Assessment of Outdoor Wood-fired Boilers

Prepared
by
NESCAUM
(Northeast States for Coordinated Air Use Management)

March 2006
(revised June 2006)

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TABLE OF CONTENTS

FIGURES

TABLES

Executive Summary

This report was undertaken by NESCAUM (Northeast States for Coordinated Air Use Management) to provide policymakers with an assessment of concerns relating to the growing use of outdoor wood-fired boilers (OWB), also known as outdoor wood-fired hydronic heaters or outdoor wood-fired furnaces. The increased use of OWBs in populated areas represents a potential public health problem in the Northeast because of the severity of health effects associated with residential wood smoke inhalation.

This report 1) overviews unique features of OWB appliances, 2) estimates OWB appliance sales trends, 3) assesses emission considerations and potential health concerns of residential wood smoke, 4) presents results of OWB ambient monitoring and stack testing conducted by NESCAUM, and 5) provides recommendations for regulatory action.

Findings from this study show that:

- OWBs, generally, do not use catalytic or non-catalytic emission control devices that other residential, wood-fired combustion devices, such as indoor wood stoves, commonly employ.
- OWB use has become more prevalent, commonly replacing indoor wood stoves, and continued increases in sales are likely.
- OWBs emit significantly more particulate matter than other residential wood burning devices and short term particulate matter spikes can be extremely high.
- OWBs could contribute almost 900,000 tons of particulate matter by 2010.
- Local populations are likely subject to elevated ambient particulate matter levels from OWB smoke.
- Current regulations do not provide surrounding areas with adequate protection from the use of OWBs in residential applications.
- There is a lack of information relating to air toxic emissions, such as polycyclic aromatic hydrocarbons (PAHs), polycyclic organic matter (POM) and dioxin.

OWBs present unique issues, unlike other residential wood burning devices, based on the following factors:

- **Year Round Operation –** OWBs are designed to provide heat and hot water year round. Owners often use them in the warmer months not only for domestic hot water but also to heat their swimming pools and/or spas.
- **Cyclic Operation -** The cyclic nature of OWB operations, unlike EPA certified wood stoves, does not allow for complete combustion and creates an environment conducive to increased toxic and particulate emissions.

- **Short Stack Heights –** Stacks from OWBs, as per manufacturer's installation instructions, are usually less than 12 feet from the ground, resulting in poor dispersion of smoke and are more likely to cause fumigation within surrounding areas.
- **Oversized Firebox –** An OWB's large firebox is built such that a user could burn a variety of inappropriate materials that could not be burned in wood stoves or fireplaces. Enforcement programs have discovered OWBs burning tires, large bags of refuse, and railroad ties. Even when used properly, overall OWBs emissions are greater than other residential wood burning devices.

With funding from the Massachusetts Executive Office of Environmental Affairs (EOEA), NESCAUM measured emissions from an OWB unit in the field under real world conditions. The test data indicate that the smallest OWB is likely to have an average in-use emission rate of approximately 161 grams of fine particulate matter per hour, which is twenty times higher than the average in-use emissions of an EPA certified wood stove. This report utilizes a gram per hour measurement in order to understand the potential ambient impacts and to make comparisons to other residential furnaces and heating units such as oil-fired furnaces, natural gas furnaces, and residential wood stoves. Furthermore, NESCAUM believes that given the health impacts associated with wood smoke and their use in residential locations (near at-risk populations such as children and the elderly), it is critical to assess particulate emissions from OWBs on a mass per unit time basis to fully understand potential health risks and appropriate protections.

Based on the test results in this report, the average fine particulate emissions from one OWB are equivalent to the emissions from 22 EPA certified wood stoves, 205 oil furnaces, or as many as 8,000 natural gas furnaces. To put these emissions into perspective, one OWB can emit as much fine particulate matter as four heavy duty diesel trucks on a grams per hour basis. Cumulatively, the smallest OWB has the potential to emit almost one and one-half tons of particulate matter every year. Based on sales estimates, OWBs could emit over 233,000 tons of fine particulate matter nationwide in 2005. Considering sales trends, NESCAUM estimates that there could be 500,000 OWBs in place nationwide by 2010. Based on that estimate, emissions from OWBs would reach 873,750 tons of fine particulate matter nationwide per year by 2010.

The cumulative impact of OWBs to ambient air quality is only one part of the problem. Because OWBs are used primarily in residential applications, they have the potential to emit fine particulate matter and air toxics at levels that could create elevated risk to nearby populations. A second pilot study conducted by NESCAUM measured ambient $PM_{2.5}$ within 150 feet of an OWB device. Relative to background levels, the study documented high 15-second average values (>1,000 micrograms per cubic meter ($\mu g/m^3$)) with spikes greater than 8,000 $\mu g/m^3$ throughout the course of normal daily OWB operating modes. These data suggest that buildings located near OWBs can experience high $PM_{2.5}$ levels during typical boiler operating conditions. Health studies have found associations of acute and chronic exposure to wood smoke with adverse health outcomes such as increases in respiratory symptoms, decreases in lung function, visits to emergency departments, and hospitalization.

States have requested several times that the U.S. Environmental Agency (EPA) develop federal regulations for OWBs but EPA has yet to act. Critical to the development of a federal emissions standard is the need to develop a technology forcing standard that would require manufacturers to employ wood combustion controls commonly employed by other residential and industrial wood-fired devices. In addition, the increasing use of OWBs necessitates that action be taken as quickly as possible. Federal action would likely take five to seven years to put protective measures into place.

In the absence of federal action, states will need to act on this emerging issue in a timely manner. Given the significant health effects OWB emissions may pose and the lack of action on the federal level, NESCAUM believes that states should take action immediately to control OWB emissions by establishing technology-forcing standards that will lead manufacturers to develop cleaner burning OWBs.

1. INTRODUCTION

As the price of home heating oil, natural gas and liquefied petroleum gas (LPG) increases, many households are looking for heating alternatives. Increasingly, people are turning to wood-burning devices to replace oil and gas heating.[1] Wood-fired devices include masonry heaters, indoor wood stoves, indoor wood furnaces, pellet stoves and outdoor wood-fired boilers. The recent increase in the use of outdoor wood-fired boilers (OWBs) are of particular concern to state environmental agencies because the cumulative stack emissions from these appliances are higher than other wood burning appliances and, unlike other wood burning devices, currently are unregulated. In the early 1990's, states became aware of OWBs, although their use at that time was primarily limited to rural settings. However, states have noted an increasing trend of OWB installation in suburban and urban neighborhoods to provide space heating, year-round heating of hot water, and heating of swimming pools, Jacuzzis, and hot tubs. Use of OWBs in commercial applications is also increasing beyond traditional use in agricultural operations.

1.1. OWB Description

An OWB is a wood-fired furnace that is usually housed within a small insulated shed located some distance from a house. Manufacturers design OWBs to burn large amounts of wood over long periods of time.[2] OWBs vary in size ranging from 115,000 Btu/hr up to 3.2 million Btu/hr, although residential OWBs tend to be less than 1 million Btu/hr. According to sales data, the size of the most commonly sold unit is 500,000 Btu/hr. OWBs heat buildings ranging in size from 1,800 square feet to 20,000 square feet. Typically, the dimensions of an OWB are three to five feet wide, six to nine feet deep, and six to ten feet tall, including the height of the chimney. Inside the OWB is an oversized firebox that can accommodate extremely large loads. Firebox sizes will vary with each unit but tend to range in size from 20 cubic feet up to 150 cubic feet. Industry literature indicates that a commonly sized residential unit can easily accommodate wood pieces that are 30 inches in diameter and 72 inches long.[3] Surrounding the firebox is a water jacket that can be heated to temperatures up to 190°F. The OWB cycles water through the jacket to deliver hot water to the building. Water pipes run underground to deliver hot water for both space heating and domestic use.

Figure 1-1 provides a schematic of an OWB installation. OWBs have a cyclical operating pattern; when the water temperature in the water jacket reaches a given temperature, an air damper closes off air to the unit until the temperature drops and the air damper opens, creating an on/off cycle.

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[1] http://www.usatoday.com/news/nation/2005-11-13-woodburning-pollution_x.htm

[2] Schreiber, Judith et al. *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State*. Office of the Attorney General; Albany, New York, 2005. Available at http://www.oag.state.ny.us/press/2005/aug/August 2005.pdf

[3] http://www.centralboiler.com/eadvantage.php

Figure 1-1. Schematic of an OWB Installation

Manufacturers advertise OWBs for operation with wood fuel, however, many states have found that users sometimes fuel OWBs with yard waste, packing materials, construction debris, and domestic wastes.[4] While most manufacturers of OWBs instruct owners of OWBs to burn wood, anecdotal data suggest that distributors instruct purchasers of OWBs they can burn "whatever they want" -- even household garbage and tires.[5]

1.2. Report Overview

This report provides data on issues unique to OWBs, an analysis of sales and distribution of OWBs, an explanation of wood smoke pollutants and their associated public health risks, analysis of OWB emissions, an overview of regulatory options, and conclusions.

[4] Conversations with representatives from enforcement staff at the New York Attorney General's Office, Connecticut Department of Environmental Conservation, Maine Department of Environmental Protection, and Massachusetts Department of Environmental Protection.

[5] Staff from a variety of environmental agencies have spoken with distributors at fairs and other distribution venues to gather information on the units.

2. ISSUES UNIQUE TO OWBS

While there are a variety of concerns surrounding wood burning devices, several issues make OWBs unique. The largest number of complaints voiced to Northeast state air quality enforcement programs relate to excessive smoke and nuisance conditions. These conditions arise due to the unique design and operating features of OWBs.

2.1. Unit Design

The smoke from OWBs appears to be greater than other wood burning appliances for several reasons. Primarily, it is because of the basic design of OWBs. Even when operated properly with seasoned wood, OWBs typically generate significant amounts of smoke. When an operator dampers down the unit, the lack of oxygen to support combustion creates a build up of materials such as creosote. When opening the damper, these materials burn and release immediately to the air. Excessive loading and/or low demand for heat further aggravates this problem. In addition, OWBs emit more pronounced smoke than wood stoves due to the short stack height, which does not disperse smoke above living spaces in neighboring homes. The addition of sophisticated combustion controls could address many of the smoke issues, however, the vase majority of units sold do not employ any catalytic or non-catalytic emission controls.

2.1.1. Combustion Cycle

The primary reason for the large amounts of smoke is the cyclic nature of the device. When an OWB is in the “off” cycle and does not need to generate heat, the air damper closes to cut off the air supply. This creates an oxygen-starved environment in which the fire smolders, creating smoke and creosote that condenses on the internal steel surfaces. When heat needs to be produced, the air damper opens and natural draft forces air into the firebox, pushing the smoke and air pollutants out the stack. Measured emissions peak when the unit has received a fresh load of fuel and the wood has not yet reached a charcoal stage. In the field test conducted by NESCAUM, the unit’s internal stack temperature never reached levels that would have resulted in complete combustion (see Section 5.3).

2.1.2. Stack Height

Another contributing factor to OWB smoke is the short stack height of OWBs. Manufacturer installation literature specifies stack heights that are generally eight to twelve feet from the ground. Stack heights this short typically fail to disperse smoke adequately, resulting in excessive ground level smoke. Because OWBs rarely provide stovepipe fans to increase the upward velocity of the smoke, there is only limited vertical dispersion of OWB emissions. Certain weather conditions aggravate this situation, such as cold weather inversions when the smoke does not rise but stays close to the ground.

2.1.3. Combustion Design

Most OWBs do not have any combustion controls, such as catalytic devices and secondary combustion. Incorporating these features could significantly reduce particulate emissions. Almost all indoor wood stoves sold today use catalytic or secondary

combustion to reduce emissions. NESCAUM's review of OWB manufacturers' data finds that only a limited number of manufacturers utilize common wood burning combustion controls. Discussions with wood combustion experts indicate that these units could incorporate combustion controls into their design in a relatively short period of time, which would result in reduced emissions, increased efficiency and an overall improvement in OWB performance.

2.1.4. Efficiency

Review of available data indicates that the operating efficiencies of OWBs are extremely low, often half the efficiency of other residential wood burning devices such as wood stoves. Several manufacturers have made claims that their OWBs are up to 95 percent efficient. Review of the data, however, suggests that heating efficiencies range from as low as 28 percent to not higher than 55 percent.[6] Test results obtained by Freedom of Information Act (FOIA) requests to EPA indicate that, in general, most units will have operating efficiencies in the range of 30 to 40 percent. A comparison with wood stove efficiencies finds that their efficiencies range from 60 to 80 percent efficient.[7] Low efficiencies translate into increased amounts of wood burned to generate heat, which in turn increases emissions.

2.2. Use Patterns

Unlike indoor wood stoves and fireplaces, manufacturers design OWBs for use year round. OWBs not only heat space but provide domestic hot water and heat swimming pools and spas. In the summer months, the smoke may seem more apparent because the smoke may be less likely to disperse as the lower flue velocities from the stack may keep the smoke closer to the ground. NESCAUM observed this condition during its stack test conducted in June 2005.

Another critical difference in OWB operations from other wood burning devices relates to long burn times. Manufacturers instruct owners that they can completely fill the OWB firebox and leave it burning for as long as 96 hours. However, completely filling the combustion chamber creates a smoldering fire that burns inefficiently, especially when warm weather or a depressed thermostat during mid-day or nighttime hours reduces demand for heat. The lack of tending for long periods of time compounds the problem, leading to inefficient burning conditions over extended periods. In contrast, owners of conventional indoor wood stoves tend them more often to optimize combustion.

2.3. Fuel Quality

While most manufacturers provide OWB owners with best burn practices and instruct users that they should only burn dry seasoned wood, the design of the OWBs encourages burning of inappropriate materials. State agencies have documented the burning of wet, large, unsplit wood, wood waste, yard waste, refuse, tires and railroad

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[6] Schreiber, Judith et al. *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State*. Office of the Attorney General; Albany, New York, 2005. Available at http://www.oag.state.ny.us/press/2005/aug/August%202005.pdf.

[7] http://www.epa.gov/woodstoves/efficiently.html.

ties. In fact some manufacturer's websites state the ability to burn green or scrap wood as one of the benefits of OWBs. For example, the Pacific Western website states that their unit, "easily burns junk wood including pallets."[8]

2.4. Application of Current Regulations to Address OWBs

Enforcement programs have attempted to use existing regulations to address OWB complaints. A detailed description of various regulatory options can be found in Section 6.1 of this report. This section provides a more general overview of the current efforts used by states to address OWBs.

2.4.1. Federal Regulation

While EPA requires indoor wood stoves, pellet stoves, and small wood-fired industrial boilers to adhere to federal air pollution standards of 7.5 g/hr for non-catalytic appliances and 4.1 g/hr for catalytic appliances, there are no federal standards for OWBs. To date EPA has received several requests from state agencies to develop federal standards. EPA has yet to act on these requests and a June 2005 letter sent by EPA to OWB manufacturers, and an EPA statement provided to the Clean Air Act Advisory Committee (CAAAC) on August 11, 2005, indicates that any action in the near-term is unlikely (see Appendix A). The August 11, 2005 statement to the CAAAC advised that EPA was reviewing the state petitions and did not expect a decision on action until spring 2006. In this same statement, EPA also indicated that it would take a minimum of five to seven years to develop and implement a federal standard.

2.4.2. State Regulations

In the absence of federal standards, the states have attempted to use several avenues to address OWB problems. Two states and several municipalities have attempted to address OWBs by adopting regulations limiting emissions or banning the sale of OWBs. Regulations in the state of Washington limit emissions from all solid fuel burning devices rated less than one million Btu/hr. Sales data obtained from manufacturers show that only a small number of OWBs have been sold in Washington. It is unlikely that the OWBs sold in Washington could meet the standard. Correspondence between Central Boiler and the Washington Department of Ecology indicates that the manufacturers dispute the application of Washington's regulation on OWBs (see Appendix A). In 1997, Vermont adopted regulations that require setback and stack height standards for OWBs. This regulation has not eliminated the OWB problem; and in fact the VT DEC continues to receive complaints.

Many states have opacity regulations that could apply to OWBs (a detailed explanation of opacity regulations can be found in Section 6.1.7.). Based on the experience of state enforcement staff, it is unlikely that an OWB could meet most states' opacity requirements even under ideal operating conditions. In fact, several states have attempted to work with homeowners to find methods to operate OWBs within state opacity limits but none to date have been able to comply. Given this scenario, the only solution is removal, which comes at great cost to the homeowner because it requires

[8] http://www.outdoorfurnaces.com/article/pacific-western-details-6.asp.

removal of the OWB and installation of a new heating system. Opacity regulations place a significant burden on the homeowner who, often unwittingly, purchases a unit that cannot meet the state regulatory opacity requirements. Further compounding the problem is the limited ability of many state enforcement agencies to enforce against residential OWBs. Most state enforcement methods aim towards mitigating conditions at industrial facilities, leaving the states reticent and ill-equipped to enforce opacity requirements at residential OWBs.

3. OVERVIEW OF OWB INDUSTRY

NESCAUM has identified twenty-seven manufacturers of OWBs (see Appendix B). Manufacturers are located throughout the United States with eight in Minnesota, three in Pennsylvania, two in Wisconsin, two in North Carolina, and one each in Missouri, Nebraska, New Hampshire, New York, Tennessee, and Washington. In addition, NESCAUM identified six manufacturers based in Canada. These companies range in size from one to over 140 employees. Some of these manufacturers participate in the Hearth, Patio and Barbecue Association (HPBA), which is an industry trade association that represents wood stove, pellet stove and fireplace manufacturers as well.

The Northeast states have focused attention on OWBs since the late 1990's. Several states have attempted to work with manufacturers to address complaints and nuisance issues with little success. The New York State Department of Environmental Conservation held a meeting with manufacturers in 2003 to gain a better understanding of the industry and to determine the direction of manufacturers. At these meetings, manufacturers stated that cleaner OWBs would be on the market in the near future. Almost three years later, there has been little change in OWB design. In fact, recent statements from the largest producer of OWBs indicate that it does not believe that OWBs emit significant amounts of pollution. Testimony prepared by Central Boiler for the Vermont draft OWB regulations[9] and statements by its vice-president Rodney Tolufsen declared that its OWBs pollute no more than EPA-certified wood stoves.[10]

3.1. OWB Costs and Distribution

The total cost to purchase and install the smallest OWB can range from $8,000-$10,000, with costs increasing with the size of the unit. The OWB itself costs approximately $5,000, excluding installation. Installation usually includes laying a concrete foundation, putting in a power source, installing underground piping from the unit to the house, and other additional piping.

Commonly, manufacturers sell OWBs directly or through a national distribution network. Distribution venues commonly include hardware stores, fairs, and direct sales. Typically, stores that sell indoor wood stoves or fireplaces do not sell OWBs. Marketing literature from manufacturers typically claims that OWBs have many advantages over gas, oil and other wood burning devices, including:

- Eliminating heating bills
- Improving indoor air quality
- Reducing the incidence of asthma or allergies
- Benefiting the environment by reducing the greenhouse emissions
- Increasing safety of heating by removing the heating unit from the building
- Requiring less time to operate than other wood burning devices
- Reducing dependence of fossil fuels[11]

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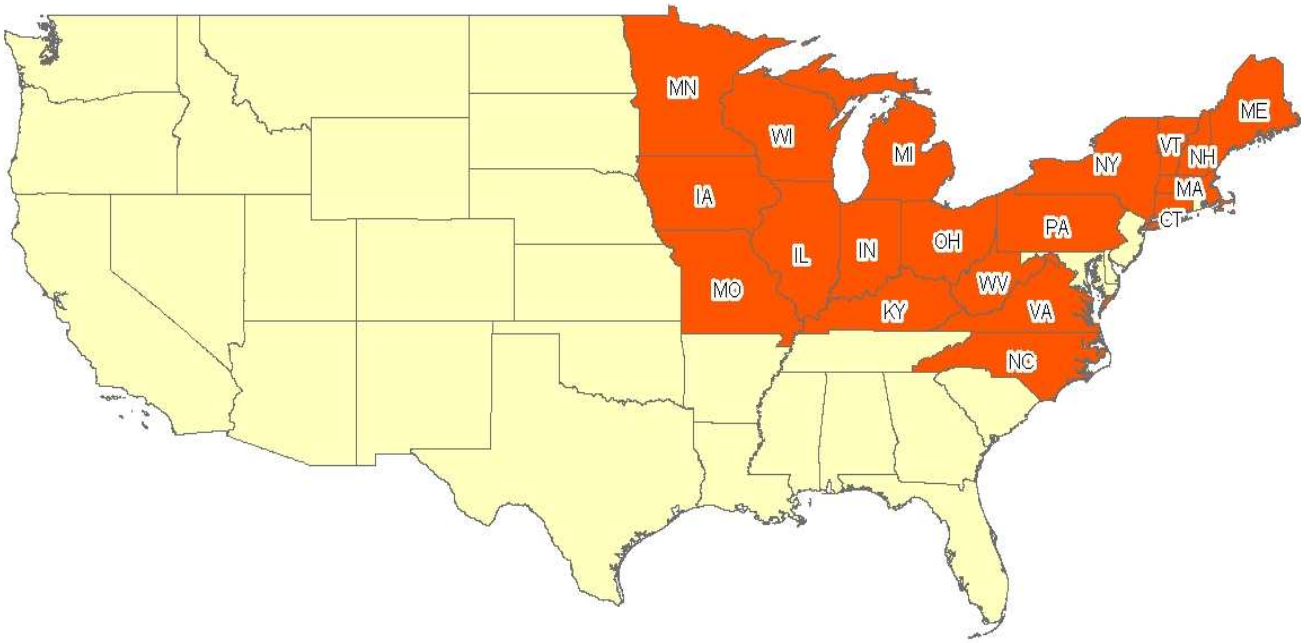
[9] Transcripts from public hearings on Vermont's proposed regulations.
[10] http://groups.yahoo.com/group/woodheat/message/6422.
[11] http://www.shol.com/mahoning/reason.HTM and http://www.centralboiler.com/eadvantage.php.

In its review of emissions and efficiency data, NESCAUM found limited or no documentation to support manufacturers' claims. Manufacturers often claim that their OWBs have relatively high efficiency ratings. Some manufacturers have made claims that their units are up to 95 percent efficient. However, review of the data suggests that heating efficiencies range from 28 to 55 percent[12] (Section 2.1.4 contains a more detailed discussion of OWB efficiency).

3.2. Sales Trend Analysis

With the recent increase in the price of heating fuels, the use of wood for residential and commercial heating is on the rise.[13] As part of this trend, there has been a rapid increase in the number of OWBs installed. Many of the OWB manufacturers began selling OWBs in the early 1980's but sales began to rise substantially after 1999. Using sales data gathered by the New York Attorney General's Office via subpoena of 21 manufacturers and by EPA from nine manufacturers via a Clean Air Act Section 114 request, NESCAUM estimates that over 155,000 OWBs have been sold nationwide since 1990 (see Table 3-1). Appendix C contains estimates of sales by state. Of the estimated 155,000 OWBs sold nationwide, 95% have been sold in nineteen states, as illustrated in Figure 3-1. These states include Connecticut, Indiana, Illinois, Iowa, Kentucky, Maine, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New York, North Carolina, Ohio, Pennsylvania, Vermont, Virginia, West Virginia, and Wisconsin.

Figure 3-1. States representing 95% of the OWBs sold



National sales have been growing in the past five years at rates of 30 to 128 percent. In October 2005, one manufacturer, Central Boiler, stated that its production

[12] Schreiber, Judith et al. *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State*. Office of the Attorney General; Albany, New York, 2005. Available at http://www.oag.state.ny.us/press/2005/aug/August%202005.pdf.

[13] http://www.usatoday.com/news/nation/2005-11-13-woodburning-pollution_x.htm.

was "double what it's ever been before."[14] In December 2004, the same manufacturer stated its peak production at that time was 200 units a week, and it had the room to make 1,000 a week, which would mean a capacity to produce over 50,000 annually.[15] The number of OWBs sold in 2003 and 2004 equals the number OWBs sold in the previous fourteen years. Given the continued rise in the cost of natural gas and petroleum fuels, it is likely that an increasing sales trend will continue. EPA has estimated that it would take a minimum of five years for rules to be put in place, at which time over 500,000 OWBs could be in place.

New construction uses OWBs as primary furnaces and OWBs are also replacing conventional indoor wood stoves and oil or gas-fired furnaces. To promote the use of EPA certified wood stoves through the Wood Stove Change Out Campaign, EPA is educating the public about the dangers of using old non-certified wood stoves. Many homeowners, however, may be choosing to install OWBs instead of certified indoor wood stoves. One manufacturer, Central Boiler, estimated that about 50% of the OWBs sold replace indoor wood stoves.[16] Therefore, while EPA's change out effort is important, it may be resulting in increased installation of OWBs due to the absence of education about OWBs relative to certified wood stoves. This will lead to greater wood smoke pollution if consumers erroneously believe OWBs are a cleaner option than non-certified indoor wood stoves.

Table 3-1. Estimated Sales of OWBs since 1990[17]

Year	US
1990	195
1991	278
1992	398
1993	568
1994	811
1995	1,159
1996	1,656
1997	2,366
1998	3,380
1999	4,828
2000	6,865
2001	15,330
2002	10,552
2003	15,342
2004	24,560
2005	67,546
Total	**155,834**

[14] Rutledge, R. Milwaukee Journal Sentinel, *Burning to Save a Buck*, Oct. 7, 2005 http://www.jsonline.com/news/gen/oct05/361678.asp
[15] Bakken, R. Grand Forks Herald, *Business Heats Up*, December 6, 2004.
[16] *Ibid.*
[17] Sales estimates derived from state specific sales data from nine manufacturers, national sales data from 21 manufacturers, and trend analysis to forecast 1990-1998 and 2005 data. Appendix C provides state specific sales estimates.

4. PUBLIC HEALTH CONCERNS

Wood smoke emissions represent a potential threat to the health of persons living in proximity to OWB devices. Scientific studies have found associations between the inhalation of wood smoke or wood smoke constituents and adverse health effects. These findings are of notable concern because a large fraction of the population is susceptible or at increased health risk from exposure to wood smoke. In addition, physical and operational factors unique to OWBs heighten the possibility that people are exposed to wood smoke in both outdoor and indoor environments.

4.1. Wood Smoke Composition

Wood smoke contains a complex mixture of particles and gases, many of which have been shown to produce acute and chronic biological effects, as well as deleterious physiologic responses in exposed humans. The abundance of fine particulates in wood smoke presents perhaps the most serious health risk to exposed populations, and will be discussed in more detail in the following section. Wood smoke also contains numerous gases, including carbon monoxide, nitrogen and sulfur oxides, volatile organic compounds (VOCs), PAHs, and chlorinated dioxins. Carbon monoxide can cause respiratory and cardiac distress because it competes with oxygen on the hemoglobin molecule, forming carboxyhemoglobin. Studies have associated exposure to nitrogen oxides with toxicological effects including pulmonary edema, bronchoconstriction, and increased infection rates. Studies have also associated VOCs, such as aldehydes, with upper airway irritation, headaches, and other neurophysiologic dysfunctions, and possibly cancer. Studies have shown that polycyclic aromatic hydrocarbons, such as benzo(a)pyrene, are carcinogenic in animals and may cause cancer in humans. Toxicologic evidence also suggests that certain dioxin congeners commonly found in wood smoke are human carcinogens.[18]

4.2. Particulate Matter Health Effects and Populations at Risk

The severity and variety of adverse health effects attributed to exposure to fine particulate matter suggests that the aerosol component of wood smoke plays a large role in the observed health effects associated with wood combustion. Because of its physical structure, $PM_{2.5}$ can bypass conductive airways and deliver exogenous materials into the deep lung. These materials include reactive organic chemicals that adsorb onto the particle. Over the past 30 years, scientific evidence has found that short- (e.g., daily) and long-term (e.g., annual and multiyear) exposure to airborne PM is associated with

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[18] Pierson WE, Koenig JQ, Bardana Jr EJ. Potential adverse health effects of wood smoke. *West J Med* 1989; 151:1-6.

Larson TV, Koenig JQ. A summary of the emissions characterization and noncancer respiratory effects of wood smoke. EPA-453/R-93-036. U.S. EPA, Office of Air Quality Planning and Standards: Research Triangle Park, NC, 1993.

Maynard RL, Waller R. Carbon Monoxide. In: Holgate, ST, Samet, JM, Koren, HS, Maynard, RL, eds. Air Pollution and Health. Academic Press: New York, NY 1999; pp. 749-796.

Zelikoff JT, Chen LC, Cohen MD, Schlesinger RB. The toxicology of inhaled woodsmoke. J *Toxicol Envron Health* 2002; Part B,5:269-282.

Steenland K, Bertazzi P, Baccarelli A, Kogevinas M. Dioxin revisited: developments since the 1997 IARC classification of dioxin as a human carcinogen. *Environ Health Perspect* 2004; 112:1265–1268.

cardiopulmonary health effects, including increased respiratory and cardiac symptoms, hospital admissions and emergency room visits, and premature death. Other harmful health effects include aggravated asthma, decreased lung function, and chronic bronchitis. Recent studies suggest that chronic exposure to air pollution may actually result in the development of new cases of asthma and atopy.[19] A review of adverse health effects of short-term exposure to particulate matter in study areas where residential wood combustion was considered a major source of ambient PM found higher health risk associations than those found in areas dominated by other sources of PM, especially for children.[20]

Population subgroups susceptible or most affected by $PM_{2.5}$ exposure comprise upwards of 50% of the general population, including children, asthmatics, persons with preexisting respiratory disease or cardiac problems, older adults, and healthy adults who work or exercise outdoors.[21] Children's exposure to air pollution is of special concern because their immune system and lungs are not fully developed when exposure begins. For example, the number of alveoli in the human lung increases from 24 million at birth to 257 million at age four. As the lung epithelium is not fully developed, there is greater permeability of the epithelial layer in young children. Also, under normal breathing, children breathe 50% more air per kilogram of body weight than adults. In addition, children's high activity levels can result in increased ventilation, increasing exposure to air pollutants such as particulate matter. These factors suggest that there is a critical exposure time for children when air pollution may have long-term effects on respiratory health.[22] However, PM exposure can adversely affect both susceptible and general populations, including healthy adults. The exact level where an individual might become ill or sensitized is unknown because of the inability of scientists to determine whether a threshold level exists or does not exist below which exposure to PM is safe.[23]

Even hourly exposures to fine particulate matter may result in acute health responses within susceptible subgroups. Clinical and epidemiological evidence now suggests cardiac health effects, including increased risk of myocardial infarction and decreases in heart rate variability, which may be associated with PM exposures with

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[19] Pope CA, Burnett RT, Thurston GD, Thun MJ, Calle EE, Krewski D, Godleski JJ. Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation* 2004;109:71-77.

Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. EPA-452/R-05-005. U.S. EPA, Office of Air Quality Planning and Standards: Research Triangle Park, NC, 2005.

Peters JM, Avol E, Berhane K, Gauderman WJ, Gilliland F, Jerrett M, et al. 2004. Epidemiologic investigation to identify chronic effects of ambient air pollutants in southern California. Contract No. 94-331. Los Angeles, CA:University of Southern California.

[20] Boman BC, Forsberg AB, Järvholm BG. Adverse health effects from ambient air pollution in relation to residential wood combustion in modern society. *Scand J Work Environ Health* 2003;29:251-260.

[21] Johnson PRS, Graham JJ. Fine particulate matter National Ambient Air Quality Standards: public health impact on populations in the northeastern United States. *Environ Health Persp* 2005;113:1140–1147.

[22] Schwartz J. Air pollution and children's health. *Pediatrics* 2004;113: 1037-1043.

[23] Daniels MJ, Dominici F, Zeger SL, Samet JM. 2004. The National Morbidity, Mortality, and Air Pollution Study, Part III: PM10 Concentration–Response Curves and Threshold for the 20 Largest US Cities. Research Report 94. Boston, MA:Health Effects Institute.

averaging times less than 24 hours (e.g., one to several hours).[24] These findings, in combination with associations between daily changes in PM and cardiovascular deaths and hospitalizations, indicate that short-duration exposures to wood smoke emissions could have serious health effects, especially for susceptible members of the population, such as those with preexisting heart disease and older persons.

While the above evidence regarding the severity of health effects and magnitude of populations affected by PM has led health scientists to conclude that exposure to wood smoke should be avoided,[25] residential wood combustion (RWC) remains one of the largest sources of $PM_{2.5}$ emissions to the atmosphere in North America.[26] Studies in urban and rural areas have found that wintertime residential wood smoke contributes significantly to ambient concentrations of $PM_{2.5}$ as well as VOCs.[27] This can be aggravated in areas subject to persistent temperature inversions, located in valleys, or which have a high percentage of wood burning households.[28] Wood smoke PM is dominated by particles with average mass diameters generally between 0.1 and 0.6 μm. Submicron particles readily penetrate residential structures as a result of the normal exchange of air.[29] Particles in wood smoke emitted from chimneys have been found to be a major source of indoor particles and thus a source of exposure to residents, even in homes without wood stoves.[30] Given the infiltration capacity of $PM_{2.5}$, exposure to wood

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[24] Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett, M. Air pollution and cardiovascular disease: a statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association. *Circulation* 2004;109: 2655-2671.

[25] Pierson WE, Koenig JQ, Bardana Jr EJ. Potential adverse health effects of wood smoke. *West J Med* 1989; 151:1-6.

Koenig JQ, Larson TV, Hanley QS, Rebolledo V, Dumler K, Checkoway H, et al. Pulmonary function changes in children associated with particulate matter air pollution in a wood burning community. *Environ Res* 1993:63;26-38.

Larson TV, Koenig JQ. Wood smoke: emissions and noncancer respiratory effects. *Annu Rev Public Health* 1994; 15:133-156.

Zelikoff JT, Chen LC, Cohen MD, Schlesinger RB. The toxicology of inhaled woodsmoke. *J Toxicol Envron Health* 2002; Part B,5:269-282.

Bates DV, Koenig J, Brauer M. Health and Air Quality 2002 – Phase I: Methods for Estimating and Applying Relationships between Air Pollution and Health Effects. Final Report. British Columbia Lung Association. May 2003.

[26] Fine PM, Cass GR, Simoneit BRT. Organic compounds in biomass smoke from residential wood combustion: emissions characterization at a continental scale. *J Geophys Res-Atmos* 2002; 107(D21):8349.

[27] Johansson LS, Tullin C, Leckner B, Sjövall P. Particle emissions from biomass combustion in small combustors. *Biomass Bioenerg* 2003; 25:435-446.

McDonald JD, Zielinska B, Fujita EM, Sagebiel JC, Chow JC, Watson JG. Fine particle and gaseous emission rates from residential wood combustion. *Environ Sci Technol* 2000; 34:2080-2091.

Polissar AV, Hopke PK, Poirot RL. Atmospheric aerosol over Vermont: chemical composition and sources. *Environ Sci Technol* 2001; 35:4604-4621.

[28] Sexton K, Spengler JD, Treitman RD, Turner WA. Winter air quality in a wood-burning community: a case study in Waterbury, Vermont. *Atmos Environ* 1984; 18:1357-1370.

[29] Boman BC, Forsberg AB, Järvholm BG. Adverse health effects from ambient air pollution in relation to residential wood combustion in modern society. *Scand J Work Environ Health* 2003; 29:251-260.

Abt E, Suh HH, Catalano P, Koutrakis P. Relative contribution of outdoor and indoor particle sources to indoor concentrations. *Environ Sci Technol* 2000; 34:3579-3587.

[30] Anuszewski J, Larson TV, Koenig JQ. Simultaneous indoor and outdoor particle light-scattering measurements at nine homes using a portable nephelometer. *J Exposure Anal Environ Epidemiol* 1998; 8:483-493.

smoke indoors—where individuals typically spend the majority of their time—can occur across large residential areas.

4.3. Unique Factors Relating to OWB Emissions and Potential Public Health Threats

Outdoor wood boilers are a unique emission source with operational and design factors not typically found in other residential wood burning appliances. First, the design of OWBs is to operate intermittently following the heat load of a building. This design enables boilers to burn wood in low temperature and oxygen-starved conditions to prolong the fuel source. In general, $PM_{2.5}$ mass concentration increases during unsatisfactory operating conditions, especially where lower excess air ratios or low-quality fuel can yield more condensable gas and organic condensation nuclei.[31] Reduced combustion air supply favors the emission and formation of especially harmful pollutants, as inefficient smoldering conditions can result in high emissions of particles and unoxidized gaseous compounds, leading to the formation of particle-bound PAHs.[32] Unlike EPA-certified residential wood stoves, the design of many OWBs do not provide for the oxidation of incomplete combustion vapors. As a result, these are available for formation of $PM_{2.5}$ rich in relatively high molecular weight organic compounds.

Second, in addition to poor combustion properties, the relatively short stack height of OWBs creates dangerous dispersion conditions to nearby buildings, including an increased likelihood of worst-case emission scenarios such as fumigation and impingement. In contrast to indoor wood stove stacks that extend through the roof of a home to heights of 20 to 30 feet, OWBs come with short stacks typically between 8 to 10 feet tall. In addition, the regular use of OWBs further exacerbate the potential impact of their emissions on nearby buildings because the appliances supply hot water for domestic consumption and heating every day, all year long—not just during wintertime. In-field ambient $PM_{2.5}$ monitoring recently conducted by NESCAUM illustrate the potential for OWBs to affect nearby ambient air quality as discussed in Section 5.2 of this report.

Finally, the use of OWBs for trash burning increases potential emission and public health problems related to these devices. The sizeable firebox capacity and large loading door dimensions characteristic of OWBs facilitate the loading and combustion of non-wood materials, such as household waste (e.g., paper, plastic, and packaging). The combustion of these materials in devices that have low stacks, lack emissions control systems, and operate under low temperature conditions creates the potential for generating hazardous air pollutants in close proximity to homes, schools, businesses and other areas where people spend significant amounts of time. Using OWBs without emission controls to burn trash is analogous to the use of burn barrels and burn piles,

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[31] Barrefors G, Petersson G. Volatile hydrocarbons from domestic wood burning. *Chemosphere* 1995; 30:1551-1556.

Johansson LS, Tullin C, Leckner B, Sjövall P. Particle emissions from biomass combustion in small combustors. *Biomass Bioenerg* 2003; 25:435-446.

[32] Hueglin C, Gaegauf C, Kunzler S, Burtscher H. Characterization of wood combustion particles: morphology, mobility and photoelectric activity. *Environ Sci Technol* 1997; 31:3439-3447.

McDonald JD, Zielinska B, Fujita EM, Sagebiel JC, Chow JC, Watson JG. Fine particle and gaseous emission rates from residential wood combustion. *Environ Sci Technol* 2000; 34:2080-2091.

which many states and local governments have banned because they emit a variety of pollutants, including acidic gases, heavy metals, and dioxin. Inhaling these substances has the potential to cause health problems including eye and throat irritation, respiratory problems, and an increased risk of cancer.[33]

4.4. Cause for Concern

Because OWBs are conducive to the formation of high PM emissions relative to background levels during routine operating conditions, OWBs may present a potential health risk to nearby populations. Should the use of OWBs become more prevalent in populated areas, OWB wood smoke particulate emissions could result in short- and long-term ambient and indoor air quality impacts on nearby neighbors, in light of the ability of fine aerosols to permeate readily into dwellings. These impacts likely would also affect populated areas subject to pollution loading arising from terrain and meteorological conditions favorable to inversion formation. This raises public health concerns because of the known health effects associated with exposure to PM, including a suite of respiratory and cardiac morbidity outcomes as well as premature mortality. Susceptible populations, such as the elderly, children, and persons with preexisting cardiopulmonary disease, may be at higher health risk and therefore disproportionately affected.

Consideration of operating and design features typical to OWBs that can influence emissions supports these public health concerns, including poor combustion design, low stack height and poor dispersion, four-season utility, large firebox chamber capacity, and the potential to burn trash. Currently, few field assessments of OWB ambient emissions have been conducted, thereby limiting regulatory efforts to evaluate this potential public health problem, especially within the context of whether 24-hr and annual PM standards are suitably protective in areas with heavy wood burning. It is reasonable and prudent to assume that OWBs can present a public health risk to populations in proximity to these devices.

[33] Lemieux PM. Evaluation of Emissions from the Open Burning of Household Waste in Barrels. EPA Project Summary. EPA/600/SR-97/134. U.S. Environmental Protection Agency, National Risk Management Research Laboratory: Cincinnati, OH, 1998.

5. EMISSIONS INFORMATION

This section reviews previous studies of OWB emissions and describes the results of two studies conducted by NESCAUM.

5.1. Previous Test Data

A search of available data revealed limited information on OWB emission characterizations. Below are the results of this review.

- EPA funded an OWB study conducted by Valenti and Clayton in 1998.[34] The comparisons detailed within this study primarily provide data based upon a heat input basis. For reasons cited earlier in this report, the data have been converted to grams per hour measurements where possible. The testing was performed using a modified Method 28 fueling protocol and a modified Method 5G for measuring particulate matter, PAHs, and POMs. The OWBs tested under this effort exhibited PM emission levels as high as 143.2 g/hr for high heat removal firing and 55.4 g/hr at low heat removal. The application of a prototype catalyst on one device lowered PM emissions to 53.8 and 37.8 g/hr respectively. Table 4-5 of the study compared PM emissions in milligrams PM per megajoules heat output for two OWB units; Furnace A produced 1,048 mg/MJ and Furnace B[35] produced 681 mg/MJ. Table 4-5 indicated that non-catalytic wood stoves built in the 1990's tested at 383 mg/MJ, catalytic stoves at 425 mg/MJ and pellet stoves at 110 mg/MJ.

  Testing for total chromatographable organics (TCOs) showed emission rates as high as 5.4 g/hr at high heat removal to 8.31g/hr for low heat removal. The PAH emissions were as high as 2.8 g/hr for high heat removal and 0.64 g/hr at low heat removal. Surprisingly, the catalyst runs generated substantially higher levels of TCO and PAH compounds. The study did not provide comparison data on a grams per hour basis for TCOs or PAHs, however, it provided comparison data in micrograms per megajoules input basis. This data showed that PAH emissions for Furnace A were 15.6 mg/MJ, Furnace B 16.1 mg/MJ, non-catalytic wood stoves 28 mg/MJ, catalytic stoves 24 mg/MJ and certified pellet stoves 0.082 mg/MJ. However, EPA caveated these data due to the different test methods, stating that only differences of an order of magnitude should be considered significant. The only publicly available data to compare PAH emissions on a grams per hour basis (total stack emissions) between OWBs and wood stoves is from an EPA wood stove field study on Phase 2 units in Klamath Falls and Portland, Oregon.[36] This study found that the average "in-use" PAH

[34] Valenti JC, Clayton RK. *Emissions from Outdoor Wood-Burning Residential Hot Water Furnaces. EPA Project Summary*, EPA/600/SR-98/017. U.S. EPA, National Risk Management Research Laboratory: Cincinnati, OH 1998.

[35] Furnace B is a Central Boiler Model CL 17 (letter from Robert C. McCrillis, EPA, to Rodney Tollefson, Central Boiler, November 23, 1998).

[36] Fisher, L, Houck, J, Tiegs, P. *Long Term Performance of EPA Phase 2 Woodstoves, Klamath Falls and Portland, Oregon, 1998/1999.* EPA NRMRL RTP-195 (R3-27-00).

emissions for Phase 2 wood stoves, which had been in-use for over five years, was 0.149 g/hr for non-catalytic stoves and 0.165 g/hr for catalytic stoves. Based upon these data, OWBs may emit 4.3 to 18.8 times more PAHs than non-catalytic wood stoves and 3.9 to 16.9 times more than catalytic wood stoves.

- Vermont Department of Environmental Conservation (VT DEC) determined, pursuant to litigation, that a unit produced by Central Boiler (Model CL-7260) had an "adjusted emission rate" of 93.76 g/hr for PM. This number was derived by state review of laboratory testing conducted by the manufacturer. Central Boiler claims in their submission of the tests that the actual rate was 3.6 g/hr. However, after thorough review, the Vermont DEC Air Pollution Control Agency concluded that Central Boiler incorrectly interpreted the data and believes that the state's calculations of 93.76 g/hr are accurate.

- US EPA and the New York Attorney General's Office have obtained sales and emissions data from manufacturers. Table 5-1 contains emissions data made public by the New York Attorney General's Office. OWB manufacturers have claimed that these data are Confidential Business Information and therefore NESCAUM has not been able to review the test reports or underlying test procedures[37] and therefore cannot confirm the test results nor determine the amount of emissions that may not have been measured in the condensable portion of the emissions. However, the data do show high emission rates and indicate that manufacturers are aware of these high emission rates from their OWBs.

Table 5-1. Unevaluated OWB Emissions Data[38]

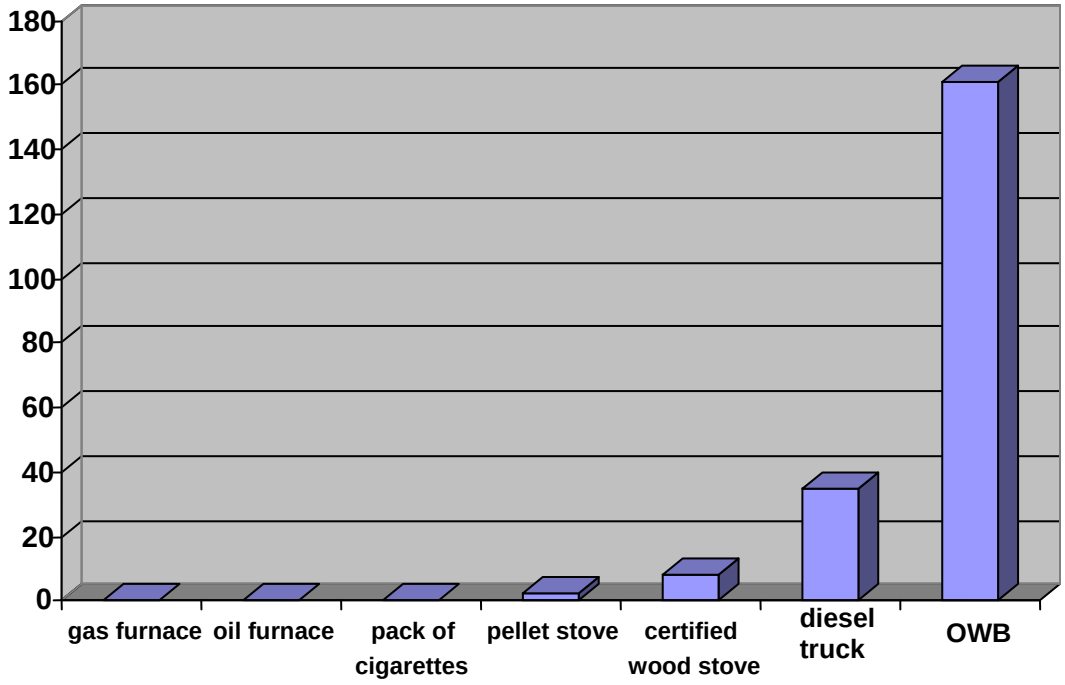
Unit	PM Emissions g/hr	PAH Emissions g/hr	Heating Efficiency	Number of Test Runs
OWB 1*	84	Not Available	30%	5
OWB 2*	60	Not Available	37%	4
OWB 3*	108	Not Available	28%	2
OWB 4*	18	Not Available	31%	2
OWB 5*	49	Not Available	55%	7
OWB 6*	33	Not Available	37%	2
OWB 7**	147	Not Available	55%	2
OWB 8**	118	Not Available	53%	2
OWB 9***	179	Not Available	45%	
OWB 10***	269	Not Available	46%	

* Intertek Laboratories 2004
** Omni Laboratories 2004
*** Intertek Laboratories 2004 from ASTM subcommittee, older model not currently being sold.

[37] Correspondence with EPA Region 1 in response to NESCAUM's FOIA request of data submitted to EPA as a result of a Section 114 action.
[38] Schreiber, Judith et al. *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State*. Office of the Attorney General; Albany, New York, 2005. Available at http://www.oag.state.ny.us/press/2005/aug/August%202005.pdf

While there is only limited data at this time, the data show that PM emissions from OWBs are very high. One study concluded that OWB emissions are 10 to 20 times higher than certified indoor wood stoves.[39] Such high emissions result from low efficiency and incomplete combustion of fuel. The Connecticut Department of Environmental Protection completed a comparison of homes heated with natural gas, oil, and OWBs, and concluded that emissions from one OWB are equivalent to emissions from four non-certified wood stoves, 18 certified wood stoves, 205 oil furnaces or 3,000 to 8,000 natural gas furnaces.[40] To put these emissions into perspective, one OWB can emit as much PM as four heavy duty diesel trucks. Figure 5-1 provides a chart comparing particulate emissions from various sources.[41]

Figure 5-1. PM Emission Comparison (g/hr)



[39] Schreiber, Judith et al. *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State*. Office of the Attorney General; Albany, New York, 2005. Available at http://www.oag.state.ny.us/press/2005/aug/August%202005.pdf.

[40] CTDEP. Connecticut Department of Environmental Protection. Connecticut DEP Fact Sheet: Outdoor Wood Burning Furnaces. State of Connecticut, Connecticut Department of Environmental Protection. July 2004; available at: http://www.dep.state.ct.us/air2/consumer/index.htm; accessed June 14, 2005.

[41] Based upon an average emission rate of 36 g/hr for diesel trucks; http://www.burningissues.org/comp-emmis-part-sources.htm.

5.2. Near-Source Ambient Emission Field Monitoring

Currently, few assessments exist of OWB impacts to ambient air quality, limiting regulatory efforts to evaluate exposure conditions and the potential health risks posed to nearby populations.[42] In order to characterize ambient $PM_{2.5}$ emissions near an OWB, NESCAUM performed a screening level evaluation in March 2005.

Pilot field monitoring was conducted in Central New York State at a site within 50-150 feet of a Hardy H5-1-07 "Economy" boiler.[43] The device had a fire chamber 22.6 cubic feet in size, maximum capacity of 180,000 Btu/hr, and stack height of about 10 feet. Fuel usage during monitoring was a mix of green oak logged 11/01/04 and split 12/04 (stored dry) and maple/cherry/other hardwood seasoned about one-year (stored dry). The $PM_{2.5}$ monitoring interval was a 15-second averaging time in order to capture high temporal resolution during different boiler operating modes and fuel loads. A Thermo Electron DataRAM 4000 performed the monitoring of $PM_{2.5}$. This is a portable nephelometric monitor that employs light scattering to measure the fine particle fraction of airborne pollutants. The DataRAM has the ability to estimate particle size below $PM_{2.5}$ and is an ideal instrument for portable and highly time-resolved applications.

Results indicate that areas within 150 feet of an OWB can experience high $PM_{2.5}$ concentrations relative to background levels. Continuous sampling recorded periodic values >1,000 $\mu g/m^3$ and frequent values >400 $\mu g/m^3$ throughout the course of routine OWB operating conditions, including damper open (oxygen rich) and damper closed (oxygen starved) modes and within about 1 hour and 24 hours after fuel loading. The monitor found high $PM_{2.5}$ levels at all sampled distances, recording values upwards of 4,000 $\mu g/m^3$ over distances of 50, 100, and 150 ft. The monitor observed a peak value of 8,880 $\mu g/m^3$ at 50 ft.

The time-series plotted in Figures 5-2 and 5-3 show selected results. Figure 5-2 displays fine particle values that the monitor obtained about 24 hours after the OWB had been loaded with a wheelbarrow of wood fuel. (Wind was calm and variable/southerly, temperature about 8 °C, and relative humidity about 44% with light snow.) As shown in Figure 5-3, the study also conducted $PM_{2.5}$ monitoring before and within 1 hour after OWB loading with ½ wheelbarrow of wood fuel. (Wind was calm and variable/southerly, temperature about 6 °C, and relative humidity about 50% with light snow.) In both figures, the monitor recorded high $PM_{2.5}$ readings during both damper open and damper closed modes at all distances along the monitoring transect. It found the highest values within 1 hour after fuel loading, with damper open. General observations of wind direction and speed indicate that changes in monitored $PM_{2.5}$ concentrations occurred when the measurement device was directly downwind or not directly downwind of the OWB plume.

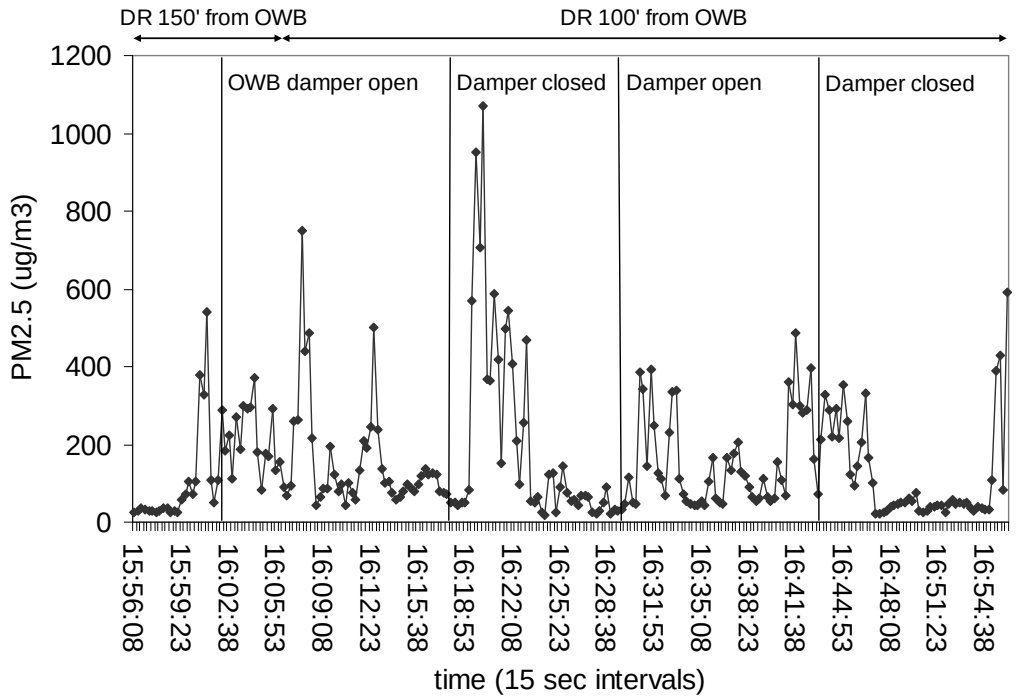
While this screening level pilot study was not intended to quantify 24-hour or longer-term average exposures (e.g., a complete heating season), such information would be useful to collect in order to compare typical ambient OWB PM levels to current 24-

[42] The Michigan Department of Environmental Quality modeled the impacts of an OWB based on theoretical emissions (see Appendix D).

[43] A detailed presentation of findings has been submitted for peer-reviewed publication to the Journal of Health and Ecological Risk Assessment by Philip RS Johnson, NESCAUM.

hour or annual PM national ambient air quality standards. There are no health-based benchmarks for $PM_{2.5}$ for 15-second averaging times. However, the high $PM_{2.5}$ 15-second concentrations observed in this study could indicate the potential for elevated 24-hour average concentrations relative to current health-based standards.[44] EPA's current national ambient air quality 24-hr and annual $PM_{2.5}$ standards are 65 $\mu g/m^3$ (98th percentile form) and 15 $\mu g/m^3$, respectively. EPA recently proposed a revised 24-hr $PM_{2.5}$ standard of 35 $\mu g/m^3$ (98th percentile form) with no proposed revision of the annual standard.[45] Canada's more stringent $PM_{2.5}$ 24-hr objective is 30 $\mu g/m^3$.[46] Because of this study's findings of high $PM_{2.5}$ concentrations in proximity to an OWB under routine operating conditions, NESCAUM recommends further research to quantify the nature and magnitude of OWB ambient emissions in populated areas.

Figure 5-2. Field measurements of $PM_{2.5}$ near outdoor wood boiler



[44] Because the monitored data NESCAUM obtained was from an economy-sized OWB (180,000 Btu/hr), there is the potential that other OWB devices emit higher PM2.5 concentrations; OWB models can range from about 115,000 to 3,200,000 maximum Btu/hr output.

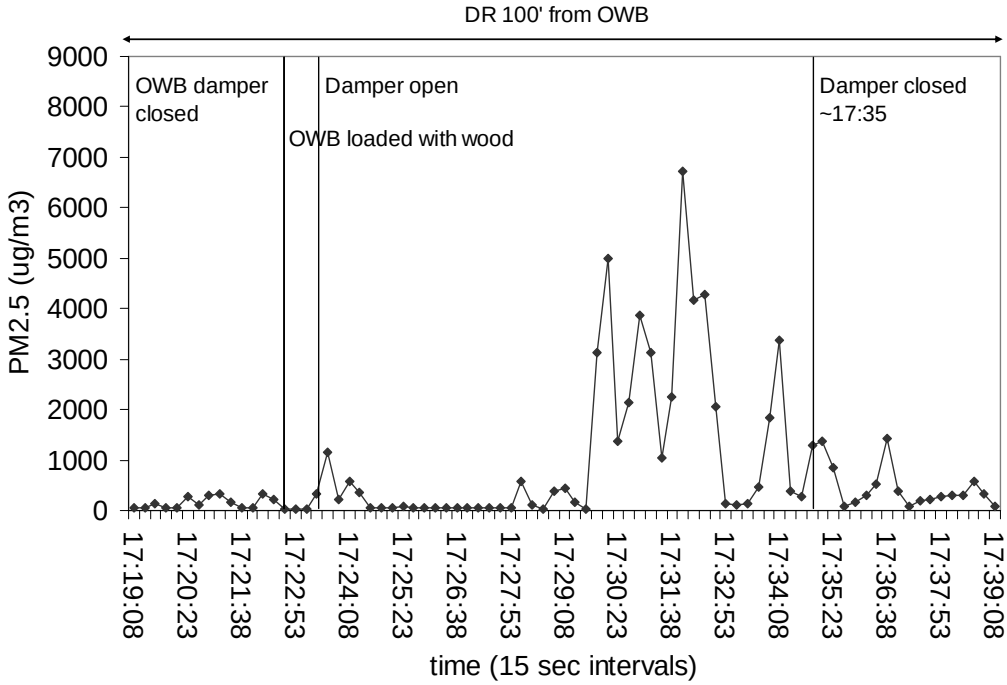
[45] US Environmental Protection Agency. Revisions to the National Ambient Air Quality Standards for particulate matter. Final rule. Fed. Reg. 1997;62:38652–38760.

Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. EPA-452/R-05-005. Office of Air Quality Planning and Standards, US Environmental Protection Agency: Research Triangle Park, NC, 2005.

US Environmental Protection Agency. National Ambient Air Quality Standards for particulate matter. Proposed rule. Fed. Reg. 2006;71:2620–2708.

[46] Canadian Council of Ministers of the Environment. Human Health Effects of Fine Particulate Matter: Update in Support of the Canada-wide Standards for Particulate Matter and Ozone. Health Canada: Ottawa, Canada, 2004. URL for CWS is www.ccme.ca/publications/.

Figure 5-3. Field measurements of PM2.5 near outdoor wood boiler



5.3. Results of NESCAUM OWB "In Use" Stack Test

In June 2005, NESCAUM completed stack testing on a 250,000 Btu/hr Central Boiler unit to gain a better understanding of OWB operations. NESCAUM made pilot measurements on an "in-use" (field, not laboratory) residential OWB to determine emission rates for different burn scenarios using real-time measures and short duration filter samples. In addition, the test also obtained data on particle size, stack temperature and flue velocity. The results from these measurements are anecdotal in nature because NESCAUM tested only a single furnace and wood type. Nevertheless, combined with other laboratory emissions data, these tests provide a better understanding of the potential impact of these sources on air quality. The experience gained from these tests in how to better characterize the real-world emissions from OWBs will be useful in guiding the design of future testing programs.

5.3.1. Testing Methods

NESCAUM performed testing in June 2005 on an OWB, Central Boiler CL-17, rated at 250,000 Btu/hr that was installed in 2000 to heat a residence, provide hot water, and heat a swimming pool. For this test, the heat load was the swimming pool; the damper was manually controlled to simulate moderate heating loads observed in NESCAUM's previous test. The wood used was from the furnace owner's wood pile. The wood consisted of mixed hardwoods with moisture contents ranging from 20 to 40%. Appendix E contains information on the moisture content along with opacity readings taken by USEPA Method 9-certified staff from the VT DEC. On day one of testing, the OWB received an initial load of wood with no coal bed that was not disturbed until the end of the test runs that day. On day two, the OWB started with a full load of wood on a bed of coals. The loading door was opened once during the second day of testing to

check the load and rake the coals. Nothing else was done to the wood load in the OWB during the testing period.

A Thermo Electron DataRAM 4000 made continuous stack PM concentration measurements using light scattering to estimate $PM_{2.5}$ concentrations. The OWB stack sample was diluted with ambient air by a factor that varied between approximately ten to twenty times (the actual dilution ratio was repeatedly measured and applied to the reported data). The dilution air was added within the stack to minimize water vapor condensation problems. The sample train provided sufficient residence time (several seconds) and near-ambient temperatures to allow organic gases in the sample to condense to particle phase. Thus, this method should be considered to be measuring both the "hot" and "cold" (condensed organic vapor) fractions of the stack PM emissions. Observed stack PM concentrations were five to ten times higher than expected, so there were some problems with the continuous PM measurements. The inlet probe clogged (partially or completely) several times, and concentrations exceeded the DataRAM's useful range a significant amount of the time. Data from these periods have been excluded from this report, with the exception of a few brief periods that are noted as "saturated" on the continuous data plots. The continuous PM data have been converted into emission rate data (grams per hour) based on the average dry flow for each of the two burn modes (idle fire or damper closed mode and full fire or damper open mode). For the scatter plot comparing data from the DataRAM continuous PM method with the filter gravimetric method (see below), mass concentrations of PM in the stack are used. The DataRAM also reports a semi-quantitative measurement of the volume (mass) median particle diameter (an approximate estimate of particle size).

A modified EPA Method 17 sampling system (using 0.3 µm pore-size glass fiber filters) collected short-term (3 to 20 minute) filter gravimetric PM samples. The stainless steel filter holders were preheated to 275° F prior to sampling, but were outside the stack and unheated during sampling (no hot-box was used), so the actual temperature of the filter varied with the furnace burn mode resulting in a substantial variation in the amount of "condensable" (semi-volatile organic) PM collected on the filters. "Full fire" mode (damper open) stack temperatures were usually above 400°F; this resulted in substantial under-measurement of PM due to the inability to measure the condensable PM. "Idle fire" mode stack temperatures were as low as 130°F, and much of the condensable PM was collected under these conditions even though the filter holders were preheated.

5.3.2. Results and Discussion

The following sections provide specific details on the testing results using the DataRam and filter test methods.

Results from DataRam Measurements

Figures 5-4a through 5-4e are time series plots of continuous PM emission data, particle mass median diameter, and stack temperature. Times and values of gravimetric filter sampling are also indicated on these plots. Missing time periods are when the DataRAM data are invalid for various reasons as noted above.

The continuous PM emission data demonstrate the short-term dynamics of emission rates in more detail than filter sample data. In some cases, changes in emission rates can be related to changes in burn conditions (damper state changed), but often the rates change dramatically for no obvious reason. One possible explanation is settling of the wood load inside the furnace, but this could not be observed without interrupting the testing process. The wide range of PM emission rates even under similar conditions demonstrates the need for more extensive testing to properly characterize sources. The mean emission rate from the continuous monitor was 161 g/hr.[47] This rate does not include start up emissions (worst case scenario) and represents mid-range emissions, operating through several operating cycles. This rate is higher than the mean of filter emission rates for either mode (93 g/hr for full fire mode and 64 g/hr for idle fire mode), which is likely due to the filter sampling method's inability to measure condensibles.

Results from filter samples

Table 5-2 gives a summary of filter test results for damper open or full fire, and Table 5-3 gives results for damper closed or idle fire. The mean PM emission rate for all full fire filter runs is 93 grams per hour (g/hr) with a range of 13 to 237 g/hr. For idle fire conditions, the mean is 64 g/hr with a range of 13 to 148 g/hr. To put these emissions into a hypothetical ambient PM concentration context, if the maximum rate of 237 g/hr were emitted into a totally stagnant air mass of 100 cubic meters (for example, an area of 100x100 meters and a height of 100 meters), the ambient PM concentration would be 237 $\mu g/m^3$ after one hour.

We must note that caution should be taken in making relative comparisons of emission rates from the two burn modes based on the filter data. These data imply that on average, full fire PM emission rates are approximately 50% higher than idle burn rates. As noted above, and discussed in detail below, the filter data from full fire samples is likely to be biased low by a large factor because of the loss of condensable PM from the hot filter. This implies that the actual full fire emission rate is much higher than the idle rate. An additional uncertainty in calculation of idle fire emission rates is the stack flow measurement; the flows were very low in that mode and thus difficult to measure accurately.

Comparison of two testing methods

To assess the comparability of the two PM measurement methods used (continuous and filter-based), Figure 5-5 shows scatter plots of matching time periods when collecting both filters and valid continuous PM data. Data from the two burn modes are compared separately because of the substantial difference in how much condensable PM was presumably collected with the filter method between the two modes. Table 5-4 presents the data used in Figure 5-5. Note that Table 5-4 presents these data as concentrations (grams per cubic meter) rather than emission rates.

The difference in both numerical agreement and correlation between the two PM measurement methods between the two burn modes is consistent with the differences in

[47] This measurement came from a mostly contiguous 3.5 hour period on day two of testing after two initial modulations of the unit running a period beginning 2.5 hours after the fuel charge and ending six hours after fuel charge.

filter temperature between the two modes. In the idle burn (damper closed) mode, stack (and therefore filter) temperatures are relatively low, allowing collection of much of the condensable organic PM. In this mode, the two methods correlate well and the mean PM is within 30%. In the full burn (damper open) mode, the stack (and filter) temperatures are much higher, so the filter is not collecting much of the condensable PM. In this mode, the two measurement methods do not correlate, and the filter PM data are much lower than the continuous PM data. In the damper open mode, the continuous data range is approximately a factor of 10; the filter data range for this mode is small, with five of the six samples between 0.13 and 0.21 g/m^3. The mean of the continuous DataRAM PM is nearly seven times higher than the mean of the filter PM for this sample subset period. These differences between the two PM methods are not unexpected, because the modified method 17 used for the filter measurements does not attempt to efficiently collect the condensable organic PM fraction.

Stack Conditions

Stack temperatures varied widely, from as low as 130°F (idle burn) to 600°F (full burn). Median particle size also varied widely, from 0.1 to over 1 µm in diameter. Smaller sizes were generally associated with full (hot) burn modes, with larger sizes during idle (cooler) burns. This is consistent with what could be expected; hotter burns would have less organic carbon material because the higher temperatures combust more of the organic carbon.

Conclusions

While it would be reasonable to assume that a “fresh” load of burning wood in the OWB would result in higher emission rates compared to an “aged” load that is more charcoal-like, this was not the case. The idle burn mode filter test results were insufficient to show this and the full burn mode tests would not be appropriate to use because the filter measurements did not capture the majority of PM emissions. Idle burn filter PM data from June 21 were too limited (2 samples, both 2-3 hours after loading) for this assessment. On June 22, six idle-fire filter measurements were made from about ½ hour after the OWB was loaded to almost 6 hours after. The successive idle burn filter PM emission rates were 51, 83, 109, 148, 27, and 13 grams/hour. Although the two lowest PM emission rates were at the end of the test sequence, the highest value of 148 g/hr occurred almost five hours after the wood was loaded. Thus, no clear conclusion from these limited data can be made regarding emissions and age of load.

Table 5-2. Filter Measurements Idle Burn Mode

Test Run	**3**	**5**	**7**	**10**	**12**	**14**	**16**	**17**	
Date	6/21/2005	6/21/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005	
Clock Time (24 hour)	15:08 – 15:23	16:15 – 16:31	10:03 – 10:22	11:21 – 11:40	12:47 – 12:50	14:18 -14:21	15:08 – 15:11	15:18 – 15:21	
Test Duration (minutes)	15	16	19	19	3	3	3	3	
Sample Volume (dscf)	4.583	4.838	6.09	5.416	0.865	0.862	0.862	1.014	
Test Measurements									**Means**
Isokinetics (%)	88.9	87.9	92.2	82.1	101.6	95.5	91.6	97.8	92.2
Moisture Content (%)	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Temperature (F)	200	200	200	200	356	280	250	140	228.25
Gas Composition – CO_2 (%)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
O_2 (%)	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3	13.3
CO (%)	0	0	0	0	0	0	0	0	0
N_2 (%)	80.3	80.3	80.3	80.3	80.3	80.3	80.3	80.3	80.3
Gas Velocity (fps)	2.4	2.4	2.4	2.4	2.6	2.5	2.5	2.3	2.4375
Gas Volumetric Flow (dscfm)	37	37	37	37	32	34	36	39	36.125
(acfm)	50	50	50	50	54	52	52	48	50.75
PM Emission Determinations									
Concentration (grains/dscf)	0.268	0.2705	0.354	0.5804	0.8778	1.1171	0.1933	0.0852	0.468288
Emission Rate (lbs/hr)	0.08	0.09	0.11	0.18	0.24	0.33	0.06	0.03	0.14
Concentration (grams/meter^3)	0.614	0.619	0.811	1.329	2.010	2.558	0.443	0.195	1.072378
Emission Rate (grams/hour)	38.56	38.92	50.93	83.50	109.22	147.69	27.06	12.92	63.60

Table 5-3. Filter Measurement Full Burn Mode

Test Run	**1**	**2**	**4**	**6**	**8**	**9**	**11**	**13**	**15**	
Date	6/21/2005	6/21/2005	6/21/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005	
Clock Time (24 hour)	14:11 – 14:19	14:38 – 14:45	15:37 – 15:56	09:44 – 09:49	10:43 – 10:50	10:59 - 11:00:30	12:16 – 12:31	13:50 – 14:06	14:39 – 14:55	
Test Duration (minutes)	8	7	19	5	7	1.5	15	16	16	
Sample Volume (dscf)	2.583	3.701	4.662	1.586	1.946	0.36	4.06	4.223	4.198	
Test Measurements										**Means**
Isokinetics (%)	134	95.3	99.3	133.4	116.7	193.4	102.3	101.6	101.1	119.6778
Moisture Content (%)	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7	21.7
Temperature (F)	450	590	630	360	455	455	478	500	500	490.8889
Gas Composition – CO2 (%)	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
O2 (%)	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8	11.8
CO (%)	0	0	0	0	0	0	0	0	0	0
N2 (%)	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9	79.9
Gas Velocity (fps)	6.4	6.9	7	6	6.4	6.4	6.5	6.5	6.5	6.511111
Gas Volumetric Flow (dscfm)	60	56	55	63	60	60	60	58	58	58.88889
(acfm)	134	144	147	126	130	134	136	136	136	135.8889
PM Emission Determinations										
Concentration (grains/dscf)	0.9965	0.0763	0.0755	0.9691	0.2244	0.9774	0.0908	0.0771	0.0588	0.393989
Emission Rate (lbs/hr)	0.51	0.04	0.04	0.52	0.12	0.06	0.05	0.04	0.03	0.156667
Concentration (grams/meter^3)	2.282	0.175	0.173	2.219	0.514	2.238	0.208	0.177	0.135	0.902235
Emission Rate (grams/hour)	232.49	16.61	16.15	237.40	52.35	228.03	21.18	17.39	13.26	92.76336

Table 5-4. Comparison of Filter Data and DataRam

Full Burn Data

	6/21/2005	**6/21/2005**	**6/22/2005**	**6/22/2005**	**6/22/2005**	**6/22/2005**
	14:38 – 14:45	15:37 – 15:56	10:43 – 10:50	12:16 – 12:31	13:50 – 14:06	14:39 – 14:55
	PM Concentration, g/m^3					
DR	3.070	0.340	1.355	1.174	1.900	1.532

Idle Burn Data

	6/21/2005	6/22/2005	6/22/2005	6/22/2005	6/22/2005
	16:15 – 16:31	12:47 – 12:50	14:18 -14:21	15:08 – 15:11	15:18 – 15:21
	PM Concentration, g/m^3				
DR	0.661	2.586	2.956	1.269	0.501
Filter	0.619	2.010	2.558	0.443	0.195

Figure 5-4a. VT Outdoor Wood Furnace Stack Sampling
Continuous PM (Data RAM) 21-June 2005

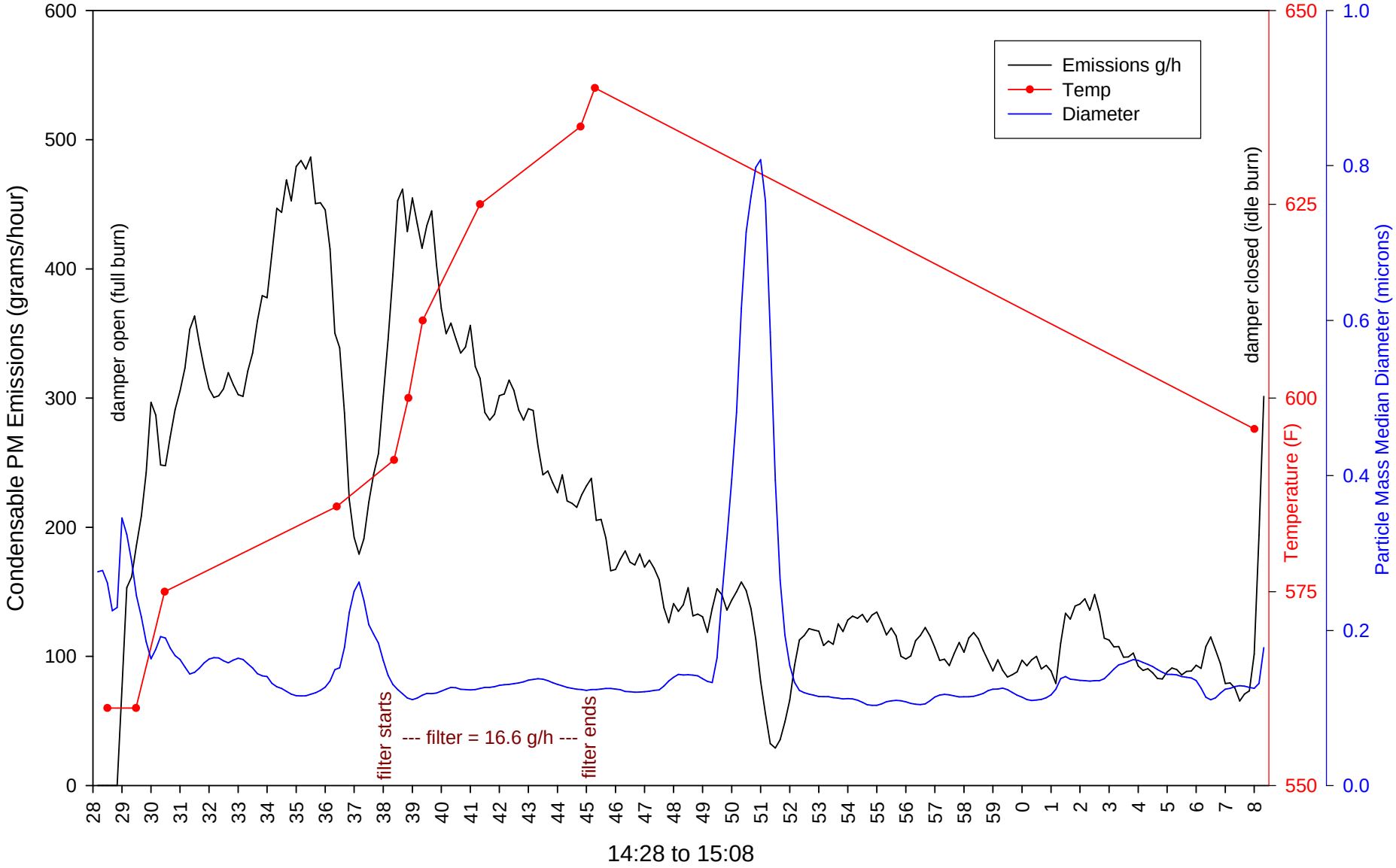


Figure 5-4b. VT Outdoor Wood Furnace Stack Sampling
Continuous PM (Data RAM) 21-June 2005

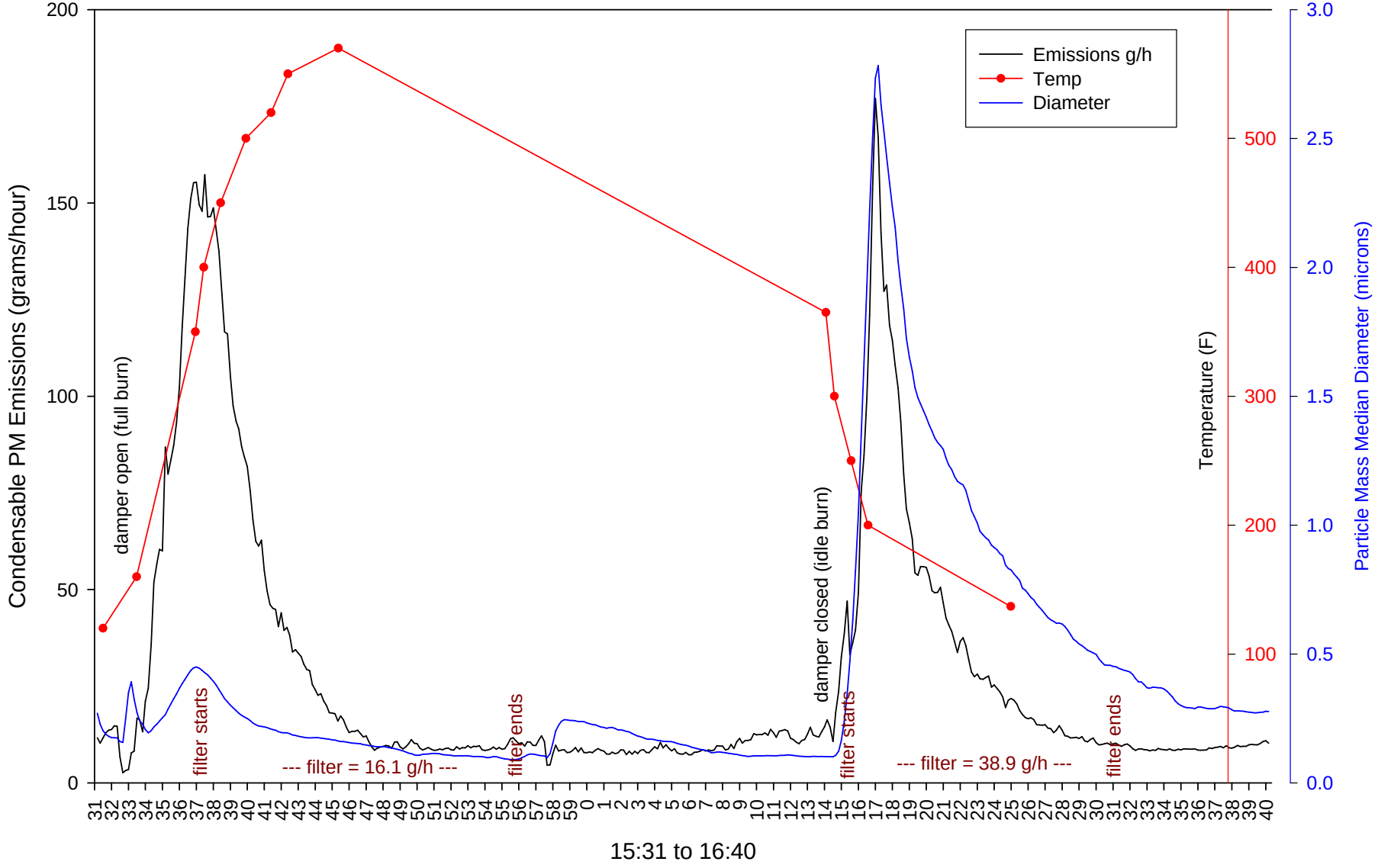


Figure 5-4c. VT Outdoor Wood Furnace Stack Sampling
Continuous PM (Data RAM) 22-June 2005

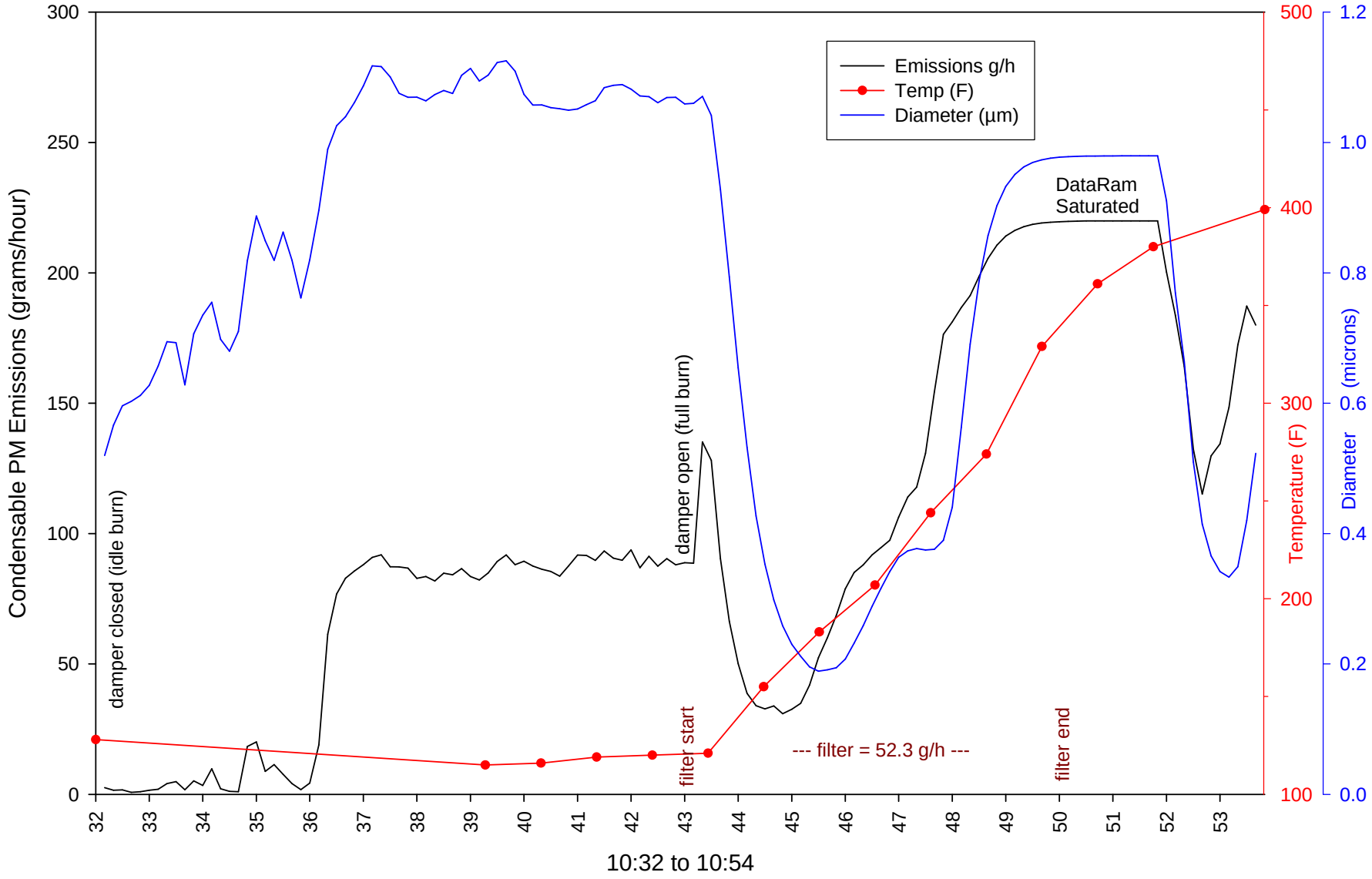


Figure 5-4d. VT Outdoor Wood Furnace Stack Sampling
Continuous PM (Data RAM) 22-June 2005

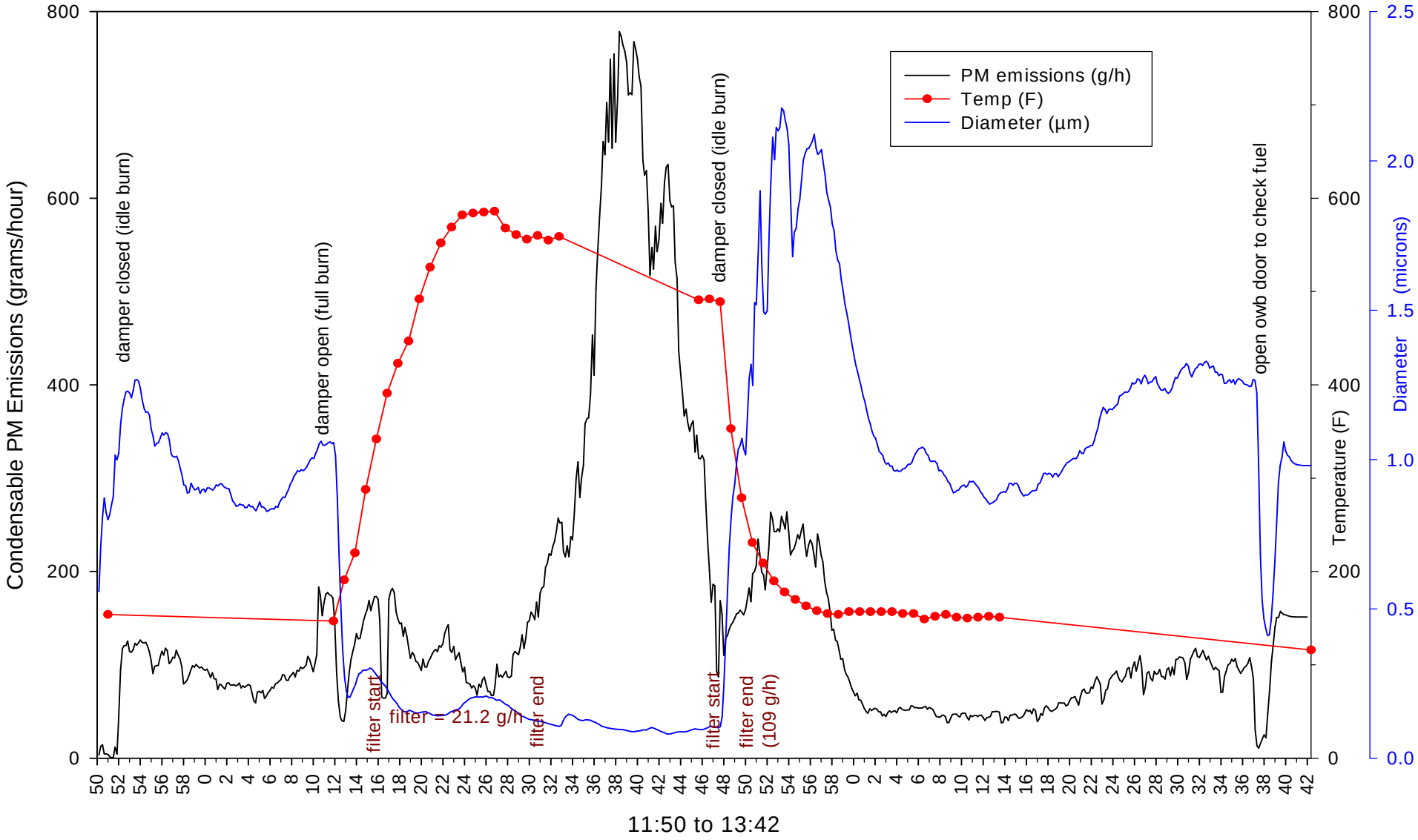
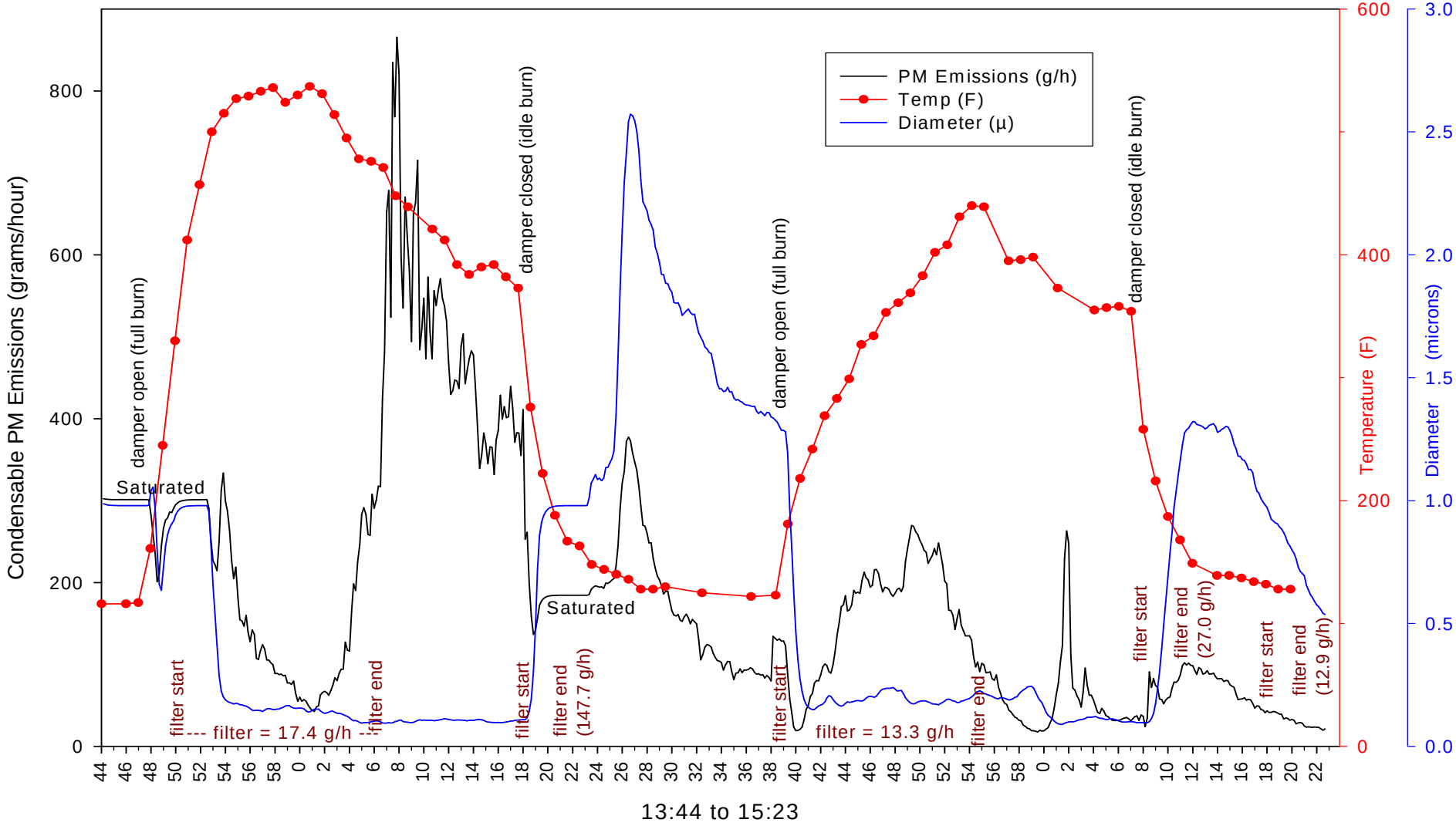


Figure 5-4e. VT Outdoor Wood Furnace Stack Sampling
Continuous PM (Data RAM) 22-June 2005



5.4. ASTM Test Protocol

In June 2004, the ASTM sub-committee was formed to develop a standardized, replicable laboratory method to measure particulate emissions from OWBs. The goal of this process is to develop a laboratory-based test method that evaluates emissions between different OWBs and measures particulate emissions and delivered heating efficiency at a minimum of four heat output rates. This will provide accurate and reliable data on the performance of OWBs as an aid in developing cleaner technology. There are currently thirty voting members on the committee; nineteen are manufacturers, three are from OWB testing companies, two are from state environmental agencies, one is from a state attorney general's office, one is a consultant, one is a coordinator for the HPBA trade association, one is from a state economic development agency, one is from Environment Canada, and one is from EPA.[48]

5.5. Conclusions on Emissions Testing

Both the ambient and stack testing conducted by NESCAUM on smaller OWBs burning appropriately seasoned hardwood showed high $PM_{2.5}$ emissions, suggesting that people living near OWBs may be affected by unhealthy levels of $PM_{2.5}$. Because manufacturers are selling OWBs primarily for use in residential settings, NESCAUM believes a single PM emission limit expressed in grams per hour should be developed to reduce emissions and assure public health protections.

NESCAUM also concludes that it may be appropriate to use newer, continuous PM measurement methods to measure emissions from OWBs and other wood burning devices. In order to accurately quantify emissions for OWBs, the testing method must have the capability to provide accurate results given the likelihood of filter loading and excessive moisture content. In addition, it is critical that any robust measurement of OWB emissions be capable of measuring the condensable fraction of PM because the majority of wood smoke emissions are in the condensable fraction. Traditional "back-end" techniques (such as method 202) are not designed for wood smoke and may not efficiently capture the condensable fraction. Unlike power plant stack aerosols, wood smoke is not water soluble, and the small particle sizes generated in full fire mode are difficult to collect using inertial techniques. Therefore, the use of alternative technologies and test methods such as continuous PM measurement may be more appropriate for OWBs. Such alternatives already exist and EPA has conditionally approved them as alternatives to traditional Method 5 testing. Continuous PM monitors allow for PM measurement throughout the burn cycle rather than averaging several runs in a burn cycle. These methods would allow for accurate, continuous measurements in both low and high firing modes throughout the entire fuel charge, resulting in an accurate average emission rate for an entire burn cycle. Second, these methods overcome many

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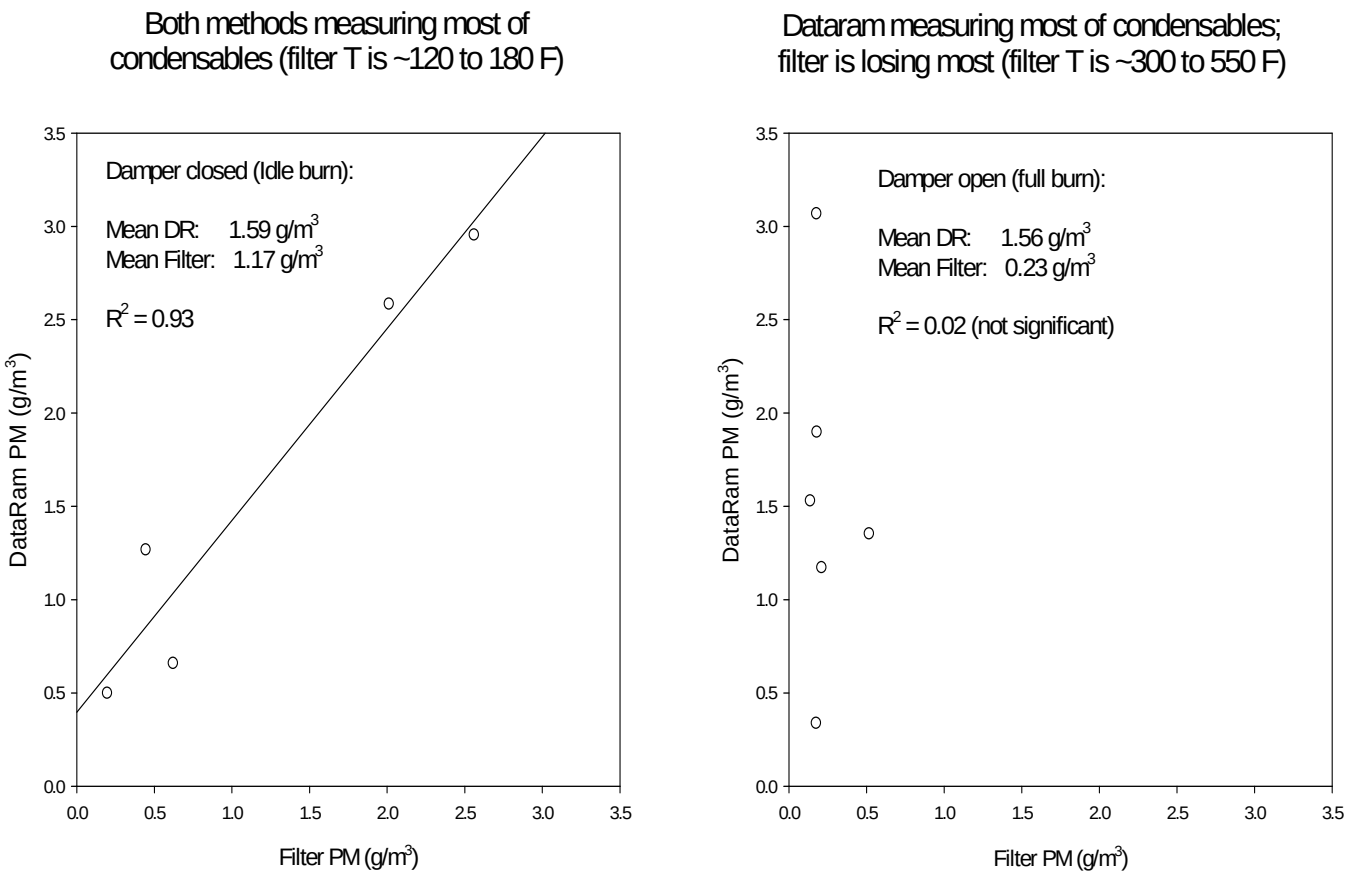
[48] Information regarding the ASTM work can be found at http://www.astm.org/cgi-bin/SoftCart.exe/DATABASE.CART/WORKITEMS/WK5982.htm?L+mystore+kltm0898.

of the issues associated with filter-based testing including filter loading, excessive moisture content and condensable losses.

Figure 5-5. VT Outdoor Wood Furnace Stack Sampling Continuous PM (Data RAM) vs. Filter PM 21-22 June 2005



6. OWB CONTROL STRATEGIES

Policy makers often face challenges in determining emission control and exposure reduction requirements with uncertain and often conflicting scientific and toxicological opinions before them. However, there is mounting evidence to support the need for action to reduce emissions from OWBs in order to maintain public health protections. The options government agencies should consider are to rely on existing regulations, adopt new requirements, or invest in voluntary initiatives. This section outlines these options and provides an overview of relevant judicial rulings and enforcement actions.

6.1. Regulatory Action

Regulatory agencies can institute one or more strategies to address emissions from OWBs. These strategies include setting emission standards for OWBs, requiring permits for OWB installation, requiring the removal of non-certified appliances, establishing no burn days, instituting and implementing nuisance rules and/or opacity rules, and developing standards for fuels. The following section provides a brief overview of the options available to regulatory agencies.

6.1.1. Ban/Removal of OWBs

One strategy would ban the sale of all new OWBs and establish a timeline for removal of all existing OWBs. This strategy would address the installation of new OWBs by placing an immediate ban on the sale of new OWBs, and would address existing OWBs by establishing a timeline to remove them. Several states and municipalities have attempted to put bans into effect but only a few municipalities have succeeded. In 2004, Connecticut considered legislation that would ban the sale of OWBs until a federal emission standard had been adopted but this legislation was defeated under strong lobbying efforts from OWB manufacturers. A similar strategy would prohibit the sale of OWBs until clean burning units come to the market. These strategies are the only avenue that would immediately address emissions from all OWBs.

6.1.2. Emission Standards

Another strategy would create a PM emission limit for OWBs and prohibit the sale or installation of any unit that did not meet the standard. There are three potential approaches to creating a standard for OWBs:

- a simple mass emission rate limit (grams/hour) regardless of an OWB's rated output or actual thermal output,
- an emission rate limit that is tied to an OWB's rated output or actual average thermal output (grams of PM/Btu/hr or mg PM/megajoule), or
- a limit on the concentration of the PM in an OWB's stack (grams/cubic meter or grains/cubic foot of exhaust gas).

Although all three of these approaches could reduce PM emissions from OWBs, only the first approach (grams/hour) specifically addresses both the regional and local aspect of OWB smoke. If the goal of a standard is in part to protect against local (50 to 1000 feet from source) high PM concentrations, then the total PM emitted from a given

stack must be controlled without regard to OWB size. The second and third approaches above would not accomplish this because they allow a unit's overall emissions to increase as the unit's output increases.

Both the second and third approaches address PM emissions from a relative efficiency perspective (PM emissions per unit heat produced). The second approach creates additional hurdles when developing and implementing a test protocol. First, it requires a clear definition on how to define Btu/hr – heat input, heat output as it leaves the OWB or heat output as it reaches the area to be heated. In addition, it will require that the testing precisely measure this additional feature. Another disadvantage to this method is that measurement would allow for dilution to minimize emissions when OWBs are tested in a laboratory setting. In addition, this method does not normalize with different fuel sources. The third approach, a grain loading standard, is similar to measurement based on heat ratings. However, a grain loading standard with a correction for carbon dioxide would ensure that the measurements in the testing are not diluted to reduce emissions. Furthermore the grain loading measurement that mandates a correction for carbon dioxide levels minimizes variability that may arise due to inconsistency in the fuel source.

The state of Washington has adopted a mass emission rate regulation that requires all solid fuel burning devices, including OWBs, to meet an emission limit of 4.5 g/hr PM for non-catalytic appliances and 2.5 g/hr for catalytic appliances. The state of Vermont has proposed a regulation based on the third approach. The proposed Vermont standard would limit OWB emissions to 0.20 grains per dry standard cubic foot of exhaust gas corrected to 12% CO_2. Calculations based on testing data estimate that the mass emission limit for smaller OWBs would approximate 22-36 g/hr PM, assuming a 50% duty cycle. Because the Vermont standard is a concentration-based standard, a residential wood boiler larger than the 250,000 Btu/hr used for these tests could have higher PM emission rates (assuming similar duty cycles). Appendix F includes copies of the Vermont and Washington regulations.

Establishing an OWB emission standard would reduce PM emissions from new OWBs and place the burden for reductions on manufacturers rather than homeowners. This option would allow the sale of clean burning OWBs while prohibiting the sale of dirty units. This strategy, however, would not address existing installations, but when combined with another strategy to address existing OWBs, it could present the best option to address OWB emissions.

6.1.3. Fuel Requirements

Another strategy would require that all wood burning devices burn seasoned wood and eliminate any state loopholes that would allow the burning of trash, yard waste or other waste materials. Several municipalities in Colorado, California, Washington, and Canada have this type of regulation. However, this strategy has several disadvantages. First, even under ideal conditions, burning seasoned cordwood, OWBs emit extremely high levels of particulate matter and air toxics. Second, enforcement of this rule would be a challenge. Finally, using wood that is too dry, such as pallets, may also cause excessive smoke and air emissions due to the increased likelihood of explosive incineration.

6.1.4. Mandatory Removal

Mandatory removal requires removal of any wood burning appliance that is not certified by a certain date and/or rendered permanently inoperable by a certain date. This strategy would reduce emissions from the older, dirtier OWBs and significantly reduce particulate emissions from these devices. However, it also would encumber the homeowner with substantial costs and require extensive enforcement.

6.1.5. No Burn Days

No Burn Days would prohibit the use of any wood burning device during episodes when the likelihood exists for high PM levels. New Mexico and municipalities in Alaska, California, Colorado, Oregon, South Dakota, Utah, and Washington have instituted a no burn day program. This strategy would address high emission events but would not address the day to day contribution of pollution from OWBs to ambient air quality. In addition, it does not address the severe local impacts that may occur. It also could be difficult to implement and enforce statewide no burn days.

6.1.6. Nuisance Rules

Nuisance rules would establish new regulations or more aggressively enforce existing regulations that limit or prohibit actions from causing or contributing to a nuisance condition. Many states have such regulations, however, using these rules to protect neighboring properties have proven difficult. Connecticut's rule calls any visible emission crossing the property line at ground level a nuisance violation. Once the agency documents a violation, it issues a notice of violation (NOV) giving the OWB owner thirty days to remedy the violation. In the past, OWB owners have attempted to burn smaller loads, use dry wood, raise the stack height of the unit and install baffles without resolution of the underlying problem. Connecticut DEP has issued several NOVs for nuisance situations where the conditions causing the nuisance were not mitigated but none has resulted in the elimination of the issue. After many attempts to modify fuel use (using seasoned wood), add-on equipment (catalysts or baffles) and limit use, enforcement programs have indicated that shutting down or limiting OWB operation are the only viable remedies for nuisance and odor issues.

6.1.7. Opacity Rules

Many states, including Massachusetts, have requirements establishing smoke opacity limits. There is mounting evidence that suggests that OWBs cannot meet current opacity standards.[49] A strategy to ensure that OWB's comply with opacity regulations could require a permit to install and/or operate an OWB and require a demonstration that the unit meets the opacity limit before it can commence operation. This strategy would ensure that only clean OWBs are installed, but the burden of proof would be placed on the homeowner rather than the manufacturer. Furthermore, testing could only commence once the OWB owner had already invested in the purchase and installation of a unit. Experiences within the NESCAUM states have shown that once a unit is installed, it is very difficult for the state to remove the unit or prohibit operation. Therefore, even with

[49] During NESCAUM's stack testing, a certified smoke reader recorded opacity readings. Appendix E includes a copy of the field report.

opacity regulations in place, states still face a high hurdle to enforce against OWBs based on opacity regulations.

The following lists are the opacity regulations for the NESCAUM states:

- Connecticut's air regulations (RCSA Section 22a-174-18) limit opacity (except for periods of startup, shutdown, and malfunction) to 20% during any six-minute block average or to 40% during any one-minute block average.
- Maine's regulations (ME DEP Chapter 101) limit visible emissions from any wood-waste or biomass unit to 30% opacity on a six-minute block average basis, except for no more than two six-minute block averages in a three-hour period.
- Massachusetts' regulations [310 CMR 7.06(1)] limit opacity to 20% for a period or aggregate period of time in excess of two minutes during any one hour, with a maximum of 40% at any time.
- New Hampshire's air regulations (Env-A 2002.02) limit average opacity from fuel-burning devices installed after May 13, 1970 to 20% for any continuous 6-minute period, except for periods of startup, shutdown, malfunction, soot blowing, grate cleaning, and cleaning of fires.
- New York's air regulations (NYCRR Section 211.3) require that no person shall cause or allow any air contamination source to emit any material having an opacity equal to or greater than 20% (six minute average) except for one continuous six minute period per hour of not more than 57% opacity.
- Rhode Island DEM's Air Pollution Control Regulation No. 1 states that no person shall emit into the atmosphere from any source any air contaminant for a period or periods aggregating more than three minutes in any one hour which is greater than or equal to 20% opacity.
- Vermont's regulation (Section 5-211) limits opacity to 20% for an aggregate period of six minutes during any one hour with a maximum of 60% opacity for any two minute average; however the Vermont regulation exempts any wood-fuel burning equipment with a rated output of less than 40 horsepower (1 boiler hp = 34,500 Btu/hr).

6.1.8. Removal Prior to Sale or Transfer of Property

Another strategy would require a certification prior to the completion of a sale or transfer of any real property on or after a certain date, that all wood burning appliances that are not certified would be required to be replaced, removed or rendered permanently inoperable. This would require an investment from the homeowner as would the mandatory removal. This strategy relies on the strength of the real estate market and the thoroughness of the home inspector. Enforcement of the program could be implemented via the building inspection process.

6.1.9. Zoning Regulations

Another strategy would establish property line setbacks for OWBs to protect neighboring properties from nuisance smoke and odors. Vermont and Connecticut both have such regulations. Connecticut's rule requires a 200 foot setback and stack heights greater than the roofline of the neighboring properties. This rule was adopted in spring 2005 and therefore there is no experience to estimate the efficacy of this rule. Vermont adopted a "zoning" type regulation in 1997 that sets minimum setbacks, stack heights, and requires that purchasers of OWBs be notified about the Vermont rule requirements. Vermont has experienced many problems with this rule and has found that it has not addressed the underlying public health, nuisance and odor conditions created by OWBs. Setbacks and stack height requirements do not address the overall emissions from OWBs. In August 2005, Vermont proposed a new regulation that would establish an OWB emission standard.

6.2. Voluntary Programs

Voluntary programs rely on the consumer to purchase cleaner burning units or the manufacturer to make cleaner units. The section below overviews two voluntary strategies.

6.2.1. Change-out Programs

This strategy eliminates the use of old, dirty burning appliances by providing incentives for the public to purchase new, clean burning equipment. This strategy addresses $PM_{2.5}$ emissions generated by wood burning appliances and eliminates older, dirtier OWBs. Because the program is voluntary in nature, the program needs significant participation and a large amount of resources to be successful. It is likely that a change-out program will have a better chance of success if it is supported by a rule prohibiting the installation of wood-burning appliances that do not meet specified standards for low emissions.

6.2.2. Voluntary Industry Actions

Another strategy would rely on manufacturers to voluntarily commit to developing cleaner OWBs. In 2001, New York held a meeting where manufacturers stated that they had plans to redesign their OWBs. Manufacturers once again made this claim to the Connecticut legislature during their regulatory process in June 2004. In June 2005, EPA unsuccessfully asked for a meeting with manufacturers. To date none of these efforts have led to cleaner burning OWBs. Appendix A includes a copy of EPA's request and a response from one of the largest OWB manufacturers.

6.3. Court Actions

NESCAUM has identified six lawsuits in the Northeast relating to OWBs. In every case, the end result has been the removal of, or prohibition to operate, the offending OWBs. In many cases, this has been the only option for neighboring properties to find adequate resolution to the nuisances created by OWBs.

In Connecticut, five civil suits have been brought under Connecticut's General Nuisance Laws. In every case, the outcome has been in the complainant's favor. In at

least three of the Connecticut cases, the OWB manufacturer provided an attorney at no cost to the OWB owner. In only one case did the OWB owner go to trial; the other cases were settled out of court, and required confidentiality of the settlement. In all cases the OWB was either removed or prohibited from operating so long as the complainant resides in the neighborhood.

In Stamford, Vermont, a landscape company that had improperly installed an OWB filed suit against the distributor and manufacturer (Central Boiler) of the OWB. In this case, the owner placed the unit within 200 feet of a neighboring residence, in violation of the Vermont OWB regulation. The OWB owner claimed that he had not been informed about the notification and setback requirements. The unit was eventually removed, and the details are not available because the case was settled out of court.

In Grafton, Massachusetts, a resident made numerous complaints to the Massachusetts DEP about his neighbor's OWB. The smoke from the OWB was coming directly into the complainant's house causing him to have chronic bronchitis for the first time in his life. The Town of Grafton Board of Health issued a cease and desist order until the unit had been inspected and had the proper permits issued. The complainant ultimately took his neighbor to Housing Court and won. The owner of the OWB is no longer allowed to use it in the summer, had to increase the stack height, adjust the air flow, and change burning practices.

While individuals have been successful in bringing these suits under nuisance laws, it seems unreasonable to expect that all affected individuals have the financial resources and other wherewithal to pursue such actions for the vast majority of potential OWB nuisances. In addition, public health harm can arise from the collective impact of emissions from many OWBs even if no individual OWB can by identified as causing unique harm to a specific person, as may be required under nuisance law. Therefore, it may not be an option available to all members of the public nor broadly covering OWBs.

6.4. Enforcement Actions

Several states have issued Notices of Violations (NOVs) for OWBs, however, enforcement actions against residential OWBs tend to be resource intensive and difficult to resolve. The following provides an overview of the available data.

6.4.1. Connecticut

Connecticut has issued approximately fifteen NOVs; none of these have resulted in assessed penalties, OWBs removed, or consent orders. OWBs complaints continue to increase. Implementation of Connecticut's new rule requiring setback distances and stack heights has not eliminated complaints but has increased enforcement efforts and resources to address improperly installed units.

6.4.2. Massachusetts

An overview of fourteen actions taken by Massachusetts against OWBs:

- A residential property owner installed an OWB in the spring of 2005 for heat and hot water. The smoke from the unit impacted the nearest residential neighbor. The neighbor complained of smoke infiltrating the house and

resulting health issues. The complainant also alleged that the smoke in their yard was so thick that it is like fog and even filled up the garage and car. The Board of Health told the owner of the OWB to shut the unit down for the summer. Before the unit can be restarted, the owner must change the air mixture, increase the stack height, and change his wood burning practices. If these measures do not improve the excessive smoke, the unit will have to be closed down.

- Massachusetts DEP staff observed large amounts of smoke from the highway in Auburn, MA. They traced the smoke to an OWB operating at Brady Sunroom. The facility was burning glued boards in the unit for heat recovery. The facility entered into a consent order with penalty and removed the unit.

- A company in Auburn, MA uses an OWB to heat their facility. When the unit was first put in operation, the fire department received many complaints about the unit. A trailer home park is located directly behind the company. The Massachusetts DEP staff have driven by this company on numerous occasions to try to verify excess smoke from this unit. The fire department has agreed to call the DEP this upcoming heating season if the unit is still causing a problem.

- Massachusetts DEP received anonymous complaints about smoke and odors from an OWB. A daytime drive by on a cold day showed an OWB operating on a small farm but no opacity was observed. The Fire Department worries that the unit is burning large amounts of cardboard. The Fire Department will continue to monitor the OWB and wait for further complaints.

- A residential property owner installed an OWB approximately six years ago and the neighbor has been having problems with smoke from that unit since the date of installation. The unit releases a great deal of smoke that goes all over the property and into their home. The homeowners have expressed concern about the health effects, difficulty in breathing by the neighbor, the inability of their daughter to visit them due to the smoke, and their inability to use their yard. The homeowner worked with the Board of Health to try to resolve the situation but was informed that he would need to hire an attorney.

- A residential property owner installed an OWB to heat their home, pool and Jacuzzi. The large amounts of smoke from the unit were impacting the nearest neighbor who has two daughters with asthma. The smoke from the OWB was coming directly into their home and yard allegedly causing the children to have increased asthma attacks. The Board of Health required the owner of the OWB to cease using the unit during the summer.

- A residential property owner installed an OWB to heat their home and provide hot water. Residents several miles downwind were getting smoke coming into their homes in the middle of the night, thus waking them up and giving them

headaches. The neighbors traced the source of smoke and odor to the OWB. The Board of Health and the Groton Fire Department investigated the matter and have met with the owner of the OWB several times but no formal action to date has been taken.

- In summer of 2003, a resident began complaining about smoke from an OWB unit. A member of the town Board of Selectman was in the process of building a new home adjacent to the resident's house and installed an OWB. The resident claimed that the owner of the OWB was also using the unit as an incinerator to burn construction debris. The resident complained about the large amounts of smoke coming from the OWB, the inability to use his lakeside property, and the inability to feed the numerous song birds that no longer come to his house. The resident was 84 years old, and reported that he had severe health issues. The resident has many photos of the OWB smoking. Visits by the Massachusetts DEP confirmed the presence of the OWB but did not observe it operating. The Board of Health took the lead in the matter.

- One municipality received numerous residential complaints about an OWB located at a manufacturing facility. The facility purchased the OWB to burn pallets in order to reduce disposal costs and provide building heat. The Board of Health and fire department made many visits to the facility and witnessed excessive smoke from the OWB. The town eventually requested that the Massachusetts DEP provide some assistance in shutting down the unit. The DEP conducted an unannounced inspection and found the unit to be operating with excessive smoke while burning pallets. It issued a notice of noncompliance to the company, which removed the unit.

- In another municipality, residents contacted the Massachusetts DEP and the town's Board of Health regarding smoke complaints from their neighbor's residential OWB. The unit was located in a historical district and operated without any town permit. The unit smoked so much that it obscured visibility several times on Main Street. The local paper even documented and published one of these instances. The complainant's wife has had numerous respiratory problems due to the operation of the OWB. The town's historical commission had the owner remove the unit. It is currently in the owner's backyard and not hooked up. The town's Board of Health contacted the Massachusetts DEP about guidance on regulations to restrict the location and operation of OWBs. The town has held two of three public meetings on a proposed regulation.

- A residential property owner installed an OWB to heat the home and provide hot water. Five neighbors have complained to the Board of Health and fire department that the smell from the OWB forces them to keep their windows shut at all times. Even so, the odor still seems to seep through into their homes. The owner of the OWB was burning green pine in the unit. The Board of Health and fire department worked with the owner to improve the

smoke from this unit. Massachusetts DEP worked with the town in an advisory capacity.

- While visiting a facility, a Massachusetts DEP inspector observed large amounts of smoke coming out of an OWB located at a land clearing company. The company burns waste wood to heat their building. At the time of the inspection, a 2.5 diameter by 3 foot long unsplit log was being burned in the unit. The Department issued a Notice of Non-Compliance (NON) requiring the source to stop the excessive smoke. The company could not meet the requirements in the NON and agreed to cease use of the unit.

- A residential property owner installed an OWB to heat his home and provide hot water. The smoke from the unit impacted several of his neighbors. The neighbors called the Board of Health and Massachusetts DEP to complain about how the smoke was harming them (i.e., could not use yards, had to keep windows closed on beautiful days, etc.). The Board of Health required the owner of the OWB to cease using it for the summer.

6.4.3. Vermont

Vermont has taken action against one unit not related to their zoning regulation in Brandon, VT. In this instance, the Vermont Department of Environmental Conservation (VT DEC) determined that a nuisance condition existed and required the owner to not to operate the OWB during the summer months and to increase the OWB stack height.

Vermont has taken enforcement actions against dealers and owners who have violated their setback and notification regulation. These actions have led to the shutdown or removal of six OWBs. In other instances, it required the unit owner to raise the stack height of the OWB. Currently, Vermont has four pending OWB violations.

7. CONCLUSIONS/RECOMMENDATIONS

There is mounting evidence that supports the need for action to reduce emissions from OWBs. Based upon the data, NESCAUM has reached the following conclusions:

- Sales of OWBs continue to increase by 25-50 percent annually. NESCAUM estimates that there are over 155,000 OWBs nationally. Recent manufacturer statements indicate that sales in 2005 increased by 200 to 350 percent. If sales trends continue, there is the possibility that there will be almost 5,000 OWBs in Massachusetts and 500,000 OWBs nationally by 2010.
- State experience suggests that manufacturers are unlikely to voluntarily improve OWB performance.
- EPA is unlikely to develop a federal standard and even if it were to act immediately, it would take a minimum of five to seven years to enact a standard.
- EPA's focus on wood stove change-outs could result in an increase in installation rates for OWBs.
- Without aggressive public policy to limit fine particle and air toxic emissions from OWB sources, the number of potentially exposed at-risk individuals will continue to grow.
- Emissions from OWBs are 22 to 40 times greater than EPA certified indoor wood stoves.
- Near-source ambient monitoring indicates that OWB emissions have the potential to create significant public health concerns.
- Existing state regulations are inadequate to address OWBs and state environmental agencies lack the tools to effectively enforce against residential OWBs. Currently, the only viable route in some states to address OWB complaints is via state opacity requirements that are resource intensive to investigate and civil legal action, but this may not be equitable or broadly applicable.
- Complaints and enforcement actions against OWBs continue to increase, draining both state and local agency resources.

Based on these conclusions, NESCAUM recommends the following:

- Given that federal action is unlikely to take effect in the near term, states should move quickly to address OWB emissions.
- States should adopt regulations that establish emission limits for OWBs, similar to those of other residential woodburning units, because this is the best strategy for addressing the elevated emissions of fine particles (and the cancer-causing substances associated with particles) from OWBs.

- Because OWBs are most often used in residential settings and vary greatly in size, states should base an emission standard on a grams per hour basis to adequately protect public health.
- Additional studies should be conducted to assess impacts and determine acceptable exposure levels.
- EPA should support additional testing to gain a better understanding of the overall emissions profile of OWBs, specifically particulate matter and toxics.
- EPA should develop tools to assist states in addressing OWBs. Tools could include model regulations, outreach materials, SIP credit, and research data.

Appendix A: Outdoor Wood-fired Boiler Correspondence

NESCAUM
Northeast States for Coordinated Air Use Management

Connecticut Bureau of Air Management, Anne Gobin, Acting
Maine Bureau of Air Quality Control, James Brooks
Massachusetts Bureau of Waste Prevention, Barbara Kwetz
New Hampshire Air Resources Division, Robert Scott
New Jersey Division of Air Quality, William O'Sullivan
New York Division of Air Resources, David Shaw
Rhode Island Office of Air Resources, Stephen Majkut
Vermont Air Pollution Control Division, Richard Valentinetti

July 29, 2004

Jeffrey R. Holmstead
Assistant Administrator for Air and Radiation
U.S. Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N. W.
Washington, DC 20460

Re: Outdoor Wood Boilers

Dear Mr. Holmstead:

Over the past several years, a number of state air pollution control programs, as well as municipalities, have experienced a marked increase in the number of complaints related to Outdoor Wood Boilers (OWBs). The Northeast States for Coordinated Air Use Management (NESCAUM) believe the growing use of OWBs is a serious problem and are therefore exploring ways to take immediate action to prevent the continued proliferation of these sources until the units can be re-designed to ensure they meet stringent emissions standards. Concurrently, we would like to work with EPA because OWBs are sold nationwide and numerous states are facing similar problems with them. We believe a national regulatory approach is warranted, and we respectfully request that your office consider adopting a national strategy to regulate OWBs. Inasmuch as we have been collaborating with other states on this issue, you may receive similar correspondence from them.

With recent increases in the price of heating fuels, the use of wood for residential and commercial heating is on the rise and the number of OWBs has increased to the point that they constitute a significant compliance issue. While the nuisance smoke and odor problem associated with OWBs is well documented, limited emission testing demonstrates that OWBs are also large generators of fine particulate matter. Exposure to particles can lead to a variety of adverse respiratory and cardiac health effects, especially among people with heart or lung diseases who comprise a substantial percentage of the population. Moreover, testing for Hazardous Air Pollutants may demonstrate that OWBs pose an additional threat to human health, suggesting a need to regulate these sources under an area source MACT.

For a number of reasons, OWBs present problems not normally observed with indoor wood stoves, wood furnaces, or fireplaces. An OWB has a very short stack which emits

Kenneth A. Colburn, Executive Director
101 Merrimac Street, 10th Floor
Boston, Massachusetts 02114
Phone (617) 367-8540
Fax (617) 742-9162
www.nescaum.org

smoke near the ground and allows for little dispersion. The majority of units are designed to provide long burn times and be loaded once a day, or less frequently. The large fuel capacities and automatic damper controls, typically combined with primitive combustion design, frequently result in poor combustion, heavy smoke, noxious odors, and high concentrations of fine particulate and other air pollutants associated with low temperature combustion of wood fuel. Because they are also used to provide hot water for heating swimming pools, many OWBs are operated during summer months, when windows in nearby residences are open.

Emission testing performed under the direction of the U.S. Environmental Protection Agency in 1997 found particulate emissions from two common OWBs ranged from 1.5 – 3.1 pounds/mmBTU heat input. These tests were conducted on new units operating under controlled conditions, at a fraction of rated capacity, while burning seasoned firewood. In practical application, particulate emissions are likely to be much higher. However, OWBs were exempted from compliance with the national "Standards of Performance for New Residential Wood Heaters" (40 CFR Part 60, Subpart AAA) and are currently regulated by only a few state and local governments. Therefore, we feel that it is critical that EPA take immediate action to regulate these sources.

Thank you for your consideration of this timely and important concern.

Sincerely,

Kenneth A. Colburn

Kenneth A. Colburn
Executive Director

cc: John DuPree, EPA Headquarters
Fred Weeks, EPA Region 1
Denny Dart, EPA Region 1
Gil Wood, EPA OAQPS
Vinson Hellwig, Michigan DEQ

STATE OF NEW YORK
OFFICE OF THE ATTORNEY GENERAL

ELIOT SPITZER
Attorney General

DIVISION OF PUBLIC ADVOCACY
ENVIRONMENTAL PROTECTION BUREAU

August 11, 2005

VIA OVERNIGHT MAIL

The Honorable Stephen L. Johnson
Administrator, Environmental Protection Agency
Ariel Rios Building
1200 Pennsylvania Avenue, N.W.
Washington, DC 20460

Re: Petition for rulemaking under 42 U.S.C. § 7411(b)(1)
Regarding Outdoor Wood Boilers

Dear Administrator Johnson:

The States of New York, Connecticut, Maryland, Massachusetts, Michigan, New Jersey and Vermont, and the Northeast States for Coordinated Air Use Management (NESCAUM) hereby petition the U.S. Environmental Protection Agency (EPA) to use its authority under section 111(b)(1) of the Clean Air Act (the "Act"), 42 U.S.C. § 7411(b)(1), to list outdoor wood boilers (OWBs) as a category of stationary sources under section 111(b)(1)(A) and to promulgate standards of performance for OWBs under 42 U.S.C. § 7411(b)(1)(B). In the alternative, after listing OWBs as a category of stationary sources under section 111(b)(1)(A), EPA could revise the existing standards for residential wood heaters, at 40 CFR §§ 60.530-60.539b, to include standards for OWBs.

As explained in the attached report of the New York Attorney General's Office, Environmental Protection Bureau, entitled, *Smoke Gets in Your Lungs: Outdoor Wood Boilers in New York State* (the "New York Report"), OWBs are becoming increasingly common in rural and suburban towns and villages throughout much of the nation. Emissions of fine particulate matter (particulate matter with a diameter less than 2.5 microns [PM 2.5]) and toxic materials from OWBs exceed those from indoor wood stoves (called wood heaters by EPA), both on a per-device basis and in proportion to the energy created. Despite polluting at a significantly higher rate than residential wood heaters, OWBs are exempt from the standard applicable to residential wood heaters and are not required to meet any testing, performance, or emission standards.

The Capitol, Albany, NY 12224 ● (518) 474-8096 ● Fax (518) 473-2534

Notable findings of the New York Report include:

- While advertised as a clean economical way to heat one's house and water, OWBs may be among the dirtiest and least economical modes of residential heating, especially when improperly used;

- Even when used properly, OWBs emit, on an average per hour basis, about 4 times as much PM 2.5 as conventional wood stoves, about 12 times as much PM 2.5 as EPA-certified wood stoves, 1000 times more PM 2.5 than oil furnaces, and 1800 times more PM 2.5 than gas furnaces;

- When OWBs are used improperly to burn wet or treated wood, scrap, or garbage, they generate even more smoke and emit additional toxic chemicals;

- The pollutants emitted by OWBs can cause or contribute to short-term health harms such as eye, nose, throat, and lung irritation, coughing and shortness of breath, and long-term health effects such as asthma, heart and lung disease, and cancer;

- The generally short chimneys and reduced draft of OWBs fail to disperse emissions adequately and can cause smoky conditions at or near ground level;

- OWBs are generally more expensive to install than comparable heating sources using oil, or gas, or indoor wood stoves, and may be more expensive to operate depending on the availability and price of dry seasoned wood;

- OWBs do not currently have to meet federal or state performance emission standards;

- The absence of any federal regulations has led to various state and local efforts to regulate OWBs.

Since the problems associated with OWBs are widespread and exist across much of the northern U.S., it is sensible for the federal government to enact federal standards of performance, as it has with respect to indoor wood heaters, so as to avoid the development of a patchwork of state and local regulations.

Section 111(b)(1)(A) requires EPA to include in the listing of categories of stationary sources under section 111 a category that "causes, or contributes significantly to, air pollution which may reasonably be anticipated to endanger public health and welfare." The findings in the New York Report establish that OWBs should be listed. Accordingly, the EPA should promulgate regulations for OWBs under section 111(b)(1)(B), establishing standards of performance that reflect the degree of emission limitation achievable through the best system of emission reduction that has been adequately demonstrated. 42 U.S.C. § 7411(a)(1). Consistent with the general framework of the Act, such federal regulations should serve as a "floor," allowing states or municipalities to enact more stringent regulations as necessary to combat particularized local air quality problems.

Petition to EPA by NY, CT, MD, MA, MI, NJ, VT and NESCAUM
August 11, 2005

The time has come for EPA to regulate emissions from OWBs in order to protect public health and the environment. Therefore, please consider this letter to be a formal request pursuant to the Administrative Procedure Act, 5 U.S.C. § 553(e), for a rulemaking to list OWBs as a category of stationary sources and to establish standards for emissions from new OWBs.

Sincerely,

ELIOT SPITZER
Attorney General
State of New York

On behalf of:

RICHARD BLUMENTHAL
Attorney General
State of Connecticut

THOMAS F. REILLY
Attorney General
Commonwealth of Massachusetts

STEVEN E. CHESTER
Director
Michigan Department of Environmental Quality

JOHN J. FARMER, JR.
Attorney General
State of New Jersey

WILLIAM H. SORRELL
Attorney General
State of Vermont

ARTHUR N. MARIN
Executive Director
Northeast States for Coordinated Air Use Management (NESCAUM)

New York State Department of Environmental Conservation
Division of Air Resources
Bureau of Stationary Sources, 2nd Floor
625 Broadway, Albany, New York 12233-3254
Phone: (518) 402-8403 • **FAX:** (518) 402-9035
Website: www.dec.state.ny.us

Erin M. Crotty
Commissioner

May 14, 2003

Mr. Dennis T. Brazier
Central Boiler, Inc.
20502 160th Street
Greenbush, MN 56726

Dear Mr. Brazier:

The New York State Department of Environmental Conservation (Department) is responsible for responding to air pollution complaints in New York State and for ensuring compliance with New York State air pollution laws and regulations. As such, this letter is to notify you that the Department has received an increasing amount of complaints arising out of the operation of wood fired outdoor furnaces, and to provide you with information regarding the manner in which New York State air pollution regulations apply to your customers' use of these products.

New York State Regulation, at 6 NYCRR Part 211.2, prohibits any person (defined as an individual, corporation, partnership, association, or other legal entity) from causing or allowing emissions of air contaminants that unreasonably interfere with the comfortable enjoyment of life or property. The complaints the Department has received reflect that the quantity and nature of smoke emissions that result from the operation of outdoor wood furnaces have violated this provision, by interfering with the enjoyment of neighboring properties and surrounding areas. In addition, 6 NYCRR Part 227-1.3(a) limits opacity from stationary combustion installations to not greater than 20 percent (six minute average) except for one six minute average per hour not to exceed 27 percent. The Department has documented the violation of this standard in responding to complaints in several cases, and will continue to assess compliance with this standard when addressing other nuisance complaints arising out of emissions from outdoor furnaces. You should also be aware that if any material other than clean wood or fossil fuels is burned in the stove, then the device is considered an illegally operating incinerator.

The Department has sought and will continue to seek to prevent the operation of any wood fired outdoor furnaces that violate New York State air pollution control laws and regulations. In cases to date where the Department has issued tickets or notices of violation, the furnace owner/operator has been cited for noncompliance with the law. The Department is concerned, however, that these products are not designed or manufactured in a manner necessary to operate them in compliance with New York State regulations. As such, the Department is exploring whether the sale and use of wood fired outdoor furnaces in New York also violates New York State air pollution control laws and regulations.

In the interim, and in the interest of reaching an amicable resolution to the potential for nuisance caused by wood fired outdoor furnaces, the Department would like to meet with you and other manufacturers to evaluate your ability to manufacture and sell outdoor furnace products that comply with the above laws. We are also interested in discussing technical solutions to the problem that exists with the operation of devices that have already been sold in this State. Please contact our Director's office at 518-402-8452 at your earliest convenience, to schedule a meeting with Department staff. Thank you for your anticipated cooperation.

Sincerely,

Robert G. Sliwinski
Acting Director
Bureau of Stationary Sources
Division of Air Resources

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

JUN 10 2005

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

Mr. Dennis T. Brazier, President
Central Boiler Company
20502 160th Street
Greenbush, MN 56726

Dear Mr. Brazier:

The purpose of this letter is to invite you to discuss air pollution concerns resulting from outdoor wood-fired hydronic heaters (OWHH) used to provide heat for residences and businesses. My office has received several inquiries from the public, State and local environmental protection agencies, and elected officials regarding the health and environmental impacts of OWHH. Many of these stakeholders are urging the Environmental Protection Agency (EPA) to take actions to limit the emissions from these units.

EPA is not at this time considering any specific regulatory actions. Instead, we want to work cooperatively with your sector of the wood heating industry to develop cleaner burning products. I am very interested in learning more about specific short- and long-term actions you may be considering to address the concerns raised by the general public and others. Members of my staff have advised me of efforts by your industry to characterize the emissions of air pollutants from OWHH through the American Society for Testing and Materials. I am encouraged to know that consensus standards may eventually evolve from this work. In addition, I am interested in characterizations of emissions from your company's products, and any plans you may have to build and sell OWHH with emissions lower than those exhibited by currently available models.

I have asked Scott Mathias of my staff to follow up with you to discuss the issues above and any others you might wish to raise.

Thank you in advance for considering the concerns raised in this letter. I look forward to hearing from you or your representative as we address this important matter.

Sincerely,

Gregory A. Green for

Stephen D. Page
Director
Office of Air Quality Planning
and Standards

OAQPS/ITPID/PIRG/DPainter:cja:919-541-5515:RTP:MC-E143-02
CONTROL No. OAR-05-000-6598

Identical Letters were sent to the Following:

Mr. Frank Moore, President
Hardy Manufacturing Co., Inc.
12345 Road #505
Philadelphia, MS 39350

Mr. Ron Taylor
Taylor Manufacturing Company
P.O. Box 518
Elizabethtown, NC 28337

Mr. John Kehrwald, General Mgr.
Heatmor Inc.
105 Industrial Park Court, NE
P. O. Box 787
Warroad, MN 56763

Mr. David Laursen, Pres.
Aqua-Therm
48301 State Highway 55
Brroten, MN 56316

Ms. Robin E. Weaver, Pres.
Mahoning Outdoor Furnaces, Inc.
208 Whiskey Run Road
Mahaffey, PA 15757

Mr. Trevor Guentor, President
Pro-Fab Industries Inc
Box 112
Arborg, Manitoba R0C 0A0
Canada

Mr. Chuck Gagner
Northwest Manufacturing
600 Polk Avenue, SW
Red Lake Falls, MN 56750 -0124

Mr. Martin Lunde
Dectra Corporation
3425 33rd Avenue, NE
St. Anthony, MN 55418

United States Environmental Protection Agency
Research Triangle Park, North Carolina 27711
Office of Quality Planning and Standards
Stephen Page, Director

June 27, 2005

Dear Mr. Page:

We are in receipt of your letter of invite concerning outdoor wood-fired hydronic heaters, (OWHH). Central Boiler looks forward to addressing these concerns.

It is our understanding that the inquiries you have received from the state and local agencies are a result of their need to address nuisance complaint issues. We have worked with several state and local agencies concerning the OWHH and have found that all complaints have been a result of nuisance issues caused by improperly installed and/or operated OWHH. Complaints from new installations have been dramatically reduced as a result of proper training of dealers and end users of correct installation and operation.

Currently, test methodology is not well established or internationally recognized to accurately characterize emissions or efficiency for OWHH.

We have current projects and initial testing showing potential for a cleaner more efficient OWHH. Upon completion of an internationally recognized (ASTM) standard, Central Boiler will be able to allocate sufficient resources to bring a cleaner furnace to production levels for distribution to the consumer with confidence that there will be a measurable difference for the environment.

We look forward to EPA's assistance in working with the ASTM committee to proficiently develop and complete the OWHH ASTM standard so new products can be tested and proven to be better for the environment.

Please contact us if you have any questions or feel that we may be of any assistance to you.

Sincerely,

Rodney Tollefson, VP

Rodney Tollefson
Vice President
Central Boiler, Inc.
218-782-2575
rodney@centralboiler.com

COPY

STATE OF WASHINGTON
DEPARTMENT OF ECOLOGY
PO Box 47600 • Olympia, WA 98504-7600 • 360-407-6000
TTY 711 or 800-833-6388 (For the Speech or Hearing Impaired)

May 12, 2005

Central Boiler, Inc.
20502 160th Street
Greenbush, MN 56726

Dear Wood Furnace Manufacturer/Distributor:

The purpose of this letter is to clarify Washington State's solid fuel burning device regulations, as they pertain to the sale of wood furnaces, and point out the differences between Washington's requirements and federal EPA requirements.

Effective January 1, 1995, Washington regulations required that all solid fuel burning devices offered for sale in Washington meet Emission Performance Standards described in Washington Administrative Code 173-433-100 (3). These standards limit particulate matter emissions to:

- two and one-half grams per hour for catalytic woodstoves, and
- four and one-half grams per hour for **all other** solid fuel burning devices.

A solid fuel burning device is any device that burns wood, coal, or any other non-gaseous or non-liquid solid fuels for aesthetic or space-heating purposes in a private residence or commercial establishment, which has a heat input less than one million British thermal units (Btu) per hour. Therefore, by state definition, a wood furnace is a solid fuel burning device, and therefore must meet the particulate matter emission standard of four and one-half grams per hour before it may be offered for sale in Washington.

The Washington state standards differ from EPA New Source Performance Standards (NSPS) for Wood Heaters in the following ways:

- Washington's particulate emission limits are more stringent than those specified in the federal NSPS, and
- Washington's particulate emission limits apply to all solid fuel burning devices, including wood furnaces.

While EPA regulations still exempt certain devices from testing and/or certification requirements, Washington regulations require that all devices be tested and certified to comply with the more stringent Washington particulate emission limits.

Therefore, wood furnaces with heat inputs of less than one million Btu may not be sold anywhere within the state of Washington unless the Department of Ecology has determined that the furnace meets state emission standards. Any retailer, wholesaler or distributor offering for sale or selling a non-compliant device may be subject to formal enforcement action.

Wood furnaces with heat inputs of **one million Btu per hour or more**, while not subject to solid fuel burning device standards, upon operation, must not exceed the visible emission standard of 20% opacity for more than three minutes in any one hour, contained in WAC 173-400-040(1). In addition, some local air authorities may require a demonstration that the units meet specific grain loading standards, as measured by EPA method 5 test in Appendix A to 40 CFR Part 60.

Complete text of the Washington state solid fuel burning device rule can be found at http://www.ecy.wa.gov/pubs/wac173433.pdf.

If you have any questions, please call Tom Todd at (360) 407-7528.

Sincerely,

Sarah Rees
Program Development Section Manager
Air Quality Program

June 8, 2005

Sarah Rees
Program Development Section Manager
Air Quality Program
Department of Ecology
State of Washington
PO Box 47600
Olympia, WA 98504-7600

Dear Ms. Rees:

We are in receipt of you letter, dated May 12, 2005, stating that outdoor furnaces cannot be sold in the state of Washington. We have communicated in the past and provided information to the Washington Department of Ecology (DOE) that showed the emission levels of Central Boiler outdoor wood furnaces comply with Washington emission standards and should be approved for sale in the State of Washington.

Central Boiler is well aware, as is the DOE, there is no test standard or protocol for testing outdoor wood furnaces. Your letter refers to an emission standard determined by the DOE as being more stringent than those contained in the EPA New Source Performance Standard (NSPS).

To quote Washington Administrative Code 173-433-100 (3), [WAC 173-433-030 **Definitions.** (2) "Certified" means that a woodstove meets emission performance standards when tested by an accredited independent laboratory and labeled according to procedures specified by the EPA in "40 CFR 60 Subpart AAA – Standards of Performance for Residential Wood Heaters" as amended through July 1, 1990.] A "wood stove" is very specifically defined by size, burn rate, weight, etc. in the NSPS. The USEPA does not allow appliances that fall outside of the definition of "wood stoves" to be certified to the NSPS. Attempts to test other solid fuel burning devices to this standard would not provide meaningful emission data that could be used for rating such devices.

You are suggesting a 4.5 g/h level that must be met by an appliance that does not have a standard (testing protocol) that allows the furnace to be tested and rated. As we are aware, the NSPS certification process consists of four test burns. The EPA certification rating that is determined by this testing process is a weighted average of those four test burns. The certification rating (hang-tag) is not equivalent to the emissions level produced when the wood stove is being operated.

20502 160th Street, Greenbush, MN 56726 **Central Boiler** Phone: 218-782-2575 Fax: 218-782-2580
www.centralboiler.com

The 4.5 g/h WAC "emission number" is merely a number without a standard (test protocol). The appliances that fall outside of the definition of "wood stoves" can easily meet a 4.5 g/h emission level by operating within parameters that would generate such emission levels. Without test protocol that determines burn rates, fuel crib and other crucial criteria, a 4.5 number is meaningless.

We have previously provided information to Mr. Tapas K. Das P.E., Quality Air Program of the Washington Department of Ecology on July 18, 2003. We are also aware of communications between Spokane County and the State of Washington concerning emissions data provided by Central Boiler. Neither office could determine that Central Boiler outdoor wood furnaces do not meet a 4.5 g/h emission level. Central Boiler believes the data provided illustrates Central Boiler outdoor wood burning furnaces do comply with the 4.5 g/h Washington Emission Performance "Standard", WAC Code 173-433.

Central Boiler understands by state and federal laws when a regulation does not provide criteria to determine compliance or noncompliance such a regulation is not enforceable. Central Boiler has requested, from the DOE, the criteria needed to determine compliance and the DOE has not provided an established test standard or a statistically reliable conversion factor.

Sincerely,

Rodney Tollefson
Vice President

Cc: John Adrian – CB Sales, LLC

Appendix B: Outdoor Wood-fired Boiler Manufacturers

Alternate Heating Systems, Inc
2395 Little Egypt Road
Harrisonville, PA 17228
http://www.alternateheatingsystems.com/

Aqua-Therm LLC
48301 State Hwy 55
Brooten, MN 56316
www.aqua-therm.com

Alpha American
10 Industrial Blvd
Palisade, MN 56469
http://www.yukon-eagle.com

Central Boiler, Inc.
20502 160th Street
Greenbush, MN 56726
www.centralboiler.com

Charmaster Products, Inc.
2307 Highway 2 West
Grand Rapids, MN 55744
www.charmaster.com

Dectra Corporation
3425 33rd Ave NE
St Anthony, MN 55418
www.dectra.net/garn

Freedom Outdoor Furnace
7958 Curwensville Tyrone Hwy
Olanta, PA 16863
www.freedomoutdoorfurnace.com

Global Hydronics
Box 717
Winkler, Manitoba, CANADA R6W 4A1
www.globalhydronics.com

Hardy Manufacturing
12345 Road 505
Philadelphia, MS 39350
www.hardyheater.com

Heatmor Inc.
105 Industrial Park Court NE
Warroad, MN 56763
www.heatmor.com

Heat Innovations
499 Manitoba Road
PO Box 989
Winkler, Manitoba, R6W 4B1
CANADA

Heatsource1
2201 Ridgeview Drive
Beatrice, NE 68310
www.heatsource1.com

Hicks Waterstoves and Solar Systems
2541 South Main Street
Mount Airy, NC 27030

Horstmann Industries, Inc.
301 Second Street
Elroy, WI 53929
www.royalfurnace.com

Innotech Developments
2015 James Street South
Thunder Bay, Ontario P7J1G6
CANADA
www.outdoorfurnaces.com

Johnson Manufacturing
PO Box 345, 8187 State Rte 12
Barneveld, NY 13304
www.hud-son.com/woodfurnaces.htm

Mahoning Outdoor Furnace
RD #1 Box 250
Mahaffey, PA 15754
www.shol.com/mahoning

Noonan's Welding and Heating
105 1st Street South
Keewatin, MN 55753
www.northlandoutdoorwoodfurnace.com

Northwest Manufacturing
600 Polk Ave SW
Red Lake Falls, MN 56750
www.woodmaster.com

Outside Heating Systems – Wood Doctor
Box 567
Stewiacke, Nova Scotia B0N2J0
CANADA
www.wooddoctorfurnace.com

Pacific Western
Box 267
Atikokan, Ontario P0T 1C0 CANADA

Pro-Fab Industries Inc./Empyre/Cozeburn
Box 112
Arborg, Manitoba R0C 0A0 CANADA
http://www.burnsbest.com or
www.profab.org

SFC Industries
2219 County Highway G
Rhinelander, WI 54501

TARM USA, Inc.
Main Street Box 285
Lyme, NH 03768
www.woodboilers.com

Taylor Manufacturing, Inc.
1585 US HWY 701 South
Elizabethtown, NC 28337
www.taylormfg.com

Timber Ridge, Inc.
2020 Highway 11-E
Jonesborough, TN 37659
www.freeheatmachine.com

Turbo Burn, Inc.
4225 E Joseph
Spokane, WA 99217
www.turboburn.net

Appendix C: Estimated National Sales of OWBs

State	**Estimated number of OWBs sold since 1990**
Alabama	74
Alaska	185
Arizona	24
Arkansas	574
California	182
Colorado	271
Connecticut	1,538
Delaware	77
District of Columbia	13
Florida	32
Georgia	50
Hawaii	0
Idaho	401
Illinois	4.798
Indiana	7,518
Iowa	2,762
Kansas	515
Kentucky	1,148
Louisiana	3
Maine	1,968
Maryland	872
Massachusetts	1,308
Michigan	29,568
Minnesota	13,936
Mississippi	0
Missouri	4041
Montana	350
Nebraska	190
Nevada	1
New Hampshire	1,981
New Jersey	215
New Mexico	12
New York	13,182
North Carolina	2,561
North Dakota	87
Ohio	13,605
Oklahoma	76
Oregon	555
Pennsylvania	11,836
Rhode Island	206
South Carolina	124
South Dakota	40
Tennessee	573
Texas	16
Utah	38
Vermont	2.033
Virginia	4.658
Washington	393
West Virginia	3,725
Wisconsin	27,452
Wyoming	66
US Total	**155,834**

Appendix D: Michigan DEQ Modeling

Residential Wood Boiler Study

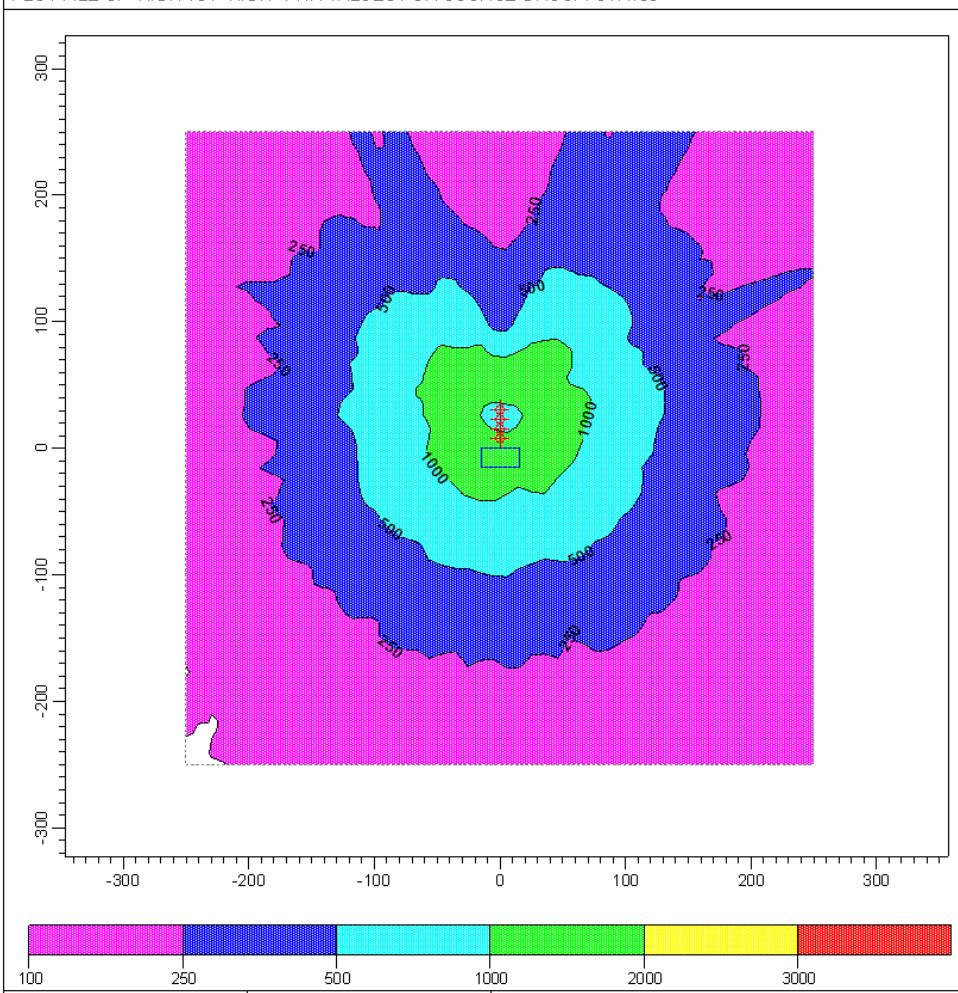
MAXIMUM PREDICTED 1-HR AVG CONCENTRATIONS

Four contour plots of the max 1-hr concentration at an emission rate of 1lb/hr. Since its 1 stack, the impacts can be scaled (linear relationship) to a different emission rate. Modeling is based on the following:

stack height = 8'
temperature = 250F
vel=1.5 m/s
diameter = 6"
50' x 100' bldg 22' high

Ran 25', 50', 75', and 100' set back distances from the bldg due north using 1983 KIS met data.

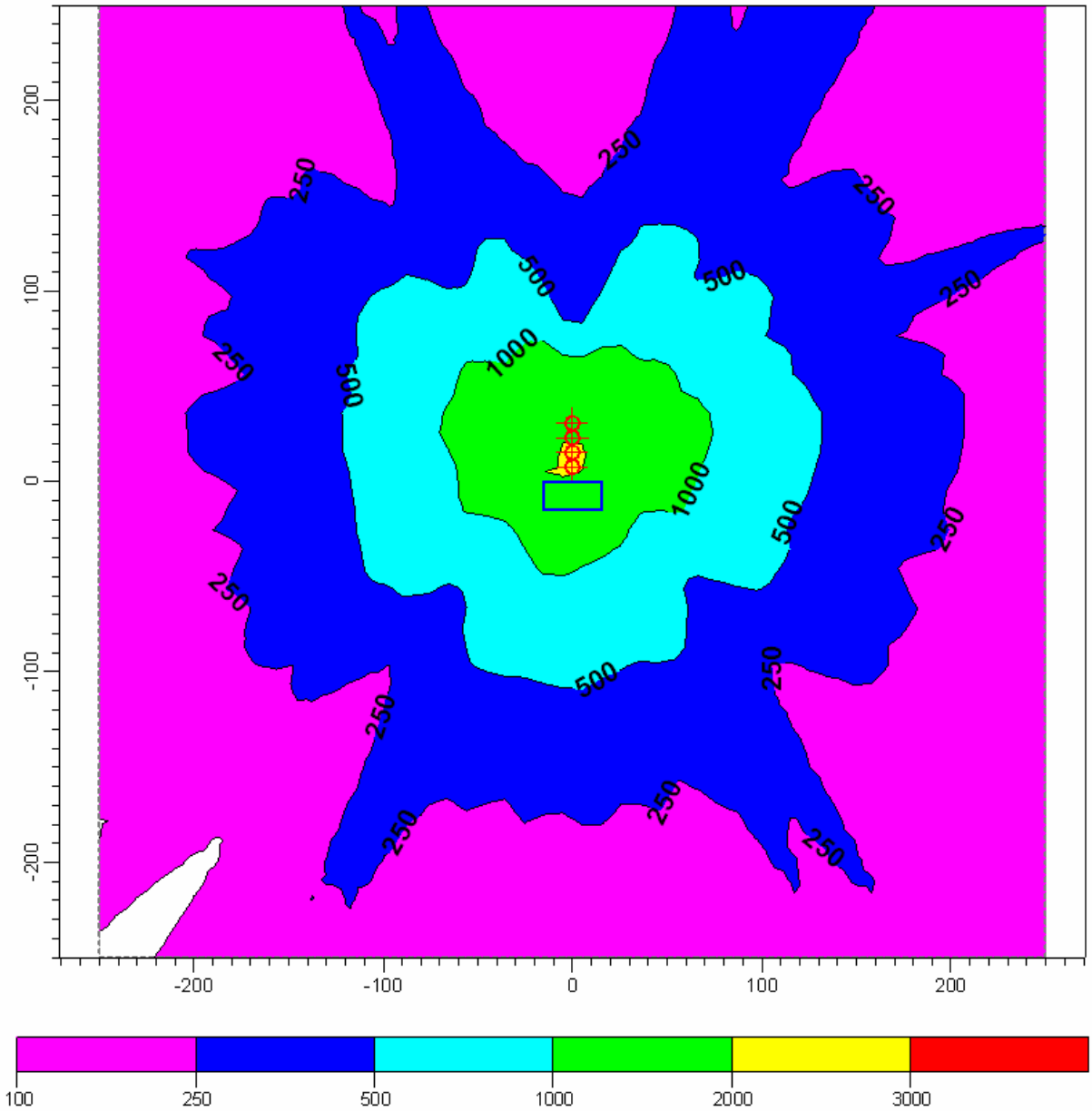
PROJECT TITLE:
C:\ISCView4\RESDWOOD.isc
PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: STK100



COMMENTS:	MODELING OPTIONS:		COMPANY NAME:	
100FT SET BACK DUE NORTH FROM HOUSE 1HR AVG IMPACT @ 1 LB/HR	CONC, RURAL, FLAT, DFAULT		Residential Wood Boiler	
			MODELER: 1983 KIS Met Data	
	OUTPUT TYPE: CONC	RECEPTORS: 2598	0 0.1 km	
	MAX: 2846.72754	UNITS: µg/m³	DATE: 6/18/2004	PROJECT NO.:

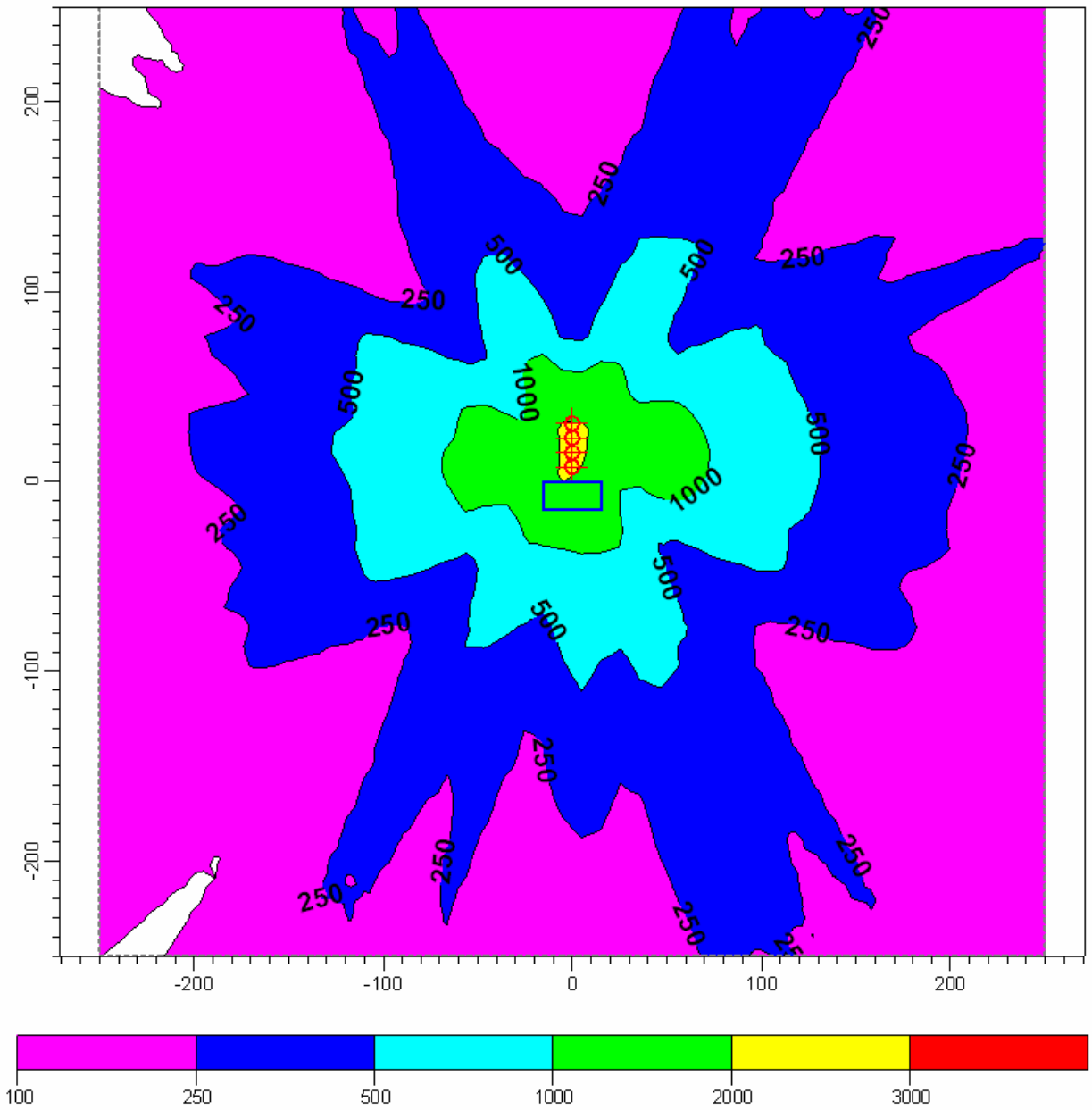
POST View - Lakes Environmental Software C:\ISCVIEW4\RESDWOOD.IS\01H1G004.PLT

PROJECT TITLE:
C:\ISCView4\RESDWOOD.isc
PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: STK75



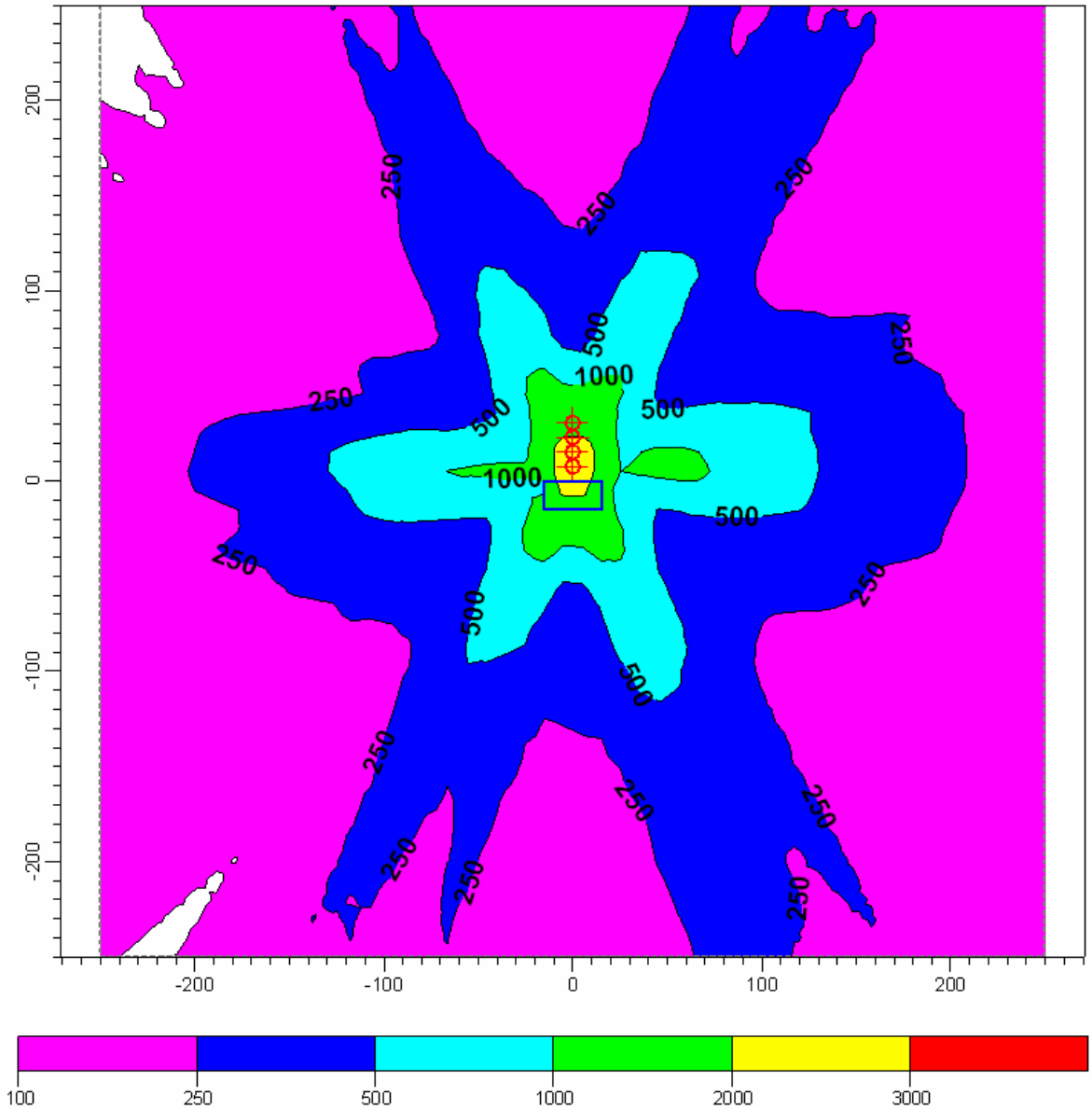
COMMENTS:	MODELING OPTIONS:		COMPANY NAME:	
75FT SET BACK DUE NORTH FROM HOUSE 1HR AVG IMPACT @ 1 LB/HR	CONC, RURAL, FLAT, DFAULT		Residential Wood Boiler	
			MODELER: 1983 KIS Met Data	
	OUTPUT TYPE: CONC	RECEPTORS: 2598	0 0.05 km	
	MAX: 4361.85889	UNITS: µg/m³	DATE: 6/18/2004	PROJECT NO.:

PROJECT TITLE:
C:\ISCView4\RESDWOOD.isc
PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: STK50



COMMENTS:	MODELING OPTIONS:		COMPANY NAME:	
50 FT SET BACK DUE NORTH FROM HOUSE 1HR AVG IMPACT @ 1LB/HR	CONC, RURAL, FLAT, DFAULT		Residential Wood Boiler	
			MODELER: 1983 KIS Met Data	
	OUTPUT TYPE: CONC	RECEPTORS: 2598	0 0.05 km	
	MAX: 4306.479	UNITS: µg/m³	DATE: 6/18/2004	PROJECT NO.:

PROJECT TITLE:
C:\ISCView4\RESDWOOD.isc
PLOT FILE OF HIGH 1ST HIGH 1-HR VALUES FOR SOURCE GROUP: STK25



COMMENTS:	MODELING OPTIONS:		COMPANY NAME:	
25 FT SET BACK DUE NORTH OF HOUSE 1-HR AVG IMPACT @ 1 LB/HR	CONC, RURAL, FLAT, DFAULT		Residential Wood Boiler	
			MODELER: 1983 KIS Met Data	
	OUTPUT TYPE: CONC	RECEPTORS: 2598	0 0.05 km	
	MAX: 6761.25586	UNITS: µg/m³	DATE: 6/18/2004	PROJECT NO.:

Appendix E: Field Report on Moisture Readings and Opacity

Vermont Department of Environmental Conservation
Air Pollution Control Division

AIR POLLUTION TRIP REPORT

PROPERTY: Confidential **DATES OF SITE VISIT:** June 21 & 22, 2005

PURPOSE OF VISIT: To observe/assist with testing of an outdoor wood boiler.

LOCATION OF SITE: Vermont

PEOPLE PRESENT: Lisa Rector, NESCAUM
George Allen, NESCAUM
John Jasko, Air Quality Technical Services
Chris Jones, Vermont DEC (6/21/05)
Philip Etter, Vermont DEC

WEATHER: Temperature: Highs generally 80s°F
Wind: 0-15 mph, Direction variable
Cloud Cover: Clear to Partly Cloudy
Precipitation: None

INVESTIGATOR: Philip L. Etter, Environmental Analyst

We attended the emissions testing of an outdoor wood boiler (OWB) to assist with the testing and observe the operation of the OWB unit. While on site I made some measurements of the moisture content of the wood fuel being used during the test using a Delmhorst moisture meter and conducted some visible emissions observations for general informational purposes. I also took numerous digital photos during the testing on 6/22/05.

Wood Moisture Measurements

All wood moisture measurements were done on 6/22/05. The wood supply consisted of mixed hardwoods but mainly maple and red oak in two to three foot lengths. Most of the wood had been split, but some of the wood was in the round. The wood was uncovered and stacked in a semi sunny location. I checked the moisture content of three pieces of maple and two of red oak. One of the maple pieces was round but all the others had been split. I tried to choose pieces of larger size from various places in the small pile that had been designated as the fuel for the test. Using wedges and a sledge hammer, I

split each piece roughly in the center just before taking measurements. I then took three measurements on the inside split surface, one in the center and one on either side of center roughly halfway from the center to the ends of the piece. The upper moisture content limit of the meter is 40%. Moisture readings above this limit were recorded as greater than 40%, but were treated as 40% when calculating averages. Readings are documented in the following table.

PERCENT MOISTURE IN WOOD FUEL					
Species	Rough Size (inches)	Reading 1 %	Reading 2 %	Reading 3 %	Average %M
Maple	5" split	26.8	29.3	24.3	26.8
Maple	5" round	28.5	28.5	25.6	27.5
Maple	7" x 4" split	30.5	27.7	32.6	30.3
Red Oak	5" split	>40	37.5	>40	>39.2
Red Oak	8" x 3" split	>40	>40	>40	>40

Note that the moisture content measurements were done for general information only. No attempt was made to weigh the fuel charged to the unit or to count the chunks of various species of wood being charged. Some of the wood charged on the second day was taken from another part of the pile that had been recently rained on. Overall, the moisture content appeared to be fairly high. Oak generally takes longer to dry than many other hardwood species but the history of particular pieces of wood is unknown so it may be that the oak was cut later than the maple.

Visible Emissions

In an attempt to determine how the visible emissions vary over time and the burn mode cycling of the OWB, I evaluated visible emissions for 24 minutes on 6/21/05 and for nearly two hours on 6/22/05 (see attached VE evaluation forms). These observations were purely informational. Currently, OWBs are exempt from Vermont's visible emissions standards due to their small size. The green foliage of the woods behind the OWB provided a good contrasting background for the light colored smoke. The sun was always well within appropriate angles for Method 9 observations. I ceased making observations on 6/22/05 at about 1140 hours as the sun's vertical angle was becoming potentially inappropriate. During midday hours in late June, the vertical angle of the sun is inappropriate for observations in most situations. Observations were made difficult by the highly variable wind speed and direction, the plume often down washing, looping or blowing away from the observer making proper readings impossible.

The nature of the plumes also made VE evaluation more difficult. Much of the time, especially during the open damper mode, the plume appeared to be largely condensed organics; with the densest part of the plume a few to several feet beyond the top of the stack. On 6/21 I tended to read the plume a couple feet above the stack before the densest smoke formed. On 6/22/05 I was reading the opacity in the densest part of the plume, a few to several feet above the stack. I did not notice any indications of a

condensed water vapor component in the plume although I can't rule-out with absolute certainty that some moisture condensation was occurring. Meteorological conditions would have caused any condensed water vapor in the plume to rapidly dissipate leaving a less dense trailing particulate plume. This was not apparent during the test burns as the dense plumes carried for a considerable distance, gradually dispersing.

I also found evaluating the opacity during the idle mode to be difficult due to the very low gas flows emanating from the stack. Often the plume seemed to narrow beyond the top of the stack perhaps causing the plume to appear denser than if it were spread over the full width of the stack. The idle mode plumes appeared to be fully condensed as they exited the stack, which isn't surprising given the very low stack gas temperatures recorded during the idle mode.

The observations on the morning of 6/22/05 represent the worst case, as they were made during the beginning of the burn cycle. The OWB was loaded before the beginning of the test in the morning but not later. Although I didn't conduct formal observations later in the day during the charcoal stage of the burn cycle, informal observations indicated that visible emissions were greatly reduced with opacities more in the 40-50% range during the charcoal stage operating modes rather than the 90-100% opacities near the beginning of the burn cycle. The observations done on 6/21/05 were later in the day but I am uncertain how long it had been since the OWB was charged.

Summary

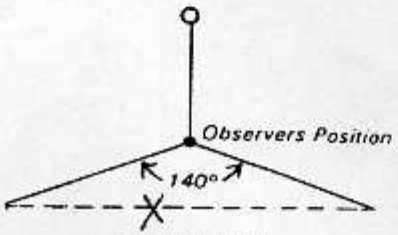
These visible emissions observations indicate that the smoke from this OWB was densest during the first hours of the burn cycle and less dense during the latter charcoal phase burning. The opacities and total volume of visible smoke (i.e. the overall size or volume of the plumes) were also heaviest following the opening of the damper. Opacities and total smoke volume were much reduced during the idle mode and were greatly reduced as the duration of the idle mode increased probably due to the cooling of the fire greatly reducing combustion gas production. Opacities also seemed to decrease somewhat as the stack temperatures increased with the length of the open damper operating mode.

VISIBLE EMISSIONS EVALUATION FORM

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
AIR POLLUTION CONTROL DIVISION
103 SOUTH MAIN STREET
WATERBURY, VERMONT

SOURCE NAME: OWB	
ADDRESS:	
CITY:	STATE: VT / ZIP:
PHONE:	SOURCE ID NUMBER:
PROCESS EQUIPMENT: Outdoor Wood boiler	OPERATING MODE:
CONTROL EQUIPMENT: None	OPERATING MODE:
DESCRIBE EMISSION POINT: Metal Stack	
HEIGHT ABOVE GROUND LEVEL: ~9'	HEIGHT RELATIVE TO OBSERVER: ~9'
DISTANCE FROM OBSERVER:	DIRECTION FROM OBSERVER:
DESCRIBE EMISSIONS: Smoke	
EMISSION COLOR: White	PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
"STEAM" PLUME PRESENT: NO ☒ YES ☐	IF "STEAM" PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: ~2 ft. above stack	
DESCRIBE BACKGROUND: Hardwood foliage	
BACKGROUND COLOR: Green	SKY CONDITIONS: Clear
WIND SPEED:	WIND DIRECTION:
AMBIENT TEMP: 80's	PRECIPITATION/FOG: None

SOURCE LAYOUT SKETCH



OBSERVATION DATE: 6/21/05 START TIME: 1531 STOP TIME: 1555

MIN \ SEC	0	15	30	45	MIN \ SEC	0	15	30	45
1	0	0	0	0	31				
2	0	0	0	0	32				
3	0	0	0	10	33				
4	10	20	25	30	34				
5	35	40	40	35	35				
6	35	40	40	45	36				
7	40	40	45	45	37				
8	45	40	40	40	38				
9	~	45	45	40	39				
10	40	40	40	~	40				
11	45	40	30	35	41				
12	35	30	30	30	42				
13	~	20	25	30	43				
14	30	25	30	30	44				
15	30	25	20	20	45				
16	25	20	20	25	46				
17	20	15	15	15	47				
18	15	15	15	~	48				
19	15	15	10	15	49				
20	10	15	10	15	50				
21	15	15	10	10	51				
22	5	10	5	10	52				
23	5	5	10	10	53				
24	10	10	5	5	54				
25					55				
26					56				
27					57				
28					58				
29					59				
30					60				

MINUTES > 20% OPACITY

MINUTES > 40% OPACITY

MINUTES > 60% OPACITY

OFFICIAL INTERVIEWED

TITLE

OBSERVER'S NAME (PRINT): Philip Etter

OBSERVER'S SIGNATURE: Philip Etter DATE: 6/21/05

COMMENTS

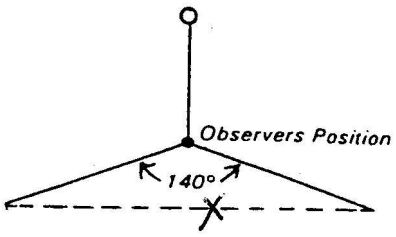
MISSING DATA SYMBOLS: ~ LOOPING/BLOWING PLUME; X INTERFERENCE; — OTHER

VISIBLE EMISSIONS EVALUATION FORM

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
AIR POLLUTION CONTROL DIVISION
103 SOUTH MAIN STREET
WATERBURY, VERMONT

SOURCE NAME: OWB Test	
ADDRESS:	
CITY:	STATE: VT / ZIP:
PHONE:	SOURCE ID NUMBER:
PROCESS EQUIPMENT: Outdoor Wood Boiler	OPERATING MODE: variable
CONTROL EQUIPMENT: NA	OPERATING MODE: NA
DESCRIBE EMISSION POINT:	
HEIGHT ABOVE GROUND LEVEL: ~9'	HEIGHT RELATIVE TO OBSERVER: ~9'
DISTANCE FROM OBSERVER: ~40'	DIRECTION FROM OBSERVER: West
DESCRIBE EMISSIONS:	
EMISSION COLOR: wt / light gray	PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
"STEAM" PLUME PRESENT: NO ☐ YES ☐	IF "STEAM" PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED:	
DESCRIBE BACKGROUND: foliage	
BACKGROUND COLOR:	SKY CONDITIONS: Clear
WIND SPEED: 5-10 mph	WIND DIRECTION: E + SE + NE
AMBIENT TEMP.: ~80	PRECIPITATION/FOG:

SOURCE LAYOUT SKETCH



OBSERVATION DATE: 6/22/05 START TIME: 0935 STOP TIME:

MIN \ SEC	0	15	30	45	MIN \ SEC	0	15	30	45
1	90	~	90	80	31	~	~	60	50
2	80	85	80	85	32	45	~	50	—
3	80	75	80	~	33	40	~	35	~
4	~	~	80	80	34	40	35	40	~
5	75	80	85	75	35	25	20	25	20
6	~	80	80	90	36	20	~	~	~
7	~	80	75	70	37	20	~	20	~
8	75	75	70	75	38	25	20	20	15
9	75	75	80	~	39	15	~	15	10
10	—	75	80	75	40	15	10	10	10
11	80	75	75	~	41	15	10	~	15
12	80	75	~	80	42	15	10	15	~
13	~	75	75	75	43	20	~	20	~
14	70	75	70	80	44	20	25	~	20
15	~	~	75	75	45	25	20	25	25
16	~	~	~	80	46	~	20	25	~
17	80	70	75	80	47	20	25	~	~
18	80	85	75	80	48	20	20	20	15
19	~	~	~	70	49	20	~	~	25
20	75	80	~	75	50	15	25	20	20
21	80	~	75	70	51	20	25	20	15
22	75	—	90	85	52	20	20	—	20
23	80	90	~	80	53	~			
24	90	85	85	75	54	↓			
25	80	85	85	~	55	Checking			
26	70	85	95	90	56	Probe			
27	85	~	~	~	57				
28	80	75	75	—	58				
29	70	75	70	75	59				
30	80	~	~	65	60				

2930 D closed

MINUTES > 20% OPACITY

MINUTES > 40% OPACITY

MINUTES > 60% OPACITY

OFFICIAL INTERVIEWED

TITLE

OBSERVER'S NAME (PRINT): Philip Etter

OBSERVER'S SIGNATURE: Philip Etter DATE: 6/22/05

COMMENTS

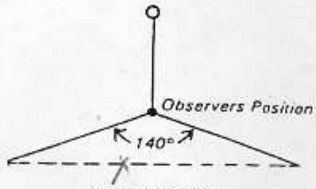
MISSING DATA SYMBOLS: ~ LOOPING/BLOWING PLUME; X INTERFERENCE; — OTHER

VISIBLE EMISSIONS EVALUATION FORM

VERMONT DEPARTMENT OF ENVIRONMENTAL CONSERVATION
AIR POLLUTION CONTROL DIVISION
103 SOUTH MAIN STREET
WATERBURY, VERMONT

SOURCE NAME: OWB Test	
ADDRESS:	
CITY:	STATE: VT / ZIP:
PHONE:	SOURCE ID NUMBER:
PROCESS EQUIPMENT: Outdoor Wood Boiler	OPERATING MODE: Variable
CONTROL EQUIPMENT: NA	OPERATING MODE: —
DESCRIBE EMISSION POINT: Metal Stack	
HEIGHT ABOVE GROUND LEVEL: ~9'	HEIGHT RELATIVE TO OBSERVER: ~9'
DISTANCE FROM OBSERVER: 40'	DIRECTION FROM OBSERVER: West
DESCRIBE EMISSIONS:	
EMISSION COLOR: white/gray	PLUME TYPE: CONTINUOUS ☐ FUGITIVE ☐ INTERMITTENT ☐
"STEAM" PLUME PRESENT: NO ☐ YES ☐	IF "STEAM" PLUME: ATTACHED ☐ DETACHED ☐
POINT IN THE PLUME AT WHICH OPACITY WAS DETERMINED: 3-6 ft. beyond stack (operating mode)	
DESCRIBE BACKGROUND: foliage	
BACKGROUND COLOR: Green	SKY CONDITIONS: clear
WIND SPEED: 10-15 mph	WIND DIRECTION: W highly variable
AMBIENT TEMP.: ~80	PRECIPITATION/FOG: None

SOURCE LAYOUT SKETCH



OBSERVATION DATE: 6/22/05 START TIME: 1037 STOP TIME:

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1	25	25	20	~	31	~	85	85	80	
2	~	25	~	25	32	90	~	~	~	
3	25	20	20	~	33	~	~	85	85	
4	25	20	~	~	34	~	~	~	80	
5	~	30	25	25	35	80	80	~	80	
6	25	~	~	25	36	75	75	75	80	10:43:3
7	25	25	*40	35	37	80	75	75	70	Open D
8	35	30	35	40	38	75	75	75	—	
9	~	~	45	40	39	70	70	75	75	
10	40	45	45	45	40	~	75	75	75	
11	45	50	50	55	41	75	70	75	75	
12	60	65	~	75	42	75	70	70	65	
13	75	80	80	~	43	60	60	~	55	
14	~	75	90	95	44	55	50	55	50	
15	85	90	100	85	45	50	50	*40	50	11:21:30
16	95	~	~	95	46	85	~	40	50	D closed
17	—	95	~	100	47	60	45	45	45	↓ low flow!
18	95	—	100	~	48	50	45	40	35	
19	~	100	90	100	49	30	30	~	30	
20	100	100	90	90	50	25	30	25	30	
21	95	100	95	—	51	25	25	25	20	
22	100	90	90	90	52	20	15	15	15	
23	90	~	~	100	53	15	15	15	15	
24	85	85	90	95	54	~	15	15	20	
25	90	~	~	100	55	15	15	20	~	
26	90	~	90	85	56	15	15	15	15	
27	~	~	85	90	57	15	10	~	10	
28	90	85	100	90	58	10	15	10	15	
29	90	85	90	90	59	15	~	15	10	
30	85	85	85	~	60	10	10	~	10	
MINUTES > 20% OPACITY					61	15	10	15	15	
					62	10	~	15	~	
MINUTES > 40% OPACITY										
MINUTES > 60% OPACITY										

OFFICIAL INTERVIEWED:

TITLE:

OBSERVER'S NAME (PRINT): Philip Etter

OBSERVER'S SIGNATURE: Philip Etter DATE: 6/22/05

COMMENTS:

MISSING DATA SYMBOLS: ~ LOOPING/BLOWING PLUME; X INTERFERENCE; — OTHER

Appendix F: Outdoor Wood-fired Boiler Regulations

AGENCY OF NATURAL RESOURCES
Waterbury, Vermont

ENVIRONMENTAL PROTECTION REGULATIONS

CHAPTER 5

AIR POLLUTION CONTROL

Subchapter II. Prohibitions

5-204 SITING AND STACK HEIGHT STANDARDS FOR OUTDOOR ~~WATERSTOVES~~ WOOD FIRED BOILERS; NOTIFICATION TO PURCHASERS

(a) Applicability.

~~(1)This section shall apply to all *outdoor waterstoves* installed after October 1, 1997 except *outdoor waterstoves* with weighted average *particulate matter emissions* of less than 4.1 grams per hour. Compliance with this standard shall be determined in accordance with federal test method 28 for establishing test conditions and weighted *emission* values and federal test methods 5G or 5H for determining particulate *emission* concentrations (40 CFR Part 60, Appendix A), or other methods approved by the *Air Pollution Control Officer*.~~

This section shall apply to each outdoor wood-fired boiler installed after October 1, 1997, except those outdoor wood-fired boilers that are subject to and compliant with Section 5-205 herein.

(b) Definitions. For the purpose of this section and Section 5-205 herein, the following definitions apply, in addition to those of Section 5-101 of this chapter.

~~*"Outdoor Waterstove"* means any individual hand-fed furnace designed to burn wood and used for the purpose of heating water where the furnace is located outside the structure into which the hot water produced thereby is piped.~~

"Outdoor Wood-Fired Boiler" means a fuel burning device designed: (1) to burn primarily wood by hand-firing; (2) not to be located inside structures ordinarily occupied by humans; and, (3) to heat spaces or water by the distribution through pipes of a fluid heated in the device, typically water. Examples of common uses of outdoor wood-fired boilers include: residential or commercial space heating, heating of domestic hot water, and heating of water for swimming pools, hot tubs or whirlpool baths.

(c) Prohibition.

No *person* shall install or allow the installation of an *outdoor* ~~*waterstove*~~ *wood-fired boiler* subject to the requirements of this section unless the *outdoor* ~~*waterstove*~~ wood-fired boiler:

(1) Is located more than 200 feet from any residence other than a residence served by the *outdoor* ~~*waterstove*~~ *wood-fired boiler* or owned by the owner or lessee of the *outdoor* ~~*waterstove*~~ *wood-fired boiler*;

(2) Has an attached permanent *stack* extending higher than the ~~roof line~~ peak of the roof of the structure(s) being served by the *outdoor* ~~*waterstove*~~ *wood-fired boiler,* if any residence is located more than 200 but less than 500 feet from the *outdoor* ~~*waterstove*~~ *wood-fired boiler* other than a residence owned by the owner or lessee of such *outdoor* ~~*waterstove*~~ *wood-fired boiler*; and,

(3) Complies with all applicable laws, including but not limited to local ordinances, but excluding Section 5-205 of this chapter, and its operation does not create a public nuisance.

(d) Notice to Buyers.

(1) No *outdoor* ~~*waterstove*~~ *wood-fired boiler* subject to the requirements of this section shall be sold or offered for retail sale or lease within the State unless prior to any sales or lease agreement, the seller or dealer provides the prospective buyer or lessee with written notice stating that:

(i) Only untreated *natural wood* may be burned in an *outdoor* ~~*waterstove*~~ *wood-fired boiler*;

(ii) Installation of the *outdoor* ~~*waterstove*~~ *wood-fired boiler* is subject to the distance and *stack* height requirements provided in this section. [Each notice shall expressly disclose each such requirement];

(iii) Use of an *outdoor* ~~*waterstove*~~ *wood-fired boiler* that meets the distance and *stack* height requirements provided in this section is not appropriate in some areas due to terrain that could render the operation of an *outdoor* ~~*waterstove*~~ *wood-fired boiler* to be a nuisance or a public health hazard.

(2) The written notice specified above shall be signed by the prospective buyer or lessee to indicate receipt of notification of the requirements of this section. Prior to making delivery of an *outdoor* ~~*waterstove*~~ *wood-fired boiler* into the possession of any buyer or lessee, the seller or dealer shall mail or otherwise provide a copy of the signed notice specified above to the:

Air Pollution Control Division
103 South Main Street
Building 3 South
Waterbury, Vermont 05671-0402.

Said notice shall contain the name, address and telephone number of both the seller or dealer and the buyer or lessee, the location where the *outdoor* ~~*waterstove*~~ *wood-fired boiler* will be installed and the make and model of the *outdoor* ~~*waterstove*~~ *wood-fired boiler*.

5-205 CONTROL OF PARTICULATE MATTER FROM NEW OUTDOOR WOOD-FIRED BOILERS

(a) Applicability

This section shall apply to any outdoor wood-fired boiler that is distributed or sold in Vermont or for installation in Vermont on or after January 1, 2006, except that this section does not apply to any outdoor wood-fired boiler that: (1) is or has been owned by an individual for his or her own personal use and is distributed or sold to another for his or her own personal use; or (2) was purchased and received by any person other than the manufacturer before January 1, 2006.

(b) Definitions. For the purposes of this section, the following definitions apply, in addition to those of Sections 5-101 and 5-204 of this chapter.

"*Distribute or Sell*" means to distribute, sell, advertise for sale, offer for sale, hold for sale, ship, deliver for shipment, release for shipment, or receive and (having so received) deliver or offer to deliver. This term also includes conditional sales and long-term leases. This term does not include the distribution or sale by a manufacturer of an outdoor wood-fired boiler that is installed outside Vermont.

"*Manufacturer*" means any person who constructs or imports an outdoor wood-fired boiler.

"*Model line*" means all outdoor wood-fired boilers offered for distribution or sale by a single manufacturer that, in the judgment of the Air Pollution Control Officer, are similar in all material respects.

(c) Standard for Particulate Matter; Certification

(1) No person shall distribute or sell an outdoor wood-fired boiler in Vermont or for installation in Vermont unless the Air Pollution Control Officer has issued a certification to the manufacturer that the boiler, or the boiler model line to which it belongs, complies with the following particulate matter emission limit: An outdoor wood-fired boiler shall not emit, or cause or allow to be emitted, any gases that contain particulate matter in excess of 0.20 grains per dry standard cubic foot of exhaust gas corrected to 12% CO_2, as determined in accordance with the test methods and procedures in subsection (d) of this section.

(2) Unless revoked sooner by the Air Pollution Control Officer, a certification issued under this subsection shall be valid for five years from the date of issuance.

(3) The distribution or sale of each outdoor wood-fired boiler subject to this section that has not been certified by the Air Pollution Control Officer as meeting the particulate matter emission limit in this subsection shall constitute a separate violation and be subject to civil or criminal penalties as provided in 10 V.S.A. Chapters 201 and 211, or 10 V.S.A. §568.

(d) Emission Test Methods and Procedures

(1) In order to obtain certification of an outdoor wood-fired boiler under subsection (c) of this section, the manufacturer of any such boiler shall have emission test(s) conducted to determine compliance with the particulate matter emission limit under subsection (c) of this section and furnish the Air Pollution Control Officer a written report of the results of such tests, including a detailed description of the operating conditions of the boiler during the tests. Said written report shall contain such documentation and other information and follow such format as may be specified by the Air Pollution Control Officer. In the discretion of the Air Pollution Control Officer, a manufacturer of an outdoor wood-fired boiler subject to this section may have emission testing conducted of a representative boiler within a model line of outdoor wood-fired boilers and may use those tests to demonstrate compliance of all units manufactured in that model line.

(2) All emission testing required under this section shall be conducted by independent testing consultants who have no conflict of interest and receive no financial benefit from the outcome of the testing. Manufacturers of outdoor wood-fired boilers shall not involve themselves in the conduct of any emission testing under this section nor in the operation of the unit being tested, once actual sampling has begun.

(3) Emission tests shall be conducted and data reduced in accordance with 40 CFR Part 60, Appendix A, Test Methods 1 through 5, and 40 CFR Part 51, Appendix M, Test Method 202, or alternative methods approved by the Air Pollution Control Officer. All tests shall be conducted in accordance with Vermont's "Source Emission Testing Guidelines" (January 2002 revision, as amended) and under a test protocol which has received the prior approval of the Air Pollution Control Officer. Emission tests shall be conducted under such conditions as the Air Pollution Control Officer shall specify, based on representative performance of the outdoor wood-fired boiler under actual field operating conditions.

(4) The manufacturer of the outdoor wood-fired boiler shall provide the Air Pollution Control Officer with at least 30 days prior notice of any emission test to afford the Air Pollution Control Officer the opportunity to have an observer present. The manufacturer of an outdoor wood-fired boiler(s) being tested as required by this section shall reimburse the state of Vermont for the reasonable expenses incurred by any such Agency observer for out-of-state travel to observe such testing, including among other items the costs of transportation, lodging and meals.

(e) Notification by Manufacturers

(1) By March 1st of each year and as necessary when an outdoor wood-fired boiler is certified, each outdoor wood-fired boiler manufacturer shall provide the following information in writing to any person to whom the manufacturer has distributed or sold, intends to distribute or sell, or actually distributes or sells

outdoor wood-fired boilers in Vermont or for installation in Vermont:

(i) A list of all the models of outdoor wood-fired boilers it manufactures; and

(ii) An identification of which, if any, of said models or boilers has received a certification of compliance under subsection (c) of this section and thus may be distributed or sold in Vermont or for installation in Vermont.

(2) By March 15th of each year, a copy of all written information provided to comply with paragraph (1) of this subsection and a list of persons to whom it was provided shall be submitted to the Air Pollution Control Officer.