AP42 Section 1.10 Ref #9

Elements Unlimited

WOODSTOVE FIELD PERFORMANCE IN KLAMATH FALLS, OREGON

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WOOD HEATING ALLIANCE

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February 12, 1991

Emission Factor and Methodologies Section (MD-14)
US EPA
Research Triangle Park, NC 27711

Gentlemen:

In response to your invitation to provide data for consideration in the revision of AP-42, the Wood Heating Alliance is submitting a copy of the report of the in-situ testing done in Klamath Falls, Oregon on 1990 EPA-certified woodstoves.

We hope that this data and any supplemental information that you might request from the Omni Environmental Services, the project contractor, could be used in the revision of section 1.10 of the document.

One additional source of data that should be included is the demonstration project conducted on the airshed of Crested Butte, Colorado. Since EPA Region 9 (Jack Hidinger) was involved in the management of this project, I assume that you will get all necessary input from them.

Should there be any questions on the materials that are enclosed, please feel free to contact us.

Sincerely,

Gary T. Satterfield
Technical Director

ACKNOWLEDGEMENTS

The Wood Heating Alliance would like to express its appreciation to the contributors listed below. This project would not have been possible without their generous contribution of woodstoves and funds:

STOVE CONTRIBUTIONS
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Earth Stove Marketing
Jotul U.S.A., Inc.
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Osburn Manufacturing, Inc.
Haugh's Products

OTHER FINANCIAL CONTRIBUTIONS
****

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We would also like to thank Jim Gillam of Ash Brothers Chimney Sweeps in Klamath Falls for insuring study participants had safe heating systems.

And of course, our biggest thanks to the study participants themselves.

WOODSTOVE FIELD PERFORMANCE IN KLAMATH FALLS, OREGON

EXECUTIVE SUMMARY

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The Wood Heating Alliance (WHA) sponsored a field study of woodstove emission performance in six homes in Klamath Falls, Oregon. The primary objective of the study was to determine the field performance of both "conventional" and "advanced technology" woodstoves. Early field studies indicated that "advanced technology" woodstoves were not performing to expectations. But some previous field studies are limited in application due to the use of outmoded appliance and installation technology, and testing conducted in colder than average climates. Data on particulate emissions of conventional stoves were also limited.

The woodstoves used in this study are considered representative of the advanced technology units available today, and all were certified to the Environmental Protection Agency's (EPA) most stringent Phase II (1990) emission standards. Today, "advanced technology" applies to the incorporation of design factors such as secondary air systems, balanced air intake and mixing systems, insulated baffles, and catalytic combustion systems. The term also refers to the treatment of the appliance as only one part of a four-part heating system that includes not only the stove, but a correctly sized and installed flue, fuel of correct length and moisture content, and knowledgeable operators.

In-situ emissions sampling was conducted by OMNI Environmental Services on three conventional and six advanced technology woodstoves (three catalytic and three non-catalytic). One week of sampling was conducted on the conventional stoves and two sampling periods of one week each were conducted on the advanced-technology stoves. Data collection included particulate emissions, burn rate, and fuel moisture and type. It was beyond the scope of this project to determine average flue and combustor temperatures, fuel loading frequency and density, or appliance durability.

Particulate emissions for the conventional stoves averaged 42.8 grams/hour (g/hr). Catalytic stoves averaged 6.4 g/hr, non-catalytics emitted an average of 5.0 g/hr. The average emissions for all the advanced technology stoves were 5.8 g/hr (difference is due to rounding). The EPA emission factors for conventional, catalytic, and non-catalytic stoves are 21.3, 6.2, and 9.4 g/hr, respectively. The advanced technology units in Klamath Falls exhibited the best overall performance of any field testing to date. The high emission rates measured in conventional units indicate that woodstove control strategies that remove incentives to upgrade existing conventional systems are potentially self-defeating.

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INTRODUCTION

This document presents results from a field study of woodstove emission performance in six homes in Klamath Falls, Oregon. The study was sponsored by the Wood Heating Alliance (WHA), a not-for-profit national trade association representing the hearth-related products industry, including woodstoves, fireplaces, pellet stoves, hearth furnishings, and other related products. The WHA Stove Technical Committee identified the need for a field performance study using only woodstove models which were considered representative of the newest generation of products certified to meet the Environmental Protection Agency's (EPA) most stringent emission standards.

Appliances which burn solid fuel (woodstoves, pellet stoves, and some fireplaces) are regulated by the EPA and numerous state and local agencies. Appliances are tested at accredited laboratories and required to pass strict particulate emission standards. Recent field performance studies (1, 2) have indicated that some "advanced technology" appliances are not able to duplicate lab values in the field. Some of these field studies were limited to early appliances that are being phased out this year as "Phase II" of the EPA emission standards takes effect. The Klamath Falls performance study was limited to stoves that were representative of the most advanced appliances available.

Both "conventional" and "advanced technology" woodstoves were tested. In-situ testing and data reduction were conducted by OMNI Environmental Services of Beaverton, Oregon, using the OMNI Data LOG'r(TM) and Automated Woodstove Emission Sampling (AWES) systems. Elements Unlimited was retained by the WHA to prepare this report on the results of the field testing conducted during January and February, 1990.

Project Objectives

The primary objective of the Klamath Falls project was to determine the emission performance of catalytic and non-catalytic stoves that had been certified to the EPA "Phase II" (1990) emission standards. This project is the first field study that limited the definition of "advanced technology" woodstoves to include only EPA 1990-certified models. Previous in-home field studies were usually confined to non-certified, EPA 1988-certified, or early Oregon-certified models.

The second objective of this study was to determine the emission performance of conventional, "traditional technology" woodstoves. Most of the data concerning conventional woodstoves were from testing conducted in the Northeastern U.S. and the city of Whitehorse (Yukon Territory, Canada) from 1985 to 1988 (1). The WHA desired to collect additional data that would reflect conventional stove performance in a more representative (milder) climate, since burn rates are known to affect emissions levels. Klamath Falls was selected as the testing site not only because it had the desired climate, but because the city often experiences episodes of air quality degradation due to woodsmoke trapped in the airshed.

The discrepancies between laboratory and field performance have raised the issue of durability of stove components, especially catalytic combustors. A recently released study (2) identifies stove component and combustor durability as significant factors in field performance degradation over the sample period. It was beyond the scope of this project to determine stove or combustor durability of the tested models.

Differences between lab and field performance can also be attributed to variations in operating and fueling practices found in the field. Home installations show leaner operating conditions, more dilute flue gases, and higher drafts than are produced with standard test methods (2).

Emission Factors

The EPA established in-situ particulate emission factors for both conventional and advanced technology woodstoves based on results from early field studies (1). Regulatory agencies use the emission factors as part of the calculation to determine the current and projected contribution of woodstove emissions to airshed particulate loading.

The conventional stoves tested in Klamath Falls averaged 42.8 grams/hour (g/hr), almost twice the value determined by the EPA (21.3 g/hr). Although the amount of data from Klamath Falls is limited, it highlights the potential variability of emissions performance in the field.

The EPA emission factor for advanced technology catalytic woodstoves is 6.2 g/hr. The average emissions of the catalytic stoves used in the Klamath Falls was 6.4 g/hr. Non-catalytics in Klamath Falls averaged 5.0 g/hr, compared to the EPA emission factor of 9.2 g/hr. The overall average for all advanced technology stoves in Klamath Falls was 5.8 g/hr (rounded).

BACKGROUND

Regulatory Control of Woodstoves

Residential Wood Combustion (RWC) has been identified as a contributor to air quality degradation, especially in areas like Klamath Falls, where local geographic and atmospheric conditions can result in temperature inversion layers which trap pollutants near the ground. By 1983 the contribution of woodstove emissions to poor air quality prompted the Oregon Department of Environmental Quality (DEQ) to develop the first stove certification program in the nation (3). Klamath Falls is one of several local areas designated a non-attainment area for "PM-10" by the DEQ.

"PM-10" refers to particulate matter less than 10 microns in diameter (the period at the end of this sentence is about 1000 microns in diameter). Particles this small are easily respirable and present a health threat because they can lodge deep in the lungs. PM-10 particles can be produced by a variety of combustion sources, including woodstoves, slash and field burning, motor vehicles, and industrial processes, although the largest single source of PM-10 in Oregon is dust from roads, agriculture, and other industrial activities (4).

In February of 1988 the EPA promulgated federal "New Source Performance Standards" (NSPS) for Residential Wood Heaters (5). The NSPS is based on estimates of the current number of households using wood heat, the average emissions of the conventional woodstoves assumed to be in use in these homes, the turnover rate as these woodstoves are replaced by new generations of advanced technology stoves, and the desired reduction in emissions. The emission standards were implemented in two phases so that the industry would have time to conduct the research and development necessary for cleaner and more efficient burning technology.

The wood heating industry participated in the "Regulatory Negotiation" process to set Phase I and Phase II standards. Phase I standards were set at 5.5 grams/hour for catalytic stoves and 8.5 for non-catalytics. Phase II standards, effective in July, 1990, are 4.1 grams/hour for catalytics and 7.5 for non-catalytics. At this time, testing and sampling methods were limited to laboratory applications.

The Oregon DEQ continued to pursue its state certification program even after the promulgation of federal regulations. In 1988 the DEQ conducted a study entitled the "BEST" project (Best Existing Stove Technology) which endeavored to identify design and operation parameters critical to long-term durability and emissions performance in the field (6). They constructed several units incorporating the design factors and conducted stress and in-situ emission testing. The DEQ is now considering further standards for woodstove performance and durability. Other state and local air quality agencies are considering, or have already implemented, woodstove control strategies.

Field Performance

Between 1985 and 1989 the pressure of increasingly stringent regulations forced accelerated advances in wood burning design and operating technology. The rapid advance was at a severe economic cost to the industry, both in dollars and diversity. Eighty percent of the woodstove manufacturers active in 1985 have since withdrawn from the market.

Certification programs required test methods that would give reproducible results so that each woodstove model would be compared under the same conditions. But standard test methods developed during the early phases of the certification programs did not reflect fueling and operating practices in field installations. The wide variety of uncontrolled variables in the field has made it difficult to duplicate lab performance values.

There were very little reliable data available prior to 1985 concerning the emissions performance of woodstoves in the field, primarily because no reliable and practical sampling methods existed. In recent years accurate field sampling methods have been developed and field performance has been studied in several projects. Results from some of the earliest studies showed that advanced technology woodstoves were not achieving the performance levels obtained in the laboratory setting. This prompted some agencies to consider further use restrictions on woodstoves, even those that had been certified to the EPA Phase II standards.

But the early studies often used stove models that were not EPA-certified and/or were no longer in production. Some studies tested "advanced technology" stoves that were installed with incorrectly sized flues and/or unlined masonry chimneys. These types of installations are now considered obsolete by industry members.

"Conventional" vs. "Advanced Technology"

Numerous factors have been identified that can affect emissions performance, including design and durability of stove components; operating practices; fuel moisture and loading methods; and installation method (1, 2, 6, 7). The design technology now being utilized relies on all components of the heating system to function correctly. The wood heating industry has been working to standardize installation and operation practices through a variety of educational and professional certification programs.

Conventional woodstoves popular in the 1970's and early 1980's rarely consisted of much more than a combustion chamber with primary air intakes and a flue exhaust. Little thought was given to combustion or heat transfer efficiency, and units were often oversized for the area being heated. Early flue installation methods often included multiple bends and connections to oversized masonry chimneys.

An advanced technology woodstove can be differentiated from a conventional woodstove by its use of proven design factors and professional installation. Advanced design factors can include secondary air systems, balanced air intake and mixing systems, insulated baffles, and catalytic combustion systems. Advanced technology includes the treatment of the woodstove as just one part of a complete system that includes a properly sized stove and flue, a knowledgeable operator, and fuel of the correct size and moisture content.

Industry Viewpoint

The wood heating industry feels that some regulatory agencies are developing control strategies based on performance data that are not reflective of the advanced technology heating systems now being produced and installed. Inaccurate assumptions concerning emissions are often combined with incorrect estimates of current stove populations, replacement rates, and cordwood fuel usage. The result can be a woodstove control strategy that is unnecessarily strict. Some communities have banned the use of all wood-fired appliances during periods of poor air quality.

The conventional woodstoves in the Klamath Falls study emitted more than seven times the amount of particulate matter than the advanced technology systems. The industry is concerned that indiscriminate application of burning restrictions to both certified and non-certified units removes the homeowner's incentive to upgrade existing conventional woodstoves. Without upgrading, these units will continue to have a severe negative impact on local airshed particulate loading.

STUDY METHODS

Klamath Falls is located in southern Oregon at an altitude of 4800 feet above sea level. The local topography contributes to the formation of winter inversion layers, and trapped wood smoke has been identified as a significant contributor to local air quality problems. Because very few of the field studies conducted in the past used the latest available technology, the Klamath Falls study was designed to generate data about the field performance of both "conventional" and "advanced technology" woodstoves. The advanced technology stoves selected for Klamath Falls were all stoves that had been certified to the EPA's most stringent emission standards (Phase II, 1990).

It was determined that a minimum of three units per stove type (conventional, catalytic and non-catalytic) was required to generate sufficient data for analysis. Sampling was conducted over three one-week periods from January to early March, 1990. Sampling on the three conventional stoves was conducted during the week of January 9-17, 1990 (Week 1). Sampling on the advanced technology stoves was conducted during early and late February (Weeks 2 and 3, see Appendix A for exact sampling periods). The mean temperature during January and February was 29.8 and 36.9 degrees Fahrenheit, respectively (average for the Klamath Falls area).

Cordwood fuel was not generally provided to the study participants, each home used whatever fuel they had on hand for their existing woodstove. Home H-1 was provided with fuel (Juniper cordwood) from a local source during Week 3 to augment their existing supply. The predominate fuels used by the study participants were all softwoods, with juniper, fir, and pine the most common.

Home Selection

With the assistance of a local chimney sweep, six study homes were selected; five of the six were located along the same neighborhood block and had been constructed by the same builder. Houses H-1, H-2, and H-3 were selected for the conventional stove testing. Each had a conventional woodstove with a large firebox. All three of the conventional stoves had primary air supplies that were thermostatically controlled, although the thermostat on the stove in House H-1 was not functioning (See Appendix A).

Woodstove Installation

A local chimney sweep and other project representatives interviewed homeowners and inspected the existing installations for safety violations. Some minor upgrading was conducted to bring installations into compliance with local safety codes. All homes except for Home H-4 required hearth extensions. In addition, door gasketing was inspected (part of a normal maintenance program) and replaced when required. The chimneys of all the study homes were cleaned prior to the start of sampling.

All advanced technology stoves were installed in strict accordance with the manufacturer's installation instructions. Both catalytic stoves and one of the non-catalytics (H-2) had ash pans (See Appendix A for firebox sizes). Homes H-1 and H-6 contained the same catalytic model. Each installation of an advanced technology stove included a properly designed flue system. All flue connectors and chimneys were 6" diameter, matching the flue collar size of the study stoves. In all homes except for H-5, the existing 8" chimney system was re-lined with a 6" stainless steel liner.

The chimneys in Homes H-2 and H-4 were lengthened prior to the start of the advanced technology sampling period. (The sampling of the conventional stove in Home H-2 was conducted on the pre-existing flue system.) The chimney of Home H-3 was lengthened between Week 2 and Week 3 sampling. No other modifications were made during or between sampling periods, although the primary air control in Home H-5 was adjusted after it was found to be sticking.

Operator Training

Operation manuals were provided to every study participant, and in some cases operators also received individual review of stove operation from a manufacturer's representative (using the operation manual as a guide). Homes H-1, H-2, H-4, and H-6 all received personal instruction (prior to sampling) concerning the operation of their advanced technology stove. Home H-3 received only a follow-up call to answer any of their questions about the manual. Home H-5 received only the operation manual, with no additional follow-up. No "special" operating instructions were given; the instructions were limited to those that a competent stove dealer would provide to a new customer.

During sampling Week 2 it was observed that Home H-3 (catalytic) was loading the stove with very small loads and then burning at a high rate. This home was requested to use larger fuel loads burned at a lower air setting, which is more representative of normal fueling patterns. Home H-2 (non-catalytic) was found to be loading fuel that was too long for the stove, necessitating fuel loads that often consisted of one large fuel piece loaded diagonally in the firebox. This home was requested to split/cut their fuel into the correct size for the stove, in accordance with the manufacturer's operating instructions.

Data Collection/Analysis

Emissions sampling was conducted by OMNI Environmental Services, Inc., using the AWES/Data LOG'r (TM) system developed from previous studies. At pre-determined intervals the AWES system measures and records exhaust gas concentrations and temperatures, and stove and combustor temperatures. Fuel loads are weighed as they are loaded into the stove.

A sample of the flue gases is extracted, and subsequent laboratory analysis calculates burn rates and particulate emissions. Sampling was conducted for one-week sampling periods. Thermocouples were mounted approximately one foot and four feet above the flue collar, and upstream and inside of the combustor (if present). AWES sample logs and fuel data sheets can be found in Appendix B.

OMNI provided emissions and burn rate summary data for each week, in addition to fuel type and mosture data for each study home. It was beyond the budget of this project to contract for information concerning flue and catalyst temperatures and fuel loading data, although this information might be acquired at a later date.

RESULTS

Conventional (traditional) Woodstoves

Week 2 of testing was conducted on three "conventional" stoves that were installed in existing systems in Homes H-1, H-2, and H-3. All the conventional stoves had thermostatically controlled air supplies and large fireboxes. Table 1 below shows the results for Week 1 of sampling (See Figure 1 on Page 12 for a graph of emissions vs. burn rate):

Table 1. Conventional Woodstoves, Sampling Week 1. Fuel Moisture, Particulate Emissions, and Burn Rate.

HOME #	FUEL H20 (% D.B.)	PARTICULATE EMISSIONS GRAMS/HR	GRAMS/KG	BURN RATE (DRY KGS/HR)
H-1	8.3	23.6	10.8	2.18
H-2	15.8	55.3	34.5	1.55
H-3	18.2	51.6	29.0	1.78
AVERAGE:	14.1	42.8	24.8	1.84
STD. DVN.:	5.2	16.7	12.4	0.3

The particulate emissions performance of the conventional stoves in Homes H-2 and H-3 (average 52.5 g/hr) was more than double the emissions of conventional stoves cited in previous studies (21.3 g/hr, Ref. 1). The average burn rate for these two homes was 1.67 kg/hr, compared to 2.18 kg/hr in Home H-1, which showed emissions of 23.6 g/hr.

Home H-1 had an inoperative thermostat, which resulted in a constant "high" air setting. The relatively low emissions of H-1 compared to H-2 and H-3 is probably the effect of burn rate on particulate emissions, combined with the low moisture content (8.3% dry basis) of the fuel. As burn rate is increased emissions decrease, due to the improved combustion effciency obtained with higher firebox temperatures and better air/fuel mixing. Table 2 on Page 10 shows the fuel types used by each home during Week 1 testing on the conventional stoves.

Table 2. Conventional Woodstoves, Week 1. Fuel Type and Percent Use.

HOME	FUEL TYPE	PERCENT USE
H-1	Yellow Pine	90
	Lodgepole Pine	10
H-2	Yellow Pine	50
	Cedar	50
H-3	White Fir	100

Advanced Technology (1990-certified) Woodstoves

Table 3 below shows the average emissions and burn rate results for each home in the study over both weeks of sampling, and the average by stove type. The average emissions rate of the catalytic stoves was 6.4 g/hr at a burn rate of 1.13 kg/hr. Non-catalytics averaged 5.0 g/hr at 1.04 kg/hr. The overall average emissions rate for all advanced technology stoves was 5.8 g/hr (difference due to rounding). Tables 4 and 5 (Page 11) show the results for each study home by sample week. Figure 1 (Page 12) plots all data points by emissions and burn rate. Figure 2 (Page 13) shows results by stove type (catalytic and non-cat).

Table 3. Advanced Technology Woodstoves, Average Particulate Emissions and Burn Rate for Both Sample Weeks, and Overall Averages by Stove Type.

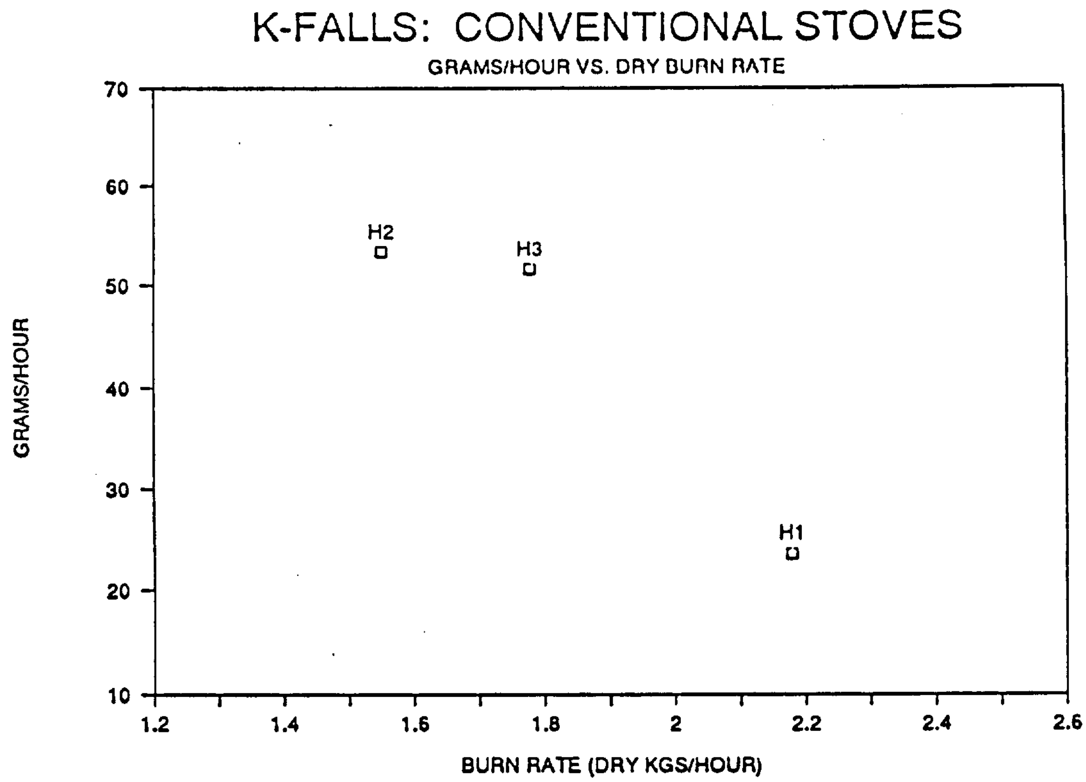
HOME #	STOVE TYPE	PARTICULATE EMISSIONS GRAMS/HR	PARTICULATE EMISSIONS GRAMS/KG	BURN RATE DRY KGS/HR
H-1	CAT	6.7	6.3	1.15
H-2	NON	5.8	6.4	0.89
H-3	CAT	5.3	5.4	0.99
H-4	NON	3.3	2.4	1.35
H-5	NON	6.1	7.0	0.88
H-6	CAT	7.4	6.0	1.24
AVERAGES:	CONVENTIONAL:	42.8	24.8	1.84
	ALL ADV. TECH:	5.8	5.6	1.08
	CATALYTIC:	6.4	5.9	1.13
	NON-CATALYTIC:	5.0	5.3	1.04

Table 4. Advanced Technology Woodstoves, Sample Week 2. Fuel Moisture, Emissions, and Burn Rate.

HOME #	STOVE TYPE	FUEL H20 (% D.B.)	PARTICULATE EMISSIONS GRAMS/HR	GRAMS/KG	BURN RATE (DRY KGS/HR)
H-1	CAT	10.0	4.9	3.6	1.36
H-2	NON	19.1	6.6	6.8	0.96
H-3	CAT	19.7	5.0	4.9	1.02
H-4	NON	13.4	3.4	2.2	1.50
H-5	NON	17.6	6.2	6.5	0.97
H-6	CAT	21.2	6.6	4.9	1.34
WEEK 2 AVERAGES:					
ALL ADV. STOVES:			5.5	4.8	1.19
CATALYTIC:			5.5	4.5	1.24
NON-CATALYTIC:			5.4	5.2	1.14
SAMPLE STD.DVN.:			1.3	1.7	0.2

Table 5. Advanced Technology Woodstoves, Sample Week 3. Fuel Moisture, Emissions, and Burn Rate.

HOME #	STOVE TYPE	FUEL H20 (% D.B.)	PARTICULATE EMISSIONS GRAMS/HR	GRAMS/KG	BURN RATE (DRY KGS/HR)
H-1	CAT	21.4	8.4	8.9	0.94
H-2	NON	18.4	4.9	6.0	0.81
H-3	CAT	19.6	5.5	5.8	0.95
H-4	NON	12.9	3.1	2.6	1.20
H-5	NON	15.0	5.9	7.5	0.78
H-6	CAT	22.7	8.1	7.1	1.14
WEEK 3 AVERAGES:					
ALL ADV. STOVES:			6.0	6.3	0.97
CATALYTIC:			7.3	7.3	1.01
NON-CATALYTIC:			4.6	5.4	0.93
SAMPLE STD.DVN.:			2.0	2.1	0.2



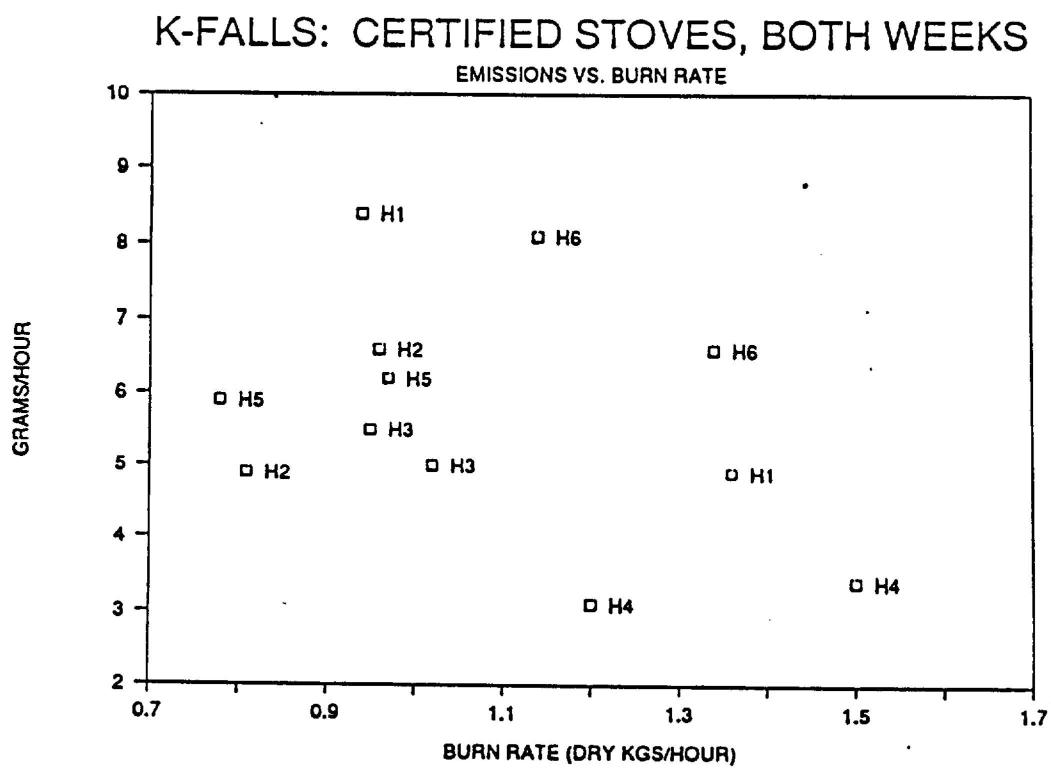


Figure 1. Emissions vs. Burn Rate for all Sample Points. Advanced Technology and Conventional Woodstoves.

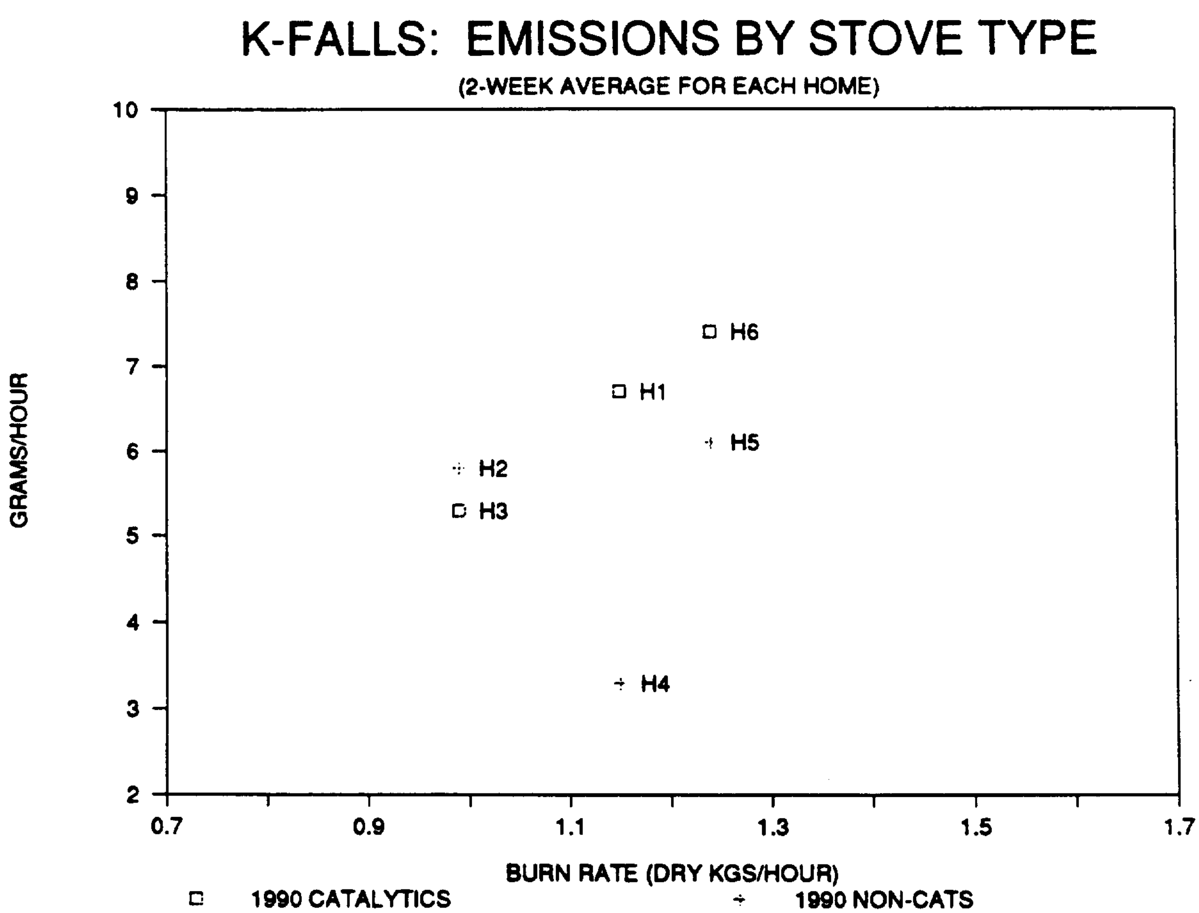


Figure 2. Emissions vs. Burn Rate by Stove Type for Both Sample Weeks.

The type of fuel used by each home during each week of sampling is presented in Table 6 below. With one exception the study homes used some type of softwood, the most common fuel in the area. Homes H-2 and H-5 used juniper exclusively, Home H-3 used only white fir, and H-6 used mostly red fir. Homes H-1 and H-4 used a mix of other softwoods, including lodgepole pine. Home H-4 used small amounts of oak, the only home in the study to use any hardwood fuel at all.

Table 6. Advanced Technology Woodstoves, Weeks 1 and 2. Fuel Type and Percent Use.

	WEEK 1		WEEK 2	
HOME	FUEL TYPE	PERCENT USE	FUEL TYPE	PERCENT USE
H-1	Yellow Pine	100	Juniper	60
			Red fir	40
H-2	Juniper	100	Juniper	100
H-3	White fir	100	White fir	100
H-4	Lodgepole Pine	50	Juniper	70
	Juniper	25	Oak	30
	Oak	25		
H-5	Juniper	100	Juniper	100
H-6	Red fir	100	Red fir	50
			Lodgepole Pine	50

Differences Between Sampling Periods

"Sample Week 2" (the first week of testing on advanced technology stoves) was conducted during the first week of February (except Home H-6, which was sampled during the week of February 6). Sample Week 3 was conducted approximately two weeks later for all homes except H-2 and H-6, where the interval between sample weeks was three weeks. Table 7 on Page 15 compares the fuel moisture and burn rates for each sample week.

None of the study homes showed statistically significant changes in burn rates between the two sampling periods (See Appendix C for Test Statistics), although all study homes showed a slightly lower burn rate during Week 3. The only marked change in operating conditions between sample weeks occurred in Home H-1 (catalytic), where the fuel moisture more than doubled between Week 2 and 3 when the homeowner changed fuel sources.

The increased fuel moisture, combined with a lower burn rate, appears to have had a detrimental effect on the performance of the H-1 catalytic stove during Week 3. The non-catalytic homes showed no statistically significant change in emissions rates between sample weeks (Table 8 on Page 16, and Table C-1, Appendix C). The only statistically significant difference in emissions occurred in the grams/kg emissions of catalytic models (Table C-1, Appendix C).

Homes H-1 and H-6, which contained the same catalytic model, both showed increased emissions during Week 3. But the largest emissions increase occurred in Home H-1 (4.9 g/hr [3.6 g/kg] in Week 2 to 8.4 g/hr [8.9 g/kg] in Week 3), which used notably wetter fuel and burned at a lower burn rate during Week 3.

Both of these conditions (wet fuel and low burn rates) are known to detrimentally affect performance. It is likely that temperatures dropped below the threshold required to keep the combustor catalytically active, but temperature and fuel loading data are not available for review at this time.

The difference in burn rate betwen sample weeks for Home H-6 (0.2 kg/hr less during Week 3) did not appear to be a factor in the emissions rate increase observed in this home. The emissions increase was not as marked as Home H-1, climbing from 6.6 to 8.1 g/hr. The third unit (Home H-3) exhibited the best performance of the catalytic models, with emissions of 5.0 g/hr in Week 2 and 5.5 g/hr during Week 3.

Table 7. Advanced Technology Woodstoves, Differences Between Sampling Periods in Fuel Moisture and Burn Rate.

	FUEL MOISTURE (% DRY BASIS)			BURN RATE (DRY KGS/HR)		
HOME #	WEEK 2	WEEK 3	CHANGE	WEEK 2	WEEK 3	CHANGE
NON-CATALYTIC:						
H-2	19.1	18.4	- 0.7	0.96	0.81	-0.15
H-4	13.4	12.9	- 0.5	1.50	1.20	-0.30
H-5	17.6	15.0	- 2.6	0.97	0.78	-0.19
CATALYTIC:						
H-1	10.0	21.4	+11.4	1.36	0.94	-0.42
H-3	19.7	19.6	- 0.1	1.02	0.95	-0.07
H-6	21.2	22.7	+ 1.5	1.34	1.14	-0.20

Table 8. Advanced Technology Woodstoves, Differences Between Sampling Periods in Particulate Emissions.

	PARTICULATE EMISSIONS (GRAMS/HOUR)			PARTICULATE EMISSIONS (GRAMS/KG)		
HOME #	WEEK 2	WEEK 3	CHANGE	WEEK 2	WEEK 3	CHANGE
NON-CATALYTIC:						
H-2	6.6	4.9	-1.7	6.8	6.0	-0.8
H-4	3.4	3.1	-0.3	2.2	2.6	+0.4
H-5	6.2	5.9	-0.3	6.5	7.5	+1.0
CATALYTIC:						
H-1	4.9	8.4	+3.5	3.6	8.9	+5.3
H-3	5.0	5.5	+0.5	4.9	5.8	+0.9
H-6	6.6	8.1	+1.5	4.9	7.1	+2.2

DISCUSSION

Table 9 below shows the results of the Klamath Falls testing (grams/hour) as compared to some of the field studies conducted in the past. Catalytic values are equivalent to the emission factors used by EPA, and better than those obtained in the most recent "CONEG" study. Overall, the emissions performance of the advanced technology woodstoves in Klamath Falls was the best yet exhibited in a field study.

Table 9. Comparison of Klamath Falls Results with Previous Woodstove Field Performance Studies.

STUDY (REF. #)	CONVENTIONAL (GRAMS/HOUR)	CATALYTIC (GRAMS/HOUR)	NON-CATALYTIC (GRAMS/HOUR)
KLAMATH FALLS	42.8	6.4	5.0
EPA (1)	21.3	6.2	9.2
NCWS/CONEG (2)		8.7	10.3
OREGON "BEST" (6)		4.5	14.5

Although the Klamath Falls data are limited, Elements Unlimited feels that the low level of emissions of the advanced technology woodstove models in this study can be attributed to two primary factors:

1) The units used in this study were of the latest design and representative of the advanced technology woodstoves available today.

2) The stoves were treated as one part of a complete system, which included correct flue sizing and operator training. (The installations in this study followed recommendations contained in manufacturer's operation manuals, and it is accepted industry practice to provide customers with the information required to help them learn about the latest advances in wood-burning technology.)

Past studies often ignored the potential effects of short flues with multiple bends, wet fuel, or operators that were not sensitive to the operating differences between their old stove and an advanced technology stove. But even when there are attempts to control these variables, field performance rarely matches what is seen in the lab. The most recent "CONEG" study controlled installations and provided operator training, but four out of the five stoves still exceeded their "certification" emissions values (2). The remaining stove closely matched its lab values, and showed the best field performance of all five units, but was still unable to pass an actual certification test because it exceeded the emissions "cap" limit at high burn rates.

Performance discrepancies between lab and field have been attributed to differences in fuel piece size and loading geometry (1, 2). Standard test methods use smaller fuel pieces than are normally found in the field. Small pieces expose large surface areas to flames, resulting in rapid volatilization of gases. Stove manufacturers trying to pass the standard test methods are forced to "tune" the combustion air to supply enough oxygen for the fuel-rich conditions of the certification tests.

Homeowners tend to load their stoves with larger (and fewer) pieces of wood than used in the standard tests--the volatilization rate is much slower, and the result is high levels of excess air that can negatively impact performance. Home installations usually show leaner operating conditions, more dilute flue gases, and higher drafts than in the lab.

Figure 3 on the following page illustrates the dramatic reduction in particulate emissions that advanced technology woodstoves are capable of achieving. Airsheds impacted by wood smoke could reduce particulate loading by encouraging replacement of conventional woodstoves with more advanced designs, and by educating the public about the latest clean-burning technology.

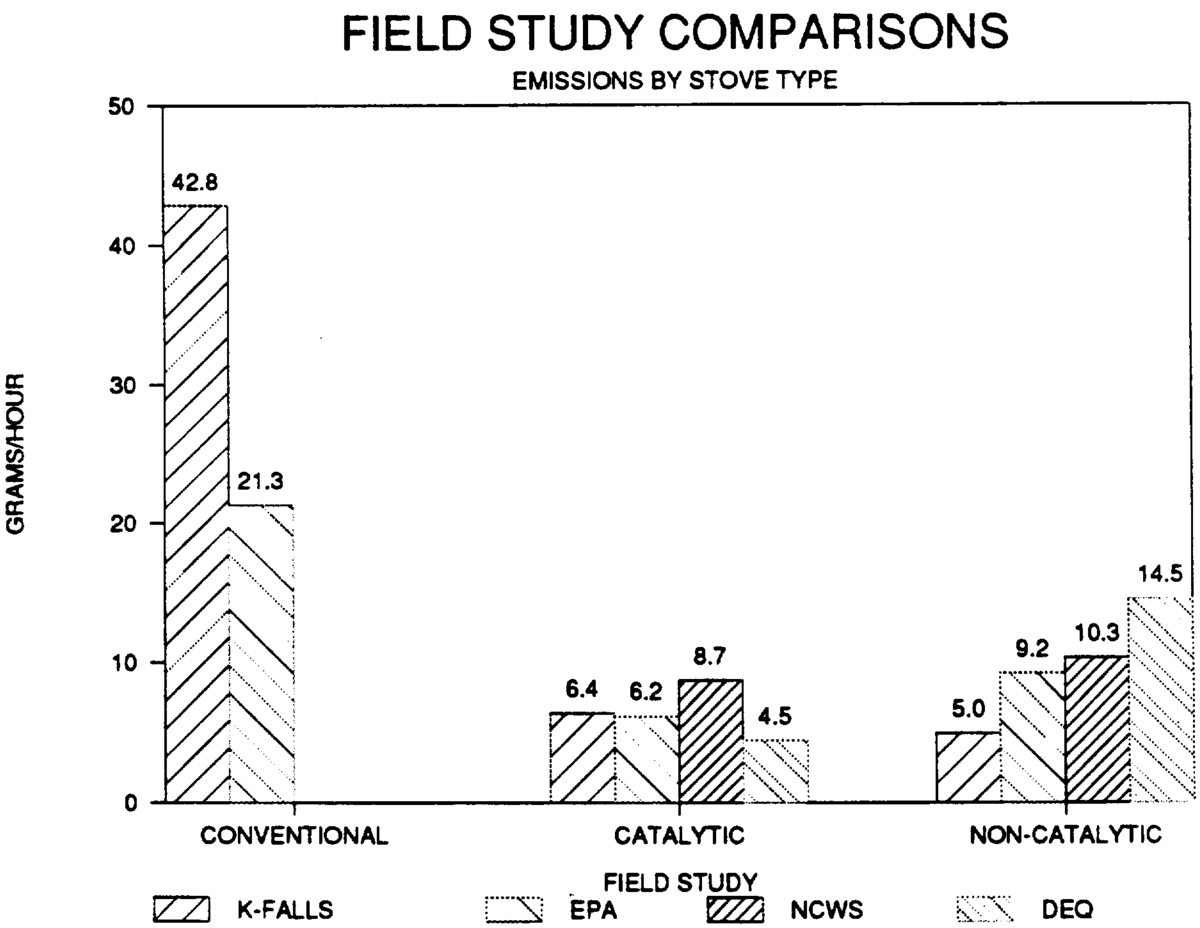


Figure 3. Emissions vs. Burn Rate, Advanced Technology and Conventional Woodstoves, Klamath Falls and Other Field Studies (See Table 9).

REFERENCES

1 U.S. Environmental Protection Agency, "In-Situ Emission Factors for Residential Wood Combustion Units." Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, December, 1988 (EPA-450/3-88-013).

2 Barnett, Stockton, "Field Performance of Advanced Technology Woodstoves in Glens Falls, N.Y., 1988-1989, Volume I." Prepared for New York State Energy Research and Development Aurthority, U.S. EPA, and CONEG Policy Research Center, December, 1989.

3 Oregon Department of Environmental Quality, Oregon Revised Statute 468.630 thru .655, OAE 340-21-100 thru -190, Salem, Oregon, 1983.

4 Oregon Department of Environmental Quality, "1986 Oregon Air Quality Annual Report," Air Quality Control Division, Portland, Oregon, 1987.

5 U.S. Environmental Protection Agency, "Standard of Performance for New Stationary Sources; New Residential Wood Heaters." Federal Register, Volume 53, Number 38, Section 40 CFR, Part 60, February 26, 1988.

6 Simons, Carl A. and S.K. Jones, "Performance Evaluation of the Best Existing Stove Technology (BEST) Hybrid Woodstove and Catalytic Retrofit Device." Prepared for Oregon Department of Environmental Quality, Project #PS-320, July, 1989.

7 Burnet, Paul B., and C.A. Simons, "Identification of Factors Which Affect Combustion Efficiency and Environmental Impacts from Woodstoves." Task D, U.S. Department of Energy Biomass Energy Program, Contract No. DE-AC79-85BP18508, July, 1988.

8 Statistical Analysis Provided by Gary Hazard, Chairman, Stove Technical Committee, Wood Heating Alliance, April, 1990 (See Appendix C).

KLAMATH FALLS FIELD STUDY

APPENDIX A

TEST HOME DESCRIPTIONS

TEST HOME DESCRIPTION

HOME # H-1

ORIGINAL "CONVENTIONAL" STOVE: Earth Stove 101. Approximately 10 years old, thermostatically controlled. (Stove had minor crack inside, thermostat was inoperative.)

1990 STOVE TYPE: Catalytic
FIREBOX SIZE: 2.9 cubic feet

TEST WEEK 1: January 9 - 17
TEST WEEK 2: February 1 - 7
TEST WEEK 3: February 22 - 28

FUEL USED: Yellow Pine
Juniper
Red fir

OPERATOR INSTRUCTIONS: Received operating instructions on-site from a manufacturer's representative.

OTHER NOTES: This home was provided with Juniper fuel (common fuel in the area) during Week 3 when it appeared their supply would run out.

Chimney re-lined with 6" stainless steel liner prior to start of Week 2 sampling.

TEST HOME DESCRIPTION

HOME # H-2

ORIGINAL "CONVENTIONAL" STOVE: Earth Stove 101. Approximately 10 years old, thermostatically controlled. (Test Week 1: January 10-16)

1990 STOVE TYPE: Non-catalytic
FIREBOX SIZE: 1.8 cubic feet

TEST WEEK 1: January 10 - 16
TEST WEEK 2: January 31 - February 6
TEST WEEK 3: February 26 - March 4

FUEL USED: Juniper

OPERATOR INSTRUCTIONS: Instruction was provided before the stove was actually installed. A representative of one of the other manufacturers in the study used the woodstove model in Home H-4 to provide general operating instructions to Home H-2.

OTHER NOTES: Operator is a renter who just recently moved in. House has had a chimney fire in the past. The chimney was lengthened prior to the start of advanced technology sampling (Weeks 2 and 3).

During Week 2 of sampling this home was requested to cut their fuel smaller in accordance with the operating instructions.

Chimney re-lined with 6" stainless steel liner prior to start of Week 2 sampling.

TEST HOME DESCRIPTION

HOME # H-3

ORIGINAL "CONVENTIONAL" STOVE: Centennial. 10 years old, thermostatically controlled.

1990 STOVE TYPE: Catalytic
FIREBOX SIZE: 2.0 cubic feet

TEST WEEK 1: January 10 - 16
TEST WEEK 2: January 31 - February 6
TEST WEEK 3: February 23 - March 1

FUEL USED: White Fir

OPERATOR INSTRUCTIONS: A retailer from Portland gave operating instructions verbally by telephone.

OTHER NOTES: Homeowners were found to be using very small fuel loads and then burning at a high rate. This home was requested to load larger fuel pieces and burn at a lower air setting, in accordance with the instructions in the operating manual.

The flue was lengthened between Weeks 2 & 3.

Chimney re-lined with 6" stainless steel liner prior to start of Week 2 sampling.

TEST HOME DESCRIPTION

HOME # H-4

1990 STOVE TYPE: Non-catalytic
FIREBOX SIZE: 2.0 cubic feet

TEST WEEK 1: (Not Applicable)
TEST WEEK 2: January 31 - February 6
TEST WEEK 3: February 22 - 28

FUEL USED: Juniper
Lodgepole Pine
Oak

OPERATOR INSTRUCTIONS: Received firing demonstration and instructions from a manufacturer's representative.

OTHER NOTES: The chimney was lengthened prior to the start of advanced technology sampling (Weeks 2 and 3).

Chimney re-lined with 6" stainless steel liner prior to start of Week 2 sampling.

TEST HOME DESCRIPTION

HOME # H-5

1990 STOVE TYPE: Non-catalytic

FIREBOX SIZE: ___ cubic feet

TEST WEEK 1: (Not Applicable)
TEST WEEK 2: January 31 - February 6
TEST WEEK 3: February 23 - March 1

FUEL USED: Juniper

OPERATOR INSTRUCTIONS: No instructions (other than the operator's manual) were provided to this home.

OTHER NOTES: The flue connector included a 45 degree offset. On February 20 the air inlet control was adjusted with a screw driver for easier operation.

TEST HOME DESCRIPTION

HOME # H-6

1990 STOVE TYPE: Catalytic
FIREBOX SIZE: 2.9 cubic feet

TEST WEEK 1: (Not Applicable)
TEST WEEK 2: February 6 - 12
TEST WEEK 3: March 3 - 8

FUEL USED: Red Fir
Lodgepole Pine

OPERATOR INSTRUCTIONS: Received operating instructions from a manufacturer's representative.

OTHER NOTES: Chimney re-lined with 6" stainless steel liner prior to start of Week 2 sampling.

KLAMATH FALLS FIELD STUDY

APPENDIX B

AWES SAMPLE LOG
AND
FUEL DATA SHEETS

KLAMATH FALLS FIELD STUDY

HOME H – 1

Elements Unlimited

AWES Log Book

Home Code: K01   Sampling Rotation: 1 ☑ 2 ☐ 3 ☐ 4 ☐ 5 ☐ B ☐

Sample I.D.: K01-1

AWES Box #	~~26~~ 1032	Filter #	K002
Teflon Line #	~~K01~~ P.S.	Probe #	20
XAD#	195		

Installation	Removal
Date AWES Installed 1/8/90	Date AWES Removed 1/19/90
by: P.S.	by: JWF, P.S.
1. Programmed Start time	**1. Programmed Stop time**
Date: 1/9/90 Time: 0:00	Date: 1/19/9 Time:
2. Leak Check (inlet plugged, outlet open)	**2. Leak Check (inlet plugged, outlet open)**
max. vacuum, ~~right~~ top gauge 21.75 "Hg	max. vacuum, right gauge 21.25 "Hg
max. vacuum, ~~left~~ bottom gauge 21.5 "Hg (P.S.)	max. vacuum, left gauge 20.75 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.75 "Hg	max. vacuum, right gauge 20.75 "Hg
max. vacuum, left gauge 21.5 "Hg	max. vacuum, left gauge 20.50 "Hg
3. Free-flow check (inlet open, outlet open)	**3. Free-flow check (inlet open, outlet open)**
vacuum, right gauge 19.0 "Hg	vacuum, right gauge 19.0 "Hg
vacuum, left gauge 0.0 "Hg	vacuum, left gauge 0 "Hg
rotometer 1.05 "Hg	rotometer 1.05 "Hg
4. Heater works: Yes ☑ (if no, use substitute AWES	**4. Heater works:** Yes ☑ No ☐
5. O_2 cell calibrated ☑ Yes	**5. O_2 cell on ambient air** 21.5 %
	Ambient temp. 71 °F
	AWES temp. strip 82 °F

AWES.C

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK01 Resident Name: Charles Land Technician P.J.

Sampling Rotation: 1 ☑ 2 ☐ 3 ☐ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Yellow pine	Cedar	Juniper	Moisture (%DB)
		9.0, 8.5, 6.5	70							90% P.J.			
		6.5, 6.0, 10.0	70							✓			
		9.5, 9.5, 9.0	70							✓			
		8.0, 8.5, 9.0	70							✓			
		7.5, 8.0, 9.5	70							✓			
		6.0, 5.5, 8.0	70								10 5		
		9.0, 8.5, 10.5	70									5	
		8.35, 9.0, 8.0	63							✓90%			
		8.25, 8.0, 9.0	↓										
		9.75, 10.5, 9.25											
		9.35, 8.25, 8.0											
		7.75, 8.75, 9.0											
		16.0, 17.25, 17.5									Lodgepole 10%		
		18.0, 19.5, 19.0									✓		
		17.5, 16.5, 16.0											
		14.0, 13.5, 19.0											
		18.5, 20.5, 19.0											

Make notation if wood block(s) obtained.

AWES Log Book

Home Code: WK01 Sampling Rotation: 1☐ 2☑ 3☐ 4☐ 5☐ B☐

Sample I.D.:_______

AWES Box # 11	Filter # K030	XAD# 190	
Teflon Line # 20	Probe # 2		

Installation	Removal	
Date AWES Installed 2/1/90 (1/31/90)	Date AWES Removed 2/12/90	
by: RR, JJ, C	by: JJ, RJ	
1. Programmed Start time	1. Programmed Stop time	
Date: 2/1 Time: 0	Date: 2/7 Time: 23:59	
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)	
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 20.6 "Hg	20.8
max. vacuum, left gauge 20.0 "Hg	max. vacuum, left gauge 20.0 "Hg	20.7
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds	
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 19.6 "Hg	20.8
max. vacuum, left gauge 20.0 "Hg	max. vacuum, left gauge 18.6 "Hg	20.6
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)	
vacuum, right gauge 19 "Hg	vacuum, right gauge 18.8 "Hg	
vacuum, left gauge 0 "Hg	vacuum, left gauge 0.0 "Hg	
rotometer 1.05 "Hg	rotometer 1.05 "Hg	
4. Heater works: Yes ☑ (if no, use substitute AWES	4. Heater works: Yes ☑ No ☐	
5. O_2 cell calibrated ☑ Yes	5. O_2 cell on ambient air _______%	
	Ambient temp. _______ °F	
	AWES temp. strip _______ °F	

AWES.C

from previous visit to home

Sample Data

Lab Cleanup Date ______________ Technician ______________

Probe Rinse—Sample No. ________

Filter # ______________

XAD # ______________

Samples delivered to OMNI? ☐ Yes

Delivered by: ______________________________

Comments

NOTE: THIS UNIT STARTED UP IMMEDIATELY AFTER BEING RE-PROGRAMMED.

– 2/1/90 18:20 STRONG FLAME - SETTING - MED-LOW (SEE DRAWING)

COT TEMP = 1650°+
COT GLOWING BRIGHTLY. O_2 = 5.5%

2/12/90

Homeowners told us that ByPass on stove was not all the way pushed in on 1 or 2 nights

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK0102 Resident Name: Loud Technician DI

Sampling Rotation: 1 ☐ 2 ☑ 3 ☐ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Yellow Pine			Moisture (%DB)
	2/12/90	9.75, 9.5, 10.0	70°							100%			
		10.5, 10.5, 10.5	↓							✓			
		10.75, 9.75, 10.25	↓							↓			
		9.0, 9.0, 8.25	↓							↓			
		10.0, 10.5, 11.5	↓							↓			
		12.0, 10.5, 11.25	↓							↓			
		9.5, 9.75, 10.75	↓							↓			
		9.25, 9.75, 10.0	↓							↓			
		10.0, 9.5, 9.25	↓							↓			
		10.0, 10.5, 9.5	↓							↓			

Make notation if wood block(s) obtained.

AWES.B1

AWES Log Book

Home Code: WK91 Sampling Rotation: 1☐ 2☐ 3☒ 4☐ 5☐ B☐

Sample I.D.: WK91Φ3

AWES Box # -11	Filter # KΦ7Φ	XAD# 5
Teflon Line # 20 [new filter]	Probe # 25	

Installation	Removal
Date AWES Installed 2-21-90	Date AWES Removed 3/2/90
by: JWF	by: BS
1. Programmed Start time	1. Programmed Stop time
Date: 2-22 Time: 0	Date: 2/28 Time: 23:59
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.0 "Hg
max. vacuum, left gauge 21.0 "Hg	max. vacuum, left gauge 20.7 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.0 "Hg
max. vacuum, left gauge 21.0 "Hg	max. vacuum, left gauge 20.7 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 18.9 "Hg	vacuum, right gauge 18.8 "Hg
vacuum, left gauge Φ "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.05 "Hg	rotometer 1.05 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES	4. Heater works: Yes ☑ No ☐
5. O_2 cell calibrated ☑ Yes	5. O_2 cell on ambient air 20.9%
	Ambient temp. ______ °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics—Log Sheet
Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WKØ1 Resident Name: LOUD Technician JWF

Sampling Rotation: 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	100% Lodgepole	Juniper		Moisture (%DB)
2/21/90		30	30										
		32,22,23											
		22,20,23											
		23,23,32											
		22,29,29											
		23,20,31											
		29,31,21											
		31,26,24											
		31,24,31											
		28.0,22.0,27.0									60 ✓		
		19.5,20.0,20.0									↓		
		24.0,20.5,23											
		19.5,19,22											
		20.5,20,20.5											
		20,20.5,20.5											
		16,14.5,14.5					✓40						
		16,13.5,					↓						
		14.5,13.5,14											
		13.5,12											
		16.5,16.5,19											

Make notation if wood block(s) obtained. —

AWES.B1

2/22 — THE LOUD'S STARTED USING THE SAME RED-FIR AS IN THE LAST SAMPLE-WEEK — WHA IS PROVIDING THE FAMILY WITH WOOD OTHER THAN THE PILE THAT WAS MEASURED — ASK THE LOUD'S WHAT ~~[illegible]~~ WOOD WAS USED ON WHICH DAY OF THE STUDY. JWF.

Red fir during day (earlier)
[illegible] [illegible] from WHA 2/23/90 mostly at night

KLAMATH FALLS FIELD STUDY

HOME H – 2

Elements Unlimited

AWES Log Book

Home Code: K02 Sampling Rotation: 1☑ 2☐ 3☐ 4☐ 5☐ B☐

Sample I.D.: K02-1

AWES Box # 8641-29 Filter # K005 XAD# 33

Teflon Line # 23 Probe # 5

Installation	Removal
Date AWES Installed 1/10/90	Date AWES Removed 1/17/90
by: P.J.	by: P.J.
1. Programmed Start time	1. Programmed Stop time
Date: 1/10/90 Time: 0:00	Date: 1/16 Time: 23:59
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.75 "Hg	max. vacuum, right gauge 21.5 "Hg
max. vacuum, left gauge 21.50 "Hg	max. vacuum, left gauge 21.0 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.75 "Hg	max. vacuum, right gauge 21.0 "Hg
max. vacuum, left gauge 21.50 "Hg	max. vacuum, left gauge 21.0 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.5 "Hg	vacuum, right gauge 19.25 "Hg
vacuum, left gauge 0.0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.15 "Hg	rotometer 1.10 "Hg
4. Heater works: Yes ☑ (if no, use substitute AWES	4. Heater works: Yes ☑ No ☐
5. O_2 cell calibrated ☑ Yes	5. O_2 cell on ambient air 21.7 %
	Ambient temp. 78 °F
	AWES temp. strip 87 °F

AWES.C

Wood Characteristics—Log Sheet
Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: W K02

Resident Name: Sherri Terrell

Sampling Rotation: 1 ☑ 2 ☐ 3 ☐ 4 ☐ 5 ☐

Technician P.J.

	AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
	Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Yellow Pine	Cedar		Moisture (%D
			18.0, 16.0, 13.0	73										
			14.25, 16.75, 16.5	↓							80			
			15.0, 14.5, 15.25								✓			
			15.5, 13.0, 14.0								✓			
			17.5, 16.0, 17.25								✓			
			10.0, 12.0, 10.75								✓			
			13.25, 11.75, 12.0									20		
			9.5, 10.0, 10.25									✓		
			10.25, 11.0, 11.5									✓		
			9.0, 9.5, 10.5	↓								✓		
												✓		
cedar {			15.0, 12.75, 13.5	100										
			23.0, 22.0, 24.0								50%	50%		
			14.5, 14.25, 15.0	↓								✓		
			17.25, 24.0, 16.5											
			12.75, 15.25, 13.5											
Pine {			17.25, 17.0, 21.75											
			16.25, 16.25, 16.5								✓			
			13.5, 13.75, 13.5											
			14.0, 16.5, 13.5											
			15.0, 15.25, 16.5	↓										

Make notation if wood block(s) obtained.

AWES Log Book

Home Code: WK02 Sampling Rotation: 1☐ 2☒ 3☐ 4☐ 5☐ B☐

Sample I.D.:________

AWES Box # 26	Filter # K025	XAD# 220
Teflon Line # 6	Probe # 10	

Installation	Removal
Date AWES Installed 1/29/90	Date AWES Removed 2/11/90
by: Jim V.	by: PJ
1. Programmed Start time	1. Programmed Stop time
Date: 1/31/90 Time: 0	Date:________ Time:________
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21 "Hg	max. vacuum, right gauge ~~20.5~~ P.J. 21.0 "Hg
max. vacuum, left gauge 20.5 "Hg	max. vacuum, left gauge 20.75 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 20.5 "Hg	max. vacuum, right gauge 21.0 "Hg
max. vacuum, left gauge 20 "Hg	max. vacuum, left gauge 20.75 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 20 "Hg	vacuum, right gauge 19.0 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.05 "Hg	rotometer 1.10 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air 20.7 %
	Ambient temp.________ °F
	AWES temp. strip________ °F

AWES.C

Wood Characteristics—Log Sheet
Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK02

Resident Name: Terrell

Sampling Rotation: 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐

Technician C. Lyon

AWES Service Date: Installation	AWES Service Date: Removal	Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Juniper			Corrected Moisture (%DB)
1/29/90		20	40										
"		19	"							100			
"		14	"										
"		21	"										
"		13	"										
"		20	"										
"		21	"										
"		24	"										
"		18	"										
"		20	"										
	2/11/90	19, 22, 17,	70										
		23, 23, 27	↓							100%			
		23, 14.5, 14.75	↓							↓			
			0							↓			
	2/12/90	18.0, 18.5, 16.0	70°							↓			
	↓	13.0, 16.75, 19.5								100%			
	↓	20.5, 20.0, 20.0	↓										
	↓	19.5, 15.5, 19.5	↓							↓			
	↓	24.0, 24.0, 24.0	↓							↓			
	↓	19.5, 22.0, 19.25	↓							↓			
	↓	20.25, 17.25, 19.75	↓							↓			

Make notation if wood block(s) obtained.

AWES Log Book

Home Code: WK02 Sampling Rotation: 1☐ 2☐ 3☒ 4☐ 5☐ B☐

Sample I.D.: WK0203

AWES Box # 26 Filter # K072 XAD# 155

Teflon Line # 8 Probe # 5

Installation	Removal
Date AWES Installed 2-21-90	Date AWES Removed 3/7/90
by: JJF	by: [illegible]
1. Programmed Start time	1. Programmed Stop time
Date: ~~0:00~~ 2/26 Time: 0:00	Date: 3/4 Time: 23:59
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.4 "Hg	max. vacuum, right gauge 21.2 "Hg
max. vacuum, left gauge 20.8 "Hg	max. vacuum, left gauge 20.8 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.3 "Hg	max. vacuum, right gauge 21.2 "Hg
max. vacuum, left gauge 20.7 "Hg	max. vacuum, left gauge 20.5 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.0 "Hg	vacuum, right gauge 19.0 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0 "Hg
rotometer 1.1 "Hg	rotometer 1.1 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES)	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air 20.9 %
	Ambient temp. ______ °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK02

Resident Name: ~~[illegible]~~ Terre

Technician: PJ

Sampling Rotation: 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5 ☐

AWES Service Date: Installation	AWES Service Date: Removal	Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Cedar	Juniper	Corrected Moisture (%DB)
2/21		22,17,19.5	40									
		18,22,17.5	↓							100		
		21,21,20.5	35							↓		
		16.5,19,14.5	↓							↓		
		16,17.5,20										
	AVG. 17.425	15,17.5,13.5										
		15.5,18,15.5										
		16.5,19.5,17.5										
		14,13.5,12.5										
		16.5,16.75,17.75										
			↓							↓		
	3/7/90	19,16.5,14.5	60° (garage)									
		23.5,21,21.5								10%	90%	
		17,18,15										
		19,20.5,18.5										
		20,19,18										
		17.5,16.5,15										
	*	22.5,20,28										
		15.5,17.5,18.25										
		15.5,14,16.5										
	AVG.	22,22,21.5										
	19.432	23,22,23										

Make notation if wood block(s) obtained.

AVG = 18.428

* warmed for 12 hrs to 70°

17.5	17.75	18.0	70°
16.5	16.75	17.0	35° (original)

→ switched to Juniper for most of test

KLAMATH FALLS FIELD STUDY

HOME H - 3

AWES Log Book

Home Code: K03   Sampling Rotation: 1☑ 2☐ 3☐ 4☐ 5☐ B☐

Sample I.D.: K03-1

AWES Box # 8641-12   Filter # K001   XAD# 211

Teflon Line # 7   Probe # 10

Installation	Removal
Date AWES Installed 1/9/90	Date AWES Removed 1/20/90
by: RJ.	by: RJ/J.F.
1. Programmed Start time	1. Programmed Stop time
Date: 1/10/90 Time: 0:00	Date: ______ Time: ______
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge (Top) 21.2 "Hg	max. vacuum, right gauge 21.2 "Hg
max. vacuum, left gauge (bottom) 20.8 "Hg	max. vacuum, left gauge 21.0 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.0 "Hg
max. vacuum, left gauge 20.8 "Hg	max. vacuum, left gauge 20.9 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.2 "Hg	vacuum, right gauge 19.2 "Hg
vacuum, left gauge 0.0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.05 "Hg	rotometer 1.05 "Hg
4. Heater works: Yes ☑ (if no, use substitute AWES	4. Heater works: Yes ☑ No ☐
5. O_2 cell calibrated ☑ Yes	5. O_2 cell on ambient air 20.9 %
	Ambient temp. 70 °F
	AWES temp. strip 82 °F

AWES.C

Sample Data

Lab Cleanup Date ____________ Technician ____________

Probe Rinse—Sample No. ____________

Filter # ____________

XAD # ____________

Samples delivered to OMNI? ☐ Yes

Delivered by: ____________

Comments

1/20/90 - TC indicates 1124° initially when set to 1000° - After 5 mins, portable TC ~~[illegible]~~ readout attached to the ~~[illegible]~~ calibrator along with the data logger TC. The data logger then indicated 999°.

SCALE INDICATOR READS 218.4 lbs

NEED TO SWITCH OUT SCALE.

SCALE OCCASIONALLY GAVE READINGS OF 270+ lbs.

O_2 LOOKS GOOD

HOME SCALE

CAL WT	INDICATED
10.0	9.9
40.0	41

AWES.D

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK03

Resident Name: Harris

Technician: P.J.

Sampling Rotation: 1 ☑ 2 ☐ 3 ☐ 4 ☐ 5 ☐

AWES Service Date: Installation	AWES Service Date: Removal	Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	White Fir			Corrected Moisture (%DB)
1/90/90		18.5, 16.5, 14.0	74°							100%			
		9.5, 9.5, 9.0								✓			
		9.75, 8.0, 8.0								✓			
		17.5, 20.0, 17.75								✓			
		19.0, 16.0, 17.5								✓			
		13.5, 14.0, 15.5								✓			
		17.0, 15.5, 14.5								✓			
		14.0, 13.75, 15.0								✓			
		15.0, 13.0, 13.5								✓			
		9.0, 10.0, 10.0								✓			
	1/20/90	24.0, 23.5, 26.5	71°							100%			
		13.5, 13.25, 18.75											
		24.0, 26.5, 23.0											
		21.0, 19.75, 24.0											
		15.5, 20.5, 19.0											
		* sawdust											

Make notation if wood block(s) obtained.

* all of the wood that was left indoors

AWES.B

AWES Log Book

Home Code: WK03 Sampling Rotation: 1☐ 2☑ 3☐ 4☐ 5☐ B☐

Sample I.D.:________

AWES Box # 29 Filter # K026 XAD# 10

Teflon Line # 7 Probe # WK0302

Installation	Removal
Date AWES Installed 2/11	Date AWES Removed 2/11/90
by: JWF	by: PJ
1. Programmed Start time	1. Programmed Stop time
Date: 1/31 Time: 0:00	Date: ________ Time: ________
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.3 "Hg	max. vacuum, right gauge 21.5 "Hg
max. vacuum, left gauge 21.0 "Hg	max. vacuum, left gauge 21.0 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.1 "Hg	max. vacuum, right gauge 21.25 "Hg
max. vacuum, left gauge 21.0 "Hg	max. vacuum, left gauge 21.0 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.3 "Hg	vacuum, right gauge 19.5 "Hg
vacuum, left gauge 0.0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.05 "Hg	rotometer 1.10 "Hg
4. Heater works: Yes ☑ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☐ Yes	5. O_2 cell on ambient air ________%
	Ambient temp. 83 °F
	AWES temp. strip ________ °F

AWES.C

From previous page (chg)

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK03

Resident Name: Harris

Technician: PS.

Sampling Rotation: 1 ☐ 2 ☑ 3 ☐ 4 ☐ 5 ☐

AWES Service Date: Installation	AWES Service Date: Removal	Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	W. Fir			Corrected Moisture (%D
1/29/90		24	68°										
		22								100%			
		21											
		16											
		19											
		23											
		22											
		14											
		20											
		22											
	2/11/90	21.0, 19.5, 20.25	75°										
		16.5, 17.75, 18.0											
		17.25, 18.0, 17.0								100%			
		18.25, 18.5, 17.0								✓			
		16.5, 16.5, 21.0								✓			
		24.0, 23.0, 22.5								✓			
		20.5, 19.5, 21.0								✓			
		20.25, 18.5, 17.25								✓			
		19.25, 18.5, 17.0								✓			
		17.5, 18.0, 19.5								✓			
										✓			
										✓			

Make notation if wood block(s) obtained.

AWES Log Book

Home Code: WK03 Sampling Rotation: 1☐ 2☐ 3☒ 4☐ 5☐ B☐

Sample I.D.:______

AWES Box # 29 Filter # K078 XAD# 4

Teflon Line # 69 Probe # K0303

Installation	Removal
Date AWES Installed 2-22-90	Date AWES Removed 3/2/90
by: JWF	by: PJ, GB
1. Programmed Start time	1. Programmed Stop time
Date: 2/23 Time: 0:00	Date: 3/1 Time: 23:59
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.9 "Hg	max. vacuum, right gauge 21.5 "Hg
max. vacuum, left gauge 21.5 "Hg	max. vacuum, left gauge 21.0 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.8 "Hg	max. vacuum, right gauge 21.3 "Hg
max. vacuum, left gauge 21.4 "Hg	max. vacuum, left gauge 21.0 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.5 "Hg	vacuum, right gauge 19.4 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.10 "Hg	rotometer 1.15 "Hg
4. Heater works: Yes ☑ (if no, use substitute AWES	4. Heater works: Yes ☑ No ☐
5. O_2 cell calibrated ☑ Yes	5. O_2 cell on ambient air 21.1 %
	Ambient temp. ______ °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WKΦ3   Resident Name: HARRIS

Sampling Rotation: 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 ☐   Technician JWF

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	WH. FIR			Moisture (%I
2-22-90		21,19,23	56										
		21,23,23											
		24,23,26											
		15,15,16.5											
		20,21,20											
		24,23,24											
		19,22,19											
		19.5,21.5,22											
		23,22,22											
		22,22,24											
	3/2/90	16.92	75°										
		23.17								100%			
		23.17											
		18.5											
		20.08											
		19.58											
		22.67											
		20.17											
		17.83											
		17.67											

Make notation if wood block(s) obtained.

Avg. already

KLAMATH FALLS FIELD STUDY

HOME H - 4

Elements Unlimited

AWES Log Book

Home Code: WK0402 Sampling Rotation: 1☐ 2☒ 3☐ 4☐ 5☐ B☐

Sample I.D.: WK0402

AWES Box # 12 Filter # K024 XAD# 308

Teflon Line # 23 Probe # 5

Installation	Removal
Date AWES Installed 1/29/90	Date AWES Removed ~~Jan~~ 2/11/90
by: SEE PREVIOUS SHEET	by: JWF, PJ
1. Programmed Start time	1. Programmed Stop time
Date: ______ Time: ______	Date: 2/6 Time: ~~14~~ 23
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.2 "Hg
max. vacuum, left gauge 20.6 "Hg	max. vacuum, left gauge 20.5 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 20.8 "Hg	max. vacuum, right gauge 20.8 "Hg
max. vacuum, left gauge 20.6 "Hg	max. vacuum, left gauge 20.5 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 18.5 "Hg	vacuum, right gauge 18.8 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0 "Hg
rotometer 1.05 "Hg	rotometer 1.0 "Hg
4. Heater works: Yes ☑ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☐ Yes	5. O_2 cell on ambient air 20.9 %
	Ambient temp. 80 °F
	AWES temp. strip 84 °F

AWES.C

Sample Data

Lab Cleanup Date ____________ Technician ____________

Probe Rinse—Sample No. ________

Filter # ____________

XAD # ____________

Samples delivered to OMNI? ☐ Yes

Delivered by: ____________________

Comments

NOTE: TC #1 WAS READING LOW AT TAKEDOWN - APPROX 1/2 REAL TEMP (POSSIBLE SHORT AT CONNECTOR, AVERAGING ROOM & STACK TEMP

(AFTER REVIEWING FILE) NOTE: TC #1 HAD A SPORADIC SHORT, ONLY SOMETIMES READING LOW. USE TC #2

AWES.D

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK04 02 Resident Name: Rickard Technician PJ

Sampling Rotation: 1 ☐ 2 ☑ 3 ☐ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	AVE LODGE POLE	Juniper	O	Moisture (%D
[illegible]		10	40°							50	50		
1/29/90		11	↓										
		9											
		13											
		9											
		11											
		13											
		17	62°										
		15	↓										
		14											
		12											
		13/12											
	2/11/90	11.5, 9.0, 12.25	50° (outsi…								100%		
		10.5, 11.5, 9.75	(see below)								✓		
		10.5, 12.75, 14.0									✓		
			↓	[illegible]									
		21.0, 19.5, 21.0		30%									
		12.5, 12.0, 12.5		✓									
		21.0, 17.25, 19.5		✓									
		20.5, 19.5, 19.5		✓									
		16.5, 17.5, 16.0		✓									
		11.5, 11.5, 12.25	↓										
	2/12/90	12.75, 12.5, 12.5	62°							✓10%			
		11.0, 10.5, 11.5	62°								✓		
		14.0, 14.0, 13.5	62°	✓							✓		

Make notation if wood block(s) obtained.

See Previous Sheet (installation rows)

100% outside (rows of 2/11/90)

None inside (rows of 2/12/90)

wood probably 45°

For test: mostly Juniper
Some Oak at night
for start ups Lodgepole

AWES Log Book

Home Code: WK34 Sampling Rotation: 1☐ 2☐ 3☒ 4☐ 5☐ B☐

Sample I.D.: ________

AWES Box # 12	Filter # K077	XAD# 217	
Teflon Line # 7	Probe # 2 (on tape)		

Installation	Removal
Date AWES Installed ________	Date AWES Removed 3/2/90
by: ________	by: [signature]
1. Programmed Start time	1. Programmed Stop time
Date: ________ Time: ________	Date: 2/28 Time: 23:59
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.1 "Hg
max. vacuum, left gauge 20.9 "Hg	max. vacuum, left gauge 20.9 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 20.9 "Hg
max. vacuum, left gauge 20.6 "Hg	max. vacuum, left gauge 20.8 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.0 "Hg	vacuum, right gauge 18.8 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0 "Hg
rotometer 1.05 "Hg	rotometer 1.05 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air ________ %
	Ambient temp. ________ °F
	AWES temp. strip 84 °F

AWES.C

– missed wood loading on 2/28/90

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK 04

Resident Name: ____________

Technician ____________

Sampling Rotation: 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	[illegible]			Moisture (%DB)
2/21/90		10.5, 12, 11.5	70	25-30,									
		11.5, 11.0, 10.0											
		13, 14, 13.5											
		16, 12.0, 12.5											
		12, 12.5, 11.5											
		12, 13.5, 13											
		15.5, 13, 10											
		13, 10, 11.5											
		19, 17, 17											
	3/2/90	15.5, 15.8, 15.0	50°	30									
		15.6, 16.4, 15.8								70			
		17.3, 21, 19.5											
		10.75, 11.0, 12.5											
		11.3, 11.0, 12											
		11.5, 13.0, 12.5											
		11.0, 11.0, 12.0											
		11.0, 11.5, 11.0											
		10.5, 11.0, 11.5											
		11.0, 11.0, 11.0											

Make notation if wood block(s) obtained.

NOTE - OAK IS MAINLY USED FOR THE LAST LOAD OF THE NIGHT - THE OAK IS SCRAPS FROM MAKING PALLETS

KLAMATH FALLS FIELD STUDY

HOME H - 5

AWES Log Book

Home Code: WKO5 Sampling Rotation: 1☐ 2☒ 3☐ 4☐ 5☐ B☐

Sample I.D.: 02

AWES Box # 21	Filter # X003	XAD# 007	
Teflon Line # 10	Probe # ~~4~~ 9 P.J.		

Installation	Removal
Date AWES Installed 1/30/90	Date AWES Removed 2/12/90
by: JWF	by: JF, PJ
1. Programmed Start time	1. Programmed Stop time
Date: 1/31 Time: 0	Date: ______ Time: ______
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.75 "Hg
max. vacuum, left gauge 20.0 "Hg	max. vacuum, left gauge 21.0 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 21.75 "Hg
max. vacuum, left gauge 20.0 "Hg	max. vacuum, left gauge 21.0 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19 "Hg	vacuum, right gauge 19.25 "Hg
vacuum, left gauge .0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.1 "Hg	rotometer 1.10 "Hg
4. Heater works: Yes ☐ (if no, use substitute AWES	4. Heater works: Yes ☑ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air ______ %
	Ambient temp. ______ °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WKOS

Resident Name: Neubert

Technician: Lyon

Sampling Rotation: 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)								Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Cedar	Juniper	Moisture (%DB)
1/30/90		25	35°									
		24	"							~~10~~		
"		14	"							10		
"		14	"								90	
"		15	"								"	
"		16	"								"	
"		17	"								"	
"		18	"								"	
"		19	"								"	
"		20	"								"	
											"	
	2/15/90											
		18	70									
		16.5										
		16.25										
		17										
		18										
		17.5										
		16.75										
		16.75										
		18.0										
		14.0										

Make notation if wood block(s) obtained.

AWES.

AWES Log Book

Home Code: WK05 Sampling Rotation: 1☐ 2☐ 3☒ 4☐ 5☐ B☐

Sample I.D.: WK0503

AWES Box # 21 Filter # K067 XAD# 107

Teflon Line # 10 (new) Probe # 4

Installation	Removal
Date AWES Installed 2/22/90	Date AWES Removed 3/3/90
by: JWP	by: PJ, GB
1. Programmed Start time	1. Programmed Stop time
Date: 2-23 Time: 0	Date: 3/1 Time: ~~3/1~~ 23
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 22.0 "Hg	max. vacuum, right gauge 21.7 "Hg
max. vacuum, left gauge 21.3 "Hg	max. vacuum, left gauge 21.2 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 22.0 "Hg	max. vacuum, right gauge 21.7 "Hg
max. vacuum, left gauge 21.2 "Hg	max. vacuum, left gauge 21.2 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.3 "Hg	vacuum, right gauge 19.3 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0.0 "Hg
rotometer 1.15 "Hg	rotometer 1.10 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air 20.5 %
	Ambient temp. ______ °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics—Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WKΦ5 Resident Name: NUBERT Technician JWF

Sampling Rotation: 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 ☐

AWES Service Date		Moisture	Woodpile (ambient)	Wood Species (% of Woodpile)									Corrected
Installation	Removal	Reading (%DB)	Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Smal			Moisture (%DB)
2/22/90			80										
		18.5, 18.5, 18											
		17, 17.5, 16											
		20, 18.5, 23											
		19, 18, 18											
		18, 18, 21											
		17.5, 18, 19											
		15, 16, 16.5											
		18, 17, 20											
		16, 16, 15.5											
		18.5, 21, 19											
	3/3/90	16.5, 15.5, 16.0	70										
		14.0, 16.0, 13.5								100%			
		11.5, 12.5, 12.0											
		12.5, 14.0, 14.0											
		11.0, 9.5, 12.0											
		11.0, 12.0, 13.0											
		14.0, 14.5, 14.5											
		13.0, 15.0, 14.0											
		13.0, 13.5, 12.0											
		12.0, 13.0, 14.0											

Make notation if wood block(s) obtained.

KLAMATH FALLS FIELD STUDY

HOME H - 6

AWES Log Book

Home Code: WC06 Sampling Rotation: 1☐ 2☒ C 3☐ 4☐ 5☐ B☐

Sample I.D.: WC0602C

AWES Box # 04	Filter # K053	XAD# 25	
Teflon Line # 9	Probe # 4		

Installation	Removal
Date AWES Installed 2/5/90	Date AWES Removed 2/12/90
by: JVF	by: JVF
1. Programmed Start time	1. Programmed Stop time
Date: ______ Time: ______	Date: 2/13/90 Time: 1140
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.4 "Hg	max. vacuum, right gauge 20.6 "Hg
max. vacuum, left gauge 20.4 "Hg	max. vacuum, left gauge 19.9 "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 21.0 "Hg	max. vacuum, right gauge 20.1 "Hg
max. vacuum, left gauge 20.2 "Hg	max. vacuum, left gauge 19.5 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.4 "Hg	vacuum, right gauge 19.4 "Hg
vacuum, left gauge 0.0 "Hg	vacuum, left gauge 0 "Hg
rotometer 1.00 "Hg	rotometer 1.0 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air ______%
	Ambient temp. 76 °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics — Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WKΦ6 **Resident Name:** McDougle **Technician** JVF

Sampling Rotation: 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐

AWES Service Date		Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Wood Species (% of Woodpile)									Corrected Moisture (%DB)
Installation	Removal			Oak	Maple	Ash	Red Fir	D.Fir	Madrone				
2/12/90		25	70°				100%						
		14	(35° outside)				↓						
		14											
		26											
		21											
		27											
		17.5											
		25											
		23											

Make notation if wood block(s) obtained.

AWE

Wood Characterization Log Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK06

Resident Name: McDougle

Technician JWK

Sampling Rotation: 1 ☐ 2 ☒ 3 ☒ 4 ☐ 5 ☐

AWES Service Date: Installation	AWES Service Date: Removal	Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Oak	Maple	Ash	Red Fir	D.Fir	Madrone	Lodge Pole			Corrected Moisture (%DB)
2/22/10		26,26,25	70										
		32,30,30											
		28,27,26											
		19,20,19											
		17,18,19											
		18,19,19											
		18,18,16											
		17,18,20											
		20,21,19											
		26,24,21											

Make notation if wood block(s) obtained.

— Homeowner will indicate when they switch from Red-Fir to Lodgepole pine.

AWES

③

AWES Log Book

Home Code: WK06 Sampling Rotation: 1☐ 2☐ 3☒ 4☐ 5☐ B☐

Sample I.D.: WK0603B

AWES Box #	28	Filter #	K086	XAD#	306
Teflon Line #	1	Probe #	14		

Installation	Removal
Date AWES Installed 3/2/90	Date AWES Removed 3/10/90
by: [signature]	by: PJ, GB
1. Programmed Start time	1. Programmed Stop time
Date: 3/3/90 Time: 0	Date: 3/8 Time: 23:59
2. Leak Check (inlet plugged, outlet open)	2. Leak Check (inlet plugged, outlet open)
max. vacuum, right gauge 21.1 "Hg	max. vacuum, right gauge 21.1 "Hg
max. vacuum, left gauge 20.9 "Hg	max. vacuum, left gauge 20.c "Hg
Close toggle, turn off pump, wait 30 seconds	Close toggle, turn off pump, wait 30 seconds
max. vacuum, right gauge 20.7 "Hg	max. vacuum, right gauge 20.6 "Hg
max. vacuum, left gauge 20.9 "Hg	max. vacuum, left gauge 20.0 "Hg
3. Free-flow check (inlet open, outlet open)	3. Free-flow check (inlet open, outlet open)
vacuum, right gauge 19.2 "Hg	vacuum, right gauge 18.9 "Hg
vacuum, left gauge 0 "Hg	vacuum, left gauge 0 "Hg
rotometer 1.0 "Hg	rotometer 1.0 "Hg
4. Heater works: Yes ☒ (if no, use substitute AWES	4. Heater works: Yes ☒ No ☐
5. O_2 cell calibrated ☒ Yes	5. O_2 cell on ambient air 20.8 %
	Ambient temp. ______ °F
	AWES temp. strip ______ °F

AWES.C

Wood Characteristics [illegible] Sheet

Important: A Minimum of 10 Readings Are Required Per House Visit.

Home Code: WK06

Resident Name: McDoyle

Technician: [illegible]

Sampling Rotation: 1 ☐ 2 ☐ 3 ☑ 4 ☐ 5 ☐

AWES Service Date		Moisture Reading (%DB)	Woodpile (ambient) Temp. (°F)	Wood Species (% of Woodpile)									Corrected Moisture (%DB)
Installation	Removal			Oak	Maple	Ash	Red Fir	D.Fir	Madrone	[illegible]			
3/2/90		24, 26, 23	60°				50			50			
		15.75, 16, 16.25											
		24, 23, 23											
		27, 27.5, 26											
	AVG.	21, 20.5, 22											
	20.104	23 (avg.)											
		17.25 (avg.)											
		15.5, 15.5, 15.0											
		15 (avg)											
		15.5, 15.25, 15.5											
	3/10/90	27, 23, 23.5	60										
		27, 22.5, 23	(garage)							100			
		42, 40, 35											
		22, 23, 24											
		21.5, 22.5, 23.5											
		26.5, 22, 19.5											
		27, 23.0, 30											
		21.0, 21.5, 22											
	AVG. 25.273	23.5, 32.0, 23											
		20.5, 24, 24											
		24, 24, 24											

Make notation if wood block(s) obtained.

Avg = 22.688

AWES.I

(2)

KLAMATH FALLS FIELD STUDY

APPENDIX C

TEST STATISTICS

KLAMATH FALLS PERFORMANCE STUDY
STATISTICAL ANALYSIS *

ASSUMPTIONS:

1. $X_{11}, X_{12}, X_{13} \ldots X_{1N_1}$, are random samples
2. $X_{21}, X_{22}, X_{23} \ldots X_{2N_2}$, are random samples
3. $X_{11}, X_{12}, X_{13} \ldots X_{1N_1}$ are independent from $X_{21}, X_{22}, X_{23} \ldots X_{2N_2}$, and both are normally distributed.
4. $\sigma_1^2 \neq \sigma_2^2$

HYPOTHESIS FOR ALL COMPARISONS:

$H_0: \mu_1 = \mu_2 \qquad \alpha = 0.05$

$H_1: \mu_1 > \mu_2$

REJECT H_0 IF
$$T = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}} > t_{1-\alpha}(D)$$

$$D = \frac{N(S_1^2 + S_2^2)^2}{s_1^4 + s_2^4} \qquad \text{FOR } N_1 = N_2 = N$$

*Statistical Analysis Provided by Gary Hazard, Chairman of the Stove Technical Committee, April, 1990.

TABLE C-1. Test Statistics, Week 2 vs. Week 3.

PARAMETER	STOVE TYPE	WEEK 2 $\bar{x}_1$	s_1	n_1	WEEK 3 $\bar{x}_2$	s_2	n_2	T	D	t(D)	(NOTES 1 & 2) DECISION
EMISSIONS (GRAMS/ HOUR)	CAT	5.5	0.95	3	7.3	1.59	3	-1.68	4.89	-2.03	F.T.R.
	NON	5.4	1.74	3	4.6	1.42	3	0.62	5.77	1.96	F.T.R.
	CAT & NON	5.5	1.30	6	6.0	2.00	6	-0.51	10.30	-1.81	F.T.R.
EMISSIONS (GRAMS/ KG)	CAT	4.5	0.75	3	7.3	1.56	3	-2.80	4.32	-2.09	REJECT
	NON	5.2	2.57	3	5.4	2.51	3	-0.10	5.99	-1.94	F.T.R.
	CAT & NON	4.8	1.70	6	6.3	2.10	6	-1.40	11.50	-1.79	F.T.R.
BURN RATE (KG/HR)	CAT	1.24	0.19	3	1.01	0.11	3	1.81	4.8	2.04	F.T.R.
	NON	1.14	0.31	3	0.93	0.23	3	0.94	5.5	1.48	F.T.R.
	CAT & NON	1.20	0.20	6	1.00	0.20	6	1.73	12.0	1.78	F.T.R.

NOTES:
1. F.T.R. = FAIL TO REJECT THE NULL HYPOTHESIS (H_0).
2. REJECT = REJECT THE NULL HYPOTHESIS AND ACCEPT THE ALTERNATE HYPOTHESIS.

RESULT: The emissions, in grams/kg, from the three catalytic stoves were higher in Week 3 than Week 2, for those same three stoves.

No other result was statistically significant.

TABLE C-2. Test Statistics, Catalytic vs. Non-catalytic.

PARAMETER	WEEK NO.	CATALYTIC $\bar{x}_1$	s_1	n_1	NON-CATALYTIC $\bar{x}_2$	s_2	n_2	τ	D	t(D)	(NOTES 1 & 2) DECISION
EMISSIONS (GRAMS/ HOUR)	2	5.5	0.95	3	5.4	1.74	3	0.09	4.6	2.06	F.T.R.
	3	7.3	1.59	3	4.6	1.42	3	2.19	5.9	1.95	REJECT
	2 & 3	6.4	1.55	6	5.0	1.48	6	1.60	11.9	1.78	F.T.R.
EMISSIONS (GRAMS/ KG)	2	4.5	0.75	3	5.2	2.57	3	1.25	3.5	2.24	F.T.R.
	3	7.3	1.56	3	5.4	2.51	3	1.11	5.0	2.02	F.T.R.
	2 & 3	5.9	1.88	6	5.3	2.28	6	0.49	11.6	1.79	F.T.R.
BURN RATE (KG/HR)	2	1.24	0.19	3	1.14	0.31	3	0.48	5.0	2.02	F.T.R.
	3	1.01	0.11	3	0.93	0.23	3	0.54	4.3	2.09	F.T.R.
	2 & 3	1.13	0.19	6	1.04	0.27	6	0.67	10.8	1.80	F.T.R.

NOTE: 1. F.T.R. = FAIL TO REJECT THE NULL HYPOTHESIS (H_0).

2. REJECT = REJECT THE NULL HYPOTHESIS AND ACCEPT THE ALTERNATE HYPOTHESIS.

RESULT: The only statistically significant result is the lower emissions, in grams/hour, of the non-catalytic stoves in week 3 compared to the catalytic stoves in the same time span.

No other result was statistically significant (at 95% confidence level).