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Project Summary

Proceedings: Conference on Wood Combustion Environmental Assessment (New Orleans, February 1981)

Franklin A. Ayer, Compiler

These proceedings are for the "Wood Combustion Environmental Assessment Conference," which was held February 21-24, 1981, in New Orleans. The objective of the conference was the dissemination of recent research and development findings on the subject of residential wood combustion. The five sessions of the conference dealt with: (1) an overview of environmental assessment activities, (2) specific emissions and heating efficiency assessments, (3) emissions control techniques, (4) highlights of the first three sessions, and (5) residential wood combustion issues and their resolution.

In summary, the previously reported high concentrations of polycyclic organic matter (POMs) in residential wood stove emissions were verified in several papers. One paper even reported high POM concentrations in the indoor environment in homes with operating wood combustors. High ambient values were not attributed to residential wood combustion but many of the ambient impact studies were just beginning. Emissions control techniques which were considered for controlling organic emissions included secondary combustion and the introduction of a combustion catalyst. These two control techniques were already being marketed; however, their reliability and structural stability were questioned by several researchers. Future regulation of wood stove emissions was considered unlikely due to problems of enforcing a residential emission standard.

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).

This report is a summary of the proceedings of the EPA Conference on Wood Combustion Environmental Assessment, held on February 21-24, 1981, in New Orleans. This conference was held in cooperation with and at the same time as the Wood Heating Alliance International Trade Show and Wood Heating Seminar The conference brought together representatives of industry, associations, stove and fireplace manufacturers and suppliers, government, researchers, scientists, academia and journal writers, with the purpose of disseminating new information on wood combustion

The conference was opened by Carter Keithley of the Wood Heating Alliance, who welcomed the participants and introduced Michael C Osborne, General Chairman, USEPA, IERL-RTP. Osborne also welcomed the participants and thanked the Wood Heating

Alliance for including the conference on the agenda of their International Trade Show In addition, he informed them that the objective of the conference was to focus their attention on the recent development of new information on wood combustion An overview of wood combustion and assessment, assessments of residential wood heating efficiency and emissions, emissions control techniques for wood burning appliances, environmental assessment and control—highlights from earlier sessions, and a panel discussion on issues related to the residential combustion of wood and how they may be resolved, were covered

The chairman of Session 1, Overview of Wood Combustion Environmental Assessment, Henry Anderson, U.S. Department of Energy, Washington, DC, presented a paper entitled Residential Wood Program Overview. In addition, he presented a paper prepared by Charles Bendersky, Pyros, Inc., entitled Results of the DOE Think Shop on Residential Wood Combustion Other speakers and their topics were. Overview of Emissions from Wood Combustion by Kenneth J Lim, Acurex, Ambient Air Assessment in a Rural New England Village Where Wood is the Dominant Fuel by James F Hornig, Dartmouth College, and An Integrated Environmental Assessment of Biomass Energy Development in the Tennessee Valley by Paul Schwengels, EPA/ORD

The chairman of Session 2, Assessments of Residential Wood Heating Efficiency and Emissions, Jerome P Harper, Tennessee Valley Authority at Chattanooga, TN, presented a paper entitled Residential Wood Heating Efficiency and Emissions—An Overview. Other speakers and their topics were Wood Combustion Emissions at Elevated Altitudes by Thomas W Hughes, Monsanto Research Corporation, The Effects of Woodburning on the Indoor Residential Air Quality by Joseph Zabransky, Jr., Geomet Technologies, Inc.; Performance of Domestic Wood-Fired Appliances by A. C. S. Hayden, Canadian Research Laboratories; An Assessment of the Efficiency and Emissions of Ten Wood Fired Furnaces by Robert J Brandon, Institute of Man and Resources, and Results of Laboratory Tests on Wood Stove Emissions by Bill R. Hubble, Argonne National Laboratory.

Papers presented under Session 3, Emissions Control Techniques for Wood Burning Appliances, chaired by Wade H. Ponder, USEPA, IERL-RTP, were Catalytic Combustion in Residential Wood Stoves by Robert V VanDewoestine, Corning Glass Works; Results of Research on Catalytic Combustion in Wood Stoves by Jay W. Shelton, Shelton Energy Research; Measurements of Chemical Changes Due to Catalysts of Woodstove Effluent by Dennis R. Jaasma, VPI; The Effects of Woodstove Design on Condensable Particulate Emissions, In-Home Delivery Efficiency and Creosote Formation Rate by Stockton G. Barnett, State University of New York at Plattsburgh, and Control of Emissions from Residential Wood Burning by Combustion Modification by John M. Allen, Battelle-Columbus Laboratories

Session 4, Environmental Assessment and Control—Highlights of Earlier Sessions, was chaired by Robert E. Hall, USEPA, IERL-RTP Session 1 Highlights were presented by Henry Anderson, DOE, Washington, DC; Session 2 Highlights by Jerome P Harper, TVA; and Session 3 Highlights by Wade H. Ponder, USEPA, IERL-RTP.

The Panel—Issues Related to the Residential Combustion of Wood and How They May be Resolved—was chaired by Michael C. Osborne, USEPA, IERL-RTP. Panel presentations and speakers were Combustion of Wood/Environmental Restrictions in Sweden by Jan Nilsson, The National Swedish Environment Protection Board; Institutional and Regulatory Approaches to Control Residential Wood Burning Emissions by William T Greene, Oregon Department of Environmental Quality; Residential Wood Combustion Issues for the Tennessee Valley by Charles E. Bohac, TVA; Wood Energy—The North Carolina Effort by Phyllis Brooks Wainwright, N.C. Department of Natural Resources and Community Development; Preliminary Analysis of the Ambient Impacts of Residential Woodburning in Waterbury, Vermont, by Cedric R. Sanborn, Vermont Department of Water Resources and Environmental Engineering; and Pollution and Fire Places in California by Peter H. Kosel, California Air Resources Board.

The forum was highlighted by the frank exchange of information between participants of varied backgrounds, interests, and associations. The interchange initiated the communication between stove and fireplace manufacturers, wholesalers, retailers, academia, researchers, and government agencies. In addition, the cooperation and support provided by the Wood Heating Alliance was excellent.

Abstracts of the speakers' remarks follow:

Henry Anderson,
Space Heating Appliances, DOE, Washington

The DOE Office of Buildings and Community Systems, Technology and Consumers Products Branch, convened a "Think Shop" to address the technology needs in the area of residential wood combustion emissions The meeting was held at Battelle-Columbus Laboratories on March 27-28, 1980, and was attended by a group of program managers from DOE, EPA, TVA, and the Canadian Government, and a group of the leading researchers active in the field The results were recommendations of needed activities to be undertaken in the areas of air quality, combustion technology, equipment development, and emissions measurements. It was recommended that to be effective, these activities must be initiated immediately and be completed in FY 85. The needs of the program require the cooperation of the management and scientific expertise of the DOE, EPA, and TVA, the pooling of available financial resources, and the participation of a number of qualified research organizations. The report provides statements of needs, definitions of specific tasks, and estimates of the resources and manpower for accomplishment. This report was prepared by Pyros, Inc., as a source document for DOE study and for use in program development and does not reflect firm actions planned for or by DOE or other federal organizations.

Kenneth J. Lim,
Acurex Corporation

An assessment is made of emissions and their control from wood-fired boilers, home stoves, and fireplaces. The major pollutants are particulates, organics, and CO; NO_x are also emitted. The important parameters affecting emissions are furnace design, excess air level, and burning rate. For boilers, optimal emission control and efficiency are achieved with 50 to 200% excess air, with overfire air maximized for stokers Data on other techniques and operational impacts are minimal. On a normalized basis, residential woodburning units tend to produce higher emissions than do boilers. Data on wood-fired stoves indicate that certain

designs (e.g., crossdraft) emit less particulate matter The limited data suggest that low burning rates are conducive to POM formation, a pollutant of major concern. As the combustion conditions for fireplaces are even more difficult to quantify and control, emission trends for those devices are even less established However, POM emissions appear to be less from fireplaces than from stoves.

James F. Hornig,
Dartmouth College

During the 1979-80 heating season, 50 standard hi-vol filter samples of ambient air were taken in a small town and in semi-rural areas in New Hampshire where wood is the dominant heating fuel In addition to total suspended particulate (TSP) values, concentrations of 15 polycyclic organic materials (POM), 12 of which are priority pollutants, were determined using HPLC with UV and fluorescence detection, and by GC/MS techniques. Concentrations of benz(a)pyrene were found to be in the range 0.5-0 8 ng/m^3 The measurements are compared to recently published POM values from diverse sources. This comparison includes discussion of troublesome methodological problems which potentially compromise ambient air POM analyses.

Paul F. Schwengels,
Office of Research and Development, EPA-Washington

In recent years, rising prices and availability problems associated with other fuels have generated a great deal of interest in biomass (particularly wood) as an energy source At the same time, concerns have been raised about the possibility of negative effects on the environment and on public health and safety which might result from extensive use of this energy source. This paper describes a study currently in progress which attempts to pull together the available information on the potential for biomass utilization in the Tennessee Valley Authority (TVA) region and the possible environmental and health hazards associated with this development The study also evaluates a range of public policy options which might be implemented at various levels of government to promote environmentally sound development of biomass energy resources. The paper describes the study approach used and presents preliminary findings. Expected results at the completion of the study are also identified

Thomas W. Hughes,
Monsanto Research Corporation

Combustion of wood in fireplaces and in wood-burning stoves is growing in popularity as the cost for other fuels increases. The growing use of wood combustion for aesthetic and primary and secondary home heating has attracted widespread environmental concern due to the significantly increased particulate, CO, and polycyclic organic material (POM) emissions over other residential fuel types. A recent study conducted for the EPA indicated that residential wood combustion is the largest stationary source of POM emissions. Recently, high levels of particulates and POMs have been found in the mountainous resort areas. Local EPA officials were concerned that wood stoves operated at high elevations had significantly higher pollutant emissions than stoves operated at low elevations. The EPA conducted a study quantifying high elevation emissions, this paper presents the results of the study

Joseph Zabransky, Jr.,
Geomet Technologies, Inc.

Data from suburban residences in the Boston metropolitan area reveal a potential adverse impact on indoor air quality from woodburning in woodstoves and fireplaces. Ambient pollutant concentrations at each residence were compared to corresponding pollutant levels indoors at three locations (kitchen, bedroom, and activity room). Individual gaseous pollutant samples were averaged hourly while 24-hour integrated samples of particulate matter were obtained Ten gaseous pollutants were sampled along with total suspended particulates (TSP) Chemical analyses further determined 10 components of TSP including trace metals, benzo-a-pyrene (BaP), respirable suspended particulates (RSP), and water soluble sulfates and nitrates. Monitoring lasted two weeks at each residence and was conducted under occupied real-life conditions.

Observed, elevated indoor concentrations of TSP, RSP, and BaP are attributed to woodburning. Data indicate that average indoor TSP concentrations during woodburning periods were about three times corresponding levels during nonwoodburning periods The primary 24-hour national ambient air quality standard (NAAQS) for TSP was exceeded once indoors during fireplace use, and the secondary, 24-hour TSP NAAQS was also exceeded indoors by RSP concentrations. Indoor BaP concentrations during woodstove use averaged five times more than during nonwoodburning periods At this stage, results are only indicative, but the potential impact from elevated indoor concentrations of TSP, RSP, and BaP, attributed to woodburning, may have long-term health implications.

A. C. S. Hayden,
Conservation and Renewable Energy, The Canadian Combustion Research Laboratory

The Canadian Combustion Research Laboratory has developed an indirect or stack loss method to measure the performance of domestic wood-fired space heaters, giving detailed information on operating characteristics and emissions Flue gas composition, including CO_2, CO, O_2, HC, and NO_x, as well as temperatures and wood-burning rate, are monitored continuously over the burning cycle on a data logging system and stored on magnetic tape for computer retrieval and analysis. This allows an accurate reconstruction of the burning cycle and complete detail on appliance performance over that cycle.

Results of experiments on a series of appliance types are presented These show that a fireplace or non-airtight space heater is extremely inefficient in utilizing the potential energy in the wood, while a well-designed and well-constructed controlled combustion unit can have efficiencies comparable to a fossil-fuel-fired appliance

Robert J. Brandon,
Wood and Solar Energy Programs, Institute of Man and Resources

Significant use of wood for residential space heating will require development of improved combustion systems that approach the operational attractiveness of oil- or gas-fired equipment. Seven innovative wood-fired residential central heating systems, together with three conventional wood furnaces, were installed and operated in single-family homes over the 1979-80 heating season in a demonstration funded by the Canada-P.E I Agreement on Renewable Energy Development. Four

of the systems use chip wood fuel; one uses pellet wood fuel; and two involve water thermal storage During the heating season, thermal performance evaluation and emission testing were carried out on all 10 units

A high volume sampling technique was used to collect flue gas at the chimney exit enabling particulates and condensable organics to be trapped in a glass fibre filter. Average emission factors ranged from a low of 0.72 g/kg for the wood pellet stoker to a high of 38 6 g/kg for a wood chip stoker. Sampling for CO, NO_x, and SO_x was also carried out. A creosote probe was used to determine the tendency of each unit to form creosote in the chimney. At the end of the heating season an examination was made of the type and amount of flue deposits produced by each unit.

Thermal efficiencies of the systems were tested for comparison using an input/output method. The wood-fired units showed a high standby heat loss which is difficult to apportion correctly to either a direct loss or an indirect house heating gain.

Bill R. Hubble,
Argonne National Laboratory

This report discusses results from the Argonne environmental testing program for airtight wood-burning stoves. These experiments were performed with stove configurations and in a manner consistent with typical residential operation of wood stoves Emission data are reported for particulate and CO in the stove stack gas as functions of stove operating variables and calculated estimates of stove efficiency. These data are also comparable with creosote production rates obtained during these experiments and are reported as preliminary estimates of stove emission factors.

Robert V. VanDewoestine,
Special Process Research,
Corning Glass Works

Laboratory tests with a modified wood stove showed that condensable emissions could be reduced 79-95% by using a monolithic honeycomb catalytic converter to initiate secondary combustion. The experiments defined the cell size and combustor volume necessary for various levels of effectiveness. Field tests have confirmed the laboratory data and have indicated the stove changes necessary for practical operation.

Jay W. Shelton
Shelton Energy Research

Two aspects of catalytic combustion in wood stoves have thus far been investigated in our ongoing research· potential safety issues and the thermal performance of a catalytic stove.

Safety issues investigated include the very high temperatures that can be achieved and the possibility of plugging (with creosote, ash, and soot) Although significant, neither problem appears to be insurmountable.

A nonproduction stove was tested with and without its catalyst to determine the effectiveness of the catalyst. The measurements were performed in a calorimeter room and included direct measurement of the flue gas velocity The determined perimeters included the three energy efficiencies—overall, combustion, and heat transfer. The results were not available when this abstract was written.

Dennis R. Jaasma,
Virginia Polytechnic Institute and State University

Pollutant emissions from wood stoves are responsible for chimney fires and may also have a serious effect on human health. Since wood stove stack emissions contain negligible amounts of SO_x, NO_x, and ash, all of the pollutants of concern are combustibles and can be eliminated by oxidation to CO_2 and Hg_2. Use of a catalyst to encourage the oxidation process is an attractive idea from both energy conservation and air pollution standpoints. Potential problems with use of a catalyst to reduce emissions to acceptable levels include fouling before operating temperature is reached, production of secondary products such as ammonia or hydrogen cyanide during fuel-rich operation, and a draft requirement in excess of that required by conventional chimneys. The recent commercial debut of a stove containing a monolithic catalyst indicates that start-up and natural draft operation can be achieved, but details of the chemical nature of the effluent are not yet available. Experiments to characterize the chemical and physical transformations of woodstove effluent as it passes over anoble metal catalyst are underway at the VPI Solid Fuels Research Laboratory. Preliminary results are presented and discussed

Stockton G. Barnett,
State University of New York at Plattsburgh

In the past three years, six generic types of woodstoves have been evaluated. These include a thin-walled convective box heater, double-door 0.25-in. plate unbaffled step stove, baffled box stove, crossdraft stove (two brands), true downdraft stove, and a new prototype stove. All tests were made at typical burning rates for the northeast (2 to about 7 lb/hr) using air-dried native hardwoods.

Condensable particulate emissions were sampled using a moderately high volume sampler to concentrate flue gas particles on filter paper. Abundant ambient air was bled into the sample tube to ensure that flue gas condensation was complete The flow rates of both stack and sampler were monitored. The filter residue was weighed, this weight was related to the wood's burning rate, and the emission factor (particulates per kilogram of wood burned) was calculated.

Results indicate that high temperature burning produces much lower emission factors than does smolder burning. However, this temperature-dependent emission pattern varies for different stove types.

Interior stove design is also correlated with emissions. Stoves without baffles, with inclined and horizontal baffles, appear to produce essentially the same emission levels. Crossdraft stoves reduce emissions to about one-half to one-third of the above levels.

Creosote accumulation rates were measured by both removing a stovepipe section and removing cutout pipe sections and weighing them every 4 days. Creosote weights per unit area were then related to average burning rate and stove type. Generally there was a positive correlation between creosote accumulation rates and particulate emissions.

Woodstove efficiency was measured in two homes in the cold climate of northernmost New York where annual degree days average 8000. One home has 5 ft of exposed flue pipe and the other has only 1 ft. A small fan circulates room air in both homes.

Each home's heating load per degree day was measured by metering electric heat loads for 15 to 20 days without the woodstove in operation. Additional measured variables include: average indoor temperature, average outdoor

temperature, solar gain, wind velocity, and human energy gains and losses.

Woodstove efficiency was determined by comparing the daily weight of wood burned (adjusted for moisture content) with the home's net daily heat loss over continuous periods which averaged about 20 days per stove.

The results indicate that there is little difference in delivered efficiency between most of the various stove designs, in spite of the wide variety of types which are represented. The one exception, the thin-walled convective box heater, is about 10% less efficient.

However, a control device developed by the author to produce very even burns provides a significant efficiency improvement of 5 to 10% above either manual or standard thermostatic control of these stoves.

John M. Allen,
Fuels and Combustion Section,
Battelle-Columbus Laboratories

Air pollution emissions from residential wood-burning appliances are affected by many variables, including stove design, operator techniques, and fuel properties. Several of these variables have been investigated in the laboratory to identify relationships between the independent combustion variables and the stove emissions.

The two most significant emissions are CO and organic species, the latter including both hydrocarbons and some partially oxidized materials. These organic materials are also the source of creosote when they condense in the flue and are collected on the cooler surfaces before being emitted to the atmosphere. They also include some polycyclic aromatic hydrocarbons which have been found to be carcinogenic. The two principal mechanisms of pollution formation are incomplete combustion in the active burning region usually associated with a restricted air supply, and wood pyrolysis without burning of the pyrolysis products. Several factors can prevent or restrict the burning of these combustible species, including low temperatures, limited oxygen supply, poor mixing, and lack of ignition source.

Several approaches are identified to reduce the emissions from residential woodstoves, including mode of burning provided by the stove design, operator techniques in using the stove, and characteristics of the fuel being burned. Some problems in applying some of the corrective actions are noted, and promising techniques are recommended for development.

Highlights of Sessions 1, 2, and 3 were presented by the Session Chairmen in Session 4·

Session 1, Overview of Wood Combustion Environmental Assessment by Henry Anderson.

Session 2, Assessments of Residential Wood Heating Efficiency and Emissions by Jerome P. Harper.

Session 3, Overview and Challenges for the Future by Wade H. Ponder

Panel discussion (Session 5) speakers' abstracts follow:

William T. Greene,
Portland Air Quality Maintenance Area,
Oregon Department of Environmental Quality

After an introduction on the severity of pollution impacts from residential wood heating in Oregon, different potential institutional and regulatory approaches to control pollution from this emission source were discussed. Approaches include testing and certification programs under government or trade association sponsorship, weatherization programs to reduce heating needs, educational programs, governmental efficiency/emissions/safety inspection programs as in West Germany, and government or trade association research programs to develop improved emission control techniques. The importance of developing a simpler, yet repeatable, emissions measurement method is emphasized.

Charles E. Bohac,
Environmental Research and Development Staff, TVA

Impacts on air quality standards, industrial development, human health and safety, and forest resources are the major issues relating to residential wood combustion in the Tennessee Valley.

Although regional particulate levels might not be significantly elevated and regional sulfur emissions could potentially be reduced because of increased wood combustion, residential heating emissions can comprise a high percentage of winter particulate emissions for urban areas. Additionally, the chemical content of these emissions can be represented so as to be alarming—dozens of carcinogenic and toxic chemicals contained in small particles that penetrate deep into the lungs. Therefore, the local air quality impacts are of primary concern.

Preliminary estimates indicate that although there is ample wood available to support even the highest estimates of residential wood heating, the combination of all potential demands when considered in the context of accessibility, topography, landowner preference, and the general market-price competition will create many local areas where demand will exceed supply.

Other issues addressed include accelerated erosion, nutrient loss, increased sediment load to receiving waters, increased flash flood potential, safety hazards to wood harvesters, and fire hazards from improper heater installation and operation.

Alternative means of resolving these issues which are available to local, state, and Federal agencies are also discussed.

Phyllis Brooks Wainwright,
Division of Environmental Mangement,
N.C. Department of Natural Resources and Community Development

The State of North Carolina is committed to wood as an alternative energy source and at the same time recognizes its responsibility to the environment. Because of conflicting polycyclic organic material (POM) emission data available, the State of North Carolina has undertaken a sampling study for POM emissions from wood-fired boilers. The North Carolina wood energy project and the POM sampling study are discussed.

Cedric R. Sanborn,
Agency of Environmental Conservation, Department of Water Resources and Environmental Engineering

During the winter of 1979-80, the Air Pollution Control Program of the State of Vermont conducted an ambient air monitoring program in Waterbury, VT, to study the effects of residential wood-burning on the particulate level within the Village. The ambient monitoring program consisted of 10 high-volume samplers at 5 sites, 2 meteorological stations, and an ambient particulate monitor (APM) for outputting hourly total and respirable particulate levels.

The monitors were placed to measure microscale impact in residential areas that had high concentrations of wood-burners.

The average 24-hour TSP levels ranged from 26 to 81 $\mu g/m^3$ at the residential sampler sites. Several excursions of the 150 $\mu g/m^3$ National Ambient Air Quality Standard (NAAQS) were recorded at two of the sites.

Based on modeling techniques, it is estimated that as much as 35% of the measured TSP could be due to wood smoke. The modeling was based on the APM emissions which were based on wood use forms filled out by 30 wood-burning residents in Waterbury over a 12-week period. Additional filter analysis is being conducted to confirm or deny these estimates of ambient impacts.

In addition to working on the residential aspects of wood-burning, the State of Vermont has also conducted a study of emissions from industrial wood-fired boilers. Currently work is progressing under a DOE grant to improve the combustion efficiency of several types of residential wood-stoves.

Peter H. Kosel,
Air Resources Board

An examination of air pollution test results and the demography of wood-burning in California indicates that although wood-burning is less important than some other urban pollution sources, it may be a major contributor to pollution in some residential areas. To reduce emissions from wood-burning equipment, it is better to apply design specifications to new equipment than to impose emission limits on existing equipment. The potential for marketing retrofit devices and hints for more efficient and less polluting wood-burning are discussed.

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***Michael C. Osborne** is the EPA Project Officer (see below).*
The complete report, entitled "Proceedings: Conference on Wood Combustion Environmental Assessment (New Orleans, February 1981)," (Order No. PB 81-248 155; Cost: $24.50, subject to change) will be available only from:
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