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Project Summary

Survey and Analysis of Current European Technologies for Wood Combustion

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This report summarizes current European technologies and air pollution policies pertaining to wood combustion. Twenty concepts for wood burning equipment are described. Also included are section diagrams, size ranges, and comments regarding efficiency and convenience. Many of the system types are not currently available on the U.S. market. A list of manufacturers and their addresses is included. The report also contains emission data for many of the systems described. European emission regulations and test procedures are presented. Finally, a brief overview of health research related to suspected carcinogenic materials in wood combustion emissions is presented. This information was gathered both in the U.S. and in Europe by engineers familiar with wood combustion on both continents. The work was funded by EPA's Industrial Environmental Research Laboratory to supplement their other activities relating to air pollution from wood combustion.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Unlike in the U.S., use of wood as a fuel has not dramatically increased in recent years in Europe. Rather, it has always been an important fuel for certain applications. This long history combined with the relative scarcity of wood has resulted in a wide variety of efficient wood burning equipment on the European market. Some of the systems are not presently available in the U.S.

This report examines 20 wood firing systems. Their operation is described and displayed graphically. Typical manufacturers are listed and comments are made regarding their efficiency, ease of operation, and applications. Pollutant emission data are presented for all system types. Finally, specific regulations and supporting health research are discussed briefly.

Trends in European fuel wood use for the most part are a continuation of previous applications. Only in Sweden is there strong encouragement for increased wood combustion. This is manifest in the recent construction of several wood-fired district heating plants in Sweden. Elsewhere wood continues to be an important fuel in rural areas where it is often burned with coal. Wood related industries (such as cabinet shops, furniture, and pulp and paper) are the prime consumers of waste wood. They, too, often supplement the wood with coal. Another interesting trend is found in urban/suburban areas where multi-fuel boilers have become popular. The unique aspect of this is that wood is seen as an auxiliary, emergency fuel to back up oil or gas.

In the residential and small commercial market, down- and cross-draft units have displaced up-drafters. Thermal storage in masonry or water has also become relatively common. Industrial wood combus-

tion equipment appears to be moving toward cyclone burners and fluidized-bed combustors. Several companies have gasifiers in the pilot stage. The main emphasis appears to be to use the gas to fire internal combustion engines, often to generate electricity.

Emission regulations tend to be simple and not particularly stringent. Great emphasis is placed on enforcement. Probably the most remarkable aspect of the pollution control strategies is the requirement of regular inspection and maintenance by licensed chimney sweeps and other technicians. This policy has resulted not only in decreased emissions, but also in improved efficiency and safety. Boilers must be inspected and tested annually. Those failing must undergo the required adjustments to be certified. Through the inspection/maintenance program the user gains an understanding of the equipment and its proper operation. This may be as valuable as the adjustments.

As in the U.S., equipment manufacturers strenuously oppose emission standards. Their main contention is that to meet any standard the equipment must be designed for a very specific type of fuel when in fact the consumer demands versatility. In Switzerland and West Germany, multi-fuel boilers have outsold single-fuel gas or oil boilers for the past 5 years. This flexibility in fuel types usually results in a decrease in overall efficiency.

Since wood is relatively scarce, European officials do not appear particularly concerned about emissions from wood combustion. With the exception of Sweden, research on health effects of Polycyclic Organic Matter (POM) and Polycyclic Aromatic Hydrocarbons (PAH) has been aimed at auto and industrial emissions and occupational exposure rather than at wood combustion. Sweden has done some research specifically on PAH emissions from wood heaters. Unfortunately, the results were inconclusive.

Air Pollution Considerations

Most standards applicable to wood combustion derive from early European concern about particulate emissions from coal combustion. Since many types of coals were used, categorization was necessary to accommodate their different emission characteristics. Percent volatile matter became an accepted distinguishing feature. Wood then was included with other high volatile fuel such as brown coal briquets. Since smoke output is generally proportional to volatile matter content, wood and other high volatile fuels became known as "smokey fuels." Eventually regulations and equipment design reflected this distinction between "smokey" and "smokeless" fuels.

The authors reported that down-drafters produced significantly less pollution than up-drafters. This early knowledge was the basis for German regulations for small stoves, and resulted in the universal application of the "slow combustion" or Dauerbrenner stove.

Since emissions from wood combustion have not been of great national concern in any of the European countries, regulations relating to wood are a part of those pertaining to particulate emissions from coal. As in the U.S., in recent years there has been increasing concern about emissions from residential appliances. Visibility problems have been documented in alpine valleys which are subject to frequent inversions. To date, however, these problems have not resulted in any regulatory action. There has also been increasing concern about the effects of PAH emissions from wood combustion as reflected by recent conferences and health research.

In Germany combustion emissions are regulated by the Federal Air and Noise Protection Law of 1974. Switzerland is still awaiting passage of its federal environmental protection law so emissions are controlled by guidelines established by insurance companies and professional organizations (e.g., engineering societies). Some local governments have passed ordinances but enforcement is possible only through nuisance complaints.

In Sweden only large equipment (>900 MJ/h) is regulated by the federal Environmental Protection Act. The National Environmental Protection Board can, however, recommend standards or regulations for any pollution source.

Reported Emissions

Most of the emission data found in Europe are produced by government agencies who are responsible for testing and certifying equipment. Most of this is done using VDI (Association of German Engineers) standards. References may be found in Appendix E of the full report. Manufacturers are required to test their own equipment and verify that it meets the regulations.

Table 1 summarizes available emission data.

Residential and Commercial

Two fireplaces were tested by Rudling and Ahling (1). Braskamin I was a fireplace without a warm air heat exchanger, but with a glass door and outdoor combustion air. Braskamin II had a built-in warm air heat exchanger. Pollutant concentrations in the stack gases of the two fireplaces were very similar. The higher thermal efficiency of the Braskamin II, however, resulted in lower emission rates per unit of heat output (mg/MJ out). Emission rates from Braskamin II were about half those from I. Note that in both cases the reported efficiency was much higher than commonly reported in the U.S. literature.

All of the residential boilers described in the full report had to meet the West German TSP standard. Capacities and efficiencies were based on information from the manufacturers; therefore, no specific data was available. All that is known is that the standard was met.

A detailed emission analysis of two types of residential boilers was also performed by Rudling. Emissions from a prechamber boiler were compared with those from a standard-grate-fired boiler. Both of them were fired with wood chips, controlling for firing rate, moisture content, and excess air. Tables 2 and 3 contain the significant data from that study.

In the standard-grate residential boiler the only factor influencing TSP and POM was the excess air level. The highest CO value was accompanied by extremely high PAH values. The moisture content of the wood and the firing rate appeared to have little influence on the pollutant concentrations.

The prechamber system was composed of the standard-grate-fired boiler used in the first system, but with a gravity fed prechamber. It was difficult to draw conclusions from the data presented in Table 2, since too many variables changed from one test to the next. Again, the excess air level, as indicated by the CO_2 concentration, seemed to be the most important variable associated with the changes in TSP and PAH concentrations. In Test 4 the excess air seemed to be too high to maintain adequate combustion temperatures at the given firing rate. Rudling concluded that increased firing rates would produce higher TSP and POM emissions and that higher moisture content would result in higher PAH emissions.

Table 1. *Summary of Emission Data of Wood-Fired Equipment in Europe (for manufacturers, see Appendix D of full report)*

Equipment Type	Output Capacity MJ/h	Efficiency %	Manufacturers	Average Emissions (μg/J) TSP	POMs	Others μg/J	Remarks
Residential							
Fireplaces							
Braskamin I	21.5	40-45		5.7-170	0.3-17	CO:0.6-7.3	(5)
Braskamin II	43.0	70-80		16-78	0.3-7	CO:1.1-0.8	(5)
Tile Stoves	2.5-6.3	75-85					Capacity in MJ/m^2h(6)
Boilers							
Multifuel (1 Firebox)	61-600	65-85	1,2	≤79*			lower efficiency for oil
Multifuel (2 Fireboxes)	61-600	70-85	1,2	≤79*			
Solid Fuel	60-1420	70-85	1,2	≤79*			
Solid Fuel w/DHW tank	60-146	50-85	1	≤79*			lower efficiency summer
Pre-Chamber (for Logs)	125-2000	70-85	3	≤79*			
Pre-Chamber (for Chips)	125	80-85	14	45-1600	0.004-8.3	CO:0.06-5	(5)
Commercial							
Boilers							
Handfired/Susp. Comb.	$277\text{-}2\cdot10^3$	70-80	4,5,6	≤156*			
Pre-Chamber, Handfired	$250\text{-}3\cdot10^3$	75-85	15	≤ 79*			
Moving Grate (Chips)	$1.4\text{-}6\cdot10^3$	75-85	6	≤156*			
Industrial							
Boilers							
Retort, Stoker	$3\text{-}5\cdot10^3$	75-84	7,8	194			w/multi-cyclones (4)
Cyclone Burner	$1\text{-}50\cdot10^3$	84-88	9,10	26-77	0.001		w/elec. precip. (7)
Fluidized Bed	$1\text{-}50\cdot10^3$		16	2.0			w/baghouse (10)
Inclined Moving Grate	$16\cdot10^3$		6,11	28			fired w/wet bark (8)
Handfired/Susp. Comb.			6	77-155			(4)
Dutch Oven Type	$2.6\text{-}16.2\cdot10^3$		6	103-252			(4)
Gasifiers	$3\cdot10^3$		11,12,13			CO:1.26 Ald.:0.76	pollutants measured in exhaust gas of IC-engine (9)

*Standard of West Germany.

It was difficult to compare emissions from the two systems since moisture content and firing rates were not well controlled. At design capacity (7 kg/h) TSP concentrations in the prechamber system were reported to be lower by a factor of 1.5 to 5. PAH concentrations were also reported to be much lower in the prechamber configuration.

Industrial

There is a wide variety of industrial combustion equipment. Retort under-fed stokers are very common in the lower capacity ranges. They reach efficiencies up to 85% and can handle dry and green chips. TSP emission is not excellent because the forced combustion air carries all the ash through the boiler. Manufacturers claim, however, that the particulate matter passing through the multi-cyclone is exclusively light fly ash.

Tests of a Swedish cyclone burner revealed very low TSP and POM emissions (4). The burner is part of a district heating system in southern Sweden (Vaxjo) and burns a mixture of wet bark and green chips. The cyclone burner exhausts to a normal oil-fired boiler. The system is equipped with an electrostatic precipitator.

A fluidized-bed plant has been tested in Eksjo, Sweden (5). The plant is equipped with a baghouse and fires wet bark and green chips and, for a few hours every day, municipal solid waste. This multi-fuel approach with fluidized-bed combustors has created great interest in Sweden. The Swedish National Board of Environmental Protection conducted an emission test on that particular unit and found average TSP concentrations as low as 5 mg/m^3, or approximately 2 mg/MJ.

Inclined moving grate boilers are often found in pulp and paper mills where wet bark and even waste water treatment plant sludge is burned. One particular

Table 2. Emissions from a Standard-Grate-Fired Wood Chip Boiler

Parameter	Units	Test 1	Test 2	Test 3
Firing Rate	kg/h	7.0	7.0	13.0
Moisture Content of Wood	%	14	14	36
Stack Gas Temperature	°C	200	200	190
CO_2	%	8.0	5.7	5.0
CO	ppm	8,000	6,000	6,500
H_xC_y	ppm	NA	NA	NA
TSP	mg/m^3 (at 10% CO_2)	360	120	260
PAH	$\mu g/m^3$ (at 10% CO_2)	16,000	25,000	2,800

Table 3. Emissions from a Prechamber Wood Chip Boiler

Parameter	Units	Test 1	Test 2	Test 3	Test 4
Firing Rate	kg/h	4.2	7.0	7.0	7.0
Moisture Content of Wood	%	21	48	48	48
Stack Gas Temperature	°C	150	190	190	180
CO_2	%	6.5	6.7	7.0	4.0
CO	ppm	60	700	2,100	2,500
H_xC_y	ppm	30	50	110	400
TSP	mg/m^3 (at 10% CO_2)	72	72	80	2,300
PAH	$\mu g/m^3$ (at 10% CO_2)	<6.8	42	220	2,300

boiler of this type has been tested for particulate matter (6). Average TSP emission was found to be only 28 mg/MJ using simple mechanical filters.

The Swiss Federal Materials Testing and Research Institute (3) has done an emission field survey among typical wood fired industrial boilers in Switzerland. Dutch-oven, suspension burner, and stoker retort boilers were the most prevalent. The investigators suggested that a nationwide TSP emission standard of about 85 mg/MJ could be justified since more than half of the tested installations met such emission levels. In some cases 85 mg/MJ can be reached using only a settling chamber.

Combustion Technologies

The combustion equipment presented here is divided into three categories: Residential Space Heating, Commercial Applications, and Industrial Applications. The equipment described represents a good cross-section of the technologies available on the European market. For each piece of equipment, a brief explanation of its specific use and a description of the equipment is followed by a list of its special features and their influence on efficiency, emissions, and convenience.

Residential Equipment

Unlike in the U.S., free-standing metal wood stoves are not extremely popular. Instead, wood is usually burned in one of four types of appliances: a masonry/tile stove, a combination cookstove and boiler, a multi-fuel boiler, and, in some cases, fairly efficient fireplaces.

Since most of the forests are owned by local government, wood is normally gathered and prepared by the user rather than by commercial wood dealers. Towns issue permits to cut trees which have been marked by the town forester. This results in professionally managed forests which produce far greater yields than most privately owned forests in the U.S. In Switzerland, a law requires planting new trees on a one-for-one basis even on private land. A permit is required to clear cut anywhere. This concern for preservation is also manifest in the wood burning equipment commonly found in Europe.

Commercial Equipment

Wood working shops have created a demand for wood residue burners. These are used to burn sanderdust, sawdust, shavings, and all sizes of scrap wood. Space heating, wood dryers, and hot water needs are the most common end uses. The great variation of fuel size created in these shops has resulted in rather complex combustion equipment design. Shavings, sawdust, and sanderdust are burned in suspension, whereas larger pieces of wood are fed manually and burned on a grate.

Industrial Equipment

The larger combustion installations are located either in industrial or utility plants, including district heating plants. Wood fired boilers are most often found in the pulp and paper and in the wood working industry. A more recent application of wood fueled boilers is in district heating or public cogeneration plants, where wood waste is available.

There are only a few major manufacturers of industrial-size wood-fired boilers in Germany, Switzerland, and Scandinavia. There, specialization in wood and/or other solid fuel fired equipment has brought them international recognition.

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The complete report, entitled "Survey and Analysis of Current European Technologies for Wood Combustion," (Order No. PB 83-156 729; Cost: $11.50, subject to change) will be available only from:
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