
   3. Periodic inspection of RWC equipment

Source: U.S. EPA (1984b; Task 6)

TABLE V-3. Comparison of Estimated Particulate Emission Reductions Achievable by Generic RWC Control Strategy Approaches

Generic RWC Emissions Control Strategy Approach	Potential Particulate Emissions Reductions (%)			
A. Improving Burning Unit Design				
	YEAR			
	1985	1990	1995	2000
1. Promotion of design and use of cleaner new stoves/furnaces				
a. Testing/certification as prerequisite to sales or installation.	2	8	22	30
b. Test/certification as prerequisite to sales, plus $400 (33%) tax credit.	3	11	30	39
c. Testing/certification as basis for mandatory labeling prior to sales, specifying efficiency and emissions performance.	1	3	8	11
d. Testing/certification/labeling, plus $400 (33%) tax credit.	1	5	15	21
2. Modifications of installed stoves				
a. Air inlet modifications.	2a. No basis for emission reduction credits.			
b. Insertion of firebrick in stove box.	2b. No basis for emission reduction credits.			
c. Heat transfer improvement (fans).	2c. Negligible (0-1%)			
d. Add-on Particulate control devices	2d. Negligible (0-1%)			
3. Improved design or add-on devices for fireplaces				
a. Underfire air.	3a. 1% by 1990; 2% by 2000.			
b. Electrostatic precipitator.	3b. 46% (single test); expensive ($1,400).			
c. Glass doors.	3c. No basis for emission reduction credits.			

Source: U.S. EPA (1984b; Task 6)

TABLE V-3. (Continued)

Generic RWC Emissions Control Strategy Approach	Potential Particulate Emissions Reductions (%)
B. Reducing Wood Usage	B. Reducing Wood Usage
1. Reducing home heating requirements - Weatherization	
a. All households.	1a. For 1990 3.5%; for 1995 7.0%.
b. Households installing new wood stove/furnace.	1b. For 1990 2.5%; for 1995 5.0%.
2. Improving wood fuel quality	
a. Select fuel with higher heating value.	2a. No basis for emissions reduction credit.
b. Moisture control.	2b. 6.2%
3. Direct restrictions on wood usage	
a. Episode controls.	3a. 33% per episode day.
b. Emission Density Zoning.	3b. No basis for emissions reduction credit.
C. Improving RWC Operating Practices	C. Improving RWC Operating Practices
1. Initial selection of burning unit	
a. Sizing.	1a. 7% by 1990; 10.5% by 2000.
2. Operating techniques	
a. Discouraging airtight operation.	2a. No basis for emissions reduction credit.
b. Charging larger pieces of wood.	2b. 11.5%.
3. Inspection of RWC households.	3. No basis for emissions reduction credit.

Source: U.S. EPA (1984b; Task 6)

was primarily because it assumed higher average emissions rates for certified stoves, based on limited test data available at the time, than the eventual Oregon standard. Oregon's subsequent estimates had much more test data and other information to draw on, and hence should be much more repesentative of Oregon's program potential.

The same general caveat applies to the emissions reduction potential estimated for any of the other RWC control measures in Table V-3. Those estimates involved assumptions deemed reasonable at the time, based on limited test data, and discussions with experts. The main value of the analysis as a whole lies in comparing a wide range of control measures in a systematic fashion, and evaluating their relative strengths and weaknesses.

The generic approaches estimated to achieve the greatest reductions in RWC emissions included: a) all of the stove testing and certification approaches intended to improve new stove designs; b) weatherization; c) properly sizing stoves to the space to be heated; d) encouraging use of larger pieces of firewood; and, e) wood moisture controls. Episode controls were effective on worst case days, but their effect on seasonal or annual average TSP levels were unknown.

Drawing upon the foregoing assessments, fifteen generic RWC control strategies were selected (Table V-4) for evaluation and ranking, using the Keppner-Tregoe process. These fifteen strategies included the highest rated control measures from the preliminary analyses described above, as well as leading examples of RWC controls actually implemented somewhere. The intent was to systematically and quantitatively compare a comprehensive group of the most practical and promising RWC control measures which states and localities could implement.

Table V-5 summarizes the results of the Keppner-Tregoe analysis and ranking of the fifteen strategies. It contains a brief description of each strategy, its score/ranking, and notable major advantages and disadvantages. Table V-6 shows the fifteen strategies in their final

TABLE V-4. Final Fifteen RWC Control Strategies Evaluated

Strategy #1	Testing/Certification as Prerequisite to Sales or Installation of New Stoves/Furnaces
Strategy #2	Strategy #1, with 33% Tax Credit ($400.00)
Strategy #3	Testing as Basis for Mandatory Labeling of New Stoves/Furnaces Prior to Sales; Label Specifies Emissions Performance and Efficiency
Strategy #4	Strategy #3, with 33% Tax Credit ($400.00)
Strategy #5	Testing/Rating by RWC Industry Trade Association
Strategy #6	Mandatory Weatherization of All Households
Strategy #7	Mandatory Weatherization Only for Households Installing New Stove/Furnace
Strategy #8	Firewood Moisture Content Controls
Strategy #9	Stove Sizing
Strategy #10	Encourage Larger Firewood Piece Size
Strategy #11	Require Underfire Air Source for New Fireplaces
Strategy #12	Episode Controls
Strategy #13	Research and Development of Improved RWC Appliances and/or Practices
Strategy #14	Encourage Alternative Fuels
Strategy #15	Periodic Inspection of RWC Equipment

Source: U.S. EPA (1984b; Task 6)

TABLE V-5. Description of Most Effective Control Strategies

Strategy Description	Keppner - Tregoe		Major Advantage(s)	Major Disadvantage(s)
	Rank	Points		
Mandatory testing/certification of all new wood stoves, with only clean burning stoves allowed to be sold. Tax credit (rebate) of $400 to purchaser.	1	535	Significant emissions reduction	Expensive
Mandatory testing/certification of all new wood stoves, with only clean burning stoves allowed to be sold. No tax credit.	2	508	Significant emissions reduction; less expensive than above strategy	Lack of public acceptance due to higher stove costs.
Encourage use of larger firewood piece size through public education	3	490	Inexpensive; public acceptance expected to be high since bigger pieces mean less work splitting wood	None
Mandatory testing and labeling of all new wood stoves by pollution and efficiency levels, but all stoves can be sold. Tax credit for cleaner units.	4	469	Substantial public acceptance expected; significant emissions reductions (but less than when only clean stoves are sold)	Expensive
Encourage use of other fuels by reducing costs of conventional fuels, encourage solar energy use, restrict availability of wood.	5	458	Technology available	Encourageing oil use contrary to federal policy. Poor public acceptance for restricting wood supplies. Other heating sources may not be available or maybe too expensive.

Source: U.S. EPA (1984b; Task 6)

TABLE V-5 (Cont'd)

Strategy Description	Keppner - Tregoe		Major Advantage(s)	Major Disadvantage(s)
	Rank[1]	Points		
Government funded research and development of improved equipment, operating procedures, and testing methods.	6	445	The lack of data currently hampering efforts to evaluate control efforts and stove design/ operating procedures will be deminished.	Specific emissions reductions are not quantifiable
Promote proper sizing of new wood burning units of public education and requiring appropriate labeling of new units. Could limit size with building permit restriction.	7	443	Minor cost, good public acceptance. Reduction of creosote and fire problems	Slight user inconvenience in that more frequent charging of smaller units will be required
Mandatory testing and labeling of all new wood stoves by pollution and efficiency levels, but all stoves can be sold. No tax credits.	8	438	Good public acceptance	None
Mandatory weatherization of all households to a cost effective level (fuel savings greater than expense).	9	432	Energy conservation for all fuels	Public resistance, expensive
Stove testing and rating by Trade Association.	10	422	High public acceptance.	Totally voluntary, relies on vigorous implementation by Trade Associaiton with minimal return for Trade Association

Source: U.S. EPA (1984b; Task 6)

TABLE V-5 (Cont'd)

Strategy Description	Keppner - Tregoe		Major Advantage(s)	Major Disadvantage(s)
	Rank[1]	Points		
Mandatory weatherization for households buying new or replacement wood burning devices to a cost effective level.	11	411	Will discourage new woodburning units	May be perceived as unfairly affecting one group of people. Expensive
Encourage burning of drier firewood by public education, restricting firewood gathering to as far in advance of heating season as possible, and require firewood suppliers to state moisture content.	12	400	Minimal cost. Potential for substantial decrease in emissions	Public resistance to restricting times of firewood gathering
Voluntary curtailment of RWC during air pollution episodes. Mandatory curtailment required if voluntary curtailment does not work.	13	381	Minimal cost. Reduction of emissions during periods of worst air pollution	Dependent on public cooperation. Effect on annual attainment of standards unknown
Annual inspection and maintenance of woodburning units, including cleaning chimney.	14	321	Will encourage replacement of catalysts at appropriate times; substantial safety benefits expected	Extremely high resistance from public; high expense
Require underfire air for new fireplaces (building code or ordinance).	15	292	Inexpensive, substantial reduction in fireplace emissions	Fireplaces will be used less in future, be a relatively small proportion of emissions

Source: U.S. EPA (1984b; Task 6)

TABLE V-6. Summary for Fifteen Final RWC Control Strategies of the Keppner-Tregoe Ranking vs. WANT Criteria and Major Strategy Costs and Benefits*

RWC Control Strategy[1]	Keppner-Treoge Ranking vs WANT Criteria[2] (Rank)	(Points)	Estimated Implementation Costs[3] ($)	Benefits[3,4] of Implementation
Testing/Certification; Tax Credit (Strategy #2)	1	535	-$50,000[5] -$130,000/year[6] -$1.8 - 7.2 million per year tax credits[7]	-Potential Emissions Reduction (%): 1985: 3; 1990: 11; 1995: 30; 2000: 39
Testing/Certification (Strategy #1)	2	508	-$130,000/year[6] -$50,000[5]	-Potential Emissions Reduction (%): 1985: 2; 1990: 8; 1995: 22; 2000: 30
Larger Firewood Piece Size (Strategy #10)	3	490	-$45,000/year[6]	-Potential Emissions Reduction: 11.5%
Testing/Labeling; Tax Credit (Strategy #4)	4	469	-$50,000[5] -$160,000/year[6] -$0.8 - 3.2 million per year tax credits[7]	-Potential Emissions Reduction (%): 1985: 1; 1990: 5; 1995: 15; 2000: 21

[1] From Table 9.

[2] From Appendix E.

[3] From Appendix F.

[4] From Appendix D.

[5] One time start-up costs.

[6] Annual administrative costs.

[7] Based on $400 per certified unit; 5,000 to 20,000 total units sold, and % of total units sold assumed to be certified units.

Source: U.S. EPA (1984b; Task 6)

*Refer to discussion in text regarding assumptions used in arriving at rankings.

TABLE V-6. (Continued)

RWC Control Strategy[1]	Keppner-Tregoe Ranking vs WANT Criteria[2] (Rank)	(Points)	Estimated Implementation Costs[3] ($)	Benefits[3,4] of Implementation
Encourage Alternate Fuels (Strategy #14)	5	458	Not quantifiable	Not quantifiable
Research and Development (Strategy #13)	6	445	Not quantifiable	Not quantifiable; but significant - can enable many other strategies to have their efficiencies improved
Stove Sizing (Strategy #9)	7	443	-$45,000/year[6]	-Potential Emission Reduction (%): 1990: 7%; 2000: 10.5%
Testing/Labeling (Strategy #3)	8	438	-$50,000[5] -$130,000/year[6]	-Potential Emission Reduction (%): 1985: 1; 1990: 3; 1995: 8; 2000: 11
Mandatory Weatherization for All Households (Strategy #6)	9	432	-$150,000 to $600,000[6] -$1,400 to $1,500 per household	-Potential Emission Reduction (%): 1990: 3.5 - 16.0[8]; 1995: 7.0 - 16.0[8]
Stove Testing/Rating by Trade Association (Strategy #5)	10	422	-$50,000/year[5,7] -$130,000/year[6,7]	-Potential Emission Reduction (%): 1985: 1; 1990: 3; 1995: 8; 2000: 11

[1] From Table 9.

[2] From Appendix E.

[3] From Appendix F.

[4] From Appendix D.

[5] One time start-up costs.

[6] Annual administrative costs.

[7] Costs paid by private sector.

[8] Emissions reduction depends on assumptions used regarding changes in RWC practices after weatherization.

Source: U.S. EPA (1984b; Task 6)

TABLE V-6. (Continued)

RWC Control Strategy[1]	Keppner-Tregoe Ranking vs WANT Criteria[2] (Rank)	(Points)	Estimated Implementation Costs[3] ($)	Benefits[3,4] of Implementation
Mandatory Weatherization for New/Replacement RWC Households (Strategy #7)	11	411	-$20,000 to $80,000 per year[6] -$1,450 per household.	-Potential Emission Reduction (%): 1990: 3.5 - 16.0[7] 1995: 7.0 - 16.0[7]
Moisture Controls (Strategy #8)	12	400	-$45,000/year[6]	6.2%
Episode Controls (Strategy #12)	13	381	-$25,000[5] -$8,000/year[6]	33% reduction on Episode days
Annual Inspection (Strategy #15)	14	321	-$.75 to 1.5 million/year for an area with 50,000 to 100,000 stoves.[6]	-No emissions reductions credited. -18% less home fires (est.). -Lower fire insurance costs.
Underfire Air Controls for New Fireplaces (Strategy #11)	15		-$.1 to .3 million/year installation costs for an area with 1,000-3,000 new fireplaces per year.	-Potential Emission Reduction (%): 1990: 1% 2000: 2%

[1] From Table 9.

[2] From Appendix E.

[3] From Appendix F.

[4] From Appendix D.

[5] One time start-up costs.

[6] Annual administrative costs.

[7] Emissions reduction depends on assumptions used for changes in RWC operation after weatherization.

Source: U.S. EPA (1984b; Task 6)

ranked order, along with rough estimates of their implementation costs and benefits - the latter expressed mostly in terms of estimated particulate reductions. The overall observations and conclusions from this analysis are summarized below.

The two highest ranked strategies also provided the highest estimated particulate emissions reductions, by the year 2000. Both involve mandatory testing and certification of new stoves, and banning the sale of stoves which cannot comply with an established emission standard characteristic of clean burning operation. Their only difference was that one strategy offers a financial incentive (a $400 tax credit) to help purchase certified stoves, which were expected to cost more.

The emissions reductions from such certification approaches necessarily take many years to be fully realized, but they reduce emissions from existing as well as from new stoves. That is, when existing units are eventually replaced, only certified cleaner units will be available. The tax credit costs were shown to be reasonable, compared to industrial pollution control tax credits which have been available for years from states like Oregon.

Mandatory certification is effective because it limits consumer choice dramatically. This could be a source of consumer backlash especially if the only available (certified) appliances are much more costly. The financial incentive could offset this, at significant cost to the government. The other emissions testing/certification strategies considered in this study relied upon labeling to induce consumer purchase of certified appliances. They ranked lower than the mandatory certification approach, even with a financial incentive added (tax credit), because consumer choice was not limited enough to ensure how much emissions reduction would result.

Several other strategies emerged from this analysis as low in cost, convenient, and potentially capable of significant emissions reductions. These include: encouraging larger firewood piece size; moisture control

(seasoning) measures; stove sizing, and; episode controls. All are based on public education, and could be jointly implemented, with relatively modest administrative costs.

However, there were two major uncertainties inherent in these "least cost" strategies. The most obvious was uncertainty in how much people would respond to the public education and alter their wood burning practices in the desired manner. The second uncertainty involved the very limited research base upon which some of the projected RWC emissions reductions were based. For example, the extent to which use of larger pieces of firewood might reduce particulate emissions was very speculative. Accordingly, agencies adopting these strategies would have little control over, or ability to measure, the emission reductions.

The two strategies based on weatherization of households to reduce heating demand did not rank very highly (9th and 12th out of 15). They produced potentially good emissions reductions, but these were more uncertain (e.g., than for a mandatory certification strategy). This was primarily because the extent to which weatherization would alter household RWC practiculate emission was not determinable. Public acceptance of weatherization requirements was rated low, primarily due to its high initial costs (despite eventual payback through fuel savings).

Strategies considered most acceptable to the public at large were those involving the least inconvenience and/or costs to it - e.g., testing/certification and labeling, research and development, and the least cost strategies mentioned above. Episode controls which rely on voluntary compliance, also ranked high in public acceptance.

Mandatory episode controls, such as Missoula, Montana has adopted, or restricting RWC via stove permits, such as Missoula has proposed (Section V.C.2), would have ranked relatively low in public acceptance if they had been included in the group of fifteen strategies evaluated. Mandatory episode controls were not included, because it had ranked 50th out of 75 possible approaches in the initial Keppner-Tregoe screening analysis. The woodstove permit concept was not analyzed because of potential conflicts

with state laws, many of which prohibit direct regulation of air pollution sources at the household level. In retrospect, these are both viable strategies which should be considered, if feasible, in any analysis of potential approaches.

Overall, strategies most directly effective in reducing RWC emissions tend to also reduce public convenience and choice, risking loss of public acceptance. Accordingly, developing effective RWC control measures is a sensitive undertaking, and must be carefully tailored to each community's characteristics.

C. Leading Examples of RWC Control Strategies Adopted or Proposed

1. Oregon

The Oregon Department of Environmental Quality (DEQ) was the first state agency to recognize and to document that RWC contributed significantly to elevated ambient particulate levels. The 1977-79 Portland Aerosol Characterization Study (PACS) (Watson, 1979) estimated the relative contributions of RWC and other particulate sources, in a landmark application of newly developed (Friedlander 1973) Chemical Mass Balance (CMB) techniques.

CMB and other analyses in Medford, Eugene, and other localities confirmed substantial RWC impacts from both wood stoves and fireplaces (Nero and Associates, Inc. 1984). This was especially true in Medford, where valley terrain and winter meteorology greatly exacerabated ambient concentrations (DeCesar et al, 1981). Household wood usage surveys and projections using dispersion models by DEQ, in conjunction with CMB findings, provided the basis for particulate State Implementation Plans (SIPs) for Oregon's three non-attainment areas (Portland, Eugene and Medford) in the early 1980's.

All three SIPs explicitly addressed RWC impacts and control strategies, which were developed with extensive participation of local citizen advisory committees. All of these SIP processes evaluated a

range of RWC control strategies, to assess their potential air quality benefits and implementation costs. Example strategies evaluated included:

- weatherizing homes to reduce wood heat demand;
- promoting better seasoning of wood fuel to control moisture content;
- public education to improve selection and operation of wood burning appliances; and,
- measures to promote the development of cleaner burning stoves, such as through stove testing and certification.

The most detailed and substantive local RWC control strategy proposed/adopted was in Medford, where RWC impacts were higher than anywhere else in Oregon, and where total particulate levels exceeded primary (health related) national ambient air quality standards.

In addition to developing TSP SIPs which addressed RWC control, DEQ initially concentrated on public education. The agency prepared and distributed a number of publications on wood heating, as summarized in Table V-7 (DEQ, 1979-81). Eventually, DEQ became convinced that controlling increasing RWC impacts would require measures capable of reducing baseline RWC emissions and improving existing air quality - not just slowing projected increases in RWC emissions. In 1983 DEQ asked the Oregon Legislature for authority to establish a statewide testing and certification program, as the most practical approach to roll back RWC impacts.

Medford's RWC control measures, and Oregon's stove testing and certification program are further described below.

a. Medford

In August, 1982, the Jackson County (Medford) Board of County Commissioners adopted Ordinance No. 82-6 which provided for the following RWC control measures (Jackson County, 1982):

TABLE V-7. Oregon Woodstove Publications[a]

Publication	Distribution
Woodstoves: Energy Solution or Air Pollution?	18,000
Woodstove Bibliography	5,000
Interpretation of Woodstove Emission Testing Results	5,000
Oregon Woodheat Handbook	70,000
Burn Wood Better	20,000
DEQ Views on Woodheating	34,000

Source: Hough and Kowalczyk (1983).

[a] References: DEQ 1979-81; Hazen, 1980.

- Mandatory weatherization for residences wishing to install a wood stove, fireplace, or any other form of solid fuel, space heating device.

- The residence must meet cost-effective levels of weatherization within 90 days of wood stove installation, and have an alternative form of space heating other than solid fuel burning for use during pollution episodes.

  Cost-effective weatherization was to be based on the recommendations from energy audits available free from local utilities. Such audits were also required by this ordinance as a condition of sale or rental, as part of Jackson County's stated goal of helping all citizens weatherize to cost effective levels by January 1, 1987.

- All homes with wood heating systems must be weatherized to cost-effective levels at the time of sale or rental, if the primary particulate health standard is not attained by January 1984.

- Prohibition of RWC within the Air Quality Maintenance Area whenever particulate levels exceed, or are projected to exceed, the primary particulate health standard (260 ug/m^3, 24-hour average), except for residences with no other form of space heating.

- If the primary particulate standard is not attained in the AQMA by July 1, 1984, RWC is prohibited whenever DEQ issues an air stagnation advisory (occurs about 10-40 days per year).

The particulate standard was not attained by 1984, but the ordinance described above was replaced by another in October, 1984, which changed some of its provisions, partly in response to the efforts of local realtors (Jackson County, 1984). Major changes include:

- Establishing minimum weatherization standards, but with options, instead of basing weatherization requirements entirely on an energy audit.

  - Installing weatherization measures proven cost-effective by an authorized audit remains one way to satisfy minimum weatherization standards.
  - Another option was insulation of R-30 in the ceiling, R-19 in the floor, and double glazed windows or storm windows.
  - Another option is those weatherization alternatives entirely authorized for installation through any federal, state or utility company sponsored loan or grant program.

- Effective January 1, 1985, the owner of any residence (except a mobile home) constructed before January 1, 1979, which does not meet minimum weatherization standards, must provide an energy audit to potential purchasers of such residence.

- Effective January 1, 1985: Prior to sale of the any residence (other than a mobile home) constructed before January 1, 1979, and which has a solid fuel heating device, the owner must ensure that the home will meet minimum weatherization standards by:

  - Bringing the home up to those standards; or
  - Filing a proposal with the Jackson County Department of Planning and Development, signed by the new owner of the residence, stating that the new owner will be responsible for bringing the residence up to minimum weatherization standards within 90 days of the sale.

- Mobile homes and homes outside the Jackson County Air Quality Maintenance Area were exempted.

  Sales within incorporated cities, including Medford, had been exempted in the original ordinance. This exemption was retained.

The City of Medford adopted a very similar weatherization ordinance (City of Medford, 1982) requiring cost-effective weatherization of RWC homes at the time of sale or rental, if primary particulate standards were not met by January, 1984. The City repealed their ordinance in February, 1984, out of concern for its enforceability, and in response to concerns of local realtors who felt that enforcement burdens fell on them. However, the City will consider a revised ordinance for particulate pollution control in the fall of 1985 (Eisenhard, 1985), which would reestablish weatherization requirements for certain existing RWC homes at the time of sale, and any residences installing solid fuel heating devices in the future. It would also ban RWC on any days when the primary health standard is projected to be exceeded, or when the National Weather Service issues a Air Stagnation Advisory.

Appendix B contains copies of both Jackson county ordinances, as well as summaries of ordinance provisions by the county and by a representative of local realtors.

The technical basis for the Medford RWC control strategy was described in "A Comprehensive Strategy to Reduce Residential Wood Burning Impacts in Small Urban Communities" by Hough and Kowalczyk (1983). This may be the most complete assessment published to date of a range of proposed RWC control strategies for a specific community. It includes estimates of expected reductions in wood usage and emissions, ambient air quality benefits, and associated costs for each control measure proposed. These findings and conclusions are summarized briefly below.

Table V-8 summarizes nine RWC control measures recommended by the Jackson County Air Quality Advisory Committee, to help comply with the primary particulate standard by 1985. For five of these measures, reductions in ambient total suspended particulate (TSP) concentrations were estimated, based on technical analyses prepared by DEQ staff.

TABLE V-8. Medford Residential Wood Burning Control Measures Effectiveness

Control Measures	Projected Annual TSP Reduction (ug/m^3)
Woodstove Operation Education	a
Weatherization Before New Woodstove Installation	3.2
Weatherization of Homes With Existing Stoves	5.5
Weatherization Assistance to Elderly/Low Income	a
Stove Sizing Requirements	a
Firewood Moisture Control	4.2
Woodstove Curtailment During Pollution Episodes	2.8
Alternative Heat Source for New Homes	a
Solar Access and Orientation	0.3
Total	16.0

[a] These measures are not assigned a direct benefit but are essential to the success of other measures.

Source: Hough and Kowalczyk, 1983.

The weatherization and episode controls were included in the County Ordinance described above. Firewood moisture control was pursued separately through public education and cooperative efforts with the U.S. Forest Service and Bureau of Land Management. Fuelwood moisture control was pursued by promoting wood cutting in the spring, to allow more time for seasoning. Stove certification and testing was not included in the Medford recommendations, because it was a longer range strategy, and enabling legislation had not yet been enacted. However, Hough and Kowalczyk (1983) estimated that a woodstove certification program would result in 10-15 ug/m^3 lower TSP concentrations over a 10-20 year period - or, potentially as much as all of the other control measures combined.

Table V-9 summarizes the potential reduction in particulate emissions estimated by DEQ for the RWC control measures proposed for Medford, as well as the time required to implement them, and to fully realize their estimated emission reductions. Here stove certification is listed for comparison. It reduces emissions by almost as much as, or more than, the other control measures combined, but requires much longer time.

Table V-10 shows DEQ's estimates of how these estimated emissions reductions would affect RWC wood usage and associated emissions for a typical Medford woodstove household. Household surveys had shown that the average woodstove household in the Medford area used 3.0 cords/year of wood in 1980-81. Implementation of the strategies in Table V-8 were estimated to reduce per household wood use and particulate emissions by slightly more than half. Adding a woodstove certification program would further reduce wood usage somewhat, but would further reduce emissions by a factor of five (over 10-20 years), due to the gradual replacement of existing woodstoves with more efficient and much cleaner burning models.

TABLE V-9. Particulate Emission Reduction Potential

Control Measure	Time to Implement (yr)	Time to Achieve Significant Benefit (yr)	Particulate Emission Reduction Potential (%)
Curtailment During Pollution Episodes	1/2	1-2	5-15
Improved Operation & Firewood Seasoning	1	2-3	10-20
Weatherization and Proper Stove Sizing	2	3-10	30-50
Certification Program (for high-efficiency/ low-emission designs)	3	10-20	75-85
Overall	3	1-20	80-95

Source: Hough and Kowalczyk (1983).

TABLE V-10. Potential Emission Reductions per Household

Control Measure	Emission Reduction (%)	Resultant Firewood Use (cords/yr)	Particulate Emissions (lb/yr)
None (based on typical Medford woodstove household)	0	3.0	210
Add Curtaillment During Pollution Episodes	10	2.7	190
Add Improved Operation & Firewood Seasoning	15	2.3	160
Add Weatherization & Proper Stove Sizing	40	1.4	100
Replace Existing Woodstove with New Woodstove Design	80	1.1	20
Overall	90	(-1.9)	(-190)

Source: Hough and Kowalczyk (1983).

Overall, the RWC control strategies identified for Medford were estimated to reduce RWC particulate emissions by 40% by 1985, and by up to 90% by the year 2000, with a stove certification program. This would be accompanied by an estimated 60% reduction in firewood usage, and a 40% reduction in space heating requirements.

The RWC control measures adopted for Medford were part of a larger TSP SIP program which included industrial controls. Table V-11 compares the estimated energy and economic impacts of both the residential and industrial particulate control measures. The residential control measures were considerably more cost effective, and often saved energy, while the more expensive industrial controls also increased energy use.

Too little time has elapsed (two years) since adoption of Medford's RWC control strategy to attempt to estimate its actual effectiveness. However, Oregon has recently implemented a stove testing and certification program, so all of the control measures discussed above are now underway concurrently.

b. Mandatory Woodstove Certification Program

After years of special studies and SIP development work, DEQ concluded that RWC emissions were a major and growing cause of particulate standard non-attainment - especially in the Portland and Medford airsheds. After evaluating the potential effectiveness of many RWC control measures, DEQ also concluded that to attain and maintain ambient air quality standards, effective RWC control measures would have to promote the development and use of new, cleaner burning appliances. These would also eventually need to replace existing appliances, in order to substantially reduce existing (baseline) RWC emissions levels.

DEQ had concluded that virtually all existing wood stoves were poorly engineered with respect to combusion efficiency (emissions), and would emit relatively large amounts of pollutants

TABLE V-11. Energy and Economic Impacts of Medford Control Measures

Measure	Energy Requirement	Annual Cost Per TSP Reduction	
		Per Ton	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 $hp/ug/m^3$	$ 4,550	$ 500,000
Small Boiler Controls	350 $hp/ug/m^3$	$17,000	$ 130,000
Large Boiler Controls	No Change	$ 3,400	$ 120,000

Source: Hough and Kowalczyk (1983).

no matter how carefully they were operated. Thus, RWC control measures based on public education - e.g., about the benefits of proper stove sizing and operation, firewood seasoning and weatherization - could not achieve the improvements in particulate levels needed for compliance with standards in places like Medford and Portland.

Figure V-1 illustrates the relative magnitude and projected trends of particulate emissions from RWC and industrial point sources. It also shows the estimated reductions in projected RWC emissions achievable with several control measures, for the Portland airshed (Kowalczyk and Tombleson, 1982). During the last decade, growth in RWC emissions had virtually negated industrial particulate emissions reductions achieved through earlier SIP programs. Continuing non-attainment threatened to stifle future industrial and other economic development, unless sufficient particulate emissions reductions could be achieved to attain standards and to provide a growth margin of unused airshed capacity.

Figure V-1 illustrates the emissions reductions projected for the following types of RWC control measures, which were selected because they would actually promote cleaner burning woodstoves: a) voluntary or mandatory labeling of new stoves, to show consumers their emissions performance; b) labeling combined with a financial incentive (tax credit); and, c) mandatory testing and certification of new woodstoves for compliance with an emission standard, as a prerequisite of sale. The mandatory certification was judged to be clearly the most effective at reducing both existing and future emissions. DEQ estimated that a 68%-75% reduction in RWC particulate emissions was achievable through mandatory certification, and was needed to attain standards, as explained below.

DEQ requested and obtained from the 1983 Oregon Legislature the necessary authorization for a statewide certification program that

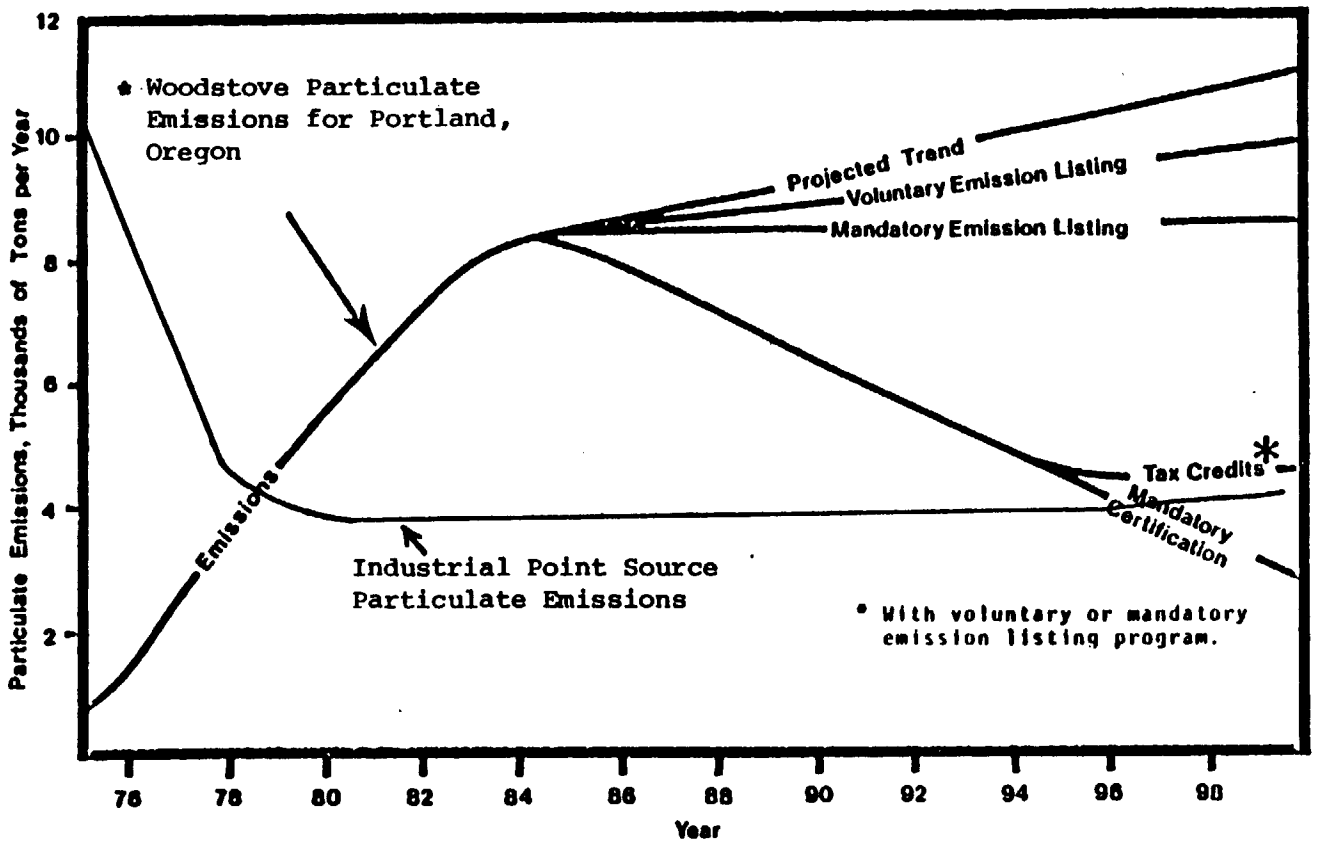


Figure V-1. Effects of Potential Programs to Promote Cleaner Burning Woodstoves

Source: Adapted from Kowalczyk and Tombleson, 1982; and, Kowalczyk and Tombleson, 1984.

would regulate new woodstoves at the point of sale. Opposition from the woodstove industry was countered by support from a coalition of other interests, including not only environmentalists but also medical professionals and other industrial groups. The resulting enabling legislation (House Bill 2235, 1983) established the basis for Oregon's woodstove certification program, which a DEQ staff paper (Kowalczyk and Tombleson, 1984) recently summarized as follows:

> "The first program in the United States to restrict the sale of woodstoves to only the cleaner burning models was enacted by the 1983 Oregon legislature. Specific rules to implement the program were adopted in June 1984 to address emissions and efficiency test procedures, laboratory accreditation requirements, emissions and efficiency labeling specifications, acceptable particulate emission levels and stove certification procedures. The rules were developed with the aid of a broad-based advisory committee and input from national and international members of the woodstove industry. An extensive woodstove emissions and efficiency database was developed to assist in formulating the rules. A two-stage emission standard was adopted, which requires new stoves marketed in Oregon to achieve a 50 percent reduction in particulate emissions by July 1986 and a 75 percent reduction by July 1988. The certification program is designed to bring all areas of the state into compliance with national ambient air quality standards for particulate matter by the year 2000. The program is expected to save owners of certified woodstoves up to 1/3 on firewood consumption because of the inherently higher heating efficiency of lower polluting stoves, as well as providing increased fire safety because of reduced creosote formation and increased health benefits because of reduced polycyclic organic matter emissions."

Oregon's certification program applies to woodstoves and stovelike fireplace inserts, but not to fireplaces. The program has five major elements, including:

- A testing procedure;
- An emission standard;
- A testing laboratory accreditation process;

- Labeling requirements; and,
- Certification procedures

Appendix B contains copies of Oregon's enabling legislation (HB 2235), and administrative rules adopted to implement the program, including detailed specifications for measuring woodstove emissions and efficiencies. Several fact sheets which describe various aspects of Oregon's program and requirements are also included in Appendix B. Highlights of the major program elements are briefly discussed below.

Test Procedure

Oregon's enabling legislation requires new woodstoves to be tested and permanently labeled both for emissions and heating efficiency. Four tests are run on each stove - at low, medium, high and maximum heat output levels, using a standardized fuel charge (Douglas Fir). The results are averaged to determine whether the stove meets the emission standard.

By testing over a full range of heat outputs, DEQ satisfies a wood stove industry request to produce performance data which would be usable in all areas of the country. In calculating the average of the four emissions tests, weighting factors are used based on Oregon climate and population distribution, as specified by rule (Appendix B). Thus, a stove's performance is rated on how it would perform under Oregon's heating demands.

Particulate sampling uses an EPA Method 5 apparatus, modified with an extra impinger and filter to better collect condensible particulates, which account for about 60% of a typical catch. Either a Calorimeter Room method or a stackloss heating method may be used to measure heating efficiency.

It should be noted that development by Oregon of a woodstove certification program, with stipulated procedures for testing the

emissions and heat transfer efficiencies of stoves, has stimulated lively debate about a number of related issues and technical questions. Inclusion of Oregon's "Standard Method of Measuring the Emissions and Efficiencies of Woodstoves" in Appendix B does not in any way constitute an EPA recommendation of these procedures. EPA is currently developing a New Source Performance Standard (NSPS) for woodstoves, during which the agency will provide its own guidance on stove testing methods.

Several other professional and trade organizations have taken an active role in the debate on woodstove standards and test methods - especially, the Wood Heating Alliance (WHA) and the American Society of Testing and Materials (ASTM). An ASTM subcommittee has undertaken research on woodstove testing methods. A central focus of this research is a dilution tunnel approach which might serve as an alternative to Oregon's testing approach. This work is not reported here, because the ASTM studies are not yet sufficiently complete to allow definitive comparisons of alternative test methods Oregon's test method description is included in Appendix B, because it is the only such procedure completed and adopted to date, and because it is referenced by several of the other states or localities whose RWC control measures are discussed in this section. However, EPA stresses that it does not favor any particular testing approach at this time.

Emission Standard

In selecting its emission standard, DEQ primarily considered three items: a) airshed improvements (emission reductions) needed to attain and maintain ambient air quality standards; b) the emissions performance capability of available stove technology; and, c) in the case of catalytic stoves, the deterioration with age of catalytic combusters.

For both Portland and Medford DEQ estimated that a 72%-78% reduction in RWC emissions was needed, in conjunction with control

strategies for other sources, to fully meet all national ambient standards for total suspended particulate. DEQ estimated the average emissions from existing or baseline stoves at 30-34 grams/hour (20-21 grams/kilogram of wood burned times an estimated baseline burn rate of 1.7 kilograms/hour (DEQ, 1984)). The woodstove emission standards adopted to achieve the needed reduction in this baseline emissions level are summarized in Table V-12.

Tests showed catalyst-equipped stoves were cleaner burning, but deteriorated in performance by an average factor of 2.5 over an expected catalyst life of 6,000 to 12,000 hours of operation. Accordingly, the standard for non-catalyst stoves was set to result in equivalent performance with catalyst stoves over the expected (two year minimum) life of the catalyst. That is, catalyst stoves which initially emit six grams/hr are expected to deteriorate to 15 grams/hour over the lifetime of the catalyst component. Catalytic combusters are expected to have to be replaced as often as every two years for frequently used appliances. DEQ will require a two year replacement warranty on the catalytic combuster elements of catalyst-equipped stoves as a condition of certification. The 50% emission reduction is based on DEQ's estimate that the average stove now on the market emits more than 30 grams/hour, and certified stoves would emit no more than 15 grams/hour on the average.

By mid-1988, the standard is tightened to nine grams/hour for noncatalyst stoves and four grams/hour for stoves with catalytic combusters. This would achieve a 70%-75% reduction in current baseline RWC emissions, over the 10-20 year period required for Oregon's entire stove population to be replaced by cleaner burning certified stoves. This would provide the overall RWC emissions reduction DEQ estimates is needed for most areas in Oregon to attain ambient standards, by the year 2000.

TABLE V-12. Oregon's Woodstove Particulate Emissions Standards (grams/hour)

	By July 1986	By July 1988
Catalytic	6	4
Non-Catalytic	15	9
Actual Emission Reduction	50%	70%-74%

[a] Weighted average of four emissions tests, per Oregon procedures.

Source: Kowalczyk and Tombleson 1984.

DEQ concluded that several different manufacturers of catalyst equipped appliances had production model stoves which already met the 1988 standard of four grams/hour. The testing to confirm this used the Oregon procedures. This testing was done at a 13,000 Btu/hr reference heat output level, which corresponds to Oregon's climate (heating demand), and estimated baseline burn rate of 1.7 kg/hour.

The nine grams/hour second stage (1988) standard for noncatalyst-equipped stoves was based on equivalency with the four grams/hour standard, taking into account the catalyst deterioration factor of 2.5. This standard is not necessarily achievable with present non-catalytic technology, as DEQ acknowledges. However, this level of emissions reduction was considered necessary to meet airshed requirements. DEQ hopes the lead time available will result in sufficient advances in non-catalyst technology, so that the standard does not become what some of its critics call a "catalytic mandate". However, if this does not occur, Oregon is prepared to rely solely on catalytic technology to achieve its airshed targets. DEQ cites the U.S. auto industry's experience in relying on catalyst technology as an example of the workability of such a policy.

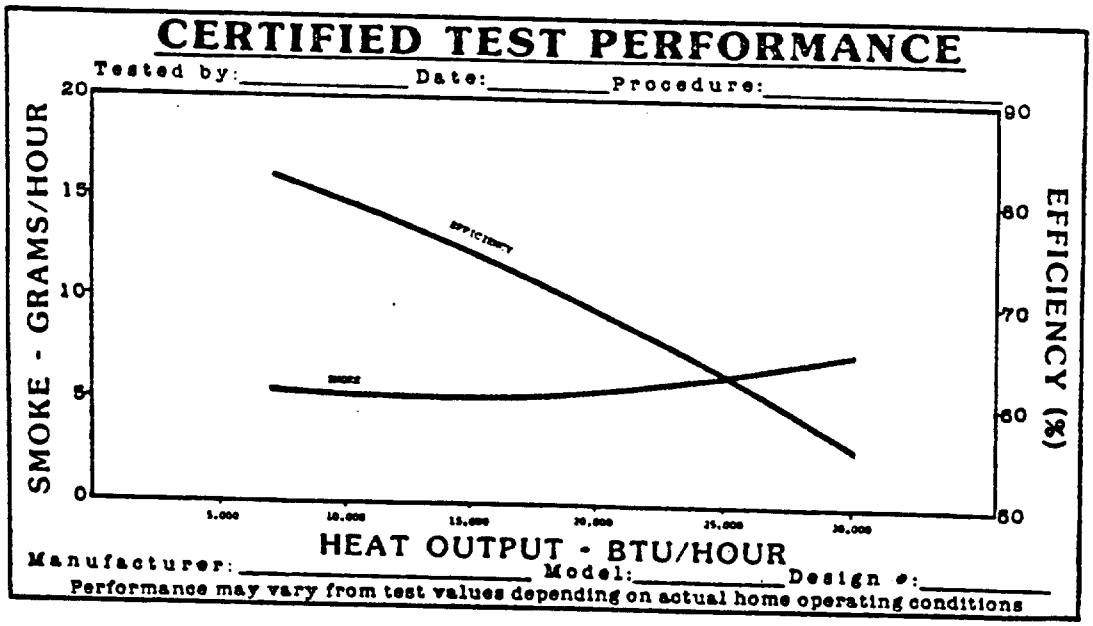
Laboratory Accreditation

Most of the work in Oregon's certification program, once it is fully implemented, will be done by private testing laboratories, which must meet stringent Oregon accreditation requirements. These include demonstrating testing proficiency using an Oregon supplied stove, standardized data calculations using Oregon supplied software, audit provisions, and specific accreditation enforcement procedures.

Labeling Requirements

Enabling legislation required that certified stoves be permanently labeled to show both their tested emissions and efficiency. Figure V-2 shows two labels, both of which will be used in Oregon. The permanently attached label will show tested emissions

Permanent Woodstove Label
(Example)



Removable Woodstove Label
(Example)

EMISSIONS AND EFFICIENCY PERFORMANCE
(non-catalytic stoves)

Smoke _____ grams/hour (DEQ Standard: 15 until 07/88)
9 after 07/88)

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 until July 1, 1988.

Figure V-2. Woodstove Labels to be used by Oregon Certification Program

and efficiency performance over the whole range of heat output levels. Its format was designed to provide useful data for all areas of the country, allowing manufacturers to avoid additional testing costs that might be imposed outside of Oregon. It will also help consumers evaluate stove performance.

A second label, removable by the consumer, was also intended to help the consumer compare appliances based on their average efficiences and emissions levels. It also shows the rate of heat output levels the stove can provide, for use in sizing stoves to residences. Labels must be produced and affixed by manufacturers, with DEQ approval, prior to stove certification.

Certification Program Timetable and Costs

Oregon's program is now underway, with the voluntary phase of its testing and certification program. The first stage mandatory standards are not in effect until July 1, 1986. One laboratory had been accredited and nine stoves had been certified, as of March 14, 1985 (See Appendix B for list of stoves). Other applications are in process, or expected soon. The State of Colorado has adopted, and Missoula, Montana is considering adopting, certification programs similar to Oregon's as described later in this section.

Estimated certification program costs have included the following:

- DEQ has estimated that increased costs to consumers of certified stoves may range from $200-$500 on the average (Kowalczyk and Tombleson, 1984, and 1982).

- Testing costs to manufacturers were estimated by DEQ in 1981-82 at $1,500-$2,000 per model tested. This is comparable to their present costs for safety and efficiency testing (Kowalczyk and Tombleson, 1982).

- Catalytic combuster replacement: $60 to $140 as often as every two years (Kowalczyk and Tombleson, 1984).

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- Catalytic combuster replacement: $60 to $140 as often as every two years (Kowalczyk and Tombleson, 1984).

- DEQ's administrative costs may not exceed one to two staff persons, because so much of the program's cost and work will be borne by the manufacturer and private testing labs.

- Potential loss in business (sales) to RWC manufacturers and retailers due to higher appliance prices has been a concern, but no quantitative estimates were available.

Benefits

DEQ has estimated the following benefits of their certification program (Kowalczyk and Tombleson, 1984):

- Seventy-five percent reduction in particulate emissions by the year 2000, including in TSP, fine particulate (PM_{10}) and polycyclic organic matter (POM).

- Proportional reductions in carbon monoxide from RWC, which should aide in achieving attainment of CO standards too - especially wherever these are exceeded in residential neighborhoods.

- Higher woodstove heating efficiencies, which can save consumers up to 33% in the amount of firewood needed, thereby reducing costs associated with gathering firewood; and, conserving renewable wood energy resources.

- Reduced fire hazards, because cleaner burning stoves will emit up to 90% less creosote, thereby also reducing chimney cleaning costs.

- Overall estimated savings of $10-20 per cord of wood burned, available to offset higher purchase prices for certified stoves.

- Health benefits from the 75% reduction of respirable particulate and POMs, the latter already identified as a major air toxicant.

2. Montana

The State of Montana Clean Air Act gives the Board of Health and Environmental Sciences broad powers to regulate any source of air pollutant emissions, including residential sources since these are not excluded. However, the Act prohibits entry and inspection of private residences for this purpose. This could limit the ability of agencies to measure RWC emissions, or to enforce RWC control strategies, at the household level.

The State of Montana Department of Health and Environmental Sciences can identify potentially significant RWC ambient impacts in at least ten western Montana communities, with observable impacts in some localities which occur as frequently as twenty-five times or more in a heating season (Nero and Associates, Inc., 1984). The state agency has concentrated on monitoring TSP problem areas, and has sponsored RWC wood usage surveys in a number of cities (Erickson et al, 1981). The state approach is to establish a strong data base, and to measure the magnitude of RWC impacts, before proposing any RWC control measures, partly because regulation of RWC is a controversial topic in Montana.

The state is closely watching developments in Oregon. As in Oregon, state enabling legislation would be needed to regulate RWC appliances at the point of sale. The only direct regulatory action related to RWC in Montana has occurred in Missoula, but it has been a major effort.

a. Missoula

Missoula has been a nonattainment area for TSP (primary standard) since monitoring began (1969), except for several years in the mid-1970's. Industrial controls and street paving achieved attainment, but area source growth - suspected to be primarily from RWC - has restored nonattainment conditions (Carlson, 1984). The local air pollution control agency, the Missoula City-County

Health Department (MCCHD), has taken an active role in RWC assessment and control, in response to direction from its governing body, the Missoula City-County Air Pollution Control Board, and strong citizen concern.

A 1976 petition with 10,000 signatures asked the Missoula County Board of Commissioners to "do something" about deteriorated air quality in Missoula. In early 1981, after several studies involving citizen committees, the MCCHD began working with Missoula citizens to develop a plan to reduce wintertime air pollution from all sources, but especially from RWC. That effort resulted in a public education campaign, which included radio and TV commercials, and slide/tape and video presentations, as well as brochures.

It also lead to a package of regulatory measures designed to reduce the severity of air pollution episodes. An Air Stagnation Plan was adopted, which was initially based on voluntary curtailment not only of RWC but also of industrial point source emissions, if an air pollution Alert was declared.

In November, 1983 RWC control measures were strengthened, to produce one of the most comprehensive RWC control strategies enacted by any community. The main elements of this program are as follows:

- Visible emission limits
  - Smokestack plume opacity cannot exceed 60% at any time, except for 15 minutes in any four hour period, allowed to start up a fire. This applies at all times to all residential and commercial solid fuel burning devices within the Missoula Air Stagnation Zone, which encompasses most of the Missoula Valley.

- Episode Controls (Missoula Air Stagnation Plan)
  - Stage I Air Pollution Alerts and Stage II Warnings are called if the eight-hour average TSP level exceeds, or is projected to exceed, 150 ug/m^3 and 300 ug/m^3, respectively.

  - No visible emissions are allowed from any residential or commercial solid fuel burning devices, except by special permits of the following types: sole source of heat permits; dealer demonstration permits; and, special need permits.

    Permit holders may burn, but cannot exceed 20% opacity, except during fire start-up (20 minutes every four hours).

  - Alerts and Warnings are voluntary in the Air Stagnation Zone, but mandatory within a smaller High Impact Zone, which includes urban areas of Missoula.

  - People are also requested to limit vehicle driving to necessary trips and use mass transit.

- Enforcement/Penalties
  - Inspectors check for improper visible emissions, issue written warnings (first violation per season) and citations for repeat violations, which can result in fines of $20-100, or loss of special permits to burn.

  - Enforcement is on-going for the visible emission (60% opacity) limit.

  - For episodes, MCCHD must give public notice of Alerts and Warnings at least three hours prior to taking enforcement action.

MCCHD uses the media to announce Alerts and Warnings, and maintains an Air Pollution Hot Line with a recorded message on RWC curtailment status. Last winter the agency had to increase the number of phone lines to seven, and shorten the recorded message to 10 seconds to handle episode calls (Hedstrom, 1984).

Last winter (1983/84) was the first heating season under the new mandatory Alerts. One hundred ten warnings were issued, and one citation, which was successfully appealed. Alerts or Warnings typically occur 10-30 times during a heating season.

MCCHD staff have estimated and compared the air quality benefits of the all-voluntary RWC curtailment measures (pre-November '83) versus the mandatory and voluntary curtailment program now in place. Previous voluntary curtailment was estimated to reduce emissions by 6%-12%, based on an estimated compliance rate of 30% (Grotheer, 1984). The present program, with mandatory RWC curtailment during episodes, could reduce RWC emissions by as much as 23%-44% based on 100% compliance. Curtailment requirements are expected to occur on 28-53 days each winter (120 day season). The 60% opacity limit is projected to reduce emissions by 3%, based on a 10% violation rate, only 25% of which occur when enforcement is possible - i.e., before dark (Grotheer, 1984).

MCCHD also estimated that the Alerts reduced daytime burning by 30%-35%, with mandatory alerts more effective than voluntary. Based on a meteorological regime analysis, MCCHD has also estimated ambient air quality improvements from the Alert strategy, both in their 24-hour and seasonal average TSP concentrations (Carlson, 1984).

A new phase of the RWC control program has been recently proposed, in the form of proposed performance standards for new installations of all residential solid fuel burning devices. These are contained in <u>proposed</u> revisions to Missoula's air pollution regulations. They would incorporate Oregon's woodstove

testing/certification methods, and utilize an expanded permit system for implementation as follows:

- Woodstoves may be issued a Class I permit by MCCHD to operate during Alerts, if they meet a lowest achievable emission rate (LAER) standard. The initial LAER standard proposed by MCCHD is emissions which do not exceed 6 grams per hour, when tested in conformance with the Oregon procedures.

- Within Missoula's High Impact Zone, emissions from solid fuel devices with Class I permits must not exceed 10% opacity during Alerts, except for 20 minutes in any four hour period.

- Class I permits expire in two years, and repermitting may require evidence at that time that the device can still meet emission limits -- e.g., evidence that catalytic combusters have been replaced as needed.

- July 1, 1985 is the proposed start date for issuing Class I permits. Thereafter, no new sole source permits would be issued, and special need (hardship) permit duration and eligibility rules would be tightened.

Appendix B contains: a) a copy of Missoula's regulations for solid fuel burning devices, which indicates proposed language for adding woodstove performance standards and Class I permit requirements; and, b) a summary of Missoula's current wood burning regulations, which feature mandatory Alerts and Warnings, and areawide visible emissions (60% opacity) limits.

The thrust of Missoula's latest proposed RWC control measures are to promote the installation of cleaner burning woodstoves, without regulating this at the point of sale, as Oregon does. The performance (emissions) standard proposed is stringent enough to promote stoves with catalyst technology. The Class I permit

renewal requirements (two years) would help guard against deterioration of catalyst-equipped stove performance, but would also add to the administrative burden of the program.

This is the first full-fledged permit system proposed to regulate RWC. The Missoula Air Pollution Control Board must now decide if the administrative and political burdens of this approach are acceptable. RWC controls have created vocal opposition to woodstove regulation in Missoula. A group called "Woodburners United" tried but failed to put a measure on the ballot in the fall of 1984 to repeal current RWC regulations and to prohibit their readoption for two years.

3. Colorado

Concern about RWC impacts in Colorado was first evidenced by a number of ski communities. Their winter populations swell with temporary visitors, and RWC is widespread. Meteorology and terrain features reduce ventilation, and ambient concentrations of TSP and CO periodically exceed federal standards in winter. Recent research also indicates that woodstoves may emit more pollutants at high altitudes, other factors being equal (Shelton, 1985; Oregon DEQ, 1985).

Due to high fugitive dust levels often associated with winter road sanding, many of these communities have avoided formal non-attainment status for TSP. Visibility impairment and hazy conditions are one of the chief air quality concerns voiced about RWC, partly because it directly threatens local economies which are dependent on tourism.

Following are brief descriptions of RWC control measures adopted or proposed in several Colorado ski communities, and state level RWC control actions.

a. Colorado Ski Communities

The Pitkin County (Aspen), Colorado community has been concerned about RWC impacts for over ten years. Vigorous public education has long been conducted, to increase public awareness that RWC causes problems, and in order to ask for voluntary curtailment

when pollution levels are high. An active Citizens Clean Air Advisory Board reviews RWC control statutes and works closely with the City-County Environmental Health Department. The County has long had air quality regulations, which spell out alert procedures, and call for vehicle restrictions during high CO levels, but resources are lacking for monitoring and enforcement. Both TSP and CO national ambient air quality standards are exceeded in winter.

RWC problems were originally attributed largely to fireplaces. In 1977 the County adopted a fireplace ordinance (Pitkin, 1977) limiting new fireplaces as follows: one per single family dwelling, restaurant or bar; one per 3,500 $ft.^2$ for four-plex and other multifamily structures; one per 1,000 $ft.^2$ for duplexes or triplexes; and, one per lobby or guest entertainment room for hotels, motels, lodges, and inns (no fireplaces in guest rooms were allowed).

Fireplace design standards were also adopted to reduce heat loss from structures. Their requirements included glass (or other) doors and air ducts to admit "other than room air". This was to prevent room air from being drawn up the chimney, in order to discourage cold air infiltration into the room from outside. A copy of the original fireplace ordinance and design standards are included in Appendix B.

Woodstoves were not addressed because: a) there were more fireplaces than stoves, b) fireplaces were thought to be more polluting, and c) growth in stove use was considered unlikely, due to anticipated growth limitations within the city of Aspen. This also prompted the City of Aspen not to adopt RWC regulations as the County had done.

However, stove use did grow, and in 1983 the City and County adopted ordinances which limit the number of conventional fireplaces or woodstoves per building, but allows unlimited numbers of "certified" clean burning stoves (Pitkin, 1983).

Currently, a list of "clean" wood burning devices is maintained by the City-County Environmental Health Officer, based on emissions test data from manufacturers and the literature. The ordinance specifies that Oregon test methods be used, and that testing be done at specified burn rates and other conditions. A copy of this ordinance is referenced in Appendix B.

Vail, Colorado in 1978 adopted an ordinance (Vail, 1978) limiting the number of new solid fuel burning devices per dwelling unit (not per building, as Pitkin County had done). It also established fireplace construction standards similar to Pitkin County's. Voluntary curtailment of RWC was also asked whenever carbon monoxide levels or coefficient of haze index exceeded specified limits (U.S. EPA, 1984b).

In 1983 Vail adopted another ordinance (Vail, 1983) which allowed a second solid fuel burning device in any dwelling unit, provided it complied with Oregon's (then draft) particulate emission standard for wood stoves, of 0.067×10^{-6} grams/Joule. The ordinance specified that Oregon's test procedures, or an equivalent procedure, be the basis for judging woodstove emissions performance.

The town's Environmental Health Officer must certify in writing that a woodstove meets this criteria, before a building permit can be issued for its installation. The Environmental Health Officer will maintain and publish a list of devices known to be certified.

This ordinance also prohibits the burning of coal or refuse in solid fuel burning devices. Appendix B contains a copy of this ordinance.

The town of Telluride, Colorado has also by ordinance limited the number of solid fuel burning devices to one per building, regardless of the number of dwelling units (Telluride, 1976). Continuing ambient standard violations include some of the higher particulate air pollution levels in the state.

A high level of public concern exists as evidenced from a recent door to door survey in the town of Telluride, for the local Environmental Commission, in which over 90% of respondents expressed support for legislation, that would help clean up wood stove pollution (Selby, 1984). At the present time City and County officials are considering ways to respond to this situation and concern. One approach receiving attention is to adopt RWC regulations for a "Telluride region", which would encompass an area larger than the Town of Telluride but smaller than San Miguel County.

Snowmass Village, Colorado allows only one solid fuel burning device per dwelling unit, restaurant or lodge (U.S. EPA, 1984b).

Crested Butte, Colorado limits woodstoves to one per new building regardless of its number of dwelling units, and only if certain conditions are met (Radderman, 1984), which are designed to encourage highly insulated structures and use of solar heating.

To obtain a building permit to install a solid fuel burning device as a primary heat source, an applicant must demonstrate that his entire building (walls, windows, etc.) is insulated to an overall "envelope" factor of R-22 (Crested Butte, 1980). The town zoning ordinance is the vehicle for regulating RWC, along with other solid fuel burning devices. It also calls for active or passive solar heating designs. It gives credit toward a permit for a wood burning device for building designs which achieve "solar gain" - e.g., which emphasize south facing windows and avoid north facing windows.

Crested Butte is situated at an elevation of 9,000 feet, with a population of about 1,000, a very high percentage of which burn wood as their primary source of heat. Residential coal burning has been banned due to air quality concerns, although coal is readily available at competitive prices.

The Beavercreek Resort Company, near Avon, Colorado is a private development of expensive homes which have instituted a unique RWC control strategy. Regulations have been adopted which: a) place restrictions on fireplace construction and prohibit woodstoves entirely, b) monitor and enforce restrictions on starting or continuing fireplace fires during high air pollution conditions. The regulations (copy in Appendix B) will become effective when the number of completed homes reaches 500.

An elaborate monitoring system includes a heat sensor and warning light at each fireplace, wired to a central communication system. Whenever the company concludes that continued RWC could result in violations of Colorado's ambient air quality standards, the warning light is activated in all homes. Thereafter, no new fires can be started, or new wood added. The heat sensor allows monitoring by the central office to ensure that burning has stopped. If burning is not stopped, fines can be levied. The Resort Company may even enter a home and extinguish a fire, if it deems such action necessary.

b. State Level RWC Control Measures

State level concern and activity in Colorado related to RWC has also increased in recent years to include the adoption of laws and regulations to mitigate RWC impacts, as summarized in this section.

Denver has been the main focus of the few air pollution studies in Colorado that have estimated RWC ambient impacts (Wolff et al, 1980; GMRL, 1982; Dennis, 1983; Poincenot, 1982). All of these estimated significant RWC contributions to fine particulate mass and/or to visibility impairment. Studies of RWC wood usage in Colorado have also indicated that: a) about half of all households have wood burning devices (Ryan, 1981; TRC 1985); and; b) fireplaces are much more prevalent than woodstoves. In most Colorado communities surveyed, fireplaces account for more wood usage and resultant emissions than woodstoves, despite the fact that average wood usage and emissions per burning unit are both higher for stoves than fireplaces (TRC 1985; King, 1984).

An Advisory Committee on Residential Wood and Coal Combustion recommended the following types of RWC control approaches to the Colorado Air Quality Control Commission (Colorado AQCC, 1983):

- Public education to promote proper selection and operation of fireplaces, inserts and stoves;

- Emissions standards for all new stoves, inserts and fireplaces sold in Colorado; and,

- Economic incentives to decrease pollution from existing fireplaces, inserts and stoves through retrofitting or replacement with improved designs.

Based on these recommendations, the State of Colorado initiated a public education program for wood stove users through pamphlets distributed at wood stove dealers (Grotheer, 1984). The State also enacted enabling legislation (House Bill 1187, 1984), intended to reduce both particulate and carbon monoxide emissions from RWC, by providing for the following RWC control measures:

- continued public education efforts;

- an evaluation and certification program governing the sale of woodstoves in Colorado;

- voluntary no-burn days, whenever RWC is likely to adversely affect air quality in any non-attainment area; and,

- structural design standards for fireplaces to reduce their emissions.

Appendix B contains a copy of HB 1187, which was effective July 1, 1984. It calls for the Colorado Air Quality Control Commission to promulgate rules to implement all of its provisions by July 1, 1985. Appendix B also contains a preliminary draft of a rule to implement the woodstove requirements by July 1985.

Deadlines established in this law will require that stove testing and certification standards and procedures be established by July 1985, and that new wood stoves cannot be sold in Colorado after January 1, 1987, unless they have been tested, certified, and an emissions performance label attached.

Colorado may pattern its stove testing and certification program after Oregon's, but alternative approaches are being actively promoted by affected manufacturers, through their trade association, the Wood Heating Alliance. Colorado may have to develop and include carbon monoxide (as well as particulate) emissions standards in its certification program. Oregon's program only uses particulate emissions standards.

House Bill 1187 provided that new fireplace design specifications be adopted by the Commission by July 1, 1986, based on performance tests of different designs. It also provided that all counties and municipalities in Colorado which have building codes must include the resulting fireplace design specifications, or stricter specifications, by July 1, 1987.

To finance the start-up costs of this state RWC control program, House Bill 1187 provided $49,134 and one full time position, and authorized acceptance of $75,000 in federal grant funds, for the fiscal year beginning July 1, 1984. Fees for certification of new wood stoves will also be established to help defray future costs of the program.

4. Alaska

The Alaska Department of Environmental Conservation (ADEC) air quality control regulations provide for designation of a Wood Smoke Control Areas, if TSP from RWC alone exceeds 150 ug/m^3 on a minimum of two separate days (ADEC, 1983). Such levels must be measured by ADEC-approved Chemical Mass Balance (CMB) receptor modeling methods. To date only the Mendenhall Valley of Juneau has been so designated.

In Wood Smoke Control Areas the following restrictions apply (Air Quality Control Regulations 18 AAC 50):

- Visible emissions may not exceed 50% more than 15 minutes in any one hour.

  - During an areawide air quality Alert, this 50% opacity limit applies everywhere outside Wood Smoke Control Areas too. Alert criteria were expanded to include not only the typical areawide TSP ceiling of 375 ug/m^3, but also a 150 ug/m^3 ceiling on particulate matter solely from RWC within a Wood Smoke Control Area.

- During an air Emergency, no RWC is allowed which results in the emission of smoke.

  - Air Emergency criteria were expanded to include not only the typical areawide TSP ceiling of 875 ug/m^3, but also a 260 ug/m^3 ceiling on particulate matter from RWC within a Wood Smoke Control Area.

Burning in a way that creates black smoke is always prohibited, anywhere.

The State Air Quality Control Plan says ADEC will monitor in areas where RWC impacts are considered significant (ADEC, 1983). When particulate levels reach 150 ug/m^3, where RWC is considered the major contributor, chemical analysis of particulate samples and Chemical Mass Balance (CMB) receptor modeling techniques are explicitly called for in the Plan, to determine the actual impact from all local sources to ambient particulate levels.

As described in Chapter IV of this report, CMB analysis can distinguish quantitatively the contribution of locally generated RWC emissions from any other sources of particulate matter for which a unique chemical composition profile is established experimentally or from literature sources. Thus, CMB analysis can estimate how much of

the total particulate levels measured are from local RWC vs various fugitive dust sources, vehicle exhaust, nearby industry (if any), etc. It can similarly estimate "background" contributions from remote sources, if appropriate monitoring samples are available.

Thus, ADEC's RWC control strategy explicitly relies on CMB analysis to help determine whether regulatory action is appropriate. That is, Wood Smoke Control Areas would not be designated unless CMB analysis showed that ambient TSP levels exceeded 150 ug/m^3 from RWC alone, exclusive of other source contributions.

The State Plan also emphasizes that local government should manage adverse air quality conditions, with state assistance. The City and Borough of Juneau (CBJ) has adopted several ordinances to regulate RWC which implement the state rule locally. For example, CBJ Ordinace No. 84-30 (1984) designates the same Mendenhall Valley area as a Smoke Hazard Area, and establishes the following RWC control measures for that area:

- Visible emissions may not exceed 50% more than 15 minutes in any one hour.

- Open burning is prohibited between November 1 and March 31. This ordinance also prohibits open burning outside the Smoke Hazari area during these dates, unless a permit is obtained from the CBJ, based on a finding that the resulting smoke conditions are not likely to endanger public health or become generally objectionable.

- Solid fuel burning may be temporarily prohibited entirely. This requires the CBJ Manager to determine (and give public notice) that a smoke hazard condition exists within a Smoke Hazard Area. This determination is defined as follows: "a determination that weather conditions or smoke conditions within the smoke hazard area are such as to be, or are likely to become, any danger to the health of persons within the smoke hazard area or to become generally objectionable to such persons".

Exemptions to the last provision are available for persons whose sole source of heat is RWC, but only until January 1, 1986. Another proposed CBJ Ordinance No. 84-18 (1984) would amend the building code to require that every dwelling unit and guest room have heating facilities capable of maintaining a room temperature of 70° Fahrenheit, without combustion of solid fuel.

CBJ Ordinance No. 84-30 provides for fines up to $300 for the first violation and up to $500 or 30 days in jail, or both for subsequent violations. The CBJ Police Department, Animal Control Unit, has been designated to enforce the ordinance, including inspecting premises to determine eligibility for exemptions (CBJ, PD, 1983). Written warnings are authorized for first violations, but citations are required thereafter.

A citizen Air Pollution Advisory Committee has been actively involved before and after adoption of the RWC ordinances. Their recommendations to the CBJ Manager had included the following (not an exhaustive list):

- A moratorium on the installation of wood burning devices as a major source of heat, until emissions standards and a certification program is established for such devices.

- That CBJ establish an Environmental Health Unit to monitor RWC and other environmental health concerns.

- Extend the 50% opacity limitation throughout the CBJ.

Appendix B includes copies of: a) CBJ Ordinances 84-30 and 84-18; b) ADEC State Air Quality Control Plan, Section G, "Wood Smoke Pollution Control"; and, c) excerpts from ADEC's Air Quality Control Regulations, 18 AAC 50.

The ADEC has also addressed RWC through public education, and through cooperative efforts with other agencies. For example, ADEC and the USDA Forest Service encourage wood cutting in the spring rather than in the fall (U.S. EPA, 1984b). This is to promote better seasoning of wood. Firing inadequately seasoned wood is considered by ADEC to be a prime cause of exceedances of the opacity limitations established to control RWC impacts. A majority of RWC wood supply may originate from Forest Service land in communities like Juneau and Fairbanks, both, of which experience high RWC impacts.

5. Reno, Nevada

The Washoe County District Health Department regulates air pollution in the Reno/Sparks metropolitan area, which lies within the Truckee Meadows airshed. The Reno/Sparks area is a non-attainment area for both total suspended particulate (TSP) and carbon monoxide (CO). The Truckee Meadows Air Quality Implementation Plan (AQIP) addressed RWC primarily in terms of attaining National Ambient Air Quality Standards for CO (Truckee Meadows AQIP, 1982).

The AQIP was based on a CO emissions inventory which estimated that RWC produced 7,845 tons/year of CO emissions, or 39.3 tons per winter day in 1980. This was projected to grow to 10,199 tons/year by 1987, and 52.7 tons per winter day, if no RWC controls were applied. The AQIP's proposed strategy for reducing RWC CO emissions consisted of the following three elements.

- Better wood burning techniques

  Public education through publication of a "Woodburners Guide" (Regional APA, 1982) and media coverage were projected to induce 60% of all woodburners to adopt and exercise proper burning techniques on a continuous basis. The improved techniques were projected to achieve sufficiently higher burn rates to reduce CO emissions by 64%, based on emissions test results reported by De Angelis et al, 1980. Thus, a 38.4% reduction (.6 x .64) in uncontrolled 1987 CO emissions from RWC was projected for such voluntary efforts, or 20.2 less tons of CO per winter day.

- Institutionalized wood burning reductions

  A "Developers Guide" (Washoe COG, 1981) was prepared, which encouraged builders not to install woodstoves or fireplaces in dwelling units, but instead to emphasize solar and energy conservation building design. This was projected to result in 20% of the 1987 single family dwellings not having woodstoves or fireplaces that otherwise would have, resulting in 8.4 less tons of CO per winter day.

- Voluntary curtailment during episodes

  An estimated 35% of all wood burners (RWC households) were projected to stop burning during air pollution alerts or inversion advisories announced to the public through the media. Temperature data monitored and reported by 30 volunteers at locations throughout the area were to be used to anticipate inversions (Grotheer, 1984). This estimated 35% curtailment effectiveness was projected to reduce uncontrolled 1987 emissions by 18.4 tons per winter day.

Thus, these three largely voluntary RWC control measures were projected to reduce uncontrolled 1987 CO emissions on a winter episode day by 47 tons (20.2 + 8.4 + 18.4) or by over 89%. The public education materials were prepared and distributed, and the Washoe County District Board of Health adapted its Air Pollution Control Regulations, Emergency Episode Plan, to include RWC curtailment measures and criteria, as discussed below.

The Emergency Episode Plan, criteria for RWC control actions were strengthened in (October, 1984) and now provide for the following actions, whenever ambient pollution concentrations reach the indicated levels:

> "Whenever the measurements of total suspended particulates, carbon monoxide or ozone reach Stage I (Alert) levels (15 ppm CO, 0.2 ppm O_3, or 375 ug/m^3 TSP, respectively) and adverse meteorological

conditions are predicted to persist, the burning of wood or coal in commercial or residential stoves and/or fireplaces shall be suspended unless it can be demonstrated that such fuels supply the only heat available to the person burning them. The suspension shall remain in effect until all episode stages have terminated". (Washoe County, 1984; part 050.015)

A copy of the Emergency Episode Plan is included in Appendix B.

The strengthening revisions adopted in October 1984 lowered the ambient pollutant concentrations at which the mandatory cessation of RWC is to be triggered to those levels indicated above. These correspond to the Stage I Alert level criteria in the Emergency Episode Plan. At these lower trigger levels, Washoe County Health Department staff who will enforce these rules expect four to five curtailment days to occur in a typical winter season (Bonderson, 1984). Prior to this, only one curtailment day occurred (January, 1983) at higher trigger levels, which had been established at 75% of stage II Warning levels (e.g., at 469 ug/m^3 of TSP, and 22.5 ppm of CO).

Stage I Alerts cannot be declared until pollutant concentrations which exceed the trigger levels have actually been measured. However, Health Advisories can be declared when pollution reaches 80% of the Stage I Alert Level (i.e., at 12 ppm CO and 300 ug/m^3 TSP). Voluntary curtailment of RWC is requested under Health Advisories, and public information announcements are increased to warn the community that air pollution levels are increasing toward Alert levels.

On episode days, public notice of a Stage I Alert would be prominently announced in the media. Health Department staff would immediately begin patrolling and responding to complaints, and issuing information packets to wood burners, on how to burn properly. After an Alert has been declared, three hours is allowed for people to let their fires burn down before any Notices of Violation would be issued. The number

of agency staff available for surveillance and enforcement is so limited that public notice and voluntary cessation of RWC is actually relied upon for these episode controls to be effective.

Notices of Violation are intended primarily for flagrant violators. The first, second and third violations of these episode regulations during a period of twelve consecutive months are considered "minor violations", subject to fines of $25-50, $50-100, and $100-200, respectively. Violation notices may be appealed to a Hearings Board, or to the Washoe County District Board of Health, which ultimately levies any fines.

In 1984, the first rigorous household survey of RWC was conducted for the Reno/Sparks area, which indicated a much lower CO emissions inventory attributable to RWC than had been the basis for the AQIP (Pitter et al, 1984). For example, the 52.7 tons of CO emissions per winter day projected for 1987 from RWC was reestimated at 15.6 tons, less than a third of the original estimate. EPA Region IX has also recently indicated that it cannot agree to the proposed effectiveness estimates for the three RWC control measures, as summarized above.

As a result, the area's CO control strategy must be reviewed. The strategy's CO "design values" - i.e., the reduced CO emissions levels that must be achieved by 1987 in order to project attainment of the CO standards - have also been reduced. This is due to the lower total CO emissions now estimated from all sources, as processed through EPA's rollback procedures for establishing CO design values for SIP development (Pitter et al, 1984).

However, after subtracting the CO emissions reductions projected in the AQIP for proposed vehicular emission controls, the remaining CO emissions reductions needed (21.2 tons/day) to achieve the new design value is greater than the total CO emissions currently estimated for RWC element. That is, if RWC CO emissions were eliminated entirely, the CO design value would still not be achieved.

While alternative RWC control measures are developed or refined, Washoe County plans to conduct field studies this winter (1984-85) which will directly assist their CO SIP development. One of these will use radiocarbon analysis of CO samples to directly estimate the relative contributions to elevated CO ambient levels from vehicle exhaust versus RWC.

D. Approaches to Evaluation of the Potential Effectiveness of RWC Emissions Control Measures

This section begins by providing an overview of pertinent considerations in estimating the potential effectiveness of regulatory control measures designed to reduce emissions and ambient impacts from Residential Wood Combustion (RWC). The use of dispersion and receptor modeling to evaluate RWC control measures is briefly discussed. Evaluation of the following types of control measures is then discussed and illustrated: emission standards for new woodstoves; weatherization of houses; wood moisture controls; episode controls; and, public education. The role of a citizen advisory process in developing and selecting control measures is also briefly discussed.

1. Overview of RWC Control Measure Evaluation

Estimating the potential effectiveness of any RWC control measure(s) generally consists of analyzing the extent to which baseline RWC conditions will be altered by implementing the measure(s). Baseline RWC conditions, as illustrated in Figure V-3, refer to the level of present (and projected future) RWC wood usage, emissions and ambient impacts which are estimated to exist in a locality, if no RWC control measures are used. Section III.D of this document discusses how household surveys and other approaches can be used to quantify RWC wood usage and emissions, including projecting future RWC emissions. Section IV of this document describes approaches for estimating ambient RWC impacts using field monitoring and modeling methods.

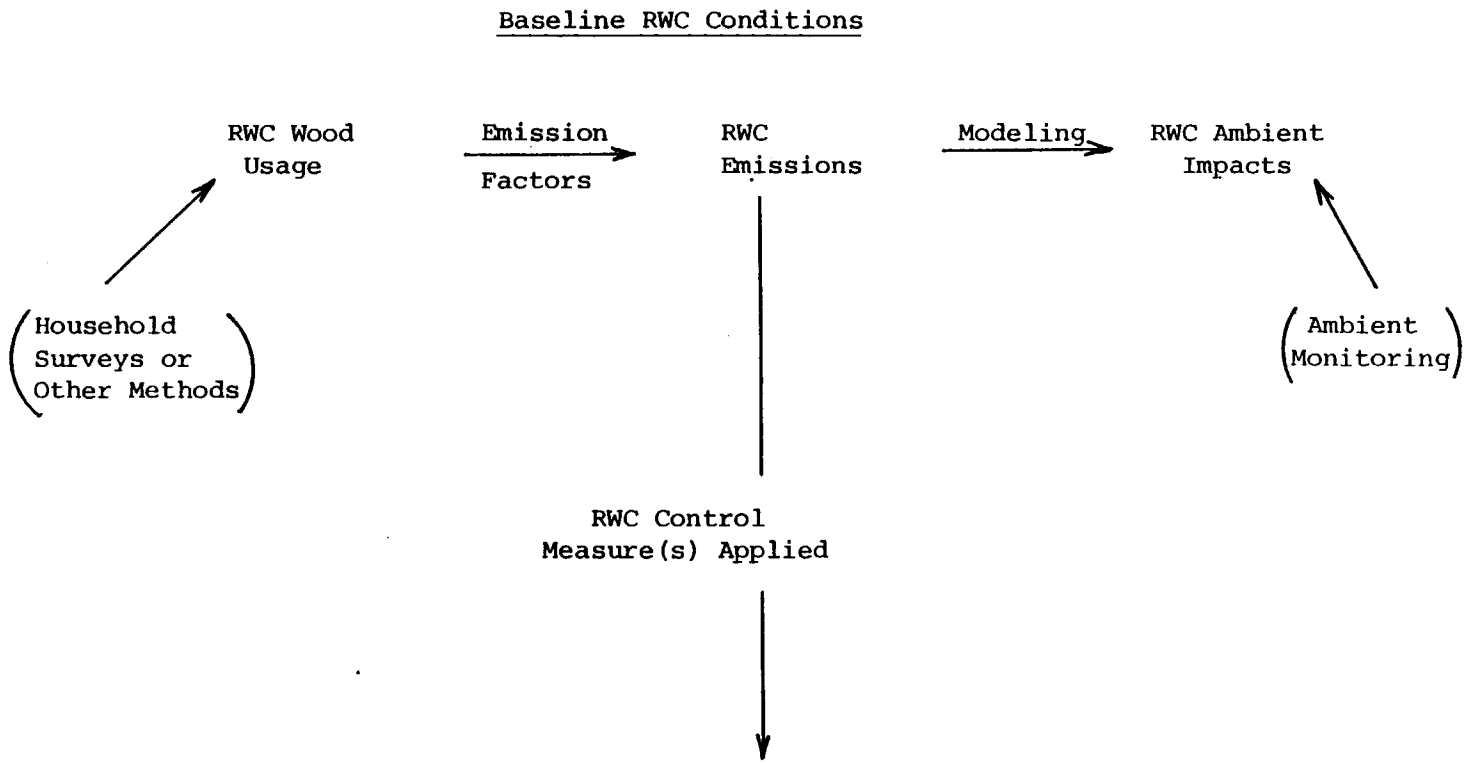


Figure V-3. Schematic Illustration: RWC Control Measures Can Alter RWC Baseline Conditions in Several Ways

Assessing the effect on ambient pollutant concentrations is usually the main goal in evaluating RWC control measures - e.g., to determine how much a control measure(s) helps in attaining or maintaining compliance with ambient air quality standards. Figure V-3 helps visualize that this may involve first estimating how a control measure would alter baseline wood usage or emissions. These would then be translated into corresponding reductions in RWC ambient impacts using appropriate RWC emissions factors or modeling.

The more completely local baseline RWC conditions can be characterized, the better RWC control measures can be evaluated (and targeted). As discussed in several sections of this document, some of the parameters most useful for characterizing RWC conditions are summarized in Table V-13.

As discussed in Section III.D, many of the parameters in Table V-13 are most reliably determined through local household surveys, because of limitations inherent in other approaches. In the absence of survey information, some of the parameters in Table V-13 may have to be estimated using best available local information and judgement. This is because the first essential step in control measure evaluation is quantitative characterization of baseline RWC conditions as completely as possible.

Then control measures can be evaluated in terms of the estimated changes they cause in various parameters such as those in Table V-13, and how much these changes reduce RWC emissions. Subsequent translation of estimated RWC emission reductions into improvements in ambient air quality should utilize the best available models of the local airshed. These may involve simple rollback models or more complex dispersion models, as discussed in more detail in the following subsection.

TABLE V-13. Useful Parameters For Characterizing RWC Conditions

- Ambient pollutant levels specifically attributable to RWC - e.g., ug/m^3 of particulates or ppm of carbon monoxide-preferably based on chemical mass balance (CMB) or radiocarbon analysis, or on dispersion models calibrated using such RWC tracer analyses.

- Emissions inventories for RWC pollutants, preferably based upon quantification of some or all of the following types of parameters:

  - Number of households which burn wood ;
  - Average amount of wood burned per household ;
  - Average household wood burning rates (e.g., in kg/hr) ; and,
  - Pollutant emission factors for wood burning devices (e.g., in g/kg of wood burned).

- The fraction of RWC wood usage or emissions associated with:

  - woodburning for primary house heating, secondary house heating, or burning for aesthetic purposes only ;
  - major categories of wood burning devices, e.g., stoves, fireplaces, inserts, furnaces, etc.;
  - Certain woodburning practices, e.g., starved air ("airtight") burning vs higher burn rates; and,
  - various demographic characteristics of woodburning households, e.g., location, income, age, degree of weatherization, etc.

- Trend factors related to RWC activity levels, e.g.:

  - population and household growth projections ;
  - projected numbers of wood-burning devices by type, e.g., from sales or construction forecasts ;
  - price forecasts for wood and other fuels ;
  - factors representative of wood use trends, e.g., wood cutting permits issued ; and,
  - factors representative of trends in RWC emissions or ambient impacts, e.g., nephelometer (Bscat) data.

The estimated benefits attributable to each control measure can then be compared with estimated costs to implement each measure. For example, the relative cost-effectiveness of various candidate measures could be assessed in terms of dollar costs per unit of emission reduction or per unit of ambient air quality improvements. It may also be feasible to further translate these benefits into other terms-e.g., improved visibility, or reduced exposure to toxic air contaminants.

RWC control measures reduce emissions of all of the following pollutants for which federal ambient standards or other regulatory efforts exist:

- total suspended particulates (TSP);
- fine particulate matter, e.g., up to ten microns in particulate diameter (PM_{10});
- carbon monoxide (CO); and,
- certain toxic air pollutants, including polycyclic organic matter (POM) such as benzo(a)pyrene (B(a)P), or polyaromatic hydrocarbons (PAH).

Most characterization of RWC impacts and controls to date have involved particulates. However, EPA studies have identified RWC as the single largest source nationally of POM emissions (Radian, 1983), and a potentially significant source of CO emissions under certain conditions (Nero and Associates, Inc., 1984). Thus, RWC control measures have multiple pollutant reduction benefits.

For localities with substantial woodburning activity, RWC may be an especially important PM_{10} emissions source. Virtually all RWC particulate emissions are well below this particulate-size ceiling (Watson, 1979; DeCesar and Cooper, 1981). RWC can account for substantial total or fine particulate sample mass, and source activity is concentrated during winter when meteorology is often poorest for pollutant dispersion.

Characterizing the effectiveness of some control measures is inherently more speculative - e.g., the potential for public education activities which promote cleaner wood burning practices to cause RWC emission reductions. Subsection three below discusses factors to consider in estimating RWC emissions reductions from five different types of RWC control measures, including public education.

Section V.B above described the findings of a quantitative analysis of generic RWC control measures. These are most useful as estimates of relative particulate emissions reductions potentially available from a wide variety of RWC control measures. These estimates cannot be assumed to apply to any particular locality, although the approaches used may be applicable.

Consideration of RWC control measures can be politically sensitive, because many citizens may be directly affected. A local citizens advisory committee can be especially helpful in formulating airshed pollution control strategies which consider RWC control measures. Subsection four below discusses the role and importance of such a citizens advisory process relative to RWC control selection.

In the early 1980's, the State of Oregon developed State Implementation Plans (SIPs) for particulate matter for its three Air Quality Maintenance Areas (AQMAs) - Portland/Vancouver, Washington, Eugene/Springfield and Medford/Ashland. All three contained RWC control measures supported by quantitative technical analyses of RWC wood usage, emissions and ambient impacts. These are still the only completed and EPA-approved SIPs which address RWC comprehensively. Results of SIP-related analyses for the Medford/Ashland AQMA have been published and were discussed in Section V.C.1.a above. These and other Oregon SIP-related analyses are used to illustrate the following discussions.

2. Use of Dispersion and Receptor Models to Evaluate RWC Control Measures

Various receptor modeling and dispersion modeling approaches to RWC analysis were described in Sections IV.C and IV.D respectively. This section discusses the use of such models in evaluating candidate RWC emission control measures.

Basically, the use of these models involves two steps: a) estimating reductions in baseline RWC emissions attributable to the control measure; and, b) translating these emissions reductions into the corresponding reduction in ambient pollution levels using an appropriate model. The estimated improvement in ambient air quality is the ultimate measure of control strategy effectiveness in terms of compliance with ambient air quality standards.

Dispersion modeling has been traditionally used for translating emissions changes into corresponding changes in ambient air quality. However, the recent development of Chemical Mass Balance (CMB) receptor modeling described in Section IV.C, has introduced a powerful new tool for analyzing impacts from RWC and other sources in conjunction with dispersion modeling.

CMB analysis of individual particulate monitoring samples can apportion total sample mass into contributions from RWC and other sources. As indicated in IV.C.5 and V.D.3.d, this enables validation of particulate dispersion model predictions for individual emissions source impacts, as well as for the combined particulate impacts from all sources. Previously, only the latter was feasible. This enables refinements in individual source emissions databases, and/or model adjustments, both of which should improve the correlation of dispersion model predictions with actual monitoring data.

In Oregon's SIP development, CMB analysis discovered unexpectedly large particulate impacts from vegetative burning and soil dust area sources. This prompted research into defensible approaches for improving emissions inventories for RWC and soil sources, as well as

their geographic distribution for dispersion modeling purposes. Spatially resolved emissions inventories for area sources such as RWC and soil dust were developed using a 1-2 kilometer grid system.

As discussed in Section IV.D, models applicable to RWC analysis range from simple proportional rollback and box models, to dispersion models designed to simulate how emissions from many different point and area sources are dispersed under the influence of local meteorology and terrain. In Oregon, GRID cell models (see Section IV.D.2.b) were developed for the Portland and Eugene area AQMAs. These were considered more capable of simulating complex wind patterns in these areas. Sufficient meteorological monitoring data were available to satisfy GRID model requirements. The Medford area AQMA had the highest RWC impacts, due to extensive RWC activity, and valley terrain and wintertime meteorology which severely restricted pollutant dispersion. However, since available meteorological data were insufficient for the Eulerian grid cell model, a Gaussian model was adapted for this AQMA (CDMQC, see Section IV.D.2.a). CMB analyses of particulate monitoring samples were used to validate both types of models in all three AQMAs.

For all three AQMA's, spatially resolved emissions inventories were developed for area sources such as RWC and road dust. Household telephone surveys in each area were used to estimate RWC wood usage for stoves and fireplaces separately. These were converted to RWC emissions estimates using RWC emissions factors developed from Oregon source testing, coupled with GRID model and CMB findings, as discussed in Section IV.D.2.b. Future RWC emissions were projected using short term trend factors based on wood cutting permits issued by nearby national forests, and longer term trends based on population projections. For the Portland area, the results of a modeling study of long term RWC wood usage (discussed in Section III.D.3.d) was used to project future baseline RWC emissions.

Calibrated grid cell or CDMQC models were used in all three AQMAs to evaluate potential RWC control measures in the following way. Basically, two model runs were compared: both represented the same time period and set of conditions, except that different RWC emission database inputs were used. One model run used baseline emissions for all sources including RWC. The other used baseline emissions minus RWC emissions reductions attributed to a control measure(s). The resulting differences in model-predicted ambient pollutant levels at various monitoring sites were the principal indicators of RWC control measure effectiveness.

In this manner, various RWC control measures, and combinations of control measures for RWC and other sources, were tested for each AQMA in Oregon. Both the annual and shorter term average pollutant levels were modeled, under average and worst case meteorological conditions. The implementation costs, and energy use implications, of candidate controls were assessed. In consultation with a citizens advisory group in each AQMA, air pollution control agencies selected a package of proposed control measures for RWC and for other particulate sources as the basis for their SIPs. The RWC controls selected for the Medford-Ashland AQMA are summarized in Table V-8, and further described in Tables V-9, V-10, and V-11.

Table V-8 indicates estimates of reductions in annual average TSP concentrations attributed to five different RWC control measures based on dispersion modeling. Uncertainty in such dispersion modeling evaluations will vary primarily with: a) how satisfactorily the model simulates the spatial and temporal distribution of emissions and their dispersion under the influence of local meteorology and terrain; and, b) the level of uncertainty in the emissions changes attributed to the RWC control measures and used as model inputs. The former type of uncertainty can be addressed by validating dispersion model estimates against ambient monitoring (especially CMB) data over a range of meteorological conditions. The latter type of uncertainty can be addressed through studies to better characterize RWC emissions, e.g.,

through spatial (e.g., gridded) and/or temporal (e.g., day/night) resolution of emissions input data. Sensitivity analysis can also be conducted, using a range of emissions estimates (resulting in a range of potential air quality improvements).

Substantial time, resources and adequate supporting data and special studies are required to develop more complex dispersion models of the type described above. The payoff lies in their capability to more reliably characterize the impacts of sources such as RWC. This minimizes the chances of faulty targeting of pollutant control measures, the costs of which could be substantial.

For example, Oregon's SIP related studies revealed the need for more emphasis on controls for area sources, such as RWC and road dust, and less emphasis on industrial emission controls. Database development and modeling efforts were essential in developing an understanding of the magnitude of RWC impacts, and the potential effectiveness of various RWC control measures. Without such knowledge, and facing continuing exceedances of particulate standards, Oregon's past emphasis on industrial point source controls might have continued to be the main focus of its particulate control plans. Instead, each AQMA was able to justify and develop a package of control measures which targeted both selected area sources as well as particular industrial sources. These were considered most cost effective based on various SIP related studies, which helped define the primary sources of particulate emissions (as illustrated in Figure V-1).

As discussed in Section IV.D analysis of RWC impacts should begin with simple screening models, and progress to more refined models, if preliminary impact assessment warrants the additional effort. Localities with particulate non-attainment problems and very limited resources and/or monitoring data may have to rely on simpler modeling efforts - e.g., proportional rollback or box models (see Section IV.D.2.c). CMB analysis of even a few selected particulate filters would also be very useful in identifying the relative impacts from various local sources (and backgroumd), as well as in validating a box model.

Even when simple models are used, characterizing emissions from RWC and other major sources will still be required. Estimated reductions in emissions for control measures will still govern the potential improvements in ambient air quality projected by the simpler models, as they do for more refined models.

3. Evaluating Potential Emissions Reductions from RWC Control Measures

This section discusses some of the main considerations involved in estimating potential emission reductions achievable from the following types of RWC control measures:

- emissions standards for new woodstoves;
- home weatherization;
- wood moisture controls;
- episode controls; and,
- public education.

This is not an exhaustive listing, but contains most of the major types of RWC control measures likely to be of interest to most localities.

a. Emissions Standards for New Woodstoves

Examples of this RWC control measure are Oregon's statewide mandatory woodstove certification program (described in Section V.C.1.b), and the New Source Performance Standard (NSPS) for woodstoves currently under development by the U.S. Environmental Protection Agency. These standards will limit permissable emissions rates from new stoves to much lower levels than the average emissions rates of existing stoves. As described in Section V.C.1.b, Oregon's Department of Environmental Quality estimates that its standards (Table V-12) will reduce baseline RWC emissions by 70-74% over the 10-20 year period required for certified stoves to largely replace existing stoves. This was based on an estimated average emissions rate from existing stoves in Oregon of 30-34 grams per hour compared to certified stoves, which should not exceed nine grams per hour after 1988.

Areas considering adoption of this type of control measure may need to estimate potential emissions reductions at different points during its implementation. Achievable reductions in emissions for a future year would primarily be a function of the following factors:

- growth (or decline) projected in the number of operating stoves in a baseline year;
- replacement rate of existing stoves with certified stoves; and,
- the difference in average emissions between baseline and certified stoves, which is governed by the emission standard selected.

The percentage of stoves certified at any given time is a function of the rate at which new stoves are purchased and the portion of these which replace existing stoves. The replacement rate depends primarily on average stove life. Market penetration rates for new stoves must decline as available markets become saturated, but may also rise rapidly during a period of booming interest in RWC as a primary or secondary home heating source. If purchase of a certified stove is optional, price differences between certified and non-certified stoves would be a major factor governing the market penetration by certified stoves.

For a given year, an estimated fraction of all stoves which are certified, multiplied by the estimated difference in average emission rates between certified and non-certified (baseline) stoves, is one approach to quantifying achievable emissions reductions. Since average stove life may be 10-20 years, this control measure achieves increasing emission reductions over many years. RWC emissions reductions will be greater for mandatory woodstove certification measures than virtually any other practicable control measure, because baseline stoves will be replaced with cleaner burning models at a maximum rate. If purchase of certified stoves is not mandatory, or some level of non-compliance is anticipated, estimated annual emissions reductions will be correspondingly lower.

Thus, key assumptions in quantifying reductions in emissions include: a) average baseline emission rates for existing stoves (average rates for certified stoves can be assumed to be equal to the emission standard); b) average stove life; and, c) the number of stoves operating in future years, and the percentage of these which are certified.

b. Home Weatherization

Weatherizing houses generally reduces the amount of space heat (fuel) needed to maintain indoor temperatures at a given temperature level. Thus, weatherization could reduce wood usage, and hence, RWC emissions would decrease. The extent of reduction in emission will depend primarily upon: a) the number of wood burning houses which are weatherized; b) the change in energy efficiency resulting from weatherization (i.e., the magnitude of decrease in the heating fuel use expressed in Btu or equivalent units); and, c) how weatherization affects the installation and/or operation of woodstoves or other RWC appliances particularly when the woodburning is not a primary source for space heating.

The last factor is difficult to assess, and can cause substantial uncertainty in evaluating the effectiveness of home weatherization as an RWC control measure. For example, when homes heated primarily with wood are weatherized, their wood usage could be reduced in proportion to their reduced heating demands. This could be as much as a 30-50% reduction for a fully weatherized home (Table V-9). However, homes heated with wood as a secondary fuel prior to weatherization might reduce their reliance on their primary fuel (e.g., gas, oil, electricity), while maintaining or even increasing their wood usage. Some non-wood burning households might weatherize and add RWC capability in order to reduce conventional fuel costs.

Owners of houses weatherized prior to installing a woodstove, could select a smaller stove (than they would have prior to weatherization) to heat the same space. This could increase use of stoves with smaller fireboxes, which tend to be cleaner burning

(Section III.B.5). However, if wood burning houses which weatherize have to decrease their burning rates, to avoid overheating the home, their average RWC emissions may increase. This could be especially true if stoves are operated more in an airtight mode after weatherization. However, catalyst-equipped stoves may not tend to increase their emissions at lower average burn rates (Section III.B.1).

Uncertainty about how weatherization could affect woodburning in weatherized houses could be reduced by surveying such households. Characterizing existing wood usage in terms of how much is for primary and secondary space heating, or the extent to which wood burning households are already weatherized, would also help determine potential RWC emissions reductions from weatherization. If a substantial fraction of houses in a wood burning community are not yet weatherized, the potential RWC emissions reductions attributable to an extensive weatherization program would be quite significant.

In Medford, Oregon, weatherization ranked behind only mandatory emissions standards for new woodstoves in terms of potential RWC emissions reductions achievable (Table V-9). The RWC control measures included in the 1983 Medford area SIP relied most heavily on weatherization (Table V-8), because Oregon's statewide mandatory woodstove certification requirements had not yet been adopted.

Projected reductions in emissions in the Medford area corresponded to an ambitious weatherization goal, established by local government, of weatherizing all residences to cost-effective levels within five years (by January 1, 1987). If weatherization was not proceeding satisfactorily on a voluntary basis with incentives, it was to be required as a condition of sale or rental after January 1984. It was estimated that 70% of local homes needed additional weatherization. A local utility estimated that an average reduction in space heating demand of 40% was achieved

by homes in its weatherization program (Oregon DEQ 1983a). For the two weatherization control measures quantitatively evaluated in Table V-8, esimated reduction in particulate emissions from RWC were approximately 300 tons/year and 500 tons/year respectively (Oregon DEQ, 1981d).

c. Wood Moisture Controls

Seasoning firewood reduces its moisture content, which increases its heating value, due to less heat energy dissipated in vaporizing water in the wood. Seasoning can also reduce particulate emissions per pound of wood burned, under certain circumstances. Particulate emissions can be higher from wetter wood, presumably because the additional steam in the combustion area reduces combustion zone temperatures, resulting in less complete combustion of the wood. The combination of these two potential benefits of lowering firewood moisture content have prompted efforts to promote better wood seasoning as an RWC pollution control measure.

However, as discussed in Section III.B.3 current information is very limited upon which to base general relationships between firewood moisture content and corresponding wood combustion emissions for various RWC pollutants. Work by Shelton also indicates that such relationships may be different for wood burned in stoves and fireplaces (Shelton, 1981).

Shelton estimated that fireplace combustion efficiency declined steadily as wood moisture content increased (Figure III-5). However, he also found that woodstove combustion efficiency peaked for wood moisture contents ranging from 20%-25% (wet basis), in limited testing. The latter finding implies higher pollutant emissions on either side of this range. A subsequent study by others similarly found an optimum wood moisture content range of 20-26% (wet basis), based on stove test results illustrated in

Figure III-4 (U.S. EPA 1984b, Task 4). Thus, the effectiveness of wood moisture control strategies should ideally consider fireplace and stove wood usage separately. Unfortunately, the information needed to do this properly is generally lacking.

To evaluate potential emission reductions achievable from firewood moisture controls generally calls for information about parameters which include: a) average wood moisture content before and after control measures are implemented; b) the amount of wood usage affected by control measures; and, c) a quantitative relationship(s) between wood moisture content and heat energy content and/or pollutant emissions per pound of wood burned.

Wood moisture controls were included in the SIP developed for the Medford, Ashland, Oregon area (Oregon DEQ, 1983a). Household surveys indicated that: a) over 40% of the firewood in the area was cut in the fall; b) 52% of wood burning households seasoned their firewood for six months or less; and, c) 25% seasoned it for three months or less. Controls were designed to encourage 6-8 months minimum seasoning prior to burning. These included: a) vigorous public education on proper seasoning of firewood; and, b) working with public forest agencies to shift firewood cutting to spring, both for the public and for commercial cutters if possible.

The Medford-Ashland SIP claimed that "firewood seasoning programs are expected to reduce the amount of firewood burned and particulate emissions by 10% in the Medford area by 1984." While this estimate was not documented in the SIP, supporting technical documents indicate that the following assumptions were involved (Oregon DEQ, 1981d.)

- Typical moisture contents of wood, related to seasoning and/or storage conditions, include the following:

  - 40-50% moisture in fresh cut, "green" wood;

- 35% moisture in Douglas Fir logging residues after six months outdoor exposure, including a rainy winter season; and,
- 15-20% moisture in well seasoned wood stored in a very dry location

- The average moisture content of wood used in the Medford area was assumed to be 25-30%.

- Wood moisture content and relative heat energy content were assumed to vary as shown in Table V-14.

Based on the SIP assumptions in Table V-14, heating with wood with 20% moisture content produces 31% more heat than using wood with 30% moisture content (88-67 ÷ 67 = 31). Thus, a household heating with 20% moisture content firewood, would use 31% less wood fuel, to produce the same amount of heat, than a household using 30% moisture content wood.

The drier wood should also burn with less particulate emissions than the wetter wood, although how much less is difficult to determine. If it is assumed that the drier wood affords 20% less particulate emissions, then an overall emissions reduction of 45% can be attributed to seasoning wood from 30% to 20% moisture content: (100% - 31%) x .8 = 55% of emissions attributable to 30% moisture content wood. Thus, even if only 20-25% of RWC households accomplish this, total RWC particulate emissions would be reduced by about 10%.

d. Episode Controls

As described in Section V.C, a number of the localities have already adopted RWC controls which include voluntary and/or mandatory curtailment of wood burning during episodes of high pollution. Estimating reduction in emissions associated with such episode controls requires the following types of information: a) the number of episode days per heating season; b) the degree of

TABLE V-14. Impact of Moisture on Relative Heat Content of Firewood

Wood Moisture Content (%)*	Relative Heat Content
10%	1.00
20%	.88
30%	.67
40%	.59
50%	.47

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

Source: Oregon DEQ (1981d)

anticipated compliance with voluntary and/or mandatory curtailment requests - e.g., the percentage of wood burning households which cease burning, or reduce burning by a specific amount; and, c) the percentage of wood-burning households with no alternative heat source, since such households are less likely to comply, and are often exempted from episode control requirements, at least initially.

In the Medford RWC control strategy, episode controls consisted of several elements, as follows: a) voluntary curtailment during Air Stagnation Advisories (ASAs), estimated to occur 10-40 times per year; b) mandatory curtailment during exceedances of the primary (health related) particulate standard of 260 ug/m^3 (24-hour average), which were occuring about 5-15 times per year in Medford in 1980; and, c) mandatory curtailment during ASA's, if the primary standard was not attained by January, 1984.

Table V-8 indicates that these episode controls were estimated to be about two-thirds as effective in reducing RWC particulate levels as firewood moisture controls. The following hypothetical analysis would result in a similiar level of effectiveness.

Assume that the heating season runs from October through March (180 days), during which 25 Air Stagnation Advisory days occur. Assume that on ten of these days the primary standard is exceeded, resulting in mandatory curtailment, which is 80% effective (i.e., wood burning is reduced by 80%). Assume that voluntary curtailment is requested on the other fifteen ASA days, and is 25% effective. Over the course of this heating season, RWC emissions would be reduced to 93.5% of what they could have been without these episode controls (180 - 10(.8) - 15(.25) = 93.5% of 180.) If RWC emissions on episode days are higher than the average daily emissions during the heating season, the episode controls would be even more effective.

Thus, curtailments would reduce seasonal total RWC emissions by at least 6.5%, with reductions concentrated on days with the worst pollution levels. The major uncertainties in this analysis are the number of episode days and the degree of compliance by the public.

e. Public Education

An important part of any effort to control RWC emissions is educating the public about the need for RWC controls, and what they can do to help. Public education efforts can promote a variety of public actions which can reduce RWC emissions. Examples include: a) proper operation of existing stoves and fireplaces, b) proper seasoning of firewood, c) properly sizing new stoves to the space to be heated, d) how to recognize and respond to pollution episodes; and, e) benefits of home weatherization.

The effectiveness of any public education effort is aimed at reducing RWC emissions depends upon: a) the percentage of the affected population taking action; and, (b) the effectiveness of these action(s). Neither of these two factors can be measured, except perhaps by extensive surveys, which may still not provide accurate estimates. Unlike advertising, which can be evaluated based on sales of the advertised product, measures of public response to RWC educational efforts could be elusive.

Estimation of potential emission reductions attributable to public education programs would require assumptions about changes in behavior which could not be confirmed. To make justifiable assumptions would require a fairly detailed description of RWC households in terms of their wood burning habits and demographic characteristics. Thus, it is more practical to treat public education as a vital activity, supporting other RWC control measures, without attributing emissions reductions to it. This approach is reflected in Table V-8.

4. The Importance of a Citizens Advisory Process

EPA regulations require involvement of the general public, certain special interest groups, local and areawide governmental organizations, elected officials of local governments, state agencies and the State Legislature, and Federal land managers in the development or revision of State Implementation Plans (SIPs). The SIP must describe how this was carried out, significant issues raised by such participants, and how these were disposed of (40 CFR 51.252, 1983).

A citizens advisory group can render valuable assistance in SIP development in many ways. They can review detailed agency staff analyses and proposed control measures, and provide advice and opinion which represents a broad spectrum of community interests and viewpoints.

This process can be especially useful where proposed control measures are controversial. Regulation of RWC and other area sources, which directly affect everyday activities of the general public, can be much more controversial than industrial controls, which usually affect the public indirectly, if at all.

For example the Medford RWC control strategy relied most heavily on home weatherization, including a requirement that cost effective weatherization be completed within 90 days of installing any space heating device using solid fuel such as wood. Despite strong opposition, due to its initial cost and mandatory nature, the Jackson County Air Quality (citizens advisory) committee recommended approval of this particulate control strategy element. It was eventually enacted by county ordinance (Appendix B; Ordinance 82-6).

In all three Oregon Air Quality Maintenance Areas, citizens advisory committees have played major roles in SIP development. All such committees have endorsed RWC controls as elements of SIP strategy.

Each of these committees was active over a period of six months or more. Each faced internal disagreements, and often sharply questioned agency staff. The advisory process afforded an effective forum to air various issues and concerns, and to identify further documentation needed from the agency staff. The agency gained support for its SIP by taking time to explain local pollution data and problems, as well as proposed solutions and options.

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d. Task 2B - "Household Information Survey"
e. Task 3 - "Wood Fuel Use Projection"
f. Task 4 - "Technical Analysis of Wood Stoves"
g. Task 5 - "Emissions Testing of Wood Stoves-Volumes 1 & 2"
h. Task 5 - "Emissions Testing of Wood Stoves - Volumes 3 & 4"
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APPENDIX A

Information Related to RWC Household Surveys

APPENDIX A

Information Related to RWC Household Surveys

This Appendix contains the following information related to RWC household surveys developed by the Oregon Department of Environmental Quality (DEQ), 522 S.W. 5th Avenue, Portland, Oregon 97204.

Contact persons: a) John Kowalczyk, 502-229-6459
b) Marianne Fitzgerald 503-229-5353

Contents

1. "Survey Design and Costs" (undated)
2. Excerpts from presentation entitled "Creating an Inventory" by Ms. Carol Cummings of DEQ, to "Residential Wood and Coal Combustion Workshop" November 30, 1983, Portland, Oregon, including:

   a. "Summary Outline" of workshop presentation
   b. "Sample Size Calculation", for mailback questionnaires
   c. "Sampling Errors at a 95% Level of Confidence for Various Percentages and Sample Sizes, Assuming a Simple Random Sample", also for mailback questionnaires.
   d. Sample calculation of RWC emissions from survey findings, for Portland, Oregon, 1982.

3. Cover Letter and sample questionnaire for a 1985 household RWC Survey by DEQ in Medford, Oregon.

Survey Design and Costs

SURVEY DESIGN AND COSTS

Below is an outline of survey design and cost factors to be considered prior to doing a survey by mail. This summary is based on experience gained from the first DEQ wood heating surveys completed in Portland and Medford in 1981 and 1982.

SURVEY PLANNING

1. Outline the objectives of the survey and determine the uses for the data to be gathered, for example emission inventory, planning, tracking trends.

2. Select a few individuals to help with the question design and review process, preferably including staff who will use the data most, as well as someone from data processing and public affairs.

3. After drafting the questionnaire, send it to an outside research agency (such as Northwest Attitudes) for review. They can provide valuable information and comments at a fairly low cost (~$100) and help avoid future problems with data reliability.

4. Do an in-house questionnaire pre-test using a few randomly selected staff (~20). Have them fill out the questionnaire and comment on any problems they found with the survey.

5. Allow approximately 1 month for survey design and review prior to mailing.

DETERMINING SAMPLE SIZE

1. According to Northwest Attitudes, for statistically reliable results (95% confidence level), it is necessary to have at least 400 completed questionnaires returned from a selected random sample.

2. To calculate the number that needs to be mailed, consider:

   a. a 30-35% return rate can be expected.

   b. If you are interested in information about a particular sub-group of individuals from the survey population (ex. woodburners), then you must receive 400 completed questionnaires from this sub-group.

3. An example of determining sample size for the Portland wood heating survey:

   a. Needed 400 completed questionnaires from people who burn wood.

   b. Assumed that 50% of the population burn wood, then we needed at least 800 questionnaires returned.

   c. Assuming a 30-35% return rate, we needed to send at least 2666 questionnaires or ~3000.

4. Contact a few mailing list companies (ex. Statewide Mailing Lists) and find out how much they charge for pre-sorted random mailing lists with detachable (Avery) labels. Have purchase order made up and sent to them along with a request for the number of copies of the list (usually 2), the number of names to be selected, the zip codes or areas they are to be sent to and whether you want only single family dwellings or all residences (including apartments). Allow 1 week for delivery.

5. Notify the mail room as soon as the sample size and date of mailing are determined, to allow them enough time to plan ahead for xeroxing and mailing. Make sure they have enough business reply envelopes on hand for the return mailing. Allow 1 week for xeroxing and mailing of the survey.

ESTIMATING SURVEY COSTS

1. Mailing Lists: (Using Avery labels, Statewide Mail List Co.)

   - $20/1000 names for first copy
   - $18/1000 names each additional copy.
   - Cost for Portland survey (3 copies of 3000) = $168

2. Survey Review: (Northwest Attitudes)

   - Cost for Portland survey = $100

   - This included a 1 hour meeting with staff to discuss their comments and provide suggestions.

3. Materials:

   - Paper .007¢/page
   - Envelopes 2¢/DEQ and business reply
   - Colored report covers 2¢/sheet
   - Cost for Portland survey ~$210

4. Postage:

   - Pre-sorted mail 17¢/envelope. 18¢ 4/85 - for each one sent
   - Return postage 25¢/business reply 29¢ 4/85 - for each one returned
   - Cost for Portland $787

Approximate cost (not including personnel time) for a survey of 3000 = $1250 to $1300.

my estimate 4/85 = $1700

SURVEY DESIGN

Attached is a copy of the Portland questionnaire as an example of survey format.

1. The cover letter should be personalized as much as possible. It should briefly outline the purpose of the survey and stress the importance of participation. Also include an explanation of how to return the questionnaire, the date to be returned by, and the confidentiality of

of the responses. You should give a person and phone number to contact in case of questions.

2. The questions and possible responses should be numbered and brief with an explanation of how to answer after each questions. The simpler the better (ex. circle the number of the response).

3. Ideally, all possible responses should be listed, write-in answers can cause interpretation and data processing problems.

4. A few demographic questions such as zipcode, age, income, number of household occupants should be included, to give an indication of the randomness of the sample.

5. A note at the end of the questionnaire thanking the respondents for their participation as well as how to get copies of the results is a good idea.

DATA PROCESSING

Allow approximately 3 weeks from the date of mailing for questionnaire returns.

1. Contact data processing for help in developing screen formats or programs to handle the data entry. Allow at least one week to develop the format and programs and plan to use the questionnaire pre-test data to test them.

2. Notify those who will help with data entry and Quality Assurance prior to survey return. Allow about 2 weeks for data entry and QA.

SURVEY COMPLETION

1. Allow about 2 weeks for data processing and summary (if using SIPs on the Harris).

2. Allow 2 weeks for writing the final report, copying and distribution.

3. Work with public affairs to make up a survey summary sheet, if general distribution is expected, to save costs.

4. The total amount of time that can be expected to complete a survey is about 3 - 4 months. This allows approximately 1 month for planning and design prior to mailing, 1 month to receive the questionnaires and for data entry, and 1 month for data analysis and final report completion.

Excerpts from Presentation entitled "Creating an Inventory" by Ms. Carol Cummings of DEQ, to "Residential Wood and Coal Combustion Workshop" November 30, 1983, Portland, Oregon

RESIDENTIAL WOOD AND COAL COMBUSTION WORKSHOP

CREATING AN INVENTORY - SUMMARY OUTLINE

Carol Cummings
Oregon Department of Environmental Quality

Wednesday, November 30, 1983, 1:30 p.m.

1. Air Pollution from RWC (Residential wood Combustion)
   a. Airshed Studies in Medford and Portland, Oregon
   b. Increasing Nephelometer and CO in Residential Areas
2. Annual Wood Heating Surveys
   a. Medford - 1981, 1983
   b. Portland - 1982
   c. Eugene - 1982
3. Objectives of Wood Heating Surveys
   a. Creating an Emission Inventory
      -- No. of Devices (Woodstoves, inserts, fireplaces)
      -- No. of cords burned per year by device
      -- Age of device
      -- New and Replacement devices
   b. Trends, Education, and Controls
      -- Purpose of wood heat (Primary, supplemental, recreational)
      -- Device operation rate and time
      -- Source and type of wood
      -- Wood seasoning
      -- Home insulation
      -- Comments
   c. Demographics
      -- Age of respondent
      -- Home ownership
      -- Length of residence
      -- Income
4. Mail vs. Phone Survey
   a. Cost
   b. Length of Survey
5. Survey Design
   a. Cover Letter
      -- Personalize
      -- Confidential
      -- Contact for questions
      -- Closing date of survey

b. Format
   -- Directions for responding
   -- Organization
   -- Request for results

6. Sample Size
   a. Reliability of Results
   b. Response Rate
   c. Assumptions about Population
7. Survey Checks
   a. Outside Review
   b. In-house Pre-test
8. Survey Mailing
9. Data Processing
   a. Quality Assurance
   b. Statistical Package for Analysis
10. Survey Results
   a. Portland, Oregon
   b. Medford, Oregon
11. Information for Emission Inventory
   a. No. of Households
   b. Percent (%) households with Each Type Wood Burning Device
   c. No. Cords Burned per Year in Each Device
   d. Emission Factors for Woodstoves and Fireplaces
12. Calculation of Emissions
   a. Woodstove and Insert Emissions
   b. Fireplace Emissions
13. Problems in Inventory Process

SAMPLE SIZE CALCULATION:

- DETERMINE DESIRED RELIABILITY OF RESULTS (EX. +/- 5%, 95% C.L.)
- EXPECT A RETURN RATE OF 30 TO 35%
- MAKE POPULATION ASSUMPTIONS (EX. 50% ARE WOODBURNERS)

∴ NEED TO SEND OUT 2500 -3000 SURVEYS

SAMPLING ERRORS AT A 95% LEVEL OF CONFIDENCE FOR VARIOUS PERCENTAGES AND SAMPLE SIZES, ASSUMING A SIMPLE RANDOM SAMPLE (PERCENTAGES)

SAMPLE OR SUBSAMPLE SIZE

APPROXIMATE PERCENTAGES	1600	1000	800	400	250	200	150	100	50
50%	2.50	3.16	3.54	5.00	6.32	7.08	8.16	10.00	14.14
40% OR 60%	2.45	3.10	3.48	4.90	6.20	6.92	8.00	9.80	13.86
30% OR 70%	2.29	2.90	3.24	4.58	5.80	6.48	7.48	9.16	12.96
25% OR 75%	2.17	2.74	3.06	4.34	5.48	6.12	7.08	8.67	12.24
20% OR 80%	2.00	2.53	2.83	4.00	5.06	5.66	6.54	8.00	11.32
15% OR 85%	1.78	2.26	2.52	3.58	4.52	5.04	5.84	7.14	10.10
10% OR 90%	1.50	1.90	2.12	3.00	3.80	4.24	4.90	6.00	9.48
5% OR 95%	1.09	1.38	1.54	2.18	2.76	3.08	3.56	4.36	6.16

NOTE: FOR A GIVEN SAMPLE SIZE, THE CHANCES ARE 95 IN 100 THAT THE VALUE BEING ESTIMATED LIES WITHIN A RANGE EQUAL TO THE REPORTED PERCENTAGE, PLUS OR MINUS THE NUMBER OF PERCENTAGE POINTS SHOWN ABOVE.

SOURCE: INTERNAL DOCUMENT, INSTITUTE FOR SOCIAL RESEARCH, THE UNIVERSITY OF MICHIGAN, ANN ARBOR, MICHIGAN.

PORTLAND AQMA
WOODBURNING PARTICULATE EMISSIONS - 1982

WOODSTOVES & INSERTS:

388,000 HOUSEHOLDS X 22% WOODSTOVES
= 85,360 WOODSTOVE HOUSEHOLDS (WH)

85,360 WH X 2.18 CORDS/YR./WH
= 186,080 CORDS/YR.

186,080 CORDS/YR. X 1.75 TONS/CORD
= 325,650 TONS/YR.

325,650 TONS/YR. X 42 LB./TON X TON/2000 LB.
= 6839 TONS PARTICULATE/YR.

PORTLAND AQMA
WOODBURNING PARTICULATE EMISSIONS - 1982

FIREPLACES:

388,000 HOUSEHOLDS X 34% FIREPLACES
= 131,920 FIREPLACE HOUSEHOLDS(FH)

131,920 FH X 0.85 CORDS/YR./FH
= 112,130 CORDS/YR.

112,130 CORDS/YR. X 1.75 TONS/CORD
= 196,200 TONS/YR.

196,200 TONS/YR. X 28 LB./TON X TON/2000 LB
= 2747 TONS PARTICULATE/YR.

TOTAL WOODBURNING EMISSIONS - PORTLAND 1982

PARTICULATES:

6839 TONS/YR. WOODSTOVES + 2747 TONS/YR.

FIREPLACES = 9586 TONS/YR.

CARBON MONOXIDE:

42,335 TONS/YR. WOODSTOVES + 16,677 TONS/YR.

FIREPLACES = 59,012 TONS/YR.

Cover Letter and sample questionnaire for a 1985 household RWC Survey by DEQ in Medford, Oregon

VICTOR ATIYEH
GOVERNOR

Department of Environmental Quality

522 S.W. FIFTH AVENUE, BOX 1760, PORTLAND, OREGON 97207 PHONE (503) 229-5696

May 3, 1985

Dear Resident:

The Department of Environmental Quality (DEQ) is conducting a survey to gather more information about home heating patterns and use of wood burning equipment of residents in the Medford area. The results of this survey will be used by the DEQ Air Quality Division for educational and planning purposes.

Your household is one of a small number in which people are being asked about home heating and wood burning. It was selected in a random sample of the entire area. So the results will be representative of the Medford area, it is important that each questionnaire be completed and returned. Information from individual households will be kept strictly confidential.

We ask that you fill out the enclosed questionnaire and return it to us on or before May 31, 1985. A self-addressed, prepaid envelope is enclosed for your convenience.

Your cooperation is appreciated. If you have any questions, please contact Marianne Fitzgerald at 229-5353, or call toll free, 1-800-452-4011. Thank you for your assistance.

Sincerely,

Fred Hansen
Director

MEF:n
AA3240

1985 MEDFORD AREA WOOD HEATING SURVEY

Please read the following questions carefully and circle, or write in the answer as indicated. Your cooperation is appreciated.

1. Your zipcode? (Please indicate in space below.)

_____

2. Do you own or rent your home? (Please circle number of answer.)

   1. OWN
   2. RENT

3. What type of residence do you live in? (Circle number.)

   1. SINGLE FAMILY HOME
   2. APARTMENT OR DUPLEX
   3. CONDOMINIUM
   4. MOBILE HOME

4. How long have you lived at your present address? (Circle number.)

   1. LESS THAN 1 YEAR
   2. 1 TO 2 YEARS
   3. 2 TO 3 YEARS
   4. 3 TO 4 YEARS
   5. 5 YEARS OR MORE

5. Which of the following areas are insulated in your home? (Circle numbers of all answers that apply.)

   1. CEILINGS
   2. WALLS
   3. FLOORS
   4. STORM/THERMAL WINDOWS
   5. STORM DOORS
   6. WEATHER STRIPPING/CAULKING
   7 DON'T KNOW
   8. NONE

6. How many people live in your home? (Indicate in space below.)

_____ PEOPLE

7. What was your total household income in 1984, before taxes? (Circle number.)

   1. LESS THAN $10,000
   2. $10,000 TO $19,999
   3. $20,000 TO $29,999
   4. $30,000 TO $39,999
   5. $40,000 TO $49,999
   6. $50,000 OR MORE

8. Your present age is? (Circle number of answer.)

1. LESS THAN 25 YEARS OLD
2. 25-34 YEARS
3. 35-44 YEARS
4. 45-54 YEARS
5. 55-64 YEARS
6. 65 AND OLDER

9. Which of the following fuel types do you use to heat your home? (Please put the corresponding number in the appropriate space.)

MAIN SOURCE OF HEAT _____

SECONDARY SOURCE OF HEAT (IF ANY) _____

ADDITIONAL SOURCE OF HEAT (IF ANY) _____

1. NATURAL GAS
2. WOOD
3. ELECTRICITY
4. OIL
5. PROPANE
6. KEROSENE
7. SOLAR
8. TRASH/PAPER
9. OTHER _____

10. Do you burn wood in your residence? (Circle number.)

1. YES
2. NO

11. Have you installed a new or replacement woodstove or stove-like fireplace insert during the past year? (Circle number.)

NEW APPLIANCE	REPLACEMENT APPLIANCE
1. YES	1. YES
2. NO	2. NO

12. Have you installed a new woodstove or stove-like fireplace insert during the past two to five years? (Circle number.)

1. YES
2. NO

13. Do you plan to install any new or replacement woodburning equipment in the next two years? (Circle number.)

NEW EQUIPMENT	REPLACEMENT EQUIPMENT
1. DEFINITELY	1. DEFINITELY
2. MAYBE	2. MAYBE
3. NO	3. NO

If you plan to purchase a new or replacement woodstove, please refer to the list of informational brochures and publications available from DEQ on page 6.

1985 MEDFORD AREA WOOD HEATING SURVEY

IF YOU BURN WOOD, PLEASE ANSWER THE FOLLOWING QUESTIONS. IF NOT, PLEASE RETURN THE QUESTIONNAIRE IN THE RETURN ENVELOPE. THANK YOU FOR YOUR COOPERATION.

14. Do you burn wood primarily for: (Circle one number.)

    1. MAIN SOURCE OF HEAT?
    2. SUPPLEMENTAL SOURCE OF HEAT?
    3. ENJOYMENT?

15. How many cords of wood did you burn this heating season (October 1984 - April 1985)? A cord is a stacked pile 4 feet high, 4 feet deep, and 8 feet long. (Please indicate amount burned below.)

    _____ CORDS

16. How much wood did you burn last heating season (1983-84) as compared to this heating season (1984-85)? (Circle number.)

    1. MORE
    2. SAME
    3. LESS
    4. NONE

17. How much wood do you expect to burn next heating season (1985-86) as compared to this heating season (1984-85)? (Circle number.)

    1. MORE
    2. SAME
    3. LESS
    4. NONE

18. Please mark the appropriate responses to the following questions.

Which of the following wood heating devices do you have? (Circle yes or no.)		How many devices do you have? (Write in number below.)	Age of each device? (Write in age below.)	Total number of cords burned per year in each device? (Indicate below.)
FIREPLACE (WITHOUT STOVELIKE INSERT)	YES NO	_____	_____ YEARS	_____ CORDS
FIREPLACE (WITH STOVELIKE INSERT)	YES NO	_____	_____ YEARS	_____ CORDS
WOODSTOVE	YES NO	_____	_____ YEARS	_____ CORDS
WOOD BURNING FURNACE	YES NO	_____	_____ YEARS	_____ CORDS
WOOD COOKSTOVE	YES NO	_____	_____ YEARS	_____ CORDS

OTHER (PLEASE SPECIFY) _____

19. If you use a woodstove or fireplace insert, in which position is the intake air control set most of the time? (Circle number.)

    1. LOW (0 TO 1/3 OPEN)
    2. MEDIUM (1/3 TO 2/3 OPEN)
    3. HIGH (2/3 TO FULLY OPEN)

20. If you have a woodstove or fireplace insert, what kind of air intake control do you have? (Circle number.)

    1. AUTOMATIC
    2. MANUAL

21. What percent of the following type(s) of firewood do you burn most often? (Circle the numbers of all answers that apply and indicate approximate percent.)

    %

    1. FIR _____
    2. MADRONE _____
    3. OAK _____
    4. PINE _____
    5. MAPLE _____
    6. CEDAR _____
    7. LUMBER OR MILL SCRAPS _____
    8. OTHERS (PLEASE SPECIFY) _____

22. What are the four most frequent times you burn wood? (Please put corresponding number in the appropriate space below.)

1.	MIDNIGHT TO 6:00 A.M...WEEKDAYS	6.	MIDNIGHT TO 6:00 A.M...WEEKENDS
2.	6:00 A.M. TO NOON.....WEEKDAYS	7.	6:00 A.M. TO NOON.....WEEKENDS
3.	NOON TO 6:00 P.M..... WEEKDAYS	8.	NOON TO 6:00 P.M.....WEEKENDS
4.	6:00 P.M. TO MIDNIGHT..WEEKDAYS	9.	6:00 P.M. TO MIDNIGHT..WEEKENDS
5.	ALL DAY.....WEEKDAYS	10.	ALL DAY.....WEEKENDS

    MOST FREQUENT TIME _____

    SECOND MOST FREQUENT TIME _____

    THIRD MOST FREQUENT TIME _____

    FOURTH MOST FREQUENT TIME _____

23. If you have a woodstove or fireplace insert, approximately how many days did you burn this heating season (October 1984 - April 1985)? (Circle number.)

    1. UNDER 60 DAYS
    2. 60 - 99 DAYS
    3. 100 - 200 DAYS
    4. MORE THAN 200 DAYS

24. What was the average time (in hours) you burned during those days? Include any time there was a fire or burning coals in your stove. (Please indicate in space below.)

_____ HOURS PER DAY

25. Where do you obtain most of your firewood? (Circle the numbers of the answer that apply.)

1. PURCHASED FROM A DEALER
2. CUT ON PERSONAL PROPERTY
3. CUT ON PRIVATE LAND (OTHER THAN OWN)
4. CUT ON STATE FOREST LAND
5. CUT ON FEDERAL FOREST LAND
6. LUMBER OR MILL SCRAPS
7. RECEIVED FROM FRIENDS, NEIGHBORS, RELATIVES
8. OTHER (PLEASE SPECIFY) _____

26. If you purchased your firewood, what was the price you paid per cord?

_____ DOLLARS PER CORD

27. If you cut your own firewood, what was the average round trip mileage to gather wood?

_____ MILES

28. If you cut your own firewood, during which of the following seasons do you cut it? (Circle the numbers of the answers that apply.)

1. WINTER (DECEMBER, JANUARY, FEBRUARY)
2. SPRING (MARCH, APRIL, MAY)
3. SUMMER (JUNE, JULY, AUGUST)
4. FALL (SEPTEMBER, OCTOBER, NOVEMBER)

29. From the time of cutting to the time of burning, how long do you store your firewood before burning? (Circle the number that is most typical for you.)

1. 3 MONTHS OR LESS
2. 4-6 MONTHS
3. 7-12 MONTHS
4. 1-2 YEARS
5. MORE THAN 2 YEARS
6. DON'T KNOW

30. Where do you store most of your firewood? (Circle number.)

1. INSIDE HOME
2. GARAGE OR SHED
3. COVERED OUTSIDE
4. UNCOVERED OUTSIDE

31. Did you hear about the 20 day air stagnation advisory in Medford in January, 1985 (January 10 to January 29)? (Circle number.)

    1. YES
    2. NO
    3. DON'T REMEMBER

32. Did you discontinue woodburning as requested during this period? (Circle number.)

    1. YES
    2. NO
    3. DON'T REMEMBER

33. Is there anything else you would like to tell us about home heating and use of wood burning equipment? If so, please use this space for that purpose.

YOUR CONTRIBUTION TO THIS EFFORT IS GREATLY APPRECIATED. IF YOU WOULD LIKE A SUMMARY OF THE RESULTS, PLEASE CONTACT THE DEQ REGIONAL OFFICE IN MEDFORD AT 776-6010.

The following publications are available free from the Department of Environmental Quality, Public Affairs Section, P.O. Box 1760, Portland, Oregon 97207, or from any DEQ Regional office. Call Public Affairs at 229-5317 in the Portland area, or toll-free from other parts of the state at 1-800-452-4011.

_____ 1. Sizing Wood Stoves - How to match heating capacity to heating needs (1985 brochure).

_____ 2. Certified Woodstoves - Describes Oregon's woodstove certification program (1985 brochure).

_____ 3. List of DEQ Certified Woodstoves - (Current).

_____ 4. Catalytic Woodstoves - Describes this new type of woodstove (1985 brochure).

_____ 5. Burn Wood Better - Shows heat values and drying times for various types of wood; shows how to operate a stove to reduce emissions.

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APPENDIX B

Examples of Laws, Regulations and Ordinances Related to Control of Residential Wood Combustion (RWC)

APPENDIX B

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1. Oregon
   a. Medford
      - o Jackson County, Oregon, Ordinance No. 82-6, Particulate Air Pollution Control Ordinance of Jackson County", adopted August 25, 1982.
      - o Jackson County Ordinance No. 84-29, adopted Oct. 17, 1984
      - o "Information Concerning County Weatherization Requirements", Jackson County Department of Planning and Development, Medford, Oregon (1984)
      - o Letter "To the Realtors of Medford and Ashland", from Jack Davis, of Davis, Ainsworth, Pinnock, Davis, and Gilstrap, Ashland, Oregon, Nov. 6, 1984.

   b. Oregon's Woodstove Certification Program
      - o "House Bill 2235", enacted by the 1983 Oregon Legislature, 1983 Regular Session
      - o "Proposed Adoption of Woodstove Certification Rules, OAR 340-21-100 Through 340-21-166 As a Revision To the State Implementation Plan", June 8, 1984, memo to the Oregon Environmental Quality Commission, from the Director, Oregon Department of Environmental Quality. Attachments included:
        - Draft rules for Woodstove Certification OAR 340-21-100 through 340-21-166.
        - Oregon Department of Environmental Quality" Standard Method for Measuring The Emissions and Efficiencies of Woodstoves"
        - Miscellaneous Fact Sheets for Oregon's Woodstove Certification Program:
          - "DEQ Woodstove Certification Program Fact Sheet"
          - Woodstove Certification Program Steps Toward Certifying a Stove in Oregon"
          - "Confirmation Testing Summary"
          - "Example Calculation of Weighted Average Emissions
      - o Summary of first nine woodstoves certified in Oregon, by the Oregon Department of Environmental Quality, March 14, 1985.

2. Missoula, Montana
   - o "Summary - Wood Burning Regulations", summarizes regulations adopted Nov., 1983 and currently enforced by the Missoula City-County Health Department

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- o Exerpts from air pollution regulations of the Missoula City-County Health Department

3. Colorado
   a. Ski Communities
      - o Pitkin County (Aspen), Colorado, Resolution No. 72-104, adopted by the Pitkin Co. Board of County Commissioners, Aug. 22, 1977
      - o Pitkin County, Colorado, Resolution No. 83-7, adopted, January 24, 1983*
      - o Vail, Colorado, Ordinance 24, related to solid fuel burning devices; adopted by the town of Vail, Colorado, August 5, 1983
      - o Beavercreek Resort Company Regulations

   b. State Level RWC Control Measures
      - o "House Bill No. 1187" enacted by the State of Colorado General Assembly, April, 1984
      - o "Notice of Public Hearing to Consider a New Regulation of the Colorado Air Quality Control Commission.." issued by Joseph Palomba, Jr., Technical Secretary, Colorado, Air Quality Control Commission, February 25, 1985.
      - o "Proposed New Regulation No. 4 - Woodstove Regulation", issued by the Colorado Air Quality Control Commission, (undated).

4. Alaska (Juneau)
   - o Ordinance No. 84-30, enacted May 21, 1984 by the City and Borough of Juneau, Alaska, which amends the woodsmoke areawide restrictions on open burning and smoke density in the Mendenhall Valley area
   - o Ordinance No. 84-18, introduced April 2, 1984 for consideration by the City and Borough of Juneau, Alaska, which amends the Building Code to require minimum residential heating facilities of a type not involving the combustion of solid fuels
   - o State Air Quality Control Plan, Section G, "Wood Smoke Pollution Control," as revised 1983, by the Alaska Department of Environmental Conservation

APPENDIX B (Continued)

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- State Air Quality Control Plan, Section G, "Wood Smoke Pollution Control," as revised 1983, by the Alaska Department of Environmental Conservation

- Excerpts from Air Quality Control Regulations 18 AAC 50, of the Alaska Department of Environmental Conservation

5. Reno, Nevada
   - "Emergency Episode Plan", (as revised Oct. 1984) from the Washoe County Air Pollution Control Regulations of the Washoe County Disrict Health Department, Reno, Nevada

MEDFORD

ORDINANCE NO. 4740

AN ORDINANCE establishing control strategies for particulate air pollution.

WHEREAS the City Council finds that prevailing weather patterns in the city tend to hold pollutants in the air; and,

WHEREAS smoke and dust are particulates which originate from many sources, and which tend to collect in the air shed of Medford; and,

WHEREAS Medford wishes to protect the general health, safety and welfare of its citizens by controlling the sources of particulate air pollution.

THE CITY OF MEDFORD ORDAINS AS FOLLOWS:

SECTION 1. GENERAL DEFINITIONS

1.1 Air stagnation advisory: Forecast made by the National Weather Service for poor ventilation conditions.

1.2 Council: The City Council of the City of Medford.

1.3 Cost-effective level of weatherization: Minimum, cost-efficient standards of weatherization, including standards for materials and installation, which shall be set by the Director of Building Safety. These standards shall reflect, but not exceed the levels defined in ORS 469.710 (2).

1.4 Medford-Ashland AQMA: That part of Jackson County, Oregon, specifically identified by the Oregon Department of Environmental Quality as an air quality maintenance area -- one of several areas in the state wherein air quality has deteriorated due to unhealthful levels of pollutants in the air.

1.5 Particulate: Airborne particles ranging from .01 to 1,000 microns in size. These particles are inhaled during breathing and can be harmful.

1.6 Person: Includes individuals, corporations, associations, firms, partnerships, and joint stock companies.

1.7 Primary particulate standard: An average particulate concentration of 260 micrograms per cubic meter of air during a twenty-four hour period.

1.8 Proof of weatherization: Certification, receipts, contracts, or other such documents specifically listing weatherization steps taken by the homeowners, which may be reviewed by building inspectors at the time of solid fuel heating system installation.

1.9 Regulations: Regulations promulgated by the Council pursuant to this ordinance.

1.10 Residential building: An existing building used for permanent or seasonal habitation by one or more persons, containing four or fewer dwelling units, and constructed prior to January 1, 1979.

1.11 Residential woodburning: Utilization of a wood heating device inside a dwelling unit.

1.12 Spaceheating: Raising the interior temperature of a room or rooms.

1.13 Total suspended particulate level: Amount of particulate in ambient air.

1.14 Trackout: The deposition of mud, dirt and other debris on paved public roadways by motor vehicles; the material being so tracked onto public roadways. Trackout can become pulverized and blown into the air by vehicular traffic, where it becomes a part of the total suspended particulate level.

1.15 Ventilation index: The National Weather Service's indicator of the relative degree of air circulation for a specified area.

1.16 Wood heating devices: A stove, heater, fireplace, or other receptacle wherein wood is heated to the point of combustion.

SECTION 2. SEVERABILITY

2.1 If any portion of this ordinance is declared to be invalid by a court of competent jurisdiction, such invalidity shall be confined to the section to which such declaration of invalidity relates, and the remainder of this ordinance shall continue to be operative.

SECTION 3. WEATHERIZATION REQUIREMENTS FOR SOLID FUEL HEATING DEVICE INSTALLATION

The purpose of this section is to reduce the amount of particulate pollution resulting from residential woodburning for building heating. Most buildings constructed before 1979 were built to lower weatherization standards than buildings constructed since that date. A highly weatherized and insulated building will require less fuel to attain and hold a given temperature. It will produce less smoke pollution and will also result in a savings of the wood or other fuel resource. Additionally, weatherization prior to or at the time of installation of a solid fuel heating device will generally result in the selection of a device more appropriately sized for the building and will lessen the potential amount of smoke produced. Therefore:

3.1 The installation of a wood stove, fireplace, or any other form of solid fuel, space heating device is allowed if:

A) The space heating device is installed pursuant to the uniform building code and regulations of the Medford Department of Building Safety.

B) The structure contains an alternate form of space heating, including natural gas, propane, electric, oil, solar, or kerosene, sufficient to meet necessary space heating requirements, so that during episodes of high pollution levels, the occupant will be able to heat the home with other than a solid fuel burning, smoke producing method.

C) The residence meets or is proposed to meet within 90 days the cost-effective levels of weatherization as defined in Section 1.3 of this ordinance.

SECTION 4. RESIDENTIAL WEATHERIZATION — repealed 2/16/89

The purpose of this section is to minimize particulate emissions from home heating devices by improving home weatherization and reducing energy loss. This section is also intended to encourage homeowners to make use of free energy audits and low-interest financing available from local utility

companies. It is the City's intent to advertise and make known programs which are already available for weatherizing homes and to assist citizens in taking advantage of those programs.

4.1 It is the goal of the City of Medford to assist citizens to weatherize all residences to the cost-effective level by January 1, 1987.

4.2 All residential buildings shall have received an energy audit prior to the time of sale or rental, and such information shall be made available to potential purchasers or renters as a condition of such sale or rental. This section shall become effective six months after adoption of this ordinance.

4.3 In January of 1984, if the primary particulate health standards are not being maintained, all homes with a wood heating system shall be weatherized to cost-effective levels at the time of sale or rental.

SECTION 5. POLLUTION EPISODE CURTAILMENT

The purpose of this section is to reduce the amount of particulate pollution during periods of air stagnation or when pollution levels are critical. Periods of air stagnation occur at various times in a year and can create a severe accumulation of pollutants. Residential woodburning can contribute as much as 50 percent of the particulate pollution during these conditions.

5.1 The use of residential woodburning devices is prohibited on each day that an air stagnation advisory announcement for the Medford-Ashland AQMA has been issued by the National Weather Service. This subsection takes effect on July 1, 1984, if the particulate health standard is not attained in the Medford-Ashland Air Quality Maintenance Area by that date.

5.2 Residences having no other form of space heating are exempt from this section.

SECTION 6. TRACKOUT

The purpose of this section is to lessen the amount of particulate pollution which originates from roads and roadways. Dirt and other debris, which may become deposited upon paved roads, can be ground and pulverized by traffic into minute particles. These particles can then become airborne adding to the particulate pollution problem.

6.1 No person shall place or deposit mud, dirt or debris upon any street, alley, sidewalk or other public way.

6.2 Violation of subsection 6.1 is hereby declared to be a public nuisance and subject to summary abatement by the City Manager or his designate. Summary abatement includes but is not limited to suspension of any and all city permits relating to construction on the site which is the source of the mud, dirt or debris.

PASSED by the Council and signed by me in open session in authentication of its passage this 4th day of November, 1982.

ATTEST /s/ Emily H. Kirkham
City Recorder

/s/ John Hallett
ACTING Mayor

APPROVED November 11, 1982.

/s/ Al Densmore
Mayor

BEFORE THE BOARD OF COUNTY COMMISSIONERS
STATE OF OREGON, COUNTY OF JACKSON

ORDINANCE NO. 82-6

AN ORDINANCE PROVIDING FOR CLEANER AIR.

WHEREAS Jackson County finds that prevailing weather patterns in certain areas of the county tend to hold pollutants in the air; and,

WHEREAS smoke and dust are particulates which originate from many sources, and which tend to collect in the air shed of Jackson County; and,

WHEREAS Jackson County wishes to protect the general health, safety and welfare of its citizens by controlling the sources of particulate air pollution.

THE BOARD OF COUNTY COMMISSIONERS OF JACKSON COUNTY ORDAINS:

SECTION 1. TITLE

1.1 This ordinance shall be known as the "Particulate Air Pollution Control Ordinance of Jackson County" and may be so cited and pleaded, and shall be cited herein as "this ordinance".

SECTION 2. GENERAL DEFINITIONS

2.1 Air stagnation advisory: Forecast made by the National Weather Service for poor ventilation conditions.

2.2 Board: The Board of Commissioners of Jackson County.

2.3 Cost-effective level of weatherization: Minimum, cost-efficient standards of weatherization, including standards for materials and installation, which shall be set by the Director of Planning and Development. These standards shall reflect, but not exceed the levels defined in ORS 469.710 (2).

2.4 Medford-Ashland AQMA: That part of Jackson County, Oregon, specifically identified by the Oregon Department of Environmental Quality as an air quality maintenance area -- one of several areas in the state wherein air quality has deteriorated due to unhealthful levels of pollutants in the air. The map of the Medford-Ashland AQMA is attached to this ordinance as exhibit "A" and incorporated herein by reference.

2.5 Open burning: Includes burning in burn barrels, incinerators, open outdoor fires, and any other burning wherein combustion air is not effectively controlled and combustion products are not effectively vented through a stack or chimney.

2.6 Particulate: Airborne particles ranging from .01 to 1,000 microns in size. These particles are inhaled during breathing and can be harmful.

2.7 Person: Includes individuals, corporations, associations, firms, partnerships, and joint stock companies.

2.8 Primary particulate standard: An average particulate concentration of 260 micrograms per cubic meter of air during a twenty-four hour period.

2.9 Proof of weatherization: Certification, receipts, contracts, or other such documents specifically listing weatherization steps taken by the homeowners, which may be reviewed by building inspectors at the time of solid fuel heating system installation.

2.10 Regulations: Regulations promulgated by the Board pursuant to this ordinance.

2.11 Residential building: An existing building used for permanent or seasonal habitation by one or more persons, containing four or fewer dwelling units, and constructed prior to January 1, 1979.

2.12 Residential woodburning: Utilization of a wood heating device inside a dwelling unit.

2.13 Spaceheating: Raising the interior temperature of a room or rooms.

2.14 Total suspended particulate level: Amount of particulate in ambient air.

2.15 Trackout: The deposition of mud, dirt and other debris on paved public roadways by motor vehicles; the material being so tracked onto public roadways. Trackout can become pulverized and blown into the air by vehicular traffic, where it becomes a part of the total suspended particulate level.

2.16 Ventilation index: The National Weather Service's indicator of the relative degree of air circulation for a specified area.

2.17 Waste: Discarded or excess material, including:

A) Agricultural waste resulting from farming or agricultural practices and operations.

B) Nonagricultural waste resulting from practices and operations other than farm operations, including industrial, commercial, construction, demolition and domestic wastes, and yard debris.

2.18 Wood heating devices: A stove, heater, fireplace, or other receptacle wherein wood is heated to the point of combustion.

SECTION 3. GENERAL EXEMPTIONS

3.1 This ordinance shall not apply:

A) Within incorporated limits of any city.

B) To federal or state lands.

C) To prescribed slash burns regulated by the Oregon State Smoke Management Plan.

D) To cooking fires or ceremonial fires.

SECTION 4. SEVERABILITY

4.1 If any portion of this ordinance is declared to be invalid by a court of competent jurisdiction, such invalidity shall be confined to the section to which such declaration of invalidity relates, and the remainder of this ordinance shall continue to be operative.

SECTION 5. WEATHERIZATION REQUIREMENTS FOR SOLID FUEL HEATING DEVICE INSTALLATION

The purpose of this section is to reduce the amount of particulate pollution resulting from residential woodburning for building heating. Most buildings constructed before 1979 were built to lower weatherization standards than buildings constructed since that date. A highly weatherized and insulated building will require less fuel to attain and hold a given temperature. It will produce less smoke pollution and will also result in a savings of the wood or other fuel resource. Additionally, weatherization prior to or at the time of installation of a solid fuel heating device will generally result in the selection of a device more appropriately sized for the building and will lessen the potential amount of smoke produced. Therefore:

5.1 The installation of a wood stove, fireplace, or any other form of solid fuel, space heating device is allowed if:

A) The space heating device is installed pursuant to the uniform building code and regulations of the Jackson County Department of Planning and Development.

B) The structure contains an alternate form of space heating, including natural gas, propane, electric, oil, solar, or kerosene, sufficient to meet necessary space heating requirements, so that during episodes of high pollution levels, the occupant will be able to heat the home with other than a solid fuel burning, smoke producing method.

C) The residence meets or is proposed to meet within 90 days the cost-effective levels of weatherization as defined in Section 2.3 of this ordinance.

SECTION 6. RESIDENTIAL WEATHERIZATION

The purpose of this section is to minimize particulate emissions from home heating devices by improving home weatherization and reducing energy loss. This section is also intended to encourage homeowners to make use of free energy audits and low-interest financing available from local utility companies. Information concerning free energy audit and low-interest financing programs is available from the Jackson County Department of Planning and Development or directly from the utility companies. It is the County's intent to advertise and make known programs which are already available for weatherizing homes and to assist citizens in taking advantage of those programs.

6.1 It is the goal of Jackson County to assist citizens to weatherize all residences to the cost-effective level by January 1, 1987.

6.2 All residences shall have received an energy audit prior to the time of sale or rental, and such information shall be made available to potential purchasers or renters as a condition of such sale or rental. This section shall become effective six months after adoption of this ordinance.

6.3 In January of 1984, if the primary particulate health standards are not being maintained, all homes with a wood heating system shall be weatherized to cost-effective levels at the time of sale or rental.

SECTION 7. RESIDENTIAL WOODBURNING

The purpose of this section is to reduce the amount of particulate pollution during periods of air stagnation or when pollution levels are critical. Periods of air stagnation occur at various times in a year and can create a severe accumulation of pollutants. Residential woodburning can contribute as much as 50 percent of the particulate pollution during these conditions.

7.1 The county shall, through its air quality information program, advise the public when air stagnation conditions exist or when suspended particulate health standards are exceeded or when suspended particulate health standards are projected to be exceeded.

7.2 The use of residential woodburning devices will be allowed within the air quality maintenance area except on days when it has been determined that the ambient air quality exceeds, or is projected to exceed, the 24-hour total suspended particulate health standard of 260 micrograms per cubic meter.

7.3) The use of residential woodburning devices is prohibited on each day that an air stagnation advisory announcement has been issued by the Department of Environmental Quality. This subsection takes effect on July 1, 1984, if the particulate health standard is not attained in the Medford-Ashland Air Quality Maintenance Area by that date.

7.4 Residences outside of the Medford-Ashland Air Quality Maintenance Area and residences having no other form of space heating are exempt from this section.

SECTION 8. TRACKOUT

The purpose of this section is to lessen the amount of particulate pollution which originates from roads and roadways. Dirt and other debris, which may become deposited upon paved roads, can be ground and pulverized by traffic into minute particles. These particles can then become airborne adding to the particulate pollution problem.

8.1 This section particularly applies to, but is not limited to, construction sites, farm operations, and commercial and industrial operations.

8.2 No person shall trackout mud, dirt or other debris from private or public lands onto paved public roads without taking reasonable precautions to prevent such particulate matter from becoming airborne. These precautions shall include, where appropriate, the prompt removal of such material from the paved road surfaces. This section does not apply to noncommercial uses of public roads.

8.3 No person shall violate the provisions of a stop-work order issued pursuant to subsection 8.4 of this ordinance.

8.4 The county may require the imposition of building permit conditions for the prevention of trackout. Conditions imposed may include, but are not limited to the following:

A) A bond of sufficient amount to be posted by the contractor to assure available funds for roadway cleanup by Jackson County if the contractor is negligent in cleanup of adjacent public roadway.

B) Street sweeping, vacuuming or other means of removing trackout material from public roadways.

C) Installation of wheel washers at exits of major construction sites.

D) Use of temporary or permanent barricades to keep traffic off unpaved areas.

E) Require graveling of access roads on site.

F) Limit the use of public roadways by vehicles.

G) Issue stop work order if trackout occurs and is not promptly corrected.

8.5 Stop work orders issued pursuant to subsection 8.4 of this ordinance shall be posted, where appropriate, at the work site, and mailed by certified mail to alleged violators. Appeals to any such orders shall be conducted pursuant to the provisions of Section 204 of the Jackson County Building Code.

SECTION 9. OPEN BURNING

The purpose of this section is to minimize the accumulation of particulate air pollution resulting from open burning. The public should be aware that open burning may be restricted during the fire season (typically June through October) by the fire districts or other fire regulating authorities. These authorities typically base restrictions of open burning on factors of low humidity, high winds, drought, or other conditions which make outside burning unsafe.

9.1 Open burning of nonagricultural wastes is prohibited in the Medford-Ashland Air Quality Maintenance Area from February 1 to November 30 of each year on days when the ventilation index is less than 400.

9.2 Open burning of nonagricultural wastes is prohibited during December and January of each year due to generally poor smoke dispersion.

9.3 Open burning of agricultural waste is prohibited on all days of the year when the maximum ventilation index is below 200.

SECTION 10. ABATEMENT

10.1 Persons acting in violation of provisions of this ordinance, or of permits issued, shall be subject to appropriate legal proceedings to enjoin or abate such violation(s).

62nd OREGON LEGISLATIVE ASSEMBLY–1983 Regular Session

Enrolled

House Bill 2235

Ordered printed by the Speaker pursuant to House Rule 12.00A (5). Presession filed (at the request of Department of Environmental Quality)

CHAPTER 333

AN ACT

Relating to air pollution; creating new provisions; and amending ORS 468.275 and 468.290.

Be It Enacted by the People of the State of Oregon:

SECTION 1. ORS 468.275 is amended to read:

468.275. As used in [*ORS 448.305, 454.010 to 454.040, 454.205 to 454.255, 454.405, 454.425, 454.505 to 454.535, 454.605 to 454.745 and*] this chapter, unless the context requires otherwise:

(1) "Air-cleaning device" means any method, process or equipment which removes, reduces or renders less noxious air contaminants prior to their discharge in the atmosphere.

(2) "Air contaminant" means a dust, fume, gas, mist, odor, smoke, vapor, pollen, soot, carbon, acid or particulate matter or any combination thereof.

(3) "Air contamination" means the presence in the outdoor atmosphere of one or more air contaminants which contribute to a condition of air pollution.

(4) "Air contamination source" means any source at, from, or by reason of which there is emitted into the atmosphere any air contaminant, regardless of who the person may be who owns or operates the building, premises or other property in, at or on which such source is located, or the facility, equipment or other property by which the emission is caused or from which the emission comes.

(5) "Air pollution" means the presence in the outdoor atmosphere of one or more air contaminants, or any combination thereof, in sufficient quantities and of such characteristics and of a duration as are or are likely to be injurious to public welfare, to the health of human, plant or animal life or to property or to interfere unreasonably with enjoyment of life and property throughout such area of the state as shall be affected thereby.

(6) "Area of the state" means any city or county or portion thereof or other geographical area of the state as may be designated by the commission.

(7) "Woodstove" means a wood fired appliance with a closed fire chamber which maintains an air-to-fuel ratio of less than 30 during the burning of 90 percent or more of the fuel mass consumed in the low firing cycle. The low firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn achievable.

SECTION 2. ORS 468.290 is amended to read:

468.290. Except as provided in this section and in ORS 468.450, 476.380 and 478.960, the air pollution laws contained in this chapter do not apply to:

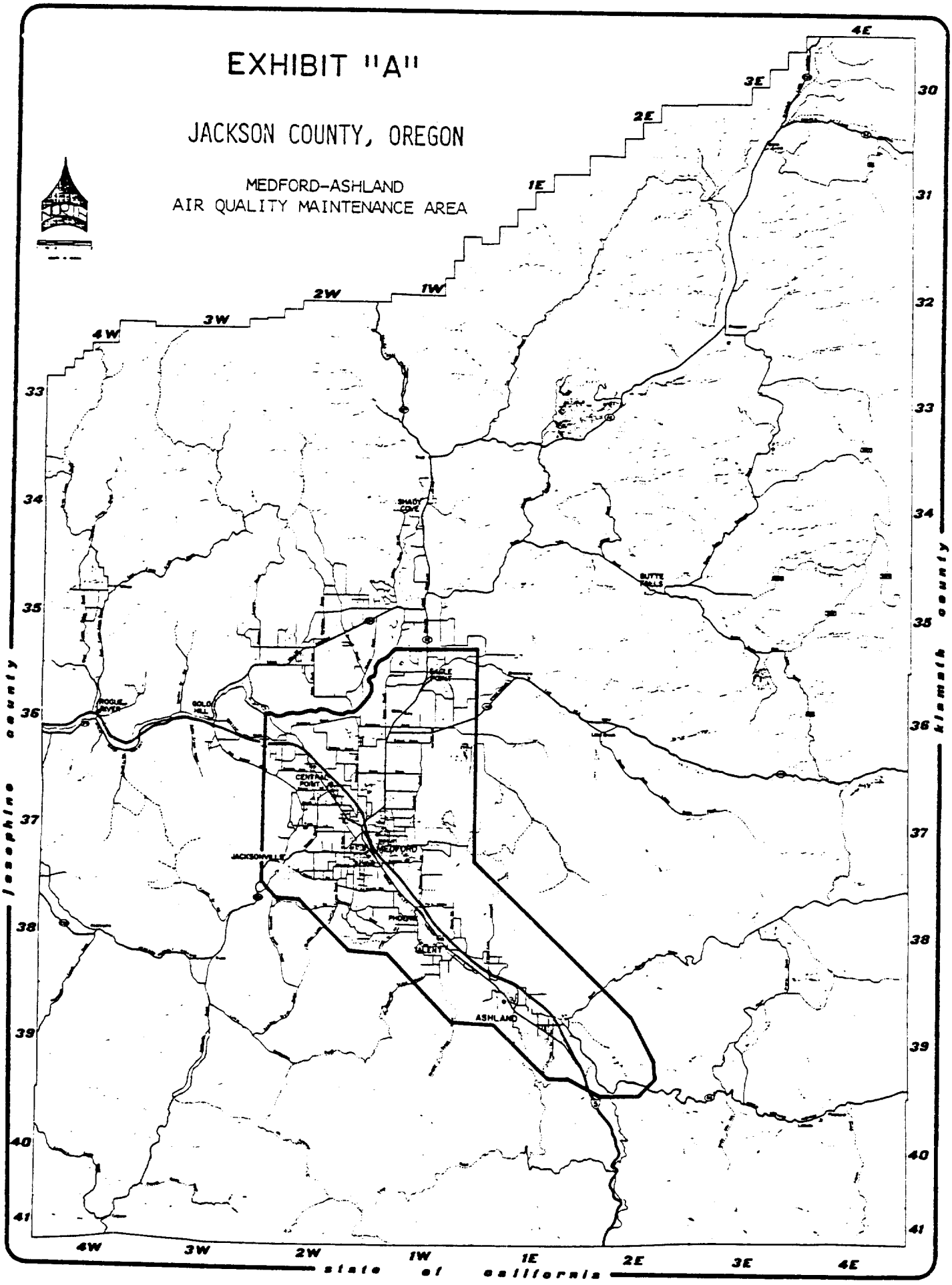

EXHIBIT "A"
JACKSON COUNTY, OREGON
MEDFORD-ASHLAND
AIR QUALITY MAINTENANCE AREA
4E
3E
2E
1E
1W
2W
3W
4W
30
31
32
33
34
35
36
37
38
39
40
41
josephine county
klamath county
state of california
SHADY COVE
BUTTE FALLS
EAGLE POINT
ROGUE RIVER
GOLD HILL
CENTRAL POINT
JACKSONVILLE
MEDFORD
PHOENIX
TALENT
ASHLAND

EXHIBIT "B"

BOUNDARY DESCRIPTION

MEDFORD-ASHLAND AIR QUALITY MAINTENANCE AREA

The Medford-Ashland Air Quality Maintenance Area is defined as beginning at a point approximately one mile NE of the town of Eagle Point, Jackson County, Oregon, at the NE corner of Section 36, T35S, R1W; thence south along the Willamette Meridian to the SE corner of Section 25, T37S, R1W; thence SE along a line to the SE corner of Section 9, T39S, R2E; thence SSE to the SE corner of Section 22, T39S, R2E; thence south to the SE corner of Section 27, T39S, R2E; thence SW to the SE corner of Section 33, T39S, R2E; thence west to the SW corner of Section 31, T39S, R2E; thence NW to the NW corner of Section 36, T39S, R1E; thence west to the SW corner of Section 26, T39S, R1E; thence NW along a line to the SE corner of Section 7, T39S, R1E; thence west to the SW corner of Section 12, T39S, R1W; thence NW along a line to the SW corner of Section 20, T38S, R1W; thence west to the SW corner of Section 24, T38S, R2W; thence NW along a line to the SW corner of Section 4, T38S, R2W; thence west to the SW corner of Section 5, T38S, R2W; thence NW along a line to the SW corner of Section 31, T37S, R2W; thence north along a line to the Rogue River, thence north and east along the Rogue River to the north boundary of Section 32, T35S, R1W; thence east along a line to the point of beginning.

INFORMATION CONCERNING COUNTY WEATHERIZATION REQUIREMENTS

DEPARTMENT OF PLANNING & DEVELOPMENT • COUNTY COURTHOUSE • MEDFORD, OREGON 97501 • (503) 776-7554

The "Particulate Air Pollution Control Ordinance of Jackson County", also known as the "Air Quality Ordinance," places responsibilities on certain Jackson County homeowners when they sell their property. This ordinance was adopted by the Board of Commissioners as part of a comprehensive effort on the part of state and local government to reduce air pollution and its resultant adverse health impact on the community. The ordinance deals with several subjects; however, this information sheet only pertains to weatherization requirements, which are designed to reduce the amount of smoke produced by homes heated with solid fuel by increasing the heat retention efficiency of these homes. The requirements are summarized as follows:

1) The following regulations apply only to residences within the Medford-Ashland Air Quality Maintenance Area (see attached map and description). The county ordinance does not apply within city limits; however, cities may adopt similar regulations.

2) Beginning January 1, 1985: The owner of any residence (other than a mobile home) constructed before January 1, 1979, which does not meet minimum weatherization standards, must provide an energy audit to potential purchasers of such residence.

3) Beginning January 1, 1985: Prior to sale of any residence (other than a mobile home) constructed before January 1, 1979, and which has a solid fuel heating device, the owner must ensure that the home will meet minimum weatherization standards by:

a) Bringing the home up to those standards; or

b) Filing a proposal with the Jackson County Department of Planning and Development, signed by the new owner of the residence, stating that the new owner will be responsible for bringing the residence up to minimum weatherization standards within 90 days of the sale.

Minimum weatherization standards are defined as any of the following, at the option of the property owner:

1) Ceiling resistance factor of 30 (R-30); and
Floor resistance factor of 19 (R-19); and
Double glazing of window areas or installation of storm windows; or

2) The installation of those weatherization alternatives which an energy audit has determined will provide or save an amount of energy during their life cycle which, based on the present cost of delivered energy, will exceed the cost of the installed improvements; or

3) Those weatherization alternatives entirely authorized for installation through any federal, state or utility company sponsored loan or grant program.

Residence is defined as a building containing two or fewer dwelling units used for habitation by one or more persons (excluding mobile homes).

Solid Fuel Heating Device is defined as a stove, heater, fireplace modified with an insert, or other similar receptacle wherein wood or other solid fuel combustion occurs for the purpose of space heating (unmodified fireplaces are excluded).

Compliance: Failing to comply with the above requirements may result in civil penalties or civil liability.

Information concerning free energy audit and low-cost weatherization programs is available from the following sources, depending upon the primary heating source of your residence:

Primary Source	Information Source
Electricity	Pacific Power P. O. Box 1148 Medford, OR 97501 776-5499
Natural Gas	CP National Weatherization Dept. P. O. Box 1709 Medford, OR 97501 772-5281
Wood, Coal, Propane, Kerosene, etc.	Weatherization Audits: Oregon Heat Institute P. O. Box 42227 Portland, OR 97242 1-800-452-8660 Weatherization Grants: Oregon Dept. of Energy Labor & Industries Bldg. Room 102 Salem, OR 97310 1-800-221-8035

A list of qualified independent energy auditors will be maintained by the Department of Planning and Development for your information. Also available are copies of the ordinance pertaining to residential weatherization. Please ask for copies of these items at the reception desk.

LAW OFFICES
DAVIS, AINSWORTH, PINNOCK, DAVIS & GILSTRAP, P.C.
515 EAST MAIN STREET
ASHLAND, OREGON 97520

SAM B DAVIS
SIDNEY L AINSWORTH
DONALD M. PINNOCK
JACK DAVIS
DAVID V. GILSTRAP

TELEPHONE
AREA CODE 503
482-3111

November 6, 1984

To the Realtors of Medford and Ashland:

It is time to become aware of the Particulate Air Pollution Control Ordinance enacted by the Jackson County Board of Commissioners on October 17, 1984. This ordinance replaces an earlier ordinance which was far more difficult to live with and suspended before it went into effect due to the efforts of local Realtors.

One purpose of the new ordinance is to encourage residents to take advantage of the weatherization programs available. Because a weatherized house with a wood stove requires less burning to maintain warmth, and therefore less smoke for our air shed, the second purpose of the ordinance is to reduce smoke in the Valley through weatherization.

Understanding the new ordinance begins with knowing which sales it does <u>not</u> apply to. Each of you should refer to this list with every sale until it is memorized.

1. The ordinance does not affect the sale of any real estate excepting buildings containing one or two dwelling units used for habitation.

2. It does not apply to the sale of any property in any incorporated city.

3. It does not apply to the transfer of any leases on state or federal lands.

4. It does not apply to the sale of any buildings constructed after January 1, 1979.

5. It does not apply to the sale of mobile homes.

6. It does not apply to the sale of buildings outside the air quality maintenance area as defined on the attached map.

The ordinance sticks us with two prongs. The first is as follows: For all sales closed on January 1, 1985 and after, the house must:

a) Have insulation of R-30 in the ceiling, R-19 in the floor, and double glazed windows or storm windows; or

b) Have installed weatherization alternatives directed by an authorized energy audit.

If the seller has not complied with either of these, the ordinance can still be satisfied if the seller provides the purchaser with an authorized energy audit at the close of escrow. A list of qualified energy auditors will be available to the public at the County Planning Department office. The energy audits of the utility companies are also considered authorized.

The second prong of the ordinance affects only those residences which have a wood stove, fireplace with an insert, or other heater or receptacle which burns wood or other solid fuel for heat. This branch of the ordinance does not apply to houses that have only an unmodified fireplace. For sales closed on or after January 1, 1985, the sellers of residences face the same alternatives mentioned in the preceding paragraph with this exception. If the house lacks the insulation mentioned above and it was not weatherized as directed in an authorized energy audit before the close of escrow, it is not enough to simply provide the purchaser with an energy audit at the close of escrow. The purchaser must file with the Planning Director a statement to the effect that those minimum standards will be met within 90 days. The purchaser will then be responsible for implementing the weatherization within that prescribed time. The Planning Director has the authority to waive or modify this requirement when the physical characteristics or intended use of the residence make it impractical or unduly burdensome to require the implementation of that minimum weatherization.

So that your deals will close smoothly in January and after, it would be prudent to now line up energy audits for the sales in escrow. Please keep in mind the categories of sales which this ordinance does not apply to. As soon as I become aware of alterations or, perhaps, the repeal of this ordinance, I will advise.

Yours truly,

DAVIS, AINSWORTH, PINNOCK,
DAVIS & GILSTRAP, P.C.

JACK DAVIS
BOARD LEGAL COUNSEL
JD/jlh

LAW OFFICES OF
DAVIS, AINSWORTH, PINNOCK, DAVIS & GILSTRAP, P.C.
515 EAST MAIN STREET
ASHLAND, OREGON 97520
(503) 482-3111

Oregon's Woodstove Certification Program

62nd OREGON LEGISLATIVE ASSEMBLY–1983 Regular Session

Enrolled

House Bill 2235

Ordered printed by the Speaker pursuant to House Rule 12.00A (5). Presession filed (at the request of Department of Environmental Quality)

CHAPTER 333

AN ACT

Relating to air pollution; creating new provisions; and amending ORS 468.275 and 468.290.

Be It Enacted by the People of the State of Oregon:

SECTION 1. ORS 468.275 is amended to read:

468.275. As used in [*ORS 448.305, 454.010 to 454.040, 454.205 to 454.255, 454.405, 454.425, 454.505 to 454.535, 454.605 to 454.745 and*] this chapter, unless the context requires otherwise:

(1) "Air-cleaning device" means any method, process or equipment which removes, reduces or renders less noxious air contaminants prior to their discharge in the atmosphere.

(2) "Air contaminant" means a dust, fume, gas, mist, odor, smoke, vapor, pollen, soot, carbon, acid or particulate matter or any combination thereof.

(3) "Air contamination" means the presence in the outdoor atmosphere of one or more air contaminants which contribute to a condition of air pollution.

(4) "Air contamination source" means any source at, from, or by reason of which there is emitted into the atmosphere any air contaminant, regardless of who the person may be who owns or operates the building, premises or other property in, at or on which such source is located, or the facility, equipment or other property by which the emission is caused or from which the emission comes.

(5) "Air pollution" means the presence in the outdoor atmosphere of one or more air contaminants, or any combination thereof, in sufficient quantities and of such characteristics and of a duration as are or are likely to be injurious to public welfare, to the health of human, plant or animal life or to property or to interfere unreasonably with enjoyment of life and property throughout such area of the state as shall be affected thereby.

(6) "Area of the state" means any city or county or portion thereof or other geographical area of the state as may be designated by the commission.

(7) "Woodstove" means a wood fired appliance with a closed fire chamber which maintains an air-to-fuel ratio of less than 30 during the burning of 90 percent or more of the fuel mass consumed in the low firing cycle. The low firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn achievable.

SECTION 2. ORS 468.290 is amended to read:

468.290. Except as provided in this section and in ORS 468.450, 476.380 and 478.960, the air pollution laws contained in this chapter do not apply to:

(2) The woodstove is certified by the department under the program established under section 5 of this 1983 Act; and

(3) An emission performance and heating efficiency label is attached to the woodstove.

SECTION 9. (1) The provisions of this 1983 Act do not apply to a used woodstove.

(2) As used in this section, "used woodstove" means any woodstove that has been sold, bargained, exchanged, given away or has had its ownership transferred from the person who first acquired the woodstove from the manufacturer or the manufacturer's dealer or agency, and so used to have become what is commonly known as "second hand" within the ordinary meaning of that term.

SECTION 10. The commission shall use a portion of the net emission reductions in an airshed achieved by the woodstove certification program to provide room in the airshed for emissions associated with commercial and industrial growth.

Approved by the Governor July 5, 1983.
Filed in the office of Secretary of State July 6, 1983.

VICTOR ATIYEH
GOVERNOR

Environmental Quality Commission

Mailing Address: BOX 1760, PORTLAND, OR 97207
522 SOUTHWEST 5th AVENUE, PORTLAND, OR 97204 PHONE (503) 229-5696

MEMORANDUM

To: Environmental Quality Commission

From: Director

Subject: Agenda Item No. A, June 8, 1984, EQC Meeting

Proposed Adoption of Woodstove Certification Rules OAR 340-21-100 Through 340-21-166 As A Revision To The State Implementation Plan.

BACKGROUND

The 1983 Oregon Legislature passed HB 2235 which requires the EQC to adopt rules by July 1, 1984 which deal with certification of new woodstoves. Over the last 9 months the Department developed proposed rules with the aid of a Woodstove Advisory Committee. The proposed rules cover testing procedures, lab accreditation requirements, certification application procedures and fees, labeling criteria, and emission standards. The Woodstove Advisory Committee, which primarily represented the Oregon woodstove industry, supported the proposed rules with the exception of the emission standard. On March 16, 1984, the EQC authorized hearings on the proposed rules drafted by the Department (Agenda Item A, March 16, 1984, EQC Meeting).

Hearing Testimony

Day and night public hearings were held on the proposed rules in Portland, Eugene, Medford, Bend and Pendleton. The hearings officers' reports are included as Attachment 1. A summary of written testimony received while the hearing record was kept open is included as Attachment 2. Copies of both timely and late written testimony have been provided to the Commission.

Fifty-six individuals testified in person at the hearings, and fifty individuals submitted written testimony while the hearing record was kept open. Six individuals submitted written testimony after the hearing record was closed. Most testimony came from the woodstove industry which primarily criticized the proposed second stage of the emission standard as being unjustified and unachievable, and not in keeping with legislative

intent. Testimony supporting this position included information to indicate the baseline stove emission rate should be higher, population growth projections in airshed strategies should be lowered and the test fuel density was too low to represent reality.

Other significant issues raised by woodstove industry testimony included:

- The Condar particulate sampling method should be recognized as equivalent to Oregon Method 7.
- The Condar heating efficiency method should be recognized as equivalent to calorimeter room and stack loss heating efficiency methods.
- Testing costs should be reduced by reducing the number of tests required.
- A provision should be made to protect confidentiality of stove designs.
- Certification fees should be paid at the retail level.
- A fireplace insert test procedure should be provided.
- DEQ should not spend time inspecting stoves at the manufacturing facility when testing laboratories can provide this service.
- DEQ should let testing laboratories review woodstove design changes.
- DEQ should not immediately revoke manufacturer's certification if a testing lab is found to have conducted an improper test.
- Uncertified stove advertising and sales should be allowed in Oregon between manufacturers and dealers and to out-of-state customers.
- Degradation of non-catalyst stoves should be considered in setting the emission standard.
- Stoves should not have to be recertified every five years.
- Catalyst warranty requirements should allow a 5-year pro-rated provision instead of 2-year full replacement provision.
- The Woodstove Advisory Committee should periodically review the program.
- Some testing equipment specifications should be revised.

Several individuals submitted testimony in support of regulation of woodstoves and some felt the Department was not being strict enough.

Several organizations, such as the Sierra Club, League of Women Voters of Oregon, Oregon Environmental Council, and Oregon Lung Association, felt the strictest standards should be adopted as a single stage standard as they expressed fears that the second stage may never be implemented.

Only one local government, the City of Union, submitted testimony and asked to be exempt from the rules.

Organizations, such as the Lane Regional Air Pollution Authority (LRAPA) and Associated Oregon Industries, generally supported the proposed rules. Suggestions were made by LRAPA that public education should be included on economic and safety benefits of catalysts and that the value of a financial incentive should not be forgotten in relation to the possibility of accelerated woodstove pollution clean up.

EVALUATION AND ALTERNATIVES

The appropriateness of the second stage 7 gram/hour non-catalytic and 3 gram/hour catalytic stove particulate emission standard (7/3 standard) was the major issue raised by hearing testimony. The woodstove industry generally supported the first-stage standard but felt that either a second-stage standard was unnecessary to clean up airsheds or that more information was necessary in order to identify an appropriate standard. The Woodstove Advisory Committee had unanimously voted (with one member abstaining and one member absent) to support a 9/4 second-stage standard and some testimony was received from a few members of the woodstove industry in support of adoption of the Advisory Committee recommendations. There was considerable woodstove industry testimony that a 7/3 standard was not achievable with available stove technology.

Airshed Model Uncertainties

In terms of the needed airshed improvements which were the basis for the second-stage emission standard, testimony cited uncertainties of about ± 25% in the airshed models used to calculate these needs. Regarding these model uncertainties, they are not considered unusual with even state of the art models such as those used by the Department. The Department believes there is an equal likelihood that airshed needs have been underestimated as overestimated. The only reasonable approach in such instances, in the Department's opinion, is to rely on average values predicted by the models as has been done.

Population Growth Projections

When the issue of population growth projections and related increased wood burning used in airshed models was reviewed with the Advisory Committee last Fall, a check was made to verify that latest available population growth projections were being used by the Department. Subsequent to this check, hearing testimony pointed out that Portland State University published preliminary revised growth projections about the first of the year which indicate revised downward growth projections of about 25% for

the Portland and Medford areas for the periods of interest. While these projections are preliminary in nature, it is clear that actual growth within the first several years of the periods of interest have been much lower than anticipated because of the lingering economic recession in Oregon. Thus, it appears reasonable that these revised growth projections, which take into account this fact, should be used in reevaluating airshed improvement needs. Revised growth projections were used to revise the Portland and Medford airshed model control strategy needs. The results are shown below.

Airshed Reduction Needs From Woodstove Certification

	Daily Standard	Annual Standard
Medford Area (original)	80%	76%
Portland Area (original)	75%	75%
Medford Area (revised)	78%	74%
Portland Area (revised)	72%	72%

As can be seen from the above table, although growth projections have been revised downward about 25%, airshed improvement needs do not go down accordingly. This is because population growth is not the major cause of the wood heating pollution problem. The main cause is the large base of existing wood heating emissions.

In general, revisions of airshed control strategy needs based on revised population projections indicate needs have been reduced from a 75-80% range to a 72-78% range. The lower end of this range would be most important, considering population weighting to the Portland area needs.

Baseline Stove Emission Rate

Once the needed airshed emission reduction from woodstove certification is identified, the appropriate emission standard to achieve such a reduction can be calculated based on the average emissions from existing or baseline stoves. The baseline emission rate identified by the Department (in the range of 30 to 34 grams per hour) was criticized by many members of the woodstove industry as too low.

The Department identified a baseline particulate emission factor of 20 grams/kilogram of wood in actual airshed monitoring and modeling studies. This compared favorably with EPA's current emission factor of 21 grams/kilogram. The Department estimated an average baseline burn rate of 1.7 kilogram/hr (which when multiplied by the 20 gram/Kg emission factor equals an emission rate of 34 g/hr) as being the baseline burn rate based on the average heat demand for an average sized home with average insulation in Oregon. The estimated 1.7 kilogram/hr average burn rate translates to an equivalent heat load of 13,000 Btu/hr. The average baseline burn rate estimated by the Department was also challenged by

certain members of the woodstove industry who thought it should be higher. A comprehensive study which measured actual burn rates in several homes under heat load conditions similar to those of Oregon indicated burn rates closer to 1 Kg/hr. This study, by Dr. Stockton Barnett in New York, concludes that average burn rates may be slightly less than calculated heat loads because extremities of homes are kept cooler. The Department has also calculated burn rates in the range of 1.7 Kg/hour based on wood use and burning habits reported in a survey in the Medford area. Thus, the Department is confident that the burn rates used to calculate the average baseline emission rate should not be higher than 1.7 Kg/hour as claimed by woodstove industry testimony.

Recent testing of conventional woodstoves (December, 1983/January, 1984) using the proposed test procedures has also indicated a baseline stove emission rate of about 30 grams/hour. The National Wood Heating Alliance (WHA), however, presented substantial testimony which pointed to much higher baseline emission rates for conventional stove tests.

WHA pointed to 4 tests conducted by DEQ in 1980 of conventional stoves which averaged 81 grams per hour. A close examination of this data indicates tests were conducted with unrealistically dry wood with a moisture content of 14%. Wood at this moisture content has been shown by EPA studies to have very high emission rates. The proposed test procedure uses a more realistic average moisture content in the range of 16-20%. If the Department's 1981 test data is adjusted from 14% moisture to 18% moisture, using EPA derived moisture/emission relationships, an emission rate of about 36 grams/hour results.

WHA also cites 2 conventional stove tests conducted in 1981 within the Department's proposed moisture range which average 48.5 grams per hour. A close examination of this data indicates both tests were at higher heat outputs than the Department's reference 13,000 Btu/hr. Projecting this data to 13,000 Btu/hr results in an emission rate of between 34 and 39 grams per hour, depending on the assumed stove efficiency (50% or 65%).

WHA further cites test data by the State of Vermont which averages 51.8 grams per hour for conventional stoves. A close examination of this data indicates an average emission factor of about 20 grams/kilogram (which agrees with DEQ's factor) but at an average burn rate of about 3 Kg/hr which is much higher than DEQ estimates and actual measured values for Oregon heat loads. The Department therefore believes its estimate of baseline stove emissions in the range of 30 to 34 grams/hour is justifiable and usable to calculate an appropriate emission standard.

Test Fuel Loading

WHA also contends that the Department's test fuel density of 7 lbs/cubic foot of fire box volume is unrealistically low and thus produces unrealistic baseline emission rates and unrealistic test conditions for certification purposes. Investigation of this issue reveals that the actual Department test fuel density is about 9 lbs/cubic foot since a test fuel bed of 20-25% of a 71bs/cubic foot test fuel charge is also

This EQC report says
70-74% reduction w/ 9/4 std
77-79% reduction w/ 7/3 std

The JAPCA paper said
75-80% reduction based on
an assumed std similar
to 7/3.

required. WHA points out that a major study o
Battelle (a national research firm) used equiv
of 5 to 16 lbs/cubic foot. This would put the
density in about the mid-range of such testing
also point out that other major studies, like
Authority (1981-1983), used densities of 2.0 t
Dr. Stockton Barnett, a leading woodstove rese
testimony that he supports DEQ's fuel loading
size stoves on the basis of extensive experie
homeowners to record weights of their fuel lo
homeowners' overnight loads of hardwoods in t
7-8 lbs/cubic foot and 9-10 lbs/cubic foot in the coldest parts of winter. He postulates that loading densities are not greater because ash buildup is irregular and several inches deep, reducing useable firebox volume; logs are often non-optimum and variable length to fully utilize firebox length; and log diameters and irregular cross-section geometry make tight packing impossible.

The Department, therefore, concludes that a baseline emission rate of 30-34 grams/hour is appropriate and justifiable, based on: airshed modeling and monitoring studies; calculated and measured heat loads and burn rates for typical average Oregon homes; and actual emission tests of conventional stoves using reasonable test fuel densities and the proposed test procedure.

Needed Airshed Improvements and Emission Standards

Estimated emission reduction achievable for a 30-34 g/hr range of baseline emission rates for the two most prominently considered emission standards are shown below.

	Emission Reductions Achievable (%)	
Emission Standard	30 g/hr Baseline	34 g/hr Baseline
9/4	70%	74%
7/3	77%	79%

Since revised airshed emission reduction needs have brought the need down from a 75-80% range to a 72-78% range with the population weighted number much closer to the lower end of this range, it appears a 9/4 emission standard is more solidly justified than a 7/3 standard. A 9/4 emission standard resulting in an emission reduction in the range of 70 to 74% would also be more in keeping with DEQ legislative testimony which indicated a 68-75% reduction in emissions was achievable from new woodstove technology. The 68% reduction estimate was based on stoves meeting a 75% emission reduction level and 10% bootlegging of non-certified stoves. The slight additional airshed improvement needed to meet the daily standard in the Medford area above and beyond that which would be provided by a 9/4 standard may be able to be achieved by an aggressive educational effort to urge consumers to buy the lower emitting of the certified models or by other control strategies.

Best Practical Woodstove Control Technology

The woodstove industry severely criticized the proposed 7/3 emission standard on the basis that it was unachievable by available technology, even catalytic technology. Such criticism even came from the manufacturers of the Blaze King stove, the stove upon which the Department justified the achievability of the standard, and the Condar Company, the company that supplied the design technology for the Blaze King stove.

The Department had substantiated the achievability of the 3 g/hr catalytic standard on the basis of a Blaze King stove test with the proposed test procedure which resulted in an emission rate of 1.2 g/hr. Industry testimony criticized this data on the basis that the stove tested was a prototype and that production models have been "detuned" in terms of emission control to provide better catalyst life and better overall stove performance. Also, it was pointed out that the 25 cell-3" thick - 6,000 hour catalyst used in the DEQ test is being phased out and replaced with a less emission efficient 16 cell - 3" thick-12,000 hour catalyst in order to provide better catalyst longevity and improved burn rate and smoke leakage characteristics of the stove.

Upon confirming these facts several weeks ago, the Department decided to test three production-model, Condar-technology stoves using the new 16 cell-12,000 hour catalyst. Testing was conducted near the 13,000 Btu/hr reference heat output level using the proposed test procedure. The results are shown below.

Condar Technology Production Stoves	Emission Rate g/hr (Btu/hr)	g/hr (Estimate at 13,000 Btu/hr)
Blaze King Princess	2.39 (11,191)	2.75
Blaze King Princess	1.44 (13,032)	1.44
Brand X	2.49 (11,520)	2.65
Brand Y	1.06 (14,381)	0.93
Average	1.85	1.94
(95% Confidence Limit)	(3.23)	(3.74)

The above results indicate there is some variability in emission performance using Condar-technology. Test results would indicate that Condar-technology production stoves with the new catalyst designs do emit slightly more than the prototype stove tested earlier by DEQ, but still slightly under 3 g/hr. A statistical analysis of the data, though, indicates that the variability at the 95% confidence limit would put Condar technology over a 3 g/hr standard but under a 4 g/hr standard. A confidence limit statistical analysis is a common technique used to identify the upper bound of a population. It is a technique the Department used to develop a potential emission standard which was presented to the legislature. The Condar Company, which analyzed past DEQ test data, had

concluded an emission standard for catalysts in the range of 4-6 g/hr was achievable, however, this conclusion was based on longer aged (higher emitting) catalysts than called for under the proposed test procedure. A 4 g/hr emission standard, therefore, is strongly justifiable on the basis of test data of several production model Condar technology stoves with latest catalyst design. A 3 g/hr catalytic emission standard, while achievable for some tests, would likely exclude a significant portion of the Condar technology stove population. Condar technology is considered the best available technology and a 3 or 4 g/hr standard would eliminate poorly designed catalyst stoves.

Recommended Emission Standard

In summary, the Department's proposed 7/3 second stage emission standard was based on a strong case of airshed needs and available technology. Information gained through the public hearing process has led the Department to conclude that airshed needs are slightly less than originally projected due to downward revisions in population projections and that best practical catalytic stove control technology is only capable of consistently complying with a 4 g/hr standard. In essence, the Department concludes that a weaker case exists to support a 7/3 standard while a stronger case can be made to support a 9/4 standard. Considering many other plus and minus arguments, (such as: potential further future population growth and wood use reductions; many actual stoves being certified at significantly less than the emission standard; some non-replacement of catalysts and bootlegging of non-certified stoves), the Department believes the most reasonable and justifiable approach is to select a 9/4 standard. The 9 g/hr portion of the standard is likely technology forcing for non-catalytic stoves, but a number of members of the woodstove industry believe that such a standard would provide a potentially achievable goal and would not discourage research in meeting this goal.

Condar Particulate Measurement Method Equivalency

Considerable testimony was submitted by the Condar Company in support of recognizing the Condar particulate sampler as equivalent to the Oregon Method 7 method now in the proposed rules. Equivalency criteria was originally proposed in the rules and the Condar sampler has been tested against this criteria. The criteria required consistency relationships between the reference method and candidate method test points of ± 24%. Fourteen simultaneous tests were run with both methods and 7 of the 14 failed the ± 24% criteria. Condar has requested that the consistency criteria be modified to ± 41.6%. At this level, Condar's analysis of the data indicates 1 of 14 data pairs would fail the new criteria, while Department analysis indicates 3 of 14 would fail.

If the weighted average of the four required tests over the full heat output of the stoves are used to compare consistency relationships between these two methods, the consistency relationship improves. EPA has new consistency criteria out for the proposed new 10 micron particulate matter standard which requires consistency between methods of ± 20%. This would be more appropriate criteria to apply to woodstove particulate testing.

Applying this criteria to the weighted average Condar data would result in 1 of 3 tests failing. However, if dual Condar sampler data is used (averaging the results of the dual samplers), then all three tests would meet the criteria. The Department proposes to modify equivalency criteria to more closely match proposed EPA ambient particulate matter equivalency criteria. This should allow dual Condar sampling to be recognized as equivalent to Oregon's Method 7 (with application of an appropriate correction factor) with just a minimal amount of further equivalency testing. The recognition of equivalency would not be expected to reduce testing costs significantly or reduce the stringency of meeting applicable emission standards. Recognition of the Condar sampler, though, would make it much easier for manufacturers to perform the same certification tests independent labs would perform. This could give manufacturers more confidence in the ability of their unit to pass the emission standard before incurring the large expense of actual independent certification testing.

There was some assertion made that the Condar sampler simulated ambient particulate measurement better than Oregon Method 7 and hence, it should be the reference method. The Department sees no convincing proof of this assertion. On the contrary, it can be argued that the Condar method includes some water associated with hydrophilic particulate in woodstove emissions. Oregon Method 7 and EPA's ambient high volume sampling method both dessicate samples, thus removing water before weighing in contrast to the Condar method which does not.

Condar Heating Efficiency Method Equivalency

Condar Company supplied extensive testimony in support of recognition of a simplified heating efficiency test method which could potentially substantially reduce certification testing costs. An actual statistical analysis of the simplified method in comparison to Department results using the reference stack loss or calorimeter room method was not provided. The Department has shown that calorimeter room data is within 1% on an average of the stack loss method. If the Condar Company can show similar consistency in the future, this method could be potentially recognized as equivalent. Equivalency criteria has been added to the proposed rules to allow recognition of other heating efficiency test methods.

Reduction of Required Number of Tests

Some testimony suggested that testing costs should be reduced by reducing the number of tests, especially for smaller manufacturers or for specialty stoves with limited sales. The Department had originally felt two tests would be sufficient to accurately judge stove compliance with emission standards near the referenced 13,000 Btu/hr heat output level. Advisory Committee and national industry views strongly supported requiring four tests over an entire heat output range in order to: provide better consumer information for optimum stove operation; correctly size stoves to home heating needs; and provide useful data for other parts of the country

which might adopt a regulatory program at heat output levels different than the Oregon 13,000 Btu/hr reference level. Manufacturers generally felt the extra cost of testing at four points would, in the long run, save manufacturers testing costs in other areas of the country. The Department concurred with the Advisory Committee and industry views.

In certain instances, though, where stove model sales are very small because of the size of the manufacturer or the specialty nature of the stove, the Department can see value in allowing a two emission/efficiency test option near the 13,000 Btu/hr reference point and a heat output efficiency test at maximum firing rate. This would provide the necessary information for determining compliance with the emission standard and for sizing stoves to home heating needs. This alternative could reduce testing costs by about 1/3 and provide an incentive to get more stoves certified and thus provide more consumer selection.

Should too many manufacturers opt for the two emission test alternative though, the overall airshed benefits of label information including optimum operating point identification could be lost. A policy of allowing the two emission test option in special cases of very small sales volume of a stove model and requiring written notification to the Department prior to such testing could provide some protection from abuse of this alternative. If the option appeared to become too widely used, the Department would propose to deal with the issue through further rule change.

Confidentiality of Stove Design

Some testimony raised concern about the need to protect certain stove design plans with a confidentiality provision. ORS 468.095(2) provides such protection if any stove manufacturer would request such confidentiality protection in writing.

Payment of Certification Fees

There were some concerns that certification fees were too high and that they should be collected through retail sales. HB 2235 specifically authorizes certification application fees to be required from the manufacturer or dealer. The proposed fees are the Department's best estimate to cover costs of the program. No other billing system is permitted by HB2235.

Fireplace Insert Test Procedure

Some testimony indicated a test procedure was needed for fireplace inserts. Stove-like fireplace inserts are consuming a large portion of the stove market and they are being proposed to be regulated in the certification program. Specific test procedures were originally incorporated in the proposed test procedure to cover testing of such devices and must have been overlooked by the person providing such testimony.

DEQ Inspection of Stove Manufacturers and DEQ Review of Stove Design Changes

Some testimony questioned the value of DEQ inspecting manufacturing facilities to see that stove manufacturers continually met certification designs. Also questioned was the need for DEQ to review and approve design changes in stoves. Suggestions were made to let accredited labs do this since they already do this for safety testing follow-up.

The Department has never had any intent to check manufacturing facilities. The Department's primary enforcement mechanism is planned to be random stove retailer checks where changes in designs by the manufacturer or retailer can be identified. The Department will also check for the selling of non-certified stoves during the retailer visits.

Considering the differences in areas of expertise between testing labs and Department staff and the overall responsibility of the Department to enforce the certification program, the Department believes it is reasonable for the Department to review design changes to determine if they have the potential to change emission and efficiency performances and hence affect the continued validity of certification status.

Revocation of Certification

Testimony was submitted requesting a one year period before revocation of certification in cases where labs are found to have improperly conducted tests.

The Department believes procedures for revocation in OAR 340 Division 11 will provide due process and reasonable time for the revocation process.

Sale of Non-Certified Stoves

In one person's testimony, it was suggested that the rules be revised to allow sales, etc. of non-certified woodstoves which are intended to be used out-of-state. The Department's Counsel has advised that the State has clear authority to prohibit retail sales, etc. of uncertified stoves in the state even though certain of the consumers intend to use them out-of-state. To base the regulations of retail sales in Oregon on the residency or intent of the buyers would raise substantial problems of enforceability. Therefore, the Department continues to propose to regulate all retail sales in Oregon and all sales to Oregon retailers. Consequently, the presence of an uncertified new woodstove in an Oregon retailer's showroom would constitute a prima facie violation, without inquiry into the intent or residency of prospective consumers.

It was this person's opinion that it did not appear to be the purpose of the legislation nor would it be within the jurisdiction of the Department to regulate out-of-state emissions. This person concluded that it would constitute an undue burden on interstate commerce in violation of the United States Constitution. Because it is not the intent of the

Department to regulate emissions throughout the country wherever Oregon manufactured woodstoves might be used, the Department proposes to revise the proposed rules to provide an exception to the prohibition of selling, etc. an uncertified new woodstove, generally to not prohibit certain wholesale transactions particularly those involving new woodstoves intended for out-of-state retailers and consumers.

Degradation of Non-Catalyst Stoves

Some testimony requested that degradation of non-catalyst stoves be considered in setting the emission standards in a manner similar to what is proposed for catalyst stoves.

The Department recognizes that degradation in non-catalyst stove emission performance can occur. However, this degradation in the form of warped doors, burned out baffles and deterioration of thermostats are common to both technologies and difficult to quantify. Catalyst degradation is quantifiable and failure is expected before the total wearout of the stove itself. Therefore, the Department feels it is justifiable to apply a degradation factor just to catalyst stoves.

Recertification Every Five Years

Some concern was raised about the need and costs for recertification every five years. The Department had originally proposed that recertification fees and testing requirements can be waived if no changes have been made to the stove design which affect emissions. The Department believes it is a reasonable policy to review the certified design specifications of each certified stove against the actual production model stove each five years to insure that no changes have been made without prior approval.

Catalytic Warranties

One catalyst manufacturer requested that the Department's proposed 2-year free replacement warranty requirement be changed to a 5-year prorated warranty. The Department believes prorated warranties do not offer as much consumer protection and, therefore, protection of the airshed. as full replacement warranties, therefore, the Department does not propose to change this requirement.

Advisory Committee Periodic Program Review

HB 2235 indicates an Advisory Committee may be formed to aid and advise the Commission on adoption of emission standards and test procedures for woodstoves. While testimony requested the Advisory Committee periodically meet to review the program, once the rules are adopted there is no specific statutory authority for this particular advisory committee to continue in existence. The Department believes the proper role of an advisory committee in the future should be to continue to review and comment on rule changes that the Department may propose in the future. The Department would propose to appoint such an advisory committee, when and if necessary.

Test Procedure Equipment Specifications

Some testimony requested some minor changes in testing equipment specification. Changes considered reasonable have been made to the proposed rules.

SUMMATION

1. The 1983 Oregon Legislature passed HB 2235 which requires the EQC to adopt rules by July 1, 1984 to cover certification of new woodstoves.

2. The Department has worked extensively with a Woodstove Advisory Committee, primarily representing Oregon's woodstove industry, to develop proposed rules.

3. The Department and Woodstove Advisory Committee have been in virtually unanimous agreement as indicated by committee votes with the parts of the proposed rules dealing with testing procedures, certification process requirements, laboratory accreditation and labeling. The Department and Advisory Committee had different views on the second stage of the emission standard.

4. Extensive hearings were held on the proposed rules throughout the state during the first week in May. Approximately 112 people testified or submitted testimony, some on behalf of major organizations.

5. The major issue raised in the hearing process came from the woodstove industry which challenged the need and achievability of the second stage of the emission standard which would represent approximately an 80% reduction in particulate emissions in comparison to conventional stoves.

6. The Department has extensively analyzed the information submitted by the woodstove industry in support of their concern about the second stage standard. The Department concludes that issues raised about the uncertainty in airshed models, emission rates of baseline stoves, and realism of test fuel density do not justify making any changes in the proposed rules. The Department finds that the issues of downward adjustments to population projections used to project future wood use and performance of production model catalyst stoves have merit.

7. Reassessment of airshed needs based on downward revised population projections of about 25% indicate woodstove certification emission reduction needs should be revised from the original 75 to 80% range in the Portland and Medford airsheds to a 72 to 78% range.

8. Woodstove industry testimony indicated that the Department had erroneously based its belief that catalyst stoves could meet a 3 gram/hr (80% reduction) standard on a prototype stove with a new

obsolete catalyst. Recent Department tests of three production model stoves using the best available technology and newly designed catalysts still indicate attainment of a 3 gram/hr standard but 2 of the 3 stoves just barely attained compliance. Statistical analysis of the variability in these stoves' emission performances indicate a standard of 4 grams per hour would be necessary to insure confidence that most of these stove designs incorporating this technology would comply.

9. Considering that slightly less airshed reductions are needed than originally thought due to recent downward revised population growth projections and that best-available-technology, production model catalyst-stoves have slightly higher emission rates than the prototype stove originally tested by the Department, the Department believes a stronger case can be made to support a 9/4 emission standard than a 7/3 emission standard. A 9/4 emission standard should provide at least a 70-74% reduction in woodstove emissions. Such reductions would also support Department legislative testimony which indicated a 68-75% reduction was achievable with available technology.

10. The Department believes a dual Condar particulate sampling technique can be recognized as equivalent to Oregon Method 7 with minimally more equivalency testing.

11. The Department believes that a two emission test option with a maximum heat output efficiency test should be allowed in lieu of 4 tests to reduce testing costs only in instances where prior written notice is given to the Department and where small sales volumes of stoves are expected, such as in the case of specialty stoves. Such tests would be limited to Oregon Method 7 measurement because of increased inaccuracies of the Condar sampling techniques with less than four tests. Should this policy be abused, further rule changes would be recommended to insure that the overall airshed benefits of full performance labelling are not lost.

12. The Department believes that the specific statutory basis for the Woodstove Advisory Committee expires with the adoption of the proposed rules. An advisory committee may be appointed in the future to comment on rule changes the Department may propose.

13. Other issues raised by testimony do not warrant modifications to the proposed rules with the exception of clarification of sales of non-certified stoves between Oregon manufacturers and dealers and to non-Oregon businesses or residents and minor revisions to test instrument specifications.

DIRECTOR'S RECOMMENDATION

Based on the Summation, the Director recommends that the Commission adopt the revised proposed rules OAR 340-21-100 through -166 in Attachment 4 as an amendment to the State Implementation Plan.

Fred Hansen

Attachments:
1. Hearings Officers' Reports
2. Summary of Written Testimony Submitted as Part of Hearing Record.
3. Draft Statement of Need For Rulemaking and Land Use Consistency Statement
4. Proposed Revisions to Draft Rules OAR 340-21-100 Through -166

AA4422
J.F. KOWALCZYK:s
229-6459
May 23, 1984

Attachment 4

(DRAFT RULES)

WOODSTOVE CERTIFICATION
Chapter 340, Division 21, Sections 100-166

340-21-100 Definitions

-110 Requirements for Sale of New Woodstoves in Oregon
-115 Exemptions

-120 Emission Performance Standards and Certification

-130 Testing Criteria and Procedures

-140 General Certification Procedures
-145 Changes in Woodstove Design

-150 Labelling Requirements
-152 Permanent Label
-154 Removable Label
-156 Label Approval

-160 Laboratory Accreditation Requirements
-161 Accreditation Criteria
-162 Application for Accreditation
-163 On-Site Laboratory Inspection and Stove Testing Proficiency Demonstration
-164 Accreditation Application Deficiency, Notification and Resolution
-165 Final Department Administrative Review and Certification of Accreditation
-166 Civil Penalties, Revocations and Appeals

Appendix: Oregon Department of Environmental Quality, Standard Method for Measuring the Emissions and Efficiencies of Woodstoves, [March 8, 1984] May 21, 1984.

WOODSTOVE CERTIFICATION
Chapter 340, Division 21, Sections 100-166

Definitions

340-21-100 Unless otherwise required by context, as used in this Division:

(1) "Accredited" means a woodstove testing laboratory holds a valid certificate of accreditation issued by the Department.

(2) "Audit test" means a test [used] conducted by the Department to verify a laboratory's certification test results.

(3) "Catalyst-equipped" means a woodstove with a catalytic combustor that is an integral component of the design and manufacture of a woodstove.

(4) "Certify" means the Department has acknowledged in writing that a woodstove meets Department emission standards when tested by an independent laboratory according to Department test procedures.

(5) "Consumer" means any person who buys a woodstove for personal use.

(6) "Dealer" means any person engaged in selling woodstoves to retailers or other dealers for resale. A dealer which is also an Oregon retailer shall be considered to be only a retailer for purposes of these rules.

[(5)] (7) "Fixed air supply" means an air supply system on a woodstove which has no adjustable or controllable air inlets.

[(6)] (8) "Heat output" means the heat output (Btu/hour) of a woodstove during one test run, measured under test conditions prescribed by OAR 340-21-130.

[(7)] (9) "Informal Departmental conference" means a meeting of a manufacturer, dealer, retailer, or laboratory representative and a representative of the Department to discuss certification or accreditation denial or revocation, or civil penalties. An informal Departmental conference is not part of a judicial process or the formal hearing process as described in Oregon Administrative Rules Chapter 340, Division 11.

(10) "Manufacturer" means any person who constructs a woodstove or parts for woodstoves.

[(8)] (11) "New Woodstove" means any woodstove that has not been sold, bargained, exchanged, given away or has not had its ownership transferred from the person who first acquired the woodstove from the manufacturer's dealer or agency, and has not been so used to have become what is commonly known as "second hand" within the ordinary meaning of that term.

[(9)] (12) "Overall efficiency (%) over the range of heat outputs tested" means the weighted average combustion efficiency (%) multiplied by the weighted average heat transfer efficiency (%) measured under test conditions

(range of heat outputs) and calculated according to specific procedures prescribed by OAR 340-21-120(5). This definition is applicable to the Stack Loss Methodology. For the Calorimeter Room Method, the weighted average overall efficiency means the useful heat output released to the room, divided by the total heat potential of the fuel consumed.

(13) "Retailer" means any person engaged in the sale of woodstoves directly to consumers.

[(10)] (14) "Smoke emission rate (grams/hour) over the range of heat outputs tested" means the weighted average particulate emissions (grams/hour) that are produced by a woodstove under test conditions (range of heat outputs) specified in OAR 340-21-130 and calculated according to procedures specified in OAR 340-21-120(5).

[(11)] (15) "Weighted average" means the weighted average of the test results to the distribution of home heating needs in Oregon. (Refer to OAR 340-211-20(5)).

[(12)] (16) "Woodstove" means a wood fired appliance with a closed fire chamber which maintains an air-to-fuel ratio of less than 30 during the burning of 90 percent or more of the fuel mass consumed in the low firing cycle. The low firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn achievable, whichever is greater.

Requirements for Sale of New Woodstoves in Oregon

340-21-110(1) On and after July 1, 1986, a person shall not advertise to sell, offer to sell, or sell a new woodstove in [the State of] Oregon unless:

(a) The woodstove has been tested to determine its emission performance and heating efficiency in accordance with criteria and procedures specified in OAR 340-21-130; and

(b) The woodstove is certified by the Department in accordance with procedures in OAR 340-21-140 as meeting the emission performance standards specified in OAR 340-21-120; and

(c) The woodstove is labelled for emission performance and heating efficiency as specified in OAR 340-21-150[.]; provided, however, that this section (1) shall not apply to any sale from any manufacturer or dealer; to any Oregon manufacturer or dealer; or to any out-of-state manufacturer, dealer or retailer; or to any offer or advertisement for such sale directed only to such a manufacturer, dealer or out-of-state retailer.

(2) No manufacturer, [or] dealer or retailer shall alter either the permanent or removable label in any way from the label approved by the Department pursuant to OAR 340-21-156.

(3) Violators of any of the above rules may be subject to civil penalties pursuant to OAR Chapter 340, Division 11 and 12 or other remedies prescribed by rule or [order.] statute.

Exemptions

340-21-115 (1) Wood-fired appliances that are not suitable for heating equipment in or used in connection with residences or commercial installations are excluded from 340-21-110. For example, portable camping stoves.

(2) Wood-fired forced air furnaces that primarily heat living space or water through indirect heat transfer using forced air duct work or pressurized water systems are excluded from 340-21-110.

Emission Performance Standards and Certification

340-21-120 (1) New woodstoves with minimum "heat output" of less than 40,000 Btu/hr advertised for sale, offered for sale, or sold in [the State of] Oregon within the period July 1, 1986 to June 30, 1988, shall not exceed the following weighted average particulate emission standards when tested to procedures in OAR 340-21-130.

(a) 15 grams per hour for a non-catalytic woodstove, or

(b) 6 grams per hour for a catalyst-equipped woodstove.

(2) New woodstoves with minimum "heat output" of less than 40,000 [Btu/hr] Btu per hour advertised for sale, offered for sale, or sold in [the State of] Oregon on or after July 1, 1988 shall not exceed the following weighted average particulate emission standard when tested and measured according to test procedures in OAR 340-21-130.

(a) [7] 9 grams per hour for a non-catalytic woodstove or

(b) [3] 4 grams per hour for a catalyst-equipped woodstove.

(3) New woodstoves with a minimum "heat output" of greater than 40,000 Btu per hour, advertised for sale, offered for sale, or sold in [the State of] Oregon after July 1, 1986 shall not exceed an average particulate emission standard equal to the sum of 8.0 grams per hour plus 0.2 grams per hour for each thousand Btu per hour heat output when tested to procedures in OAR 340-21-130.

(4) The Department will certify a woodstove as meeting the applicable woodstove emission standard after July 1, 1984 in accordance with procedures in OAR 340-21-140.

(5) The weighted average particulate emission shall be calculated as follows:

$$\bar{E} = \frac{K_1E_1 + K_2E_2 + K_3E_3 \ldots + K_nE_n}{K_1 + K_2 + K_3 \ldots + K_n}$$

where: $\bar{E}$ is the weighted average particulate emission rate in grams per hour; E_1, E_2, $E_3 \ldots E_n$ are the particulate emission rates in grams per hour from test runs 1 through n in order of increasing heat output; and K_1, K_2, $K_3 \ldots K_n$ are the weighting factors for test runs 1 through n. The weighting factors (K_i) are calculated as follows:

$$K_i = P_{i+1} - P_{i-1}$$

where P_i is the cumulative probability from Table 1 for the heat output measured during each test run, $P_o = 0$, and $P_{n+1} = 1$.

Table 1
(OAR 340-21-120)

CUMULATIVE PROBABILITY FOR A GIVEN HEAT OUTPUT
DEMAND BASED ON OREGON CLIMATE (POPULATION WEIGHTED*)

Heat Output (Btu/hr)	Cumulative Probability (P)	Heat Output (Btu/hr)	Cumulative Probability (P)
0	0.02640	24,600	0.97873
600	0.03071	25,200	0.98256
1,200	0.03503	25,800	0.98540
1,800	0.04130	26,400	0.98713
2,400	0.04888	27,000	0.98972
3,000	0.05863	27,600	0.99096
3,600	0.06879	28,200	0.99237
4,200	0.08122	28,800	0.99316
4,800	0.09837	29,400	0.99408
5,400	0.11586	30,000	0.99472
6,000	0.13522	30,600	0.99506
6,600	0.15803	31,200	0.99526
7,200	0.18394	31,800	0.99563
7,800	0.21615	32,400	0.99589
8,400	0.24867	33,000	0.99679
9,000	0.28798	33,600	0.99711
9,600	0.32621	34,200	0.99745
10,200	0.37040	34,800	0.99774
10,800	0.41575	35,400	0.99787
11,400	0.46226	36,000	0.99817
12,000	0.50831	36,600	0.99837
12,600	0.55778	37,200	0.99851
13,200	0.60326	37,800	0.99858
13,800	0.64770	38,400	0.99882
14,400	0.68572	39,000	0.99899
15,000	0.72483	39,600	0.99915
15,600	0.75743	40,200	0.99933
16,200	0.78883	40,800	0.99945
16,800	0.81816	41,400	0.99958
17,400	0.84386	42,000	0.99968
18,000	0.86822	42,600	0.99974
18,600	0.88951	43,200	0.99986
19,200	0.90667	43,800	0.99992
19,800	0.92228	44,400	0.99995
20,400	0.93620	45,000	0.99996
21,000	0.94720	45,600	0.99999
21,600	0.95545	46,200	1.00000
22,200	0.96158	46,800	1.00000
22,800	0.96699	47,400	1.00000
23,400	0.97151	48,000	1.00000
24,000	0.97515	> 48,000	1.00000

* Based on ambient temperature data during October through April, 1967-73 with population weighting from eight Oregon locations (Portland, Medford, Pendleton, Astoria, Burns, North Bend, Redmond, and Salem).

Testing Criteria and Procedures

340-21-130 (1) To be considered eligible for certification, a woodstove must be tested in strict conformance with criteria and procedures contained in the document Standard Method for Measuring the Emissions and Efficiencies of Residential Woodstoves dated [March 8;, 1983], May 21, 1984, and incorporated herein by reference and on file at the Department.

(2) All testing for certification purposes shall be conducted by a stove testing laboratory accredited by the Department in accordance with procedures specified in OAR 340-21-160.

(3) The Department may permit minor changes in the testing criteria and procedures which the Department believes does not affect its accuracy with respect to compliance with the emission standard providing such changes are approved in writing by the Department prior to the actual conducting of such tests.

General Certification Procedures

340-21-140 (1) Any woodstove manufacturer, or dealer, wishing to obtain certification of a woodstove shall file an application with the Department.

(2) An application for certification must include:

(a) An appliance description which includes the woodstove model name and design number, a copy of the appliance's operating manual and a photograph of the stove.

(b) Design plans of the woodstove, identified by design number, which include overall dimensions of the appliance and all dimensions and specifications of components critical to emission control and heating efficiency performance. These components shall include combustion chamber configurations, all air inlet controls, heat exchanger design and make and model numbers of applicable purchased parts.

(c) All test data and support documentation showing that the woodstove has been tested in accordance with OAR 340-21-130 and that it meets the emission performance standard specified in OAR 340-21-120.

(d) A non-refundable certification fee, payable to the Department at the time the application is submitted to the Department, is required for each stove model seeking certification. The fee is:

(a) $1600.00 for a manufacturer's first model seeking certification, and

(b) $ 800.00 for each additional model submitted by the manufacturer.

(3) The Department will promptly review an application for certification and:

(a) Notify the applicant in writing within 30 days of receipt of the application, of any deficiencies in the application that cause the application to be incomplete.

(b) Notify the applicant within 60 days of receipt of a completed application whether certification is granted or denied pursuant to Sections 4 and 7 below.

(4) When all the preceeding requirements have been met, the Department will issue or deny a certification document to the manufacturer or dealer for the specified woodstove.

(5) If the Department grants certification, the certification status shall be effective for no longer than 5 years unless extended or terminated by rule or order.

(6) An application for a new document of certification shall be made by submitting a completed application including retests and fees at least 60 days prior to expiration of certification. The Department may waive the retest and fees if the applicant demonstrates the previous evidence used to certify the woodstove has not changed and remains reliable and applicable.

(7) If the Department denies certification of a woodstove, the Department will notify the manufacturer or dealer in writing of the opportunity for a hearing pursuant to OAR Chapter 340, Division 11.

Changes in Woodstove Design

340-21-145 Certification of woodstoves shall be valid for only the specific model, design, plans and specifications which were originally submitted, tested and approved for certification. Any modification to the model, design, plans or specifications shall cause the certification to be ineffective and any so modified woodstoves to be uncertified, unless prior to making such modification the certification holder submits the proposed modification to the Department for approval, and the Department approves it. The Department may approve the proposed modification if the holder demonstrates and the Department finds that the proposed modification would not affect emission performance or heating efficiency.

Labelling Requirements

340-21-150 Woodstoves which must be labelled pursuant to OAR 340-21-110 and shall have affixed to them:

(1) A permanent label, that has been previously approved by the Department in writing as to form, content and location, that shows the test emissions and heating efficiency for the range of heat outputs tested.

(2) A point-of-sale removable label that verifies certification and shows how the appliance's emission test results compare with the Oregon emission performance standard; and shows the heating efficiency and heat output range

of the appliance. The label shall be affixed to the appliance at the point-of-sale near the front and top of the stove and remain affixed until sold and delivered to the consumer.

340-21-151 All woodstoves certified by the Department from July 1, 1984 on, shall be labelled with a permanent and a removable label.

Permanent Label

340-21-152 (1) The permanent label, or "Certified Test Performance" label, shall contain the following information:

(a) Testing laboratory

(b) Date tested

(c) Test procedure used

(d) Manufacturer of appliance

(e) Model

(f) Design number

(g) The statement: "Performance may vary from test values depending on actual home operating conditions."

(h) A graph showing:

(A) Smoke emission rates, in grams/hour, over the range of heat outputs tested.

(B) Overall efficiency over the range of heat outputs tested.

(2) The axis of the graph shall be identified as follows:

(a) Vertical axis, left side: "Smoke - grams/hour", with a scale of 0 to a maximum of 20, bottom to top.

(b) Vertical axis, right side: "Efficiency - %", with a scale of a minimum of 50 to a maximum of 90, bottom to top.

(c) Horizontal axis, bottom: "Heat Output - Btu/hour", with a scale from 0 to a maximum of 5,000 Btu/hour higher than the highest tested heat output.

(3) Curves describing emissions and efficiency at various heat outputs shall be printed on the graph, and will be developed by the Department as follows:

(a) The emissions curve will be developed by the Department by fitting the emission test data to the quadratic equation:

$$y = a_0 + a_1 x + a_2 x^2$$

where

y = particulate emissions (grams/hour)

x = heat output (Btu/hour)

a_0, a_1, a_2 = regression coefficients

(b) The overall efficiency curve shall be developed by the Department by fitting the efficiency test data to the quadratic equation:

$$y = a_0 + a_1 x + a_2 x^2$$

where

y = overall efficiency (%)

x = heat output (Btu/hour)

a_0, a_1, a_2 = regression coefficients

(4) If the two test option (refer to Oregon DEQ Standard Method For Measuring The Emissions and Efficiencies of Woodstoves, Section 5.8.8, May 21, 1984) is used to test for emissions and overall efficiency, then:

(a) The emissions and efficiency performance of the appliance will each be described by a line between the two test data points.

(b) The maximum heat output will be identified as a single point.

(c) The statement: "Not tested over entire heat output range of appliance" will be placed on the permanent label.

[(4)] (5) For woodstoves with a fixed air supply which have only two data points for emissions and two data points for overall efficiency the Department will:

(a) Develop the emission performance description by averaging the two emission data points and describe the performance on the graph with a single point representing the average.

(b) Develop the overall efficiency performance description by averaging the two efficiency data points and describe the performance on the graph with a single point representing the average.

[(5)] (6) The curves, lines or single points will be developed and fit on the graph by the Department and transmitted to the appliance manufacturer for printing on the label. Changes from the above criteria may be made by the Department as necessary to insure readability. Approval of the label design, layout, and location on the woodstove will be made by the Department and shall be obtained pursuant to OAR 340-21-156.

[(6)] (7) The label shall be permanently secured or fixed to the appliance

so that it is visibly located on the appliance and legible, and meets the following criteria:

(a) A permanent label shall be a label that cannot be removed from the appliance without damage to the label. The label shall remain legible for the maximum expected useful life of the appliance in normal operation.

(b) A label shall be readily visible after installation. Approval of the location of the label on a woodstove will be made by the Department and shall be obtained pursuant to OAR 340-21-156. The label may be located on:

(A) Any visible exterior surface except the bottom of the appliance, or on

(B) Any interior surface of the appliance, within stove compartments, or under overlapping covers or doors, or at another interior location, if the label can be seen after installation and will remain legible for the life of the stove.

(c) A legible label shall be quickly and easily read.

(d) It shall be acceptable to combine the permanent label with another label, such as a safety label, if the design and integrity of the

permanent label is not compromised, and if the combination label meets the approval of the Department.

[(7)] (8) Physical and Material Specifications

(a) The minimum dimensions of the label shall be at least 3-1/2" long by 2" wide.

(b) The graph on the label shall be at least 3" long by 1-1/2" wide; and any enlargement of the graph shall maintain a proportion represented by the length to width ratio of 2:1.

(c) The label must be made of a material that will satisfy the permanency rule (340-21-152(6)(a)). For instance, it may be made of aluminum, brass, galvanized steel, or another metal, and of a thickness that will ensure permanence of the label.

(d) The information on the label shall be applied to the label in a way that will satisfy the permanency and legibility rules (340-21-152(6)(a) and (c)). For instance, the information may be etched, silk-screened, or die-stamped onto the label.

(e) The label shall be secured to the appliance in a way that it will satisfy the permanency and visibility rules (340-21-152(6)(a) and (b)). For instance, the label may be riveted, screwed, or bolted onto the appliance.

Removable Label

340-21-154 (1) The point-of-sale removable label, or "Emissions and Efficiency Performance" label, shall contain the following information:

(a) "Smoke (Ave.) _____ grams/hour", weighted average of tested values.

(b) "Efficiency (Ave.) _____%", weighted average of tested values.

(c) Summary of the applicable emissions standard.

(d) Heat output range, tested values.

(e) Manufacturer of appliance.

(f) Model of appliance.

(g) Design number of model.

(h) A statement verifying certification.

(i) The statement "Performance may vary from test values depending on actual home operating conditions."

(i) If the two test option is used to test for emissions and efficiency, the statement "Not Tested Over Entire Heat Output Range of Appliance" will be placed on the removable label.

(2) The label shall be visibly located on the appliance when the appliance is available for inspection by consumers.

(3) This label may not be combined with any other label or with other information.

(4) The label shall be attached to the appliance in such a way that it can be easily removed by the consumer upon purchase. For instance, the label may be attached by adhesive, wire, or string.

Label Approval

340-21-156 (1) Permanent label

(a) The Department will provide guidance on the design of labels by supplying information that shall be placed on the label at the time certification is granted.

(b) The manufacturer or dealer shall submit to the Department:

(A) The name, phone number and address of the label manufacturer.

(B) A proof copy of the label, printed on a representative sample of the label stock, shall be submitted to the Department, if practical; if not, a sample of the label stock shall be submitted for review with a proof copy of the label. The copy shall be as representative of the intended final printed label as practical. The copy shall be actual size; and shall show the proposed label design; layout; artwork; print size, style and color; and shall show all the information required on the label, including curves or points.

(C) A drawing, diagram, or photograph that identifies the location of the permanent label on the woodstove.

(D) Information that describes or shows how the permanent label will be affixed to the woodstove. For instance, it may be a description of an adhesive type, adhesive manufacturer, and performance characteristics; or rivet type, rivet manufacturer, and performance characteristics.

(c) Within 14 days of receipt of all information required in (b), the Department will approve or deny use of the proposed label.

(2) Removable label

(a) The Department will provide the manufacturer or dealer, at the time of certification with:

(A) A copy of the standardized printed removable label, with all printing specifications, and

(B) The specific information that shall be printed in the spaces on the label by the manufacturer.

(b) The manufacturer or dealer shall submit to the Department for review:

(A) A proof copy of the proposed label with the required information printed on the labels.

(B) The method of attaching the removable label to the woodstove.

(C) The name, telephone number, and address of the label printer.

(c) Within 14 days of receipt of all the information required in (b), the Department will approve or deny use of the proposed label.

(3) The manufacturer shall submit to the Department three final printed permanent, and three final printed removable labels within 1 month of receiving the labels from the printer.

Laboratory Accreditation Requirements

340-21-160 A laboratory submitting test data pursuant to requirements in this rule shall have a valid certificate of accreditation issued by the Department. A laboratory may initiate application for an accreditation certificate by submitting written documentation to the Department that accreditation criteria contained in OAR 340-21-161 are met. In addition,

the laboratory must demonstrate stove testing proficiency pursuant to OAR 340-21-162, in order to qualify for accreditation.

Accreditation Criteria

340-21-161 (1) All laboratories shall meet the following criteria and standards at the time of application and shall continue to meet these criteria as a condition of maintaining accreditation:

(a) The laboratory shall be an independent third-party testing organization with no organizational, managerial, or financial affiliation with any manufacturer, supplier or vendor of any woodstove covered under its testing programs. For example:

(A) The laboratory shall not be owned by any manufacturer or vendor, or own any manufacturer or vendor of woodstoves.

(B) The management of the laboratory shall not control or be controlled by any manufacturer or vendor.

(C) The laboratory shall not be engaged in the promotion or design of the woodstove being evaluated or tested.

(D) The laboratory shall have sufficient diversity of clients or activity so that the loss or award of a specific contract regarding testing would not be a determinative factor in the financial well being of the laboratory.

(E) The employment security status of the personnel of the laboratory shall be free of influence or control of any one or more manufacturers or vendors of woodstoves tested.

(b) The laboratory shall be operated in accordance with generally accepted professional and ethical business practices. For example:

(A) The laboratory shall accurately report values that reflect measured data.

(B) The laboratory shall limit certification program test work to that for which it can perform competently.

(C) The laboratory shall immediately respond and attempt to resolve every complaint contesting test results.

(c) The laboratory shall be staffed by personnel competent to perform the test procedures for which accreditation is sought, for example:

(A) The laboratory shall assure the competency of its staff through the observation or examination or both of each relevant staff member in the performance of tests, examinations, and inspections that each member is assigned to perform. The observations must be conducted at intervals not exceeding one year by one or more individuals judged qualified by the person who has technical responsibility for the operation.

(B) The laboratory shall make available the description of its training program for assuring that new or untrained staff will be able to perform tests and inspections properly and uniformly to the requisite degree of precision and accuracy.

(C) The laboratory shall maintain records, including dates of the observation or examination of performance of all personnel.

(d) The laboratory shall be equipped with the necessary instrumentation and equipment to test all appliances in accordance with the Department's test procedures.

(e) The laboratory must have in place and maintain a viable record keeping system. This means that records must be easily accessible, in some logical order and contain complete information on the subject. Records covering the following items are required and will be physically reviewed during the on-site assessment either in total or by selected sampling:

(A) Measuring equipment ± [-] each instrument name and description, name of manufacturer, model, style and serial number. Specifications on range or level of precision, date and documentation of calibration, record of maintenance and frequency of calibration.

(B) Data systems ± [-] samples of raw and reduced data sheets, test report format, method (manual or automated) of data recording, analysis and reporting.

(C) Staff training dates and results .

(D) Staff competency review dates and results .

(E) Equipment calibration (or verification) records shall include the following: equipment name or description; model, style, serial number; manufacturer; notation of all equipment variables requiring calibration or verification; the range of calibration/verification; the resolution of the instrument and allowable error tolerances; calibration/verification date and schedule; date and result of last calibration; identity of the laboratory individual or external service responsible for calibration; source of reference standard and traceability.

(F) Test data and reports, including emissions and efficiency calculations fully documented and all other items required by the specific test method.

(G) Sample tracking and logging records shall trace the movement of each stove through the laboratory from its receipt through all the tests performed to the final test report. Dates, condition of sample, and laboratory personnel involved should be included.

(f) The laboratory shall maintain a quality control system to help assure the accuracy and technical integrity of its work consisting of the following:

(A) The laboratory's quality control system must include a quality control manual containing written procedures and information in response to the applicable requirements of the test procedures. The procedures and information may be explicitly contained in the manual or may be referenced so that their location in the laboratory is clearly identified. The written procedures and information must be adequate to guide a testing technician and inspector in conducting the tests and inspections in accordance with the test methods and procedures required for the stove testing for which accreditation is sought.

(B) The laboratory shall have a current copy of its quality control manual or laboratory operations control manual available in the laboratory for use by laboratory personnel and shall make the manual available to the Department for review and audit.

(C) The quality control manual shall consist of general guidelines for the quality control of the laboratory's method of operation. Specific information shall be [is] provided for portions of individual test methods whenever specifics are needed to comply with the criteria or otherwise support the laboratory's operations.

(g) The laboratory shall maintain an emissions and efficiency computer program that produces reasonably the same results to the Department's, using a standard data set provided by the Department.

(h) Neither the laboratory owners or business affiliates shall discriminate in management or business practices against any person or business because of race, creed, color, religion, sex, age, or national origin. In addition, neither the laboratory or its owners or operators shall be certified by any association or are members of any association that discriminates by business or management practices against any person or business because of race, creed, color, religion, sex, age, or national origin.

Application for Laboratory Accreditation

340-21-162 (1) A laboratory applying for accreditation shall state in writing and demonstrate by providing documentation, that they comply with the criteria and standards in OAR 340-21-161 at the time of application, and how they will continue to meet the criteria and standards on an on-going basis.

(2) The laboratory shall notify the Department in writing within 30 calendar days should it become unable to conform to any of the criteria and standards in OAR 340-21-161.

(3) The laboratory shall demonstrate to the Department that the laboratory's emission and efficiency computer program produces reasonably the same results to the Department's, using a standard data set provided by the Department.

(4) Deficiency in the application will be identified by the Department in writing, and must be resolved by the laboratory before further processing occurs.

(5) The application will not be considered complete for further processing until the laboratory certifies in writing that the deficiencies have been revolved. The application will be considered withdrawn if the applicant fails to certify resolution within 90 days of postmark of notification by the Department.

(6) When the application is approvable, the Department will inform the laboratory in writing and schedule an on-site laboratory inspection.

On-Site Laboratory Inspection and Stove Testing Proficiency Demonstration

340-21-163 (1) An on-site inspection will be conducted by a Department representative after all laboratory information required by OAR 340-21-161, has been provided by the laboratory, reviewed and approved by the Department. The on-site visit will be conducted when a laboratory initially applies for accreditation and when the laboratory reapplies for a new certificate of accreditation. [renewal.]

(2) During the on-site inspection, the Department representative will:

(a) Observe the Stove Testing Proficiency Demonstration specified in OAR 340-21-162(3).

(b) Meet with management and supervisory personnel responsible for the testing activities for which the laboratory is seeking accreditation.

(c) Review representative samples of laboratory records. To facilitate examination of personnel competency records, the laboratory should prepare a list of names of staff members who perform the tests.

(d) Observe test demonstrations and talk with laboratory personnel to assure their understanding of the test procedures. Refer to OAR 340-21-130 and 340-21-162(3).

(e) Physically examine selected equipment and apparatus.

(f) At the conclusion of the on-site visit, the Department will discuss observations with responsible members of the laboratory management pointing out any deficiencies uncovered.

(3) In order to be accredited and as a part of each on-site laboratory inspection, each laboratory must demonstrate to the Department's representative its ability to successfully and proficiently conduct and report a woodstove emission and efficiency test. Each laboratory will be:

(a) Required to test one woodstove provided by the Department. Costs for all stove shipping, catalytic combustors, or other necessary parts will be paid by the laboratory.

(b) Required to test the stove in accordance with testing criteria and procedures specified in OAR 340-21-130.

(c) Conduct the actual emission and efficiency testing in the presence of a Department observer.

(d) Submit all test data, observations and test results to the Department for technical evaluations.

Accreditation Application Deficiency, Notification and Resolution

340-21-164 (1) Any deficiencies noted during the on-site inspection and/or in the test data and test results submitted from the stove testing proficiency demonstration will be specifically identified in writing and mailed to the laboratory within 30 days of the on-site visit.

(2) The laboratory must respond in writing within 30 days of the date of postmark of the notification by the Department and provide documentation that the specified deficiencies have been corrected. All deficiencies must be corrected prior to accreditation being granted.

(3) Deficiencies noted for corrective action will be subject to thorough review and verification during subsequent on-site visits and technical evaluations.

(4) Any deficiencies in the test data and/or results may result in subsequent proficiency tests being required at the laboratory with a Department representative present.

Final Department Administrative Review and Certificate of Accreditation

340-21-165 (1) When all application material has been received, including the on-site inspection and the stove testing proficiency evaluation, and there has been time for all deficiencies to be resolved, the Department will grant or deny accreditation.

(2) Accreditation can be denied for failure to comply with or fulfill any of the criteria in OAR 340-21-161, -162, and -163.

(3) When accreditation is approved, a certificate of accreditation will be issued to the laboratory. Accreditation will be granted for a period of three years (36 months) subject to rule change or revocation for cause, pursuant to OAR 340, Division 11.

(4) A certificate of accreditation is not renewable. A holder may obtain a new certificate of accreditation by completing the application procedure in OAR Chapter 340-21-162, and demonstrates compliance with OAR [Chapter] 340-21-161 and -163.

(5) The Department may select and audit test one stove tested by the laboratory during its accredited status to verify certification test

results. Any discrepancies noted will be communicated to the laboratory by certified or registered mail. The laboratory must respond in writing within 30 days of postmark of notification and provide documentation or certification by an authorized member of the laboratory management that the specified discrepancies have been corrected or the laboratory may be subject to civil penalties or revocation of accreditation.

(6) A laboratory may voluntarily terminate its accreditation by written request at any time. The certificate of accreditation must be returned with the request.

Civil Penalties, Revocation, and Appeals

340-21-166 (1) Violation of any of these rules shall constitute cause to revoke the manufacturer or dealer's woodstove certification or laboratory's certificate of laboratory accreditation, and also may be subject to civil penalties and other remedies pursuant to rule or statute.

(2) Certification of a woodstove may be revoked if the woodstove was tested at a laboratory that was found to be in violation of accreditation criteria and rules at the time the woodstove was tested for certification.

(3) When certification or accreditation has been revoked, the holder shall return the certification or accreditation document to the Department and cease to use mention of Department certification or accreditation of the

stove model or laboratory on any of its test reports, correspondence or advertising.

(4) Stove certification and lab accreditation revocation [would be] shall be handled as contested cases pursuant to OAR Chapter 340, Division 11.

APPENDIX 1

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY

STANDARD METHOD FOR MEASURING THE EMISSIONS AND EFFICIENCIES OF WOODSTOVES

May 21, 1984

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SECTION 1: SCOPE AND PURPOSE

1.1 SCOPE

1.1.1 This document prescribes a standard method of testing woodstoves to obtain particulate emission factors based on useful heat output for appliances that produce less than 1.5×10^5 Btu/hr.

1.1.2 A woodstove is defined as an appliance having an air/fuel ratio by weight less than 30 during the burning of 90 percent or more of the fuel mass consumed in the low-firing cycle. The low firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn achievable.

1.2 PURPOSE

1.2.1 The purpose of this document is to:

a. Establish a uniform procedure for appliance operation to be used in conjunction with a standardized test method for obtaining woodstove emission and efficiency performance data.

b. Specify the types of test equipment and establish standard performance requirements for the equipment used for performing such tests.

c. Specify data required and calculations to be used.

1.3 METHOD FOR USING THIS STANDARD

1.3.1 Determine from Section 1.1.1 and 1.1.2 whether this standard is applicable for the appliance to be tested.

1.3.2 Verify that the test facility and equipment is in accordance with Sections 2 and 3.

1.3.3 Test and calculate results in accordance with Sections 5, 6, and 7.

SECTION 2: TEST FACILITY AND APPLIANCE INSTALLATION

2.1 DESCRIPTION OF TEST FACILITY

2.1.1 The testing will be conducted in an area with a height for atmospheric discharge of flue effluent at 15 ± 1 foot (4.6 ± 0.3m) above the top surface of the scale.

2.1.2 The flue exit shall freely communicate with the laboratory, that is, the area shall have essentially the same pressure such that no artificial draft is imposed on the appliance.

2.1.3 The test chamber room temperature shall be maintained between 65° F and 90° F (18° C and 32° C) during the course of any test.

2.1.4 Air velocities within 2 feet (0.6m) of the test appliance and exhaust system shall be less than 50 feet/minute (0.25 m/s) without a fire in the unit.

2.1.5 All calorimeter rooms must meet the specific criteria in the June, 1982 Wood Heating Alliance document, Standard for Testing the Heating Performance of Wood-Fired Closed Combustion Chamber Heating Appliances, for accuracy verification and calibration procedures before conducting appliance performance testing.

2.2 APPLIANCE INSTALLATION FOR FREE STANDING STOVES

2.2.1 Unless specified differently by the manufacturers, the flue pipe shall be made of No. 24 gauge black steel and shall have an insulated metal solid pack type chimney above the particulate and combustion gas sample probe port locations with a minimum 1 inch (2.5 cm) solid pack material.

2.2.2 The flue shall extend to 15 ± 1 feet (4.6 ± 0.3m) above the platform scale on which the appliance is located. All flue pipe cracks or joints shall be sealed.

2.2.3 The appliance and parts shall be assembled and installed in conformance with the manufacturer's published installation instructions.

2.3 APPLIANCE INSTALLATION FOR FIREPLACE INSERTS

2.3.1 Fireplace inserts shall be installed on the platform scale with R 12 insulation applied to all surfaces not normally exposed to the room to be heated. The appliance parts and exhaust system shall be assembled and installed in conformance with the manufacturer's published installation instructions.

2.3.2 The flue pipe shall consist of an insulated metal solid pack type chimney positively connected from the appliance flue outlet, extending to the particulate and combustion gas sample probe port locations with a minimum 1 inch (2.5 cm) solid pack material.

SECTION 3: TEST EQUIPMENT AND INSTRUMENTATION

3.1 TEST EQUIPMENT SET-UP

3.1.1 The equipment to be used for emissions and efficiency testing is illustrated in Figure 3.1 and described below.

3.2 TEST FUEL WEIGHT

3.2.1 The balance used to weigh the fuel shall be accurate to ± 0.1 pound (0.05 kg).

3.2.2 The appliance to be tested shall be centrally placed on a platform scale. The scale shall have a monitor or other feature such that the weight change of the fuel loads may be continuously displayed. The scale shall be capable of reading weights to 0.1 pound (0.05 kg) and shall have a tare feature.

3.3 FLUE GAS TEMPERATURES

3.3.1 Flue gas temperatures shall be determined with a thermocouple or other temperature sensing device at a height of 8 to 9 feet (2.4 - 2.7 m) from the top surface of the scale. The temperature sensing device shall be located in the center of the flue gas stream.

3.3.2 The temperature sensor and associated display and recording equipment shall have a resolution of 1°F (0.5°C).

3.4 STOVE SURFACE TEMPERATURES

3.4.1 Stove surface temperatures shall be determined with a shielded temperature sensing device placed at 5 locations on the appliance's exterior surfaces. Temperature locations shall be centrally positioned on the top, two sidewall, bottom and back combustion chamber surfaces (not on heat shields) if these surfaces are exposed while testing. Surface temperature locations for unusual design shapes (spherical, etc.) shall be positioned to conform to the intent of the locations described.

3.4.2 The temperature sensing device and associated display shall have a resolution of 1°F (0.5°C).

3.5 STOVE COMBUSTION TEMPERATURES

3.5.1 Radiation shielded thermocouple(s) or other equivalent temperature sensing device(s) shall be located in the primary and secondary (if applicable) combustion chambers to measure gas temperatures at a location where direct flame impingement on the sensing device does not normally occur. If a catalytic combustor is part of the stove's combustion features, an additional thermocouple must be located in the permanent temperature monitoring port required in Section 8.4.1.

3.5.2 The temperature sensing devices and associated display shall have a resolution of 1°F (0.5°C).

3.6 FLUE GAS COMPOSITION

3.6.1 Dry flue gas composition shall be measured with continuous combustion gas analyzers to include percent by volume (dry basis) carbon monoxide, carbon dioxide, and oxygen. Samples shall be extracted at the same height as flue gas temperature measurements and withdrawn through a probe and tubing made of inert materials. The probe shall be bent into the flow of the flue gases.

3.6.2 A gas stream sample conditioner using a glass fiber filter is required in line before the analyzer. The sample conditioner shall include two impingers encased in an ice bath, one water trap and a silica gel trap in sequence.

3.6.3 Minimum performance specifications for accuracy and precision for the combustion gas analyzers and recorders include:

Drift $\leq \pm$ 1% of full scale per 8 hours
Repeatability $\pm$ 1% of full scale
Resolution: 0.1% for CO_2 and O_2; 0.01% for CO by volume
Accuracy: $\pm$ 1% of scale

3.7 TRACER GAS DETECTOR

3.7.1 Minimum performance specifications for accuracy and precision for the tracer gas analyzer include:

Drift $\leq \pm 5\%$ of full scale per 8 hours
Repeatability $\pm$ 2 percent of full scale
Accuracy $\pm$ 3% of scale

3.8 FLUE MOISTURE CONTENT DETERMINATION

3.8.1 A wet bulb–dry bulb technique shall be used to determine the water vapor present in the flue gases for on-line sampling purposes to maintain proportional sampling and appropriate weighting of enthalpy losses during burn cycle. A wet bulb temperature sensor shall be placed at the same location as the flue gas dry bulb temperature sensor. The wet bulb sensor shall consist of a thermocouple or other temperature sensing device with a cloth sock placed at the sensor end and saturated with water. The wet bulb sensor shall be placed in the center of the flue gas stream until the temperature reaches a steady state. The wet bulb temperature must be taken while the sock is saturated with water. The appropriate water vapor content is determined using psychometric charts (See Oregon Source Sampling Method 4, Appendix 1).

3.9 DRAFT

3.9.1 The draft or static pressure (in inches of water) shall be measured in the flue at a location no greater than 1 foot (30.5 cm) above the flue connector at the stove outlet.

3.10 RELATIVE HUMIDITY

3.10.1 The test facilities ambient relative humidity shall be measured and recorded prior to and at the completion of each test cycle.

3.11 DATA RECORDING INTERVALS

3.11.1 Data recording shall commence upon charging of the test fuel load and all measurements shall be recorded either manually or automatically at least at every 5 minute interval for the entire test period. In addition, appliance surface and combustion chamber temperatures are also required at every five minute interval one hour prior to the test cycle.

3.12 INSTRUMENT CALIBRATION

3.12.1 Notwithstanding any standard calibration procedures designed to assure and maintain the accuracy of standard source testing equipment, the following calibration and testing methods must be utilized on the auxiliary equipment when testing woodstoves for air emissions.

3.12.2 Continuous gas analyzer(s) calibration

Upon receipt of equipment or any time the single point audit described below fails, a multipoint calibration of the

analyzer must be completed before the instrument is put into service.

a) Set up the instrument and allow it to operate for a sufficient time to stabilize as recommended by the manufacturer's published operating procedure.

b) Introduce zero gas into the instrument at the normal sample flow being careful not to pressurize the sample stream. Normally, this will be accomplished by allowing the zero gas to flow into a three port vessel at a rate of at least twice the instrument sample rate and withdrawing sample from another port on the vessel while the third port is allowed to vent to the atmosphere.

c) Introduce consecutively in the same manner as b) three certified calibration gases in artificial air noting the instrument response of each. The gases should represent approximately 20%, 50% and 80% of the instruments' full scale concentration.

d) Construct a calibration curve using the data collected in b) and c).

3.12.3 Continuous gas analyzer(s) audit

Before and after each test [and at intervals not to exceed 2 hours during the test], conduct a single point audit of the instrument as described below. <u>It is highly recommended that a single point audit of the instrument be conducted at intervals not to exceed 2 hours during the test periods.</u>

a) Disconnect the instrument sample line from the sample source at a point upstream of all sample conditioning equipment (dryers, scrubbers, etc.).

b) Being certain to avoid pressurizing the system, introduce a certified reference gas into the analyzer through all sample conditioning equipment. The sample gas should be in the range of 20% to 80% of full scale of the instrument.

c) If the instrument response to the audit gas differs by more than 5% from the calibration curve, disregard all data collected with the instrument since the last successful audit and perform a multipoint calibration.

d) Before and after each test, leak check the system by plugging the inlet and watching the sample flow rotometer.

3.12.4 Platform scale auditing

a) Upon installation of the scale, a multipoint calibration must be performed using NBS traceable weights. This function will normally be performed by the scale manufacturer. As soon as practicable after the calibration, one or more weights may be weighed for use as a calibration traceable standard weight for audit purposes. The weight should be constructed from a weight stable (non-oxidizable and non-hydroscopic) material and maintained in such a way that its weight integrity is assured.

b) Before and after each series of tests, the scale must be audited by first zeroing and then weighing at least one calibration traceable weight that corresponds to 20% to 80% of the expected charge load of the stove to be tested. If the scale does not reproduce the value of traceable weight within ± 0.4 lbs, the scale shall be recalibrated before use and void previous results.

3.12.5 Tracer gas flow measurement

a) All rotometers used in conjunction with tracer gas injection flow measurement techniques must be calibrated with the intended gas using either a calibrated volume measurement device such as a dry or wet gas meter or an accurate volume (displacement).

b) The tracer gas detector must be calibrated at the begining and end of each set of tests by introduction of a certified reference gas. The gas must be introduced through all normal gas conditioning devices and in such a way as to prevent system pressurization.

SECTION 4: TEST FUEL REQUIREMENTS

4.1 FUEL PROPERTIES

4.1.1 The test fuel shall be untreated, air dried Douglas fir lumber. Kiln dried lumber is not allowed. To insure positive identification of Douglas fir, species type is stamped D.F. on the lumber by the certified lumber grader at the mills. The oven-dried density range shall be 28.7-37.4 pounds per cubic foot (.46-0.60 gm/cm^3). The density shall be determined and reported for certification purposes.

4.1.2 The test fuel shall have a moisture content range between 16% and 20% on the wet basis (19-25% dry basis). Moisture content shall be determined by measurements made with a calibrated electrical resistance type moisture meter or other equivalent performance type meter. Note: To convert moisture meter readings from the dry basis to the wet basis: (100)(% dry reading) ÷ (100 + % dry reading).

4.1.3 Minimum performance specifications for accuracy of the moisture meter shall be ± 3% of reading.

4.1.4 Moisture content determination per load shall be an average of a minimum of three readings for each fuel piece measured parallel to the grain of the wood on three sides (end readings excluded). If an electrical resistance type meter is used, electrode penetration shall be to a one inch depth using insulated pins. Moisture content measurements shall be made within a four hour period prior to testing, and the test fuel shall be at room temperature.

4.1.5 No wetting of previously dried wood is allowed. It is recommended that the test fuel be stored in a temperature and humidity controlled room.

4.1.6 The test fuel shall be essentially free of knots, and free of any rotted or molded areas or other defects such as pitch seams.

4.1.7 The higher heat value of the fuel shall be determined by bomb calorimetry using ASTM Method D 3286-77 or D 2015-77. A composite sample from each piece of the test charge shall be analyzed and reported for each test fuel load.

4.2 TEST FUEL PIECES

4.2.1 The dimension of each piece of fuel (flanged lumber) shall conform to the nominal measurements of 2x4 and 4x4 lumber (1-1/2 x 3-1/2 and 3-1/2 x 3-1/2 in).

4.2.2 The flanged lumber dimensions will vary according to the appliance's firebox volume as indicated below:

Usable firebox volume (ft^3)	Flanged lumber piece size (nominal inches)
≤ 1.5	2x4
1.5 ≤ 3	2x4 approximately 1/2 weight of test fuel load 4x4 approximately 1/2 weight of test fuel load
>3	4 x 4

4.2.3 Each flanged piece shall be constructed in a configuration to conform to the following requirement for spacer dimensions and spacing intervals: Spacers will be constructed from air dried Douglas fir lumber (meeting the fuel specifications in Section 4.1) 5 inches in length, 1-1/2 inches in width, and 3/4 inches in height (12.7 x 3.8 x 1.9 cm). The spacers are to be attached by uncoated ungalvanized nails or staples to the lumber flush with the ends of each piece such that a 3/4 inch (1.9 cm) extension of the spacer occurs at the width of each end of the log as illustrated in Figure 4.2-A.

4.2.4 An optional acceptable flanged fuel configuration has identical spacing intervals as indicated in 4.2.3, but with a greater spacer dimension in height as depicted in Figure 4.2-A. The optional spacer configuration must conform to the conditions specified in 4.2.3 and meet the 5 inches in length, 1-1/2 inches in width and 1-1/2 inches in height (12.7 x 3.8 x 3.8 cm).

4.2.5 The length of each piece of test fuel shall be of equal length and shall closely approximate 5/6 the length of the longest usable dimension of the firebox. (See 4.3.2)

4.2.6 Test fuel pieces shall be arranged in the firebox in conformance with the manufacturers published written instructions and in a configuration which maintains air space intervals between the logs. The fuel shall be positioned so that the flanges are flat (parallel) to the floor of the firebox, with the flanged edges in contact (abutting each other). If loading difficulties result, some fuel pieces may be placed on edge. If the usable firebox volume is between 1.5 and 3.0 ft^3, alternating the piece sizes in vertical stacking layers is required to the extent possible. For example, 2x4's shall be placed on the bottom layer in direct contact with the coal bed and 4x4's on the next layer, etc. (See Figure 4.2-B). Photo documentation of the loading configuration for each test cycle shall be provided to the DEQ for certification purposes.

4.2.7 Appliances of unusual or unconventional firebox design shall load the fuel in a configuration which maintains air space intervals between the flanged lumber and is in conformance with the manufacturers published written instructions. Any appliance that will not accommodate the loading configuration specified in 4.2.6, must obtain DEQ loading configuration approval prior to testing for certification purposes.

4.2.8 Appliances that are designed to provide continuous feed pelletized or chipped fuel must prearrange an equivalent test criteria agreement with the DEQ prior to testing for certification purposes.

4.3 LOAD SIZE

4.3.1 The initial fuel load and the test fuel charge shall be based on weight per usable firebox volume. The fuel loads shall be equivalent to seven pounds of fuel as fired per cubic foot (112 kg/m^3) of usable firebox volume ± 10 %.

4.3.2 To avoid stacking difficulties, or when a whole number of fuel pieces does not result, all piece lengths may be adjusted uniformly to remain within the specified loading density.

4.3.3 Usable firebox volume means the entire volume of the (primary) combustion chamber less any volume where firewood could not reasonably be placed, such as areas restricted by baffles or firebrick. (see Figure 4.3)

SECTION 5: APPLIANCE OPERATING PROCEDURE

5.1 PRETEST START UP

5.1.1 The pretest startup phase is designed to bring the stove up to a stabilized operating temperature that is reflective of the heat output range required for the following test cycle.

5.1.2 Pretest start up will begin with ignition of kindling from a cold start with no charcoal residue in the firebox. A layer of cold wood ashes spread to a uniform depth of up to one inch in depth (2.54 cm) on the floor of the firebox or ash pan is optional. The kindling load shall consist of between 4-8 pounds (1.8 - 3.6 kg) of finely split Douglas fir with a moisture content range up to 20% on the wet basis. Crumpled newspaper balls loaded with the kindling shall be used to help attain ignition. The air supply controls may be adjusted per the manufacturer's published instructions for the kindling start up phase.

5.1.3 After 50 - 75% of the kindling by weight has been consumed, a pretest fuel load shall be added. The pretest fuel load shall meet the same fuel species and moisture content specifications as the test load. The pretest fuel load shall consist of whole 2x4 lumber pieces, without flanges, that are no less than 1/3 the length of the test fuel. Additional fuel may be added provided it meets the above requirements and that uniform charcoalization and weight specifications are adhered to before the test cycle begins.

5.1.4 The air inlet supply setting may be set at any position desired which will maintain combustion of the pretest fuel load. It is recommended that the air inlet supply setting be set at the position necessary to achieve the lowest heat output level of the following test cycle and be set at least one hour prior to addition of the test fuel load.

5.1.5 To document stabilized appliance heat storage effects and to control heat output levels, surface temperatures shall be recorded at each 5 minute interval during the one hour period prior to charging the test fuel.

5.1.6 No emissions or efficiency measurements are required during this pretest startup phase.

5.2 TEST CYCLE OPERATION

5.2.1 All stove surface temperatures shall be averaged and compared to those recorded at the beginning and the end of each test cycle. To approximate thermal equilibrium, the averaged beginning and ending test cycle stove surface temperatures must be within 125°F (51.7°C) of each other. For all appliances, a correction factor shall be made to correct for heat storage effects. The correction factor shall be 0.12 Btu/lb °F multiplied by the averaged surface temperature difference in °F obtained from the beginning and ending temperatures of each test cycle. Some stoves (e.g., high mass stoves) may require more than one pretest fuel load to stay within the required averaged temperature range at the beginning and at the end of the test cycle.

5.2.2 An appliance may be tested in one continuous testing period that encompasses discrete test cycles for each of the [four] specified heat output levels (see 5.8) provided that a one hour minimum interval between each discrete test cycle occurs. The interval between test cycles provides time to reposition the air supply adjustment to the appropriate setting, re-establish and maintain the required coal bed, and meet the surface temperature requirements for the next desired heat output level.

5.3 TEST FUEL LOADING

5.3.1 When the kindling and pretest fuel load has been consumed to leave a weight equal to 20-25 percent of the test fuel load, the test fuel load shall be charged. Manipulation of the hot coal bed prior to charging the test fuel load shall conform to the manufacturer's published written instructions. In the absence of written instructions, breaking up, raking and

24 hours for a hearing to be held before the control board or a hearings examiner appointed by the Control Board. Not more than 24 hours after the commencement of such hearing, and without adjournment, the Control Board shall affirm, modify or set aside the order. A request for a hearing does not stay or nullify an order.

(5) If a person fails to comply with an order issued under this Section XII, the Department or the Control Board may initiate action under Section XV and Section XVI of this program.

(6) The right to request a hearing before the Board under this Section shall not apply to violations of Section X 4100. Enforcement procedures for violations of Section X 4100 are described in Section X 4100 (G).

(F) When in effect, the requirements of Section XII shall supersede all other regulations under this program which are less restrictive.

(G) STAGE I - ALERT

The following provisions shall take effect when the ambient concentration of total suspended particulate (T.S.P.) meets or exceeds 150 micrograms per cubic meter as set forth in Section XII (B) (1) (b).
(1) The Department shall advise citizens via public media of the actions listed under Alert, and of medical precautions.

(2) The Department shall not issue any open burning permits and shall suspend existing open burning permits.

(3) Residential solid fuel burning devices shall comply with the applicable requirements of Section X 4100 Subsection E. Permitted devices shall comply with conditions set forth on the permit.

(4) The Department shall request citizens to limit automobile driving to necessary trips only and to avoid driving on unpaved surfaces such as dirt roads and unpaved shoulders and alleys. Alternative transportation shall be encouraged.

(5) The Department shall request construction companies to take effective dust-control action for roads under construction or repair.

(6) The Department shall request commercial boiler operators to limit boiler lancing and soot blowing to early afternoon hours.

(7) The City, County and State road departments shall be required to take actions appropriate under the prevailing weather conditions to reduce road dust along heavily travelled streets. Plans from each governmental road department describing such appropriate actions shall be submitted to the Department for review within 60 days after the effective date of this regulation and shall be approved if they demonstrate reasonable measures to minimize road dust.

(8) A point source may not switch to a higher sulfur or ash content fuel unless that source has continuous emission reduction equipment for the control of emissions caused by the alternate fuel.

(9) Each point source emitting or capable of emitting twenty-five (25) tons or

5.5 TEST CYCLE COMPLETION

5.5.1 A test cycle ends when the entire weight ± 0.1 lb (.045 kg) of the test fuel load has been consumed, (i.e., when a bed of coals equal to the beginning coal bed weight remains).

5.6 BLOWERS, FANS

5.6.1 The use of blowers for heat exchange is optional. Beginning with the start of the test cycle, blower speed may be positioned at a recommended setting but no changes in setting will be allowed throughout the entire test period and the position setting shall be recorded at the time positioning occurs.

5.7 OTHER APPURTENANCES

5.7.1 Shaker grates, by-pass handles, or other appurtenances (not primary air supply controls) may be adjusted one time only during each test cycle in accordance with the manufacturer's written published instructions, and all adjustments shall be recorded.

5.8 NUMBER OF TESTS REQUIRED

5.8.1 Simultaneous emissions and efficiency tests are required during an entire test cycle within each of four discrete heat output ranges as indicated below.

Test Cycle Heat Output

(Average Btu/hr)

Category 1.	Category 2.	Category 3.	Category 4.
< 10,000	10-15,000	15-25,000	Maximum heat output

5.8.2 If the lowest sustainable burn rate produces an average heat output greater than the first category, then two tests must be conducted near the low and high end of the second category plus tests at the remaining categories. A total of four test cycles are required.

5.8.3 If the lowest sustainable burn rate produces an average heat output greater than the second category, then two tests must be conducted near the low and high end of the third category plus a test at the remaining category. A total of three test cycles are required.

5.8.4 If the lowest sustainable burn rate produces an average heat output greater than the third category, three tests must be conducted, one at the lowest sustainable burn rate, one at the maximum heat output level and one at an intermediate level between the lowest and maximum level. A total of three test cycles are required.

5.8.5 If lowest sustainable burn rate is greater than 10,000 Btu/hr then documentation shall be submitted to demonstrate the actual burn rate is the lowest sustainable. This documentation can be in the form of proof that the appliance was run at its lowest permanent air supply setting or test data that demonstrates the burn rate approaches zero (less than 0.1 kg/hr) within the area of 1 to 1.1 times the lowest sustainable burn time and when greater than 90% of the test charge has been consumed. Such test data shall be collected by following all the stove operating procedures specified in this document.

5.8.6 If an appliance has a fixed air supply setting, two replicate tests shall be conducted at the "on" firing mode setting. A total of two test cycles are required.

5.8.7 If an appliance is unable to achieve an average heat output level of 25,000 Btu/hr at its maximum heat output, four tests must be conducted. One test must be conducted at the first category, one at the second category and two tests at the third category, one conducted near the low end of the range and one at the maximum heat output. A total of four test cycles are required.

5.8.8 Two Test Option.

(a) Two tests are allowed to be used to determine emissions and efficiency, rather than the four tests required in 5.8.1, if one test is conducted in each of the two heat output categories indicated below. A heat output and efficiency test also must be performed at the maximum heat output.

Test Cycle Heat Output
(Average Btu/hr)

Category 1.	Category 2.
10,000 - 13,000	13,000 - 15,000

(b) If the two test option is to be used, emissions tests shall be conducted in conformance with Oregon Source

Sampling Methods 5 & 7, as described in 6.1.1. Overall efficiency tests shall be conducted in conformance with the calorimeter room method or the stack loss method as described in 6.5. Equivalent methods of determining emission and overall efficiency may not be used.

(c) For the two test option to be considered for certification, the Department must be given written notice prior to actual testing for certification purposes, that such option has been chosen.

SECTION 6: TEST METHODOLOGY AND CALCULATIONS

6.1 EMISSION TESTING

6.1.1 Particulate emission testing shall be conducted in conformance with Oregon Source Sampling Methods 5 and 7 (Attachments 2 and 3) with the following exceptions: 1) no traverse of the flue is necessary, 2) sample extraction shall occur in the center of the flue at a height of eight to nine feet above the top surface of the scale, 3) on-line stack gas velocity and volumetric flow rate determination will be made using an alternate method (Section 6.3). Total volume and average flow rates for the test period will be calculated using a simultaneous stoichiometric carbon, hydrogen and oxygen balance method (Section 6.2.1). Sample extraction rates shall be maintained at or proportional to the flue gas velocity as determined by the measured concentration of a tracer gas injected into the stack gases to determine dilution rate and thus, total flow. Adjustments to the sampling rate will be made at each five minute interval during the entire test period.

6.2 PROCEDURES FOR DETERMINING EQUIVALENCE BETWEEN CANDIDATE METHODS AND THE REFERENCE METHOD FOR WOODSTOVE EMISSION TESTING

6.2.1 Determination of Equivalence

The test procedures outlined in this section shall be used to determine if a candidate method is equivalent to the reference method when both methods measure particulate emissions from woodstoves. Equivalence is shown for the methods when the differences between the measurements made by a candidate method and the measurements made simultaneously

by the reference method are less than or equal to the precision and consistency values specified [in Table 1] below.

Specifications For Woodstove Emission Test Methods

Parameter	Units	Limits
Emission rate range	g/hr	1.0-[20.0] 45.0
Minimum number of test runs		[5] 16
Minimum number of simultaneous samples per test run		4
(Candidate method)		(2)
(Reference method)		(2)
Maximum analytical precision (individual test runs)	%	18
Maximum analytical precision (standard deviation)	%	10
Maximum difference in consistent relationship (weighted averages)	%	[24] 20

6.2.2 Test Conditions

The woodstove burn rate and operating cycle shall be in accordance with procedures specified by DEQ. Testing procedures and schedules shall be approved by DEQ at least 60 days prior to testing. All test measurements or samples shall be taken in such a way that both the candidate method and the reference method receive stack gas samples that are homogenous or as nearly identical as practical.

Collect simultaneous and duplicate samples of woodstove emissions with both the reference and candidate methods until at least [12] 16 quadruple samples (duplicate pairs of both candidate and reference methods) have been obtained. The [12] 16 quadruple samples should represent [12] 16 full test runs[.], four test runs on each of four stoves. The tests on each stove shall be in each of the four heat output ranges specified in the certification procedures and 5.8.1 of this document.

Calculate the emission rates as determined by the candidate and reference methods for each test run. For the reference method, calculate the average particulate emissions for each

test run by averaging the results calculated from the duplicate analyses (A and B):

$$R_{i\ ave} = \frac{R_{iA} + R_{iB}}{2} \qquad 6.2.2.a$$

where R denotes results from the reference method and where i is the sample number. Disregard all quadruple samples for which the particulate emission rate as determined by the average of the duplicate reference method analyses falls outside the range of 1.0 to [20.0] 45.0 grams per hour (g/hr). All remaining quadruple samples must be subjected to [both of] the following test[s] for precision (in 6.2.3). [and consistent relationship. At least five samples (average of duplicate reference method analyses) must be within the 1.0 to 20.0 g/hr range and at least one sample within each of the 1.0 to 5.0, 5.0 to 10.0, 10.0 to 15.0, and 15.0 to 20.0 g/hr ranges for the test to be valid.]

Calculate the weighted emission rates, using the procedures specified in OAR 340-21-120(5), as determined by the candidate and reference methods for each of the four woodstoves tested. For the reference method, calculate the average weighted emission rate for each woodstove tested by averaging the results calculated from the duplicate analysis (A and B). One woodstove weighted emission rate (average of duplicate reference method analysis) must be within each of the following ranges for the procedure to be valid: Less than 5.0 g/hr, 5.0 to 10.0 g/hr, 10.0 to 15.0 g/hr, and greater than 15.0 g/hr. All weighted emission rates must be subjected to the consistent relationship test (in 6.2.4 following).

6.2.3 Test For Precision

Calculate the precision (P) of the analysis (in percent) for each duplicate sample and for each method, as the maximum minus the minimum divided by the average of the duplicate analyses, as follows:

$$P_{Ri} = \frac{R_{i\ max} - R_{i\ min}}{R_{i\ ave}} \times 100\% \qquad 6.2.2.b$$

$$P_{Ci} = \frac{C_{i\ max} - C_{i\ min}}{C_{i\ ave}} \times 100\% \qquad 6.2.2.c$$

where C denotes results from the candidate method, R denotes results from the reference method, and i indicates the sample number.

Calculate the standard deviation (SD) of the reference and candidate precision analyses as follows:

$$SD_R = 1.77 \times P_{R\ ave} \qquad 6.2.2.d$$

$$SD_C = 1.77 \times P_{C\ ave} \qquad 6.2.2.e$$

where $P_{R\ ave}$ is the average of the absolute values of P_{Ri}; and $P_{C\ ave}$ is the average of the absolute values of P_{Ci}.

If any reference method precision value (P_{Ri}) exceeds 18 percent [,] or if the standard deviation (SD_R) exceeds 10 percent, the precision of the reference method analytical procedure is out of control. Corrective action must be taken to determine the sources(s) of imprecision and the reference method determinations must be repeated, or the entire test procedure must be repeated.

The candidate method passes this test if the precision values of the candidate method (P_{Ci}) are less than or equal to 18 percent[.] and the standard deviation (SD_C) is less than or equal to 10 percent.

6.2.4 Test For Consistent Relationship

For each of the four woodstoves tested, calculate the weighted average emission using DEQ procedure specified in OAR 340-21-120(5).

For each quadruple sample, calculate all four possible percent differences (D) between the reference and candidate methods, using all four possible combinations of the duplicate determinations (A and B) for each method, as:

$$D_{in} = \frac{C_{ij} - R_{ik}}{R_{ik}} \times 100\% \qquad 6.2.2.[d]f$$

where i is the [filter number,] woodstove model tested and n numbers from 1 to 4 for the four possible difference combinations for the duplicate determinations for each method (j = A, B, candidate; k = A, B, reference).

If the candidate method is to include dual units and averaging of test results, then calculate the differences (D) between the reference and candidate methods as follows:

$$D_i = \frac{C_i - R_i}{R_i} \times 100\% \qquad 6.2.2.g$$

where i is the woodstove model tested, C is the average of the dual candidate results, and R is the average of the dual reference results.

The candidate method passes this test if the absolute values of all of the applicable differences (D) are less than or equal to [24] 20 percent.

6.2.5 Test For Equivalence

The candidate method must pass both the precision test and the consistent relationship test to qualify for designation by DEQ as an equivalent method. DEQ may require dual units and precision criteria between dual units, or other conditions in the designation as an equivalent method.

6.2.6 Verification Testing

DEQ may conduct verification testing of the candidate method. If DEQ testing does not verify the precision and consistent relationship of the candidate method then the candidate method will not be approved as an equivalent method.

6.3 TRACER GAS DILUTION METHOD

6.3.1 This method is used for on-line measurement of stack gas flows during the test period. Other techniques that can provide equivalent results may be accepted, provided prior approval by DEQ has been made before testing for certification purposes commences.

a) Tracer Gas Dilution Method

A pure tracer gas (sulfur dioxide or equivalent, or approved performance gas) is metered through a calibrated rotometer for injection into the flue pipe. Injection shall be made through a stainless steel multi-perforated tube loop located inside the stack at four flue diameters downstream from the particulate and gas sampling port. A downstream diluted sample extraction probe shall be located 8 flue diameters downstream from the injection loop. The dilution sample gas stream shall be processed through a sample conditioner consisting of a combustion tube furnace, and in series, a glass fiber filter and three impingers encased in an ice bath. Impingers one and two shall be empty for water collection and the third shall contain silica gel.

The tracer gas content of the diluted gas sample stream shall be determined with an appropriate calibrated analyzer. Downstream tracer gas concentrations should not exceed 0.5% of the total flue gas volume. The tracer gas shall be as non-reactive with other flue gas constituents

as possible and measurable by instrumentation capable of obtaining an accuracy of ± 1% of the instrument scale reading. Instrument calibrations shall be performed and recorded before and after each test run.

Stack gas volumetric flow rates shall be calculated using the following equations:

$$\text{Flow (cfm)} = \frac{Ir}{Dc} \times \frac{1}{60} \times \frac{Tr}{Pr \times 17.65^{*}} \qquad 6.3.1.a$$

Where: Ir = Tracer gas injection rate (ft^3/hour)

Dc = Downstream tracer gas concentration (ppm x 10^{-6})
Tr = Injection gas temperature (°R) at the rotometer
Pr = Injection gas pressure (inches Hg)
* = Density specific for SO_2

Other tracer gases such as helium may be substituted for sulfur dioxide provided prior written agreement has been made with the DEQ.

6.4 STOICHIOMETRIC CARBON, HYDROGEN AND OXYGEN BALANCE METHOD

6.4.1 A carbon, hydrogen and oxygen mass balance will be used for determining overall flue gas volume--not for on-line measurements during the test period.

a) The carbon, hydrogen and oxygen balance method for volumetric flow rates is based on the following basic combustion equation and will be determined and reported for every five minute interval.

$$@[C_xH_yO_z + pH_2O] + Tsg(1-k)(a)\,[O_2 + 3.785N_2 + mH_2O] \qquad 6.4.1.a$$
$$Tsg[(1-k)(dCO_2 + eCO + gO_2 + hN_2) + jH_2O + kCH_4]$$

Where @ = Dry weight of fuel burned (lbs)
x = Moles of carbon per lb of dry fuel (assumed 0.0425)
y = Moles of hydrogen per lb of dry fuel (assumed 0.073)
z = Moles of oxygen per lb of dry fuel (assumed 0.0256)
p = Moles of H_2O per lb of dry fuel
= Dry basis moisture (free and combined) - 1800
a = Mole fraction of oxygen in air supply
= Moles O_2 supplied per mole of stack gas
d = Mole fraction of CO_2 in stack gas

e = Mole fraction of CO in stack gas
g = Mole fraction of O_2 in stack gas
h = Mole fraction of N_2 in stack gas
j = Mole fraction of H_2O in stack gas
k = Mole fraction of unburned hydrocarbon in stack gas (as CH_4).
m = Mole fraction of H_2O in supply air (mole H_2O per mole of supply oxygen)
Tsg = Total moles of stack gas (dry)

b) Mass balance equations for the combustion of @ lbs of wood are as follows:

Carbon: $x@ = Tsg\ [(1-k)(d+e)+k]$ 6.4.1.b

Hydrogen: $@(2p + y) + Tsg(1-k)(a)(2m) = Tsg(2j + 4k)$ 6.4.1.c

Oxygen: $@(p+z) + Tsg(1-k)(a)[2+m] = Tsg[(1-k)(2d + e + 2g) + j]$ 6.4.1.d

Nitrogen: $3.785\ (a) = h$ 6.4.1.e

Stack gas total as measured by combustion gas analyzers:

$$1 = (d + e + g + h) \qquad 6.4.1.f$$

The stack gas composition equation can be solved for "h" which will then provide a solution for "a" in the nitrogen balance equation. The remaining unknown values for "@", "p", and "k" are determined by simultaneously solving the carbon, hydrogen, and oxygen balance equations.

c) Two calculation runs of the simultaneous equation set are performed for each set (5 minute test segment) of data collected. The first run is performed to determine an average weighted "@" for the test burn. This first run "@" is then used to determine a corrected Tsg for the second run as follows:

$$Tsg'(\text{corrected}) = Tsg\ (\text{tracer gas})\ @\ \frac{(\text{actual})}{@\ (\text{calculated first run})} \qquad 6.4.1.g$$

Where: @(actual) = Dry weight burn rate for test burn (lb/hour)

d) "Tsg" is converted to a flow rate by the following equation:

$$\text{Flow (cubic feet per minute)} = \frac{Tsg \times 386.2}{60} \qquad 6.4.1.h$$

This calculation procedure is necessary for each five minute test period segment, therefore a computer program is recommended.

6.5 EFFICIENCY TESTING AND CALCULATIONS

6.5.1 If a calorimeter room is used to measure appliance efficiency, combustion gas analyzers must be included to determine and report appliance combustion and heat transfer efficiencies for each heat output level required.

6.5.2 Efficiency values shall be determined based on the following stack loss method. The approach shall include determination for each heat output level for combustion, heat transfer, and overall efficiency.

a) Combustion Efficiency

Combustion effiencies are calculated as the percentage represented by the actual heat produced in the firebox relative to the total heat production potential for the fuel consumed. Actual heat production in the firebox is calculated as the difference between the heat of combustion of the incompletely combusted stack gas constituents (carbon monoxide and unburned hydrocarbon equivalents) and the gross caloric content of the fuel burned. The basic equation used for combustion efficiency is as follows:

$$\text{Combustion Efficiency} = \frac{Thi - Clo}{Thi} \quad (\times 100) \qquad 6.5.2.a$$

Where: Thi = Total heat content of the fuel consumed
Clo = Combustible losses out stack

b) The total heat content of the fuel consumed shall be calculated using the following equation:

$$Thi = Gcvf \times Wfc \qquad 6.5.2.b$$

Where : Gcvf = Gross caloric value of the fuel (use HHV determined from bomb calorimetry analysis)
Wfc = Weight of fuel consumed (lbs) dry weight

c) The heat content of the combustible losses are calculated using the following equation:

$$Clo = Tsg\ [(e \times Hco) + (k \times Huh)] \qquad 6.5.2.c$$

Where: Hco = Heat of combustion for carbon monoxide
= 128,000 Btu/mole
Huh = Heat of combustion for unburned hydrocarbons
= 181,000 Btu/mole (estimated)

This calculation procedure is necessary for each five minute test period segment.

d) Heat Transfer Efficiency

Heat transfer efficiencies are calculated as the percentage represented by the useful heat released to the room relative to the actual heat produced in the firebox. The useful heat released to the room (Uhr) is calculated as the difference between the actual heat produced in the firebox (Ahf or Thi-Clo), and the sensible and latent heat losses out the stack (Sllo). The basic equation for heat transfer efficiency is as follows:

$$\text{Heat Transfer Efficiency} = \frac{Uhr}{Ahf} = \frac{Ahf-Sllo}{Ahf} = \frac{(Thi-Clo)-Sllo}{(Thi-Clo)} \ (\times 100) \qquad 6.5.2.d$$

Where: Sllo = Sensible and latent heat losses
$= (To - Ti)\ [Tsg(dCpCO_2 + eCpCO + gCpO_2 + hCpN_2 + jC_pH_2O)] + (j-m)LH_2O$

Where: To = Temperature of stack gases out
Ti = Temperature of inlet air and fuel

C_pCO_2 = Specific heat of CO_2 = 9.3 Btu/mole
C_pCO = Specific heat of CO = 7.0 Btu/mole
C_pO_2 = Specific heat of O_2 = 7.1 Btu/mole
C_pN_2 = Specific heat of N_2 = 7.0 Btu/mole
C_pH_2O = Specific heat of water = 8.3 Btu/mole
LH_2O = Latent heat of evaporation of water
= 18,810 Btu/mole

This calculation procedure is necessary for each five minute test period segment.

e) Overall Efficiency

Overall average efficiency is calculated as the percentage represented by the heat released to the room relative to the total heat production potential of the fuel consumed. The overall efficiency is calculated as the product of the combustion efficiency and the heat transfer efficiency as follows:

Overall Efficiency = Combustion Efficiency x Heat Transfer Efficiency

$$= \frac{Ahf}{Thi} \times \frac{Uhr}{Ahf} = \frac{Uhr}{Thi} \qquad 6.5.2.e$$

6.5.3 A corrected flue gas moisture content for each five minute interval must be determined as follows:

Final flue moisture determination shall be made by calculating a corrected flue gas moisture content for each data interval taken during the test cycle. The average wet bulb-dry bulb moisture measurement must be weighted by the volumetric flow rate for that 5 minute interval. The correction factor which is applied to each 5 minute moisture determination is calculated as the ratio between the average wet bulb-dry bulb measurement and the Oregon Source Sampling Method 4 (Attachment 1) measurement (condensate catch) for the entire burn cycle.

6.6 EQUIVALENCE BETWEEN CANDIDATE METHODS AND THE REFERENCE METHOD FOR WOODSTOVE EFFICIENCY TESTING

6.6.1 Candidate methods for woodstove efficiency testing must demonstrate consistent relationship to the reference method (stack loss) comparable to the consistent relationship between the reference method (stack loss) and the calorimeter room method as described in the DEQ's Confirmation Testing Summary, Section 18, Part C, Table 1: Comparison of Calorimeter Room Method vs. Stack Loss Method, 1984.

6.6.2 DEQ may conduct verification testing of the candidate method. If DEQ testing does not verify equivalence of the candidate method to the reference method (stack loss), then the candidate method will not be approved as an equivalent method.

SECTION 7: TEST DATA

7.1 DATA TO BE REPORTED

7.1.1 All raw and reduced test data must be included in the material sent to DEQ for appliance certification. Reduced test data shall be tabulated as indicated in Sections 7.1.2 through 7.1.10.

7.1.2 Particulate Emissions For Each Test Cycle

a) Concentration: total grains/dscf, total grams/m^3
b) Emission rate: grams/hr
c) Emission factor: grams/kg (dry fuel weight basis)
d) Emission process rate: grams/10^6 joule useful heat output
e) Front half catch: % of total
f) Total mass captured: front and back catch, mg

7.1.3 Average Efficiency Values For Each Test Cycle

a) Overall appliance efficiency %
b) Combustion efficiency %
c) Heat transfer efficiency %

7.1.4 Heat Output For Each Test Cycle

a) Btu/hr average over entire test

7.1.5 Burn Rate For Each Test Cycle

The average values (kg/hr wet and dry basis) over the entire test cycle and an hourly average over the entire test cycle at each heat output level.

7.1.6 Average Fuel Moisture Content For Each Test Cycle

a) Kindling (wet basis) %
b) Test fuel (wet basis) %

7.1.7 Air/Fuel Ratio

Mass of combustion air to the mass of fuel over 90% or more of each test cycle (lbs air/lbs fuel).

7.1.8 Average Stack Gas Composition For Each Test Cycle

a) Carbon dioxide %
b) Carbon monoxide %
c) Oxygen %
d) Excess air %
e) Moisture %

7.1.9 Average Stack Gas Flow and Draft For Each Test Cycle

a) Average flow rate cfm
b) Stack flow rate dscf/min (tracer gas and CHO balance)
c) Draft, inches H_2O

7.1.10 Average Stack Gas Emission Factors and Process Rates For Each Test Cycle
a) Carbon monoxide: grams/kg, and grams/10^6 joule (measured)
b) Hydrocarbons: grams/kg, and grams/10^6 joule (calculated)

7.1.11 Average Temperatures For Each Test Cycle

a) Stack gas °F
b) Primary combustion chamber gas °F
c) Secondary combustion chamber gas (if applicable) °F
d) Above catalyst gas (if applicable) °F
e) Stove top surface °F
f) Stove sidewall surfaces °F
g) Stove back surface °F
h) Stove bottom surface °F

7.1.12 Fuel Load Weight and Burn Cycle Period [(Minutes)] For Each Test Cycle

a) Coal bed weight, lbs

b) Test fuel load weight, lbs

c) Total burn cycle time period, minutes

SECTION 8: CATALYTIC COMPONENT CERTIFICATION REQUIREMENTS

8.1 CATALYTIC COMBUSTOR DESIGN CRITERIA

8.1.1 To insure equivalent performance of catalytic combustors used in testing versus production model stoves, a combustor model number for every catalytically equipped stove evaluated for

certification shall be supplied. The model number will serve to identify catalytic combustor types by brand (manufacturer), dimensions, and design (substrate and coating material). The model number must be imprinted or inscribed on a readily visible surface (such as a metal sleeve or canned surface). This will allow DEQ field verification monitoring. Any change in combustor brand, size and design type will require retesting of the appliance with the new combustor model for performance change unless test data or sufficient information can be provided demonstrating equivalent or improved performance.

8.2 CATALYTIC COMBUSTOR AGING CRITERIA

8.2.1 [Any appliance that contains a catalytic combustor must have the combustor pre-aged before emission performance testing to a specified aging process. The aging process will consist of the catalytic combustor tested in a woodstove (specifically designed for an internal catalytic combustor) for a continuous period of 50 hours. The test fuel shall consist of Douglas fir dimensional lumber or cordwood with a moisture content range between 16-20% wet basis. The accredited testing laboratories must provide combustor temperature data and certify to the DEQ that each catalytic appliance tested for emissions and efficiency performance has met this provision.] Any appliance that contains a catalytic combustor must use a pre-aged combustor when testing for certification purposes. The combustor aging process will consist of burning Douglas fir dimensional lumber or cordwood with a moisture content range on the wet basis of 15-25% in a woodstove specifically designed for an internal catalytic combustor. The stove must be operated at its medium burn rate with a new catalytic combustor in place and in operation for a period of 50 hours. The accredited testing laboratory must document and provide combustor temperature data, hours of aging operation and certify to the DEQ that each catalytic appliance tested for certification purposes has met this provision.

8.3 CATALYTIC COMBUSTOR LONGEVITY CRITERIA

8.3.1 All catalytic combustor manufacturers must submit to the DEQ evidence in the form of test data that each combustor design type, identified by model number, has been longevity tested for 5000 hours and document that the percent reduction in particulate emissions from the new state is no less than 70%. Three test conditions are required: 1) unused (0 hours), 2) 250 hours, and 3) 5000 hours. Testing must be performed by a DEQ accredited laboratory. In lieu of this requirement, the manufacturer may substitute a 24 month non pro-rated combustor replacement warranty.

8.4 CATALYTIC COMBUSTOR TEMPERATURE MONITORING PROVISION

8.4.1 In order to qualify for DEQ certification, catalytically equipped woodstoves must be equipped with a permanent provision to accommodate a commercially available temperature sensor which can monitor combustor gas stream temperatures within or immediately downstream (within 1.0 inch or 2.5 cm) of the combustor surface.

EXAMPLE OF TEST EQUIPMENT SET-UP FOR FREE STANDING WOODSTOVES

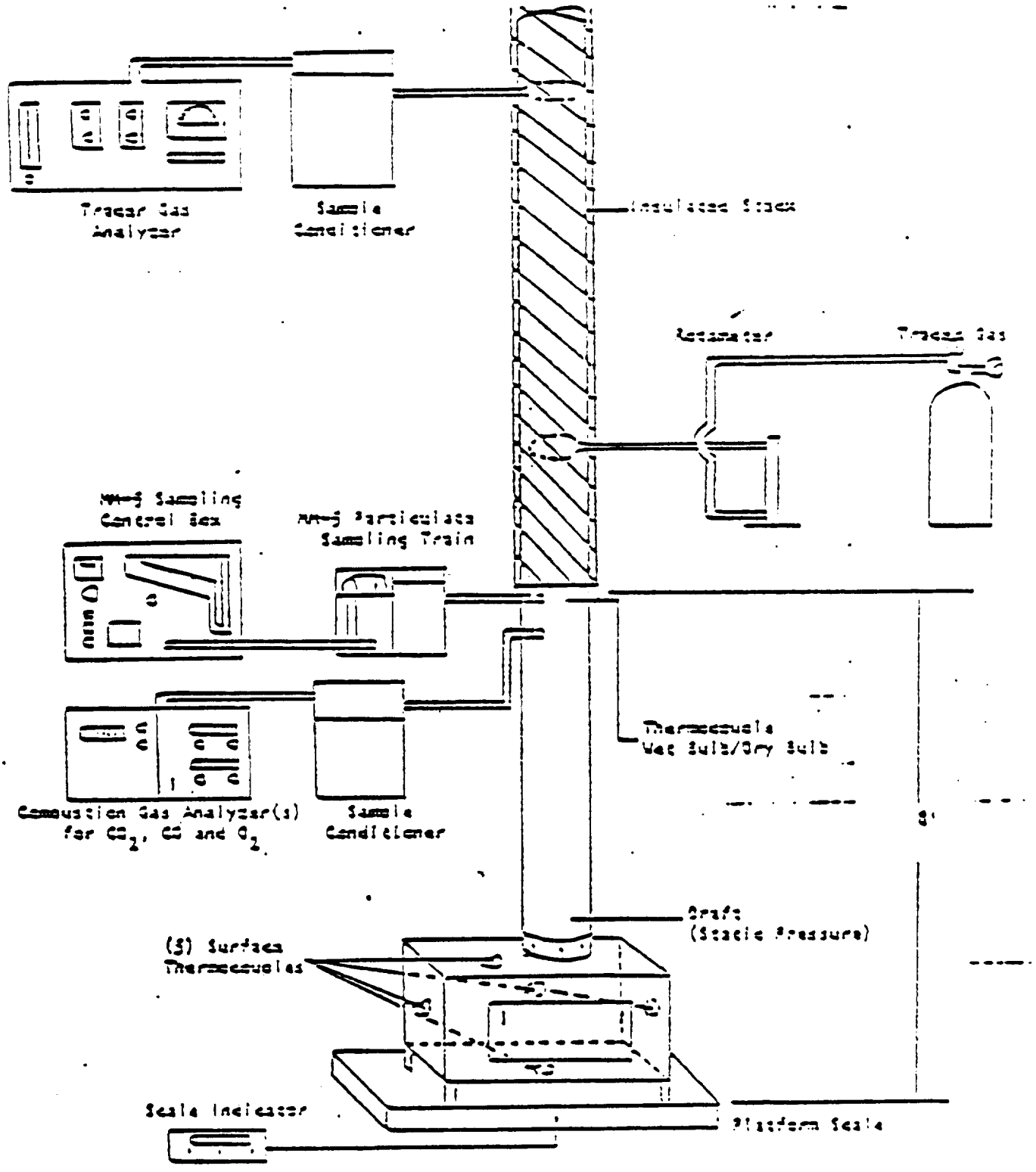
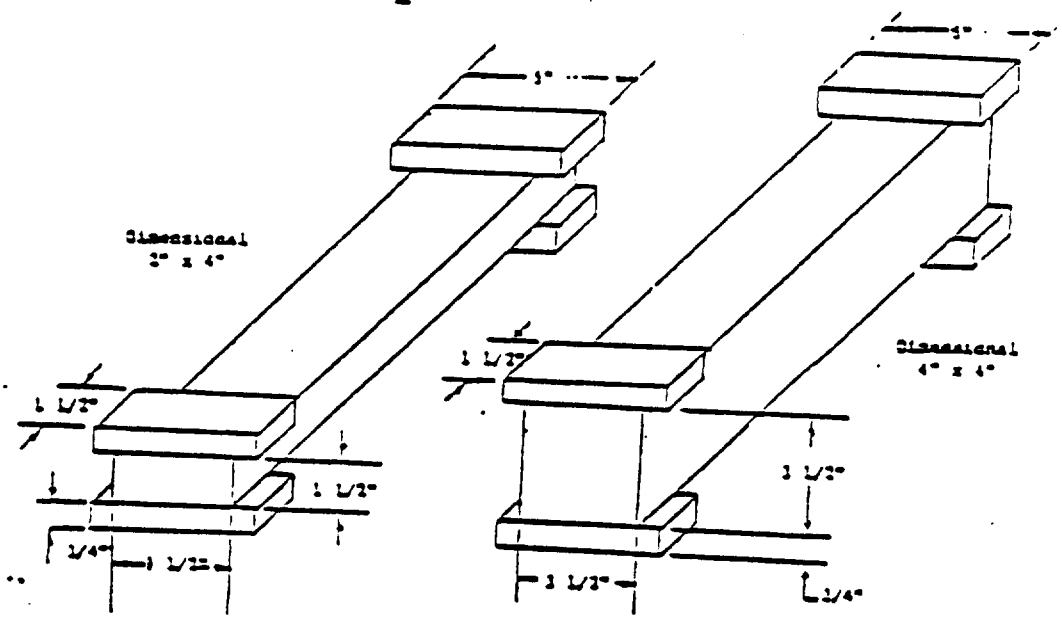


Figure 6.1

Test Fuel Size

Usable Firebox Volume (ft^3)	Size - Flanged Log (Nominal Inches)
≤ 1.5	2 x 4
$> 1.5 \leq 3$	Combination { 2x4 approximately ½ weight of test fuel load; 4x4 approximately ½ weight of test fuel load
> 3	4 x 4

Maintain 7 $\#/ft^3$ ± 10% load density



Scale 1/4" = 1"

* Length will vary depending on length of firebox

Alternative Flange Configuration

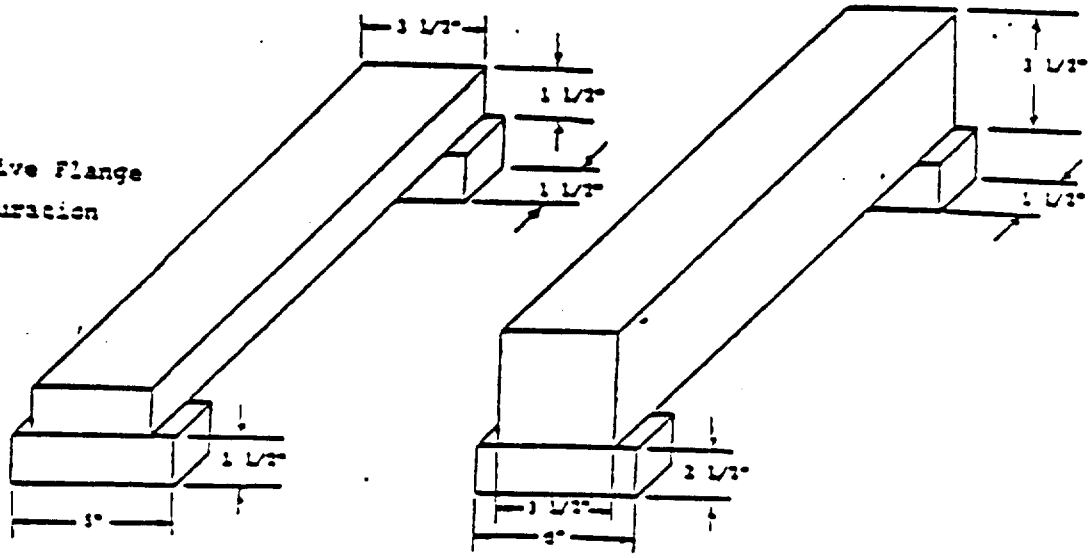
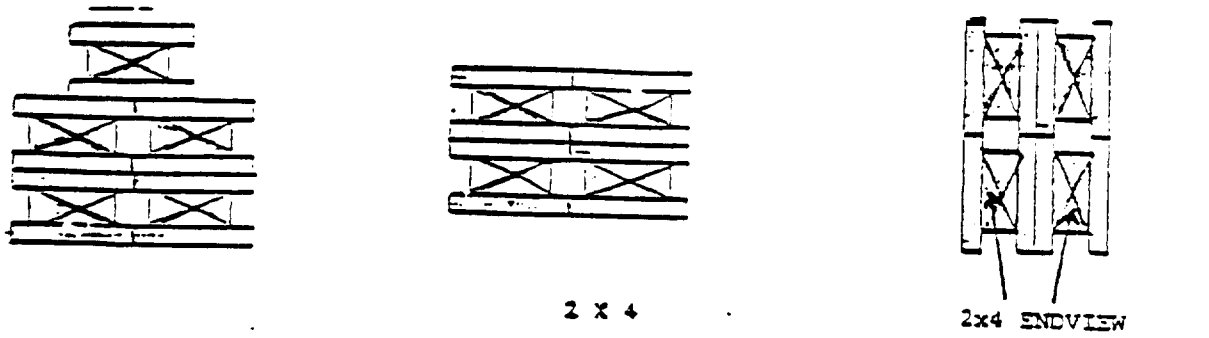
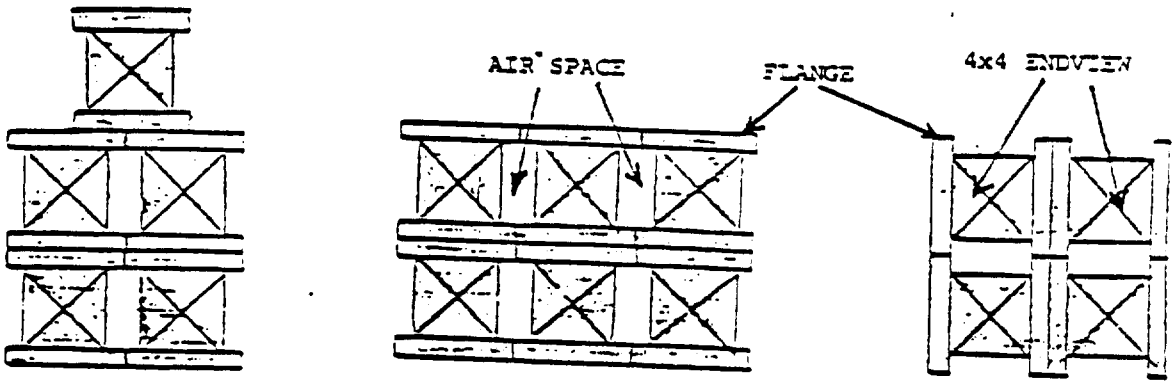
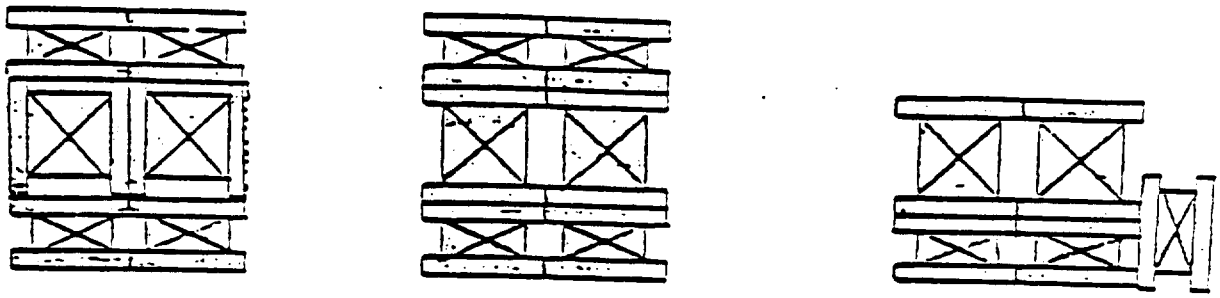
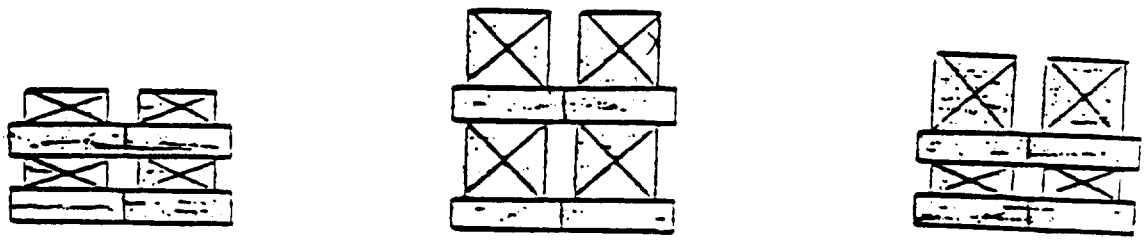


Figure 4.2-A









Woodstove Stacking & Loading Examples

Figure 4.2-B

EXAMPLES OF

USABLE FIREBOX VOLUME

(Designated by Shaded Area)

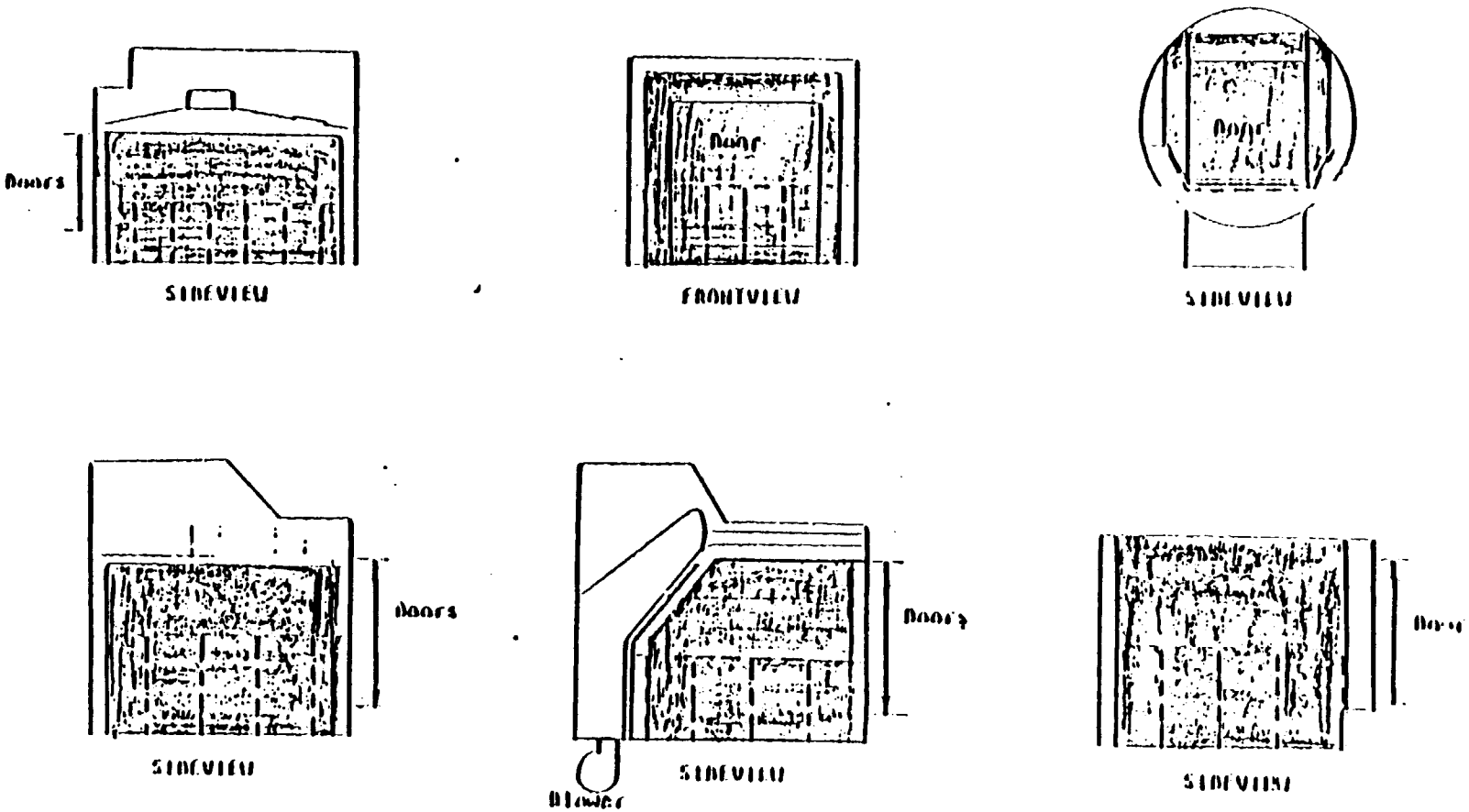


Figure 4.3

STATE OF OREGON

DEPARTMENT OF ENVIRONMENTAL QUALITY

Source Sampling Method 4

Determination of Moisture Content of Stack Gases

1. Principle and Applicability

   1.1 Principle. A gas sample is extracted from the flowing gas stream and its moisture removed and measured either volumetrically or gravimetrically. Alternately, the moisture can be estimated by less accurate techniques for the purpose of setting the nomograph for isokinetic sampling. A wet bulb-dry bulb technique is discussed.

   1.2 Applicability. The reference method is applicable for the determination of moisture in exhaust gases from stationary sources. The alternate method is to be used only for estimating the moisture content for the purpose of setting the nomograph unless otherwise specified.

2. Reference method

   2.1 The method employed is essentially the same as used in the particulate determination source sampling method 5 and will not be discussed here.

3. Alternate method

   3.1 Theory. The water vapor in a non-saturated gas stream causes a depression of the wet bulb temperature which is proportional to the fraction of moisture present.

   3.2 Procedure

      3.2.1 Measure the dry bulb temperature in the conventional way using either a thermometer or thermocouple.

      3.2.2 Insert the end of the temperature measuring device in a cloth sock and saturate the sock with water. Inset the sock into the flowing gas stream and allow the temperature to reach a steady state. Caution: after the water on the sock has evaporated, the temperature will rise to the dry bulb temperature. (Figure 4-1). The wet bulb temperature must be taken while the sock is saturated with moisture.

      3.2.3 Apply the wet bulb and dry bulb readings to the appropriate graph (Figure 4-2, 4-3, or 4-4) and determine the approximate water vapor content if the barometric pressure is near 29.92 in. Hg.

3.2.4 Alternately apply the wet bulb and dry bulb readings to equation 4-1 in Figure 4-3.

4. Interferences

4.1 The following conditions may drastically change the wet bulb reading causing erroneous results:

4.1.1 The presence of acid gases in the gas stream, i.e. SO_2, SO_3, HCl.

4.1.2 The presence of hydrocarbons in the gas stream.

4.1.3 Marked differences from atmospheric pressure (29.9 in. Hg) of the gas stream (if the graphs are used).

4.2 Should any of the above interferences be present, the tester should consider another approach to determining moisture content.

4.3 Additionally, the following conditions can lead to difficulties.

4.3.1 Very high dry bulb temperature (in excess of 500°F).

4.3.2 Very high or very low gas velocities.

4.3.3 High concentration of particulate matter which may adhere to the wet sock.

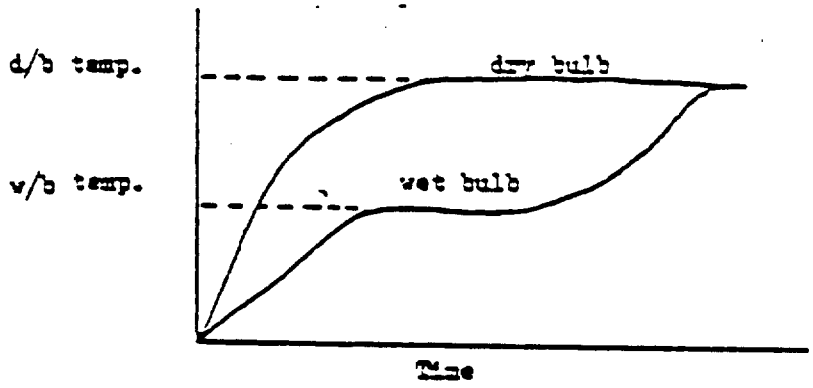


Figure 4-1

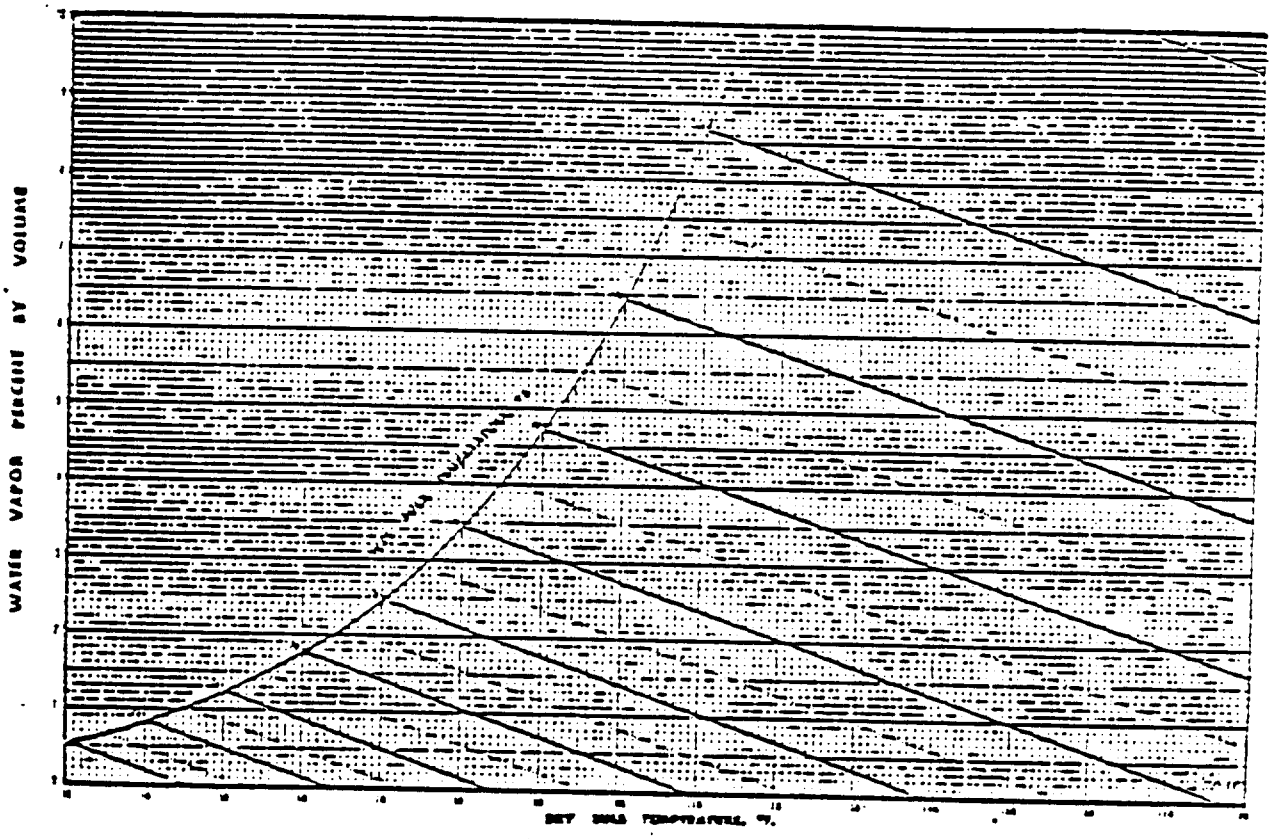


FIGURE 4-2

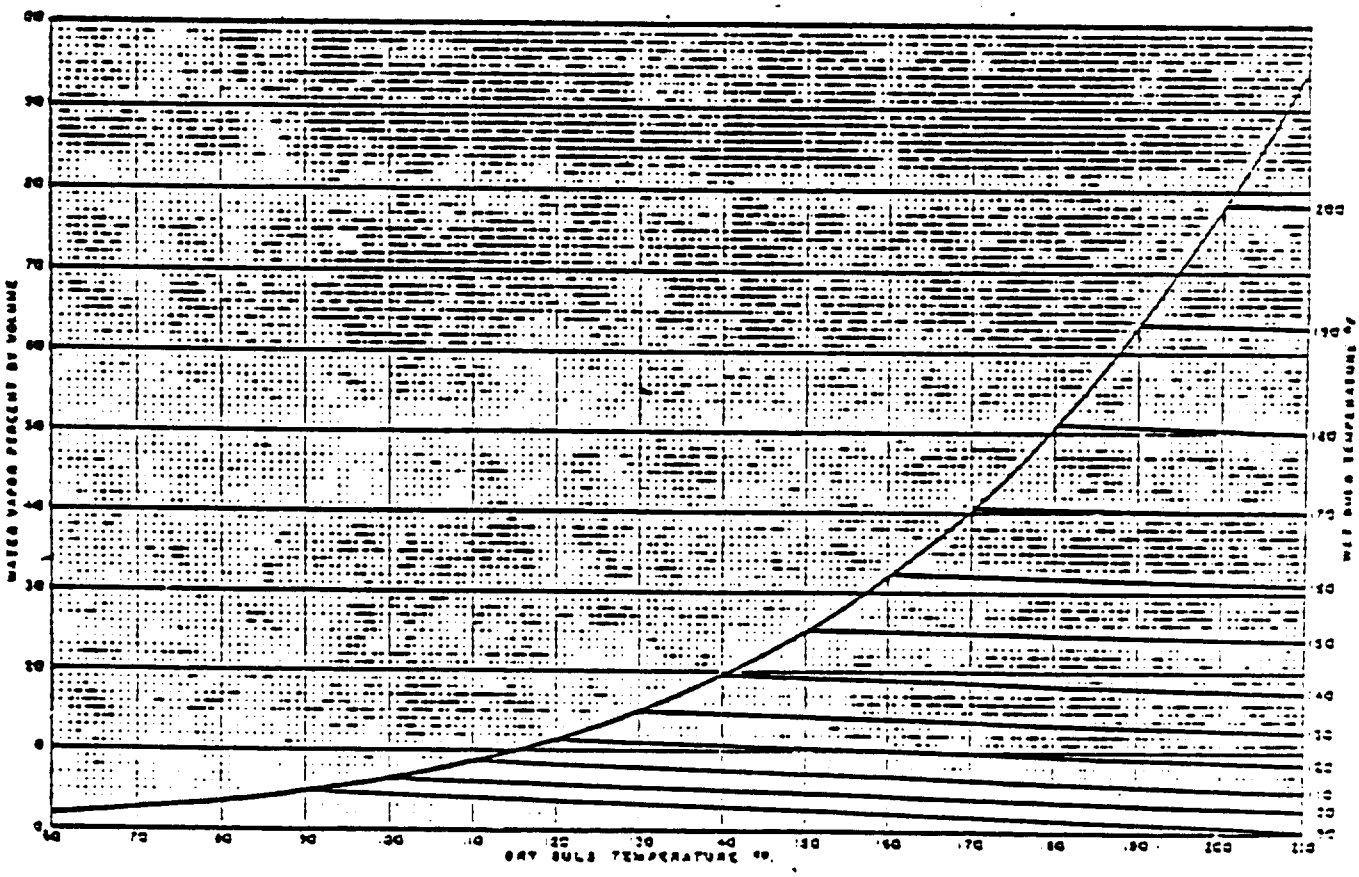


FIGURE 4-3

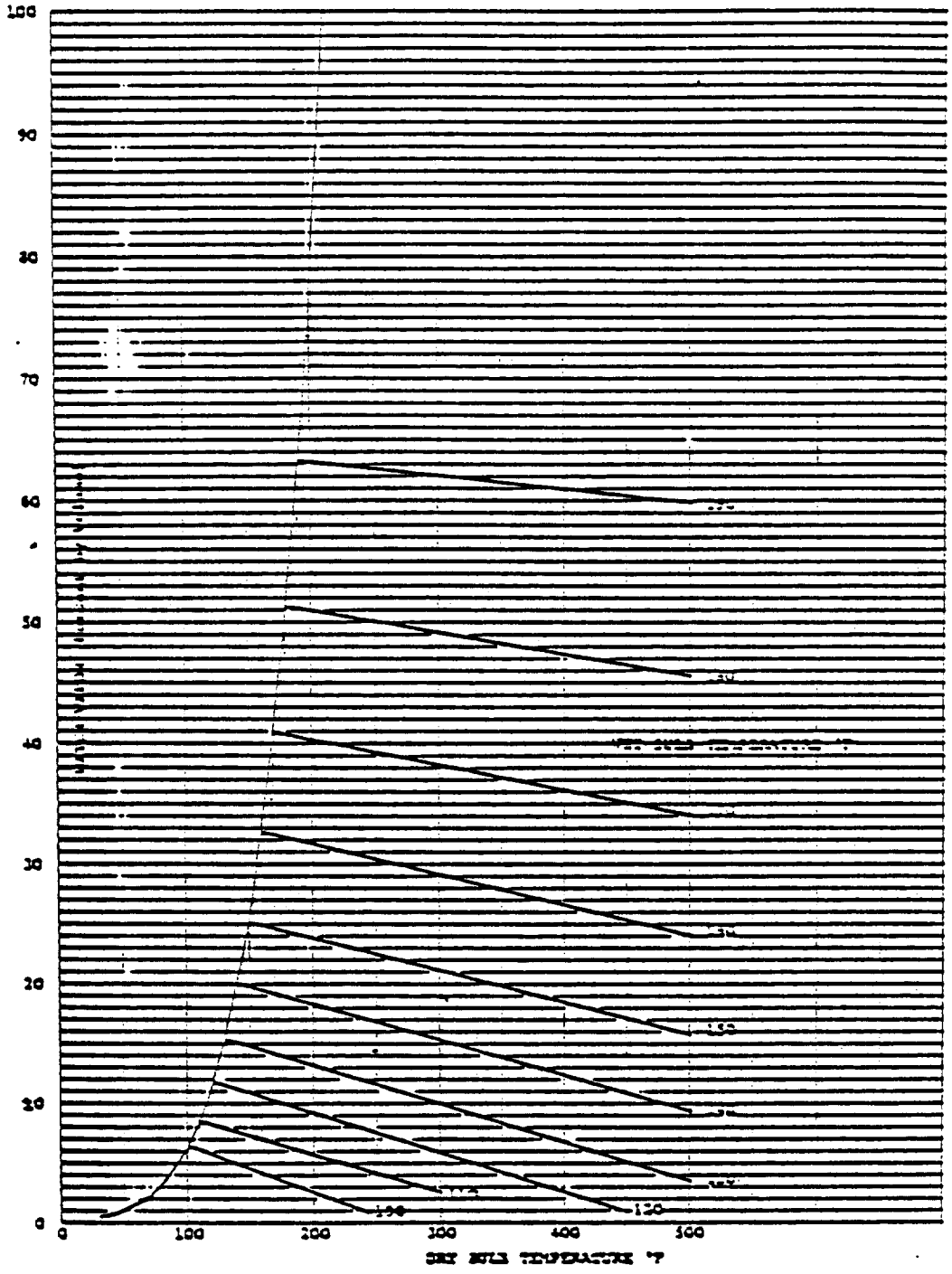


Figure 4-4

$$\% H_2O = \frac{e'' - \frac{(P_a - e'')(t_d - t_w)}{2800 - 1.3\ t_w}}{P_a} \times 100 \qquad (4\text{-}1)$$

Where:

e'' = Vapor pressure of H_2O @ t_w, in. Hg (See Figure 4-5)

P_a = Absolute barometric pressure, in. Hg

t_d = Dry bulb temperature, °F

t_w = Wet bulb temperature, °F

VAPOR PRESSURES OF WATER AT SATURATION*
(Inches of Mercury)

Temp. Deg. F.	0	1	2	3	4	5	6	7	8	9
—20	.0128	.0119	.0112	.0106	.0100	.0094	.0089	.0084	.0080	.0075
—10	.0222	.0209	.0199	.0187	.0175	.0168	.0158	.0150	.0142	.0134
—	.0378	.0359	.0339	.0324	.0306	.0289	.0275	.0259	.0247	.0233
0	.0378	.0398	.0417	.0463	.0441	.0469	.0517	.0541	.0571	.0598
10	.0631	.0680	.0836	.0725	.0788	.0810	.0846	.0882	.0922	.0962
20	.1025	.1080	.1127	.1186	.1248	.1302	.1370	.1429	.1502	.1567
30	.1647	.1716	.1803	.1878	.1955	.2035	.2118	.2203	.2292	.2382
40	.2478	.2576	.2677	.2782	.2891	.3004	.3120	.3240	.3364	.3493
50	.3626	.3764	.3906	.4052	.4203	.4359	.4520	.4686	.4858	.5035
60	.5218	.5407	.5601	.5802	.6009	.6222	.6442	.6669	.6903	.7144
70	.7392	.7648	.7912	.8183	.8462	.8750	.9046	.9352	.9666	.9989
80	1.032	1.066	1.102	1.138	1.175	1.213	1.253	1.293	1.335	1.378
90	1.422	1.467	1.513	1.561	1.610	1.660	1.712	1.765	1.819	1.875
100	1.932	1.992	2.052	2.114	2.178	2.243	2.310	2.379	2.449	2.521
110	2.596	2.672	2.749	2.829	2.911	2.995	3.081	3.169	3.259	3.351
120	3.446	3.543	3.642	3.744	3.848	3.954	4.063	4.174	4.289	4.406
130	4.525	4.647	4.772	4.900	5.031	5.165	5.302	5.442	5.585	5.732
140	5.881	6.034	6.190	6.350	6.513	6.680	6.850	7.024	7.202	7.384
150	7.569	7.759	7.952	8.150	8.351	8.557	8.767	8.981	9.200	9.424
160	9.652	9.885	10.12	10.36	10.61	10.86	11.12	11.38	11.65	11.92
170	12.20	12.48	12.77	13.07	13.37	13.67	13.98	14.30	14.62	14.96
180	15.29	15.63	15.98	16.34	16.70	17.07	17.44	17.82	18.21	18.61
190	19.01	19.42	19.84	20.27	20.70	21.14	21.60	22.05	22.52	23.00
200	23.47	23.96	24.46	24.97	25.48	26.00	26.53	27.07	27.62	28.18
210	28.75	29.33	29.92	30.52	31.13	31.75	32.38	33.02	33.67	34.33
220	35.00	35.68	36.37	37.07	37.78	38.50	39.24	39.99	40.75	41.52
230	42.31	43.11	43.92	44.74	45.57	46.41	47.27	48.14	49.02	49.93
240	50.84	51.78	52.70	53.65	54.62	55.60	56.60	57.61	58.63	59.67

*Methods for Determination of Velocity, Volume, Dust, and Mist Content of Gases, Bulletin WP-50, Western Precipitation Corp., Los Angeles, Calif.

Figure 4-5

STATE OF OREGON

DEPARTMENT OF ENVIRONMENTAL QUALITY

Source Sampling Method 5

Sampling Particulate Emissions From Stationary Sources

1. Principle and Applicability

1.1 Principle. Particulate matter including condensible gases are withdrawn isokinetically from a flowing gas stream. The particulate matter is determined gravimetrically after removal of combined water.

1.2 Applicability. This method is applicable to the determination of particulate emissions from stationary sources except those sources for which specified sampling methods have been devised and are on file with the Department.

2. Acceptability. Results of this method will be accepted as demonstration of compliance (or non-compliance) provided that the methods included or referenced in this procedure are strictly adhered to and a report containing at least the minimum amount of information regarding the source is included as described in Sections 15 & 16. Deviations from the procedures described herein will be permitted only if permission from the Department is obtained in writing in advance of the tests.

3. Sampling Apparatus (Figure 5-1)

3.1 Probe - With heating system capable of maintaining sample gas temperature at 250° F at its exit end during sampling. Probes which are to be used at temperatures of 600° F or less may have liners constructed of seamless 316 stainless steel, Pyrex Glass or Incoloy 825[1]. Probes for temperatures in excess of 600° F may be constructed of Borosilicate glass (limit 900° F) or Quartz glass (limit 1650° F). Probes for temperatures in excess of 1650° F must be approved by the Department before use. Testing in corrosive atmospheres may require a special probe liner to prevent contamination of the sample.

3.2 Probe Nozzle - Constructed of stainless steel (316) with an external taper 30° or less to a sharp leading edge. The inside diameter of the nozzle shall be constant throughout the length of the nozzle. The wall thickness of the nozzle shall be less than or equal to 0.063 in. and a straight run of at least two times the internal diameter shall be provided between the leading edge and the first bend or point of disturbance. The nozzle shall be connected to the probe liner in such a way as to provide an airtight seal with no exposed threads or gaps to collect particulate matter. Calibration of the nozzle is covered in Section 13.3.

[1] Trade Name

3.3 Pitot tube - Type S or equivalent attached to the probe. The probe nozzle and face openings of the pitot tube shall be adjacent and parallel to each other (not necessarily in the same plane) and the free space between the nozzle and the pitot tube shall be at least 0.5 in. Calibration of the pitot tube is covered in Section 3, Source Sampling Method 2 .

3.4 Differential pressure gauges - Inclined or vertical fluid manometer capable of measuring the pressure differential to within 10% of the minimum measured value. Below 0.1 in. H_2O gauge, micromanometers with sufficient sensitivities shall be used. Other differential pressure measuring devices may be used provided they are calibrated against a fluid manometer and are adequately sensitive.

3.5 Cyclone (optional) - Miniature glass cyclone used when heavy concentrations of particulate are expected. The cyclone will extend the time a filter can be used before plugging.

3.6 Filter holder - Pyrex [1] glass with a glass frit filter support and silicone rubber gasket. The holder shall provide a positive seal against leakage from the outside or around the filter.

3.7 Filter heating system - Capable of maintaining a temperature of 250° F around the filter holder. A temperature gauge shall be provided to monitor this temperature.

3.8 Impingers - Greenburg-Smith design. The first, third and fourth may be modified by replacing the tip with a 1/2 inch ID glass tube extending to within 1/2 inch of the bottom of the flask. The second impinger shall have the standard tip installed.

Note: All connections between the probe and last impinger shall be made with glass ball joints.

3.9 Metering system - Vacuum gauge, leak-free pump, thermometers capable of measuring temperature to within 5° F dry gas meter accurate to within ± 1% and flow measuring device (orifice or rotometer) enabling isokinetic sampling to be maintained.

3.10 Barometer - Mercury, aneroid or other type capable of measuring atmospheric pressure to within 0.1 in. Hg. If the barometric pressure is to be obtained from a nearby weather bureau station, the true station pressure (not corrected for elevation) must be obtained and an adjustment for elevation differences between the station and sampling site must be applied.

3.11 Temperature and pressure measurement equipment - As described in Source Sampling Method 2.

3.12 Gas analyzer - As described in Source Sampling Method 3.

3.13 Nomograph

3.14 Timer - Integrating type, accurate, readable to the nearest 1 seconds per hour.

[1] Trade Name

4. Sample Recovery Apparatus

4.1 Probe brush and nozzle brush - nylon bristle or equivalent at least as long as the probe liner and the nozzle respectively.

4.2 Wash bottles - inert to the solvent used in them (usually acetone).

4.3 Sample storage containers - glass with glass or Teflon[1] lined cap or other material which is leak tight, resistant to chemical attack from acetone and allows complete recovery of particulate matter.

4.4 Petri dishes - for filter samples, glass or plastic. Alternately, individual paper envelopes with waxed paper liners may be used, but tare and final weights should not be included in the weight of the envelope or liner.

4.5 Graduated cyliner and/or balance - to measure condensed moisture to within 1 ml or 1 g. Graduate cylinders shall have subdivisions of 2 ml or less and balances shall be sensitive to 1 g.

4.6 Plastic storage containers - air tight containers to store silica gel unless it is weighed at the sampling site or transported to the laboratory in the impinger.

4.7 Rubber policeman - to aid in recovering sample from the train previous to the filter.

4.8 Dessicator - laboratory type using Drierite [1], indicating dessicant or equivalent.

4.9 Analytical balance - accurate and sensitive to ± 0.1 mg.

5. Reagents

5.0 Separating funnel - 500-1000 ml with Teflon [1] stopcock and plug.

5.1 Beakers - 250 ml & 400 ml Pyrex[1] or equivalent.

5.2 Filters - glass fiber filters, without organic binder, of near neutral pH, free of pinhole leaks, and exhibiting at least 99.95% efficiency on 0.3 micron DOP smoke particles. MSA-1160BH or equivalent, individually numbered for identification and pre-weighed as described in Section 6.1.

5.3 Silica gel - indicating type 6-16 mesh, dried at 175°C (350°F) for 2 hours if previously used.

5.4 Water - distilled, with a maximum total residue content of 0.001%. (0.01 mg/ml).

5.5 Acetone - reagents grade with a maximum total residue content of 0.001%. (0.01 mg/ml)

5.6 Crushed ice - any grade, crushed fine enough to provide efficient cooling for the impingers.

5.7 Stopcock grease - acetone resistant, heat stable, silicone grease.

5.8 Diethyl ether - reagent grade with a maximum total residue content of 0.001%. (0.01 mg/ml)

5.9 Chloroform - reagent grade with a maximum residue content of 0.001%. (0.01 mg/ml)

6. Sampling Train Preparation

6.1 Weigh numbered glass fiber filter paper to the nearest 0.1 mg on an analytical balance after dessication over Drierite for 24 hours or more.

6.2 Insert the filter into the filter holder and assemble taking care not to tear or bend the filter. Tighten the filter holder sufficiently to prevent leaks.

6.3 Add 100 ± 1 ml of distilled water to each of the first two impingers.

6.4 Add approximately 200 g of accurately weighed silica gel (± 1 g) to the fourth impinger.

6.5 Alternately after charging each of the impingers with the appropriate material, weigh the impinger and contents on balance to the nearest 1 g.

6.6 Assemble the train as shown in Figure 5-1 and check for leaks as in Section 8.

6.7 Seal the train with aluminum foil, a blanked connector or some other means to prevent contamination.

7. Pretest Preparations

7.1 Select a sampling site and the minimum number of traverse points as described in Source Sampling Method 1.

7.2 Determine the approximate moisture content as described in Source Sampling Method 4.

7.3 Make a preliminary pitot traverse to determine the maximum, minimum, and average pitot reading, duct temperature, and static pressure as described in Source Sampling Method 2.

7.4 Choose a nozzle size based on the range of pitot readings as described in Section 12 such that it is not necessary to change the nozzle size in order to maintain the isokinetic sampling rates for all traverse points.

7.5 Clean the chosen nozzle and probe (the shortest available which will reach all the traverse points), assemble and seal each end with aluminum foil to prevent contamination.

7.6 Attach the probe to the sample case, attach the electrical and hose

connections, and turn on the probe and filter heating system. Adjust the heater controls to maintain the appropriate temperatures.

8. Leak Check

8.1 Plug the inlet to the filter.

8.2 With the fine flow adjustment (bypass) completely open, open the coarse flow adjustment completely and adjust to a vacuum of 15 in. Hg by closing the fine flow adjustment.

8.3 After sufficient time has elapsed for stabilization, measure the leakage rate for 1 minute or more and record. A leakage rate of less than 0.02 cfm at 15 in. Hg is acceptable. Use acetone resistant stopcock grease on impingers and ball joints if necessary to seal against leaks.

8.4 Slowly remove the plug from the filter inlet and immediately close the coarse flow adjustment.

9. Particulate Train Operation

9.1 Each point should be sampled a minimum of 2 minutes and a complete set of data readings should be taken at every point. If each point is sampled more than 5 minutes, a complete set of data readings should be taken at equal intervals during the sampling of every point but not less frequent than every five minutes.

9.2 Pack crushed ice around the impingers, turn on the probe heater and adjust so that the gases leaving the probe are 250°F. Add ice occasionally during the test in order to keep the temperature of the gas leaving the train at 70°F or less.

9.3 Position the probe nozzle at the first traverse point (taking care not to allow the nozzle to touch the stack walls) and block off the openings around the probe. Record the initial gas meter reading, temperatures, static pressure and pitot reading on the Particulate Field Data Sheet (Figure 5-5).

Note: The probe should never be left in the stack when not sampling as particulate will be collected in the nozzle.

9.4 Calculate (as described in Section 12) and record the desired orifice setting, open the coarse flow adjustment and immediately start the timer.

9.5 As rapidly as possible, adjust the orifice reading using the coarse and fine flow adjustments to the desired reading.

9.6 At the end of the first sampling point (or not more than 30 seconds before) reposition the probe nozzle at the next sampling point.

Note the gas meter reading exactly at the end of the first time interval.

9.7 After the pitot readings have stabilized, note the pitot reading, calculate the desired orifice setting, and adjust with the fine and coarse flow adjustments to the new setting. This should be done as rapidly as possible to avoid anisokinetic sampling.

9.8 Continue the above steps until all traverse points have been sampled an equal interval of time (except adjusted traverse points as described in Source Sampling Method 1.)

9.9 At the conclusion of the run, close the coarse flow adjustment, note the final gas meter reading and temperatures and withdraw the probe completely.

9.10 Seal the nozzle with aluminum foil as soon as it cools sufficiently to do so, disconnect the probe from the sample case, seal all other openings and transport to the cleanup (or storage) area.

9.11 Throughout the sample run, collect an integrated gas sample for composite analysis as described in Source Sampling Method 3.

9.12 Under no circumstances disconnect or loosen any part of the airtight train until the probe has been completely removed from the stack.

10. Particulate Train Cleanup

10.1 Cleanup should be performed in an area free of wind and airborne dust which may contaminate the sample or cause sample loss. If possible, the train should be cleaned in a laboratory.

10.2 After the probe and nozzle have cooled, remove the end seals and brush while rinsing with acetone into a suitable container (labelled).

> Note: Exercise caution so that none of the rinse is lost and no extraneous material enters the rinse (such as from the pitot tubes).

10.3 Should it be necessary to clean the train in the field, use the following procedure:

10.3.1 Rinse all sample exposed surfaces prior to the filter (including the front half of the filter holder) with acetone. Remove any adhering particles with the aid of a rubber policeman. Place the rinsings in the probe rinse bottle.

10.3.2 Remove the filter without disturbing the particulate cake, place in a petri dish and seal.

10.3.3 Measure and record the volume (or weight) increase of the first three impingers and transfer their contents into a labelled container. Rinse the impingers and interconnects with distilled water and add to the container.

10.3.4 Rinse all sample exposed glassware between the filter (excluding the glass frit filter support) and the fourth impinger with acetone and store in a suitable marked container.

10.3.5 Determine the weight gain of the silica gel in the fourth impinger and record. Alternately transfer the silica gel quantitatively to an airtight container to be weighed in the laboratory.

10.3.6 Collected samples should be analyzed within one week of collection in order to prevent any possibility of biological or chemical degeneration.

11. Analysis

11.1 Dessicate the filter (in the field container) for 24 hours and weigh to constant weight.

11.2 Transfer the acetone rinse (Section 10.3.1) into a tared beaker or evaporating dish. Be sure all particulate is removed from the container. Evaporate the solvent at laboratory temperature and pressure, dessicate for 24 hours and weigh to constant weight ($\pm$ 0.5 mg change in 6 hours or more).

11.3 Transfer the acetone rinse from the back-half (Section 10.3.4) to a tared beaker or weighing dish. Evaporate as in 11.2 and weigh to constant weight.

11.4 Transfer the water in the impingers to a separatory funnel (Teflon® stoppered). Rinse the container with distilled water and add to the separatory funnel. Stopper and vigorously shake the separatory funnel 1 minute, let separate and transfer the chloroform (lower layer) into a tared beaker or evaporating dish. Repeat twice more. Repeat the above procedure using three 25 ml portions of diethyl ether in place of the chloroform.

11.5 Transfer the remaining water in the separatory funnel to a tared beaker or evaporating dish and evaporate at 105° C. Dessicate for 24 hours and weigh to constant weight.

11.6 Evaporate the combined impinger water extracts from Section 11.4 at laboratory temperature and pressure, dessicate for 24 hours and weigh to constant weight.

11.7 Evaporate portions of the solvents used in a manner similar to the sample evaporation to determine the solvent blanks.

11.8 Record all laboratory data on the Laboratory Data Reporting Sheet, Figure 5-9.

12. Nomograph Operation

12.1 Correction factor

12.1.1 Determine $\Delta H@$ for the orifice as described in the calibration Section 11.1

12.1.2 Estimate the probable meter temperature, Tm, often 20° F above ambient temperature, B_{wo} in stack gas, and Ps/Pm (ratio of absolute stack pressure to absolute meter pressure) as described in Section 7.

12.1.3 Determine the correction factor "C" using the correction factor nomograph, Figure 5-2a, as described on the nomograph. Correction of the factor "C" for a pitot C_p other than 0.85 can be made using the following equation:

$$C(\text{corrected}) = C \frac{C_p^2}{(0.85)^2}$$

12.2 Operating Nomograph

12.2.1 Adjust the sliding scale on the operating nomograph, Figure 5-2b, such that the "C" factor determined in Section 12.1.3 is opposite Reference Point A.

12.2.2 Using the preliminary pitot traverse data and duct temperature determined in Section 7, draw a line from T_s to the values of ΔP and select a suitable D (nozzle diameter) from the probe tip diameter scale.

12.2.3 Draw a line from T_s through D (actual diameter of nozzle to be used) and note where the line crosses the ΔP scale.

12.2.4 Draw a line from the ΔP obtained in 12.2.3 to Reference Point B on the ΔH scale and note where the line crosses the K factor scale. This point should be marked for future reference.

12.2.5 During sampling, align the pitot reading, ΔP, with the K factor setting, Section 12.2.4, to obtain the desired ΔH.

12.2.6 If T_s (absolute) changes by more than 50° F the K factor should be recalculated starting with 12.2.3.

13. Calibration

13.1 Orifice and dry gas meter

13.1.1 Connect the components as shown in Figure 5-3. The wet test meter is a 1 cf per revolution with $\pm$ 1% accuracy and capable of operating at a rate comparable to the expected sampling rate.

13.1.2 Run the pump about 15 minutes at an orifice reading of about 0.5 in. H_2O to allow the dry gas meter and pump to warm up and to wet all interior surfaces of the wet test meter.

13.1.3 Gather the information as required in Figure 5-4.

13.1.4 Calculate γ and $\Delta H@$ as described in Figure 5-4. If an average γ of 1.00 $\pm$ 0.01 is not obtained, the dry gas meter must be adjusted. If an average $\Delta H@$ of 1.34 $\pm$ 0.25 is not obtained, the orifice opening should be enlarged or replaced. Additionally the $\Delta H@$ should not vary more than $\pm$ 0.15 over the range of operation of 0.5 to 3 inches of H_2O.

13.1.5 Calibrate the orifice and dry gas meter every month or after every 5 tests whichever occurs first.

13.2 Temperature gauges

13.2.1 Check temperature gauges against mercury-in glass thermometers of certified accuracy or against suitable temperature standards (boiling or freezing points) at least yearly.

13.3 Probe Nozzle

13.3.1 Measure the inside nozzle diameter on at least 10 different diameters to the nearest 0.001 inch using a micrometer or caliper. The nozzle diameter is the average of these readings to the nearest 0.001 inches.

13.3.2 The largest deviation from the average should not exceed ± 1% of the average diameter.

13.3.3 Calibrate the nozzle at least before every test.

14. Calculations

14.1 Gas velocity

14.1.1 Calculate the average gas velocity, V_s, from the pitot tube readings and gas temperatures using equation 5-2

$$(V_s)_{avg} = \frac{K_p C_p}{\sqrt{P_s M_s}} \sqrt{(\Delta P_s T_s)_{avg}} \qquad (5-2)$$

Where the symbols and units are the same for equation 2-2 in Source Sampling Method 2.

14.2 Gas volumetric flow rate

14.2.1 Calculate the volumetric flow rate of the gas from the duct area and the average gas velocity using equation 5-3

$$Q_s = \frac{0.123 A_s (V_s)_{avg} (1-B_{wo}) P_s}{T_s} \qquad (5-3)$$

Where the symbols and units are the same as equation (2-3) in Source Sampling Method 2.

14.3 Dry gas volume

14.3.1 Calculate the volume of gas sampled using equation 5-4

$$Q_d = \frac{17.65 Q_m (P_o + \frac{\Delta H}{13.6})}{T_m} \qquad (5-4)$$

where Q_d = volume of gas sample, SDCF

Q_m = volume of gas through meter (meter conditions), CF

P_o = barometric pressure, absolute, in. Hg.

ΔH = average pressure drop across the orifice, in. H_2O

T_m = average dry gas meter temperature, ^oR

14.3.2 In the event the gas passing through the dry gas meter was not dry, the above equation must be multiplied by $(1-B_{wm})$ where B_{wm} is the volume fraction of water in the metered gas (assume saturation at the temperature of the last impinger).

14.4 Moisture content of duct gas

14.4.1 Calculate the moisture content of the duct gas from the total volume of water vapor condensed using equations (5-5), (5-6), and (5-7).

$$Q_v = 0.0474\ V_v \qquad (5\text{-}5)$$

where Q_v = volume occupied by water vapor, SCF

V_v = volume of water condensed in impingers and on silica gel, g or ml.

$$B_v = \frac{100\ Q_v}{Q_d + Q_v} \qquad (5\text{-}6)$$

where Bv = volume percent of moisture in the sampled gas.

$$B_d = \frac{Q_d}{Q_d+Q_v} = \frac{1-B_v}{100} \qquad (5\text{-}7)$$

where B_d = volume fraction of dry gas in the sampled gas

14.5 Calculate the molecular weight of the wet gas using the volume fraction of dry gas and the dry molecular weight using equation 5-8.

$$M_s = B_d M_d + 18\ (1-B_d) \qquad (5\text{-}8)$$

where M_s = molecular weight of the wet stack gas, lb/lb mole

M_d = molecular weight of the dry stack gas as defined in Source Sampling Method 3, equation (3-2)

14.6 Calculate the total particulate grain loading and correct to 12% carbon dioxide (when necessary) from the volume of gas sampled, the total weight of particulate sample and the % CO_2 using equation 5-9, and 5-10.

$$C_g = \frac{0.0154\ W}{Q_d} \qquad (5\text{-}9)$$

where C_g = total particulate grain loading, gr/sdcf

W = weight of particulate sample, mg

$$C'_g = \frac{12\ C_g}{\%\ CO_2} \qquad (5\text{-}10)$$

where C'_g = total particulate grain loading corrected to 12% CO_2, gr/sdcf @ 12 % CO_2

$\%CO_2$ = percent by volume carbon dioxide as determined in Source Sampling Method 3.

14.7 Calculate the total particulate emission rate from the total particulate grain loading and the volumetric flow rate using equation 5-11

$$C_t = 0.00857 \; C_g q_s \qquad (5\text{-}11)$$

where C_t = total particulate emission rate, lbs/hr

q_s = Volumetric flow rate in duct, DSCFM as determined in Source Sampling Method 2.

14.8 Calculate the percent of isokinetic sampling rate from equation 5-12.

$$I = \frac{1039 \; T_s Q_d}{V_s P_s m_d D_n^2 t} \qquad (5\text{-}12)$$

where I = Percent of isokinetic sampling rate

T_s = Average stack temperature, °R

P_s = Average stack absolute pressure, in. Hg

D_n = Average nozzle inside diameter, in.

t = Total sampling time, min.

Q_d = Volume of gas sampled, SDCF

V_s = Average gas velocity, FPM

m_d = Volume fraction of dry gas

15. Minimum Acceptable Test Requirements

15.1 In order for a source test by this method to be acceptable as sufficiently accurate, the following requirements must be met unless otherwise indicated by the Department in writing:

15.1.1 A minimum sample volume of 60 SDCF of gas per run must be sampled.

15.1.2 A minimum run time of 60 minutes on continuous operations or one complete cycle covering at least 60 minutes on cyclic operations. A minimum of two runs per test is required.

15.1.3 The Department is notified in advance of all source tests so that it may have an observer present if desired.

15.1.4 All equipment used in the test shall be as specified in Section 3,4, and 5.

15.1.5 All equipment used in the test shall be calibrated at the specified

interval or more often and the calibration data and results included in the test report.

15.1.6 Accurate description of the sampling site including photographs.

15.1.7 Sufficient data to confirm that the sampling rate was within ± 10% of isokinetic.

16. Minimum Test Report Information - the following information concerning the source shall be included in the source test report.

16.1 Boilers

16.1.1 Name of manufacturer, nameplate capacity, and installation data of boiler and associated control equipment.

16.1.2 Control equipment on boiler (including cinder reinjection equipment).

16.1.3 Steam production rate, steam pressure and range of steam flow where possible. Use of a steam flow integrator is desirable.

16.1.4 Fuel composition (including estimated moisture content where applicable).

16.1.5 Opacity readings during or immediately after test by a certified reader.

16.2 Asphalt Plants (See Note 1)

16.2.1 Type, location and capacity of plant.

16.2.2 Control Equipment present.

16.2.3 Pressure drop across control equipment, water pressure on scrubber nozzles when present.

16.2.4 Production rate and type of mix during test.

16.2.5 Dryer fuel and firing rate.

16.2.6 Mix temperature (on drum mix plants)

16.2.7 Fines content of total aggregate feed.

16.2.8 Opacity readings during or immediately after test by a certified observer.

16.2.9 Photographs of plant in operation including plume after steam dissipation.

16.2.10 Special testing or production problems encountered.

NOTE 1: The source test requirements for asphalt plants constructed or modified after June 11, 1973 differ from this method in that only the particulate collected in the front half of the train (from the probe to the filter inclusive) is used for compliance evaluation. The impinger catch, however, must still be reported.

16.3 Incinerators

16.3.1 Manufacturer and capacity of incinerator.

16.3.2 Control equipment present.

16.3.3 Type and quantity of material incinerated.

16.3.4 Charging and stoking times.

16.3.5 Auxiliary fuel used and quantity consumed during test (measured).

16.3.6 Opacity readings during test by a certified observer.

16.3.7 Photographs of incinerator in operation including plume.

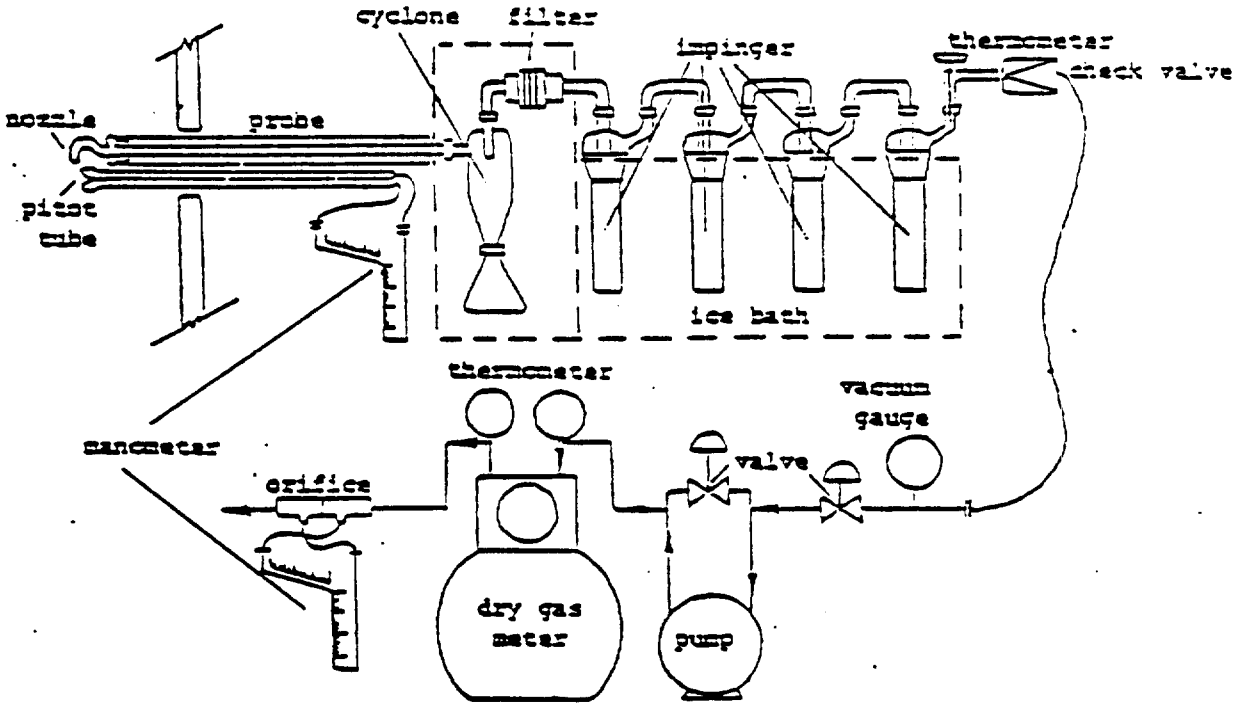

cyclone
filter
impinger
thermometer
check valve
nozzle
probe
pitot tube
ice bath
thermometer
vacuum gauge
manometer
valve
orifice
dry gas meter
pump

FIGURE 5-1

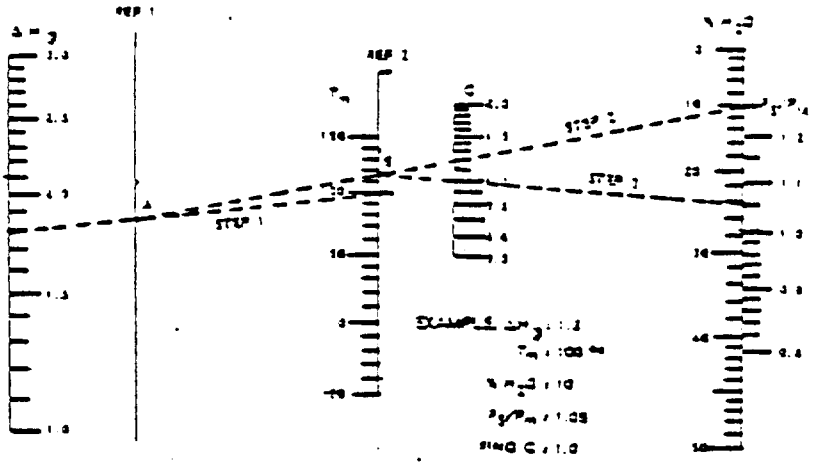


Figure 5-2(a)

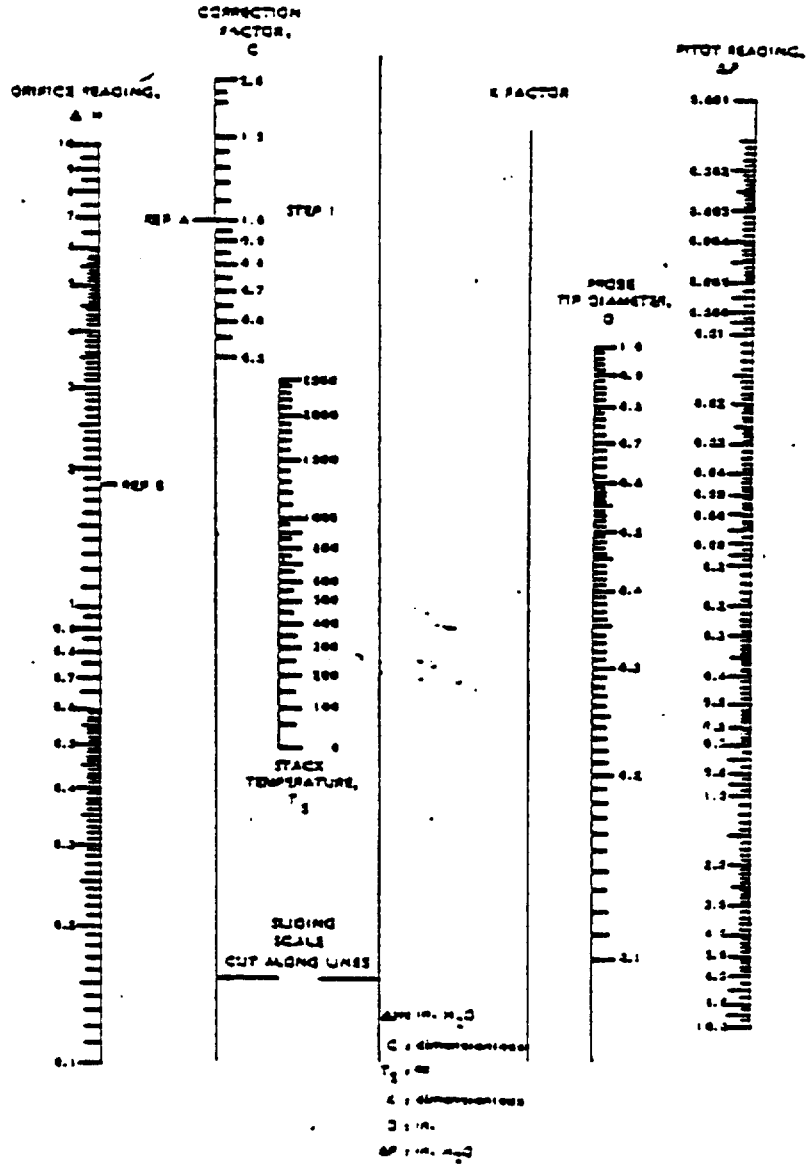


Figure 5-2(b)

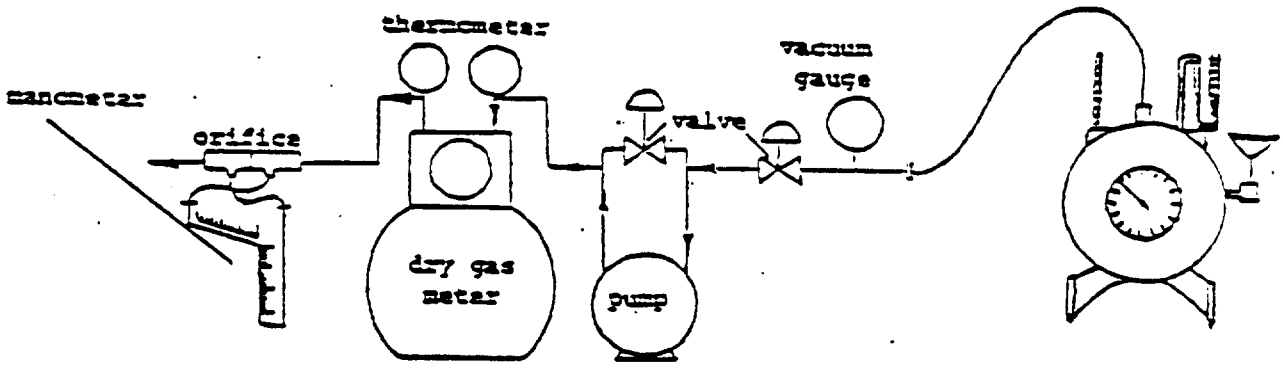

manometer
orifice
thermometer
dry gas
meter
valve
pump
vacuum
gauge

Figura 5-3

CALIBRATION SHEET

Figure 5-4

Orifice Gas Meter Date Barometric Pressure Pb:

Orifice	GAS VOLUME		TEMPERATURE				TIME	RESULTS	
Orifice Manometer ΔH in. H_2O	Wet Test Meter V_w, cf	Dry Gas Meter V_d, cf	Wet Test Meter t_w, °F	Dry Gas Meter Inlet t_{di}, °F	Dry Gas Meter Outlet t_{do}, °F	Dry Gas Meter Average t_d, °F	θ, min.	Y	ΔH@
							Average		

$$Y = \frac{V_w P_b (t_d + 460)}{V_d \left(P_b + \frac{\Delta H}{13.6}\right)(t_w + 460)}$$

$$\Delta H@ = \frac{0.0317\ \Delta H}{P_b (t_{do} + 460)} \left[\frac{(t_w + 460)\theta}{V_w}\right]^2$$

Probe Nozzle Date

D_n, in.	D_n, in.	D_n, in
		Averages

Pitot Tube Date

Forward			Reverse		
ΔP_s	ΔP_{std}	C_p	ΔP_s	ΔP_{std}	C_p
					Average

$$C_p = 0.99 \left[\frac{\Delta P_{std}}{\Delta P_s}\right]^{\frac{1}{2}}$$

SOURCE SAMPLING FIELD DATA SHEET

Figure 5-5a

Plant _____

Address _____

Source _____

Date _____ Run _____

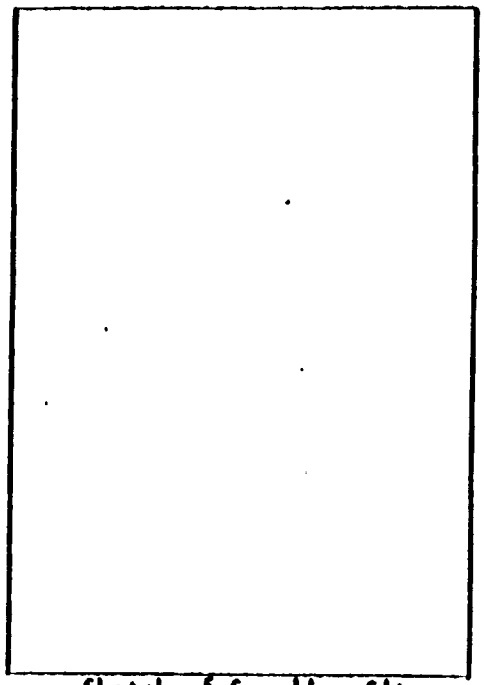
Train No. _____ Box No. _____

Probe Length _____ Probe material _____

Pitot C_p _____

Rinsings:

Other Samples:



Sketch of Sampling Site

DB Temp. _____ WB Temp. _____

Assumed Moisture _____ P. baro _____

Static Pressure _____ ΔH@ _____

"C" Factor _____ Nozzle _____

Stack Dimensions _____

Train Operator _____

Box Operator _____

Orsat

O_2				
$_2$				
O				

Remarks:

						Orifice ΔH		Gas Meter				
Point	Distance	Clock	Meter Vol.	Pitot ΔP	Stack Ts	Calc.	Act	T in	T out	Vac.	Box T	Imp. T.

Figure 5-5b

Figure 5-6

VELOCITY DATA AND CALCULATIONS

Run No._____ Date_____

Plant_____

Sampling Location_____

Point No.	Stack Pressure P_s in. Hg gauge	Stack Temp. t_s °F	Stack Temp. T_s °R	Vel. Head ΔP in. H_2O	$(\Delta P \times T_s)$	$S=\overline{\Delta P \times T_s}$
Avg.						

P_s = absolute pressure - P_s + P_o = _____ in. Hg

Ambient temp. = _____ °F

Ambient press.= _____ inches of Hg

STACK TEMP. Dry Bulb _____ °F

Wet Bulb _____ °F

CONST. C = _____

DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY DIVISION
VELOCITY DATA AND CALCULATIONS

Run No._____Date_____

Plant_____

Sampling Location_____

Point No.	Distance Inches	Stack Temp. Ts °F	Ts °R	Vel. Head ΔP in H_2O	(ΔP x Ts)	$S=\sqrt{\Delta P \times Ts}$
Avg.						

Static Pressure, Ps_____in. H_2O

Atmospheric Pressure, Pb_____in. Hg

Stack Pressure, Ps_____in. Hg

Dry Bulb Temp._____°F

Wet Bulb Temp._____°F

Moisture_____%

Figure 5-6 (Revised)

Figure 5-7

COMBUSTION GAS ANALYSIS DATA SHEET

Source _____ Date _____

Sampling Point Location _____

RUN ____

	CO_2	O_2	CO	N_2	
Analysis 1					Time _____
Analysis 2					Test conditions: ___
Analysis 3					_____
Average					_____
					_____

___	CO_2	O_2	CO	N_2	
	Atomic Wt. (44)	Atomic Wt. (32)	Atomic Wt. (28)	Atomic Wt. (28)	

_____ + _____ + _____ + _____ = Total Atomic Wt.

RUN ____

	CO_2	O_2	CO	N_2	
Analysis 1					Time _____
Analysis 2					Test conditions: ___
Analysis 3					_____
Average					_____
					_____

	CO_2	O_2	CO	N_2	
	Atomic Wt. (44)	Atomic Wt. (32)	Atomic Wt. (28)	Atomic Wt. (28)	

_____ + _____ + _____ + _____ = Total Atomic Wt.

PARTICULATE SAMPLING CALCULATIONS

Plant _____ Sampling Location _____

Date of Test _____ FIGURE 5-3

Symbol	Definition, Units	Calculating Equation	PARAMETERS TO BE CALCULATED / RESULTS Run___	Run___	Run___	Avg.
Qm	Sample gas volume at meter conditions, ft.^{3}	Avg. from field data sheet				
H_2O	% H_2O	Moisture escaping last impinger				
tm	Gas meter temp., °F	Avg. fr. field data sheet				
H	Orifice pressure drop in H_2O	Avg. fr. field data sheet				
Po	Barometric pressure (in. Hg)	Field data sheet				
Vv	Tot. vol. of condensed water	Total fr. lab data sheet				
Md	Molecular weight of dry gas	Gas analysis-Atomic Wt.				
Ps	Stack pressure in Hg abs	$.07355 \times P_s' + P_o$				
S	$\sqrt{P} \times ts$	Avg fr. Vel calc. sheet				
Cp	Pitot Tube Coeff.	From Calibration Data				
As	Stack area (in.^{2})	Field data sheet				
Ts	Stack temp., °R	Avg. fr. field data sheet				
Dn	Nozzle diameter (in.)	Field data sheet				
t	Total sampling time, min.	Total fr. field data sheet				
W	Wt. of particulate sample, mg	Total fr. lab data sheet				
$\%CO_2$	% CO_2	CO_2 analyzer				
Qd	Dry gas sample vol. at std. cond., scf	$Qd = \frac{17.65\ (Qm)\left[Po + \frac{\Delta H}{13.6}\right]}{(tm+460)}$				
Qv	Tot. vol. of condensed water vapor @ std cond. (scf)	$Qv = 0.0474Vv$				
mv	% moisture in stack gas	$mv = \frac{100\ Qv}{Qv + Qd}$				
md	Mole fraction of dry gas	$md = \frac{Qd}{Qv + Qd}$				
Ms	Molecular wt. of stack gas	$Ms = mdMd + 18\ (1-md)$				
Vs	Stack velocity at stack, fpm	$Vs = 3129(Cp)(S)\left[\frac{1}{Ps\,\delta(s)}\right]^2$				
qs	Stack flowrate at standard cond., scfm	$qs = \frac{0.123\ (Vs)(As)(md)(Ps)}{Ts}$				
I	Percent Isokinetic	$I = \frac{1039\ TsQd}{(Vs)(Ps)(md)(Dn2)(\Delta t)}$				
Cs	Total particulate grain load., gr/scf	$Cs = \frac{0.01547W}{Qd}$				
Cs'	Grain load. at 12% CO_2 gr/scf	$Cs' = Cs \times \frac{12}{(\%\ CO_2)}$				
Ct	Total particulate emission lb/hr.	$Ct = .00857\ (Cs)(qs)$				

AQ-605

Figure 5-3 (Revised)

DEPARTMENT OF ENVIRONMENTAL QUALITY
AIR QUALITY CONTROL DIVISION

PARTICULATE SAMPLING CALCULATIONS

Plant _____ Sampling Location _____

Date of Test _____

Symbol	Definition, Units	Calculating Equation	Run__	Run__	Run__	Avg.
Q_m	Sample gas volume at meter conditions, $ft.^3$	Avg. from field data sheet				
t_m	Gas meter temp., ^oF	Avg. from field data sheet				
H	Orifice pressure drop in H_2O	Avg. from field data sheet				
Pb	Barometric pressure (in. Hg)	Field data sheet				
Vv	Tot. vol. of condensed water	Total fr. lab data sheet				
Md	Molecular weight of dry gas	Gas analysis-Atomic Wt.				
Ps	Stack pressure in Hg abs	$.07355 \times P_s + P_b$				
S	$\sqrt{P \times T_s}$	Avg. fr. Vel. calc. sheet				
C_p	Pitot Tube Coeff.	From calibration data				
As	Stack area ($in.^2$)	Field data sheet				
Ts	Stack temp., ^oR	Avg. fr. field data sheet				
Dn	Nozzle diameter (in.)	Field data sheet				
Δt	Total sampling time, min.	Total fr. field data sheet				
W	Wt. of particulate sample, mg.	Total fr. lab data sheet				
$\%CO_2$	$\%\ CO_2$	CO_2 analyzer				
Qd	Dry gas sample vol. at std. cond., scf	$Qd = \frac{17.65(Qm)}{(tm+460)}\left[Pb + \frac{H}{13.6}\right]$				
Qv	Tot. vol. of condensed water vapor @ std. cond. (scf)	$Qv = 0.0474\ Vv$				
mv	% moisture in stack gas	$mv = \frac{100\ Qv}{Qv + Qd}$				
md	Mole fraction of dry gas	$md = \frac{Qd}{Qv + Qd}$				
Ms	Molecular wt. of stack gas	$Ms = mdMd + 18\ (1-md)$				
Vs	Stack velocity at stack, fpm	$Vs = 5129(Cp)(S)\left[\frac{1}{Ps}\right]^{\frac{1}{2}}$				
qs	Stack flowrate at standard cond., $scfm$	$qs = \frac{0.123(Vs)(As)(Pb)(Ps)}{Ts}$				
I	Percent Isokinetic	$I = \frac{1039\ Ts\ Qd}{(Vs)(Ps)(Dn)^2(Tm)(\Delta t)}$				
Cg	Total particulate grain load, gr/scf	$Cg = \frac{0.01540\ W}{Qd}$				
C_g'	Grain load. at 12% CO_2 gr/scf	$C_g' = Cg \times \frac{12}{(\%\ CO_2)}$				
Ct	Total particulate emission lb/hr	$Ct = .00857\ (Cg)(qs)$				

Figure 5-9

SOURCE SAMPLING-LABORATORY ANALYSIS OF PARTICULATE SAMPLE

Test _____

Date of Test _____

CONDENSED WATER DETERMINATION

Run No.	Impinger:	#1	#2	#3	#4	Total Condensate
	Final weight					
	Initial weight					
	Net weight					
	Final weight					
	Initial weight					
	Net weight					
	Final weight					
	Initial weight					
	Net weight					

GRAVIMETRIC RESULTS

Run No.	Contents	Filters	Probe & Filter Holder	Impinger Rinse	Impinger Extract	Impinger Water	Total Wt.
	Beaker No./Vol.						
	Gross wt.						
	Tare wt.						
	Net wt.						
	Blank wt.						
	Final wt.						
	Beaker No./Vol.						
	Gross wt.						
	Tare wt.						
	Net wt.						
	Blank wt.						
	Final wt.						
	Beaker No./Vol.						
	Gross wt.						
	Tare wt.						
	Net wt.						
	Blank wt.						
	Final wt.						

Sample Preparation: Volatiles evaporated at _____ C, Duration _____ hrs
Water evaporated at _____ C, Duration _____ hrs
Desicated at _____ C, Duration _____ hrs
Laboratory Balance Type _____

STATE OF OREGON

DEPARTMENT OF ENVIRONMENTAL QUALITY

Source Sampling Method 7

Sampling Condensible Emissions From Stationary Sources

1. Principle and Applicability

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

1.2 Applicability: This method is applicable to stationary sources whose primary emissions are condensible gases. It should be considered a modification of Source Sampling Method 5 and applied only when directed to do so by the Department.

2. Sampling Apparatus (Figure 7-1)

2.1 The probe, sampling train, and metering system are the same as outlined in 3. Sampling Apparatus of Source Sampling Method 5 with the following exceptions:

2.1.1 The heated filter and cyclone are optional, but should be used if significant quantities of solid particulate are present.

2.1.2 An unheated glass fiber filter is placed between the third and fourth impingers.

3. Sample Recovery Apparatus

3.1 The sample recovery apparatus is the same as outlined in 4. Sample Recovery Apparatus of Source Sampling Method 5.

4. Reagents

4.1 The reagents are the same as outlined in 5. Reagents of Source Sampling Method 5.

5. Sampling Train Preparation

5.1 The sampling train preparation is the same as outlined in 6. Sampling Train Preparation of Source Sampling Method 5 with the following exception:

5.1.1 Insert numbered and weighed filters into each of the front (if used) and rear filter holders.

6. Pretest Preparations and Leak Check

6.1 The pretest preparations and leak check are the same as outlined in Sections 7 and 8 of Source Sampling Method 5.

7. Condensible Particulate Train Operations

7.1 The train operation is the same as outlined in Section 9 of Source Sampling Method 5. It is important to note that the gas temperature leaving the last impinger must not exceed 70°F as temperatures above this may cause loss of condensible material by revolatilization.

8. Condensible Particulate Train Cleanup

8.1 Cleanup should be performed in an area free of wind and airborne dust which may contaminate the sample or cause sample loss. If possible, the train should be cleaned in a laboratory.

8.2 After the probe and nozzle have cooled, remove the end seals and brush while rinsing with acetone into a suitable marked container.

Note: Exercise caution so that none of the rinse is lost and no extraneous material enters the rinse (such as from the pitot tubes or condensed material from the outside of the nozzle).

8.3 Should it be necessary to clean the train in the field, use the following procedure:

8.3.1 Thoroughly rinse all sample exposed surfaces prior to the front filter support, with acetone. Remove any adhering particles with the aid of a rubber policeman. Place the rinsings in the probe rinse bottle. If the front filter is not used, all sample exposed surfaces prior to the first impinger should be included in this rinse.

8.3.2 Remove the front (if used) and rear filters, place in a petri dish and seal. Since a heavy loading of condensible material on the rear filter may leave a residue in the filter container which would necessitate removal with solvent, glass petri dishes are preferred.

8.3.3 Measure and record the volume (or weight) increase of the first three impingers to the nearest 1 ml (or 1 g) and transfer their contents to a labeled container. Rinse the impingers and interconnects with distilled water and add to the container.

8.3.4 Rinse all sample exposed glassware between the front filter (if used) or the first impinger (if the front filter is not used) and the fourth impinger (including glass filter frits) with acetone and place in a suitable marked container. If the moisture condensate in Section 8.3.3 was determined by use of a graduated container, it should also be rinsed with acetone and the rinse added to the impinger rinse container.

8.3.5 Determine the weight gain of the silica gel in the fourth impinger and record. Alternately transfer the silica gel quantatively to an air tight container to be weighed in the laboratory.

8.3.6 Collected samples should be analyzed within one week of collection in order to prevent any possibility of biological or chemical degradation.

9. Analysis

9.1 Desiccate the filter(s) at 70°F or less in the field container for 24 hours and weigh .

Note: In some cases, desiccation may give rise to a slow vaporization of the condensible material. Therefore it is not recommended that an attempt to weigh to constant weight be made.

9.2 Transfer the acetone rinse (Section 8.3.1) into a tared beaker or evaporating dish. Rinse the container with acetone (police to remove particulate) and add the rinse to the beaker. Evaporate the solvent at 70°F or less and laboratory pressure, desiccate 24 hours and weigh . See note in Section 9.1.

9.3 Transfer the acetone rinse from the impingers (Section 8.3.4) to a tared beaker or evaporating dish and treat as in Section 9.2.

9.4 Transfer the water (Section 8.3.3) to a separatory funnel. Rinse the container with distilled water and add to the separatory funnel. Add 25 ml of chloroform to the separatory funnel, stopper and vigorously shake 1 minute, let separate and transfer the chloroform (lower layer) into a tared beaker or evaporating dish. Repeat twice more. Repeat the above extraction using three 25 ml portions of diethyl ether in place of the chloroform. Transfer the ether (upper layer) to the same container as used to contain the chloroform.

Note: It is necessary to rinse the field container for water (if used) with solvent. This rinse may be made using the extracting reagents in which case it is added to the impinger extract container or with acetone in which case it is added to the container in Section 9.3.

9.5 Transfer the remaining water from the separatory funnel to a tared beaker or evaporating dish and evaporate at 105°C . Desiccate for 24 hours and weight.

9.6 Evaporate the combined impinger water extracts from Section 9.4 at 70°F or less and laboratory pressure, desiccate for 24 hours and weigh . See note in Section 9.1.

9.7 Evaporate portions of the solvents used in a manner similar to the sample evaporations to determine the solvent blanks.

9.8 Record all laboratory data in the Laboratory Data Reporting Sheet, Figure 5-9, Source Sampling Method 5.

10. Calculations

10.1 The calculations are the same as outlined in 14. Calculations of Source Sampling Method 5.

11. Minimum Acceptable Test Requirements

11.1 The minimum acceptable test requirements are the same as outlined in 15. Minimum Acceptable Test Requirements of Source Sampling Method 5.

12. Minimum Test Report Information

12.1 The test report should contain sufficient information about the source to accurately define its operation during the test. Also sufficient data and calculations shall be included to document the source test results.

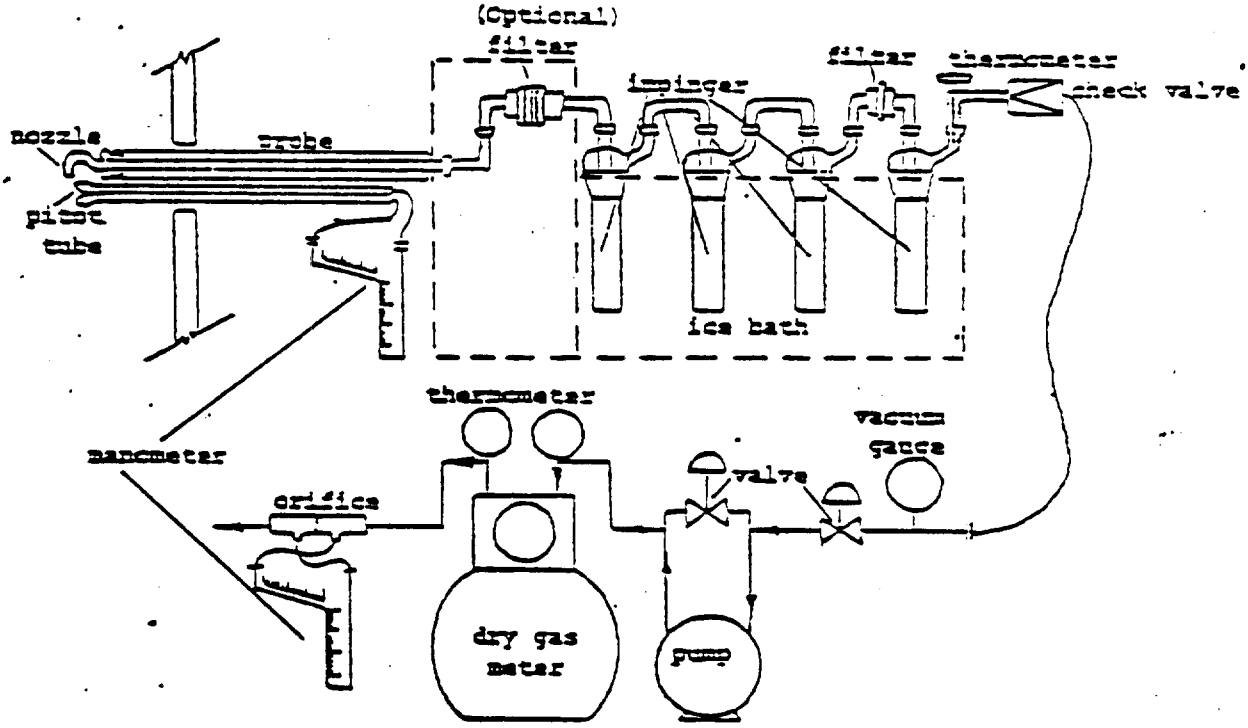

(Optional)
filter
filter
thermometer
check valve
impinger
nozzle
probe
pitot tube
ice bath
thermometer
vacuum gauge
manometer
valve
orifice
dry gas meter
pump

Figure 7-1

DEQ WOODSTOVE CERTIFICATION PROGRAM
FACT SHEET

Background

The 1983 Oregon Legislature passed a law allowing only new woodstoves and stove-like fireplace inserts that pass an emission standard to be sold in the state after July 1986. Existing installed stoves, used or antique woodstoves, and fireplaces are exempt from the rules. In developing the rules, the DEQ worked closely with an advisory committee representing woodstove manufacturers and retailers, testing laboratories, chimney sweeps, fire code experts, engineers, air quality specialists and environmentalists. Two nonvoting medical advisors also participated.

The Environmental Quality Commission (EQC)* established phased-in smoke emission standards and adopted rules in June 1984 covering:

- Procedures for testing woodstoves for emissions and efficiency
- Stove labels indicating the stoves' emissions and efficiency levels
- Procedures for certifying stoves for sale in Oregon
- Fees for certifying stoves
- Procedures for accrediting testing labs.

A two-year voluntary phase with stove labeling began July 1, 1984, and continues until June 30, 1986. The mandatory sales restrictions phase begins July 1, 1986.

All new woodstoves must be tested by an independent woodstove testing laboratory. The rules outline procedures that a testing laboratory must follow to become DEQ-accredited to perform testing for Oregon's Woodstove Certification Program. Basically, laboratories can not be financially dependent upon any woodstove business, and they must demonstrate stove testing proficiency. Under the rules, a manufacturer pays to have each stove model tested at low, medium, high and maximum heat output levels, using Douglas fir. The results are averaged to determine whether the stove meets the emission standard.

The Department of Environmental Quality (DEQ) is currently accrediting testing laboratories and manufacturers are voluntarily submitting their stoves for testing and labeling. An ongoing list of approved stoves with performance information will be made available to the public as new stoves are certified.

Emission Standard

The new emission standards limit the amount of smoke (measured in grams per hour) a stove can emit. The standards will be phased in: The 1986 standard reduces emissions by about 50 percent; the proposed 1988 standard would reduce emissions by about 70 to 75 percent.

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*The Environmental Quality Commission is a five-member citizen board that sets environmental policy and rules for Oregon and oversees the Department of Environmental Quality (DEQ).

Specifically, the rules call for new stoves equipped without catalysts to emit no more than 15 grams of smoke per hour (grams/hour) after July 1986. Stoves with catalysts will emit no more than 6 grams/hour. (The lower number is necessary for catalyst-equipped stoves because the catalyst element degrades over time. A catalyst that starts out emitting 6 grams/hour will emit an average of 15 grams/hour over its lifetime.) A catalyst, or catalytic combuster, is a device similar to those found in automobiles to improve combustion. It allows the gases and particles in wood smoke to burn at lowered temperatures before the smoke leaves the stove.

In July 1988, the emission standards will be tightened to 9 grams/hour for noncatalyst-equipped stoves and 4 grams/hour for stoves with catalysts. Some well designed catalyst-equipped stoves can already meet the stricter 1988 standard. But the average stove now on the market emits more than 30 grams/hour.

The Department proposed a phased standard in order to meet air quality standards while providing consumers a wider choice of woodstove designs. The 1986 standard will begin cleaning up our air while allowing manufacturers time to develop a variety of clean-burning designs that will meet the 1988 standard. The stricter 1988 standard should allow most areas of the state to meet air quality standards by the year 2000, and provide airshed space for growth and development.

Label Requirements

The consumer will find two labels on certified woodstoves and stove-like fireplace inserts describing their tested performance. The technical label shows the tested emissions and efficiency levels over the whole range of heat output levels; this label is attached permanently to the stove. A second label, intended for the consumer, shows the stove's average emissions and efficiency levels and the range of heat output levels as well as Oregon's emission standard; this label can be removed by the consumer and is primarily used for selection purposes when sizing stoves, and comparing appliance efficiencies.

Benefits to the Consumer

For the first time, the consumer will have appropriate and accurate information to make a knowledgeable decision, in selecting the right-size stove for the intended space to be heated when purchasing a woodstove or stove-like insert.

Because woodstove retailers will be monitored for compliance with the law, the consumer can also be assured that the stove passed an independent emission and efficiency test when the stove is sold in Oregon. DEQ monitoring will not occur in the home.

An added benefit will be the less polluted air because the consumer made the effort to purchase a better designed, cleaner burning woodstove. The cleaner burning stoves have higher efficiency ratings (more usable heat generated from less wood consumed) and safety benefits (less creosote buildup with less chimney cleaning costs). The purchase price of the new stoves may be somewhat higher, but savings in fuel usage and chimney cleaning will offset the higher initial cost.

For More Information

More information or a copy of the rules can be obtained by writing to DEQ, P.O. Box 1760, Portland, 97207; or by calling 229-6488 or toll-free 1-800-452-4011.

Department of Environmental Quality

WOODSTOVE CERTIFICATION PROGRAM

Steps Toward Certifying a Stove In Oregon

I. LAB ACCREDITATION

Before any stove models can be tested, laboratories have to be accredited by the DEQ; it takes about a month to get a laboratory accredited.

A. Labs must apply for accreditation, and document they meet the accreditation criteria:

- Cannot be financially dependent on any woodstove business;
- Must follow generally accepted professional practices;
- Lab staff must be trained and then tested for competency yearly;
- Lab must be equipped properly;
- Must keep complete and accessible records;
- Must have equipment, training records, testing data, etc. available for DEQ inspection;
- Must maintain a quality control system;
- Must have an emissions and efficiency computer program approved by DEQ;
- Cannot discriminate against persons or businesses, cannot belong to associations that discriminate.

B. DEQ will inspect labs after application is considered complete:

- Lab will have to perform in DEQ's presence one complete emissions and efficiency test on a woodstove provided by DEQ;
- Lab deficiencies must be corrected within 30 days, DEQ may revisit.

C. DEQ will approve or deny accreditation after all information is submitted.

- Accreditation is good for three years;
- DEQ may audit one stove test during the three years;
- Accreditation is not renewable, labs must go through the application procedure again.

II. TESTING PROCEDURES

Manufacturers will take their stove models to an accredited lab for emissions and efficiency testing. The testing and reporting will take approximately two weeks and will cost approximately $6000 per model.

A. Fuel

- Wood must be air dried Douglas fir lumber, room temperature, with a moisture content of 16 to 20 percent, measured within 4 hours of testing;

- Must be free of knots, pitch, rotted areas;
- Dimensions of the wood will depend upon the volume of the stove firebox; for unusual designs, the loading must be cleared by DEQ before testing.

B. Testing

- Simultaneous emissions and efficiency tests are required for four ranges of heat outputs (less than 10,000 BTUs/hour, 10-15,000 BTUs/hour, 15-25,000 BTUs/hour, maximum heat output);
- If a stove cannot achieve one or more of the heat output levels, additional tests must be conducted at the next closest range;
- Testing is finished at each range when all the wood is consumed;
- Standard method for measuring emissions is DEQ Method 7, or modified EPA Method 5;
- Standard methods for measuring efficiency are calorimeter rooms or stack loss;
- Substitute testing methods can be used, if precision and accuracy tests are performed and equivalency is proven;
- Before a stove is tested, its catalytic combustor must be aged by being used in a stove continuously for 50 hours.

III. SPECIAL CATALYST REQUIREMENTS

- Catalysts must be tested to ensure they are still 70 percent effective after 5000 hours of use, or the manufacturer must provide a 24-month complete replacement warranty;
- Stoves with catalysts must have a thermometer access installed to allow the owner to monitor stove gas temperatures, which will indicate whether the catalyst needs replacement. (The consumer can purchase the thermometer, if desired.)

IV. APPLYING FOR CERTIFICATION, AND LABEL APPROVAL

After a manufacturer has its stove test results that meet the appropriate particulate standard, they can apply for certification. When the DEQ concludes that the application is complete and that the test results are accurate, it will provide the manufacturer with the approved emissions and efficiency content for the labels. The manufacturer will produce the labels and submit them to the Department for approval. If the labels are approved, and all other requirements are met, the DEQ will certify the stove.

A. Application for certification must include:

- Description of the stove, including design plans and operating manual;
- Testing information, including particulate and gas emissions, heat output, burn rate, average efficiency values, gas composition and temperatures for each test cycle;

- Nonrefundable application fee of $1600 for a manufacturer's first model, and $800 for each additional model.

B. Label requirements

- A legible permanent label (sample attached) must be attached on the outside of the stove (except on the bottom), or on the inside the stove, if it can be seen and will remain legible;
- A removeable label (sample also attached) must be visibly located on the stove at the point of sale;
- Before the Department can approve the labels and certify the stove, the manufacturer must submit proofs of the labels, diagrams of where the labels will be attached, information on how the permanent label will be attached, and the name of the label printer;
- The Department must approve or deny the use of the labels within 14 days;
- The manufacturer must submit to the DEQ final copies of the labels within one month of printing.

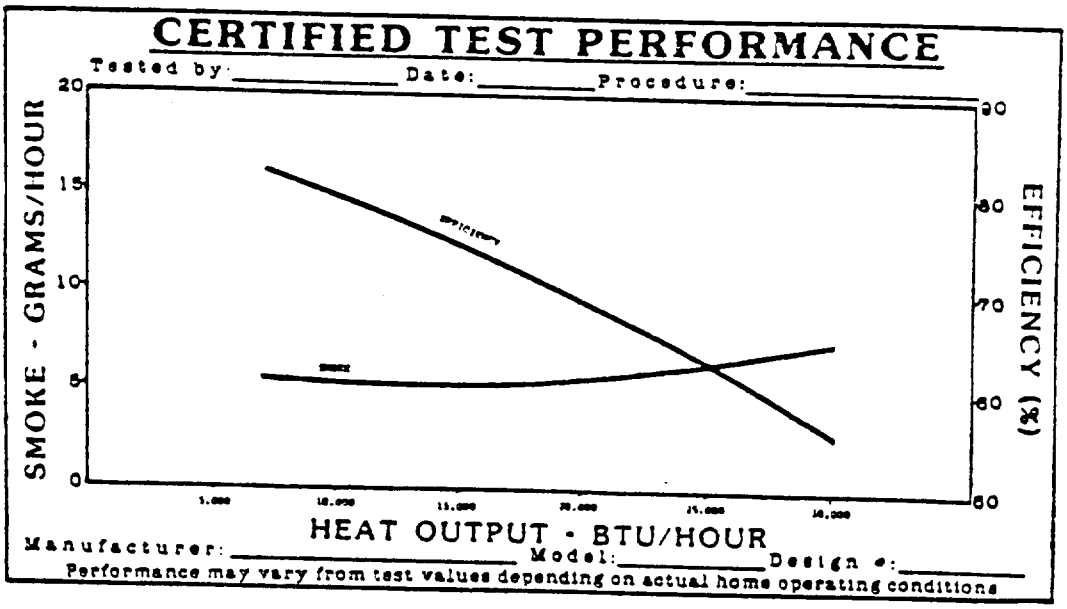
C. Certification approval

- The Department must notify a manufacturer within 60 days of receiving a completed application whether certification is granted or denied;
- Certification is good for five years, manufacturers must apply for a new certification 60 days before the old certification expires. The fees and testing requirements may be waived if no changes to the stove have been made that affect emissions or efficiency;
- Manufacturers must apply for new certification (even before five years) if the stove is altered in any way that changes its emissions or heating efficiency.

V. ENFORCEMENT

- Manufacturers, retailers or labs that violate the rules or statute are subject to civil penalties;
- If a lab violates the accreditation rules, stoves tested at that time may lose their certification;
- If certification is revoked, no one may claim the stove is approved by the Department.

Permanent Woodstove Label
(Example)



Removable Woodstove Label
(Example)

EMISSIONS AND EFFICIENCY PERFORMANCE
(non-catalytic stoves)

Smoke _____ grams/hour (DEQ Standard: 15 until 07/88)
9 after 07/88)

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 until July 1, 1988.

CONFIRMATION TESTING SUMMARY

TESTING PROGRAM DESIGN

The finalized Oregon Woodstove Testing Procedure was performed by OMNI Environmental Services, Inc. in December 1983, and January 1984 according to the following scenario:

- Four Stoves
  - o Blaze King Princess - medium size catalytic
  - o Jotul 201 - small size dual combustion chamber
  - o WHA Generic - large size conventional
  - o Oregon Mfg. Catalytic - large size catalytic
- Simultaneous Stack Loss and Calorimeter Room Heating Efficiency Methods on above four stoves.
- Dual Method 7 Particulate Sampling Trains on all four stoves
- Dual Condar Particulate Samplers on Jotul 201, Generic, and the Large Catalytic (WHA sponsored)
- 5000 hour catalytic longevity test on Blaze King Princess
- Additional two stoves - Method 7 and Jaasma Dilution Tunnel (WHA Sponsored)
  - o Medium size conventional
  - o Small size conventional

SIGNIFICANT FINDINGS

1. The revised final test procedure was found to be very workable - no problems were identified.

2. Calorimeter Room method vs. Stack Loss Efficiency method on an average, produced results within ± 1% of each other and 7% maximum difference. This was virtually identical to previous testing. Both methods are still considered acceptable.

3. Oregon Method 7 precision was found to be very good with highest deviation ± 9% between dual trains. This is better than reported for EPA M5 which does not use an impinger catch.

4. The Condar sampler had precision equivalent to Oregon Method 7. Condar accuracy as compared to Method 7 did not meet equivalency criteria previously agreed to by WHA. Criteria called for accuracy within ± 12%. Results indicated average accuracy of about ± 30% with highest and second highest deviations being 165% and 74% respectively. The deviation on a gm/hr basis averaged ± 2 gm/hr and did not exceed

4.8 gm/hr, reaffirming the Condar to be a very useful and reliable tool for screening stoves and research and development work. These results are based on latest corrections to Condar data.

5. The Jotul 201 had somewhat higher emissions than expected with a weighted average emission performance of 9 to 16 gm/hour depending on which 4 of the 7 test runs are used to develop the weighted average emission level.

6 The small conventional stove was found to emit 11 gm/hr. This very small non-catalytic unit is widely copied by other manufacturers and is readily available in some inexpensive versions ($99). Performance of the copies may be similar.

7. The two catalytic stoves performed under the DEQ and Committee proposed 6 gm/hr emission standard. A weighted average performance of 1 gm/hr was measured for the Blaze King Princess.

8. The WHA Generic stove had a large firebox size requiring only 4x4 fuel. The unit performed similarly to previous tests with 2x4 cribs except at the very low heat output where emissions dropped due to stack creosoting. The weighted average emissions were 31 gm/hour.

9. An average size conventional stove using a 2x4/4x4 mix of fuel was measured at a weighted average emission rate of 27 gm/hr.

10. Quadratic curve fitting of the four data points per stove produced reasonable curves.

11. Virtually all possible methods of calculating emissions produce very similar results (i.e., curve fit @ 13000 Btu/hr, curve fit or actual data with cumulative probability heat output, etc.).

12. A catalyst degradation test with the finalized test method confirms Corning data that the catalyst is 80% efficient at 5000 hours (i.e., about 6 gm/hr on the Blaze King Princess).

13. The medium and large conventional stove tests with the finalized test method indicate a baseline emission rate in the range of 30 gm/hr. This closely agrees with the 34 gm/hr baseline DEQ originally identified from extensive ambient monitoring and modeling (i.e., 20 gm/kg emission factor @ 1.7 kg/hr average burn rate.)

14. The Advisory Committee's original 20/10 & 9/6 (non-cat/catalyst) staged emission standard recommendation would result in only about a 33% reduction in emissions based on a 30 gm/hr baseline with the first stage and likely no existing non-catalyst stoves meeting the second stage.

15. Some optional emission standards based on confirmation test results would include:

    A. 14/6 (which would pass Jotul 201 and possibly many small conventional stove types). Approximately 50% airshed emission reduction.

    B. 12/6 (which may exclude Jotul 201 but possibly include many small conventional units). Approximately 60% airshed emission reduction.

    C. 7/3 (which would include the better performing catalysts and set a goal to reach for non-catalysts). Could achieve needed airshed reduction level of approximately 80%.

    D. A & C or B & C as 2-stage standards.

EXAMPLE CALCULATION OF WEIGHTED AVERAGE EMISSIONS

STEP ONE

A woodstove is tested at four heat outputs as outlined below:

Stove Model	Run	Emissions (g/hr)	Heat Output (Btu/hr)	Order of Heat Output
Example Catalytic	A	4.1	11,067	2nd
Example Catalytic	B	10.4	17,663	3rd
Example Catalytic	C	9.7	20,074	4th
Example Catalytic	D	2.0	7,652	1st

Note that Run D was at a heat output of <10,000 Btu/hr, Run A at 10-15,000 Btu/hr, Run B at 15-25,000 Btu/hr, and Run C at maximum heat output.

STEP TWO

The test results are now rearranged in order of increasing heat output, extra lines are added before and after the test runs, and cumulative probability figures are taken from Table 1 of the rules (OAR 340-21-120):

Order of Heat Output	Line Number	Heat Output (Btu/hr)	Emissions (g/hr)	Cumulative Probability (P)
---	0	-----	----	0.00000
1st	1	7,652	2.0	0.21615
2nd	2	11,067	4.1	0.46226
3rd	3	17,663	10.4	0.86822
4th	4	20,074	9.7	0.93620
---	5	-----	----	1.00000

STEP THREE

Now the weighting factors (K_1) are calculated:

$$K_1 = P_2 - P_0 = 0.46226 - 0.00000 = 0.46226$$
$$K_2 = P_3 - P_1 = 0.86822 - 0.21615 = 0.65207$$
$$K_3 = P_4 - P_2 = 0.93620 - 0.46226 = 0.47394$$
$$K_4 = P_5 - P_3 = 1.00000 - 0.86822 = 0.13178$$

$$K_1 + K_2 + K_3 + K_4 = 1.72005$$

STEP FOUR

Finally, the weighted average emissions ($\bar{E}$) are calculated:

$$\bar{E} = \frac{(K_1E_1 + K_2E_2 + K_3E_3 + K_4E_4)}{(K_1 + K_2 + K_3 + K_4)}$$

$$\bar{E} = \frac{(0.46226 \times 2.0) + (0.65207 \times 4.1) + (0.47394 \times 10.4) + (0.13178 \times 9.7)}{(1.72005)}$$

$$\bar{E} = 5.7 \text{ g/hr}$$

MLH:a
4/10/84
AA4374

OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY CERTIFIED WOODSTOVES
revised March 14, 1985

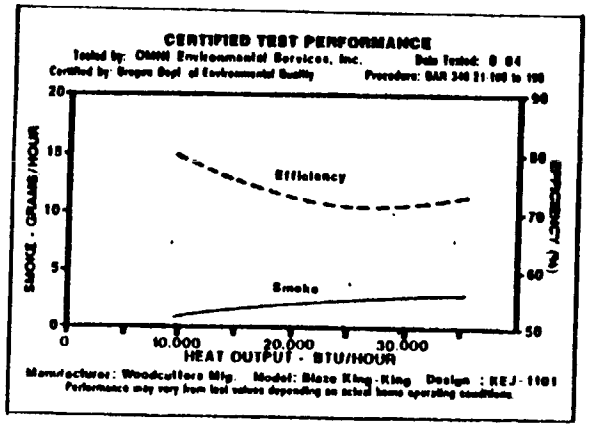
Oregon Smoke Standard: (Particulate Emissions)
After June 30, 1986: 15 grams/hr non-catalytic, 6 grams/hr catalytic
After June 30, 1988: 9 grams/hr non-catalytic, 4 grams/hr catalytic

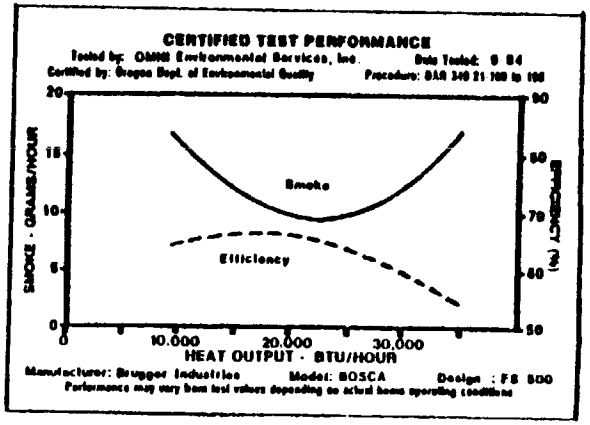
Model, Design Number Manufacturer	Type[1]	Date Certified	Average[2] Smoke (grams/hr)	Average[2] Overall Efficiency (%)	Heat Output[3] Range (Btu/hr)	Burn Time Between Refueling[4] (hours) Low	High	Average Weight of[3] Test Fuel lbs	Average[5] Draft (inches H_2O)
Blaze King 'King,' KEJ-1101 Woodcutters Mfg.	C, FS, SL	12-21-84	1.6	76.9	9,510 to 35,200	16.2	4.4	29.2	.021 to .052
BOSCA FS 500 Brugger Industries Ltd.	NC, FS, SL	12-21-84	13.5	64.8	9,832 to 35,307	3.8	1.0	9.1	.032 to .070
ANSWER A1, A2, A3 Lopi International, Ltd.	NC, FS, I, WO, SL	01-22-85	14.8	62.1	4,887 to 43,350	6.3	0.75	8.3	.023 to .070
Rawhide I RH861 Martenson Industries	NC, FS, W, SL	01-30-85	13.8	59.8	20,707 to 34,512	2.4	1.1	11.9	.051 to .069
Fisher TECH IV CESCO Industries	I, C, SL	03-01-85	2.5	79.1	18,033 to 31,794	5.6	2.8	17.2	.050 to .061
Pellefier FS-1 Collins Bio-Energy Co.	FS, NC, PF,	03-01-85	0.7	79.4	9,455 to 29,630	N/A	N/A	N/A	.009 to .015
Timber Eze 477 Timber Eze, Inc.	C, FS, SL	03-01-85	2.0	75.8	8,660 to 21,860	11.4	3.4	17.5	.027 to .050
Vista 640 The Stack Mfg. Co., Ltd.	NC, FS, SL	03-14-85	5.4	61.8	20,839 to 60,104	1.8	0.6	8.6	.064 to .093
Tile Fire Mark II LPE 566410 Kent Heating, Ltd.	NC, FS	03-14-85	14.2	64.5	8,966 to 30,062	5.0	1.6	10.2	.035 to .076

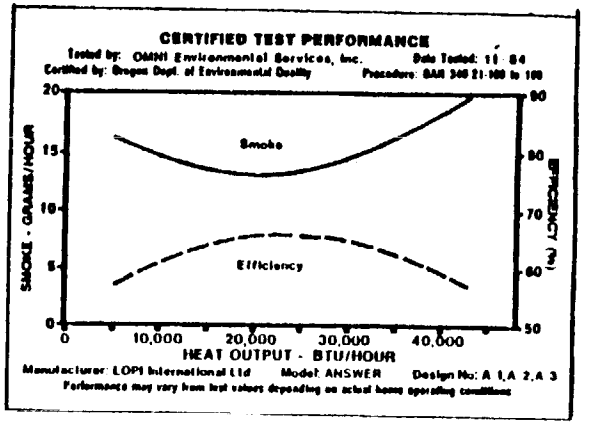
(1) C=Catalytic, NC=Noncatalytic, W=Tested with optional blower, WO=Tested without optional blower, SL=Safety Listed, FS=Free Standing, I=Insert (All inserts are tested with a direct flue connection and full length insulated chimney.) PF=Pellet Fuel
(2) Average performance based on average Oregon heating load (approximately 13,000 Btu/hr)
(3) Based on consumption of a test charge of Douglas fir at 16 - 20 percent moisture and loading density of 7 lbs wood/cubic foot of firebox volume. Stoves tested at heat output less than 10,000 Btu/hr may be capable of operating at lower than stated values. Minimum stated heat output over 10,000 Btu/hour represent the minimum heat output achievable during certification testing. Heat output may vary depending on type and quantity of fuel used.
(4) Time between refueling during certification test at low and highest heat output (refueling occurs when an entire test charge of fuel has been consumed, with a hot coal bed remaining).
(5) Measured within 1 foot of stove's flue connection. Values shown are averaged over an entire test cycle; both low and high heat output tests are displayed.

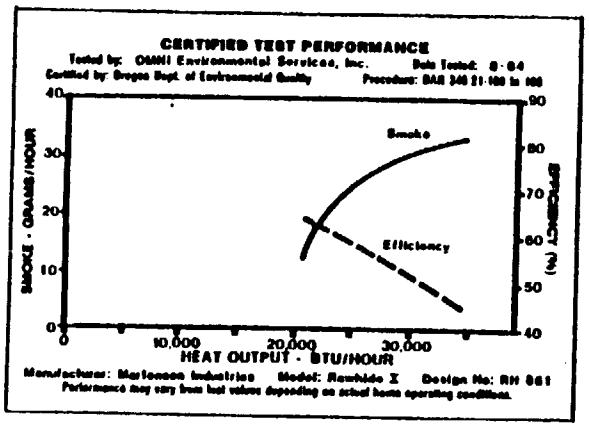
For more information write: Oregon Department of Environmental Quality, PO Box 1760, Portland, Oregon 97207, or call (503) 229-6488; in Oregon, toll-free 1-800-452-4011

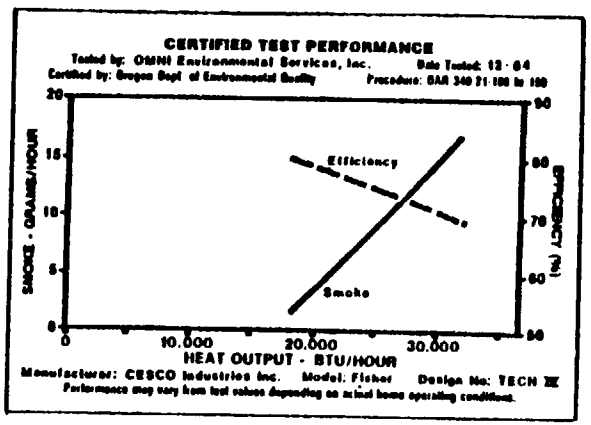
AS038 B

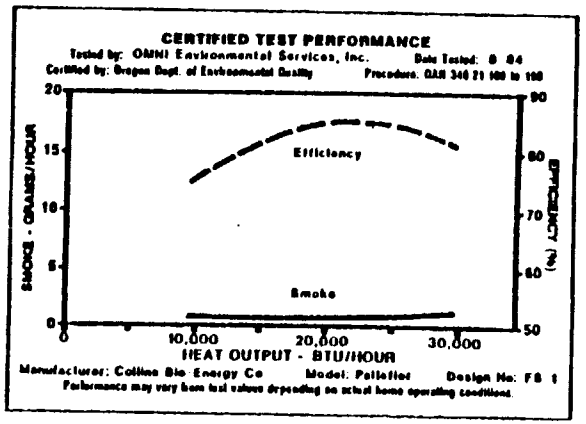

CERTIFIED TEST PERFORMANCE
Efficiency
Smoke
SMOKE - GRAMS/HOUR
EFFICIENCY (%)
HEAT OUTPUT - BTU/HOUR

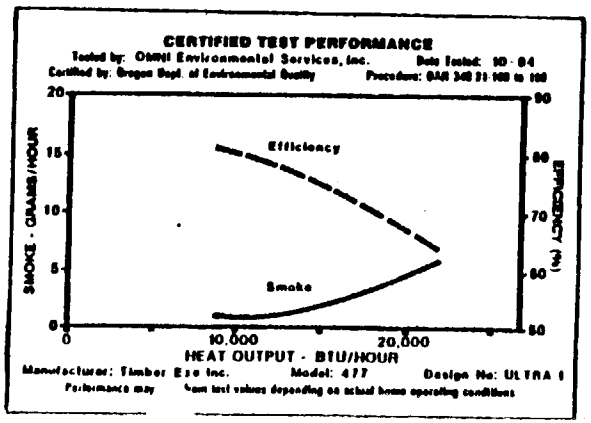

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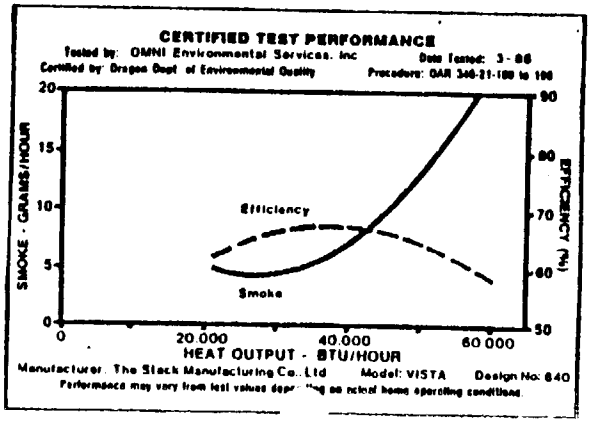

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SMOKE - GRAMS/HOUR
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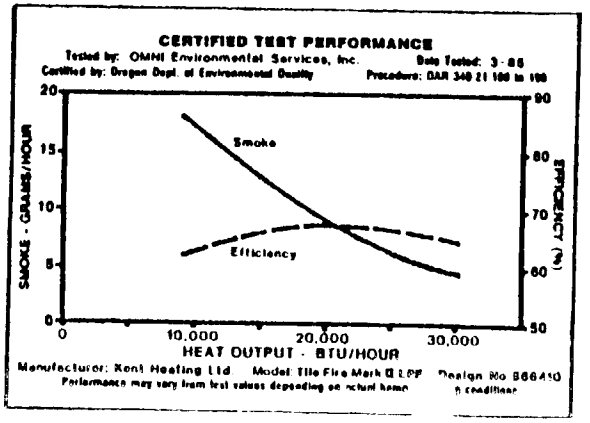

CERTIFIED TEST PERFORMANCE
Smoke
Efficiency
SMOKE - GRAMS/HOUR
EFFICIENCY (%)
HEAT OUTPUT - BTU/HOUR


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CERTIFIED TEST PERFORMANCE
Smoke
Efficiency
SMOKE - GRAMS/HOUR
EFFICIENCY (%)
HEAT OUTPUT - BTU/HOUR

MISSOULA

Maps Attached

WOOD BURNING REGULATIONS

SUMMARY

I. OPACITY (Density of Smoke)

-Opacity cannot exceed 60% (see photo) except during start-up of a fire. A 15 minute grace period is allowed for start-up.

-To whom does it apply? It applies to all residential and commercial solid fuel burning devices; no exemptions.

-Where does it apply? Both Zone 1 and Zone 2 (see maps).

-When does it apply? All times except during Alerts (when no visible emissions are allowed) in Zone 1; all times in Zone 2.

II. STAGE I AIR POLLUTION ALERTS AND STAGE II AIR POLLUTION WARNINGS

-No visible emissions from any residential or commercial solid fuel burning devices.

Exemptions: Sole Source of Heat Permits.
Dealer Demonstration Permits.
Special Need Permits.

These sources are allowed to burn with a valid permit, but opacity cannot exceed 20% (see photo) except during start-up of a new fire. A 20 minute grace period is allowed for start-up. Information concerning these permits is available at the Health Department.

-Where does it apply? Alerts and Warnings are mandatory in Zone 1 and Voluntary in Zone 2 (see maps).

-When does it apply? Alerts and Warnings will be called either at 9 AM, Noon, or 5 PM and remain in effect until the Health Department cancels them.

CALL THE AIR POLLUTION HOTLINE
728-AIRE (2473)
For The Latest Air Quality Status

-Air quality status is also available from local TV and radio stations and every 5 minutes on the 24 hour cable weather channel. The Missoulian also carries a forecast prediction on the front page. No enforcement will occur until 3 hours after and Alert has been called. However, it is your responsibility to know if an Alert or Warning is in progress.

-You are requested to limit your vehicle driving to necessary trips only and use mass transit whenever possible.

III. PENALTIES

-All first violations during any one burning season are warnings. If you wish to contest a first violation, you must submit to the Health Department a written request, within 7 days of receipt of your Notice of Violation, for a hearing before the Air Pollution Control Board.

-For all subsequent violations during any one burning season a complaint will be filed in Justice Court and can result in a maximum penalty of $100.00. If you have an exemption permit, subsequent violations are grounds for revoking your permit.

IV.

-Educational materials or an educational classroom sessions are available upon request from the Health Department.

Section XII. "EMERGENCY PROCEDURE - MISSOULA COUNTY AIR STAGNATION PLAN:"

(A) Purpose and Explanation

The following plan was devised using Missoula County air quality inventory data specifically assembled for inversion periods. The objective of the strategies is to provide protection to the community during an air stagnation period and also to aid in meeting the annual TSP compliance by reducing inversion-related high TSP values.

(B) General Provisions

(1) Total Suspended Particulates (TSP)

(a) Ambient concentrations of TSP will be determined by the Department by utilizing a reference method or functional equivalent air quality monitoring and sampling devices which have been approved in writing by the Department of Health and Environmental Sciences.

(b) The Stage I Alert and Stage II Warning shall be declared by the Department whenever the ambient concentration of T.S.P. exceeds the specified level for that stage averaged over an eight hour period and when scientific and meteorological data indicate that the average T.S.P. concentrations will remain at or above the specified level if a Stage I Alert or Stage II Warning is not called. The Department may call a Stage I Alert or Stage II Warning whenever availible scientific and meteorolgical data indicate that the ambient concentration of T.S.P. can reasonably be expected to exceed the specified level averaged over an eight hour period within the next 24 hours, as determined by the Department.

(c) Stage III EMERGENCY and Stage IV CRISIS shall be declared by the Department whenever the TSP concentrations equal or exceed the specified level for twenty-four (24) hours.

(d) Any of the above stages for TSP shall be reduced to the appropriate stage when measurements of the ambient air indicate a corresponding reduction in TSP levels.

(e) When, in the opinion of the Department, meteorological and scientific data indicate that the particulate measured is not hazardous (e.g. non-respirable), the level may be adjusted.

(2) Sulfur Dioxide, Carbon Monoxide, Oxidants, Nitrogen Dioxide

(a) Ambient concentration of sulfur dioxide, carbon monoxide, oxidants and nitrogen dioxide will be determined by the Department by utilizing reference methods or functionally equivalent air quality monitoring and sampling devices which have been approved in writing by the Department of Health and Environmental Sciences.

(b) The Stage II WARNING, Stage III EMERGENCY, and Stage IV CRISIS will be declared by the Department whenever the ambient concentation of any of the pollutants listed above equals or exceeds the level specified under each stage for the specified period of time.

(c) Any of the above stages for sulfur dioxide, carbon monoxide, oxidants or nitrogen dioxide shall be reduced to the appropriate stage when measurements of the ambient air indicate a corresponding reduction in sulfur dioxide, carbon monoxide, oxidants or nitrogen dioxide levels and available meteorological data indicates that the concentration of such pollutant will not immediately increase again.

(C) Area of Application

(1) The provisions of Section XII shall apply to all sources of air pollution located within the geographical area designated as the Air Stagnation Zone.

(2) The provisions of Section XII shall also apply to all point sources within Missoula County emitting or capable of emitting twenty-five (25) tons or more per year of any pollutant, when, based on available scientific and meteorological data, the Department determines that such source or sources are causing or contributing to ambient concentrations of any pollutant anywhere within Missoula County in excess of the concentrations set forth in this Section XII.

(D) Abatement Plan for Certain Sources

Each point source within Missoula County emitting or capable of emitting twenty-five (25) tons or more per year of any regulated pollutant shall submit a plan of abatement for reducing emissions of each such pollutant when the ambient concentration of such pollutant equals or exceeds the concentrations set forth in this Section XII. Such plan shall be subject to review by the Department and shall be approved if the plan sufficiently demonstrates the ability of the source to reduce emissions as required under each stage of the emergency plan. Such abatement plan shall be submitted within 60 days after the effective date of this regulation.

(E) Procedure

(1) Nothing in Section XII shall be construed to limit the authority of the Control Board or Department to act in an emergency situation.

(2) If any of the provisions of Section XII are being violated, or if, based on scientific and meteorological data, the Control Board or Department has reasonable grounds to believe that there exists in Missoula County a condition of air pollution which requires immediate action to protect the public health or safety, the Department or the Control Board or any law enforcement officer acting under the direction of the Department or Control Board may order any person or persons causing or contributing to the air pollution to immediately reduce or complet ely discontinue the emission of contaminants.

(3) The order shall specify the provision of the Program being violated and the manner of violation, and shall direct the person or persons causing or contributing to the air pollution to reduce or completely discontinue the emission or air contaminants immediately. The order shall notify the person to whom it is directed of the right to request a hearing. The order shall be personally directed to the person or persons in violation or their agent.

(4) If a hearing is requested by a person or persons allegedly in violation of the provisions of Section XII, the Department shall fix a time and place within

24 hours for a hearing to be held before the control board or a hearings examiner appointed by the Control Board. Not more than 24 hours after the commencement of such hearing, and without adjournment, the Control Board shall affirm, modify or set aside the order. A request for a hearing does not stay or nullify an order.

(5) If a person fails to comply with an order issued under this Section XII, the Department or the Control Board may initiate action under Section XV and Section XVI of this program.

(6) The right to request a hearing before the Board under this Section shall not apply to violations of Section X 4100. Enforcement procedures for violations of Section X 4100 are described in Section X 4100 (G).

(F) When in effect, the requirements of Section XII shall supersede all other regulations under this program which are less restrictive.

(G) STAGE I - ALERT

The following provisions shall take effect when the ambient concentration of total suspended particulate (T.S.P.) meets or exceeds 150 micrograms per cubic meter as set forth in Section XII (B) (1) (b).
(1) The Department shall advise citizens via public media of the actions listed under Alert, and of medical precautions.

(2) The Department shall not issue any open burning permits and shall suspend existing open burning permits.

(3) Residential solid fuel burning devices shall comply with the applicable requirements of Section X 4100 Subsection E. Permitted devices shall comply with conditions set forth on the permit.

(4) The Department shall request citizens to limit automobile driving to necessary trips only and to avoid driving on unpaved surfaces such as dirt roads and unpaved shoulders and alleys. Alternative transportation shall be encouraged.

(5) The Department shall request construction companies to take effective dust-control action for roads under construction or repair.

(6) The Department shall request commercial boiler operators to limit boiler lancing and soot blowing to early afternoon hours.

(7) The City, County and State road departments shall be required to take actions appropriate under the prevailing weather conditions to reduce road dust along heavily travelled streets. Plans from each governmental road department describing such appropriate actions shall be submitted to the Department for review within 60 days after the effective date of this regulation and shall be approved if they demonstrate reasonable measures to minimize road dust.

(8) A point source may not switch to a higher sulfur or ash content fuel unless that source has continuous emission reduction equipment for the control of emissions caused by the alternate fuel.

(9) Each point source emitting or capable of emitting twenty-five (25) tons or

more per year of any pollutant shall be required to implement its abatement plan to reduce emissions during an Alert. Maximum efficiency of abatement equipment shall be required.

(10) Licensed incinerators, except pathological incinerators and crematoriums, shall cease operation during an Alert.

(H) STAGE II - WARNING

The following provisions shall take effect when ambient concentrations equal or exceed those set forth in the table below and declared as set forth in section XII (B).

300 ug/m	TSP	8 hour average
800 ug/m	SO2	24-hour average
17.0 mg/m	CO	3-hour average
400 ug/m	Ox	1-hour average
1130 ug/m	NO2	1-hour average

(1) The Department shall advise citizens via public media of the actions described under Warning, and of medical precautions.

(2) All Alert conditions shall remain in effect except where Warning steps are more stringent.

(3) The Department shall strongly advise the public to eliminate all non-essential driving, and urge citizens to make prearrangements for car-pooling or use public transportation during a Warning condition.

(4) Residential solid fuel burning devices shall comply with the applicable requirements of Section X 4100. For sources other than residential solid fuel burning devices, no person shall cause, allow or discharge visible emissions from any source unless such source has a State or County air contamination permit.

(5) Each point source emitting or capable of emitting twenty-five (25) tons or more per year of any pollutant shall be required to implement its abatement plan to reduce emissions during a Warning and maximum efficiency of abatement equipment shall be required in accordance with that abatement plan. Such point sources shall be advised of possible Emergency conditions and shall be prepared to take action as advised under the Emergency conditions.

(I) STAGE III - EMERGENCY

The following provisions shall take effect when ambient concentrations equal or exceed those set forth in the table below:

625 ug/m	TSP	24-hour average
1600 ug/m	SO2	24-hour average

34.0 mg/m	CO	3-hour average
800 ug/m	Ox	1-hour average
2260 ug/m	NO2	1-hour average

(1) The Department shall advise citizens via public media of the actions described under an Emergency episode and of medical precautions.

(2) All Alert and Warning conditions remain in effect during Emergency, except where Emergency steps are more stringent.

(3) All nonessential public gatherings should be voluntarily cancelled.

(4) All trips by car should not be made without carefully considering the use of public transportation and carpooling, and the necessity of the trip.

(5) Specific advisement shall be issued that conditions are continuing to worsen and that total curtailment under a Crisis condition is possible.

(6) Each point source emitting or capable of emitting twenty-five (25) tons or more per year of any pollutant shall be required to implement its abatement plan to reduce emissions during an Emergency episode. A minimum forty percent (40%) reduction in emissions below maximum permissible operating emissions shall be required.

(J) STAGE IV - CRISIS

The following provisions shall take effect when ambient concentrations equal or exceed those set forth in the table below:

875 ug/m	TSP	24-hour average
2100 ug/m	SO2	24-hour average
46.0 mg/m	CO	8-hour average
1000 ug/m	Ox	1-hour average
3000 ug/m	NO2	1-hour average

(1) All conditions from the Alert, Warning, Emergency are in effect except where Crisis steps are more stringent.

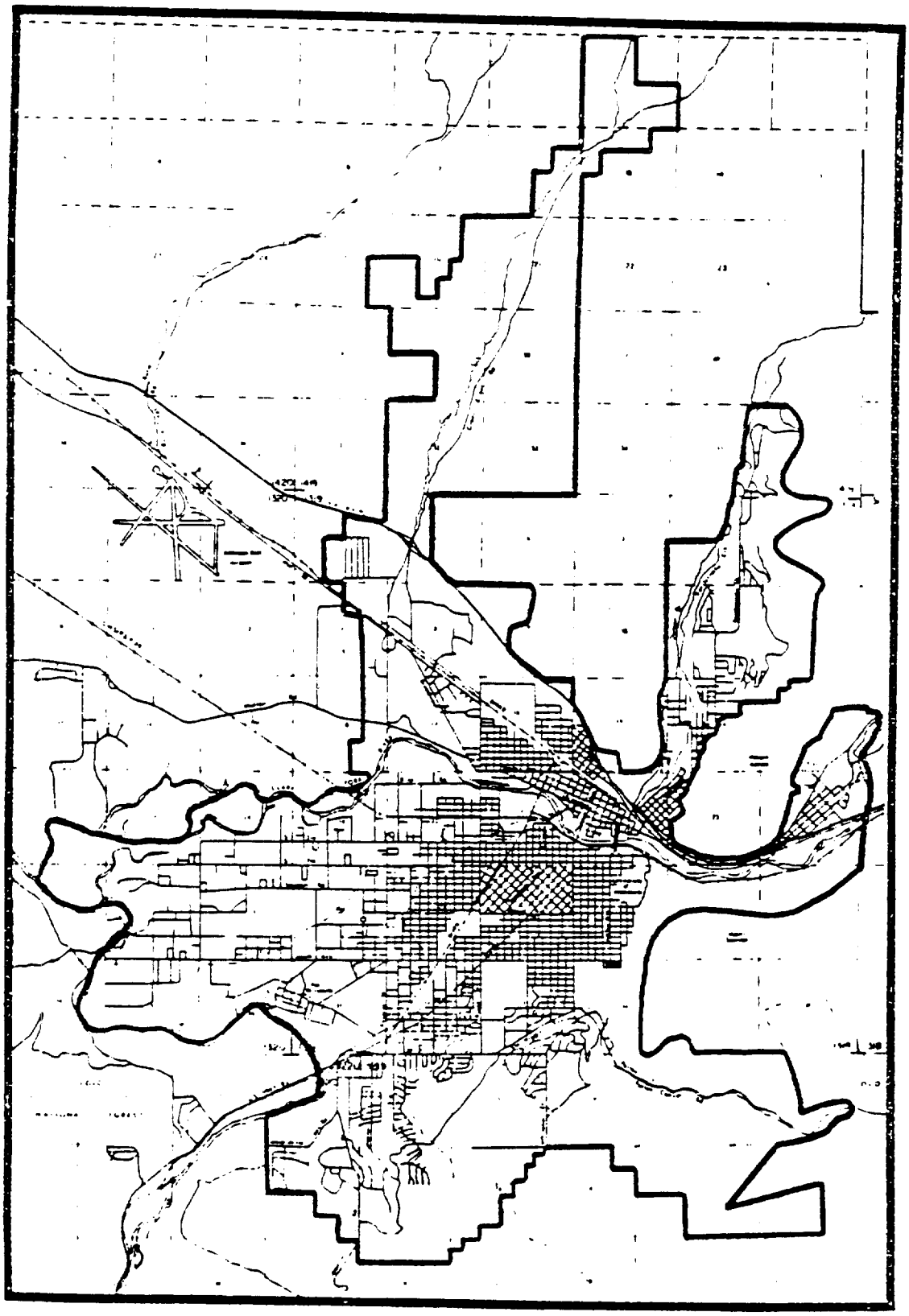
(2) Only those establishments associated with essential services may remain open. Essential services are news media, medically associated services (hospitals, labs, pharmacies), direct food supply (grocery markets, restaurants), police, fire and health officials and their associated establishments. It is expressly in tended that any sevice not defined as essential shall cease all business. Examples given here are not all-inclusive, but are instructive as to identify the general types of business considered non-essential: banks, all offices, laundries, gas stations, barber shops, schools (all levels), repair shops, amusement and recreation facilities, libraries, city, state and federal offices.

(3) Point sources shall cease all manufacturing functions, but they will be allowed to maintain operations necessary to prevent injury to persons or damage to equipment.

History:

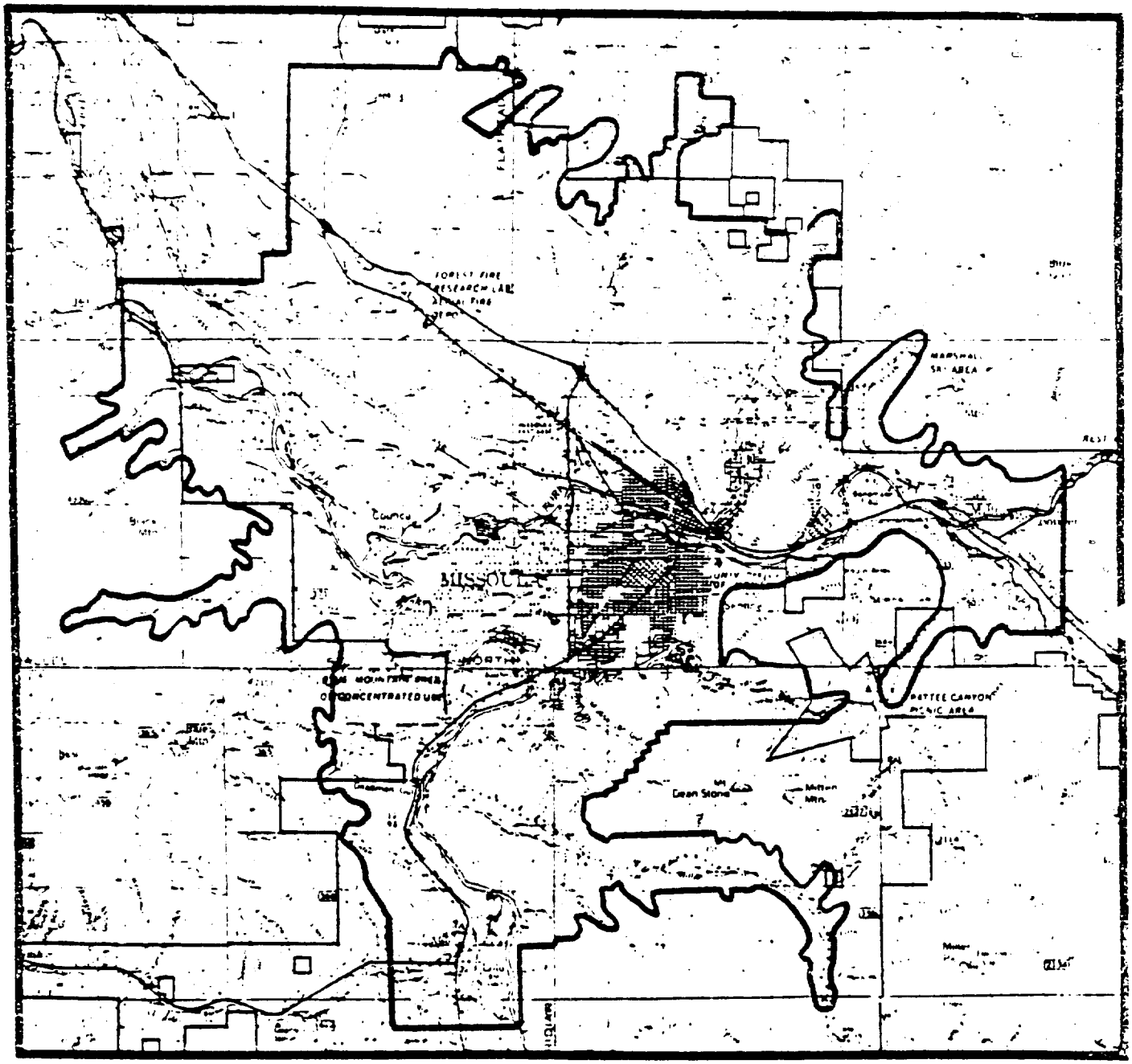
APCB Hearing	8-25-83
APCB Approval	11-10-83
DHES Approval	11-14-83
Co. Commission Approval	11-16-83

ZONE I



HIGH IMPACT AREA/MANDATORY ALERT

ZONE II



AIR STAGNATION ZONE

Section X. 4100 RESIDENTIAL SOLID FUEL BURNING DEVICES

A. The intent of this Section is to regulate and control the emissions of air contaminants from residential solid fuel burning devices in order to further the policy and purpose declared in Section II.

B. DEFINITIONS

1. Air Stagnation Zone: the geographical area designated as such by a map adopted by the Missoula City-County Air Pollution Control Board on September 24, 1981. Attached hereto and by this reference made a part hereof.

2. Burning season: that period of time from the first day of July through the last day of June of the following year.

3. "Class of device" means a group of residential solid fuel buning devices similar in technology utilized, age, heat output, or design which the department determines to be appropriate for the purpose of setting emission rates. These classes include but are not limited to existing woodstoves, fireplaces and wood furnaces.

4. Class I permit is an emissions permit issued by the Department to operate a residential solid fuel burning device during an air pollution Alert and during periods when the air stagnation plan is not in effect. Residential solid fuel burning devices must meet lowest achievable emission rate to qualify for a Class I emissions permit.

5. High Impact Zone: the geographical area designated as such by a map adopted by the Missoula City-County Air Pollution Control Board on August 25, 1983. Attached hereto and by this reference made a part hereof.

6. "Lowest Achievable Emission Rate" means an emission limitation for any one or more of the following: visible emissions, TSP, PM10, CO. This rate shall represent the most stringent limitation achieved in practice by a class of devices as set forth in Section X4100,D.1.b.

7. Residential Solid Fuel Burning Device: any fieplace, fireplace insert, wood stove, woodburning heater, wood stick boiler, coal-fired furnace, coal stove, or similar device burning any solid fuel used for aesthetic, cooking, or space-heating purposes and installed or used in a private residence or commercial establishment, which burns less than 1,000,000 B.T.U.'s per hour.

8. Sole Source of Heat: one or more residential solid fuel burning devices which constitute the only source of heat in a private residence for purpose of space heating. No residential solid fuel burner or burners shall be considered to be the sole source of heat if the private residence is equipped with a permanently installed furnace or heating system, designed to heat the residence connected or disconnected from its energy source, utilizing oil, natural gas, electricity, or propane. A sole source permit may be issued by the department when the heating system is only minimally sufficient to keep the plumbing from freezing. Only residences equipped with a woodstove which qualifies for a Class I Permit may obtain a new sole source of heat permit after July 1, 1985, unless a sole source of heat permit was issued before July 1, 1985, in which case such permit may be renewed.

9. Woodstove means a wood fired appliance with a heat output of less than 40,000 BTU/HR with a closed fire chamber which maintains an air-to-fuel ratio of less than 30 during the burning of 90 percent or more of the fuel mass consumed in a low firing cycle. The low firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn achievable, whichever is greater. Wood fired forced air combustion furnaces that primarily heat living space, through indirect heat transfer using forced air duct work or pressurized water systems are excluded from the definition of "woodstove".

C. VISIBLE EMISSIONS

1. Within the air stagnation zone, no person owning or operating a residential solid fuel burning device shall cause, allow, or discharge emissions from such device which are of an opacity greater than forty (40) percent.

2. The provisions of this subsection shall not apply to emissions during the building of a new fire, for a period or periods aggregating no more than fifteen (15) minutes in any four (4) hour period.

D. EMISSION STANDARDS AND CERTIFICATION FOR NEW INSTALLATIONS

1. Woodstoves.

a. The Board hereby adopts the Oregon Department of Environmental Quality "Standard Method for Measuring the Emissions and Efficiencies of Woodstoves", sections 1 through 8 and O.A.R. Chapter 340, Division 21 Sections 100, 130, 140, 145, 160, 161, 162, 163, 164, 165 as applicable for the sole purpose of establishing a uniform procedure to evaluate the emissions and efficiencies of woodstoves, including criteria for the acceptance of equivalent test methods.

b. The Department may issue a Class I Permit to woodstoves for which a permit application was recieved during the period July 1, 1985 and June 30, 1988 if the emmissions do not exceed six (6) grams per hour weighted average when tested in conformance with X4100 D.1.(a). The Department may issue a Class I Permit to woodstoves for which a permit application was recieved on or after July 1, 1988 if the emissions do not exceed four (4) grams per hour weighted average when tested in conformance with X4100 D.1.(a). In order to qualify for a Class I permit, catalyst equipped woodstoves must be equipped with a permanent provision to accommodate a commercially available temperature sensor which can monitor combustor gas stream temperature within or immediately downstream (within 1.0 inch or 2.5 cm) of the combustor surface.

c. The department shall accept as evidence of compliance with the emission limitation imposed in X4100, D,1,(b), labels affixed to the stove in compliance with OAR 340-21-150 or documentation which, in the opinion of the department, is sufficient to substantiate that the specific model, design, and specifications of the woodstove for which a permit is requested meet standards specified in X4100 D.(a) and (b).

d. Class I permits issued for wood stoves which may be operated during an air pollution Alert shall be valid for a period of two years. They shall not be transferable from person to person or from place to place unless repermitted by the Department. When the permitted device is repermitted , the department may require information to determine if the woodstove is capable of meeting emission

requirements. If an inspection of the appliance during operation is not allowed by the applicant, the department shall require evidence that any non-durable parts (e.g. catalytic combustor) have been replaced as necessary to meet emission limitations set forth in X4100 D.,1.,b. and E.,3.

e. The department shall issue a Class I permit when the applicant has submitted information, on forms supplied by the department, which indicates compliance with Section X4100 D.1, and other applicable provisions of this program.

E. PROHIBITION OF VISIBLE EMISSIONS DURING AIR POLLUTION ALERTS AND WARNINGS

1. Within the high impact zone, no person owning, operating or in control of a residential solid fuel burning device shall cause, allow, or discharge any visible emissions from such device during an air pollution Alert declared by the Department pursuant to Section XII (G) unless a sole source of heat permit, dealer's demonstration permit, special need or Class I permit has been issued for such device pursuant to Section X4100 F.

2. Within the high impact zone, no person owning, operating, or in control of a residential solid fuel burning device for which a sole source of heat permit, dealer's demonstration permit, or special need permit has been issued shall cause, allow, or discharge any emissions from such device which are of an opacity greater than twenty (20) percent during an air pollution Alert declared by the Department pursuant to Section XII (G). The provisions of this paragraph shall not apply to emissions during the building of a new fire or for refueling for a period or periods aggregating no more than twenty (20) minutes in any four (4) hour period.

3. Within the high impact zone, no person owning, operating, or in control of a residential solid fuel burning device for which a Class I Permit has been issued shall cause, allow, or discharge any emissions from such device which are of an opacity greater than ten (10) percent during an air pollution Alert declared by the Department pursuant to Section XII (G). The provisions of this paragraph shall not apply to emissions during the building of a new fire, or for refueling for a period or periods aggregating no more than twenty (20) minutes in any four (4) hour period.

4. For the purposes of this section, the Department shall declare an air pollution alert to be in effect whenever the ambient concentration of total suspended particulate (T.S.P.) within the high impact zone equals or exceeds 150 micrograms per cubic meter (ug/m3) averaged over any eight (8) hour period and when scientific and meteorological data indicate that average TSP concentrations will remain at or above 150 ug/m3 if an Alert is not called. The Department may call an Alert whenever available scientific and meterological data indicate that the ambient concentration of T.S.P. within the high impact zone can reasonably be expected to equal or exceed 150 ug/m3 averaged over an eight (8) hour period within the next 24 hours. When in the opinion of the Department, meterological and scientific data indicate that the particulate measured is not hazardous (e.g., non-respirable), the level may be adjusted.

5. The Department has a duty, when declaring an air pollution Alert to be in effect, to take reasonable steps to publicize that information and to make it reasonably available to the public at least three (3) hours before initiating any enforcement action for a violation of this subsection.

6. Every person operating or in control of a residential solid fuel burning device within the high impact zone has a duty to know when an air pollution Alert has been declared by the Department.

7. Within the high impact zone, no person owning, operating, or in control of a residential solid fuel burning device shall cause, allow, or discharge any visible emissions from such device during an air pollution Warning declared by the Department pursuant to Section XII (H) unless such device has a sole source of heat permit. Within the high impact zone, no person owning, operating, or in control of a residential solid fuel burning device for which a sole source of heat permit has been issued shall cause, allow, or discharge any emission's from such device which are of an opacity greater than twenty(20) percent during an air pollution Warning declared by the Department pursuant to Section XII(H). The provisions of this paragraph shall not apply to emissions during the building of a new fire, for a period or periods aggregating no more than twenty (20) minutes in any four (4) hour period.

F. FUEL

Within Missoula County no person shall burn any material in a residential solid fuel burning device except newspaper, untreated kraft paper, untreated wood and lumber, and products manufactured for the sole purpose of use as fuel. Products manufactured or processed for use as fuels must conform to any other applicable section of this program.

G. PERMITS

1. Within the high impact zone, no person owning, operating, or in physical control of a residential solid fuel burning device which is the sole source of heat shall cause, allow, or discharge any visible emissions from such device during an air pollution Alert declared by the Department unless a sole source of heat permit has been issued for the device by the Department.

2. Within the high impact zone, no person owning, operating, or in physical control of a residential solid fuel burning device which is a demonstration model in an authorized dealer's showroom shall cause, allow, or discharge any visible emissions from such device during an air pollution Alert declared by the Department unless a dealer's demonstration permit has been issued by the Department. (The intent of this subsection is to allow authorized dealers to demonstrate residential solid fuel burning devices during Alerts).

3. Within the high impact zone, no person owning, operating, or in physical control of a residential solid fuel burning device which is eligible for a Class I permit shall cause, allow, or discharge any visible emissions from such device during an air pollution Alert declared by the Department unless a Class I permit has been issued for the device by the Department. The Department shall issue Class I permits to qualified applicants beginning July 1, 1985.

4. Special need permit; Eligibility

(a) A person who demonstrates an economic need to burn solid fuel for residential space heating purposes by qualifying for energy assistance according to economic guidelines established by the U.S. Office of Management and Budget under the low income energy assistance program (L.I.E.A.P.), as administered in Missoula County by the District XI Human Resources Development Council, is

eligible for a special need permit which shall be issued by the Department.

(b) Application for a special need permit may be made to the Department at any time, and a special need permit shall be valid for a period of not more than one (1) year from the date it is issued. Special need permits may be renewed providing the applicant meets the applicable need and economic guidelines at the time of application for renewal. Special need permits shall be issued at no cost to the applicant. A special need permit is not transferable from place to place and is not transferable to a person other than the person to whom it is issued.

(c) A person may apply to the department for a temporary special need or sole source permit if not qualified for a permit under Sections X4100 G.1, 2, 3, 4a. The department may issue a temporary permit if it finds that; the emissions proposed to occur do not constitute a danger to public health or safety; and compliance with the air stagnation plan would produce hardship without equal or greater benefits to the public and; that compliance with the air stagnation plan would create unreasonable economic hardship to the applicant, or render the residence as equipped severely uncomfortable for human habitation, or cause damage to the building or its mechanical or plumbing systems. The Department may place conditions on a temporary permit which are adequate to insure that the permittee is in compliance with the Program when the permit expires. The Department shall arrange for an applicant interview to be conducted within five (5) working days of receipt of a written request for a temporary permit and shall render its decision within ten (10) working days of receipt of the written request. Application to and denial by the Department for a temporary permit shall not prevent the applicant from applying to the Board for a variance under the appropriate provisions of this program. Temporary permits issued pursuant to this section shall be valid for a period determined by the Department, but shall not exceed one (1) year and shall not be renewable.

(d) In an emergency situation the Department may issue a temporary special need permit above to a person who has applied for a special need permit variance pursuant to X4100,G.,5. The temporary special need permit shall be valid until the Board issues a decision on the application for a variance. An emergency situation shall include but is not limited to a situation where a person demonstrates that his furnace or central heating system is inoperable other than through his own actions or the situation where the furnace or central heating system is involuntarily disconnected from its energy source by a public utility or other fuel supplier.

5. A person who demonstrates a special need to burn solid fuel for residential space heating purposes in a private residence but who does not qualify for a sole source of heat permit, dealer demonstration permit, Class I permit, special need permit, or emergency special need permit, may apply to the Board for a special need permit variance under the provisions of Section XIII of this Program. The board shall consider applications for a special need permit variance on a case by case basis and may issue such variance when the criteria in Section XIII (1) are established. The Board shall consider economic hardship and special circumstances when considering an application for a special need permit variance. The Board shall conduct a hearing and issue it's decision on an application for a special need permit variance within thirty (30) days after receiving a written application.

6. Unless otherwise provided in this program, sole source of heat permits, dealers demonstration permits, special need permits, and Class I permits for residential solid fuel burning devices shall be issued, denied, suspended, and revoked, in accordance with Section XI of this Program relating to Operational Permits.

7. Whenever the Department issues a sole source of heat permit, dealer's demonstration permit, special need permit, or Class I Permit the Department shall provide the applicant with the following:

(a) A summary of Section X4100,
(b) Educational materials and/or an instructional session in good wood use techniques, and
(c) A summary of the L.I.E.A.P. guidelines.

H. ENFORCEMENT OF REQUIREMENTS RELATING TO RESIDENTIAL SOLID FUEL BURNING DEVICES

1. Unless otherwise provided in these regulations, the provisions of Sections XIV, XV and XVI, shall govern enforcement of the requirements of Section X 4100 relating to residential solid fuel burning devices and penalties for violations thereof.

2. For a first violation during any one burning season, whenever the Department determines that there are reasonable grounds to believe that a person has violated the provisions of Section X4100, the Department shall issue a written notice of violation and order to take corrective action to the person responsible, as provided in Section XIV (1) of this program. The person to whom a written notice of violation and order to take corrective action is issued under this paragraph shall have the right to request an informal hearing before the Board as provided in Section XIV. For a subsequent violation of the same provision of Section X4100 during the same burning season, the Department may initiate any enforcement action authorized by the Montana Clean Air Act and this Program, but in no event shall such enforcement action result in the imposition of a civil penalty or fine in excess of the amounts provided for in the table below.

TABLE

Maximum civil penalty or fine for subsequent violations of the same provision of Section X4100 during the same burning season after the Department has issued a Notice of Violation and Order to Take Corrective action for a first violation:

Second violation - Twenty Dollars ($20.00)
Third Violation - Fifty Dollars ($50.00)
Fourth or Subsequent Violation - One Hundred Dollars ($100.00).

3. The Department shall not issue any written notice of violation or order to take corrective action, or take any other enforcement action, against any person in violation of the provisions of Section X 4100(E) prohibiting the discharge of any visible emissions, or emissions exceeding the maximum allowable opacity, from a residential solid fuel burning device within the high impact zone during an air pollution Alert declared by the Department, unless the Department has first made the fact that an air pollution Alert has been declared to be in

effect reasonably available to the public for at least three (3) hours prior to initiating enforcement action, as provided in Section X 4100 (E)(4).

4. Whenever the Department issues notice of violation and order to take corrective action to a person for a first violation of any provision of Section X4100 during any one burning season, the Department shall provide such person with the following:

(a) A summary of Section X4100,
(b) Educational materials and/or an instructional session in good wood use techniques, and
(c) A summary of the L.I.E.A.P. guidelines.

5. Anyone against whom an enforcement action is taken by the Department under the provisions of Section X4100 may ask the Department for an administrative review after which the Deparment may rescind, modify, or affirm the enforcement action. A request for an administrative review shall not prevent a person against whom an enforcement action is taken from pursuing any other appeals process provided by this program or by law.

History:

APCB Hearing	10-25-84
APCB Approval	11-8-84
DHES Approval	11-21-84
Co. Commission Approval	11-28-84

COLORADO

PITKIN COUNTY

RESOLUTION OF THE BOARD OF COUNTY

COMMISSIONERS OF PITKIN COUNTY, COLORADO,

ADOPTING VARIOUS LOCAL AMENDMENTS TO

THE UNIFORM BUILDING CODE, 1976 EDITION

Resolution No. 77- 104

State of Oregon
DEPARTMENT OF ENVIRONMENTAL QUALITY
RECEIVED
AIR QUALITY CONTROL

WHEREAS, the Board of County Commissioners desires, for the benefit of the residents of Pitkin County, to adopt various amendments to the 1976 edition of the Uniform Building Code pursuant to the authority and procedures established in C.R.S. 1973, Section 30-28-204,

NOW, THEREFORE, BE IT RESOLVED by the Board of County Commissioners of Pitkin County, Colorado, that the 1976 edition of the Uniform Building Code adopted by this Board's Resolution No. 77-82 with amendments, be further amended, by

1. The addition of Section 3708 to Chapter 37 ("Masonry or Concrete Chimneys, Fireplaces and Barbecues") to read as follows:

Section 3708 Regulation of Number and Construction of Fireplaces

(a) The number of fireplaces that may be constructed is hereby limited to the following:

(1) Single family dwelling...one fireplace per dwelling unit.

(2) Hotel, motel, inn, lodge...one fireplace per lobby or guest entertainment room; no fireplaces in guest rooms.

(3) Restaurant or bar...one fireplace per restaurant or bar or restaurant/bar combined.

(4) Duplex or tri-plex...one fireplace per unit provided that each unit has 1,000 square feet or more of internal heated floor area with no fireplaces in smaller units.

(5) Four-plex and all other multi-family structures ...one fireplace per 3500 square feet of internal heated floor area to be allocated among the units to be constructed.

(b) All fireplaces shall be constructed such that their operation will increase heat energy supplied to the living area in quantities greater than that lost through air exchange during combustion; and, in addition, be constructed in conformance with any design standards that may be promulgated (or

approved) by the County Engineer which are designed to increase heat energy supplied.

(c) The term "fireplace" as used herein includes a conventional masonry fireplace, a prefabricated zero clearance fireplace, and any similar fireplace whose operation requires it to be built into the structure as a component of the building. Radiant room heaters, heating stoves and similar appliances designed for space heating purposes are not included within the definition of "fireplace" and are not subject to the limitations set forth in subparagraph (a) of this subsection.

2. The addition of subsection (h) to Section 7006 ("Grading Permit Requirements") to read as follows:

(h) Other provisions of this Chapter 70 to the contrary notwithstanding, no permit required herein for excavation, grading, and earthwork construction, including fills and embankments, shall issue if the work is to be done in preparation of the construction of improvements or establishment of a use which is not in conformance with all land use regulations of Pitkin County. In the event that the Building Inspector is unable to determine whether a permit shall or shall not issue under the provisions of this section, he shall direct the applicant to supply those plans and specifications described in Section 7006 (c) hereof requiring as additional information thereon all improvements and uses proposed for the site in anticipation of which the excavation, grading, earthwork construction, including fills and embankments, is to be done.

Approved by the Board of County Commissioners at its regular meeting held August 22, 1977.

Michael Kinsley
Chairman

ATTEST:

E G Stewart
Deputy County Clerk

APPROVED AS TO FORM:

PITKIN COUNTY FIREPLACE DESIGN STANDARDS

INTRODUCTION

The common masonry and free standing fireplace used to heat homes, lodges, etc., produce little more than an aesthetic effect since the combustion of wood and other combustible materials in these devices usually results in a net heat loss rather than a heat gain.

The common fireplace that has changed little in its design over the years is totally out of place in an age where fossil fuels are becoming increasingly scarce and where improved insulation has made it possible to heat homes more efficiently to conserve the dwindling fuel supply. A fireplace in a modern home or lodge allows heat to escape in large quantities thereby defeating the purpose of adequate insulation and efficient heating devices.

Heat losses from fireplaces can be divided into four components. These include: heat loss in exhaust gas up the chimney; heat loss due to infiltration of cold air; heat loss from the fire box; and heat loss from the chimney.

The largest amounts of heat are lost in exhaust gasses and infiltration of cold air. Lesser amounts through the fire box and chimney.

DESIGN STANDARDS

There are predominantly three types of fireplaces. These types include the masonry fireplaces, zero clearance and the free standing metal fireplaces with slight variations in all three types.

There are several methods which the designer can employ to reduce heat loss from fireplaces. The following design standards have been adopted to reduce heat loss through the above-mentioned areas:

I. Masonry and Zero Clearance Fireplaces

A. Doors

All masonry and zero clearance fireplaces shall be designed with glass or other fire resistant material doors to prevent room air from being drawn up the chimney. Glass doors also reduce the amount of cold air infiltration.

B. Heat-o-lators

All masonry fireplaces will be designed to accommodate any one of the several types of Heat-o-lators currently available. Heat-o-lators effectively use the heat energy to heat air circulated around the fire box. This heat would otherwise be lost through the fire box.

C. Combustion Air

All masonry fireplaces shall be designed with an air duct that will provide other than room air for combustion. A normal duct size would be approximately 4" in diameter.

D. In addition to the above standards all masonry and zero clearance fireplaces shall meet all building code requirements.

II. Free Standing Fireplaces

Most free standing fireplaces are as inefficient as the masonry fireplace. Some modification that will improve efficiency can be made. Those modifications include:

1. Installation of glass doors
2. Draw combustion air from other than the space being heated.

Because modification is difficult on free standing fireplaces, no free standing fireplace with an efficiency rating of less than 40 per cent will be permitted. If no efficiency rating is available then the above modifications must be completed before the unit is installed.

The above standards are subject to change as technology progresses and new methods become available that will further improve the heating efficiencies of the above mentioned heating units.

RESOLUTION OF THE BOARD OF

COUNTY COMMISSIONERS OF PITKIN COUNTY, COLORADO,

ADOPTING REGULATIONS OF THE INSTALLATION AND

USE OF SOLID FUEL BURNING DEVICES IN THE

MORE DENSELY POPULATED AREAS OF PITKIN COUNTY

Resolution No. 83 - 7

WHEREAS, the Board of County Commissioners believes that the use of fireplaces, wood stoves and other solid fuel burners has contributed to the degradation of air quality within the more densely populated areas of Pitkin County; and

WHEREAS, the Environmental Protection Agency indicates that airtight wood-burning stoves, as commonly operated to heat a home, emit significant amounts of carbon monoxide and particulate matter; and

WHEREAS, the County Commissioners of Pitkin County believe that the number of such solid fuel burners should be limited; and

WHEREAS, residential coal-burning appliances cause significantly more air pollution than other solid fuel burning devices and the County Commissioners wish to prevent coal-burning from becoming a problem now, before significant numbers of people switch from wood-heating to coal; and

WHEREAS, certain zone districts and other areas within Pitkin County involve high densities of human activity where air pollution is or may become a significant problem, it is hereby a finding that the densities allowed in zone districts R-30, R-15, R-6, SR, AF-2, AF-3, AR-1, AR-2 H.D., T, B-1, B-2, I, and PUD; and in all subdivisions in Pitkin County containing lots of less than five (5) acres in size (except those subdivisions zoned RS-160) are sufficiently high and of such a character to require these air pollution restrictions to protect the public health, welfare and safety.

NOW, THEREFORE, BE IT RESOLVED BY THE BOARD OF COUNTY COMMISSIONERS OF PITKIN COUNTY, COLORADO, that Resolution No. 77-104 be amended by changing Section 3708 of Chapter 37 of the Uniform Building Code as adopted by Pitkin County ("Masonary or Concrete Chimneys, Fireplaces and Barbeques") to read as follows:

Section 3708. Regulation of Number and Construction of Solid Fuel Burners.

a. In areas of Pitkin County within zone districts R-30, R-15, R-6, SR, AF-2, AF-3, AR-1, AR-2 H.D., T, B-1, B-2, I, and PMI; and in all subdivisions in Pitkin County containing lots of less than five (5) acres in size (except those subdivisions zoned RS-160); the number of solid fuel burning devices that may be constructed or installed is hereby limited to the followir

(1) Single family dwelling: One solid fuel burning device per dwelling unit.

(2) Hotel, motel, inn, or lodge: One solid fuel burning device per lobby; no such device in guest rooms.

(3) Restaurant or bar: One solid fuel burning device per restaurant or bar or restaurant/bar combined.

(4) Duplex: One solid fuel burning device per unit provided that each unit has 2,000 square feet or more of internal heated floor area. No solid fuel burning devices shall be allowed in units with less than 2,000 square feet of interna heated floor area.

(5) Multi-unit residential and all other structures: One solid fuel burning device per building.

b. Any solid fuel burning device having particulate emissions of less than 0.330×10^{-6} gm/joule of useful heat output, averaged over at least six (6) tests, or no more than 0.65×10^{-6} gm/joule of useful heat output for any single test, shall be exempt from provision (a) of this regulation.

No building permit shall be issued for installation of any solid fuel burning device in any building in Pitkin County in excess of the numbers allowed in section (a), unless the Aspen/Pitkin Environmental Health Department (hereinafter referred to as the Department) has certified that that device has particulate emissions less than those specified above. The Department will so certify any device found to have the required emissions provided tests are conducted by an independent testing lab using the Oregon Method 7 and operating procedures as determined by the Oregon Department of Environmental Quality or an equivalent procedure, as determined by the Department. Tests must be conducted at a low-medium or lower burn rate.

Prior to June 1 of each year, the Department will make public a list of devices known to be certified.

c. All solid fuel burning devices shall be constructed such that their operation will increase heat energy supplied to the living area in quantities greater than that lost through air exchange during combustion; and, in addition, they shall be constructed in conformance with any design standards that may be promulgated (or approved) by the County Engineer which are designed to increase heat energy supplied.

d. The term "solid fuel burning device" as used herein includes but is not limited to a freestanding fireplace, conventional masonary fireplace, a prefabricated zero clearance fireplace, any similar fireplace whose operation requires it to be built into the structure as a component of the building, Franklin stove, airtight stove, fireplace insert, or any other stove or appliance designed to burn solid fuel for heating and/or enjoyment purposes.

e. No solid fuel burning device shall be allowed to burn coal except for those devices already being used to burn coal on December 31, 1982. Operators of such devices shall receive an exemption from this section by applying to the Aspen/Pitkin Environmental Health Department within three months of adoption of this resolution and demonstrating to said Department that this appliance has been used to burn coal in the past for space-heating purposes. Provided, however, that upon the showing of good cause for excusable neglect, an operator can apply for such an exemption after the passage of said three months.

f. Any other provision of this Section 3708 notwithstanding, those areas of Pitkin County within the drainages of the Crystal River and Frying Pan River and any area of Pitkin County not included within the "Aspen Metro Area" as that area is defined in Section 5-510.1(a)(1) of the Land Use Code and the Aspen Area Growth Management Plan shall not be subject to this Section 3708.

APPROVED UPON FIRST READING THIS 13TH DAY OF DECEMBER, 1982, BY THE BOARD OF COUNTY COMMISSIONERS.

APPROVED UPON SECOND READING AND PUBLIC HEARING THIS 24TH DAY OF JANUARY, 1983, BY THE BOARD OF COUNTY COMMISSIONERS

ATTEST:

Lewis Scanlan
Deputy Clerk and Recorder

BOARD OF COUNTY COMMISSIONERS
PITKIN COUNTY, COLORADO

By: George Madsen
George Madsen, Chairman

APPROVED AS TO FORM:

Hesley A. Light
County Attorney

VAIL, COLORADO

ORDINANCE 24

Series of 1983

AN ORDINANCE REPEALING AND REENACTING CHAPTER 28 OF THE VAIL MUNICIPAL CODE RELATING TO SOLID FUEL BURNING DEVICES; PROVIDING CERTAIN DEFINITIONS; REGULATING THE NUMBER AND CONSTRUCTION OF SOLID FUEL BURNERS; REQUIRING HEAT EFFICIENT UNITS; PROHIBITING COAL USAGE.

WHEREAS, the setting of the Town of Vail in a valley between two mountains restricts air movement through the valley;

WHEREAS; the movement of air through the Gore Valley is further restricted in cold times of the year;

WHEREAS, the pollutants in the air caused by solid fuel burning devices have become increasingly worse;

WHEREAS, the Town Council finds that the pollution caused by solid fuel burning devices is exacerbated by the altitude, topography, climate and meteorology of the Town of Vail; and

WHEREAS, the Town Council finds that these sources of air pollution may be minimized by presently-existing, practical and economical technologies.

NOW, THEREFORE, BE IT ORDAINED BY THE TOWN COUNCIL OF THE TOWN OF VAIL, COLORADO, THAT:

Section 1. The Vail Municipal Code is amended by the addition of a new Chapter 8.28 "Air Pollution Control" which reads as follows:

8.28.010 Purpose and Applicability

These regulations are enacted for the purpose of promoting the health, safety, and general welfare of the residents and visitors in the Town of Vail. These regulations are intended to achieve the following more specific purposes:

(1) To protect the air quality in the Town of Vail;

(2) To reverse the trend towards increased air degradation in the Town of Vail;

(3) To provide heat sources that are efficient and have a reduced polluting effect;

(4) And to generally protect the air for the purpose of the public's health, safety and welfare.

The provisions of this Chapter shall apply to all areas of the Town of Vail.

8.28.020 Definitions

(1) Solid Fuel Burner: A fixed apparatus that burns fuel to provide heat, including, but not limited to, a masonry fireplace, prefabricated zero clearance fireplace, freestanding fireplace, Franklin Stove, or air tight stove.

(2) Oregon Method 7: Shall mean tests promulgated by the State of Oregon Department of Environmental Quality in effect on the date of certification as provided herein.

(3) Refuse: Means all solid wastes, garbage and rubbish, whether combustible or noncombustible, including rubble.

(4) Clean Solid Fuel Burning Device: Any solid fuel burning device having particulate emissions of less than 0.33×10^{-6} gm/joule of useful heat output, averaged over at least six tests, or no more than 0.65×10^{-6} gm/joule of useful heat output for any single test.

(5) Any word, term or phrase not hereto defined or specified shall be defined in accordance with Title 18 "Zoning" of the Vail Municipal Code or Title 8 "Health and Safety of the Vail Municipal Code.

Seciton 8.28.030 Solid Fuel Burning Devices

It shall be unlawful for any person to construct, install, maintain or operate any solid fuel burning device within the Town of Vail in a manner not in compliance with this section.

(A) No building permit shall be issued for or including the installation of any solid fuel burning device(s) or component(s) thereof unless the number of such device or devices in each structure is less than or equal to the following:

(1) Each dwelling unit may have one solid fuel burning device per dwelling unit. Reference (C) for exceptions.

(2) A hotel, motel, inn or lodge may have one solid fuel burning device per lobby. Solid fuel burning devices in individual guest rooms, accommodation units and lock-offs are hereby prohibited.

(3) A restaurant or bar may have one solid fuel burning device per restaurant or restaurant/bar combined.

(B) Gas Fireplaces: The restrictions of this Chapter shall not apply to a fireplace fueled by natural gas, propane, or any similar liquid fuel so long as said fireplace is designed and constructed so that said fireplace cannot be used or modified to burn solid fuels. Gas fireplaces shall be permitted in any unit.

(C) Additional Solid Fuel Burning Devices: Each dwelling unit may have two solid fuel burning devices in the following types of combinations: one fireplace and one clean woodburning stove or two clean woodburning stoves.

1. No building permit shall be issued for installation of any clean burning solid fuel burning device in any building of the Town of Vail unless the Vail Environmental Health Officer has first certified in writing that the device has particulate emissions less than or equal to those specified above. The Environmental Health Officer will so certify any device found to have the required emissions provided tests on that brand or class of device are conducted by an approved independent testing using the "Oregon Method 7" and operating procedures as determined by the Oregon Department of Environmental Quality or an equivilant procedure, as determined by the Environmental Health Officer. Tests must be conducted as a low-medium or lower burn rate, as defined by Oregon Method 7". On or before June 1 or each year, the Environmental Health Officer will publish a list of devices known to be certified, which list shall be available for inspection at the Community Development Officer.

2. All solid fuel burning devices shall be constructed, installed, maintained and operated in such a manner that their operation will result in an increase in heating energy, i.e. that the heat supplied to the living area will be greater than that lost through air exchange during combustion.

8.28.040 Coal Usage Prohibited

The burning of coal is hereby prohibited within the Town of Vail.

8.28.050 Refuse Burning Prohibited

The burning of refuse in any solid fuel burning device is hereby prohibited within the Town of Vail.

Section 2. If any part, section, subsection, sentence, clause or phrase of this ordinance is for any reason held to be invalid, such decisions shall not affect the vailidity of the remaining portions of this ordinance; and the Town Council hereby declares it would have passed this ordinance, and each part, section, subsection, sentence, clause or phrase thereof, regardless of the fact that any one or more parts, sections, subsections, sentences, clauses or phrases be declared invalid.

Section 3. The Town Council hereby finds, determines and declares that this ordinance is necessary and proper for the health, safety and welfare of the Town of Vail and the inhabitants thereof.

INTRODUCED, READ AND PASSED ON FIRST READING THIS 5th day of July, 1983, and a public hearing shall be held on this ordinance on the 19th day of July, 1983, at 7:30 p.m. in the Council Chambers of the Vail Municipal Building, Vail, Colorado.

Ordered published in full this 5th day of July, 1983.

Rodney E. Slifer, Mayor

ATTEST:

Pamela A. Brandmeyer
Town Clerk

INTRODUCED, READ AND APPROVED ON SECOND READING AND ORDERED PUBLISHED by title only this 19th day of July, 1983.

Pamela A. Brandmeyer
Town Clerk

BEAVERCREEK, COLORADO

3.12 Environmental Monitoring Function: The Resort Company may monitor air and water quality in Beaver Creek to determine trends, to detect violations of state pollution laws and may control and enforce fireplace construction and utilization pursuant to regulations promulgated by the Resort Company from time to time and in accordance with Declarant's Mountain Development Plan as in effect from time to time, a copy of which shall be kept in the offices of the Resort Company.

3.18 Right To Make Rules and Regulations: The Resort Company shall be authorized to and shall have the power to adopt, amend and enforce rules and regulations applicable within Beaver Creek with respect to any Facility or Function, and to implement the provisions of this Declaration, the Articles of Incorporation or Bylaws of the Resort Company, including but not limited to, rules and regulations to prevent or reduce fire hazard; to prevent disorder and disturbances of the peace; to regulate pedestrian and vehicular traffic; to regulate animals; to regulate signs; to regulate use of any and all Facilities to assure fullest enjoyment of use by the persons entitled to enjoy and use the same ; to promote the general health, safety and welfare of persons within Beaver Creek; and to protect and preserve property and property rights. All rules and regulations adopted by the Resort Company shall be reasonable and shall be uniformly applied, except such rules may differentiate between reasonable categories of Sites, Owners, Leasees, Subowners, or Guests. The Resort Company may provide for enforcement of any such rules and regulations through reasonable and uniformly applied fines and penalties, through exclusion of violators from Facilities or from enjoyment of any Functions, or otherwise. Each Owner, Leasee, Subowner and Guest shall be obligated to and shall comply

with and abide by such rules and regulations and pay such fines or penalties upon failure to comply with or abide by such rules and regulations and such unpaid fines and penalties shall be enforceable in accordance with Section 5.4.

7.2 Land Use Restrictions: In addition to the restrictions found in this Section VII, all or any portion of the Property to be sold or leased by Declarant shall be further restricted in its use, density or design according to one or more Supplemental Declarations of Land Use Restrictions for Beaver Creek recorded with the Clerk and Recorder of Eagle County, Colorado, prior to the time Declarant transfers or conveys any such Property to the Resort Company or to any third party.

7.5 No Noxious or Offensive Activity: No noxious or offensive activity shall be carried on upon any Property nor shall anything be done or placed on any Property which is or may become a nuisance or cause any significant embarrassment, disturbance or annoyance to others.

7.8 No Annoying Lights, Sounds or Odors: No light shall be emitted from any Property which is unreasonably bright or causes unreasonable glare; no sound shall be emitted from any Property which is unreasonably loud or annoying; and no odor shall be emitted from any Property which is noxious or offensive to others.

7.13 Restriction on Fireplaces: Except as permitted in writing by the Review Board there shall be no fireplaces in any Lodge or dwelling unit (as that term is defined in the Master Plan). Each fireplace built shall have an outside air intake and be provided with glass doors at the hearth except as otherwise authorized in writing by the Review Board. No fireplace shall be operated during periods of adverse meterological conditions or adverse air

pollution conditions as determined by the Resort Company. There shall be no fireplaces permitted in any building or structure other than those specifically set forth in this Section 7.13.

PROPOSED

REGULATIONS

REGARDING THE CONTROL

OF

FIREPLACE BURNING

IN

BEAVER CREEK

Pursuant to the authority granted to the Beaver Creek Resort Company in the Amended and Restated General Declaration for Beaver Creek, Eagle County, Colorado, including but not limited to the provisions of paragraphs 3.12, 3.18, 7.2, 7.5, 7.8 and 7.14, and in order to control fireplace burning and to ensure that all owners, subowners and guests of Beaver Creek may enjoy the use of fireplaces without violating the Colorado Air Pollution Control Division's air quality standards, the Board of Directors hereby adopts the following regulations:

I. REGULATION: Every fireplace shall be equipped, at the owner's cost, with a flue temperature switch with a form C contact, wired to the central communication system terminal location within the building. Said switch shall be maintained in working order at owner's expense at all times.

REASON: The flue temperature switch will detect fireplace operation.

II. REGULATION: A red pilot light shall be mounted, at the owner's expense, on or immediately adjacent to each fireplace and wired to the central communication system terminal location within the building. Said pilot light shall be maintained in working order at owner's expense at all times.

REASON: The pilot light will advise the dwelling unit owner, subowner or guest to stop fireplace burning whenever in the Resort Company's opinion, continued burning may violate State Air Pollution Control Division standards.

III. REGULATION: When the fireplace pilot light is activated, the owner, subowner or guest is prohibited from starting a new fire. If the owner, subowner or guest already has a fire burning in his fireplace and the pilot light is activated, the owner, subowner or guest is prohibited from adding fuel to the fire.

REASON: Fireplace pilot lights will be activated when, in the judgment of the Resort Company or the Eagle County Environmental Health Officer or his designated representative, the level of particulate matter concentration in the Beaver Creek Air Shed is in danger of exceeding the State Air Pollution Control Division's allowable concentration.

IV. REGULATION: In the event that a new fire is started in a fireplace while the fireplace pilot light is lighted or an existing fire in a fireplace is not extinguished within three hours of the lighting of the fireplace pilot light, (a) Resort Company personnel may enter the premises in which such fireplace is located and extinguish the fire, and (b) a fine shall be levied against the owner, subowner and/or guest of the dwelling unit or commercial space in which the fireplace is located in accordance with the following schedule:

1st offense	warning
2nd offense	$100
3rd offense	$250
4th offense	$500

REASON: The Resort Company must ensure that the visitors and residents of Beaver Creek may enjoy the use of fireplaces without violating the Colorado Air Pollution Control Division's air quality standards.

V. AMENDMENT: These regulations may be amended at any time by the Resort Company's Board of Directors if such amendment is approved by the Colorado Department of Health.

State of Colorado

RWC Control Measures

An Act

HOUSE BILL NO. 1187.

BY REPRESENTATIVES Paulson, Allison, Bath, Bowen, Brown, Dambman, Dunning, Fenlon, Fleming, Hernandez, Herzog, Knox, Markert, Neale, Reeves, Robb, Skaggs, Taylor, and Wright; also SENATORS Traylor, Glass, and Stewart.

CONCERNING THE CONTROL OF POLLUTION CAUSED BY WOOD STOVE EMISSIONS, INCLUDING EMISSIONS FROM FIREPLACES, AND MAKING AN APPROPRIATION THEREFOR.

Be it enacted by the General Assembly of the State of Colorado:

SECTION 1. Article 7 of title 25, Colorado Revised Statutes, 1982 Repl. Vol., is amended BY THE ADDITION OF A NEW PART to read:

PART 4

CONTROL OF POLLUTION CAUSED BY WOOD SMOKE

25-7-401. Legislative declaration. The general assembly hereby declares that it is in the interest of the state to control, reduce, and prevent air pollution caused by wood smoke. It is therefore the intent of this part 4 to significantly reduce particulate and carbon monoxide emissions caused by burning wood by developing an evaluation and certification program, in the department of health, for the sale of wood stoves in Colorado and by encouraging the air quality control commission to continue efforts to educate the public about the effects of wood smoke and the desirability of achieving reduced wood smoke emissions. The general assembly hereby finds that it is beneficial to the state to implement a program of voluntary no-burn days whenever the air quality control division determines that the anticipated level of wood smoke will or is likely to have an adverse impact on the air quality in any nonattainment area in the state.

Capital letters indicate new material added to existing statutes; dashes through words indicate deletions from existing statutes and such material not part of act.

25-7-402. Definitions. As used in this part 4, unless the context otherwise requires:

(1) "Evaluate" means to review woodburning appliances' emission levels, as determined by an independent testing laboratory, and compare the emission levels to the emission performance standards established by the commission under section 25-7-403.

(2) "Fireplace" means a structure designed for the burning of wood which is an integral part of the construction of a building and which would commonly be considered a fireplace.

(3) "Wood stove" means a wood-fired appliance, including a fireplace insert, with a closed fire chamber which maintains an air-to-fuel ratio of less than thirty during the burning of ninety percent or more of the fuel mass consumed in the low-firing cycle. The low-firing cycle means less than or equal to twenty-five percent of the maximum burn rate achieved with doors closed or the minimum burn rate achievable.

25-7-403. Commission - rule - making. (1) On or before July 1, 1985, the commission shall promulgate rules and regulations to carry out the provisions of this part 4 in conformity with the provisions and procedures specified in article 4 of title 24, C.R.S., and which shall become effective only as provided in said article.

(2) (a) In promulgating such rules and regulations, the commission shall:

(I) Set emission performance standards for new wood stoves;

(II) Establish criteria and procedures for testing new wood stoves for compliance with the emission performance standards;

(III) Prescribe the form and content of the emission performance label to be attached to a new wood stove meeting the emission performance standards;

(IV) Establish procedures for administering the program and for collecting fees for the certification of new wood stoves;

(V) Establish fees for certifying new wood stoves at a level such that said fees reflect the direct and indirect costs of administering the program less any general fund or federal grant moneys appropriated to cover the start-up costs of the program; and

(VI) Establish structural design specifications for fireplaces to minimize emissions.

(b) The moneys collected under this subsection (2) shall be transmitted to the state treasurer, who shall credit the same to the stationary sources control fund established in section 25-7-114 (5) (b). Any moneys not appropriated by the general assembly shall be retained in the stationary sources control fund and shall not revert to the general fund at the end of any fiscal year.

25-7-404. Wood stove testing program established. (1) There is hereby established, in the department of health, an evaluation and certification program for the control of air pollution caused by wood stove emissions, which is designed to significantly reduce particulate and carbon monoxide emissions, referred to in this part 4 as the "program".

(2) The program as implemented by rules and regulations as set forth in section 25-7-403 shall be administered by the air quality control division. The said division shall establish a program that:

(a) Determines whether or not any new wood stove complies with the emission performance standards set by the commission when tested by an independent testing laboratory;

(b) If such new wood stove complies with the emission performance standards, certifies such compliance.

(3) On or after July 1, 1985, a wood stove manufacturer or dealer may request the air quality control division to evaluate the emissions performance of any new wood stove.

(4) A new wood stove may be certified at the conclusion of an evaluation and before January 1, 1987, if:

(a) The air quality control division finds that the emission levels of the new wood stove comply with the emission performance standards established by the commission; and

(b) The wood stove manufacturer or dealer submits the fee established by the executive director of the department of health pursuant to section 25-7-403.

25-7-405. Certification required for sale. (1) On or after January 1, 1987, a person shall not advertise to sell, offer to sell, or sell a new wood stove in Colorado unless:

(a) The particular model of wood stove or the particular configuration of wood stove appliance has been evaluated to determine its emission performance and has been certified by

the air quality control division under the program established under this part 4; and

(b) An emission performance label is attached to the wood stove.

25-7-406. Fireplace design program. The air pollution control division shall establish a program to study the ways that differences in the structural design of fireplaces affect emissions. The objective of this program will be to determine those structural designs of fireplaces which effectively minimize emissions. The division shall conduct performance tests of different fireplace designs to identify those designs that minimize emissions.

25-7-407. Commission to establish design specifications for fireplaces - compliance required. (1) Based on the information supplied by the performance tests conducted by the air pollution control division and on any other relevant information, the commission shall adopt by July 1, 1986, a set of approved design specifications for the building of fireplaces in Colorado.

(2) All fireplaces installed on or after July 1, 1987, in any structure located in the state shall comply with the approved design specifications established by the commission.

25-7-408. Required compliance in building codes. (1) By July 1, 1987, every board of county commissioners of a county which has enacted a building code, and thereafter every board of county commissioners of a county which enacts a building code, shall, pursuant to section 30-28-201 (2), C.R.S., adopt a building code provision requiring any person who constructs any fireplace to comply with the approved design specifications for fireplaces.

(2) By July 1, 1987, every governing body of a municipality which has enacted a building code, and thereafter every governing body of a municipality which enacts a building code, shall, pursuant to section 31-15-601 (2), C.R.S., adopt a building code provision requiring any person who constructs any fireplace to comply with the approved design specifications for fireplaces.

(3) Nothing in this article shall prevent a board of county commissioners or a governing body of a municipality from enacting a building code which requires more stringent standards for wood stoves and for fireplace design.

25-7-409. Voluntary no-burn days. Whenever the air quality control division determines, after investigation, that the level of wood stove emissions anticipated will contribute

adversely or is likely to have an adverse impact on the air quality in any nonattainment area in the state, the commission should implement and announce a program of voluntary no-burn days.

25-7-410. Applicability. The provisions of this part 4 do not apply to a used wood stove and shall not apply to any fireplace constructed prior to July 1, 1987.

SECTION 2. 30-28-201, Colorado Revised Statutes, 1977 Repl. Vol., is amended to read:

30-28-201. Commissioners may adopt - emission standards required. (1) A board of county commissioners is authorized to adopt a building code in all or part of the county, and not embraced within the limits of any incorporated city or town. Such code shall provide for the regulation of the future construction or alteration of dwellings, buildings, and structures, together with plumbing and electrical installations therein or in connection therewith. A structure means a combination of roof and supporting walls and columns. Buildings or structures used for the sole purpose of providing shelter for agricultural implements, farm products, livestock, or poultry may be excepted. The requirements shall be uniform for each class of dwelling, building, or structure. The board of county commissioners may employ qualified technical experts to assist in the preparation of the text of the area building code.

(2) BY JULY 1, 1987, EVERY BOARD OF COUNTY COMMISSIONERS OF A COUNTY WHICH HAS ENACTED A BUILDING CODE, AND THEREAFTER EVERY BOARD OF COUNTY COMMISSIONERS OF A COUNTY WHICH ENACTS A BUILDING CODE, SHALL ENACT A BUILDING CODE PROVISION TO REGULATE THE CONSTRUCTION AND INSTALLATION OF FIREPLACES IN ORDER TO MINIMIZE EMISSION LEVELS. SUCH STANDARDS SHALL BE THE SAME AS OR STRICTER THAN THE APPROVED DESIGN SPECIFICATIONS FOR FIREPLACES ESTABLISHED BY THE AIR QUALITY CONTROL COMMISSION IN THE DEPARTMENT OF HEALTH PURSUANT TO SECTION 25-7-407, C.R.S.

SECTION 3. 31-15-601, Colorado Revised Statutes, 1977 Repl. Vol., is amended BY THE ADDITION OF A NEW SUBSECTION to read:

31-15-601. Building and fire regulations - emission standards required. (2) By July 1, 1987, every governing body of a municipality which has enacted a building code, and thereafter every governing body which enacts a building code, shall enact a building code provision to regulate the construction and installation of fireplaces in order to minimize emission levels. Such standards shall be the same as or stricter than the approved design specifications for

fireplaces established by the air quality control commission in the department of health pursuant to section 25-7-407, C.R.S.

SECTION 4. 25-7-114 (5) (b), Colorado Revised Statutes, 1982 Repl. Vol., is amended to read:

25-7-114. Air pollutant emission notices and emission permits. (5) (b) A single fee shall be charged to any applicant for any indirect source plan or plans submitted to the division at any one time. A permit shall be deemed to run with the land, and a new permit and additional permit fees may be required only when, in the judgment of the commission, plans for the indirect source have been substantially changed. The moneys collected under this subsection (5) AND IN SECTION 25-7-403 shall be remitted to the state treasurer, who shall credit the same to the stationary sources control fund, which fund is hereby created. From such fund the general assembly shall appropriate to the department of health, at least annually, only such moneys as may be necessary to cover the division's costs of processing, administration, and enforcement described in this subsection (5), AND TO COVER THE DIVISION'S COSTS OF DEVELOPING AND MAINTAINING AN EVALUATION AND CERTIFICATION PROGRAM FOR THE CONTROL OF AIR POLLUTION CAUSED BY WOOD STOVE EMISSIONS AND OF DEVELOPING AND MAINTAINING A FIREPLACE DESIGN PROGRAM FOR THE CONTROL OF AIR POLLUTION CAUSED BY FIREPLACE EMISSIONS. Any moneys not appropriated by the general assembly shall be retained in the stationary sources control fund and shall not revert to the general fund at the end of any fiscal year.

SECTION 5. Appropriation. (1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the stationary sources control fund not otherwise appropriated, to the department of health for allocation to the air pollution control division, for the fiscal year commencing July 1, 1984, the sum of forty-nine thousand three hundred twenty-four dollars ($49,324) and 1.0 FTE, or so much thereof as may be necessary, for the purposes of this act.

(2) In addition to any other appropriation, there is hereby appropriated, to the department of health for allocation to the air pollution control division, for the fiscal year commencing July 1, 1984, the sum of seventy-five thousand dollars ($75,000), for the purposes of this act. Such moneys shall be from federal grant moneys.

SECTION 6. Safety clause. The general assembly hereby

finds, determines, and declares that this act is necessary for the immediate preservation of the public peace, health, and safety.

Carl B. Bledsoe
SPEAKER OF THE HOUSE
OF REPRESENTATIVES

Ted L. Strickland
PRESIDENT OF
THE SENATE

Lorraine F. Lombardi
CHIEF CLERK OF THE HOUSE
OF REPRESENTATIVES

Marjorie L. Nielson
SECRETARY OF
THE SENATE

APPROVED April 12, 1984 9:20 pm

Richard D. Lamm
GOVERNOR OF THE STATE OF COLORADO

COLORADO
AIR QUALITY
CONTROL
COMMISSION

DEPARTMENT OF HEALTH
4210 E. 11TH AVENUE
DENVER, COLORADO 80220
(303) 331-8597

NOTICE OF PUBLIC HEARING
TO CONSIDER A NEW REGULATION
OF THE COLORADO AIR QUALITY CONTROL COMMISSION
TO BE HELD BEFORE THE COLORADO AIR QUALITY CONTROL COMMISSION

Notice of Public Hearing:

Pursuant to the notice requirements of Colorado Revised Statute 24-4-103, and 25-7-110 and the Procedural Rules for Activities of the Air Quality Control Commission, hereinafter the "Procedural Rules," and in accord with the notice provisions of 40 CFR 51.4 NOTICE is hereby given that the Colorado Air Quality Control Commission will conduct a public rulemaking hearing at the time and place and on the subject matter set forth in this notice. The proceeding may be continued at such places and times as the Commission may announce.

DATE: May 9, 1985

TIME: 9:30 a.m.

SUBJECT: New Regulation No. 4, "A Regulation Concerning the Sale of New Wood Stoves"

PLACE: Room 412, Colorado Department of Health
4210 East 11th Avenue
Denver, Colorado

Preamble:

The Colorado Air Quality Control Commission will hold a hearing to consider the views of the public regarding the proposed adoption of a New Regulation No. 4 - "A Regulation Concerning the Sale of New Wood Stoves".

The regulation would require that new wood stoves may not be sold, offered for sale, or advertised for sale on or after January 1, 1987 unless stoves meet emission standards for carbon monoxide and particulates.

The regulation would also establish a system for State approval of laboratories qualified to determine whether a stove meets the emission standards. In particular, the regulation would establish the following with regard to the sale of new wood stoves after January 1, 1987: definitions of specific terms; requirements for sale of wood stoves; reciprocal approval agreement; certification procedure; emissions standards; quality control and testing requirements; labeling requirements; independent laboratory accreditation procedures; laboratory inspection procedures and accreditation criteria; enforcement provisions; and a list of certified stoves compiled by the Division. These sections are comprehensive in nature covering all aspects of an approval and certification program for new wood stoves which must be met for any new stove sold after January 1, 1987.

Concern about the increase of residential wood burning has been mounting since the mid-1970's. Recent studies conducted by several investigators have demonstrated the contribution of emissions from woodburning as a significant part of the "Brown Cloud" in the Denver Metropolitan area and in many locations throughout Colorado such as small mountain communities and ski resorts. In addition to the visual impact of emissions from wood stoves is the concern about carbon monoxide and fine particulate emissions each of which has the potential to affect human health.

The Commission, in adopting this proposed regulation for the control of new wood stoves, sees the regulations as a first step in resolving some of the important concerns expressed about air pollution from this source. In addition, the Commission has been advised that stoves meeting the requirements of this regulation may offer a cost incentive to the owners of these stoves through a savings in fuel costs due to greater heating efficiency which will be a consequence of the designs needed in order to meet these emission requirements.

The proposed regulation is attached to and made a part of this Notice for the convenience of the public, and has been published in the Colorado Register of March 10, 1985. Additional copies are available upon request from the Commission's office at the address stated in this notice.

Issues of Particular Concern:

The Commission is especially interested in receiving comments and information from the public on the following issues:

1. Emission Standards - Several questions concerning the standards will be under discussion. These include: should the standard be technology forcing; should there be different standards for catalytic and non-catalytic stoves; what should the units of the standards be (e.g., grams per hour or pounds per million BTU); what is the cost effectiveness of the standards, and should there be a sliding scale for stoves of over 40,000 BTU per hour heat output?

2. Test procedures to be used to determine certification. Comments are especially solicited regarding loading densities to be used in conducting tests. Comments are solicited regarding benefits and/or disadvantages of the Oregon OM-7 vs. the proposed ASTM Testing Methods.

3. Fees to be charged for the administration of the program, including both primary and reciprocal certification and design changes.

4. Control of sales of wood stoves other than through retail and wholesale outlets located in Colorado; (i.e. mail order catalogues, magazine advertisements, direct mail advertisements, etc.

5. Should the label affixed to the wood stove be required to contain the heating efficiency of the particular wood stove.

6. Should the regulation be expanded to include any appliance which can burn solid fuel; i.e., wood, coal, paper logs, etc..

Public Views Encouraged:

The Commission encourages all interested persons to provide their views on the proposed Regulation No. 4, concerning the sale of new wood stoves either in writing by mail, or by making oral comments, or submitting written comments at the hearing. The Commission encourages comments and analyses from persons who will incur directly some cost or receive some benefit from the proposed regulations as well as the participation of the general public.

Persons who wish to submit written comments should mail them to the following person by the date of the hearing:

Mr. Joseph Palomba, Jr., Technical Secretary
Colorado Air Quality Control Commission
4210 East 11th Avenue
Denver, Colorado 80220

For additional information, please call Mr. Palomba at 331-8596.

Authority for the Commission's Actions:

The authority under which the Commission shall hold and conduct said hearing is prescribed by C.R.S. 24-4-103, 25-7-105, -106, -110, and -403, and the hearing will be conducted in accord with provisions of C.R.S. 24-4-103 and 25-7-110, the Procedural Rules, and as otherwise stated in this notice. This list of authority is not intended to be exhaustive. It is furnished for convenience of the public only.

Public Comment:

All persons are encouraged to present their views at this hearing. In the interest and the convenience of the public, the Commission will try to take public testimony beginning as close to 9:30 a.m. on May 9, 1985 as possible, and also from time to time during the remainder of the hearing. (Members of the public are encouraged to call the Commission's office at 331-8597 for information concerning the progress of the hearing). The Commission requests, but does not require, that written copies of expected testimony also be submitted to allow review by Commissioners prior to oral presentation at the hearing. All such written submissions should be mailed to the Technical Secretary, Air Quality Control Commission, at the above-stated address, before the scheduled date for hearing. The Commission expressly reserves the right to limit or exclude unduly repetitious, irrelevant, or incompetent evidence during these proceedings.

Obtaining the Right to Cross-Examination at the Hearing; Pre-hearing Conference:

A. In order to have the right of cross-examination at this hearing, a member of the public will be required to comply with several requirements, as set forth below:

1. As of Right:

Any person proposing a regulation differing from the Commission's regulation shall have the right to cross-examine witnesses if fifteen (15) copies of the differing regulation are filed with the Commission not less than twenty (20) days prior to the hearing (5:00 p.m., April 19, 1985). The differing regulation shall be open for public inspection at the Commission office.

2. In the Commission's Discretion:

The Commission may grant to any person the right of cross-examination if that person has submitted an application requesting that right at least twenty (20) days prior to the hearing (5:00 p.m., April 19, 1985). Such application shall include a description of the person's interest in the hearing, name, address, and telephone number. Applications filed less than twenty (20) days prior to the hearing shall not be considered except upon motion for good cause shown.

3. Pre-hearing Conference:

A pre-hearing conference, if requested, will be held at 9:30 a.m., April 25, 1985, Colorado Department of Health, Bridge Conference Room, 3rd floor, Ptarmigan Building located at 3773 North Cherry Creek Drive (at South Colorado Boulevard), Denver, Colorado. At any such conference, exhibits and pre-hearing statements will be exchanged among the parties (and party applicants) and fifteen (15) copies of each exhibit and statement will be tendered to the Commission. All pre-hearing motions also must be presented at the pre-hearing conference. Persons who have applied for the right of cross-examination twenty (20) days prior to the hearing shall receive written notice if a prehearing conference is requested. Failure to participate in the pre-hearing conference will result in denial of the right of cross-examination.

B. Pursuant to Rule V.E.5. of the Procedural Rules, the Air Pollution Control Division has elected to exercise the right of cross-examination at the hearing.

Delegation of Authority:

For purposes of this hearing, Commissioner Melvyn C. Branch has been designated by the Commission to perform the following functions (under C.R.S. 24-4-103(13), as amended): sign and issue subpoenas, fix the time of filing of documents (other than those described in this notice), approve depositions, and issue appropriate orders.

Wood Stove Subcommittee:

In developing the proposed regulation, the Commission has been assisted by a subcommittee chaired by Commissioner Branch. The subcommittee may convene again prior to the rulemaking hearing. Any person desiring to receive notice of subcommittee meetings may file a request for such notice with Mr. Joseph Palomba, Jr., Technical Secretary, Air Quality Control Commission, 4210 East 11th Avenue, Denver, Colorado 80220.

When the record will close and availability of proceedings:

The record of these proceedings may, at the discretion of the Commission, remain open for up to ten (10) days after the scheduled hearing is adjourned. The Commission will consider and make a part of that record all evidence, sworn testimony, and written submissions on the aforementioned regulations presented at these public hearings as well as any related matters properly submitted before the record of these proceedings is closed. A full and complete transcript of the proceedings shall be made and a copy thereof will be available to any person making request and paying the reporter's fee therefor. In addition, the Commission may make a reasonable charge to supply copies of any written submission or other material related to these hearings.

Minutes of general meetings and other records of the Air Quality Control Commission are always available for public inspection during the hours of 8:30 a.m. to 5:00 p.m., Monday through Friday, (holidays excepted) in the office of the Technical Secretary, Colorado Air Quality Control Commission, located in the West Tower, 3rd floor of the Ptarmigan Building, 3773 North Cherry Creek Drive (at South Colorado Boulevard), Denver, Colorado.

The Commission shall deliberate upon the evidence and testimony collected at these hearings and reach a determination with all deliberate speed and in accord with the spirit and directives of the Colorado Air Quality Control Act.

COLORADO AIR QUALITY CONTROL COMMISSION

Joseph Palomba, Jr., Technical Secretary

DATED: February 28, 1985

PROPOSED

NEW REGULATION NO. 4

WOOD STOVE REGULATION

Colorado Air Quality Control Commission

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PROPOSED

REGULATION ON SALE OF NEW WOODSTOVES

I. DEFINITIONS

A. Unless otherwise required by the context, as used in this regulation:

1. "Accredited laboratory" means an independent testing laboratory which has obtained either primary accreditation or reciprocal accredation.

2. "Catalyst-equipped wood stove" means a wood stove with a catalytic combustor that is an integral component of the stove.

3. "Certified wood stove" means a wood stove which is a unit of a wood stove model, or which contains a configuration of appliance, for which either primary certification or reciprocal certification has been granted.

4. "Dealer" means a person who sells wood stoves on a regular basis.

5. "Fixed air supply" means an air supply system on a wood stove which has no adjustable or controllable air inlets.

6. "Heat output" means the amount of heat in BTU per hour generated by a wood stove during one test run.

7. "Manufacturer" means a person who constructs a wood stove or parts for wood stoves.

8. "Model" means a group of wood stoves which are identical to one another regarding design, emissions, and heating performance.

9. "New wood stove" means any wood stove other than one which has been previously sold to an individual for his personal use.

10. "Standard method" means the applicable testing procedures and criteria set forth in "Standard Methods for Measuring the Emissions and Efficiencies of Residential Wood Stoves," set forth in Appendix A.

11. "Wood stove" means a wood-fired appliance, including a fireplace insert, with a closed fire chamber which

maintains an air-to-fuel ratio of less than 30 during the burning of 90 percent or more of the fuel mass consumed in the low-firing cycle. The low-firing cycle means less than or equal to 25 percent of the maximum burn rate achieved with doors closed or the minimum burn rate achievable.

II. REQUIREMENTS FOR SALE OF WOOD STOVES

A. On or after January 1, 1987, no person shall advertise to sell, offer to sell, or sell a new wood stove unless it is a certified wood stove that meets the requirements of section VI. at the time it is sold.

B. Following the certification of a wood stove no person shall alter the emissions plate or the compliance certificate submitted to the Division as part of an application for certification.

III. RECIPROCAL APPROVAL AGREEMENT

A. The Division may enter into a reciprocal approval agreement with another state, provided the Division determines that the other state has established a program regulating the sale of wood stoves which is at least as stringent as the program established by this regulation.

B. The reciprocal approval agreement shall include, but not be limited to, the following provisions:

1. The Division shall consider the other state's approval for sale of a wood stove as evidence that the stove should be certified.

2. The Division shall consider the other state's approval of the use of test results produced by a laboratory as evidence that the laboratory should be accredited.

3. The other state shall establish a procedure for notifying the Division of any suspension or revocation of its approval for sale of a wood stove, and of any design changes in wood stoves subject to the other state's regulatory program.

IV. CERTIFICATION PROCEDURE

A. On or after July 1, 1985 a dealer or manufacturer may apply to the Division for primary certification or reciprocal certification of a wood stove model or appliance configuration.

B. An application for primary certification shall include the following:

1. An appliance description which includes the wood stove model name and design number, a copy of the stove's operating manual and a photograph of the stove;

2. Design plans of the wood stove, identified by design number, which include overall dimensions of the stove and all dimensions and specifications of components critical to emissions control and heating efficiency. These components shall include combustion chamber configurations, all air inlet controls, heat exchanger design and make and model numbers of applicable purchased parts.

3. Either a proof copy of the emissions plate printed on a representative sample of the plate stock, or a proof copy of the plate and a sample of the plate stock. The copy submitted shall show all information required pursuant to section VI.

4. A proof copy of the compliance certificate containing all information required on the certificate pursuant to section VI;

5. All test data and support documentation showing that the wood stove has been tested in accordance with section V and that it meets the emissions performance standards of that section;

6. A drawing, diagram or photograph that identifies the location of the emissions plate on the wood stove.

C. An application for reciprocal certification shall contain documentation demonstrating that the applicant's wood stove has been approved for sale by another state with which the Division has a reciprocal approval agreement. The application shall contain the information required by section IV.B. for an application for primary certification, except that the data required by section IV.B.5 may be summarized rather than submitted in total.

D. Within 20 working days after receipt of an application for primary certification or reciprocal certification, the Division shall notify the applicant if the application is complete. Within 40 working days after receipt of a complete application for primary certification, or within 15 working days after receipt of a complete application for reciprocal certification,

the Division shall notify the applicant whether the application satisfies all requirements for certification other than the payment of a certification fee, and of the amount of the fee required pursuant to section IV.F. If all other requirements have been met, the Division shall issue a certificate granting certification upon receipt of the fee.

E. The Division shall grant certification if:

1. The applicant submits all information required by section IV.B or section IV.C., as applicable, and that information demonstrates that the wood stove model or configuration of appliance meets the requirements of this regulation; and

2. The applicant pays the fee required pursuant to section IV.F.

F. Applicants for certification shall pay a fee to the Division at a rate of $ 64.00 per hour for each hour of Division staff time spent evaluating an application. The applicant shall pay the fee regardless of whether his application is withdrawn, denied or approved. No certification shall be granted until the certification fee is received by the Division.

G. If the Division denies certification, the Division shall notify the applicant in writing of the opportunity for a hearing before the Commission pursuant to section 24-4-104(9), C.R.S. (1982).

V. EMISSIONS STANDARDS, QUALITY CONTROL AND TESTING

A. No new wood stove with a minimum heat output of 40,000 BTU per hour or less shall be advertised for sale, offered for sale, or sold, on or after January 1, 1987, unless the stove does not exceed the following weighted average particulate or carbon monoxide emissions standards:

1. Wood stoves that are not catalyst equipped shall emit less than 9 grams per hour of particulates and less than 150 grams per hour of carbon monoxide when the stove is tested prior to certification.

2. Catalyst equipped wood stoves shall either

(a) Emit less than 4 grams per hour of particulates and less than 50 grams per hour of carbon monoxide when they are tested prior to certification, or

(b) Emit, during the usable life of the stove, an average of less than 9 grams per hour of particulates and an average of less than 150 grams per hour of carbon monoxide.

B. No new wood stove with a minimum heat output of more than 40,000 BTU per hour shall be advertised for sale, offered for sale, or sold on or after January 1, 1987, unless the stove does not exceed a weighted average particulate emission standard equal to the sum of 8 grams per hour plus 0.2 grams per hour for each 1,000 BTU per hour heat output.

C. The weighted average shall be calculated by initially determining the unweighted average in accord with the applicable standard methods, and then applying the following equation:

$$\bar{E} = \frac{K_1E_1 + K_2 E_2 + K_3E_3 \ldots + K_nE_n}{K_1 + K_2 + K_3 \ldots + K_n} \qquad \text{(EQN. 1)}$$

where: $\bar{E}$ is the weighted average particulate or carbon monoxide emission rate in grams per hour; $E_1, E_2, E_3, \ldots E_n$ are the unweighted emission rates from test runs 1 through n in order of increasing heat output, and K_1, K_2, K_3, $\ldots K_n$ are the weighting factors for test runs 1 through n. The weighting factors(K_i) are calculated as follows:

$$K_i = P_{i+1} - P_{i-1}$$

where P_i is the cumulative probability from table 1 for the heat output measured during each test run, $P_o=0$. and $P_{n+1}=1$

.

If the cumulative probability for a given heat output is not stated in table 1, the probability shall be interpolated from that table.

TABLE 1

CUMULATIVE PROBABILITY FOR A GIVEN HEAT OUTPUT DEMAND BASED ON COLORADO CLIMATE (POPULATION WEIGHTED)

Heat Output (BTU/hour)	Cumulative Probability (P)
0	0.0510
525	0.0584
1050	0.0655
1575	0.0731
2100	0.0815
2625	0.0902
3150	0.1014
3675	0.1111
4200	0.1224
4725	0.1344
5250	0.1459
5775	0.1615
6300	0.1746
6825	0.1892
7350	0.2044
7875	0.2193
8400	0.2401
8925	0.2571
9450	0.2765
9975	0.2954
10,500	0.3145
11,025	0.3384
11,550	0.3598
12,075	0.3826
12,600	0.4063
13,125	0.4269
13,650	0.4544
14,175	0.4777
14,700	0.5027
15,225	0.5277
15,750	0.5512
16,275	0.5812
16,800	0.6071
17,325	0.6328
17,850	0.6619
18,375	0.6849

18,900	0.7156
19,425	0.7384
19,950	0.7626
20,475	0.7838
21,000	0.8023
21,525	0.8239
22,050	0.8404
22,575	0.8556
23,100	0.8699
23,625	0.8823
24,150	0.8961
24,675	0.9058
25,200	0.9152
25,725	0.9233
26,250	0.9305
26,775	0.9381
27,500	0.9440
27,825	0.9497
28,350	0.9550
28,875	0.9591
29,400	0.9635
29,925	0.9674
30,450	0.9707
30,975	0.9741
31,500	0.9770
32,025	0.9800
32,550	0.9826
33,075	0.9846
33,600	0.9866
34,125	0.9883
34,650	0.9900
35,175	0.9914
35,700	0.9925
36,225	0.9936
36,750	0.9946
37,275	0.9958
37,800	0.9964
38,325	0.9971
38,850	0.9976
39,375	0.9981
39,000	0.9984
40,425	0.9986
40.950	0.9988
41,475	0.9990
42,000	0.9991
42,325	0.9993
43,050	0.9994
43,575	0.9994

44,100	0.9995
44,625	0.9996
45,150	0.9997
45,675	0.9997
46,200	0.9998
46,725	0.9998
47,250	0.9999
47,775	1.0000
48,300	1.0000

D. The weighted average net efficiency referred to in section VI.E.3. shall be calculated using EQN 1 above where: $\bar{E}$ is the weighted average net efficiency in percent and $E_1, E_2, E_3, \ldots E_n$ are the unweighted efficiencies from test runs 1 through n in order of increasing heat output, and K_1, K_2, K_3, $\ldots K_n$ are the weighting factors for test runs 1 through n. The weighting factors K_i are calculated as follows:

$$K_i = P_{i+1} - P_{i-1}$$

where P_i is the cumulative probability from table 1 for the heat output measured during each test run, $P_o = 0$, and $P_{n+1} = 1$

If the cumulative probability for a given heat output is not stated in table 1, the probability shall be interpolated from that table.

E. To ensure quality control for a certified wood stove model or appliance configuration, it shall be a condition of certification that the manufacturer of the model of configuration is inspected at least twice per year by representatives of an ac-

credited laboratory and that such inspections demonstrate that units of the wood stove model or appliance configuration are constructed in accord with the requirements of this regulation. Such inspections shall be performed without notice to the manufacturer, and the results of such inspections shall be reported to the Division within 90 days.

F. All testing required by this regulation shall be conducted by an accredited laboratory.

G. All testing required by this regulation shall be performed in strict conformance with the applicable standard method, unless, prior to the commencement of such testing, the Division has approved in writing a minor variation from the applicable standard method, on the grounds that the variation will not affect the accuracy of the testing.

VI. LABELING REQUIREMENTS

A. On or after January 1, 1987 no person shall advertise to sell, offer to sell, or sell a new wood stove without a label, composed of the emissions plate and the compliance certificate described in this section. The emissions plate shall be affixed to the stove. The compliance certificate shall be affixed either to the stove or to a carton containing the stove.

B. The emissions plate shall contain the following information:

1. Name of testing laboratory;

2. Date that wood stove model or appliance configuration was tested;

3. Test procedure used;

4. Name of manufacturer;

5. Name of model;

6. Design number of model;

7. The following statement: "Performance may vary from test values depending on actual home operating conditions."

8. A graph meeting the following specifications --

a. The graph shall show the unweighted par-

ticulate emissions rate, in grams per hour, and the unweighted net efficiency, over the range of heat outputs tested.

b. The axes of the graph shall be labeled as follows:

(i) Vertical axis, left side: "Smoke-grams/hour," with a scale of 0 to 20, bottom to top.

(ii) Vertical axis, right side: "Efficiency-percent," with a scale of 50 to 90, bottom to top.

(iii) Horizontal axis, bottom: "Heat output-BTU/hour," with a scale from 0 to a maximum of 5,000 BTU per hour higher than the highest tested heat output.

c. Curves describing unweighted emissions and net efficiency at various heat outputs shall be printed on the graph, and shall be developed by the testing laboratory as follows:

(i) The emissions curve shall be developed by fitting the particulate emissions test data to a least squares multiple regression for the following second degree polynomial:

$$y = a_o + a_1 x + a_2 x^2$$

where; y = unweighted particulate emissions (grams/hour)
x = heat output (Btu/hour)
a_o, a_1, a_2 = regression coefficients

(ii) The net efficiency curve shall be developed by fitting the efficiency test data to a least squares multiple regression for the following second degree polynomial:

$$y = a_o + a_1 x + a_2 x^2$$

where; y = unweighted net efficiency (%)
x = heat output (Btu/hour)
a_o, a_1, a_2 = regression coefficients

(iii) For wood stoves with a fixed air supply which have only two data points for particulate emissions and two data points for net efficiency, the testing laboratory shall develop the particulate emissions curve by connecting the emissions data points with a straight line, and the net efficiency performance curve by connecting the two efficiency data points with a straight line.

d. The curves shall be developed and fit onto the graph by the testing laboratory and transmitted to the wood stove manufacturer for printing on the emissions plate.

C. The emissions plate shall be:

1. Permanent, so that it cannot be removed from the wood stove without damage to the plate;

2. Made of aluminum, brass, galvanized steel, or other metal, and of a thickness that will ensure the permanence of the plate;

3. Riveted, screwed, bolted, or otherwise permanently secured to the stove;

4. Legible, and shall contain information which has been applied by etching, silk screening, die stamping or some other process which ensures legibility;

5. Located on any visible exterior surface except the bottom of the stove, or on any interior surface of the stove if the plate can be seen after installation of the stove.

D. The emissions plate shall be at least 3 1/2 inches long by 2 inches wide. The graph on the plate shall be at least 3 inches long by 1 1/2 inches wide and any enlargement of the graph shall maintain a length to width ratio of 2:1. The emissions plate may be combined with another label, such as a safety label, if the design and integrity of the emissions plate is not compromised, and if the combination label is approved in writing by the Division.

E. The compliance certificate shall contain the following information:

1. "Smoke (Avg.) ___ grams/hour," weighted average of tested values;

2. "Carbon monoxide (Avg.) ___ grams/hour," weighted average of tested values;

3. "Efficiency (Avg.) ___ %," weighted average of tested values;

4. A statement of the applicable emissions standards;

5. The heat output range of the stove and the values at which the stove was tested;

6. Name of manufacturer;

7. Name of model;

8. Design number of model;

9. A statement that the wood stove has been certified;

10. The following statement: "Performance may vary from test values depending on actual home operating conditions."

F. The information to be placed in the compliance certificate shall be developed by the testing laboratory, and transmitted to the manufacturer, who shall then print the compliance certificate. The compliance certificate may not be combined with any other information, and shall be given to the purchaser of the wood stove.

VII. CHANGES IN WOOD STOVE FROM STOVES TESTED FOR CERTIFICATION

A. Where primary certification has been granted for a wood stove model or configuration of appliance, individual stoves of that model or configuration shall not be considered certified if their construction or design differs in any way from that of the stoves tested by an accredited laboratory for the purpose of obtaining certification, unless Division approval is obtained through the following procedure:

1. Prior to implementing any modification in the design or construction of any model or configuration of appliance, the manufacturer shall inform an accredited laboratory of the proposed modification. The laboratory shall then inform the Division in writing whether the proposed modification would affect the emissions rate of the model or configuration, and of the basis for its conclusion. The Division shall review the laboratory's conclusion, and within 15 working days of receipt thereof shall notify the laboratory and the manufacturer in writing whether the Division has determined that the modification may affect the emissions rate.

2. If the Division determines that the modification will not affect the emissions rate, that determination shall constitute approval of the sale of the wood stove with the modification.

3. If the Division determines that the modification may affect the emissions rate, it shall also prescribe additional tests which the laboratory must perform on the wood stove with the modification. The laboratory shall report the test results to the Division, and the Division shall assess the wood stove manufacturer a fee of $ 64.00 for each hour of Division staff time spent evaluating the results. The manufacturer shall pay the fee regardless of whether the Division approves or disapproves sale of the wood stove as modified.

4. Within 15 working days after receipt of the results of the tests, the Division shall notify the manufacturer and the laboratory whether it approves of the sale of the wood stove with the proposed modification. The wood stove, with the modification, shall be considered certified only if approval is granted.

B. Where reciprocal certification has been granted for a wood stove model or configuration of appliance, individual stoves of that model or configuration shall not be considered certified if their construction or design differs in any way from that of the stoves originally approved by the state with which the Division has a reciprocal approval agreement, unless the state has notified the Division in writing that it has approved of the sale of the stoves as modified.

VIII. LABORATORY ACCREDITATION PROCEDURES

A. A laboratory may apply to the Division for primary accreditation or reciprocal accreditation.

B. The following procedures shall apply to applications for reciprocal accreditation:

1. An application for reciprocal accreditation shall contain the following --

a. A brief description of the organization, facilities, and personnel structure of the applicant;

b. Documentation demonstrating that a state with which the Division has a reciprocal approval agreement has approved the use of test results produced by the applicant as a means of complying with the state program regulating the sale of wood stoves.

2. Within 20 working days after receipt of a complete application for reciprocal accreditation the Division shall

notify the applicant whether reciprocal accreditation has been granted or denied. If it is granted, the Division shall issue to the applicant a certificate of reciprocal accreditation, which shall remain valid as long as the applicant is considered an approved laboratory for wood stove testing by the state with which the Division has a reciprocal approval agreement.

C. The following procedures shall apply to applications for primary accreditation:

1. An application for primary accreditation shall contain all information necessary to demonstrate that the applicant complies with the criteria of section X.

2. Within 20 working days after receipt of an application, the Division shall inform the applicant whether the application is complete, and, if is not, of the deficiencies in the application. An application shall be considered withdrawn if the deficiencies have not been eliminated within 90 days after the Division issues its completeness determination.

3. Within 30 days after the submission of a complete application, the Division shall conduct an on-site inspection of the laboratory pursuant to section IX.

4. Within 30 days after the Division has completed the on-site inspection and received all data required to be submitted pursuant to section IX., the Division shall notify the applicant of any facts or conditions which indicate that the applicant does not meet the criteria for accreditation of section X.

5. Within 30 days after receipt of the notification issued by the Division pursuant to section VIII.C.4., the applicant shall inform the Division in writing of any measures it has taken to correct any deficiencies noted by the Division. The Division may then conduct further on-site inspections, and require the performance of additional tests at the laboratory, to determine whether the corrective action necessary for the granting of accredation has been performed.

6. The Division shall determine whether to grant or deny accreditation based on the criteria set forth in section X. If accreditation is granted, the Division shall issue a certificate of primary accreditation to the applicant. Each certificate of primary accreditation shall be valid for three years.

D. During each three-year period that a laboratory holds a certificate of primary accreditation, the Division shall audit

test at least one stove tested by the laboratory to verify the laboratory's test results. The Division shall notify the laboratory of any errors or deficiencies in testing indicated by the audit test. The laboratory shall then inform the Division in writing within 30 days of the measures it has taken to correct the errors or deficiencies. Failure to correct the deficiencies shall be grounds for revocation of accreditation.

E. A laboratory may voluntarily terminate its accreditation by written request at any time. The laboratory shall return the certificate of accreditation with the request.

IX. LABORATORY INSPECTION

A. Following the submission of a complete application for primary accreditation, the Division shall inspect the applicant's laboratory.

B. During the inspection, a representative of the Division shall:

1. Observe the testing demonstration required by section IX.C., and discuss test procedures with laboratory personnel;

2. Meet with management and supervisory personnel responsible for wood stove testing;

3. Review representative samples of laboratory records, including records related to the competence of each laboratory staff member who performs wood stove testing. The applicant shall furnish the Division with a list of the names of all such staff members.

4. Examine selected equipment and apparatuses;

5. Discuss with laboratory personnel, at the end of the inspection, any deficiencies in the laboratory's procedures or operations.

C. During each inspection, laboratory personnel shall perform a wood stove emissions rate and heating efficiency test, in accord with the requirements of the standard methods, on a stove furnished by the Division. The applicant for accreditation shall pay the costs for stove shipping and for catalytic combustors or other required parts. The applicant shall submit the test results and observations to the Division, for the purpose of enabling the Division to evaluate the applicant's ability

to perform tests and report test results in accord with this regulation.

X. ACCREDITATION CRITERIA

A. A laboratory shall meet the criteria and standards of subsections B through J of this section in order to obtain primary accreditation, and shall continue to meet these criteria and standards as a condition of maintaining such accreditation.

B. The laboratory shall be an independent third-party testing organization with no financial, organizational, or managerial affiliation with any manufacturer or dealer, in accord with the following:

1. No officer, director, stockholder, or employee of the laboratory shall be engaged in the sale or manufacture of wood stoves, nor shall any such person hold any financial interest in, or be employed by, any manufacturer or dealer.

2. The laboratory shall not be engaged in the promotion or design of any wood stove which it tests.

3. The laboratory shall have a diverse group of clients, or shall be engaged in activities other than wood stove testing, to the extent necessary to demonstrate that the loss or award of a specific contract for testing would not be a determinative factor in the financial well being of the laboratory.

4. The employment security of laboratory personnel shall not be subject to the influence of any manufacturer or dealer.

C. The laboratory shall be operated in accord with generally accepted professional and ethical standards, including, but not limited to, the following:

1. The laboratory shall accurately report values that reflect measured data.

2. The laboratory shall undertake only testing which it is competent to perform.

3. The laboratory shall immediately respond to, and attempt to resolve, any complaint it receives from the Division regarding testing results.

D. The laboratory shall employ personnel competent to

perform the testing for which accreditation is sought. On an annual basis, the laboratory shall require each of its employees who performs wood stove testing to pass an examination on testing procedures, or to perform satisfactorily the work for which he is normally responsible, while being observed by supervisory or managerial personnel. The laboratory shall also develop a program to train new employees in proper testing procedures, and shall make available to the Division a written description of that program.

E. The laboratory shall employ field inspectors who are adequately trained to perform the quality control inspections required for certification by section V.E. Such inspectors shall be trained to make selections of materials for testing from manufacturers' stock or from distributors' establishments, and to evaluate manufacturers' quality control records to ascertain with reasonable certainty that the manufacturer is complying with this regulation.

F. The laboratory shall hold a registered certification mark from the United States Patent Office and shall agree to authorize the use of that mark by manufacturers as evidence of compliance with this regulation.

G. The laboratory shall be equipped with the instrumentation and equipment necessary to perform tests in accord with the requirements of this regulation.

H. The laboratory shall maintain complete, readily accessible records of the following items:

1. For each piece of measuring equipment, the instrument name and description, name of manufacturer, model, style and serial number, specifications on range or level of precision, date and manner of calibration, and maintenance record;

2. Samples of raw and reduced data sheets, a test report format, a statement as to whether data is recorded manually or by automation;

3. The dates on, and manner in which, staff were trained, and the dates and results of all testing procedure examinations or observations of staff performance;

4. For each calibration or verification of a piece of equipment, the name and description of the equipment, model, style, serial number, name of manufacturer, notation of all equipment variables requiring calibration or verification, range

of calibration or verification, resolution of the instrument and allowable error tolerances, calibration/verification date and schedule, date and result of last calibration or verification, name of laboratory personnel or outside agency responsible for calibration or verification, source or reference standard, and traceability;

5. For each wood stove tested, a description of the stove, including the model name and design number; a copy of the stove's operating manual; a photograph of the stove; design plans, identified by design number, showing the overall dimensions and specifications of components critical to emissions control and heating performance, including combustion chamber configurations, air inlet controls, heat exchanger design, and make and model numbers of applicable purchased parts; documentation of all modifications to the model or appliance configuration initially tested; and all test data and results, including emissions rate and heating efficiency calculations.

6. Sample tracking and logging records tracing the movement of each wood stove through the laboratory from its receipt through all tests performed to the final test report, including information on the dates of test performance, condition of the stove, and the names of laboratory personnel performing the tests.

I. The laboratory shall develop and follow a laboratory quality control manual setting forth procedures consistent with those required by the standard methods. The manual shall be readily available to laboratory personnel and shall be made available to the Division.

J. The laboratory shall maintain an emissions rate and heating efficiency computer program that produces results similar to those calculated by the Division using a standard data set provided by the Division.

K. Reciprocal accreditation shall be granted for a laboratory if a state with which the Division has a reciprocal approval agreement has approved the use of test results produced by the laboratory as a means of complying with the state program regulating the sale of wood stoves. Such accreditation shall remain valid as long as the approval of the other state remains in force.

XI. ENFORCEMENT

A. The Division may enter and inspect the property or

premises of any manufacturer, dealer or accredited laboratory, for the purpose of investigating any actual, suspected, or potential violation of this regulation; and may, at reasonable times, have access to and copy any document, inspect any wood stove, wood stove component, or testing equipment, or test the emissions of any wood stove, possessed by any manufacturer, dealer, or accredited laboratory, for the purpose of ascertaining compliance or noncompliance with this regulation. Refusal by a laboratory to permit the Division to conduct an inspection at any reasonable time shall constitute grounds for revocation of accreditation. Refusal by a manufacturer or dealer to permit the Division to conduct an inspection at any reasonable time shall constitute grounds for revocation of the model or configuration of appliance manufactured or sold by the manufacturer or dealer.

B. The Division may revoke the certification of a wood stove model or configuration of appliance if testing to support certification was conducted at a laboratory which was not in compliance with the accreditation criteria of section IX.

C. The Division may revoke the accreditation of any laboratory which has violated the accreditation criteria of section IX.

D. Following revocation of accreditation or certification, the person to whom a certificate of accreditation or certification was issued shall return the certificate to the Division. In any correspondence, advertising, or test results, the laboratory shall then cease referring to itself as being accredited, and the person who formerly held a certificate for a wood stove model or configuration of appliance shall cease referring to the model or configuration as being certified.

E. The Division shall also enforce the provisions of this regulation through all means authorized by Part 1 of Title 25, C.R.S.

XII. LIST OF CERTIFIED WOOD STOVES.

Each dealer shall make available to consumers a current list of certified wood stoves. The list shall be compiled by the Division and distributed to dealers.

Note: Appendix A to this Proposal New Regulation No. 4 is the same as the Appendix To Oregon's "Draft Rules for Woodstove Certification", which appears earlier in this Appendix.

ALASKA

Presented by: The Manager
Introduced: 05/7/84
Drafted by: J.R.C.

ORDINANCE OF THE CITY AND BOROUGH OF JUNEAU, ALASKA

Serial No. 84-30

AN ORDINANCE AMENDING THE WOODSMOKE CODE TO REGULATE THE BURNING OF SOLID FUEL, IMPOSE AREAWIDE RESTRICTIONS ON OPEN BURNING AND SMOKE DENSITY, AND DECLARE A MORATORIUM ON THE INSTALLATION OF SOLID FUEL-FIRED HEATING DEVICES IN THE MENDENHALL VALLEY.

* Section 1. Classification. This ordinance is of a general and permanent nature and shall become a part of the city and borough code.

* Section 2. Amendment of Chapter. Chapter 36.40 of the Code of the City and Borough of Juneau is amended to read:

Chapter 36.40

SOLID FUEL-FIRED BURNING DEVICES

36.40.010 FINDINGS. The Assembly of the City and Borough of Juneau finds that there has been a significant and unprecedented increase in the installation and use of solid fuel-fired heating devices in the city and borough; that the increase in such installations and use in the Mendenhall Valley has been especially great; that such devices generally produce a high level of harmful airborne pollutants; and that the above conditions combined with atmospheric conditions throughout the municipality and other factors cause recurring smoke pollution conditions which are detrimental to the health of, and offensive to, the people of Juneau. It is the purpose of this chapter to reduce the increase of airborne pollutants from open burning and from solid fuel-fired heating devices at the times and in the areas of the city and borough that appear to be most adversely affected by such pollutants.

36.40.020 SMOKE HAZARD AREA MAP ADOPTED. There is adopted as the map identifying the smoke hazard area of the City and Borough of Juneau that map entitled, "Smoke Hazard Area Map, City and Borough of Juneau, Alaska," dated September 12, 1983.

36.40.030 DEFINITIONS. As used in this chapter, the following words and phrases have the meanings indicated:

(a) "Solid fuel-fired heating device" means a device designed for solid fuel combustion so that usable heat is derived for the interior of a building, and includes solid fuel-fired stoves, fireplaces, solid fuel-fired cooking stoves, and combination fuel furnaces or boilers which burn solid fuel.

(b) "Open burning" means the burning of a material which results in the products of combustion being emitted directly into the ambient air without passing through a stack or flue, but not including the burning of campfires, barbeques, candles, or tobacco.

(c) "Person" means an individual, partnership, corporation, company or other association.

36.40.040 SOLID FUEL SMOKE EMISSION STANDARDS. (a) No person may operate a solid fuel-fired heating device in such a manner that visible emissions reduce visibility through the exhaust effluent by fifty percent or greater for more than fifteen minutes in any one hour as determined by a test conducted in substantial compliance with the regulations applicable to the visual determination of stationary source emission opacity promulgated at 40 CFR 60, Appendix A by the United States Environmental Protection Agency; provided, and notwithstanding any contrary provisions in the regulation, opacity observation shall be made at the point of greatest opacity in any portion of the emissions plume without regard to the presence or absence of condensed water vapor.

(b) No person may engage in the open burning of material in a smoke hazard area between November 1st and March 31st.

(c) No person may engage in the open burning of material outside a smoke hazard area between November 1st and March 31st without first obtaining a permit to be issued by the manager or his designee upon a finding that weather conditions or smoke conditions are not such as to be, or are likely to become, any danger to the public health or to become generally objectionable. Such determination may be based upon reports or information from the United States Weather Service or other weather reporting service or upon the report or recommendation of the Alaska Department of Environmental Conservation or the United States Environmental Protection Agency.

36.40.050 SOLID FUEL PROHIBITION. (a) Upon notification by the manager that a smoke hazard condition exists within a smoke hazard area, no person may burn solid fuel in any manner whether within or outside of any solid fuel-fired heating device after the time stated in the notice as the time after which all solid fuel burning must cease.

(b) Notice is adequate if published in a newspaper of general circulation within the city and borough, or if given orally at least three times during a six-hour period by a least two radio stations operating within the city and borough, or if made available to the general public in the form of a recorded telephone message the telephone number for which is published in a telephone directory or newspaper of general circulation within the city and borough. The prohibition shall be effective from the earlier of the time stated in the notice, six p.m. of the day the notice is published in a newspaper, the time the last required announcement of the notice is given by radio, or two hours after the time the recorded message is first made available by telephone.

(c) The manager or his designee shall give notice under this section upon a determination that weather conditions or smoke conditions within the smoke hazard area are such as to be, or are likely to become, any danger to the health of persons within the smoke hazard area or to become generally objectionable to such persons. Such determination may be based upon reports or information from the United States Weather Service or other weather reporting service or upon the report or recommendation of the Alaska Department of Environmental Conservation or the United States Environmental Protection Agency.

(d) Any person owning a building for which, on November 5, 1983, a solid fuel-fired heating device was the sole source of heat may apply to the manager for an exemption from the provisions of this section. Such exemption shall expire no later than January 1, 1986 and may not be renewed.

36.40.060 PENALTIES. For the first violation of any section of this chapter a fine of not more than three hundred dollars may be imposed. For any violation of this chapter following conviction of a prior violation under this chapter a penalty not to exceed five hundred dollars or thirty days in jail or both may be imposed.

Adopted this 21st day of May, 1984.

Mayor

Attest:

Clerk

Presented by: The Manager
Introduced: 04/02/84
Drafted by: J.R.C.

ORDINANCE OF THE CITY AND BOROUGH OF JUNEAU, ALASKA

Serial No. 84-18

AN ORDINANCE AMENDING THE BUILDING CODE TO REQUIRE MINIMUM RESIDENTIAL HEATING FACILITIES OF A TYPE NOT INVOLVING THE COMBUSTION OF SOLID FUELS.

* Section 1. Classification. This ordinance is of a general and permanent nature and shall become a part of the city and borough code.

* Section 2. Amendment of Section. CBJ 19.11.010(9) is renumbered as subsection (10), subsequent subsections are renumbered accordingly, and a new subsection (9) is added reading:

(9) In section 1211 delete the existing language and substitute new language reading:

"Section 1211. Every dwelling unit and guest room shall be provided with heating facilities, capable of maintaining a room temperature of 70° Fahrenheit at a point three feet above the floor in all habitable rooms without involving the combustion of a solid fuel."

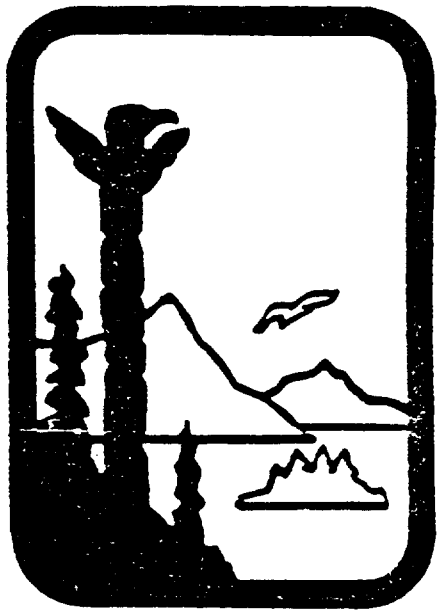
Adopted this 16th day of April, 1984.

Mayor

Attest:

Clerk

ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION



STATE AIR QUALITY CONTROL PLAN

VOLUME II: ANALYSIS OF PROBLEMS, CONTROL ACTIONS

Revised 1983

G. WOOD SMOKE POLLUTION CONTROL

1. Problem Description

Use of residential wood-fired heating devices has been demonstrated to cause air quality problems in locales where atmospheric ventilation is low, wood use per capita is high and the populations density is moderate to high. State and federal 24-hour standards for total suspended particulate matter (TSP) have been exceeded several times in portions of the Mendenhall Valley of Juneau.

Although TSP is the pollutant of primary concern, a potential for exceeding the eight-hour carbon monoxide standard does exist when particulate exposure is significantly above the health standard.

Wood use and hence wood smoke occurs in a large number of cities and communities throughout Alaska. However, climatic conditions are usually sufficient to disperse the pollution from the area. Although the Juneau area is presently the only known location to exhibit unhealthful air quality due to wood burning, this pollution problem will most likely increase in portions of the state where wood resources are plentiful.

Administrative procedures to maintain ambient air quality standards in locations where emissions from residential wood burning activities threaten public health are outlined in the following pages of this section.

2. Problem Assessment and Initial Control

The Department will install and operate air quality monitors in locations where wood smoke pollution is considered significant. If measured exposures approach or exceed the ambient standards, the relative impacts of all local activities will be assessed towards their respective contribution to the ambient exposure. If exposures are anticipated to reach or exceed the air quality alert value of 375 micrograms per cubic meter (ug/m^3) [see 18 AAC 50.610(a)(1)(B)], the Department will issue an air quality alert and enforce the requirements of 18 AAC 50.085(1). Additional air quality alerts will be issued when similar atmospheric and wood stove use conditions recur that may cause exposures above the ambient air quality standards.

Should exposures reach or exceed 150 ug/m^3 when wood smoke pollution is considered to be the major contributor, additional chemical analysis, approved chemical mass balance techniques and receptor models will be utilized to discern the actual impact of all local sources to the ambient exposure.

3. Local Government

Wood smoke pollution problems tend to be very characteristic of specific conditions such as frequency and severity of air stagnations, local terrain features, seasonal and daily wood use patterns, and type and quantity of wood and wood-burning appliances.

Because of these factors, adverse air quality conditions are best managed by the local government entities. The Department will assist communities in the development of appropriate and adequate air quality management plans. Volume III of this document contains the ordinance 83-63 of the City and Borough of Juneau.

4. Designation of Wood Smoke Control Areas

Specific locations based upon natural airshed boundaries may be designated as Wood Smoke Control Areas, allowing enforcement of stricter standards. Upon designation, the requirements of 18 AAC 50.085(3) are implemented. Boundaries for designated areas shall be defined as the natural, physical boundaries which establish the airshed or a portion of the airshed if sufficient technical information warrants designation of the smaller area. Additional control strategies to curb the existing and future emission quantities may also be needed. These additional strategies are best defined and implemented by local government. However, they can be developed and implemented by the Department.

Prior to designation as a Wood Smoke Control Area, two requirements must be met:

- Ambient exposures of TSP from residential wood-burning activities alone must have reached or exceeded 150 ug/m^3 on a minimum of two separate days using the analytical techniques outlined above in (2);
- The proposed designation requires a public notice and comment period.

5. Boundaries of Designated Wood Smoke Control Areas

Designated Wood Smoke Control areas include the Mendenhall Valley of Juneau, which is described as the area located between the terminus of the Mendenhall Glacier and the tidewaters of Gastineau Channel and Fritz Cove. This area is bounded on the east by the 500-foot elevation contour of Heintzleman Ridge, (Thunder Mountain and contiguous foothills), extending south from the Mendenhall Glacier to a point directly north of the eastern terminus of the runway for the Juneau International Airport. The western border of the area is defined as the northern border of Section (S) 6, Township (T) 40S, Range (R) 66E of the Copper River Medidian (CRM) beginning at its northeast corner and heading westerly to the northwest corner of S1, T 40S, R65E, CRM (approximately beginning at the 500-foot level of the Mendenhall West Glacier Trail and heading 2 miles directly west) and thence southerly along the western borders of Section 24 (a north-south line from the approximate southwest base of Mount McGinnis along the east side of Auke Lake to approximately 0.3 mile east southest of the southern shore of Auke Lake). At this point, the boundary is described be a westerly heading along the northern border of S26, T40S, R65E, CRM to a location directly north of the knoll named Pederson Hill. A direct southerly heading forms the described position through the top of Pederson Hill to the tidewaters of Fritz Cove serves as the final portion of the western boundary (boundary essentially divides the Mendenhall Peninsula along the north-south ridge line).

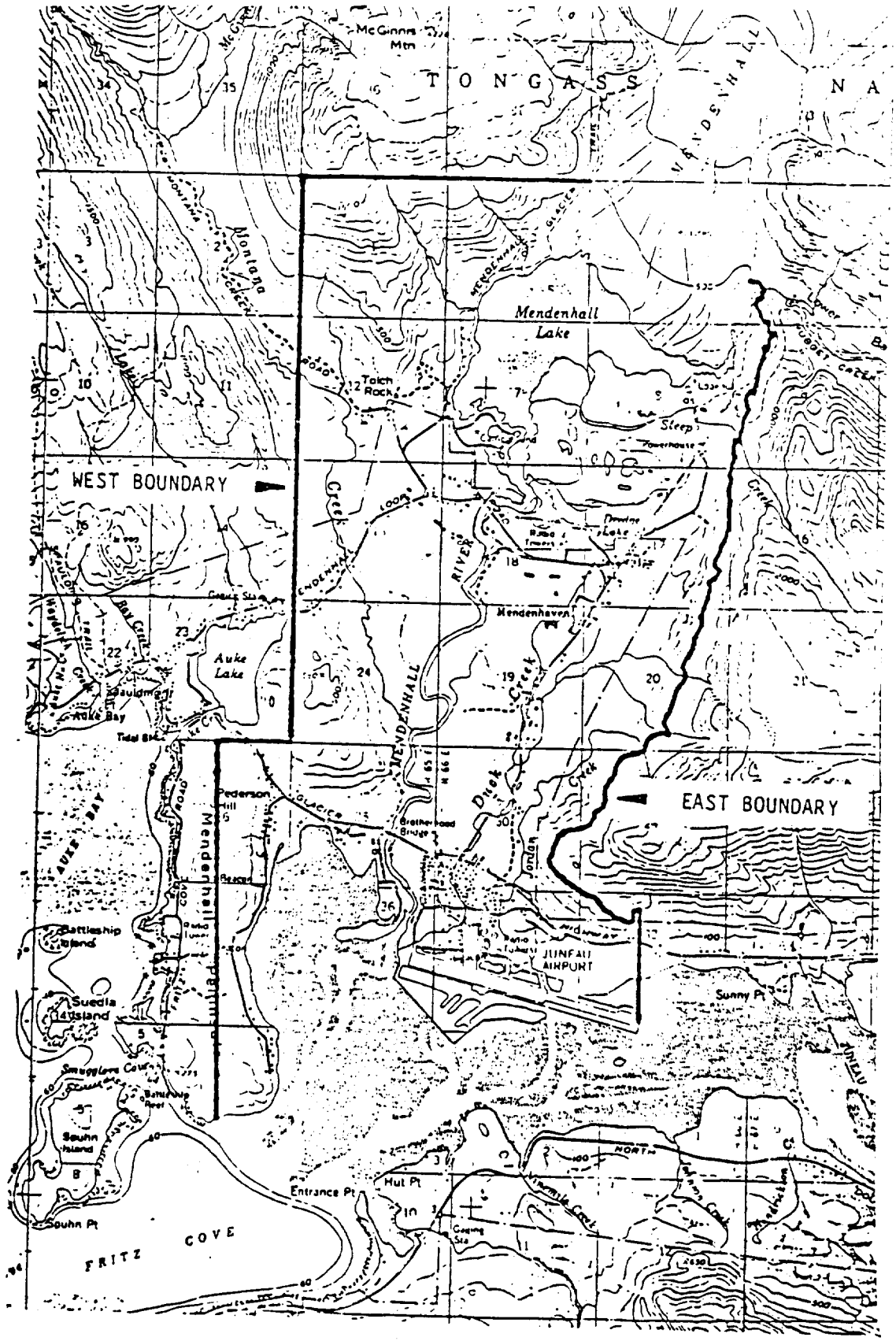


Figure III. G-1

MENDENHALL VALLEY WOOD SMOKE CONTROL AREA

AIR QUALITY CONTROL REGULATIONS 18 AAC 50



STATE OF ALASKA DEPARTMENT OF ENVIRONMENTAL CONSERVATION

18-3000 (REV. OCT. 1993)

TITLE 18. ENVIRONMENTAL CONSERVATION

CHAPTER 50. AIR QUALITY CONTROL

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CHAPTER 50. AIR QUALITY CONTROL.

ARTICLE 1. PROGRAM STANDARDS AND LIMITATIONS.

Section

10. Applicability of local government regulations
20. Ambient air quality standards
21. State air quality classifications
30. Open burning
40. Incinerators
50. Industrial processes and fuel burning equipment
60. Pulp mills
70. Motor vehicle emissions
80. Repealed
85. Wood-fired heating devices
90. Ice fog limitations
100. Marine vessels
110. Air pollution prohibited
120. Repealed
130. Repealed
140. Repealed
150. Repealed
160. Repealed
170. Repealed
180. Repealed
190. Repealed

18 AAC 50.010. APPLICABILITY OF LOCAL GOVERNMENT REGULATIONS. A local air quality control agency may establish the same or more stringent regulations, but not less stringent regulations, as the applicable regulations specified in this chapter. (Eff. 5/26/72, Register 42)

Authority: AS 46.03.020(10)(A)
AS 46.03.140

18 AAC 50.020. AMBIENT AIR QUALITY STANDARDS. (a) The concentrations of contaminants in the ambient air, corrected to standard conditions, may not exceed the following:

(1) suspended particulate matter --

(A) annual geometric mean of 60 micrograms per cubic meter; or

(B) 24-hour average of 150 micrograms per cubic meter more than once each year;

(2) sulfur oxides, measured as sulfur dioxide --

(A) annual arithmetic mean of 80 micrograms per cubic meter;

(B) 24-hour average of 365 micrograms per cubic meter more than once each year; or

(B) that portion of Bering Sea National Wildlife Refuge designated as a National Wilderness Area;

(C) that portion of Simeonof National Wildlife Refuge designated as a National Wilderness Area; and

(D) that portion of Tuxedni National Wildlife Refuge designated as a National Wilderness Area;

(2) those areas of the state not classified in (a) of this section, or (1) or (3) of this subsection are classified as Class II; and

(3) no areas in the state have been classified as Class III.

(c) For purposes of preventing impairment of visibility, the designated areas are

(1) Mt. Deborah and the Alaska Range East, as viewed from approximately the Savage River Campground area;

(2) Mt. McKinley, Alaska Range, and the Interior Lowlands, as viewed from the vicinity of Wonder Lake; and

(3) the Class I areas listed in (b)(1) of this section.

(d) For purposes of maintaining the ambient air quality standards set out in 18 AAC 50.020(a), the Mendenhall Valley of Juneau is a wood smoke control area. (Eff. 5/4/80, Register 74; am 11/1/82, Register 84; am 10/30/83, Register 88)

Authority: AS 46.03.010
AS 46.03.020(10)(A)
AS 46.03.140
AS 46.03.150

Editor's note: A complete description of the boundaries of the areas listed in 18 AAC 50.021 is in the state Air Quality Control Plan, as amended through November 1, 1983, which may be reviewed at the central office of the department, and is incorporated by reference as part of this chapter by 18 AAC 50.620.

18 AAC 50.060. PULP MILLS. Average emissions per ton of pulp produced from a sulfite pulp mill may not exceed in any 24-hour period

(1) 20 pounds of sulfur oxides (expressed as sulfur dioxide) from blow pits, washer vents, storage tanks, digester relief systems, and recovery systems; and

(2) two pounds of particulate matter from blow pits, washer vents, storage tanks, digester relief systems, and recovery systems. (Eff. 5/26/72, Register 42; am 11/1/82, Register 84)

Authority: AS 46.03.020(10)(A)
AS 46.03.160

18 AAC 50.070. MOTOR VEHICLE EMISSIONS. (a) Emissions from gasoline-powered motor vehicles, excluding condensed water vapor, may not be visible for more than any five consecutive seconds.

(b) Visible emissions from diesel powered motor vehicles, excluding condensed water vapor, may not result in a reduction of visibility of greater than 40 percent through the exhaust effluent for more than any five consecutive seconds. (Eff. 5/26/72, Reg. 42; am 5/4/80, Reg. 74)

Authority: AS 46.03.020(10)(A)
AS 46.03.140
AS 46.03.150

18 AAC 50.085. WOOD-FIRED HEATING DEVICES. For wood-fired heating devices

(1) when an air quality alert is issued under 18 AAC 50.610(a)(1)(B) for particulate matter within a specific area, except areas set out in (3) of this section, visible emissions at the point of release to the atmosphere may not reduce visibility through the exhaust effluent by 50 percent or greater for more than 15 minutes in any one hour;

(2) burning in a way that creates black smoke is prohibited; and

(3) for wood smoke control areas identified in 18 AAC 50.021(d)

(A) visible emissions at the point of release to the atmosphere may not reduce visibility through the exhaust effluent by 50 percent or greater for more than 15 minutes in any one hour; and

(B) when an air emergency has been issued under 18 AAC 50.610 (a)(3)(D), no person may operate, permit, or allow the operation of a wood-fired heating device which results in the emission of smoke. (Eff. 11/1/82, Register 84; am 10/30/83, Register 88)

Authority: AS 46.03.020(10)(A)
AS 46.03.140

(h) If an area of the state is proposed for reclassification

(1) by the department, the data specified in (b) of this section will be made available to the public at the time of public notice; the requirements of (c), (d), (e), and (f) of this section will be followed in acting on reclassifications; or

(2) by a private individual or organization without the resources to submit a complete petition under (b) of this section, the department will provide technical and coordinative assistance to ensure every reasonable opportunity for full evaluation of the proposed reclassification.
(Eff. 5/4/80, Register 74; am 11/1/82, Register 84)

Authority: AS 46.03.010
AS 46.03.020(10)(A)
AS 46.03.140
AS 46.03.150

18 AAC 50.610. AIR EPISODES. (a) An air episode will be declared when, in the opinion of the commissioner, the concentration of air contaminants in the ambient air has reached or is predicted to reach any of the following:

(1) for an air alert:

(A) sulfur dioxide - 800 micrograms per cubic meter (24 hour average);

(B) particulate matter - 375 micrograms per cubic meter (24 hour average);

(C) carbon monoxide - 17 milligrams per cubic meter (eight hour average); and

(D) particulate matter generated from wood-burning activities within wood smoke control areas - 150 micrograms per cubic meter (24-hour average);

(2) for an air warning:

(A) sulfur dioxide - 1600 micrograms per cubic meter (24 hour average);

(B) particulate matter - 625 micrograms per cubic meter (24 hour average); and

(C) carbon monoxide - 34 milligrams per cubic meter (eight hour average); and

(3) for an air emergency

(A) sulfur dioxide - 2,100 micrograms per cubic meter (24 hour average);

(B) particulate matter - 875 micrograms per cubic meter (24 hour average);

(C) carbon monoxide - 46 milligrams per cubic meter (eight hour average).

(B) particulate matter generated from wood-burning activities within wood smoke control areas - 260 micrograms per cubic meter (24-hour average).

(b) The commissioner will prescribe and publicize curtailment actions when a level of air contaminants in (a) of this section is about to be reached. (Eff. 5/4/80, Register 74; am 10/30/83, Register 88)

Authority: AS 46.03.020(10)(A)
AS 46.03.820

Editor's note: The substance of this section was contained in 18 AAC 50.140, which was repealed 5/4/80, Reg. 74.

18 AAC 50.620. AIR QUALITY CONTROL PLAN. The documents and procedures referred to in 18 AAC 50.021, 18 AAC 50.500, and 18 AAC 50.510 are included in volumes II and III of the Air Quality Control Plan. These volumes of the plan, as amended through November 1, 1983, for implementing and enforcing this chapter, may be reviewed at the central office of the department and are incorporated by reference as part of this chapter. (Eff. 5/4/80, Register 74; am 11/1/82, Register 84; am 10/30/83, Register 88)

Authority: AS 46.03.020(10)(A)
AS 46.03.140

Editor's note: The substance of this section was contained in 18 AAC 50.170, which was repealed 5/4/80, Register 74.

(32) "particulate matter" means a material except water which is, or has been, airborne and exists as a liquid or a solid at standard conditions;

(33) "petroleum refinery" means a facility engaged in the distillation of petroleum or redistillation, cracking, or reforming of unfinished petroleum derivatives;

(34) "ppm" means parts per million;

(35) "practical means available" means, when approving the open burning of liquid hydrocarbons produced during oil or gas well testing, that all alternative disposal methods will have been analyzed, and where an environmentally acceptable procedure exists, it will be required;

(36) "putrescible garbage" means a material capable of being decomposed with sufficient rapidity to cause nuisance or obnoxious odors;

(37) "reconstruct" means to make equipment or process changes for which the capital cost exceeds 50 percent of the fixed capital cost of a comparable new source or facility;

(38) "reduction of visibility" means the obscuring of an observer's vision;

(39) "regional supervisor" means the supervisor of the department's regional office located at Juneau, Anchorage, or Fairbanks;

(40) "regulated air pollutant" means an air pollutant regulated under the Clean Air Act (P.L. 91-604) as amended August 7, 1977 (P.L. 95-95);

(41) "smolder" means to burn and smoke without flame;

(42) "source" means a structure, building, installation, or other part of a facility which emits or may emit a regulated air pollutant;

(43) "stack" means a chimney or conduit installed after air pollution control equipment through which air or air contaminants are emitted into the environment;

(44) "standard conditions" means a dry gas at a temperature of 70 degrees Fahrenheit and a reference pressure of 14.7 pounds per square inch;

(45) "tpy" means tons per year;

(46) "ug/m^3" means micrograms per cubic meter of ambient air;

(47) "wood-fired heating device" means a device designed for wood combustion so that usable heat is derived for the interior of a building, and includes wood-fired stoves, fireplaces, wood-fired cooking stoves, and combination fuel furnaces or boilers which burn wood; and

(48) "wood smoke control area" means a geographic location within the state where wood-burning activities have resulted in a minimum of two individual 24-hour periods when ambient exposures of total suspended particulate matter solely from this activity have reached or exceeded 150 micrograms per cubic meter of air. (Eff. 5/4/80, Register 74; am 11/1/82, Register 84; am 10/30/83, Register 88)

Authority: AS 46.03.010
AS 46.03.020(10)(A)
AS 46.03.140
AS 46.03.150
AS 46.03.160
AS 46.03.170
AS 46.03.710
AS 46.03.820

Editor's note: The substance of this section was contained in 18 AAC 50.190, which was repealed 5/4/80, Register 74.

RENO, NEVADA



DISTRICT HEALTH DEPARTMENT

EMERGENCY EPISODE PLAN

050.000 PURPOSE

The purposes of the following Sections are:

A. To advise persons with respiratory or cardiac problems of air pollution levels which may be harmful to their health; and

B. To initiate corrective control measures to prevent build-up of air contaminants to levels which would cause significant harm to a significant portion of the population in the Washoe County Health District.

050.002 HEALTH ADVISORY

Prior to declaring a Stage 1 (Alert) episode as outlined in Section 050.005 the Control Officer may initiate a Health Advisory whenever the pollutant concentrations reach 80% of that required to declare a Stage 1 episode. The purpose of this advisory is to serve as advance notice to the public that an unhealthful pollutant level is expected and it should also provide information as to the remedial measures that the public may take to lessen the impact and possibly avoid a Stage 1 episode.

050.005 EMERGENCY EPISODE STAGES

A. Ambient air contaminant levels specified in Table I of this Section are emergency episode determinants for which control action shall be taken in accordance with provisions of this Section.

B. Whenever the concentrations of an air contaminant reach or are predicted to reach a Stage 1,2 or 3 as specified in Table I, at an air monitoring station operated by the Washoe County District Health Department, and the concentrations are expected to persist for at least eight additional hours, the Control Officer may declare that an emergency episode stage exists and take the actions specified in Sections 050.010 and 050.015.

TABLE 1
EPISODE CRITEIA LEVELS

POLLUTANT	Averaging Time	Health Advisory	Stage 1 (Alert) PSI 200	Stage 2 (Warning) PSI 300	Stage 3 (Emergency) PSI 400
CARBON MONOXIDE	8 Hour	12.0 ppm	15 ppm	30 ppm	40 ppm
OZONE	1 Hour	0.16 ppm	0.20 ppm	0.40 ppm	0.50 ppm
SUSPENDED PARTICULATES	24 Hour	300 UG/M3	375 ug/m3	625 ug/m3	875 ug/m3

050.010 NOTIFICATION OF AN EPISODE STAGE

A. When an episode stage is declared, the Control Officer shall notify:

1. The news media and shall request that they publish or broadcast all appropriate warnings, notices and advisories;

2. The Washoe County Manager and the managers of the cities of Reno and Sparks;

3. Managers and operators of all stationary sources covered under Sections 050.030; and

4. Other agencies which, in the opinion of the Control Officer, should be notified.

B. Notification of an episode stage shall include information as to which stage has been predicted or reached, the expected duration of the episode, the geographic boundaries of the affected area, the specific air contaminant for which the stage has been declared, a statement of the public health significance of the episode stage, and the appropriate voluntary or mandatory control measures to be taken, as described in Section 050.015.

1. The Public Notification shall be updated to reflect the more severe conditions;

2. For oxidant episodes - programs which involve physical exertion by persons using public parks or public recreational facilities shall be suspended;

   All commercial and industrial activities such as dry cleaning, spray painting and degreasing that emit reactive organic compounds shall be notified to cease operations. Such activities as roofing, asphalt paving and surface coating where the use of large quantities of volatile organic material is involved shall also be prohibited;

3. For carbon monoxide episodes - if the occurrence of this stage is determined to have been due to traffic congestion in that area, take measures to reduce the traffic congestion in that area.

4. For suspended particulates episodes - dust emitting construction and agricultural activities such as grading, leveling, plowing and digging shall be prohibited; and

5. A request shall be made to the general public to avoid the area of the episode.

C. Stage 3

In addition to the control measures specified in Subsections A and B above, the approprate law enforcement and civil defense agencies may be requested to:

C. If an episode stage 2 or 3 is declared, the Control Officer may request that the Director of The Division of Emergency Management for Washoe County coordinate all emergency control measures.

050.015 EPISODE CONTROL ACTIONS

The Control Officer and the appropriate law enforcement and public health officals shall take the following control actions upon declaration of the following stages:

A. Stage 1

1. A health warning for sensitive persons shall be included in all notifications given pursuant to Section 050.010;

2. All open burning must be terminated;

3. The use of permitted incinerators shall be terminated;

4. A request shall be made to the public to curtail any unnecessary motor vehicle operation;

5. Whenever, the measurements of total suspended particulates, carbon monoxide or ozone reach Stage 1 levels and adverse meteorological conditions are predicted to persist, the burning of wood or coal in commercial or residential stoves and/or fireplaces shall be suspended unless it can be demonstrated that such fuels supply the only heat available to the person burning them. The suspension shall remain in effect until all episode stages have terminated.

6. Sources covered under Section 050.030 will start curtailment of operations as per their submitted and approved plans.

B. Stage 2

All of the control measures specified in Subsection A shall be implemented under a Stage 2 episode and, in addition:

1. Close all public, commercial and industrial establishments which are not immediately necessary for public health and safety and are within the affected area;

2. Close principal streets within the affected area to the general public;

3. Require emergency carpooling or use of mass transit by the public;

4. Set-up and implement evacuation procedures if deemed necessary; and

5. Inspect stationary sources covered by Section 050.030 to insure source compliance with curtailment plans.

050.020 TERMINATION OF EPISODE

The Control Officer shall declare an episode stage terminated when the concentration of a contaminant falls below the criteria level shown in Table 1 of Section 050.005 and/or when meteorological data indicate that the contaminant concentration will decrease to below the criteria level.

050.025 NOTIFICATION OF TERMINATION

Upon declaration of termination of an episode stage, the Control Officer shall notify those persons and offices specified in Subsection A of Section 050.010. The notice shall also advise which curtailed activities may resume and which activities must remain curtailed, as specified in Section 050.015.

050.030 CONTROL PLANS FOR EMISSION CURTAILMENT

The owner or operator of any stationary or mobile source with the potential to emit 50 tons or more per year of an air contaminant therefrom shall, upon request of the Control Officer, prepare and submit a plan for reducing or eliminating such emission in accordance with the episode stages of Alert, Warning and Emergency as defined in these Regulations.

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA-450/4-85-012		

4. TITLE AND SUBTITLE	5. REPORT DATE
Technical Support Document For Residential Wood Combustion	February 1986
	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Dr. Robert Gay Dr. Jitendra Shah	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
NERO and Associates, Inc. Portland, Oregon	11. CONTRACT/GRANT NO. 68-03-3871 SB08410462

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Air Management Technology Branch Monitoring and Data Analysis Division US EPA (MD-14) Research Triangle Park, N.C. 27711	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Project Officer

16. ABSTRACT

This Technical Support Document is prepared to assist State and local air pollution control agencies in assessing and controlling Residential Wood Combustion (RWC) air pollution impacts. It provides an overview, description and leading references to many technical topics related to characterization of wood usage, pollutant emissions and resulting ambient concentrations attributable to RWC.

RWC emissions relative to other emissions sources, and various methods for estimating RWC wood usage and resulting emissions are described and quantified. Factors affecting the magnitude of RWC emissions from woodstoves and fireplaces are analyzed. Past and future trends are examined.

Leading examples of RWC emissions control strategies are described, based on programs implemented in Oregon, Montana, Colorado, Alaska, and Nevada. Example laws, regulations, local ordinances and informational materials related to these cases are included in an Appendix. Methods for estimating the potential effectiveness of RWC emission measures are described and illustrated, including the use of receptor and dispersion models.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Emissions Receptor Modeling Woodstoves & Fireplaces Dispersion Modeling State & Local Residential Rules & Regulation		

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