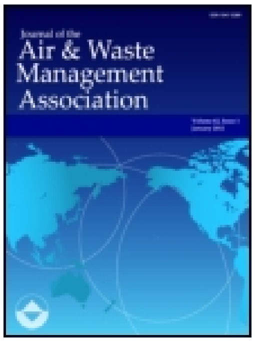

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Oregon's Woodstove Certification Program

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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% reduction in particulate emissions by July 1986 and a 75% 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 one-third on firewood consumption because of the inherently higher heating efficiency of lower polluting stoves, as well as provide increased fire safety because of reduced creosote formation and increased health benefits because of reduced polycyclic organic matter emissions.

The severe energy crisis in the 1970s has resulted in a great resurgence in the use of wood as a residential heating fuel. This trend, coupled with the introduction of the airtight stove in the same time period, has resulted in a major increase in air pollution from woodstoves in Oregon and in many other areas of the U.S.[1–8]

In Portland, Oregon, woodstove particulate emission increases have virtually negated reductions achieved by controlling industrial emissions (Figure 1). Air monitoring studies in several Oregon communities have confirmed that emissions from woodstoves are now a substantial contributor to violations of National Ambient Air Quality Standards for particulate matter. Concerns have also been raised that woodstove emissions have had major adverse impacts on consumption of federal Prevention of Significant Deterioration increments, as well as major adverse impacts on PM_{10} levels, regional visibility and toxic air pollutants like polycyclic organic matter (POM).

Emission factors[9] indicate that airtight woodstoves emit from 200 to 500 times as much particulate as do conventional oil or gas furnaces. Surveys[10–12] have indicated about 30% of the households have woodburning stoves or stove-like fireplace inserts in Oregon, and these households burn an average of 2.5 cords of wood per year. Total particulate emissions from woodstoves in the state in 1982 were estimated at 26,882 tons/year in comparison to fireplaces which were estimated to emit only 7,499 tons/year of particulates.

Comprehensive control strategies have been developed to address woodstove air pollution ranging from weatherization ordinances to programs which require curtailment of stove use during poor air quality periods.[13] Of some 75 potential woodheating control strategies considered in a study for EPA,[14] mandatory woodstove certification which restricts sales to only the cleaner burning models was ranked highest in overall social acceptability and effectiveness. Figure 1 illustrates the potentially large particulate emission reduction that can be achieved by a Woodstove Certification Program in Portland, Oregon.

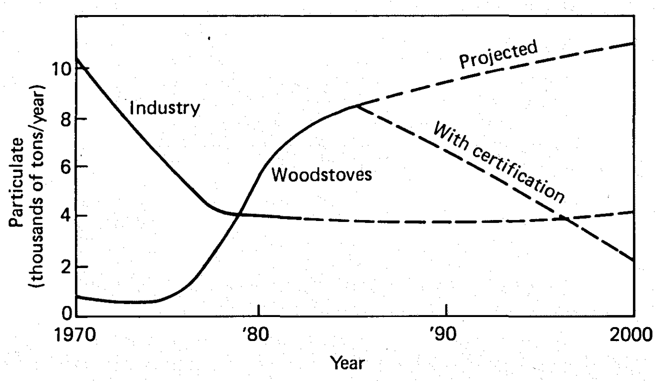

Figure 1. Industrial and woodstove particulate emissions in Portland, Oregon.

Legislative and Administrative Rule History

The Oregon Department of Environmental Quality introduced a bill to the 1983 Oregon Legislature which would authorize a statewide Woodstove Certification Program. This bill was hotly debated, with most of the woodstove industry opposed to the mandatory sales restriction feature. The woodstove industry generally favored a voluntary labeling program. A coalition of groups representing other industries, environmental organizations and the medical profession, among others, all supported the bill as introduced. A bill[15] was finally passed which authorized a mandatory statewide certification program primarily on the basis that it would clean

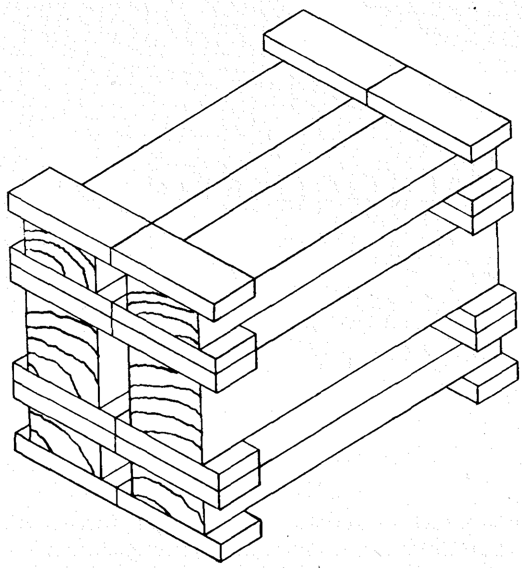

Figure 2. Typical test fuel.

up airsheds and remove a major barrier to industrial growth and development, and also on the basis that clean burning woodstove technology was currently available.

Developing administrative rules[16] to implement the program took over nine months. The process was aided by a nine member Woodstove Advisory Committee which primarily represented the Oregon woodstove industry. Substantial participation and input was also received from members of the national woodstove industry including members of the Wood Heating Alliance (WHA).

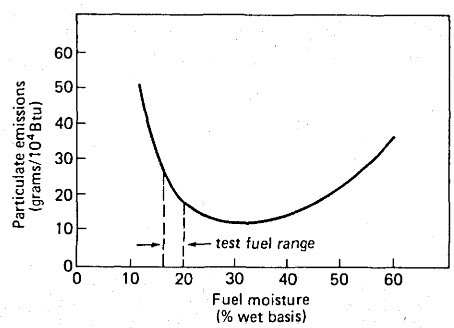

Figure 3. Wood moisture and emission relationship.

The adopted program consists of five major elements including: 1) a stove testing procedure, 2) a particulate emission standard, 3) a laboratory accreditation process, 4) stove labeling requirements, and 5) stove certification procedures. Most of the effort was spent on developing the test procedures, since there was no recognized woodstove testing procedure in existence in the U.S. at the time. During the administrative rule development process, substantial changes were made in the proposed test procedure to address comments and concerns expressed by the woodstove industry which included making the method more precise and representative of actual home use. In the end, the Oregon Woodstove Advisory Committee was in virtually unanimous agreement on the final rules that were adopted.

Test Procedure

Legislation authorizing the Oregon Woodstove Certification Program required woodstoves to be tested and permanently labeled for both emissions and heating efficiency. The testing procedure developed, therefore, included an efficiency measurement component as well as special emphasis on maximizing testing precision to assure consumers of reliable comparative labeling data.

The test fuel selected was 2×4 and 4×4 dimensional Douglas fir lumber with 1½-in. spacers to ensure uniform fuel loading densities. Dimensional lumber was selected after comparative testing with cordwood showed significantly higher precision with only slightly less emissions than cordwood. Figure 2 depicts a typical test fuel load for a moderate size woodstove. For woodstoves with small fireboxes (less than 1.5 ft^3) only 2×4s are used, and for stoves with large fireboxes (greater than 3.0 ft^3) only 4×4s are used. Douglas fir was chosen as a moderate emission test fuel, ranking between cleaner burning oak and dirtier burning pine species.

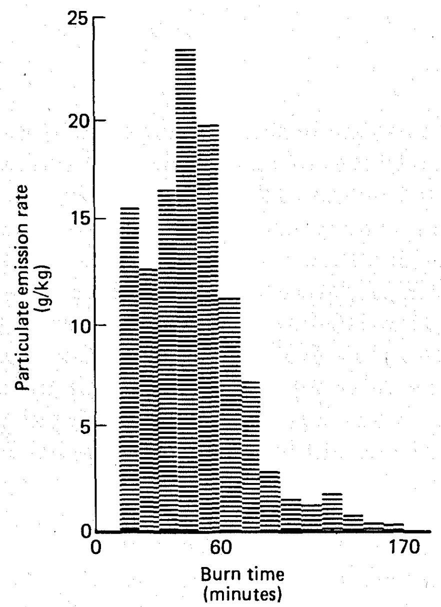

Figure 4. Emission fluctuations over complete fuel load cycle.

Test fuel moisture content was tightly controlled between 16 and 20% on a wet basis to minimize the large variability that can result in emissions if a wider range of moisture content were allowed (see Figure 3). Additionally, the selected moisture range was believed to best simulate household firewood moisture levels achieved after a reasonable seasoning time. Surveys[11,12] in Oregon have indicated over 57% of the households season their wood for at least seven months.

The test cycle was chosen to represent consumption of a complete test fuel charge. The test cycle was designed to begin with a hotbed of wood coals consisting of between 20 and 25% of the test fuel charge weight. The test cycle ends when the test fuel charge is consumed and a coal bed identical to the weight of the initial coal bed remains. The hot start was selected on the basis that it was found to produce higher precision between tests than a cold start. Omitting the startup emissions from the test cycle was also found to represent only a loss of less than 10% in the total burn cycle emissions. Figure 4 illustrates the typical variability in particulates emitted during a burn cycle and emphasizes the need to test over a complete burn cycle. Four tests covering a full range of stove heat output conditions were selected (see Table I). Although the most

Table I. Heat output testing categories.

• Less than 10,000 Btu/h
• 10,000–15,000 Btu/h
• 15,000–25,000 Btu/h
• Maximum heat output

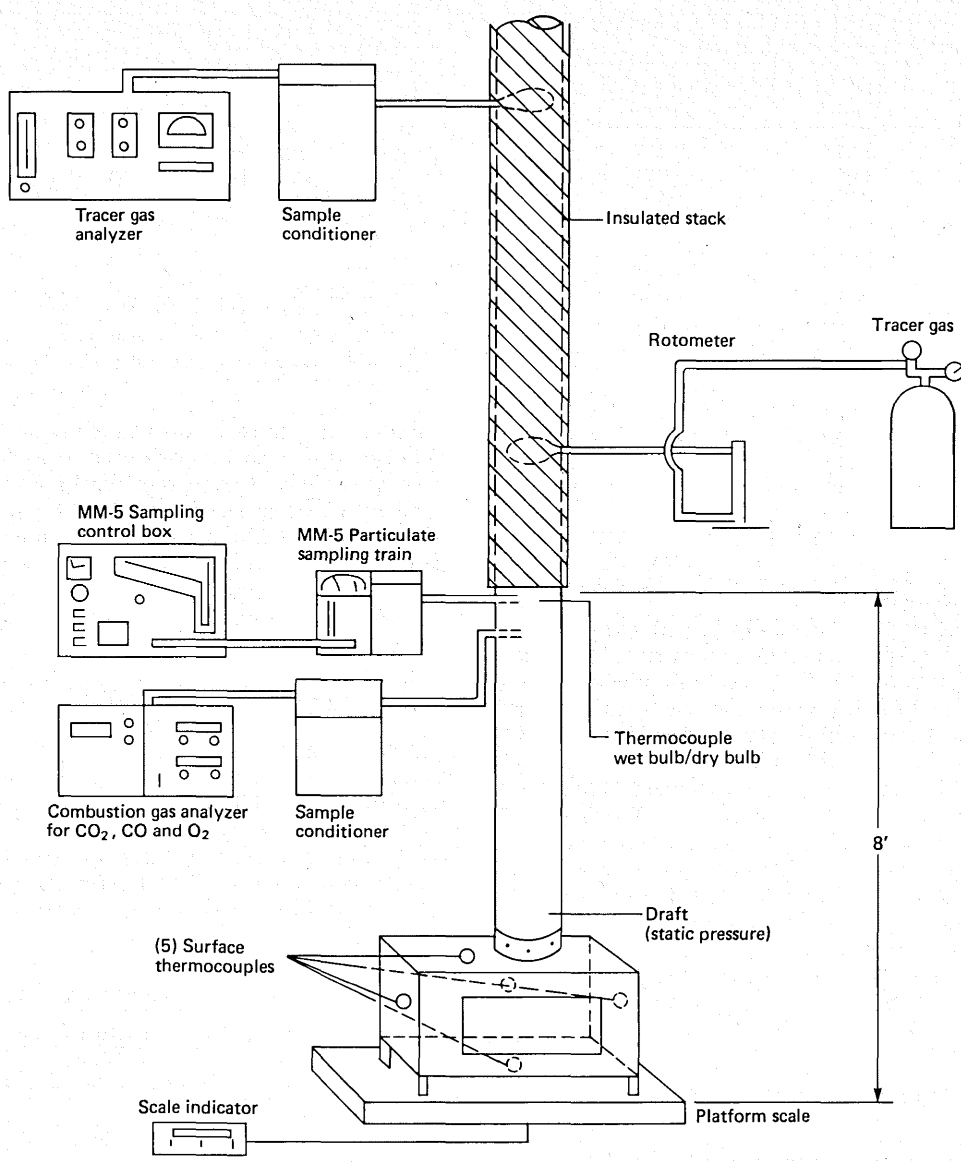

Figure 5. Woodstove test equipment setup.

frequent home heating needs for the average home in Oregon were determined to be in the 10,000–15,000 Btu/h range, the entire range of heat outputs was selected for testing to satisfy national woodstove industry representatives' desires to produce woodstove performance data which would be usable in all areas of the country.

The entire testing procedure set-up is shown schematically in Figure 5. The tracer gas system connected to the stack is used to accurately measure the low air flow rates typical in airtight stoves. This information is needed for accurate calculation of the instantaneous rate of dry wood burned, which is used in the stack loss heating efficiency calculation. The tracer gas flow method also allows proportional emission sampling. The platform scale allows accurate measurement of total test fuel consumption and the gaseous analyzers provide data needed to calculate heating efficiency. Stove surface thermocouples are used to correct heat loss calculations for thermal mass change of the stove occurring between the beginning and end of a test cycle.

Precision of Test Procedure

The particulate sampling method chosen is a modification to EPA Method 5, in which the impinger catch and catch of an unheated filter following the water impingers are included with the standard "front half" catch. Similar methods have been the most widely used in woodstove testing by other researchers.[17–19] With the highly condensible organic nature of conventional woodstove emissions, generally about 60% of the total sample train catch is found in the "back half" of the sample train as condensible particulate. The precision of the EPA Method 5 front half catch has been well documented as having a coefficient of variation of 10%.[20] However, no documentation was found on the precision of a combined front and back half catch. Fourteen tests with dual modified EPA Method 5 sample trains were run on four different woodstoves over a range of burn rates in order to document the precision of the modified Method 5.[21] Data in Table II indicate better precision of modified EPA Method 5 than that reported for the EPA Method 5 front half.

The calorimeter room method was recognized in addition to the stack loss method as an equivalent means of measuring heating efficiency. Twenty-six simultaneous tests of both methods resulted in a clear demonstration of equivalency (see Table III). The improved precision of the entire test procedure is illustrated by data in Table IV, in which a comparison of conventional cold start/cordwood tests were made with hot start/dimensional lumber tests.

Comparison of Woodstove Performance

The adopted test procedure has been applied to many different stove models and has produced considerable data (over 100 tests conducted to date). This testing gives a fairly com-

Table II. Precision data for modified EPA Method 5 using simultaneous paired sampling trains.

Run	Particulate concentration (g/scm) Train A	Train B
1	1.048	1.137
2	1.561	1.421
3	0.796	0.952
4	0.144	0.164
5	0.410	0.412
6	2.380	2.133
7	3.227	3.455
8	2.655	2.517
9	0.787	0.913
10	1.149	1.121
11	0.487	0.508
12	1.041	1.062
13	0.938	0.831
14	0.291	0.346
Mean	1.208	1.212
Coefficient of variation = 7.3%		

plete picture of stove performance and allows comparison of performances on a common basis. Figure 6 illustrates the performance of typical small and large conventional airtight stoves. These and other data indicate the major dependence of stove firebox size on particulate emissions with smaller noncatalytic stoves generally having lower emissions. Burnet and Tiegs[22] have documented this phenomenon. Best emission control technology has been found to be represented by woodstoves fitted with catalytic combustors. Performance of a well designed catalytic woodstove is illustrated in Figure 7. Catalytic woodstoves have been found to reach overall efficiencies in the range of 80%, while achieving particulate emission levels down to about 1 g/h, even at very low heat outputs. Significant variation, though, has been found in performance among different designs of catalytic woodstoves.

Table III. Comparison of efficiency measurements using simultaneous calorimeter room and stack loss methods.

Run	Overall efficiency (%) Calorimeter room	Stack loss
1	56.8	60.1
2	58.4	62.8
3	59.8	54.3
4	66.6	66.1
5	69.6	64.0
6	55.0	52.6
7	62.9	63.1
8	59.7	59.8
9	64.3	58.9
10	56.0	60.0
11	71.9	74.1
12	73.1	71.9
13	68.6	66.8
14	70.7	76.6
15	75.6	77.2
16	71.1	77.7
17	72.5	80.7
18	73.0	74.5
20	66.0	66.6
21	63.9	65.8
22	52.8	51.6
23	54.9	59.2
24	59.6	68.9
25	70.5	70.4
26	61.6	65.8
27	52.9	52.8
Mean	64.1	65.5
Coefficient of variation = 4.5%		

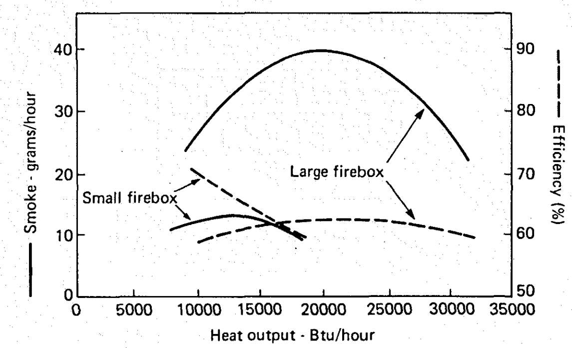

Figure 6. Conventional stove performance (example).

Historically, most woodstove emission performance data have been reported in terms of an emission factor (g/kg of wood burned) and burn rate (kg/h). Rating of woodstove performance in terms of grams per hour of emissions versus heat output was a newly developed concept in the Oregon Certification Program. These variables were felt to represent the most direct measure of woodstove impacts on airsheds and the most direct measure of homeowners' stove performance needs.

Emission Standard Development

Development of an appropriate emission standard required consideration of 1) Oregon airshed improvement needs; 2) performance of available woodstove control technology; and 3) in the case of catalytic stoves, catalytic combustor performance deterioration with age. In the Portland and Medford airsheds, the two most critical in the state, it was determined that a 72–78% reduction was needed from a Woodstove Certification Program in conjunction with other strategies in order to fully meet all national ambient air standards for total suspended particulate. Best available woodstove emission control technology was found to be generally represented by the Condar catalytic stove design. This design includes a preheated secondary air distribution system, a somewhat hemispherically shaped combustion chamber, a catalyst flame shield and a special automatic thermostat.

Table IV. Comparison of test procedure precision.

Run	Particulate emission rate (g/h) Cold start with cordwood[a]	Hot start with dimensional lumber[b]
1	5.4	
2	10.0	
3	6.8	
4	4.7	
5	11.0	
6	5.9	
A		0.9
B		1.1
C		1.5
D		1.4
Mean	7.3	1.2
Coefficient of variation	36%	22%

[a] At heat output of approximately 20,000 Btu/h.
[b] At heat output of approximately 13,000 Btu/h.

Tests of stoves made by three different manufacturers using the Condar design were found to average 1.9 g/h of particulate in the 10,000–15,000 Btu/h heat output range. Slight variations in performance among the three stoves tested indicated a maximum emission of 3.7 g/h at the 95% confidence limit. The average emission rates were calculated using the weighted average of emissions over the annual heat load distribution in Oregon for homes with average weatherization. This corresponds to an average heating need of about 13,000 Btu/h which requires relatively low burn rates because of Oregon's mild climate. Measured burn rate data from colder areas of the country (New York)[18] have actually shown similar heating needs to Oregon, apparently because of average higher home weatherization levels and limits on how hot a stove can be operated in a room without producing uncomfortably high room temperatures.

While components of both catalytic and noncatalytic stoves undoubtedly deteriorate with time, the degradation of catalysts was considered significant enough by itself to be taken into account in setting a different standard for noncatalytics which would result in equivalent performance with catalyst stoves over the expected life of the catalyst. Deterioration of catalyst performance over the expected life of catalysts (6000–12,000 hours of operation) was determined to be a factor of 2.5.

Table V. Oregon particulate standards for woodstoves.

Effective date	Particulate emission rate (g/h)[a] catalytic	noncatalytic	Emission reduction (%)[b]
July 1986	6	15	50
July 1988	4	9	75

[a] Weighted average of four tests.
[b] Relative to typical woodstove.

The adopted particulate emission standards are shown in Table V. The final standard for catalytic stoves of 4 g/h, representing about a 75% reduction in emissions, was selected on the basis of providing emission reductions in the range of needed airshed improvements in Oregon, as well as on the basis that technology was available to meet the standard. The expected emission reduction was based on information indicating that existing conventional stoves average about 30–34 g/h of particulate emission when tested according to the Oregon test procedure. The corresponding 9 g/h noncatalytic standard was selected as being equivalent in performance to the catalytic standard when considering catalytic degradation. A more lenient first stage standard requiring a 50% reduction in emissions to become effective in July 1986 was adopted in order to give manufacturers more time to develop cleaner burning noncatalytic stoves, as noncatalytic technology was not known to be available to meet the second stage 9 g/h standard at the time.

The first stage standard for noncatalytic stoves of 15 g/h was expected to allow most existing small size conventional stoves and possibly some medium sized appliances to be certified. Other parameters, such as carbon monoxide, total hydrocarbon emissions and combustion efficiency, were considered as an emission standard for simplicity of testing. They were rejected, however, because of unsatisfactory correlation with particulate emissions. A high correlation was considered necessary in order to ensure addressing ambient particulate

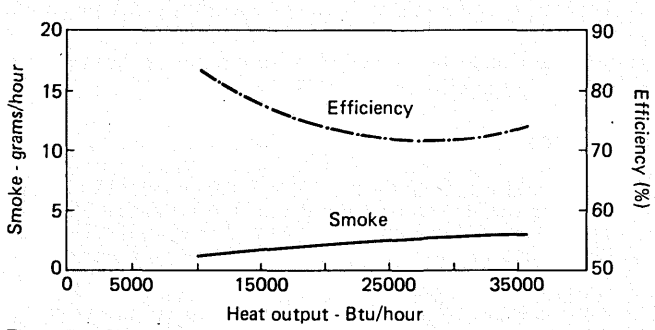

Figure 7. Catalytic stove performance (example).

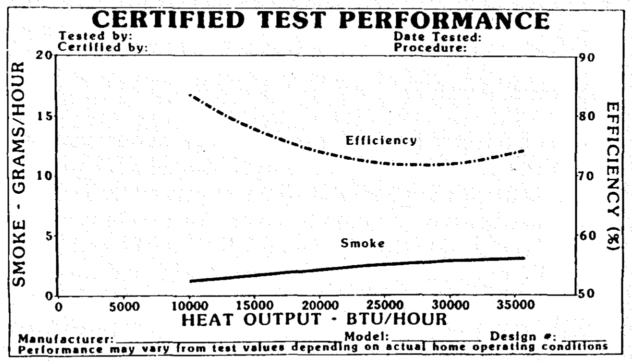

Figure 8. Permanent label.

problems. The correlation of particulate and carbon monoxide emissions was sufficient, though, to ensure that a particulate emission standard would adequately address ambient carbon monoxide problems.

Labeling

Legislation required labels reflecting woodstove emissions and efficiency to be permanently affixed to certified stoves. Figure 8 depicts an example of a permanent label. The format of this label was developed to provide useful information for all areas of the country so that manufacturers could avoid additional testing costs that might subsequently be imposed outside of Oregon. This information would also allow homeowners to determine the optimum performance level of their stove. An additional removable point-of-sale label (Figure 9) was developed to specifically relate to Oregon Certification requirements and show average emissions and efficiency for ease of consumer comparison. This label would only be utilized in Oregon retail stores. Specific label requirements in terms of materials, durability and format were generally based on U.L. safety label requirements.

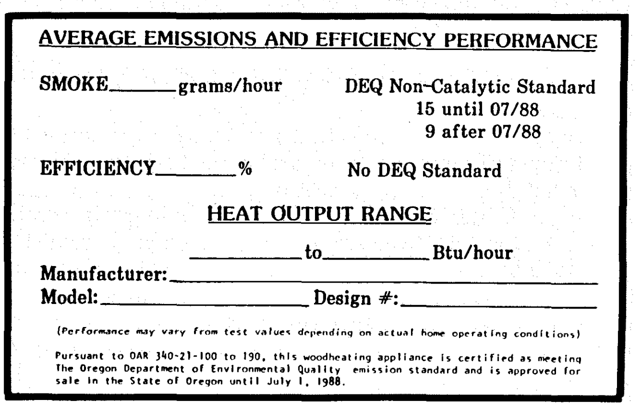

Figure 9. Removable label.

Laboratory Accreditation Process

Legislation required that independent private testing labs conduct the actual woodstove testing. A rigorous lab accreditation process was developed, patterned to some extent after the Department of Commerce's National Voluntary Laboratory Accreditation Program (NVLAP) used in woodstove safety testing. Specific additional requirements included a demonstration of stove testing proficiency using an Oregon supplied reference stove, standardized data calculations using an Oregon supplied software program, audit provisions, and specific accreditation enforcement procedures.

Criticisms of Program

Some criticism of Oregon's certification program continues to be voiced by some members of the national woodstove industry, stating their belief that the test procedure is not realistic. They believe a dilution type particulate sampler would be more appropriate than the modified EPA Method 5 sampling train. Existing test data, however, tend to indicate there are no major differences in the comparative results of the two methods, especially at low to moderate emission rates where woodstove certification would be applicable. For unexplained reasons, at high emission rates the dilution samplers measure about 20% higher emissions than the modified EPA Method 5. The adopted test procedure contains equivalency criteria for the modified EPA Method 5 particulate sampling method. It is expected that some dilution sampling methods will meet these criteria. Some national woodstove industry representatives also believe the Oregon test fuel density using 1½-in. spacers is unrealistically low and they support use of ¾-in. spacers. Data from home use in Oregon, as well as data from home studies in New York,[23] however, support the density (7 lb/ft^3 of firebox volume) specified in the Oregon test procedure.

Opponents of the certification bill were of the opinion that the public will not buy certified stoves because of their estimated increased cost ($200–300 on the average at present) over conventional stoves. They felt consumers will bootleg stoves from adjacent states which do not have woodstove certification programs. Market surveys conducted both by DEQ and the woodstove industry in Oregon indicate, however, that the vast majority of potential consumers of new woodstoves want cleaner burning, more efficient appliances and that they are willing to pay extra dollars to purchase them. Additionally, other states are considering similar woodstove certification programs.

The quality of catalytic combustors and replacement of worn out combustors was also a concern. DEQ rules require a two-year full replacement warranty for catalytic combustors as a means of addressing this issue. Additional educational efforts are being directed to point out the positive economic advantage of replacing catalysts despite the cost of catalyst replacement ($60–$140).

Many woodstove manufacturers also have been opposed to the second stage emission standard on the basis that they see it as a catalytic woodstove mandate. DEQ recognized that existing noncatalytic stoves likely could not meet the second stage standard. However, since existing technology (catalytic) was available to meet Oregon airshed improvement needs, there was a compelling desire to adopt a standard that could ultimately achieve the desired result, even though such action may ultimately rely on only one technology. It was a conscious decision that if noncatalytic technology was not developed by the July 1988 second stage standard compliance date, then the program could and would rely solely on catalytic technology. The experience of the U.S. auto industry of relying on catalytic technology in the mid-1970s was recognized as an example of the workability of such a policy.

Benefits of Programs

There are many quantitative benefits of the Oregon Certification Program. When an essentially complete turnover of old stoves is achieved (estimated 15–20 years) a particulate emission reduction (both TSP and PM_{10}) of about 75% should be achieved. Because of higher heating efficiency of cleaner burning stoves, up to 33% will be saved in firewood costs and physical work to store and load firewood. Economic analysis indicates that from $10 to $20 will be saved for every cord of wood burned with the more efficient stoves, even considering the increased cost of stoves (about $200–300 on an average), cost of catalyst replacement (about $60–140) and the cost for a cord of wood (ranging from free to $90/cord). The free wood is based on costs of chain saw depreciation and maintenance, reduction in chimney cleaning costs, wood cutting permit costs, and transportation costs for the firewood, all of which average a total of about $50 per cord of wood burned.

Certified stoves will also reduce fire hazards by reducing stack cresote formation potentially up to 90%. The general health of the public should also be improved by achievement of about a 75% reduction in POM emissions, which have been identified as one of the leading national air toxicants.

Program Implementation

At this writing, one laboratory has been accredited and three are in the review process. Nine woodstoves have been certified with other applications expected shortly. Other areas in the U.S. are now considering certification programs. The state of Colorado has adopted a bill similar to Oregon's, except for a one year delay in the voluntary and mandatory phase implementation dates compared to Oregon's program. Missoula, Montana, is also very close to adopting a program similar to Oregon's. Other areas of the country are known to be considering certification programs and EPA has indicated it may be considering New Source Performance Standards for woodstoves in the future.

Conclusions

Woodstove certification can offer numerous benefits including cleaning up airshed problems, conserving energy, and reducing fire hazards. It offers a way of controlling woodburning emissions which is most acceptable to the public while offering significant economic and other benefits. Oregon's Woodstove Certification Program has been developed over a several year period with assistance from woodstove manufacturers and researchers nationwide. It is based on probably the most extensive data base ever developed on woodstove emissions and efficiency performance. The certification program provides a sound framework to implement the very sensitive process of regulating the emissions of a household appliance while providing comparative performance information which is accurate and fair to both consumers and manufacturers.

The true success of the program, however, will be measured in the ability of woodstove manufacturers to widely produce cleaner burning woodstoves, as well as the public's response in purchasing certified stoves, and operating and maintaining them according to manufacturers' recommendations.

Acknowledgment

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