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PROCEEDINGS OF THE 1989 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP

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EXECUTIVE SUMMARY

1.0 Introduction

This report documents the proceedings of the 1989 Oil Heat Technology Conference and Workshop, conducted on March 27 and 28 at Brookhaven National Laboratory (BNL) under sponsorship by the U.S. Department of Energy - Office of Buildings and Community Systems (DOE-OBCS). The meeting was held in cooperation with the Petroleum Marketers Association of America.

The 1989 Oil Heat Technology Conference, which has been the fourth held since 1984, is a key technology transfer activity supported by the ongoing Combustion Equipment Technology program at BNL, and is aimed toward providing a forum for the exchange of information and perspectives among international researchers, engineers, manufacturers and marketers of oil-fired space-conditioning equipment. The objectives of the Conference are to:

- Identify and evaluate the current state-of-the-art and recommend new initiatives for satisfying consumer needs cost-effectively, reliably and safely;
- Foster cooperative interactions among federal and industrial representatives in accordance with the common goal of national security via energy conservation.

The 1989 Oil Technology Conference comprised: (a) two plenary sessions devoted to presentations and summations by public and private sector representatives from the United States, Europe and Canada; and, (b) four workshop sessions which focused on mainstream issues in the field of oil-heating technology.

2.0 Plenary Sessions

Highlights of the plenary session are derived from 12 presentations made in addressing:

- Current R&D supported by the Department of Energy;
- State energy conservation and mechanical retrofit weatherization programs for oil heat;
- Canadian research on oil-fired combustion equipment;
- Venting technology for oil-fired appliances;
- European developments in oil heat technology;
- Oil heat technology and education.

2.1 DOE-Sponsored Research and Development

Four project presentations were made in this area covering results from ongoing research. Planned future activities were described to invite industry comments and guidance.

The BNL oil heat research and development program was described in overview along with the multi-year plan for the future. This included a brief history of past accomplishments and the evolution of the Combustion Equipment Technology Laboratory at BNL.

Results were reported of an experimental study of sensors for advanced control systems for residential oil-fired heating equipment. The work has been aimed at a broad range of sensing options including indicators of heat exchanger fouling, fuel/air ratio and flame quality. Output or control options under consideration include local or remote indicators of "service required," tools to aid rapid and accurate air fuel ratio setting, and automatic excess air trim.

It was found that evaluation of the rate of performance degradation due to heat exchanger fouling can be done very simply using the peak flue gas temperature during heating cycles. Tests on low cost oxygen sensors based on zirconium probes showed these to be very useful for the oil heating application. The use of flame optical emissions for control was evaluated by making spectral intensity measurements over the range 200-1100 nm (ultraviolet to near infrared) and broad band emission measurements in both the visible and the infrared. Optical emissions were found to be very useful indicators of flame quality. A simple concept for using optical inputs for burner adjusting and/or indicating service required is described.

A paper was presented on the research in progress at Brookhaven National Laboratory towards the development of advanced burner concepts. Results from modeling droplet penetration from atomization measurements and from preliminary testing of air atomized nozzles in burners were presented. The model results show the advantages to be gained from smaller drop sizes and the spray measurements demonstrate that smaller mean drop sizes can be obtained from air atomizers. Burner tests suggest improvement in performance attainable from smaller drop sizes.

Detailed emissions measurements have been made and were reported for a number of currently available residential systems selected to represent recent development trends. Some additional data was taken with equipment which could be considered to be in a prototype stage including a prevaporizing burner and a retention head burner refit with an air atomizer. Measurements include NO_x, smoke numbers, CO, gas phase hydrocarbons, and particulate mass emission rates. The systems were evaluated both in steady state and cyclic operation.

Emissions of smoke, CO and hydrocarbons were found to be significantly greater under cyclic operation for all burners tested. Generally particulate emissions were about 4 times greater in cyclic operation. Air atomized burners could be operated at much lower excess air levels than pressure atomized burners without producing significant levels of smoke. As burners get better, either through air atomization or prevaporization, there is a general trend towards producing CO at lower smoke levels as excess air is descreased. The criteria of adjusting burners for trace smoke may need to be abandoned in favor of adjusting for specific excess air levels.

2.2 Mechanical Retrofit Weatherization Programs and New York State Energy Conservation Programs for Oil Heat

The Alliance to Save Energy reported on a research and technology transfer program to determine the effectiveness of installing flame retention oil burners in state low-income weatherization programs. Seventeen states implemented programs to install flame retention burners in oilheat systems; over 18,000 burners were installed and 1,500 energy auditors and heating contractors were trained.

The Alliance program demonstrated that installing these burners is an effective conservation measure (20 percent average improvement in steady-state efficiency (SSE); 16 percent average energy savings) in low-income programs. Recently, they have conducted a field study of the longevity of these energy savings by assessing retrofits installed five years ago. They found systems lost one-third of their SSE over a five year period. However, even with the loss, flame retention burners are still cost-effective to install.

A presentation by New York State ERDA included a description of an ongoing project to develop a blue flame oil burner with low firing rate capability. The oil burner design incorporates internal combustion gas recirculation to vaporize and mix oil with combustion air prior to burning. The fuel/air mix then passes through and burns on a stamped sheet metal flameholder. The burner flame is similar (short and of blue color) in appearance to the type of flame observed with pre-mix power gas burners that use flame holders.

Many of the NYSERDA projects are conducted in cooperation with participating manufacturers located in New York State. This presentation also described prospective program opportunities for research funding during the coming year as would be applicable to the oil heat industry.

2.3 Research in Canada

The ongoing work at the Canadian Combustion Research Laboratory was the subject of a paper presented by program manager A.C.S. Hayden dealing with research and development efforts being conducted on oil-fired space and water heating appliances. This included work on draft and chimney performance improvements, minimization of indoor air pollutants, the development of higher efficiency equipment, problems with tight housing, and fuel quality issues.

A recent study conducted in Yellowknife, NWT was commissioned by the Canada Mortgage and Housing Corporation to provide more definitive data on the merits of forced warm air systems and hydronic systems installed in an Arctic environment. In addition to a conventional oil-fired boiler and a conventional down draft oil furnace, two other systems were evaluated. These were a domestic hot water tank as a combination hot water and space heating appliance and a hybrid system which utilized hydronic coils inserted in a forced air recirculating system. The hybrid design was developed to satisfy the need for a forced ventilation system required in tighter houses and still enable the use of a hydronic or boiler unit. Hydronic systems are finding themselves at an economic disadvantage compared to forced air systems in tight houses. Studies cover a broad range of topics including thermal comfort, energy efficiency, life cycle cost and market acceptance.

2.4 Venting Technology for Oil-Fired Appliances

The development of a power sidewall venting system for oil-fired furnaces was the subject of a paper presented by a furnace manufacturer. The reasons that prompted the design and development of the system and the process required to obtain an Underwriters Laboratory listing for the product were discussed.

Installation concerns and initial results from field evaluations were reviewed and reported.

The drive for energy conservation has not been without its problems relative to indoor air quality and this was the subject of another speaker on the topic of "The House as a System TM." Indoor air quality problems can best be addressed by designing the vent systems to specific heating loads and the conditions under which they are expected to perform. A logical approach to improving indoor air quality is to analyze the house as a comprehensive system including the mechanical systems along with the occupants of the home and how they interact with the house and its operation.

2.5 European Developments in Oil Heat Technology

A West German combustion system with combustion gas recirculation for soot-free combustion of hydrocarbon fuels with air was described. The system itself contains - besides means for air supply and distribution and for fuel supply, atomization and distribution - a mixing tube for the introduction of recirculating combustion gas into the air-fuel-mixture stream promoting fuel evaporation and a flame tube for defining a properly sized reactor space. Certain interrelationships between certain measures of the combustor elements are obeyed to achieve proper and stable operation. Special importance for proper functioning was predicted by theory for the maximum droplet size in the fuel spray. Pollutant emission values of this combustion system are low, even at near stoichiometric operation. Due to its soot-free flame no fouling of the air metering port occurs, so that good burner performance is kept over operation periods of more than two years without maintenance. Special investigations are under way to study the conditions of NO_x - formation in the system, aiming at further reduction of this kind of emission.

The utilization of the exhaust gas residual heat in an oil fired heating plant has been connected with a high corrosion rate due to the sulfur and sulfureous acidity of the condensed water. The German Aerospace Research Establishment (DFVLR) has now developed an effective process for burners in the 10 kW range. This technique is said to enable 60-99% of the sulfur to be removed from the exhaust gas and simultaneously reduces fuel consumption by 10-35%. The DFVLR process was described during a poster presentation at the BNL conference.

2.6 Oil Heat Technology and Education

The last presentation of the final plenary session was on the topic of oil heat education and training. The speaker covered educational needs of the industry as a whole, and keyed in on the specific needs in educating the service technicians and how important this is to the future of the industry. The speaker suggested that it was time that the industry evaluate itself in this area and look to the future. It was suggested that the industry should develop a new "bible" for training people in oil heat technology and that it should encompass a wide range of topics including: fundamentals, service instructions, existing technology, new advancements being introduced currently, guidance for maximizing system performance and efficiency, and many other topics.

3.0 Workshop Sessions

The conference attendees were divided into four groups addressing specific subjects. These included:

A. Advanced Controls for Oil Heat and Performance Degradation
B. Educational Needs in the Oil Heat Industry
C. Oil Appliances with Direct Sidewall Venting - Recent Advances and Remaining Issues
D. Future Development of Advanced Oil Heating Equipment and Appliances

A brief summation of conclusions and recommendations for each workshop group is as follows:

GROUP A. ADVANCED CONTROLS FOR OIL HEAT AND PERFORMANCE DEGRADATION

- The workshop group identified the three most significant service related problems for the oil heat industry: sooting, burner set-up and service diagnostics, and oil quality. The group focused on these three items during the discussion.

- Boiler designs have been getting tighter and the attitude of the group was that this trend should not go any further. On the same topic it was also felt that improved operating reliability should not be attained at the expense of efficiency.

- Control strategies developed by BNL could be very useful for improving equipment reliability but should not cause unnecessary service calls involving the homeowner in the process.

- Many servicemen still do not use instruments to adjust burner air/fuel ratios. Digital oxygen sensors are not reliable enough and carbon dioxide (CO_2) wet chemistry analyzers (dumbell type) are troublesome to use. A new technology like the optical approaches under development at BNL would be a welcome improvement.

- The general consensus of the group was that more work is needed in the area of fuel quality. A field test of oil quality may be needed sampling tank bottoms and their combustion characteristics. Water in the oil and algae which can grow in the tank were cited as potential problems exacerbated by stirring in the tank each time fuel is delivered. Problem detection methods are needed as are means to resolve the problems by chemical treatments or tank cleaning methods.

GROUP B. EDUCATIONAL NEEDS OF THE OIL HEAT INDUSTRY

- The workshop chairman lead a forum discussion on the group's experiences concerning educational techniques used at the local (or company) level which could be useful or aid in developing a national educational effort by the industry.

- Video training tapes were a major topic with positive and negative opinions expressed. Most of the group agreed that the video format was very useful, but could not be used alone.

- Hands-on training in the field or in a training classroom equipped with oil fired equipment available for actual live firing demonstrations, along with good support materials, including an oil heat handbook and video tapes, was the more favored technique. This also assumes a knowledgeable and effective instructor.

- A discussion concerning handbooks and printed materials resulted in two concepts for future action. The first was that a clearinghouse for available information is needed by the industry. In effect this could be a catalog of what educational materials already exist, what they contain, and how to obtain copies from generally available sources. The second idea was that the industry should develop a single oil heat handbook which would be a "bible" for the industry.

- The development of an oil heat handbook is not a new idea and the question is how it should be formatted and what it should contain and how could it be distributed and updated as required? BNL volunteered to host a technical advisory committee to try to answer these questions and suggested that industry representative should attend and get involved. In all, twelve individuals immediately volunteered to join in the effort. A meeting is being planned.

GROUP C. OIL APPLIANCES WITH DIRECT SIDEWALL VENTING RECENT ADVANCES AND REMAINING ISSUES.

- The important advantages of power venting systems were discussed and prioritized. First it opens up new markets for oil heat in replacing electric heat and heat pump systems. Second it lowers installation costs by eliminating the chimney which is a high cost item. Third it can improve efficiency and lower operating costs, and last it can be used to replace problem chimneys.

- The group discussed the need to define various venting configurations; direct venting was defined as the removal of exhaust gases without a chimney (involving through the wall or other means); sealed combustion was defined as using outside combustion air and a sealed system taking in combustion air to the burner and again exhausting to the outside of the structure; and direct exhaust was defined as the case in which an inducer fan is used to remove exhaust gases from the furnace with combustion air supplied from inside the hosue.

- Sealed combustion was discussed as a means to eliminate potential off-cycle odor problems by preventing spillage of combustion fumes. However the air could produce its own problems regarding lite off and changes in air/fuel ratio that would now vary as a function of outside air temperature (density changes).

- Sidewall vented heating systems now on the market utilize direct exhaust methods with or without combustion air ducted from the outside, into the area where the burner is located, but not entirely sealed. To date no major problems have been reported.

- The group concluded by discussing the need for future research and development activities related to power venting for oil appliances. These included: better evaluation of efficiency improvements and fuel cost savings, developing reliable systems that do not have unusual servicing requirement, and concerns for materials and bearing failures, as used in induced draft exhaust vent fans.

GROUP D. FUTURE DEVELOPMENT OF ADVANCED OIL HEATING EQUIPMENT AND APPLIANCES

- In the area of high-efficiency equipment the consensus was that the primary need was for a generally accepted classifcation system that would give guidelines on what boilers and furnaces could be used with what vent systems. Lower limits might be set for flue-gas temperatures for each type of system. Climate was seen to be a factor in setting these lower limits. Available efficiency levels were seen as sufficient; there was not a lot of support for a big push to condensing systems.

- There was significant sentiment in the group that thermal distribution systems--ductwork and pipes--could provide a fertile field, not only for improved energy efficiency, but for oil heat installers to expand their business into a new area. This could be seen as a "tune up" for the heat distribution system; cleaning, adjustment, sealing, and insulating where appropriate.

- Regarding low-firing-rate systems, a need was seen for systems that could go below 0.5 gallons per hour input. It was pointed out that with conventional nozzles, few installers will go anywhere near as low as half a gallon an hour, even though that is the lower limit according to the conventional wisdom. After-drip, cracking the fuel, and coking were seen as inherent problems with conventional atomizers, pointing to the need for a different mode of atomization.

- On-line diagnostics were discussed concerning the need for systems that maintain clean burning characteristics over time. There was discussion whether this should be attained through the implementation of online diagnostics or by fail-safe system design to prevent heat exchanger fouling from occurring. On a shorter-term basis, a soot indicator in the combustion chamber was seen as a desirable compromise.

- Systems that serve two different functions were seen as a way to increase oil sales and improve efficiency at the same time. An optimized combined space and water heater was suggested. The idea of oil-fired cogeneration for the home was well received in the group as was an oil-fired absorption heat pump.

- The use of a conversion technology such as thermoelectrics to skim a small amount of electricity from the system, which would then be used to run pumps and fans, would provide insurance against electrical outages as well as lower operating costs due to purchased power in conventional systems.

- Several areas where work is ongoing were cited as appropriate, and some new areas were suggested. A real need was seen to get information about recent and ongoing developments in oil heat equipment to the public and to others in the decision chain.

4.0 DOE/BNL Perspective

The 1989 Oil Technology Conference brought into focus the realities of the marketplace and the role that federal sponsors and researchers can fill in promoting energy conservation consistent with the public benefit while recognizing the competitive nature of a free enterprise.

From a technical perspective, BNL has taken fundamental approaches to identifying and characterizing combustion phenomena which influence performance efficiency of oil-fired space conditioning equipment. The controlled interrelationships of fuel atomization, combustion, soot abatement and venting are conveyed to designers and manufacturers with the mutual understanding that their adoption may be constrained by market acceptance factors which may transcend technical considerations.

BNL announced the continuing availability of a unique, sophisticated facility to the industry. The facility provides a controlled laboratory environment, support instrumentation and data acquisition/analysis for development, list and evaluation of novel components, subsystems and systems.

Arrangements for access are such as to encourage technical interaction with BNL scientists and engineers or to recognize the user's proprietary constraints by providing access on a full cost recovery basis.

The DOE/BNL perspective is one of lending support to the industry by making available its intellectual and facilities resources while serving as an objective evaluator of private industrial accomplishments. This support is critical to the enhancement of technology development and transfer to the mutual benefit of the industry and the oil consumer.

I. INTRODUCTION

The 1989 Oil Heat and Technology Conference and Workshop was held on March 27 and 28 at Brookhaven National Laboratory (BNL) under sponsorship by the U.S. Department of Energy, Office of Buildings and Community Systems (DOE-OBCS). The meeting was held in cooperation with the Petroleum Marketers Association of America (PMAA). Two hundred people were registered and participated at the conference.

The 1989 Oil Heat Technology Conference, which was the fourth held since 1984, is a key technology transfer activity aimed towards presenting new developments in oil heat processes and equipment technology. It has provided a channel by which information and ideas can be exchanged to examine present technologies, as well as helping to develop the future course for oil heat technology advancement. More importantly, it has served as a stage for unifying government representatives, researchers, fuel oil marketers, and other members of the oil heat industry in addressing technology advancements in this important energy use sector.

The impact of the conference will hopefully promote a cohesion of efforts to hasten the achievement of the ultimate objective: that of energy conservation through the widespread use of improved oil heating equipment.

Special Addresses

Introductory remarks were provided by Bernard Manowitz, Chairman of the Department of Applied Science, who welcomed the assembly on behalf of Brookhaven National Laboratory. Mr. Manowitz stated BNL's commitment to advancing oil heat R&D technology, and addressed BNL's many significant contributions to upgrading oil heating equipment over the twelve years.

A brief opening statement was also made on behalf of DOE by Ted Kapus, Manager, Building Equipment Division, Office of Building and Community Systems (OBCS). Mr. Kapus discussed the need for a balanced energy program. The major goal being able to achieve the highest efficiency possible in the use of all energy forms, and how DOE must maintain adequate and continuous research programs to support this goal, particularly in the area of oil heat.

PMAA was represented by Dick Cahoon, Vice President for Policy at PMAA, in his welcoming remarks he commented that while research and development on oil systems over the past 12 years have cost approximately 10 million dollars in federal funds, the amount of savings that can be realized from newer, more efficient systems is estimated at about 10 billion dollars. Mr. Cahoon concluded that the funding challenge which continuously exists must be met in order to receive the substantial benefits that new oil heat technologies offer. James Pierson, also of PMAA as Chairman of the Heating Fuels Committee, presided as the master of ceremonies for the first plenary session. Mr. Cahoon presided over the second plenary session on day two of the conference.

Technical Presentations

Twelve presentations were made during the two-day program, covering a range of developmental efforts in oil heating equipment being conducted within the United States, Europe, and Canada, including such topics as:

- Advanced Control Strategies for Oil-Fired Appliances
- Research on Future Oil Burner Concepts
- Emission Characteristics of Modern Oil Heat Equipment
- Canadian Research on Oil-Fired Combustion Appliances
- State Energy Conservation and Retrofit Weatherization Programs for Oil Heat
- Power Sidewall Venting of Oil Furnaces
- Analysis of Interactions between the House, the Chimney and the Heating Equipment, as a Single System

Workshop Sessions

The object of the workshops was to allow an open forum for the researchers, equipment manufacturers, fuel oil marketers, and other members of the oil heat industry to discuss relevant issues in the field of oil heating. Attendees were provided with a list of discussion topics prior to the workshop sessions.

Four individual workshop sessions were planned for the afternoon of the second day. These were:

Group A - Advanced Controls for Oil Heat and Performance Degradation

Group B - Educational Needs in the Oil Heat Industry

Group C - Oil Appliances with Direct Sidewall Venting - Recent Advances and Remaining Issues

Group D - Future Development of Advanced Oil Heating Equipment and Appliances

All four groups assembled in separate conference rooms during the 1-1/2 hour-long sessions.

Closing Session

Following the workshop activities, the meeting reconvened for the closing session. Workshop chairmen briefly summarized for the audience some of the key issues discussed during each workshop.

To end the meeting, Robert Lynch of the Empire State Petroleum Association provided concluding remarks along with Dick Cahoon of PMAA, and adjourned the meeting.

II. TECHNICAL PRESENTATIONS

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Paper No. 89-1

OIL HEAT R&D - PATH TO THE FUTURE

AN OVERVIEW

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1.0 INTRODUCTION

The Brookhaven National Laboratory, Architectural and Building Systems Division provides technical and management support to the DOE Office of Buildings and Community Systems program in Combustion Equipment Technology (CET).

A Program Plan has been developed consistent with DOE policy, budgetary guidance and the goal of advancing the state-of-the-art of residential/light commercial space heating equipment. The Program emphasizes investigations relevent to oil-fired systems.

The substance of the plan was derived from seminars and workshops sponsored by the DOE. These inputs were complemented by BNL in-house assessments as well as independent evaluations conducted at the Pacific Northwest Laboratory. This source of information has been documented as follows:

- 1985 Oil Heat Technology Conference and Workshop - Summary of Proceedings; (BNL Report No. 52018).
- Oil Fueled Equipment Research: Program Plan; (PNL 5896).
- Supplement to Multi-Year Plan, Combustion Equipment Technology (November 1985).

1.1 Scope of Activities

The scope of activities within the framework of the CET Program addresses the following functional Program Elements:

- Planning/Management
- Technology Research
- Base Technology Development

<u>Planning/Management</u>

These efforts are dedicated to: establishing programmatic rationale; performing techno-economic assessments; coordinating sub-contract procurements; providing management support via budget tracking and documentation; and maintaining liaison with appropriate public and private sector organizations.

<u>Technology Research</u>

This program element pursues analytical and laboratory investigations, in accordance with planning/management criteria, to establish concept feasibility and provide the basis for development of new technologies.

<u>Base Technology Development</u>

This program element emphasizes the translation of bench-scale investigations of novel concepts to the engineering development of prototypical hardware. Implementation of this activity will utilize industrial expertise for the design and fabrication of advanced component and subsystems via competitive procurements. This will provide a technology base from which the private sector can evolve the advanced energy efficient oil combustion systems of the future.

1.2 Background and Rationale

Since 1976, Brookhaven National Laboratory has assumed a lead role in the DOE Conservation Program devoted to upgrading the technology applied to residential/light commercial space heating systems. Past efforts at BNL have been directed in large part to generic R&D aimed at establishing improved testing procedures which would better reflect systems performance under field use conditions. BNL has drawn upon resources from the academic and private sector to develop advanced components and systems. The Combustion Equipment Technology Laboratory at BNL has served to evaluate novel systems while also providing a mechanism for more effectively transferring technology to the marketplace.

Accomplishments derived from the BNL program in Combustion Equipment Technology include: identification, characterization and transfer of the modern flame retention head burner technology which is credited with projections of 1.5 quads of oil savings by the year 2000; identification of many energy saving space heating equipment retrofit options; identification of potential deficiencies of advanced technologies introduced in the marketplace. The BNL experience over the past decade has provided a firm basis of knowledge with regard to systems designs and performance limitations which permit definition of new approaches to advancing the state-of-the-art while giving due recognition to cost/economic and consumer preference factors.

The rationale for placing emphasis on the development of oil-fired space heating systems derives from: the vunerability of the oil heat consumer to the vagaries of oil prices and availability; the fragmented nature of the oil heat industry which virtually precludes allocation of resources to self-supporting R&D; and the unavailability and alternatives to a large fraction of the oil-heat consumers. Oil heat is used in 12 million U.S. homes with over 80% of these homes located in the Northeast, North Central and Mid-Atlantic regions where colder climates and high electricity prices prevail and where the mostly suburban homes have limited access to natural gas. This demand sector consumes approximately 2 quads/year of oil at a cost in excess of 10 billion dollars per year.

2.0 PROGRAM DESCRIPTION

The focus of the program is placed on three general objectives:

1. Improve the steady-state and seasonal performance efficiency of oil-fired space heating systems. The approach to meeting this objective is to develop the base technology for low firing-rate systems to be interfaced with appropriate heat exchangers.

2. Eliminate or minimize those factors which tend to degrade systems performance with time. The approach to meeting these objectives is to correlate gas and particulate emissions to performance and to introduce control strategies (manual or automated) for ensuring optimal performance.

3. To integrate improvements achieved from (1) and (2) into a technology base which will also incorporate benefits accruable from implementation of direct venting subsystems which the CET program also addresses.

Activities being pursued within each Program Element are summarized:

2.1 Planning/Management

- Techno-Economic Assessment - a dynamic activity maintained to develop and/or reinforce the techno-economic rationale justifying planned and ongoing projects, respectively. The results of these assessments are used for the purpose of continually evaluating programmatic progress and prospects for success.

- Public and Private Sector Liaison - a key aspect of the Planning/Management function is the maintenance of a continual dialogue with representatives of the oil heat industry as well as with other R&D sponsors associated with space heating technology. Such dialogue is comprised of informal and formal interactions ranging from personal contacts to workshops/seminar exchanges.

- Management Support Actions - are representative of routine (budget tracking, documentation, and preparation of competitive procurements) programmatic responsibilities which are discharged within the Planning/Management element of the program.

2.2 Technology Reseach

- Development of Performance Control Strategies - These control systems will maintain high efficiency operation between scheduled service times. The work includes experimental studies on the processes of soot deposition and performance degradation, a review of aspects of candidate control system measurement techniques, and studies on flame spectroscopy for diagnostics. Specific approaches for control strategies are being developed.

- Fuel Oil Atomization and Combustion Research - This project is aimed at improved understanding of combustion processes for developing clean, high efficiency, low firing rate burners. To be successful the approach must ultimately be simple and highly reliable. Work in this project includes: a detailed review of relevant past and ongoing work in liquid fuel combustion; laboratory studies on atomization and burner interactions; and the development and verification of a burner technology approach.

2.3 Base Technology Development

- Direct Venting Technology Development - This activity provides for the development of guidelines and recommendations for direct venting technology and equipment. The support of code modification actions and test standards development is included.

- Systems Integration/Development - In order to integrate the various concepts developed within the CET program a systems engineering approach will be used in the development of ultra-high efficiency (90-95%) oil-fired heating systems. The engineering development process involves a cooperative effort between government and the private sector. BNL will provide the upfront technology research, design guidance, and support the base technology engineering development (subcontracted by BNL). The private sector will support final manufacturing design, value engineering, and field test marketing activities.

- The Combustion Equipment Technology Laboratory has been updated to provide facilities for all experimental tasks within the CET program.

3.0 COMBUSTION EQUIPMENT TECHNOLOGY LABORATORY

3.1 Purpose

The Combustion Equipment Technology (CET) Laboratory at Brookhaven National Laboratory (BNL) was built and operated under the auspices of the U.S. Department of Energy to develop and characterize energy-efficiency space conditioning equipment and technology. It serves as a combustion equipment research laboratory for advanced heating technologies and novel systems, while also providing a mechanism for more effective transfer of near-commercial technology. The research laboratory also plays a critical role in developing credible information for meeting the public's education needs. These technology transfer activities provide manufacturers, distributors, and consumers current updated information on new heating equipment developments and operational efficiency improvements.

The purpose of the Combustion Equipment Test Laboratory at BNL is:

- To provide a fully-instrumented test facility dedicated to the characterization of advanced space heating equipment and component hardware.

- To perform unbiased engineering evaluations of new and emerging heating system designs.

- To promote advanced space heating technology transfer through information dissemination aimed towards creating market opportunities and increasing consumer education.

- To foster cooperative R&D with the public and private sectors.

To accomplish these goals, the test laboratory has been designated as an available facility, which makes it possible for representatives from industry, research organizations, and other laboratories to access the facility for non-government sponsored research and development activities.

3.2 Background

Past efforts at BNL have been directed in large part to R&D aimed at evaluating the potential of new and emerging heating equipment designs and performing characterization studies of specific design concepts with regard to efficiency, operating performance, safety, and reliability under field conditions.

Over the past decade BNL has been instrumental in the investigation and technology transfer of several advanced combustion equipment systems, including:

<u>Burners</u>

- Flame Retention Type
- Blue Flame
- Air Atomization (thin film)
- Sonic and Ultrasonic Atomization
- Combined Fuel/Air Pump

<u>Heat Exchangers</u>

- Hydronic Boilers
- Warm Air Furnaces
- Turbulator Effects
- Secondary Non-Condensing
- Condensing (indirect and direct contact)
- Low Mass Boiler
- Pulse Combustion Systems

<u>Retrofit Options</u>

- Vent Dampers
- Boiler Temperature Controls
- Nozzle Sizing
- Combustion Air Pre-Treatments

<u>Fuel Technology</u>

- Fuel Additives
- Fuel Emulsions
- Fuel Preheating
- Alternative Fuels
- Emissions Analysis

3.3 CET Facility Capabilities

BNL maintains a well-equipped test laboratory for combustion research. The facility contains four test stations, of which three are installed for hydronic (hot water) boiler testing and one is for warm air furnace evaluations. These test stations serve to evaluate heating equipment efficiencies and thermal performance using heat and mass flow measurement techniques. The quantity of heat transferred is measured directly and compared to the corresponding heat content of the fuel consumed, to give the efficiency of operation.

Stack gases such as CO, CO_2, O_2, smoke and NO_x can be continuously sampled and measured using on-line instrumentation in order to monitor stack emissions levels. Gas analyzers have been assembled in a console unit equipped with sample handling components for pre-conditioning.

A desktop microcomputer system installed on-line provides automated process control, and facilitates data acquisition and analysis. The computer receives the analog signals from the various flow and temperature transducers and calculates heating and efficiency values based on thermodynamic laws. Software has also been developed to operate the equipment in both steady-state (continuous) and cyclic (intermittent) modes.

In addition to the Combustion Equipment Technology Laboratory, facilities are also available for performing atomization studies using a laser spray analyzer to measure fuel drop size. This system uses the radial distribution of diffracted light to obtain the spray drop size distribution. A microprocessor converts the light distribution to a drop size distribution in minutes, providing rapid and accurate data handling.

3.4 Testing Opportunities

As a central facility, BNL's Combustion Equipment Technology Laboratory offers several opportunities for the industrial, commercial, and private sectors. Several areas of investigative research can be pursued owing to the diverse capabilities of the test facility. Typical activities consistent with energy conservation goals may include:

- Performance Analysis and Characterization of Advanced Heating Equipment Designs.
- Fuel Atomization for Improved Burner Performance.
- Stack Gas Emissions Analysis.
- Assessment of Fuel Quality.
- Soot and Fouling Reduction.
- Characterization of Reliability and Safety.
- Service and Advanced Diagnostic Techniques.
- Performance and Control Strategies.
- Support and Guidance in Implementing Field Tests.
- Technology Transfer.

4.0 PUBLICATION OF RESULTS

Reports on the work (which is ongoing) will be made available upon publication. Preliminary reports on the Performance Controls Project (BNL 52170) and the recently Advanced Atomization/Combustion Research (BNL 52173, a technology review) have recently been published and are available from BNL upon request, copies are limited.

Paper No. 89-2

ADVANCED CONTROL STRATEGIES

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ABSTRACT

Results are reported of an experimental study of sensors for advanced control systems for residential oil-fired heating equipment. The work has been aimed at a broad range of sensing options including indicators of heat exchanger fouling, fuel/air ratio and flame quality. Output or control options under consideration include local or remote indicators of "service required," tools to aid rapid and accurate air fuel ratio setting, and automatic excess air trim.

It was found that evaluation of the rate of performance degradation due to heat exchanger fouling can be done very simply using the peak flue gas temperature during heating cycles. Tests on low cost oxygen sensors based on zirconium probes showed these to be very useful for the oil heating application. The use of flame optical emissions for control was evaluated by making spectral intensity measurements over the range 200-1100 nm (ultraviolet to near infrared) and broad band emission measurements in both the visible and the infrared. Optical emissions were found to be very useful indicators of flame quality. A simple concept for using optical inputs for burner adjusting and/or indicating service required is described.

INTRODUCTION

The thermal efficiency of residential oil fired heating equipment in service is lower than the efficiencies which can be achieved under controlled conditions. Two primary factors contribute to this situation.

- o When equipment is installed and serviced, the burners are not adjusted for minimum excess air.

- o In continuous service, thermal performance deteriorates between tune-ups. This is due in part to soot accumulation on the heat exchanger surfaces.

For maximum thermal efficiency oil burners should have their air/fuel ratios adjusted to produce a "trace" smoke level in the flue. (A "trace" smoke is equivalent to a smoke number between 0 and 1 on the Shell/Bacharach Scale). A burner adjusted this way in steady state, however, will have significantly higher smoke levels during routine, cyclic operation. This is due to three factors: 1) an ignition pressure peak in the combustion chamber which has been shown to produce increasingly severe smoke peaks as excess air is reduced[1]; 2) after ignition the average temperature in the chimney is lower than in steady state, leading to reduced draft and excess air; and 3) after ignition the combustion chamber walls are still relatively cold, also leading to increased smoke. In addition, changes in fuel quality between service calls and excess air changes due to weather conditions might produce a soot problem for burners set with "marginal" excess air. Service personnel adjust burners to have generous excess air levels to prevent problems which might require a return visit to the home. Unfortunately, this results in a relatively poor operating efficiency compared with the maximum level that can be achieved.

Increasing excess air descreases efficiency by increasing the mass flow rate and temperature of the combustion products discarded to the outdoors. To illustrate the magnitude of the effect it is assumed that a burner is adjusted to 9% CO_2 instead of an optimal level, of 12%. This corresponds to 68% excess air vs the optimal level of about 30%. Stack gas temperature would be about 70°F higher due to the unneeded excess air. The steady state efficiency would be about 6% lower as a result of the two effects.

This assumes that the service personnel have the adequate instrumentation to properly set the air/fuel ratio and that they spend the time required to make these adjustments. In many cases burners are installed without proper adjustment leading to very high excess air settings with reduced efficiency and/or service problems.

Estimates of the magnitude of the annual degradation in thermal efficiency based on earlier published studies, show considerable variation between units. An average degradation of 2% per year has been used [2]. Principal causes of deterioration are seen as fouling of the heat exchanger surfaces by soot, fouling of the oil nozzle, and changes in air/fuel ratio caused by dust.

Generallly, the introduction of advanced control systems could potentially reduce fuel consumption due to both high excess air and heat exchanger fouling.

The goal of the work described in this paper was to develop recommendations for control strategies and systems for improved efficiency of oil fired residential equipment, based on current technology.

Two basic control modes can be considered for maintaining high efficiency operation:

- Service-required signals - in this mode the homeowners or service company would be made aware that smoke production and/or efficiency have degraded to the point that service is required.
- Steady-state excess-air trim - in this mode the burner would essentially tune itself continuously for maximum efficiency. Excess air would be changed in response to changes in fuel quality, draft, nozzle erosion, etc. to maintain "trace" smoke in steady state.

In implementing these control strategies an input is required which is related to air/fuel ratio and/or flame quality. This type of input could alternatively be used as a service tool. Instead of making excess air and smoke number measurements at a series of points and then selecting a setpoint, the excess air could simply be adjusted until a predetermined control signal is reached.

The service-required signal mode would reduce fuel consumption by reducing operating time in a degraded condition. The control approach might be as simple as monitoring stack temperature as an indicator of fouling. The simplicity of this approach is a great advantage. A disadvantage of this approach, however, is that the homeowner is alerted only after the heat exchanger surfaces have become fouled. A control system which alerts the homeowner when the burner has just started producing high smoke could eliminate the need for disassembly and cleaning of the unit. Potentially this mode could be achieved by measuring smoke, gaseous hydrocarbons, CO, or flame optical emissions ("color").

In this paper the results of experimental studies on a range of selected input parameters for advanced controls are described. The parameters examined were selected based on 1) the use of these inputs in larger boilers and 2) the potential use of these inputs in residential systems at low cost.

EXPERIMENTAL

To evaluate measures of heat exchanger fouling, two units, a boiler and a furnace were operated under forced cycles for a period of weeks, with unusually high smoke levels. During this time the flue gas exit temperature, combustion chamber to flue pressure drop and flue gas oxygen content were monitored continuously to evaluate use of these parameters for control inputs. The boiler tests were done using a cast iron type section boiler (Peerless Heater Co. Model NO-JOT-35-SPT) and the furnace tested was a conventional "low boy" type (Rheem Air Conditioning Division Model ROH2 120A). Both units were fired with retention head burners.

Zirconium oxide type sensors are commonly used to measure oxygen concentration in larger boiler flues and car engine exhausts. Units used in boilers are fairly expensive and incorporated electrical heaters and an accurate temperature control system. These sensors must be heated to above about 900^{o}F so that the zirconium oxide conductivity is reasonably high. The output signal is dependent upon both temperature and oxygen concentration and accurate temperature control is needed to accurately determine oxygen. Most automotive oxygen sensors, in contrast, are not heated but rely instead on heat from the engine exhaust manifold to raise the temperature of the zirconium sensor into the operating range. Sensor temperature varies widely with engine load and the output signal can only be used to indicate when the engine is operating at the stoichiometric ratio (0 excess oxygen). At this condition there is a sharp jump in sensor output which is nearly independent of temperature. The advantage of the simple automotive approach is low cost - sensor wholesale for less than $20. A similar approach was evaluated for residential oil burners. An unheated automotive type sensor was installed in the upper part of the combustion chamber of a dry base steel boiler (Burnham BB011.FR). Figure 1 illustrates the location of the sensor in the chamber and in Figure 2 the steady state temperature at the sensor location is shown as a function of excess air at two firing rates. Over this range the temperature remains within the ideal range for the automotive sensor.

Beginning in 1988 one U.S. car manufacturer (Ford) started using heated oxygen sensors in the exhaust pipe. Advantages stated for the heated sensor include faster warmup and more stable operation. One of these sensors has been tested in the flue pipe of a residential boiler. The unit has a PTC heater which was supplied with a constant 20 VDC. Cost for the sensors is about double the unheated sensor cost.

In addition to the low cost automotive type sensors a unit made by Nederlandse Philips Bedrijven, B.V. (Netherlands) was also tested. Relative to other zirconium oxygen analyzers which are commercially available, this unit was of particular interest because the manufacturer has used it on small commercial boilers and has been pursuing the development of a low cost unit for domestic heating application.[3] The sensor which has been developed by Philips for residential applications is significantly smaller (17.5 mm x 10 mm sensing head) than any of the units tested and reportedly could market for less than $75.00 in quantity.

Optical methods of flame diagnostics have received increasing attention in recent years and may be a very practical method of sensing the "quality" of an oil burner flame.[4-8] This concept was evaluated by measuring the spectral intensity of light emitted from oil burner flames over the ultraviolet and visible ranges (200-700 nm) under a broad range of conditions. In addition, broad band emissions were measured using unfiltered CdS ("cad cell") and PbSe photoconductors which respond in the visible and infrared ranges, respectively.

Figure 3 illustrates the general optical arrangement of the system used to make spectral intensity measurements. Light from the flame was directed out from the burner air tube to an external grating monochrometer (1/8 meter, .5 nm max resolution, Oriel Corporation Model 77250) and photomultiplier detector through either a fiber optic cable or liquid light guide. While other views of the flame may offer advantages it was decided to make all optical measurements from within the burner air tube. This was done because sensors in the air tube are kept cool and clean by the incoming combustion air. Any other optical access ports would require adding purge air and an additional chamber penetration.

RESULTS

For evaluating seasonal degradation due to heat exchanger fouling simple flue gas temperature was found to be the most useful parameter. Effects of variations over the firing cycle and seasons can be compensated for by using only cycle peak temperatures during the heating season or, in the case of boilers, by utilizing the stack gas to water differential temperature. This differential temperature remains essentially constant over most of a typical heating-type firing cycle.

Figure 4 shows the trend in the boiler cycle-maximum flue gas exit temperature over the fouling test. The rise in temperature observed during this test (131°F) corresponds to a decrease in thermal efficiency of 2.9%. Following the termination of the boiler test the unit was disassembled for a detailed inspection and cleaning. The thickness of the soot coating varied with location, but averaged about 1-1/2 mm. The thickest deposits were located around the extended surface in the convective section and blocked some of the flow area. The total mass of soot removed from the boiler surfaces was 250 grams. No change in the combustion chamber to flue pressure differential or the burner excess air level was observed over the test period.

In the furnace test the burner operated 10 min. on/15 min. off for 50 days and results were generally similar to those with the boiler. The rise in flue gas temperatures with the furnace was about 1/2 of the rise observed in the boiler test (131°F vs 74°F). This occurred even though the steady state smoke numbers were significantly higher in the furnace test and the burner ran longer in the furnace test (396 hours vs. 289 hours).

After termination of the test the furnace was disassembled for inspection of the heat exchanger surfaces. As with the boiler, the soot deposits varied significantly with location. Thickness ranged from 1 to as much as 6 mm. The total mass of soot removed from the heat exchanger surfaces was 175 g.

Generally, the furnace deposits and boiler deposits were comparable in magnitude. It seems likely that the greater rise in flue gas exit temperature with the boiler was due to the heat exchanger configuration. In the furnace soot deposits simply coat the surface of the steel heat exchanger drum. In the boiler, however, soot deposit bridging occurs around the extended surface. This can significantly modify gas flow, leading to channeling.

Perhaps the simplest method of monitoring the rate of fouling of the heat exchanger surface is through the use of a stack thermometer with a "peak hold" dial. This continuously indicates the peak temperature which has been observed since the last reset. A homeowner could observe the reading at any time (burner firing or not) and follow the fouling process. In Figure 5 results using this type of thermometer are shown for an actual home between fall and spring cleanings.

Tests using the commercial zirconium oxide probe, (Philips) were done both in steady state, with varied excess air and over cyclic oepration. The unit performed very well, even with extremely high smoke numbers and, in cyclic operation responded within seconds of startup. Agreement with a conventional paramagnetic analyzer was essentially exact.

The unheated automotive sensor located in the upper part of the combustion chamber also performed well in steady state, producing a stable, repeatable output signal, over a wide excess air range. Because of the uncertain temperature field at the sensor attempts to convert the output voltage to oxygen concentration, using the standard equation for this sensor did not produce good agreement with the external, paramagnetic analyzer. Over cyclic operation the sensor required almost 10 minutes of firing to reach a steady output signal and in many cases this would be a major drawback of this very low cost approach.

The heated automotive type sensor located in the flue performed better than the unheated unit. Excess air based on the sensor output voltage was close to the actual excess air and this is ilustrated in Figure 6. In cyclic operation a steady output signal was obtained within one minute.

The optimal emission spectra from oil flames consists of two primary parts. The dominant part is a continuous emission which is related to black body emission at the flame temperature. The second part is emission in narrow wavelength bands due to specific species (e.g., OH, CO_2, CO). The combined spectrum is generally illustrated in Figure 7 (for illustration only, not data). Figure 8 shows a typical example of spectral intensity data taken over the UV and a part of the visible range. The peak emission about 310 nm is due to OH. Figure 9 shows the variation of the continuum intensity at 600 nm with excess air. Smoke numbers over this range varied from 0 to 9 Bacharach. In Figure 10 the ratio of intensities 600/400 nm is shown as a function of excess air. The two wavelengths chosen (600/400) are near opposite ends of the visible wavelength range and so their ratio is roughly an indicator of "color." The trend shown would be consistent with an increase of source temperature with excess air (black body assumption).

Unlike the continuum emission the OH emission does not decrease significantly with increasing excess air. This suggests that the ratio of a continuum signal to the OH signal would be a useful indicator of air/fuel ratio. Relative to simple continuum intensity this would have the advantage of a reduced sensitivity to partial sightpath blockage and sensor misalignment.

Figures 11 and 12 show the variation in the resistance of a cad cell and PbSe photoconductive cell respectively with excess air. For these tests the photoconductive cells were moved forward in the burner air tube to about 1" behind the retention ring.

The most useful sensor for flame quality is one which would have the same setpoint for any nozzle or combustion chamber. To evaluate nozzle effects series of tests were done with firing rates ranging from 0.5 to 1.0 gph and varied spray patterns. It was found that a single value related to continuum intensity (e.g. cad cell resistance) could be used as a set point. In every case an excess air setpoint near the ideal was produced for each nozzle.

The use of a sensor as simple as a cad cell to indicate excess air or flame quality has obvious cost advantages. To illustrate how such a simple sensor could be used a comparator circuit was assembled which has as output three (LED) lights. These indicate a lean flame, a "correct" flame, and a fuel rich flame based on cad cell resistance. Using these the burner excess air could be set very quickly with a repeatability of $\pm$ 1.5% excess air (about $\pm$ .15% CO_2). In Figure 13 a sketch of the simple comparator circuit used is given. This system (see Figure 14) could be used on any burner as a flame monitor if a trim resistor were added to compensate for the variation in cad cell resistance between burners.

CONCLUSIONS

- For monitoring the condition of the heat exchanger over a heating season cycle peak flue gas temperature was found to be the most useful parameter. Tracking this, using for example a peak hold thermometer, would allow heat exchangers to be cleaned before efficiency has degraded very far.
- Flue gas oxygen sensors perform very well in oil heating systems and these could be fairly low in cost.
- For indicating flame quality, optical methods have been found to be very useful and potentially very low in cost.

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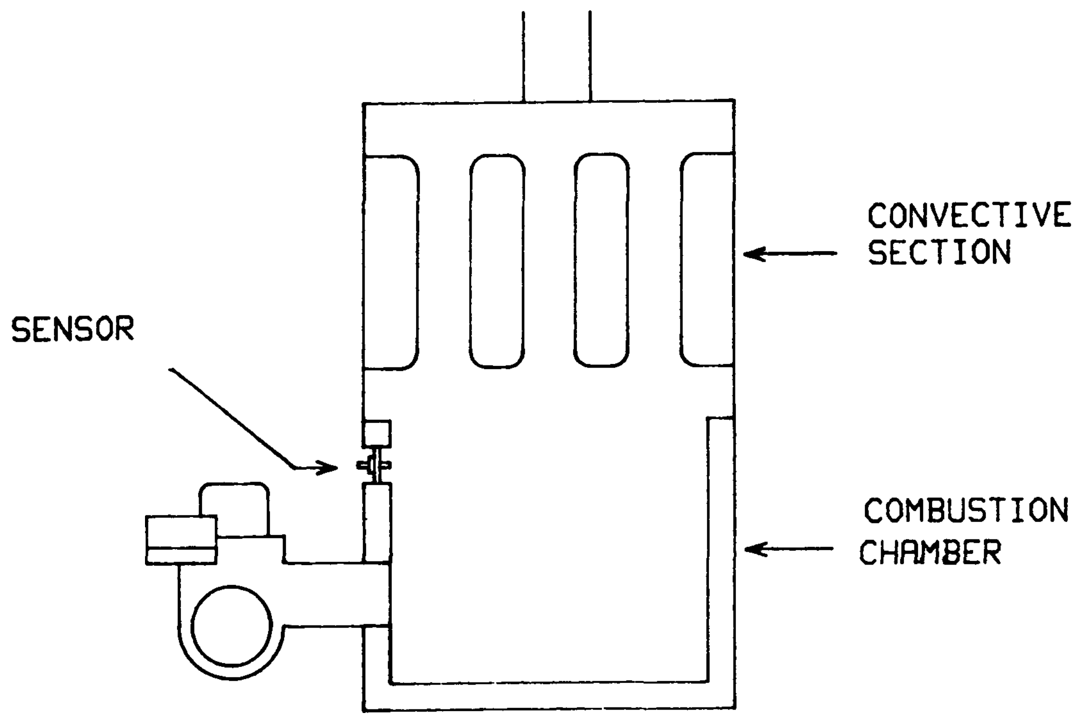

Figure 1. Location of unheated automotive oxygen sensor in the upper part of the combustion chamber.

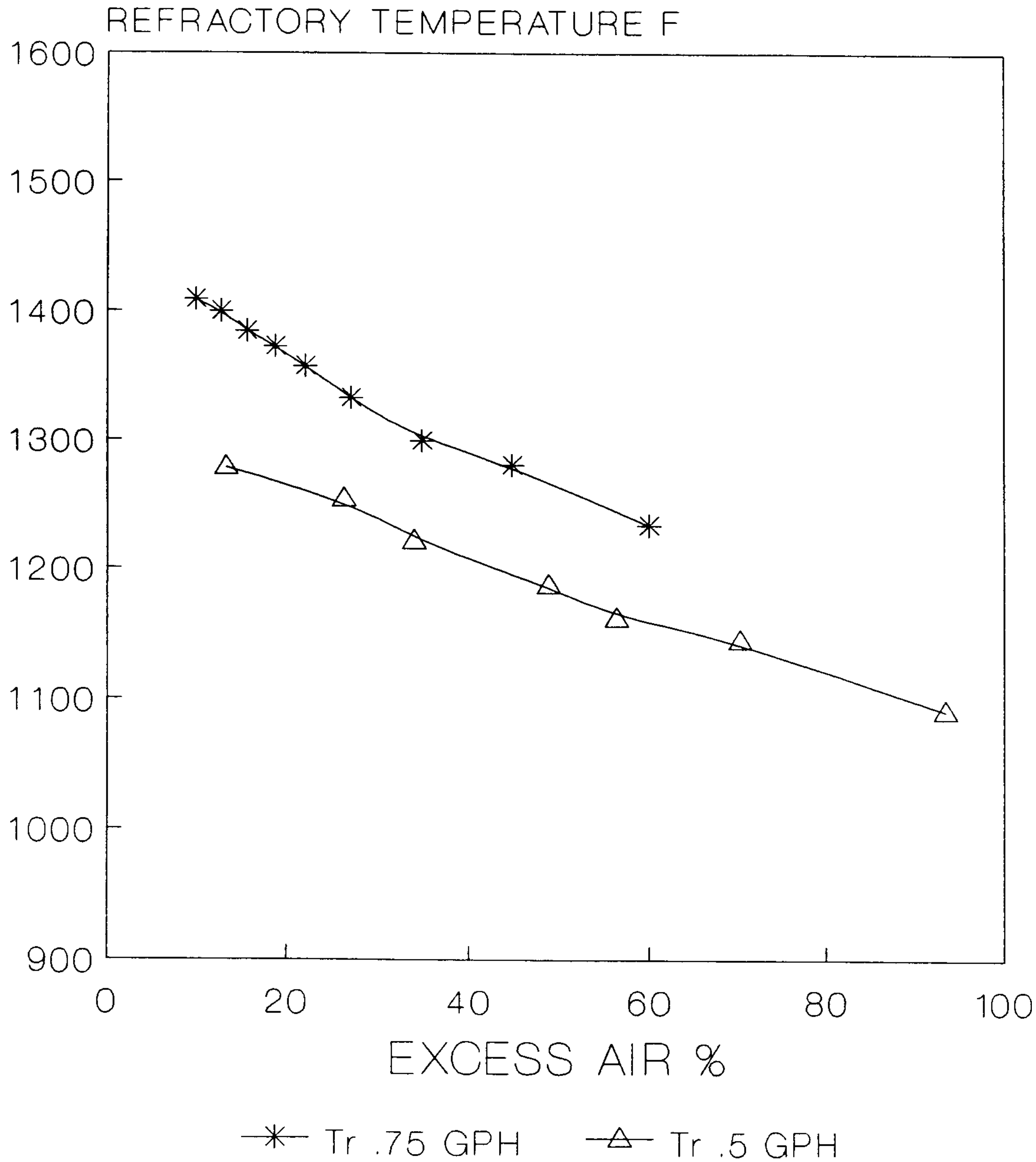

Figure 2. Refractory temperature at the oxygen sensor location. 0.5 and 0.75 gph.

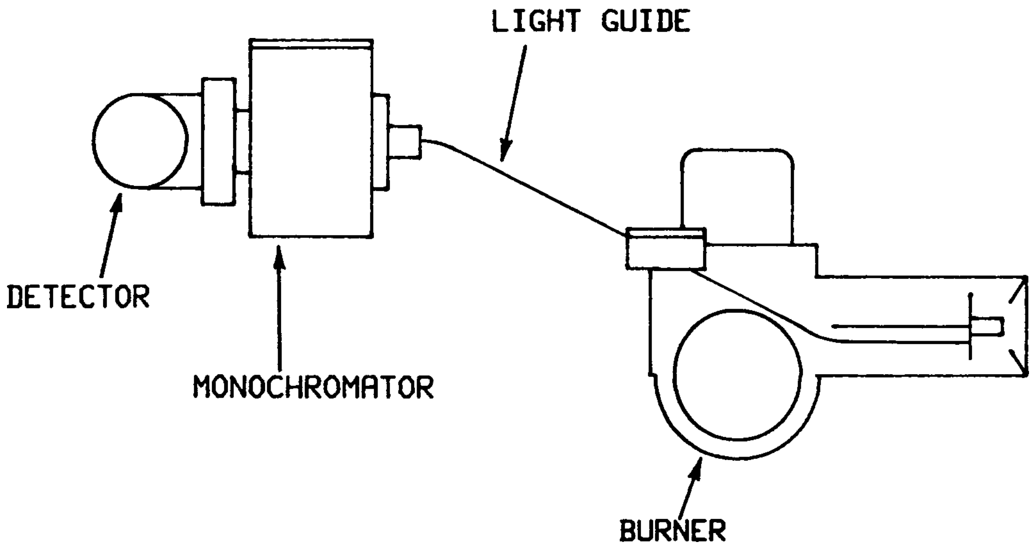

Figure 3. Optical arrangement used for spectral intensity measurements.

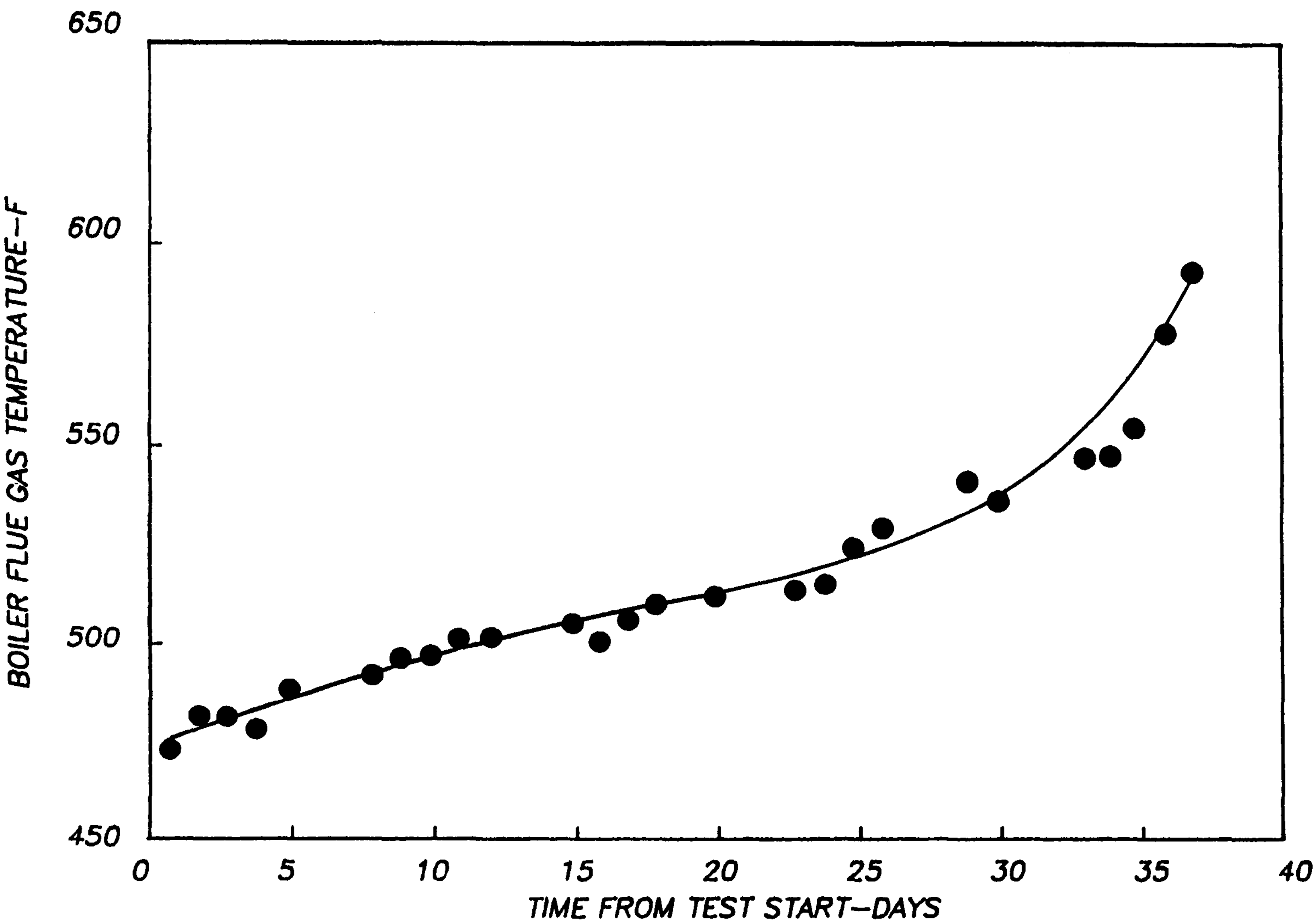

Figure 4. Trend in boiler flue gas temperature (cycle peak) over fouling test period.

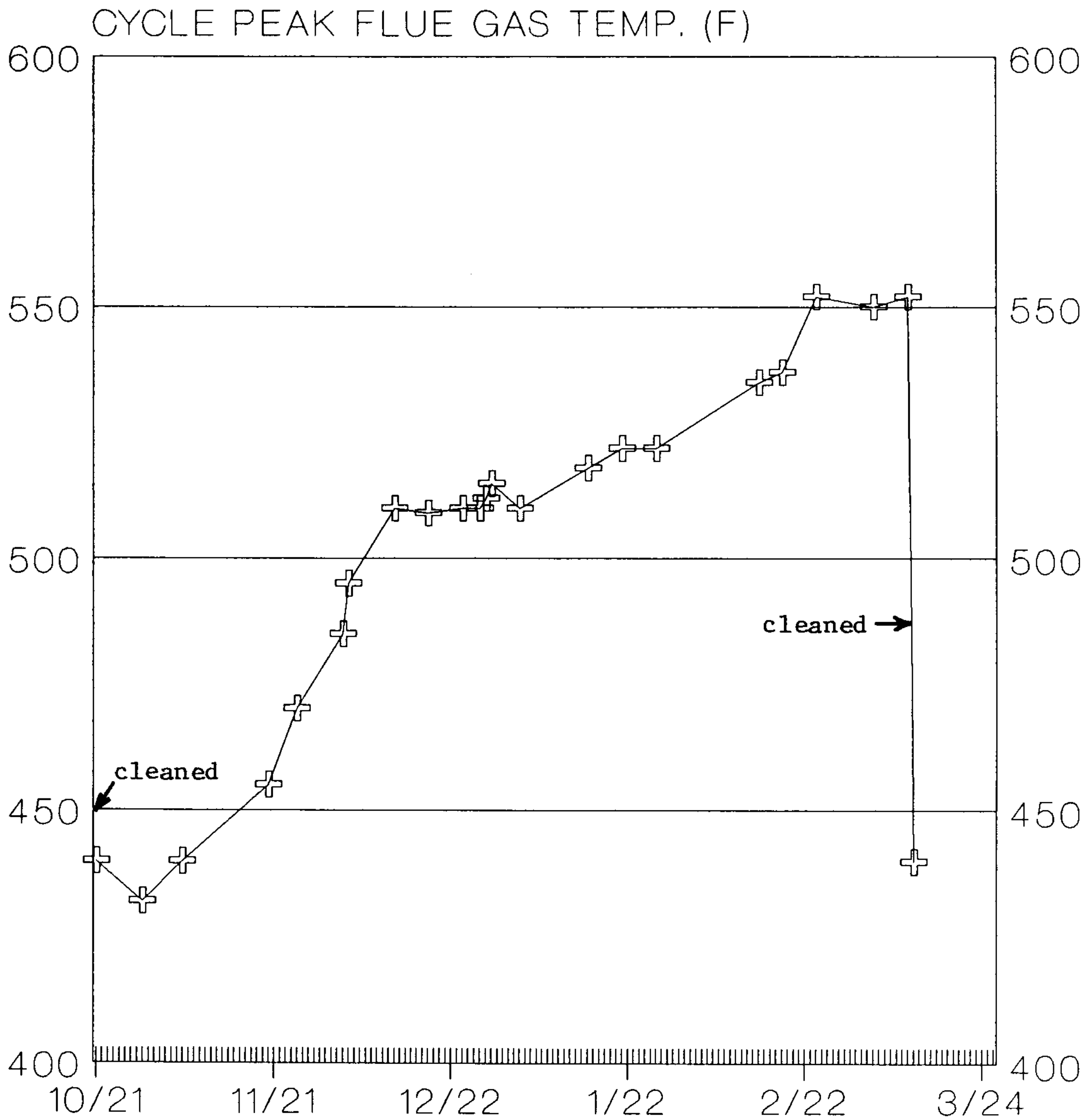

Figure 5. Use of a peak hold dial type thermometer to track heat exchanger fouling between cleanings in a home.

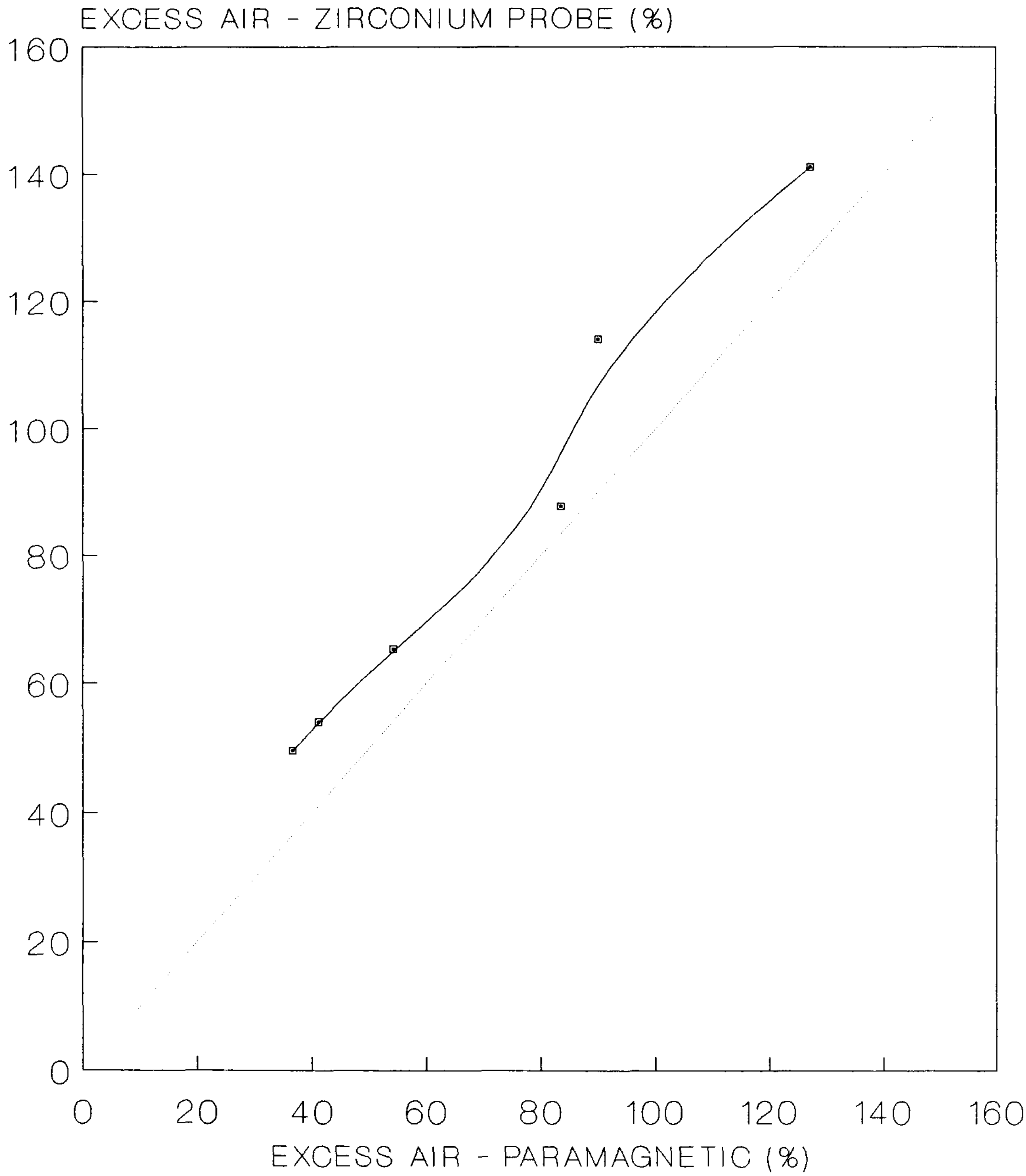

Figure 6. Heated automotive type oxygen sensor. Comparison of excess air with excess air determined using paramagnetic O_2 analyzer.

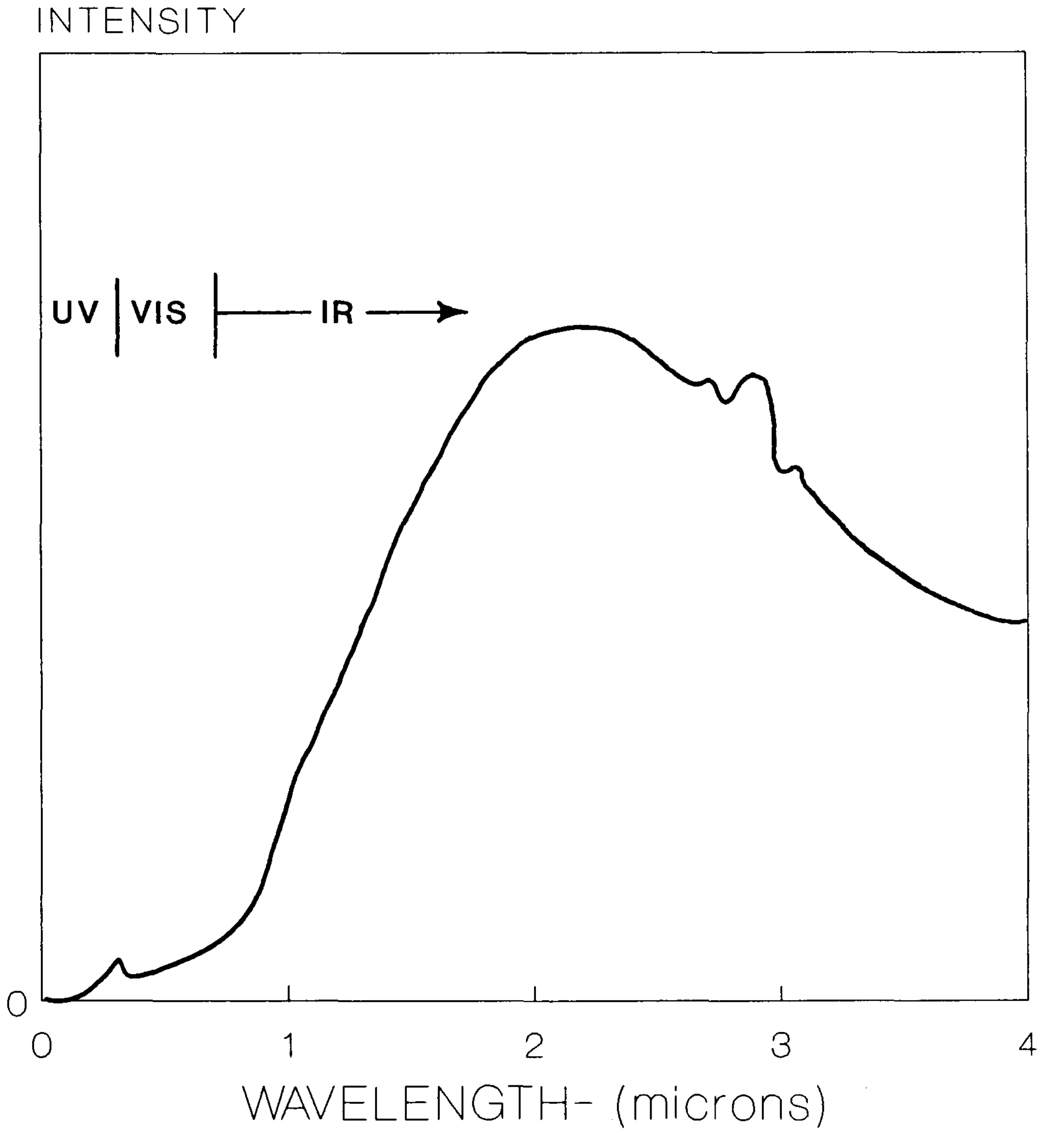

Figure 7. General illustration of an oil flame emission spectra.

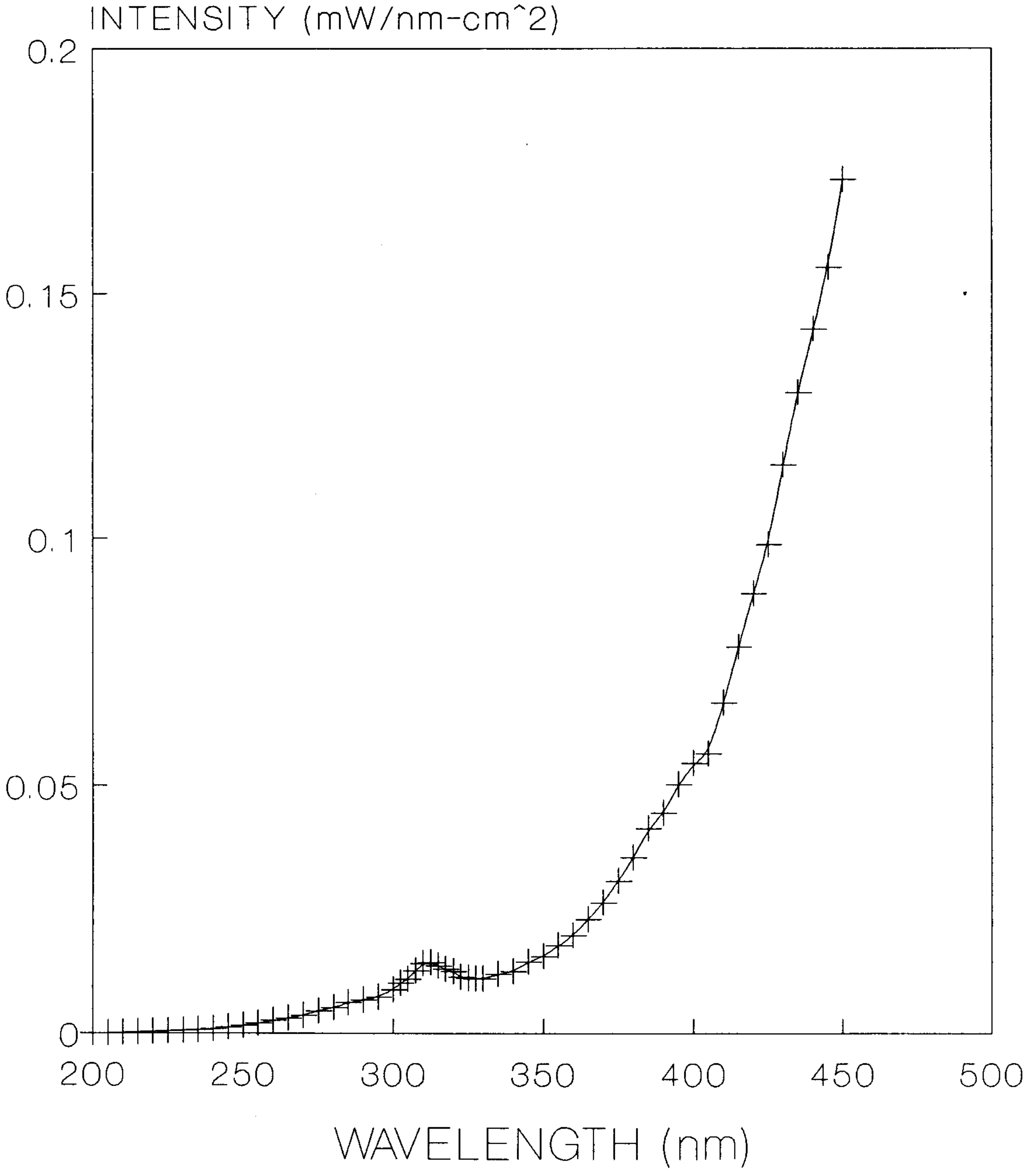

Figure 8. Spectral intensity from an oil flame over the ultraviolet.

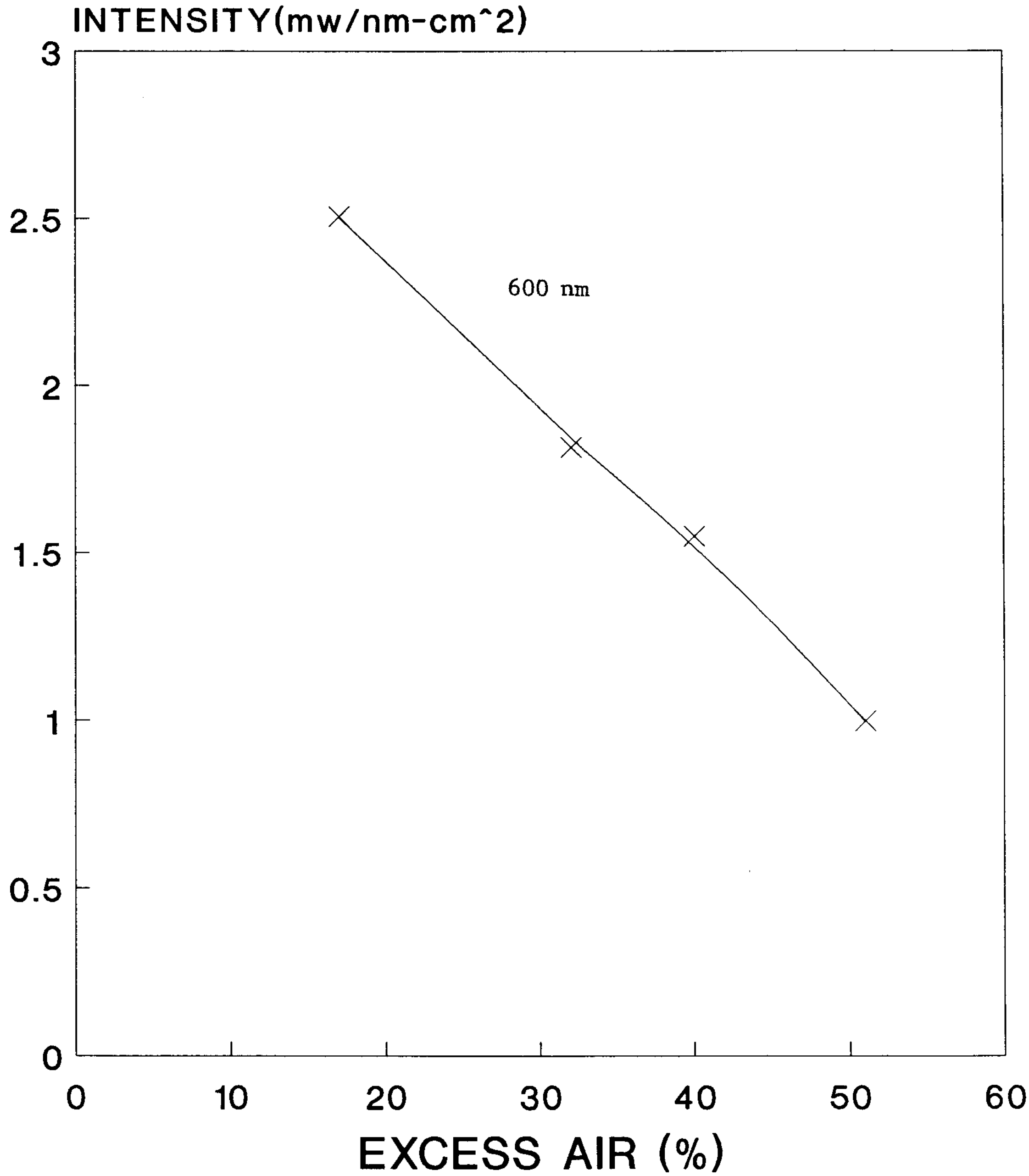

Figure 9. Variation of continuum intensity with excess air (at 600 nm, 1 gph).

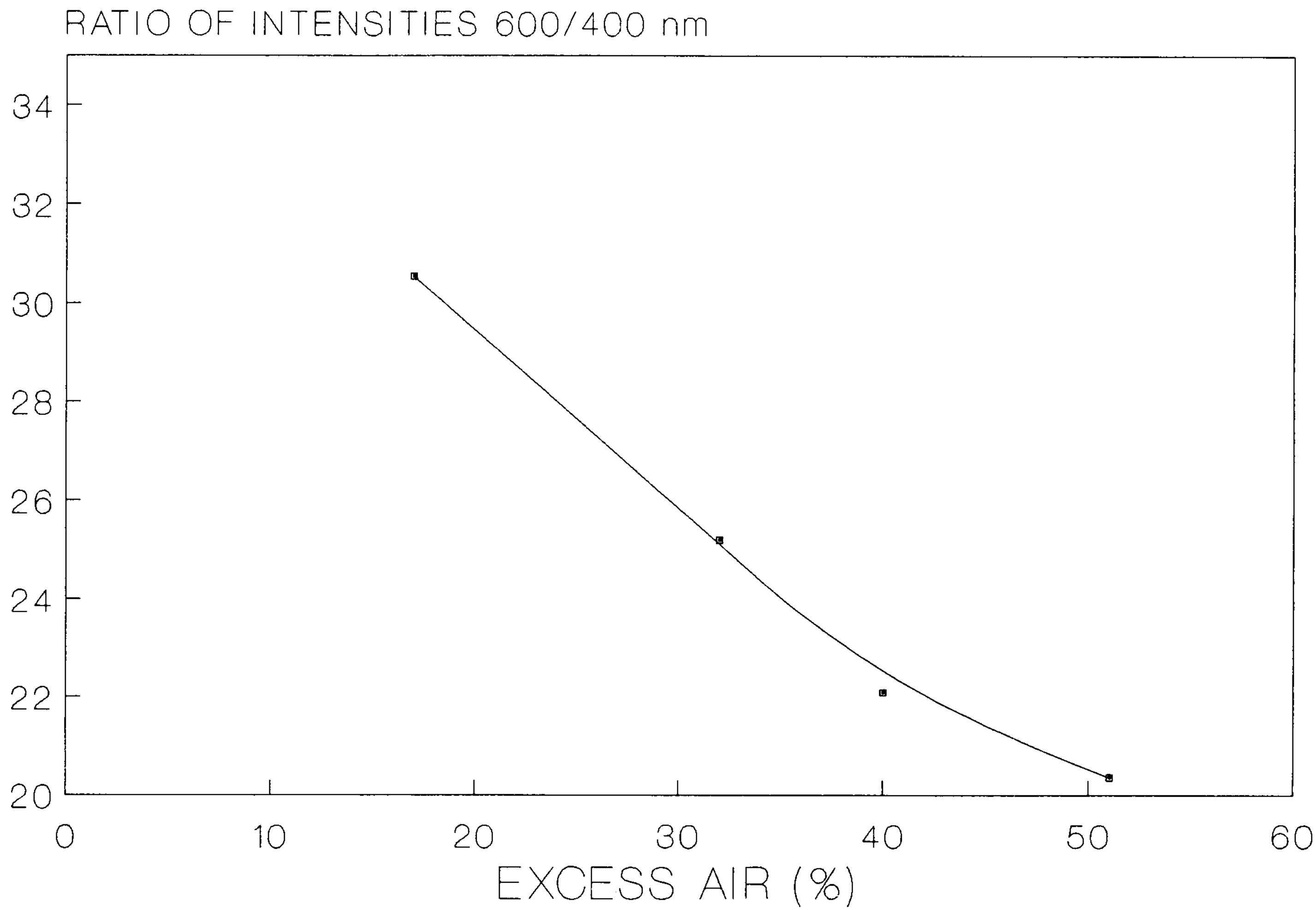

Figure 10. Variation of the intensity ratio (600/400 nm) with excess air.

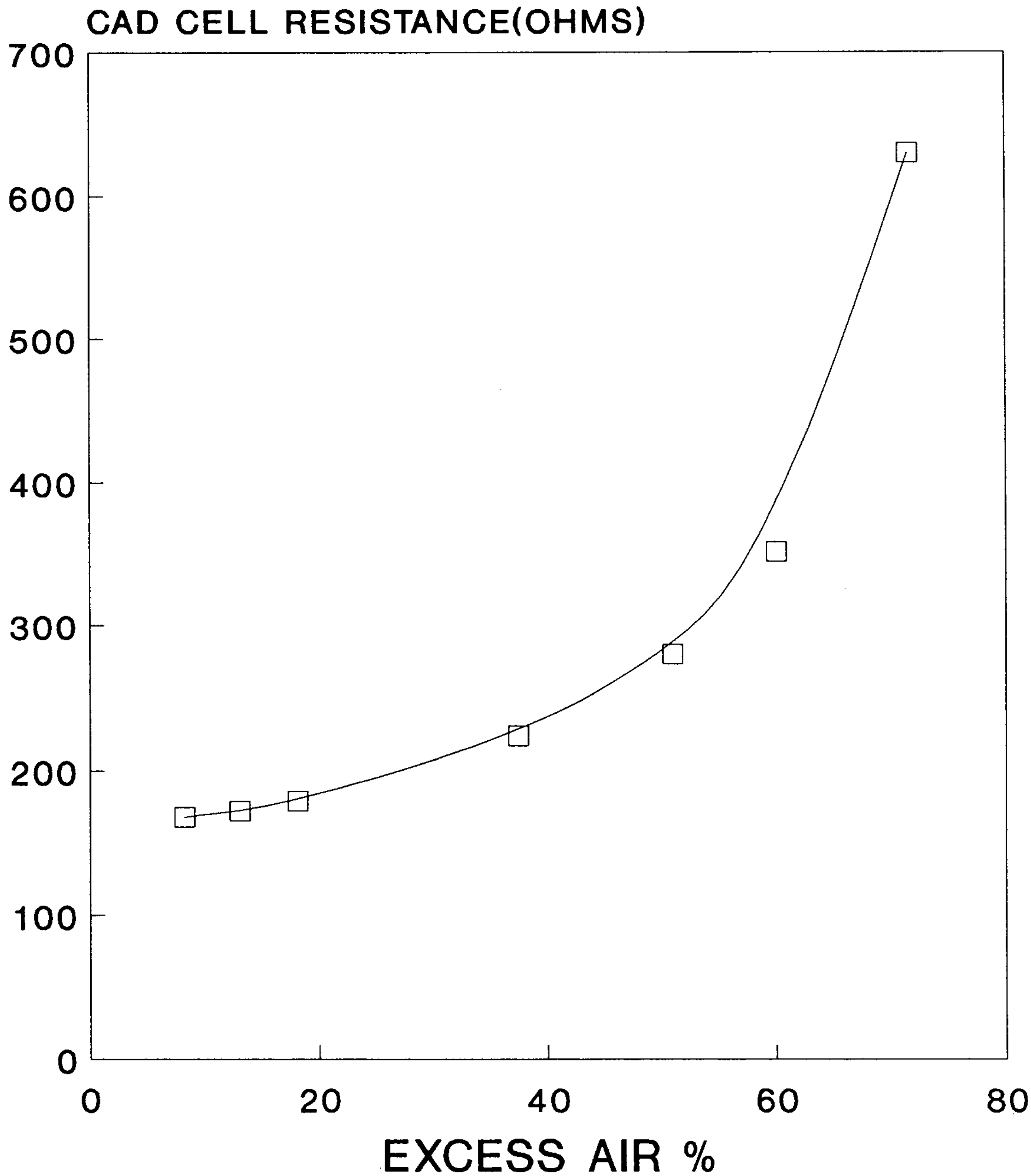

Figure 11. Variation in the resistance of a cad cell located just behind the retention head with excess air.

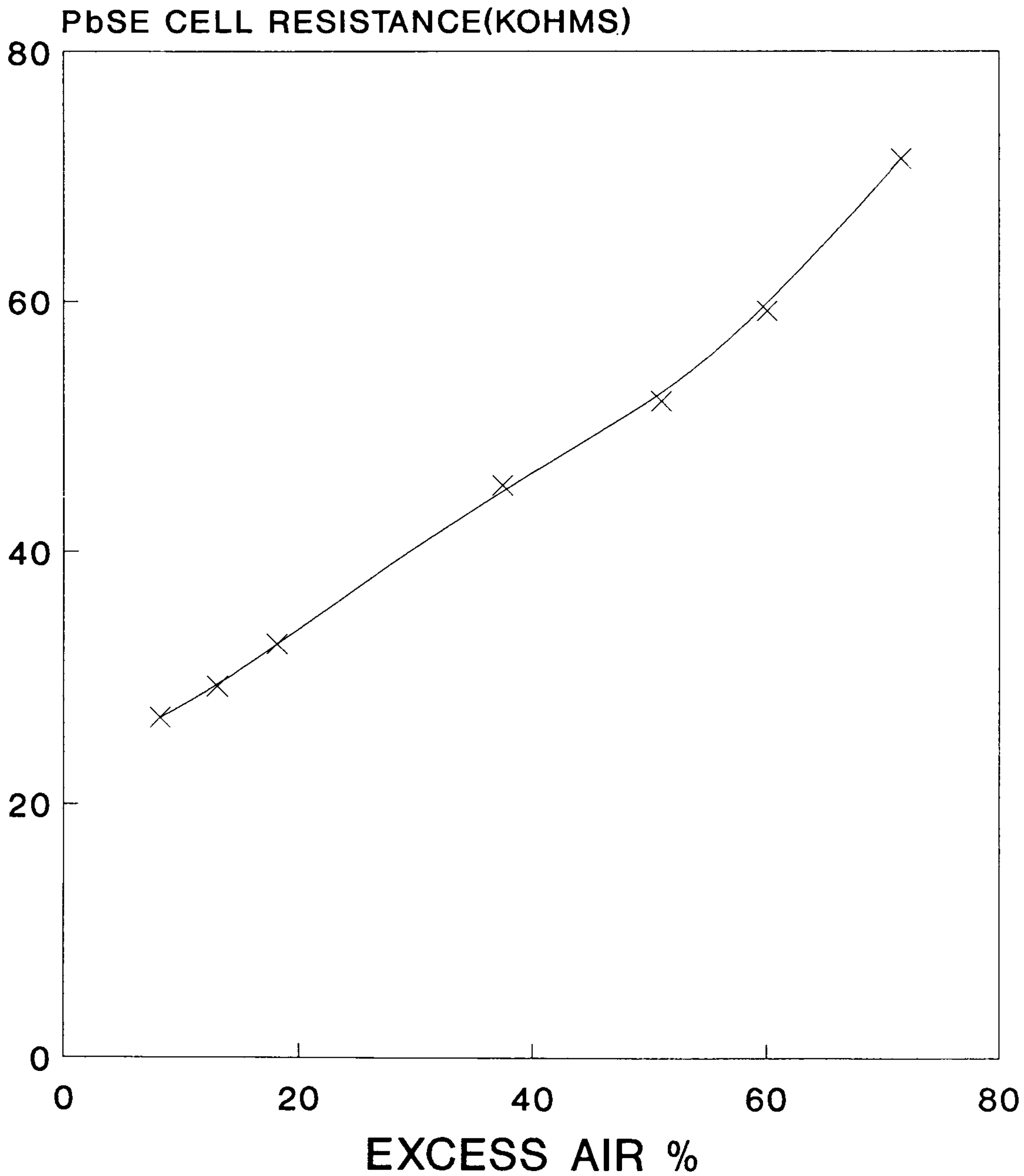

Figure 12. Variation of the resistance of a PbSe cell located just behind the retention head with excess air.

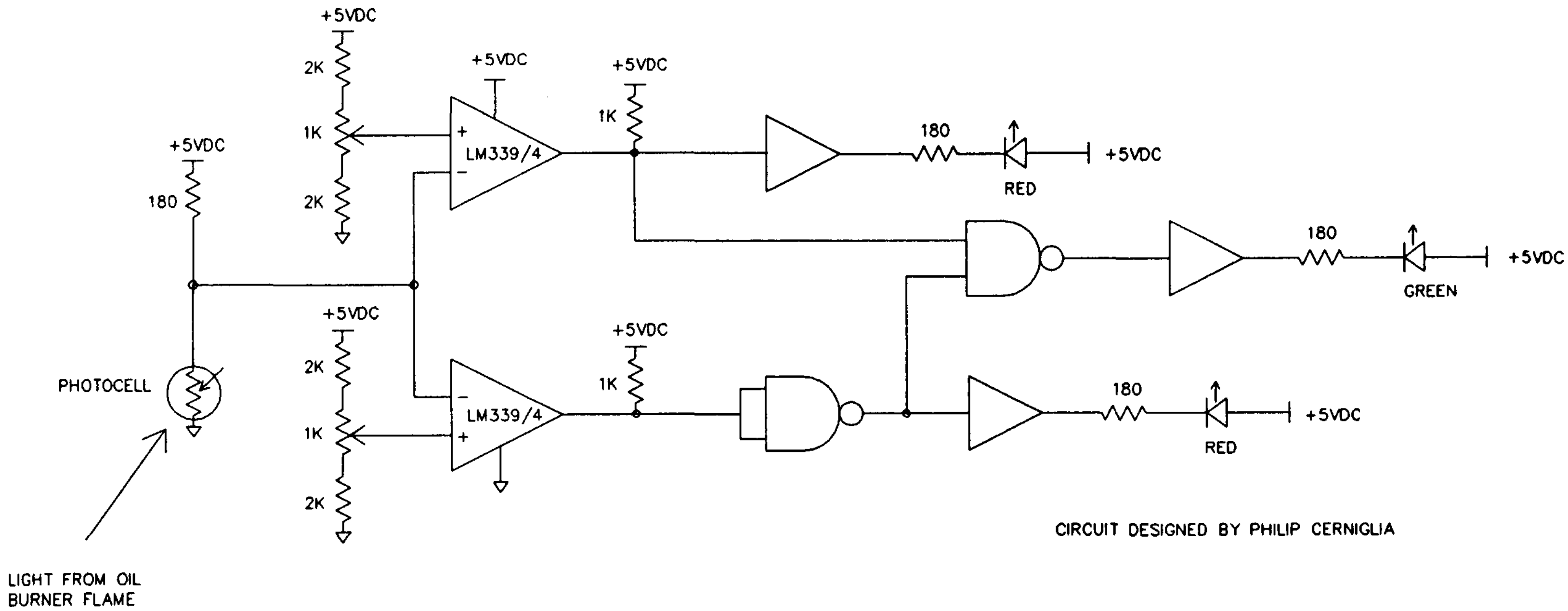

Figure 13. Comparitor circuit used with cad cell to indicate flame quality.

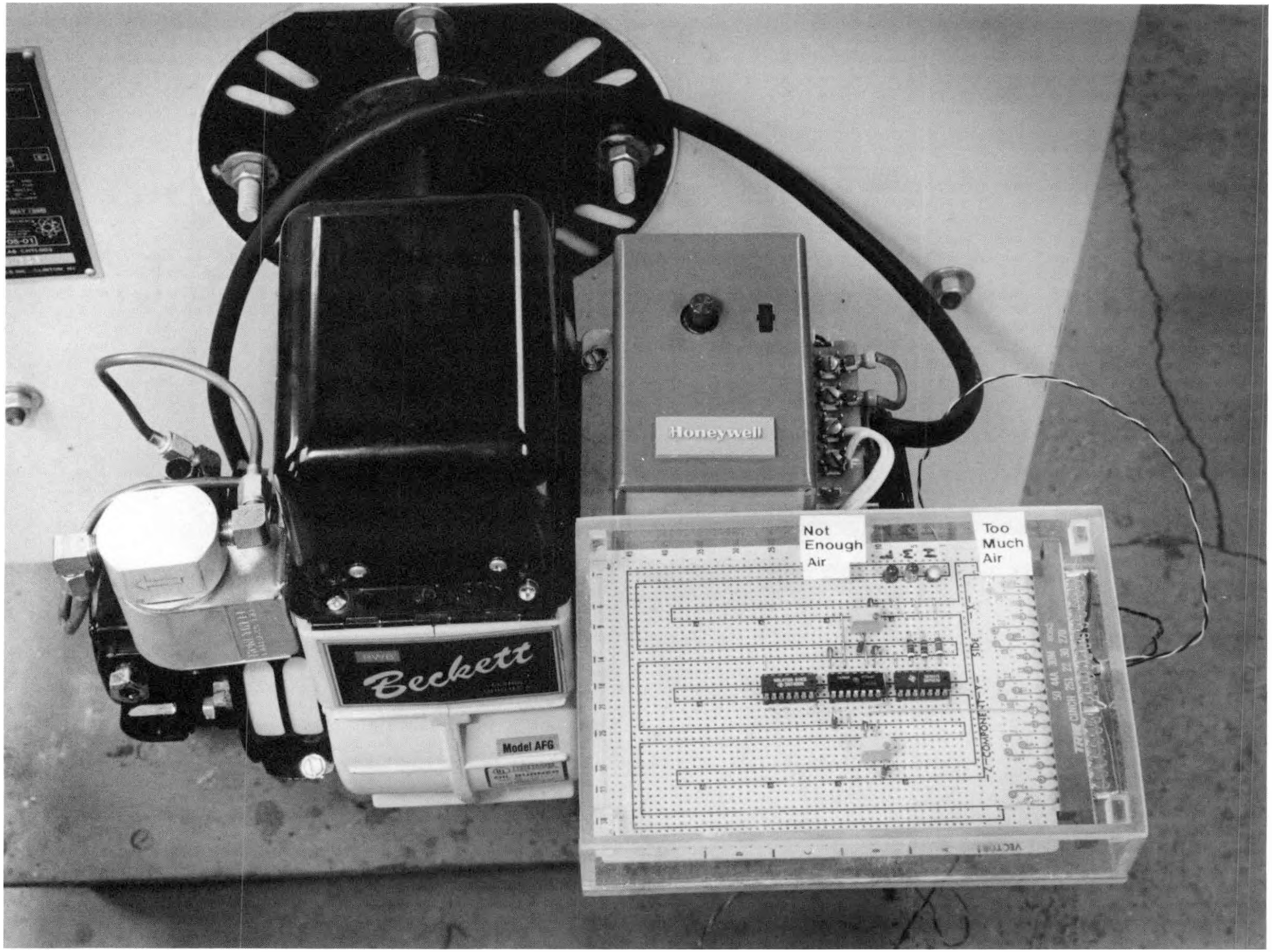

Figure 14. Prototype Flame Quality Monitor System Developed at Brookhaven National Laboratory.

Paper No. 89-3

FUTURE DEVELOPMENT OF ADVANCED OIL HEATING EQUIPMENT AND APPLIANCES

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ABSTRACT

This paper describes the research in progress at Brookhaven National Laboratory towards the development of advanced burner concepts. Results from modeling droplet penetration from atomization measurements and from preliminary testing of air atomized nozzles in burners are presented. The model results show the advantages to be gained from smaller drop sizes and the spray measurements demonstrate that smaller mean drop sizes can be obtained from air atomizers. Burner tests suggest improvement in performance attainable from smaller drop sizes.

SUMMARY

The reduction in the heating requirements of homes through better insulation and lowering of thermostat set temperatures has been spurred by the increasing cost of energy. This makes existing as well as new heating units (boilers, furnaces) built to previous requirements oversized for the load. Because of the cyclic nature of operation of these systems, this leads to significant reduction in thermal efficiency of these systems and hence to increased cost to the user. For this reason, there is a need to develop lower firing rate boilers and furnaces.

Inherent in the use of oil in combustion systems is the possibility of formation of soot. Soot deposition on heat exchanger surfaces results in degradation of heat transfer and hence efficiency. Therefore, there is a need to develop combustion techniques that will minimize or eliminate the formation and emission of soot.

A study of what the above requirements entailed[1] showed the importance of drop size and momentum in drop combustion. A model was developed which incorporated diffusion-limited combustion at different excess air levels and the results of calculations reinforced earlier conclusions on the impact of drop size and initial momentum on the residence time and distance required for complete combustion. It could also be inferred that preheating (by recirculation for example) would not have a significant effect in reducing drop penetration beyond a certain point.

Drop size distributions in sprays from different atomizers were measured using a Malvern laser diffraction particle sizer. The results show that the spray from pressure nozzles have mean diameters that vary with the flow and the design. For two nozzles of similar design, the one with a design flow rate of 0.5 gallons per hour (GPH) had larger mean size than a 1.0 GPH nozzle. The air atomizers could be operated at atomizing air to fuel ratios that give much finer sprays than pressure atomizers at similar fuel flow rates. Soot production is critically dependent on drop size. Hence, there is potential for low soot production by using air atomizers.

The Airtronic burner uses a patented Babington air atomizer. Another burner using a commercial air atomizer and a conventional retention head (without the pressure nozzle) was assembled. Preliminary testing was carried out on both of these. They both demonstrated zero Bacharach smoke numbers during start-up and shut-down in contrast to conventional burners. The work on the development and testing of these burners is being continued.

1.0 INTRODUCTION

The reduction in the heating requirements of homes through better insulation and lowering of thermostat set temperatures has been spurred by the increasing cost of energy. This makes existing as well as new heating units (boilers/furnaces) built to previous requirements oversized for the load. Because of the cyclic nature of operation of these systems, this leads to significant reduction in thermal efficiency of these systems and hence to increased cost to the user. For this reason, there is a need to develop lower firing rate boilers and furnaces.

Inherent in the use of oil in combustion systems is the possibility of formation of soot. This is true of conventional home heating systems as well. Soot produced during combustion deposits on the heat exchanger surfaces (especially in boilers) and results in degradation of heat transfer and hence efficiency. There are other problems (emissions, visibility, etc.) associated with soot as well. Therefore, there is a need to develop combustion techniques that will minimize or eliminate the formation and emission of soot.

A study of the above requirements[1] in the development of residential combustion systems showed the importance of drop size and momentum in drop penetration and the paucity of published information on spray characteristics of even conventional (i.e. pressure) atomizers. During the course of this work the drop motion in a combustion environment was modeled, atomization characteristics of both conventional and air atomizers were measured. Preliminary work has been done towards developing and measuring the particulates emission characteristics of burners incorporating air atomizers.

2.0 DROP EVAPORATION - COMBUSTION MODEL

In the present model, combustion at different excess air levels of a moving drop is simulated in the following way. The amount of fuel in the vapor phase is assumed to burn instantaneously with the stoichiometric amount of oxygen (diffusion limited combustion) and the heat of the reaction is convected into the entire volume of air associated with the drop. Heat loss from the flame can also be taken into account similarly.

Figure 2-1 shows the distance a drop travels before complete burnup. Clearly, the larger drops travel significantly farther before being completely burned. This would suggest that decreasing mean sizes, could make for reduction in soot production as it is primarily a function of the large drops present.[1]

3.0 MEASUREMENT OF ATOMIZATION CHARACTERISTICS

This section describes the work done in evaluating the characteristics of both conventional pressure atomizers and air assist atomizers. The results provide a comparison in performance between different designs and types of atomizers and also a basis for relating to soot formation in burners.

The spray drop-size measurements were made in the Atomizer Test Facility shown schematically in Figure 3-1. All the tests were done under ambient pressure and temperature conditions. The fuel used was primarily ASTM No. 2 fuel oil. To determine the effects of reasonable changes in viscosity of fuel oil, mixtures of glycerine in water were used in a series of tests. Pressure nozzles with design flow rates of 1.0 gph and 0.5 gph were tested. Two types of air atomizers were also tested.

Figure 3-2 compares for two pressure nozzles the mass median diameters (MMD). The nozzles are of the same generic design but rated at flow rates of fuel oil of 1.0 gallon per hour (GPH) and 0.5 GPH. In this case a lower flow rate atomizer has poorer spray characteristics as defined by the mean diameter. This is reinforced by the data in Figure 3-3 which shows that there is a larger fraction of drops over 70 microns in the smaller nozzle.

There are different designs of pressure atomizers available.[4] The data reported in Figures 3-2 and 3-3 are for conical swirl plug nozzles. Another generic design is an atomizer with multiple tangential entry ports.[4] One nozzle each of the two types designed for a nominal flow rate of 0.5 GPH at 100 PSI was tested. Figure 3-4 compares the MMD at three different pressures and indicates that the atomizer with the tangential entry ports gave lower median diameters. It should be emphasized that one cannot generalize on the relative merits of different designs as only one of each type was tested.

There has been some concern[1] that the quality of the home heating fuel oil may deteriorate. One of the properties that could be affected by this change in quality is viscosity. The fuel oil used in the measurements reported thus far had a viscosity of about 3 centipoises. In order to test for the effects of small changes in viscosity of the atomized liquid, mixtures of different percentages of glycerine in water were made up. Such mixtures offer the advantage of changes in viscosity without altering surface tension significantly. These mixtures were sprayed at a nominal operating pressure of 100 psi and Figure 3-5 shows that changing the viscosity from 3 centipoises to 9 centipoises can nearly double the MMD. This is expected with pressure atomization and is in contrast to air atomization as will be shown below.

The two air atomizers selected for testing are an internal-mix commercial design and the unique patented atomizer based on the Babington atomization principle (Figure 3-6). In this design, fuel flows on the outside surface of a hollow sphere. Atomizing air supplied to the inside of the sphere emerges through a slit, ruptures the film of fuel, thus, both atomizing and delivering it to the burner. The fuel supply in excess of what is delivered to the burner is returned to the fuel reservoir. The Airtronic Burner, available commercially in Europe incorporates two such atomizers in each burner.

In previous work[6] on air atomizers, it had been domonstrated that the ratio of atomizing air flow to fuel flow rate was a key variable in controlling the drop-size distribution. The drop size data in Figures 3-7 and 3-8 for the internal mix air atomizer show this dependence. It can be seen, not surprisingly, that very small mean drop sizes can be obtained using such an atomizer.

Figures 3-9 and 3-10 show the drop size data obtained with the Babington atomizer. The flow settings on the figures represent fuel flow rates increasing from 1 to 4 and it is consistent to assume that the air to fuel flow rate ratio decreases. It can be seen that this atomizer's performance is similar to that of the internal-mix air atomizer.

To determine the effects of increasing viscosity, glycerine-water mixtures were tested again in the internal mix air atomizer and the results are shown in Figure 3-11. It is clear that the increase of drop size with viscosity is not very substantial for the air atomizer in contrast to the pressure atomizer. The same conclusion had been reached for a much wider range of viscosity in the earlier work.[6]

4.0 AIR ATOMIZED BURNERS

It is clear that low flow rates can be obtained in air atomized nozzles without compromising quality of atomization as defined by the mean size. Tests on burners using air atomizers are being conducted to evaluate their potential.

The Babington atomizer incorporated into the Airtronic burner will be tested extensively for emission performance. The internal-mix atomizer whose performance was measured and reported above has been incorporated into a conventional retention head burner in the place of the pressure nozzle. This burner, designated the BNL burner hereafter, will also be tested in the same boiler at the Combustion Equipment Technology Laboratory.

The measurements reported here are of a preliminary and scoping nature. They include steady state and transient performances of the two burners at one set of input parameters. The firing rate was constant at about 0.5 GPH and steady state excess air level was about 25% for comparison. Performance of a retention head burner was also measured.

Figures 4-1 and 4-2 show how the gaseous emissions and smoke number in the stack vary with excess air for the Airtronic burner. The performance of the retention head burner is shown in Figures 4-3 and 4-4. Figure 4-5 shows the performance of the BNL burner. It can be seen that, while the performance of all the three burners are broadly similar, the air atomized burners achieve zero smoke number at lower excess air levels. This is consistent with better atomization quality in these burners.

Figures 4-6 to 4-11 show the transient performance of the three burners. In this case, there is a significant difference in the observed performance between the pressure atomized and the air atomized burners. The pressure atomized burner (Figs. 4-8 and 4-9) has significant transient peaks in the emission smoke numbers at start-up and shut-down. In marked contrast, for the air atomized burners (Figs. 4-6 and 4-10) the smoke numbers were practically zero throughout. For the transient carbon monoxide emission, Figure 4-9 shows a significant peak at start up while the air-atomized burners (Figs. 4-7 and 4-11) show both start-up and shut-down peaks. From the contrasting transient performances, it is anticipated that there would be significant differences in soot emission between the conventional and air atomized burners.

5.0 DISCUSSION AND CONCLUSION

The model for drop motion and combustion reinforces the previous conclusion about the importance of drop size and initial momentum to drop penetration. A major conclusion from spray measurements is that the air atomizers give lower mean drop sizes and are less sensitive to viscosity variations than pressure atomizers. The Babington and the internal-mix atomizers show similar drop size distributions.

In preliminary burner testing, it was found that the burners using air-atomized nozzles generally performed better than the conventional retention head burners with pressure atomizers. A major difference was at start-up and shut-down when the air atomized burners showed practically zero Bacharach smoke numbers while the retention head burner showed significant peak values for the smoke number.

Future testing will be carried out to establish the comparative soot emission performance of the burners. The BNL burner will also be used to relate the atomization quality to soot emission characteristics.

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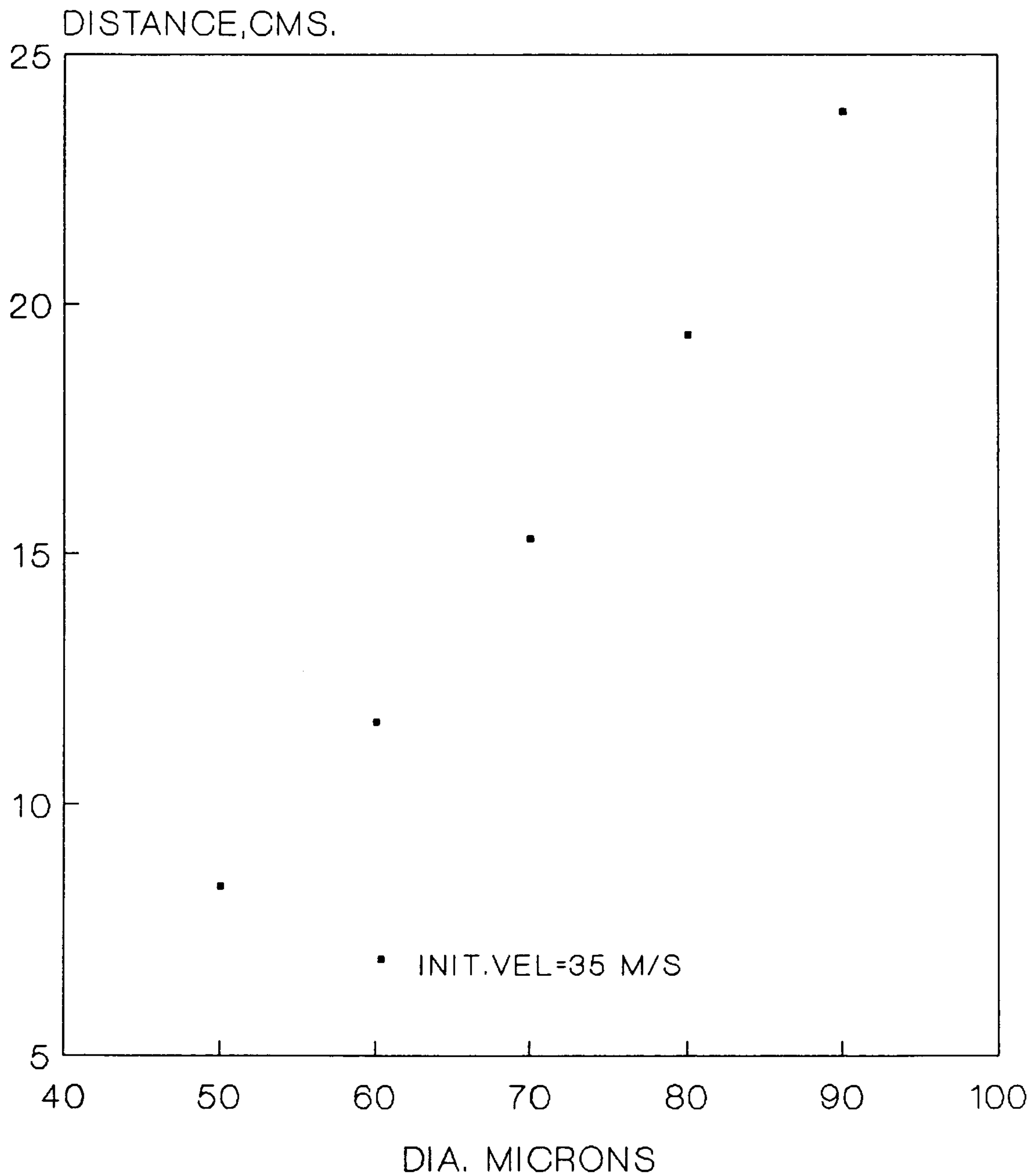

Figure 2-1. Drop Travel as a Function of Drop Size.

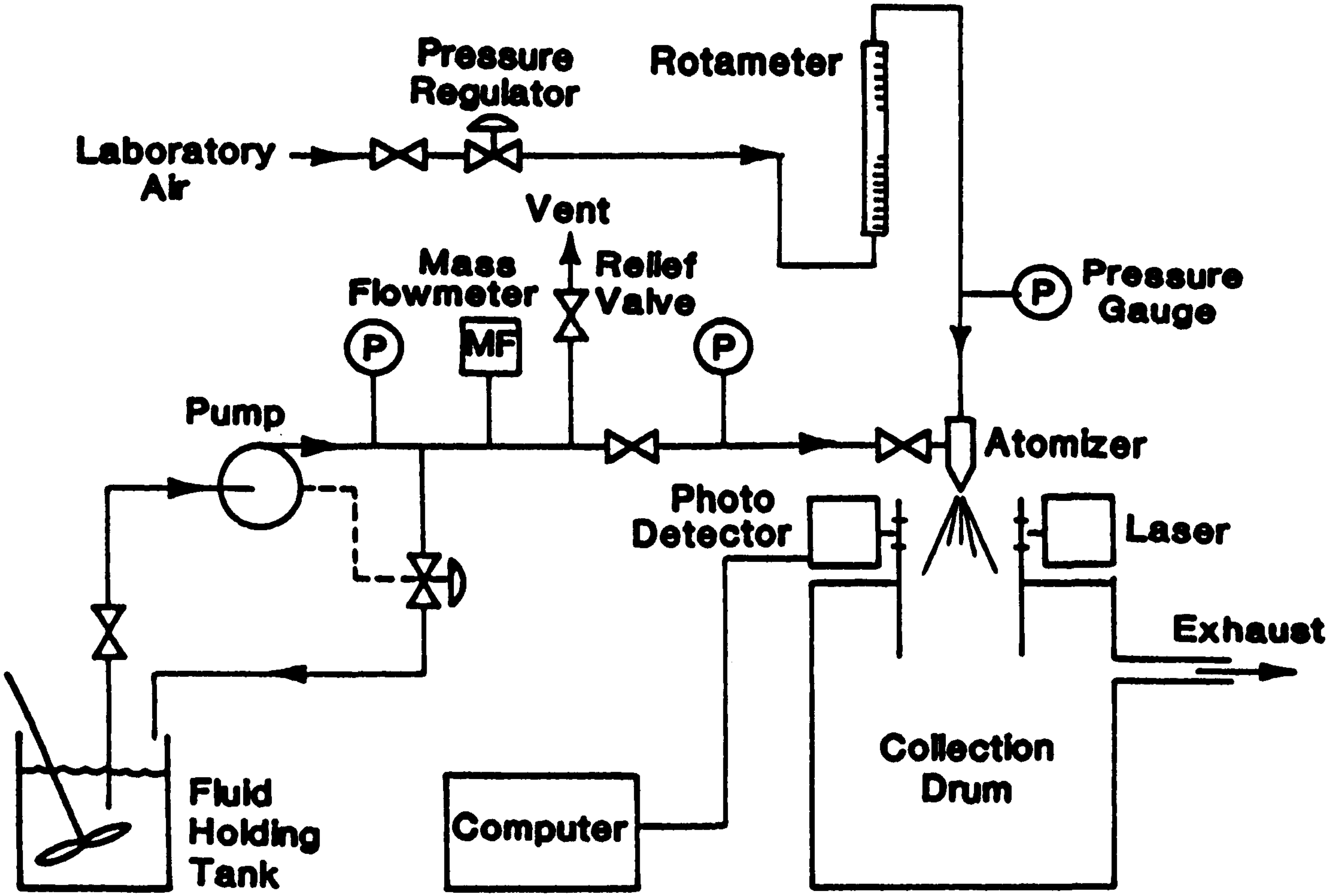

Figure 3-1. Atomization Test Facility.

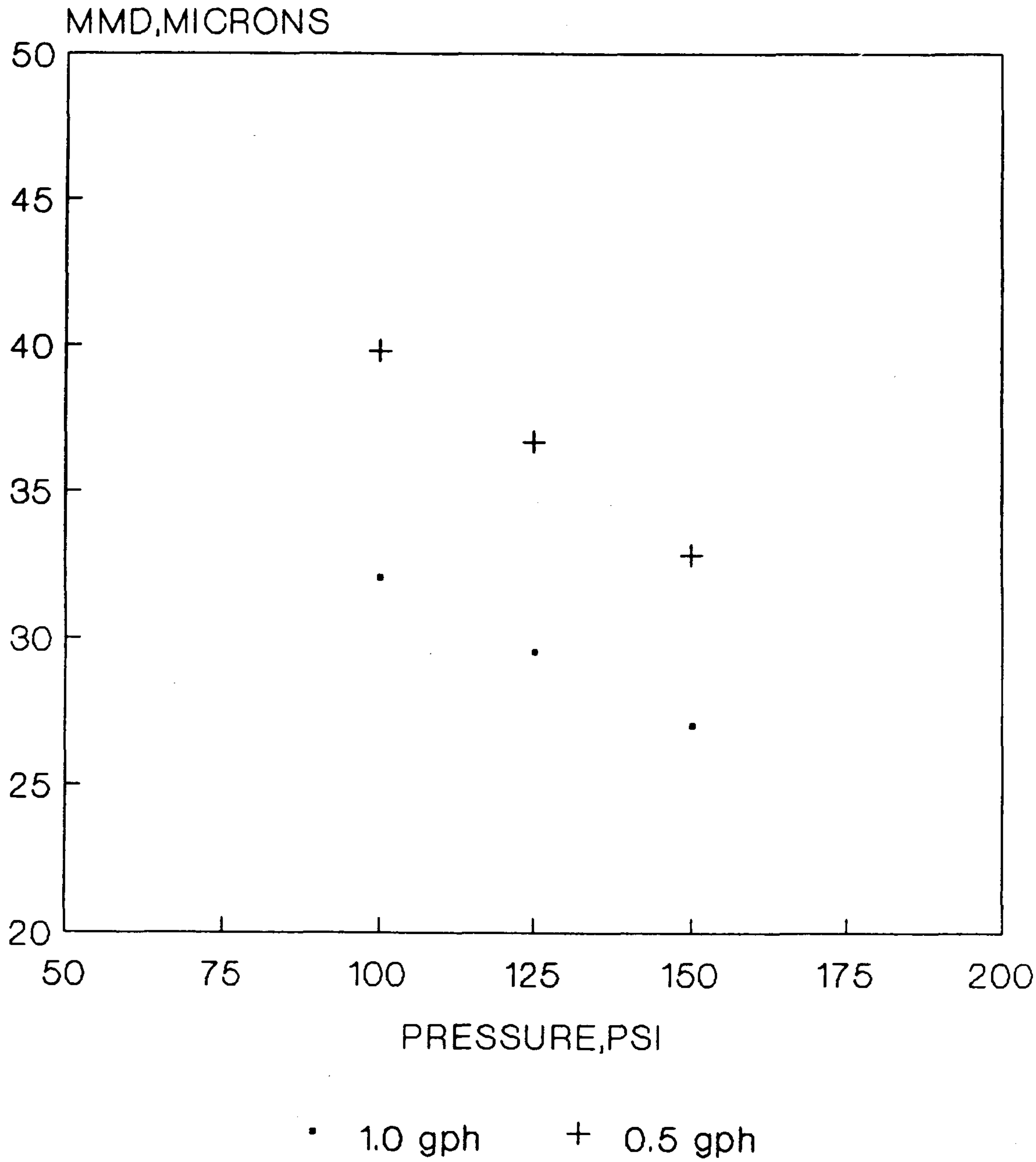

Figure 3-2. Mass Mean Diameter (MMD) as a Function of Pressure for Two Nozzles Designed for 1.0 gph and 0.5 gph Flow Rates.

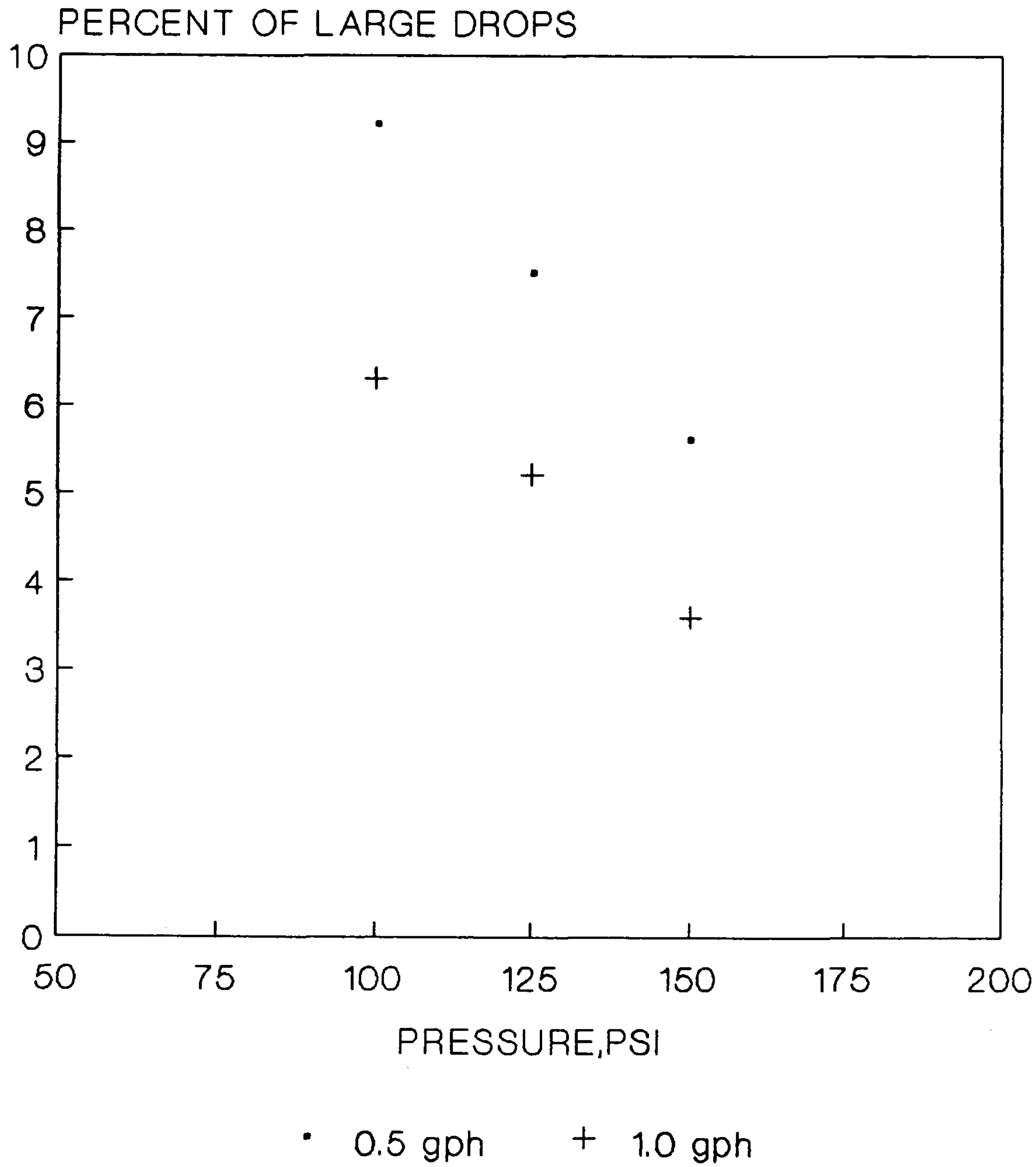

Figure 3-3. Amount of Large Droplets in Sprays from Pressure Nozzles.

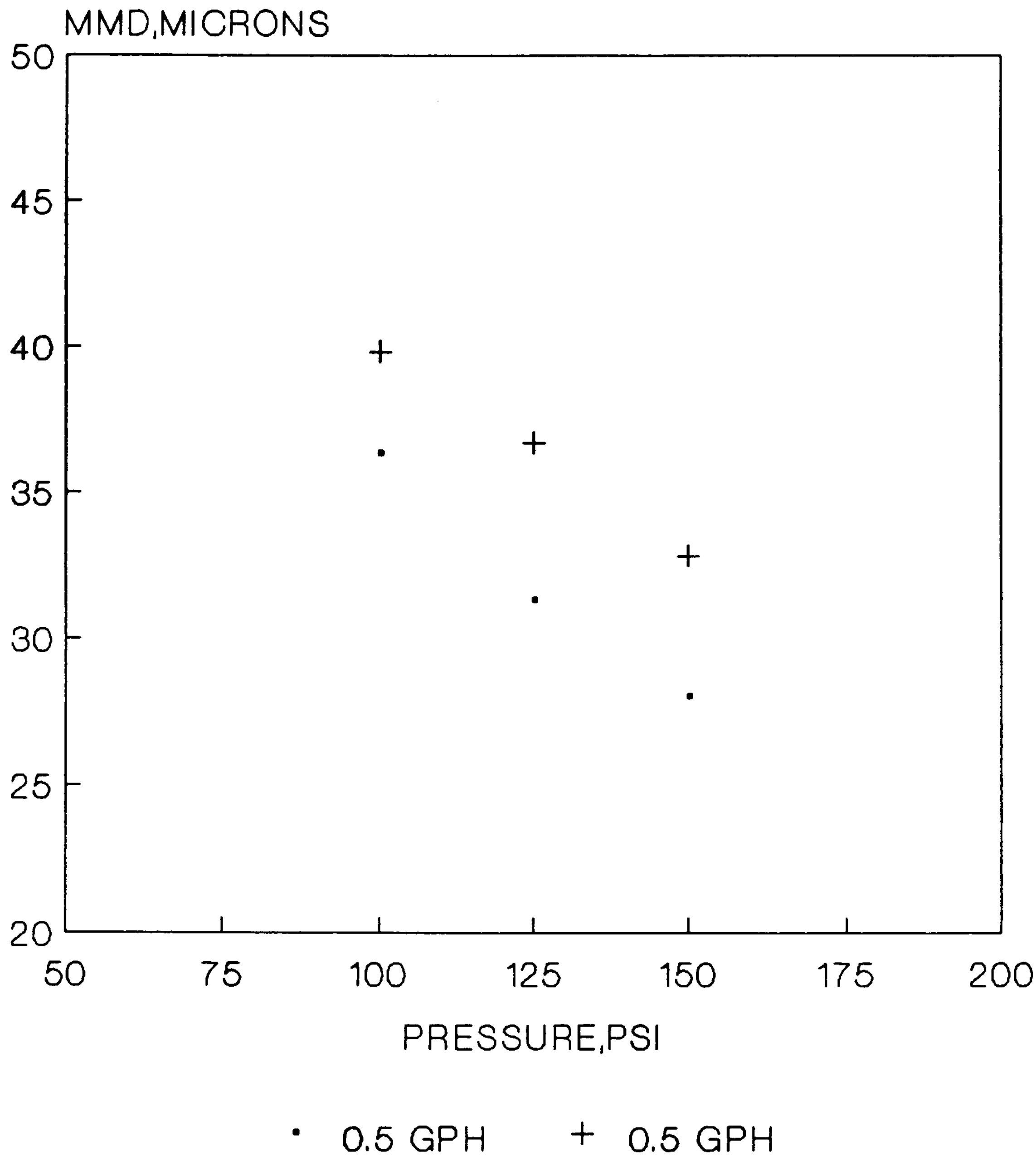

Figure 3-4. Mass Mean Diameter (MMD) as a Function of Pressure for Pressure Nozzles of Different Designs.

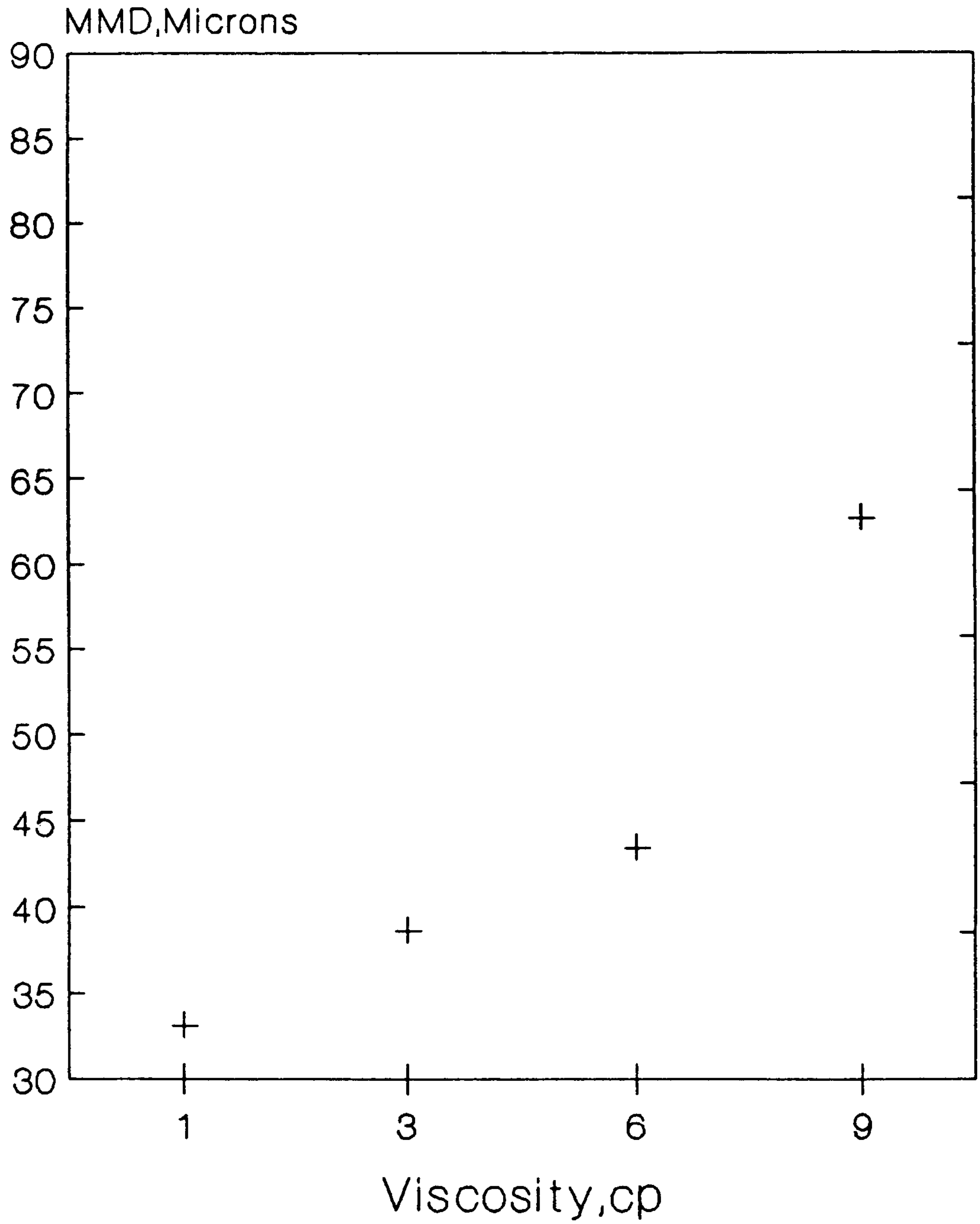

Figure 3-5. Effect of Viscosity on Mean Diameter for Pressure Nozzle.

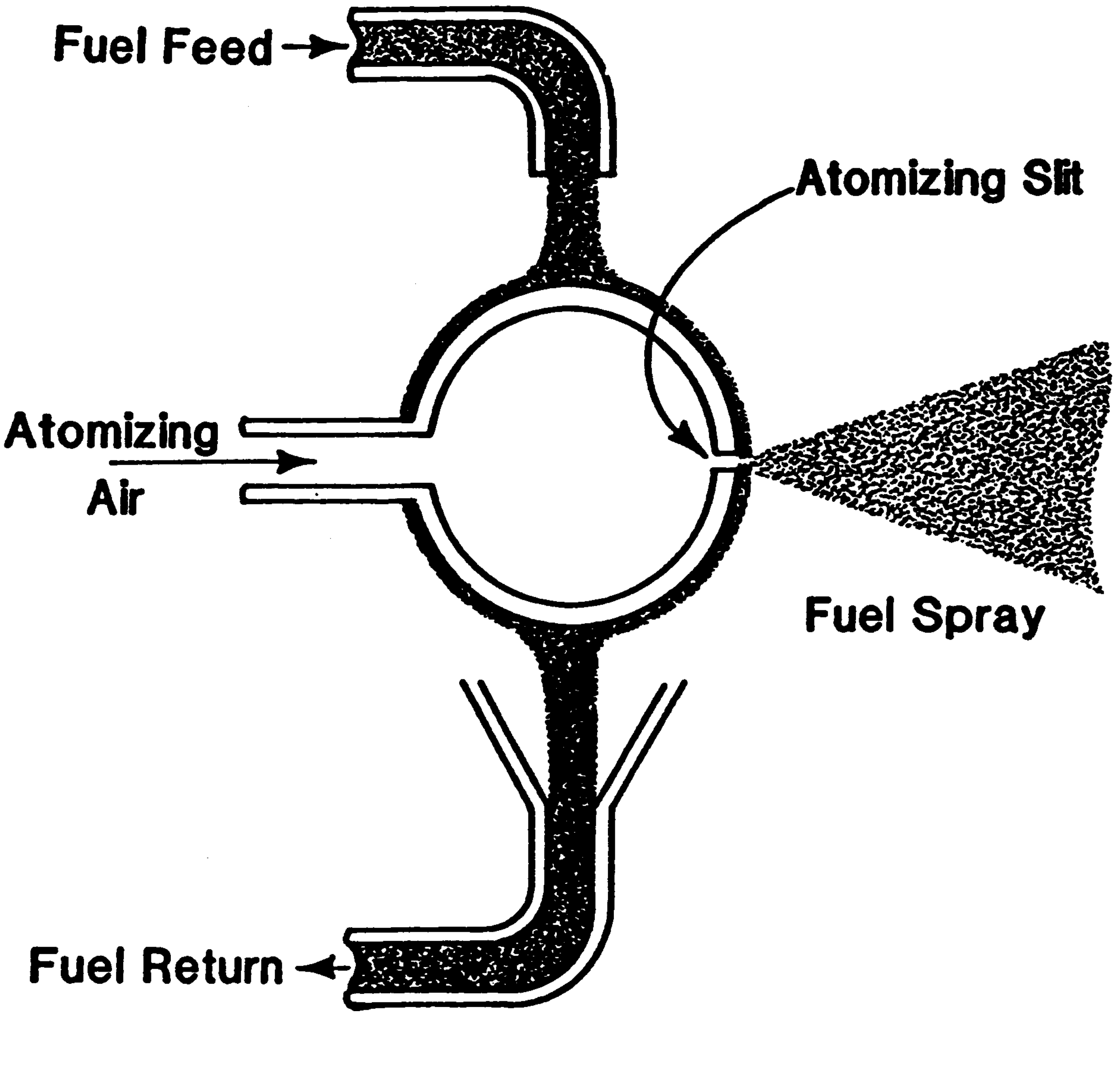

Figure 3-6. Principle of Babington Air Atomizer.

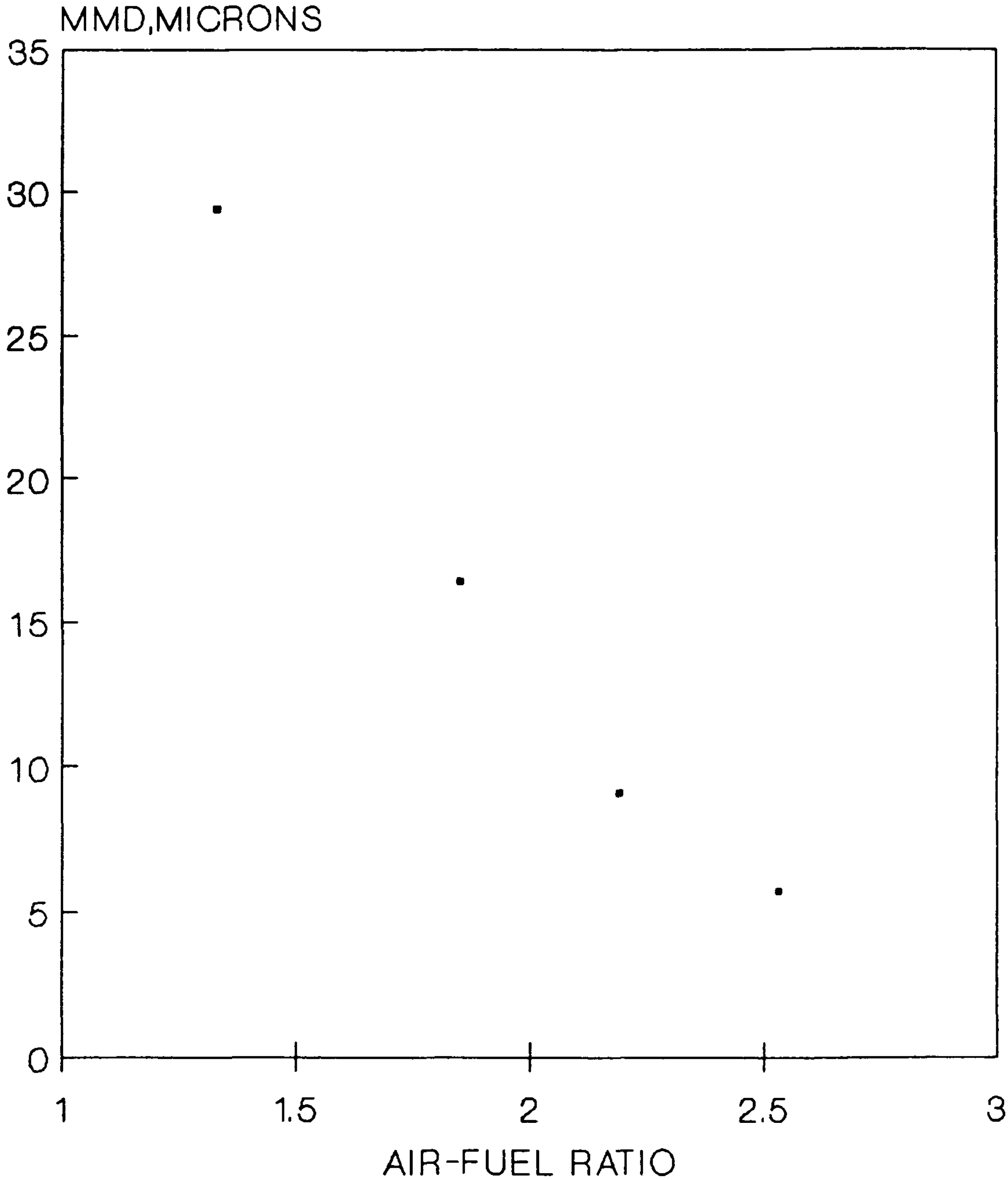

Figure 3-7. Mass Mean Diameter (MMD) as a Function of Nozzle Air-Fuel Mass Ratio for an Internal-Mix Air Atomizer.

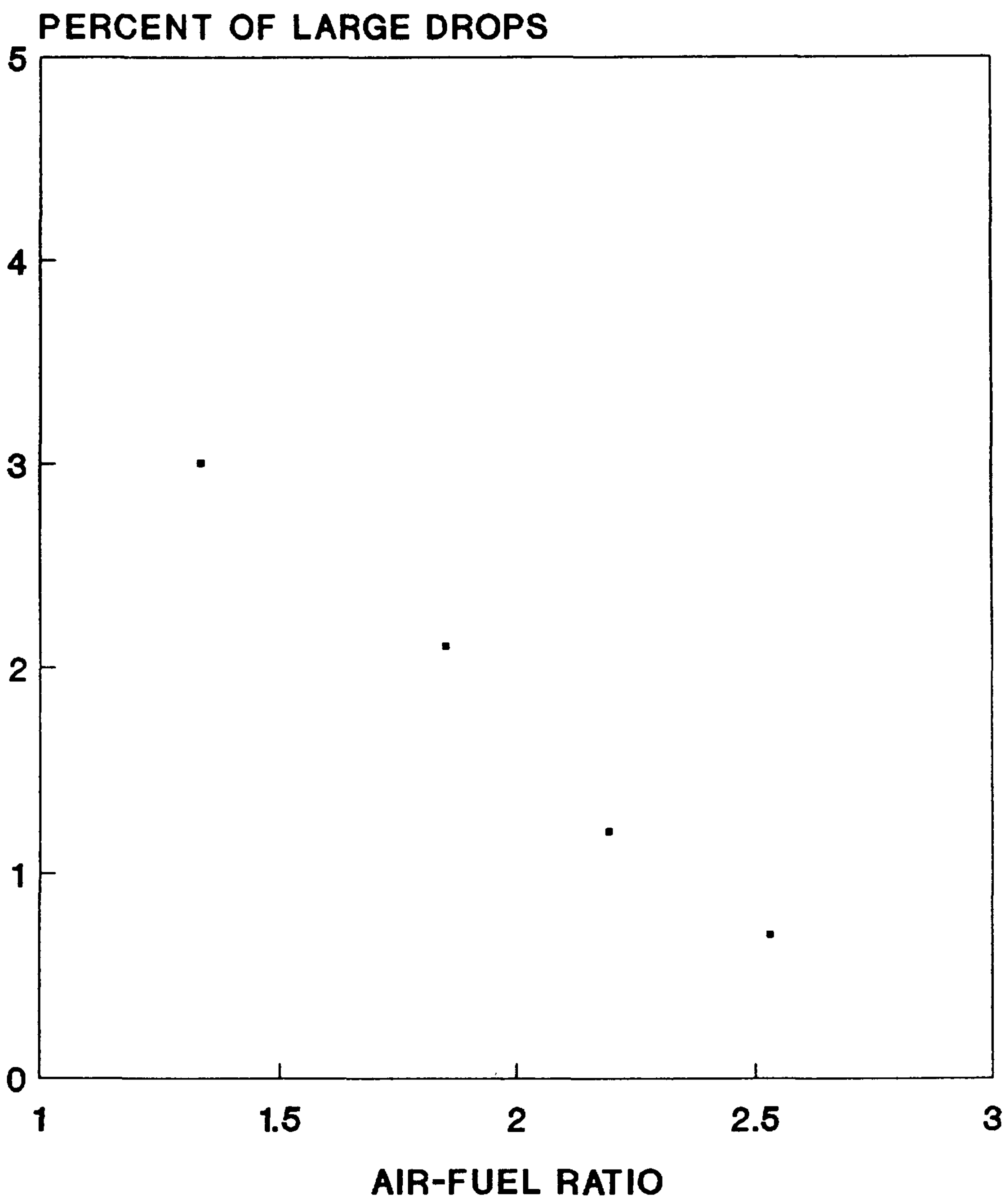

Figure 3-8. Amount of Large Droplets as a Function of Air-Fuel Mass Ratio for an Internal-Mix Air Atomizer.

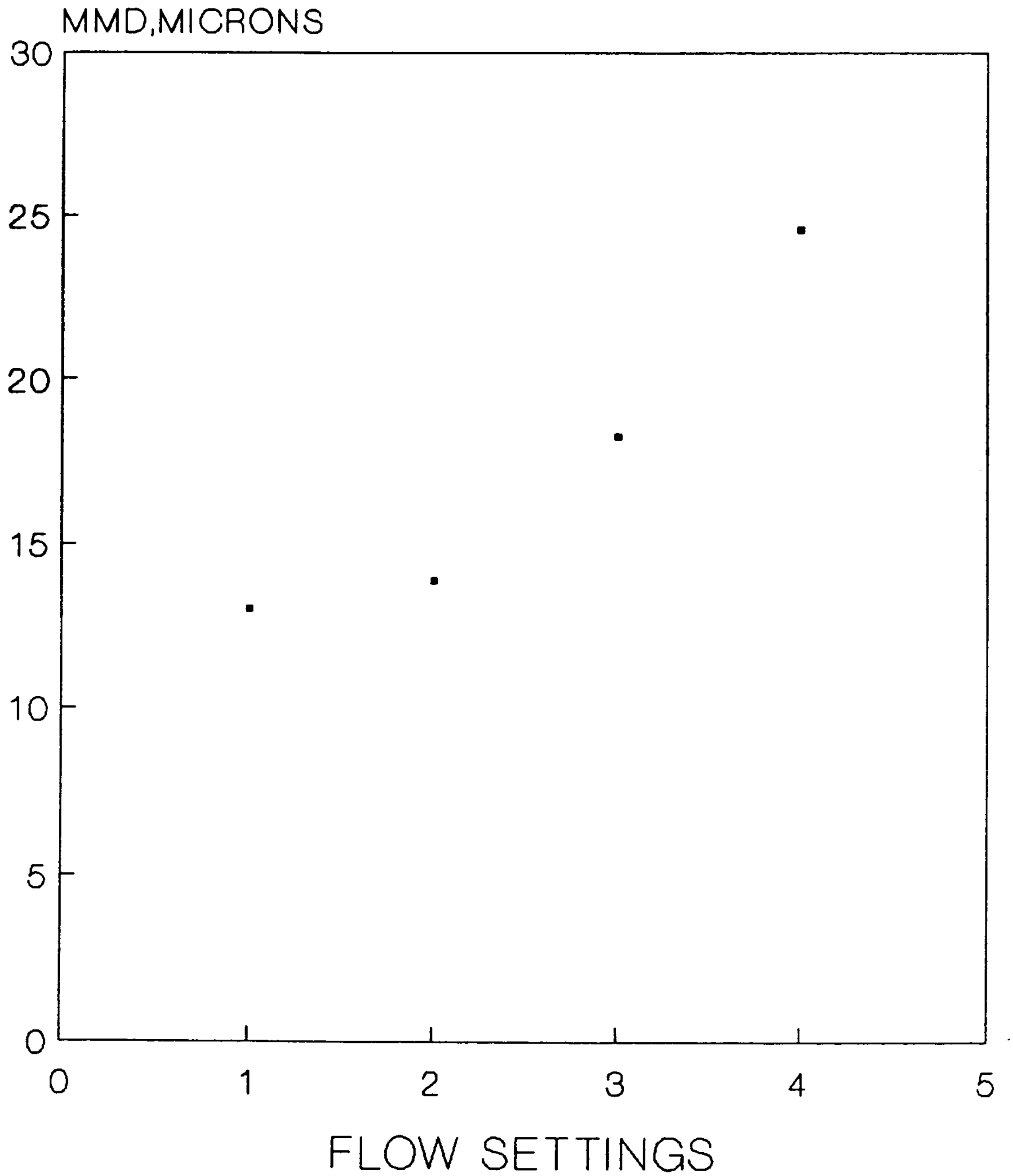

Figure 3-9. Mass Mean Diameter (MMD) for the Babington Atomizer.

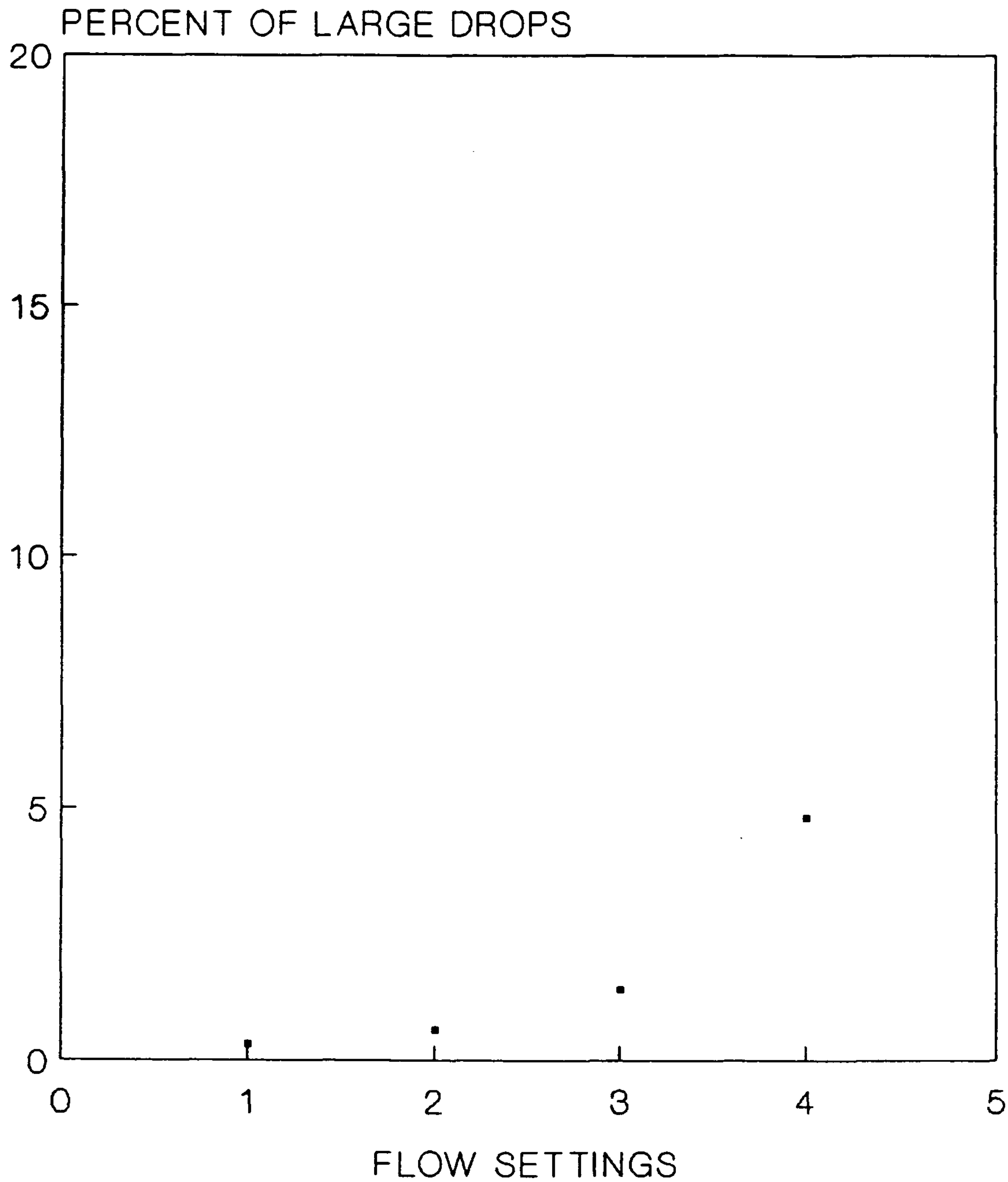

Figure 3-10. Amount of Large Droplets for the Babington Atomizer.

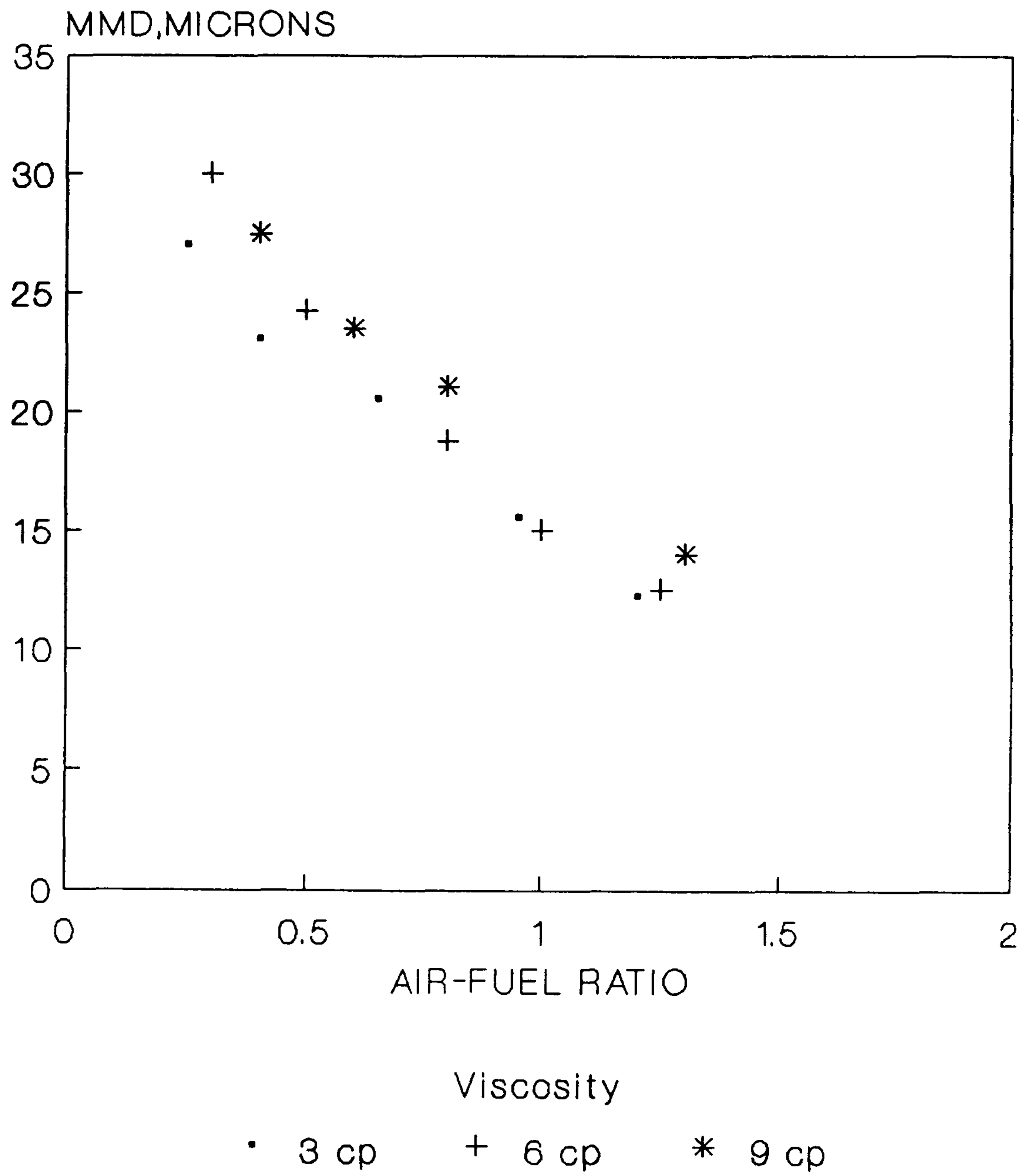

Figure 3-11. Mass Mean Diameter (MMD) as a Function of Viscosity and Atomizing Air-to-Fuel Mass Ratio for an Internal-Mix Air Atomizer.

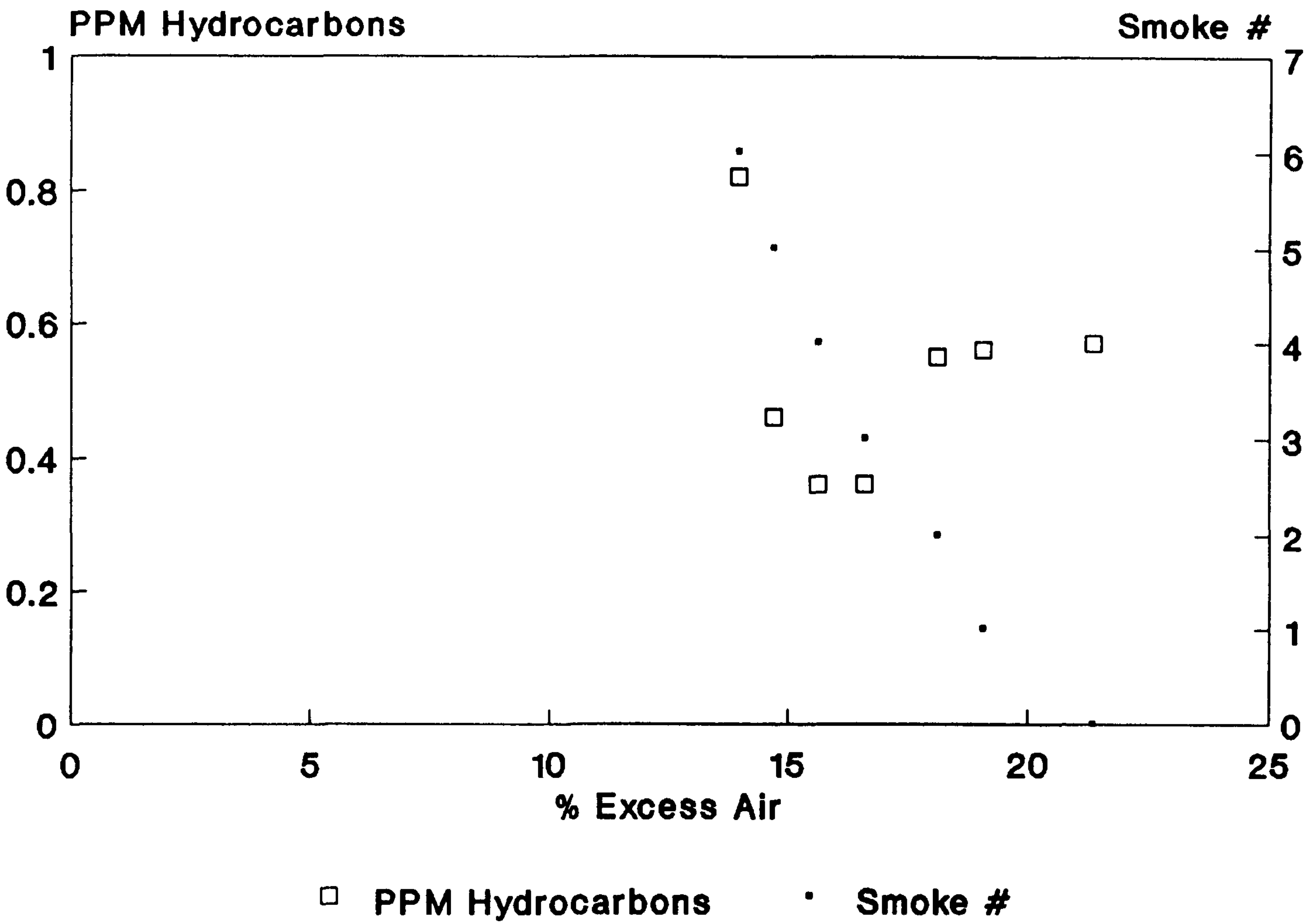

Figure 4-1. Steady State Smoke and Hydrocarbons Emissions of the Airtronic Burner.

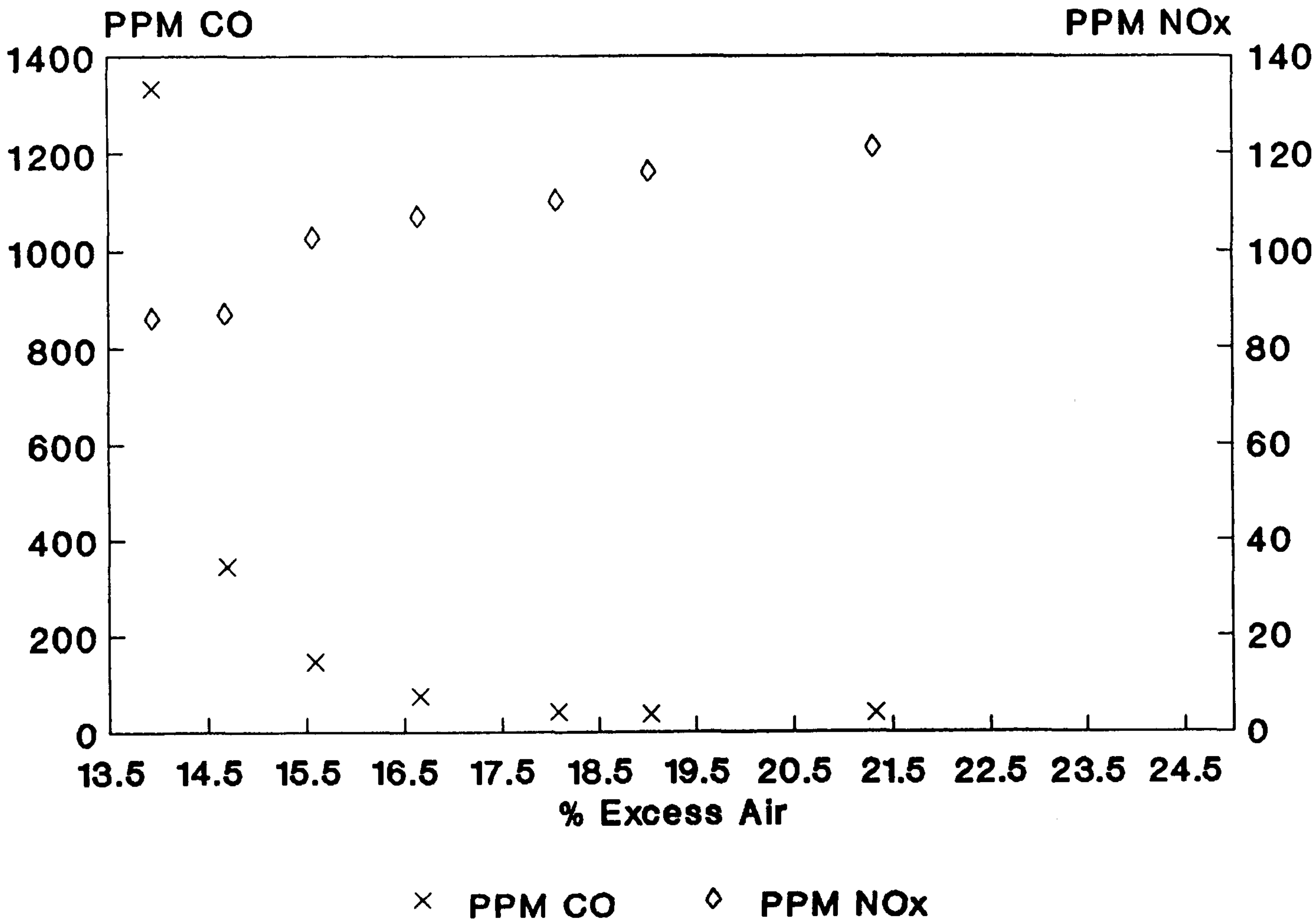

Figure 4-2. Steady State CO and NO_x Emissions Performance of the Airtronic Burner.

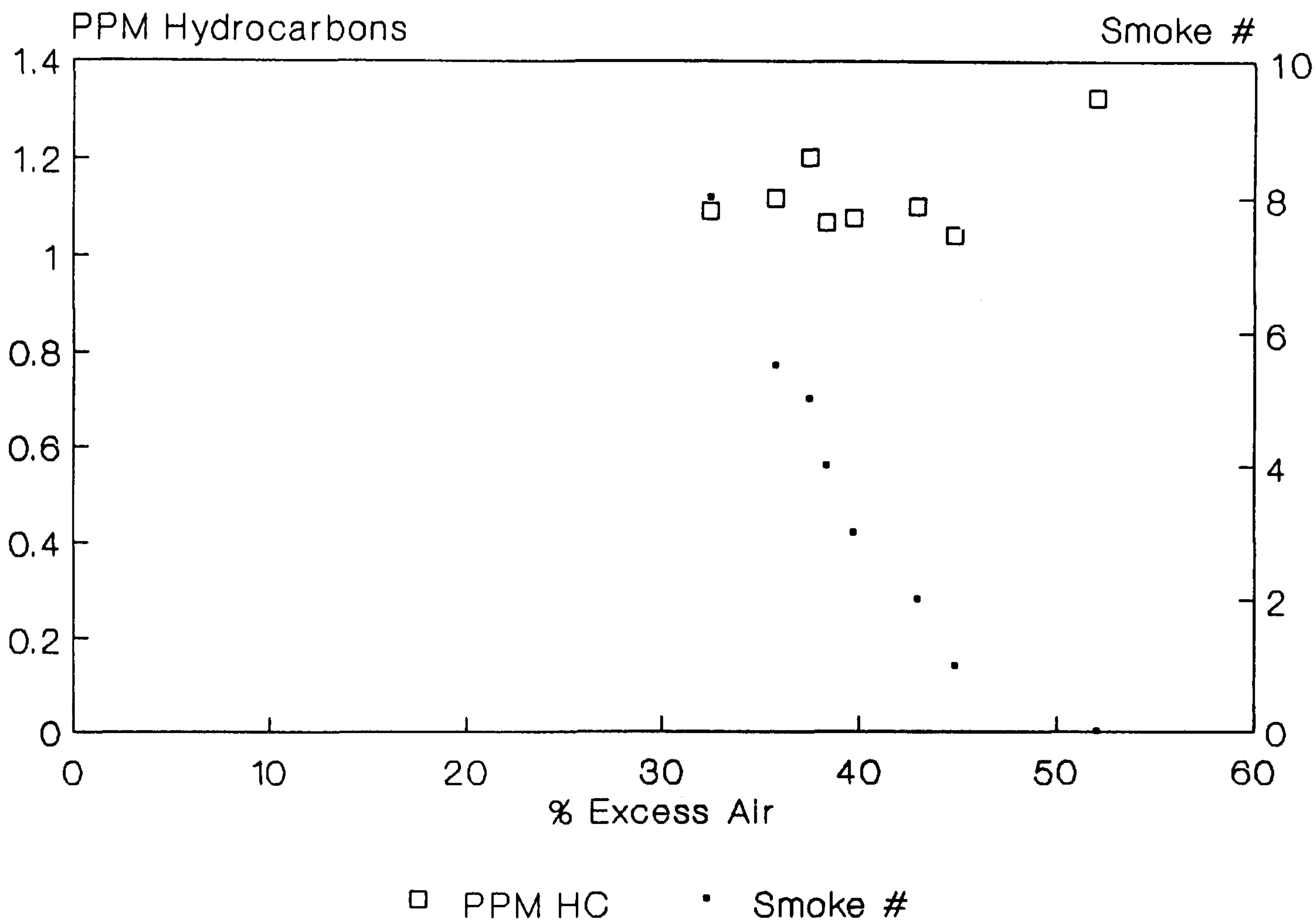

Figure 4-3. Steady State Smoke and Hydrocarbons Emissions of a Retention Head Burner.

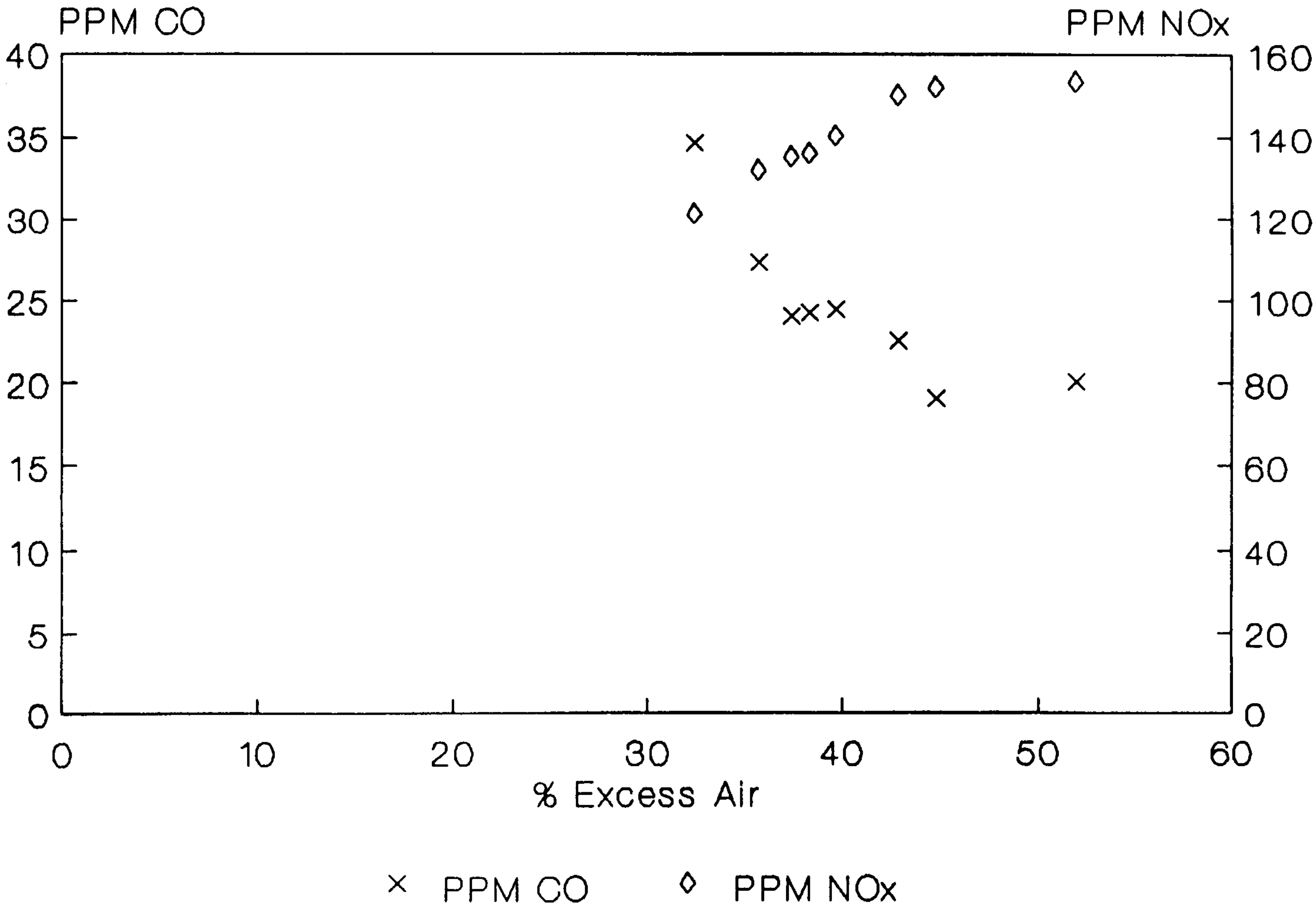

Figure 4-4. Steady State CO and NO_x Emissions from a Retention Head Burner.

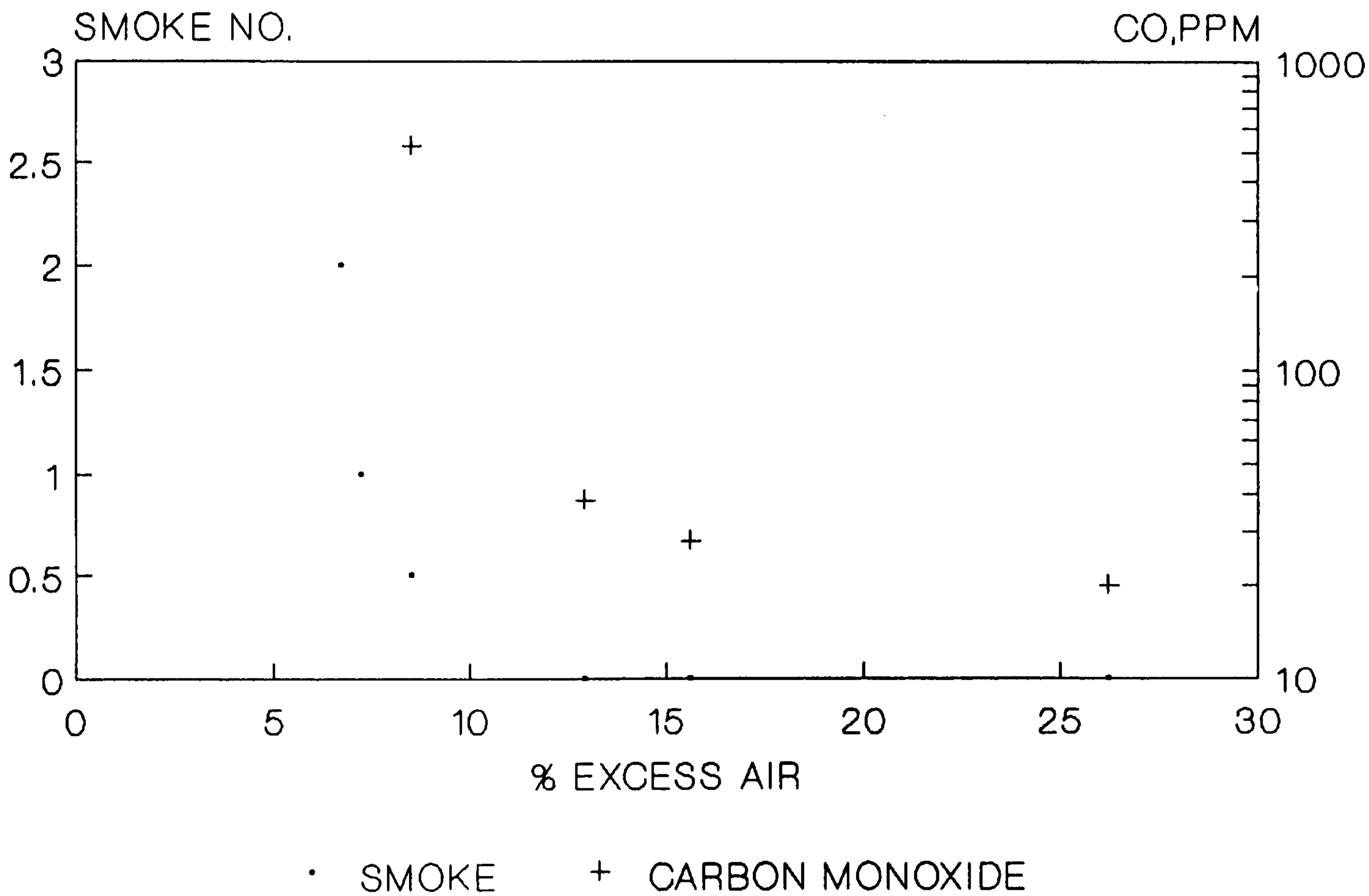

Figure 4-5. Steady State Smoke and Carbon Monoxide Emissions of the BNL Burner.

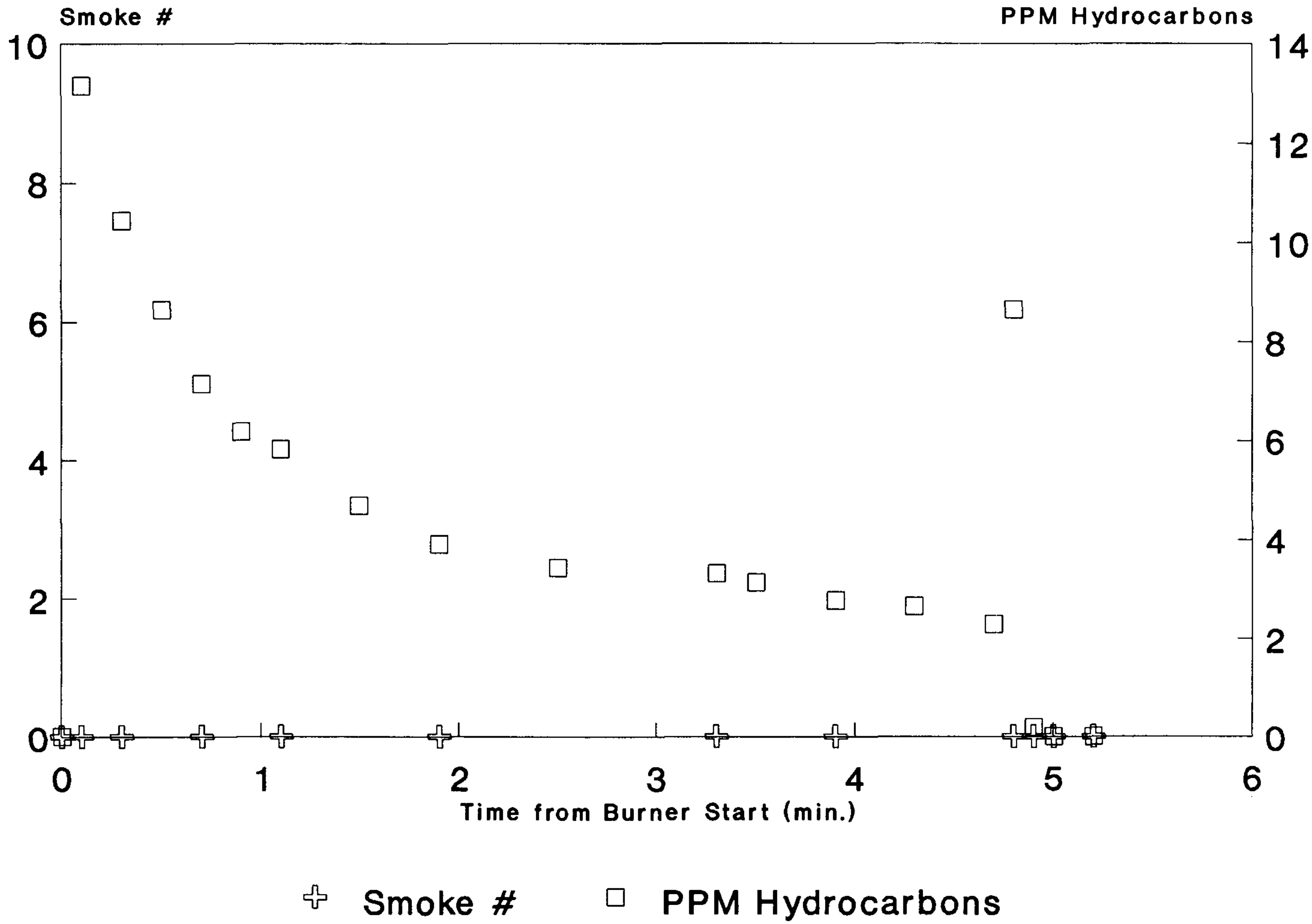

Figure 4-6. Transient Smoke and Hydrocarbons Emissions of the Airtronic Burner.

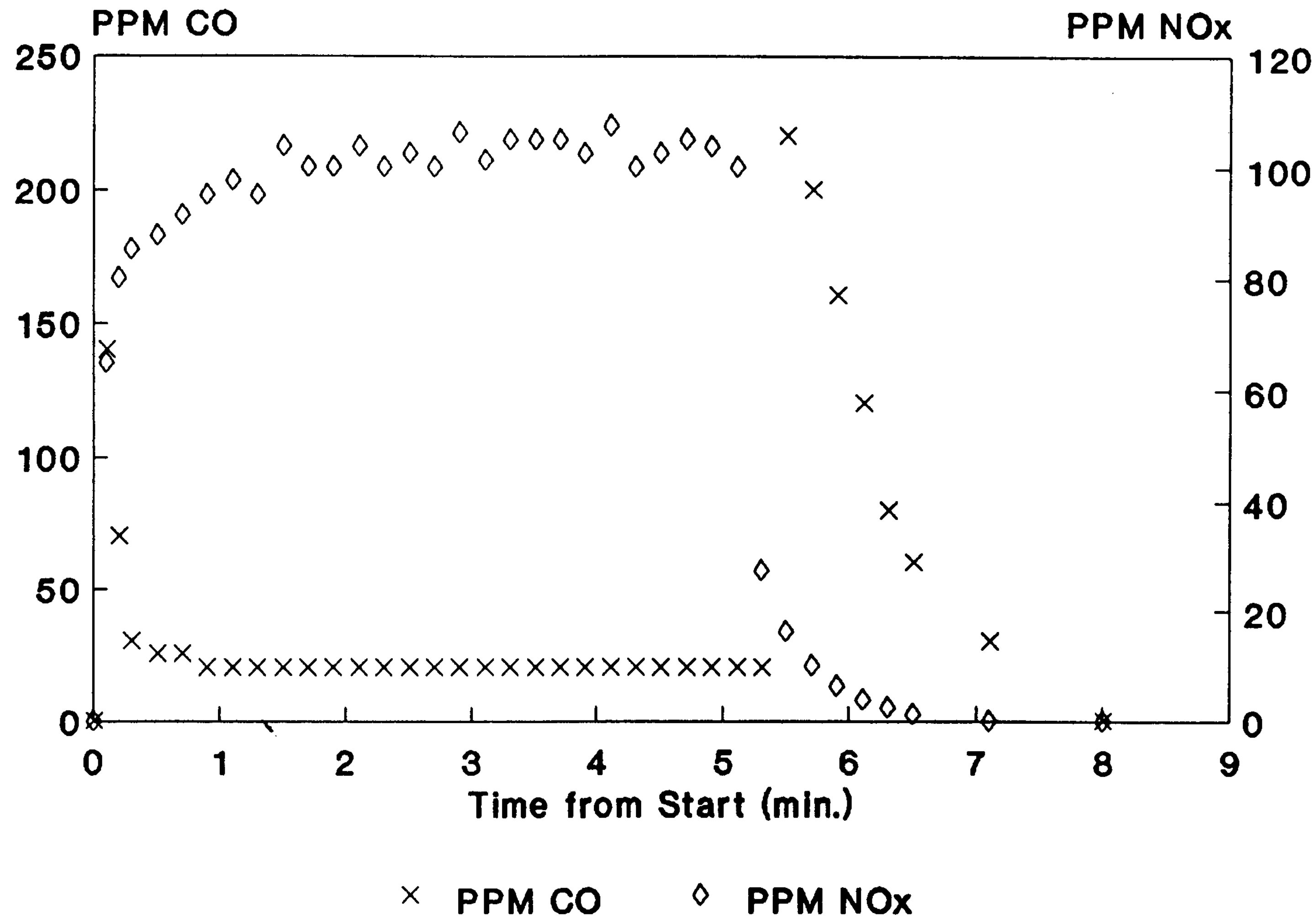

Figure 4-7. Transient CO and NO_x Emissions Performance of the Airtronic Burner.

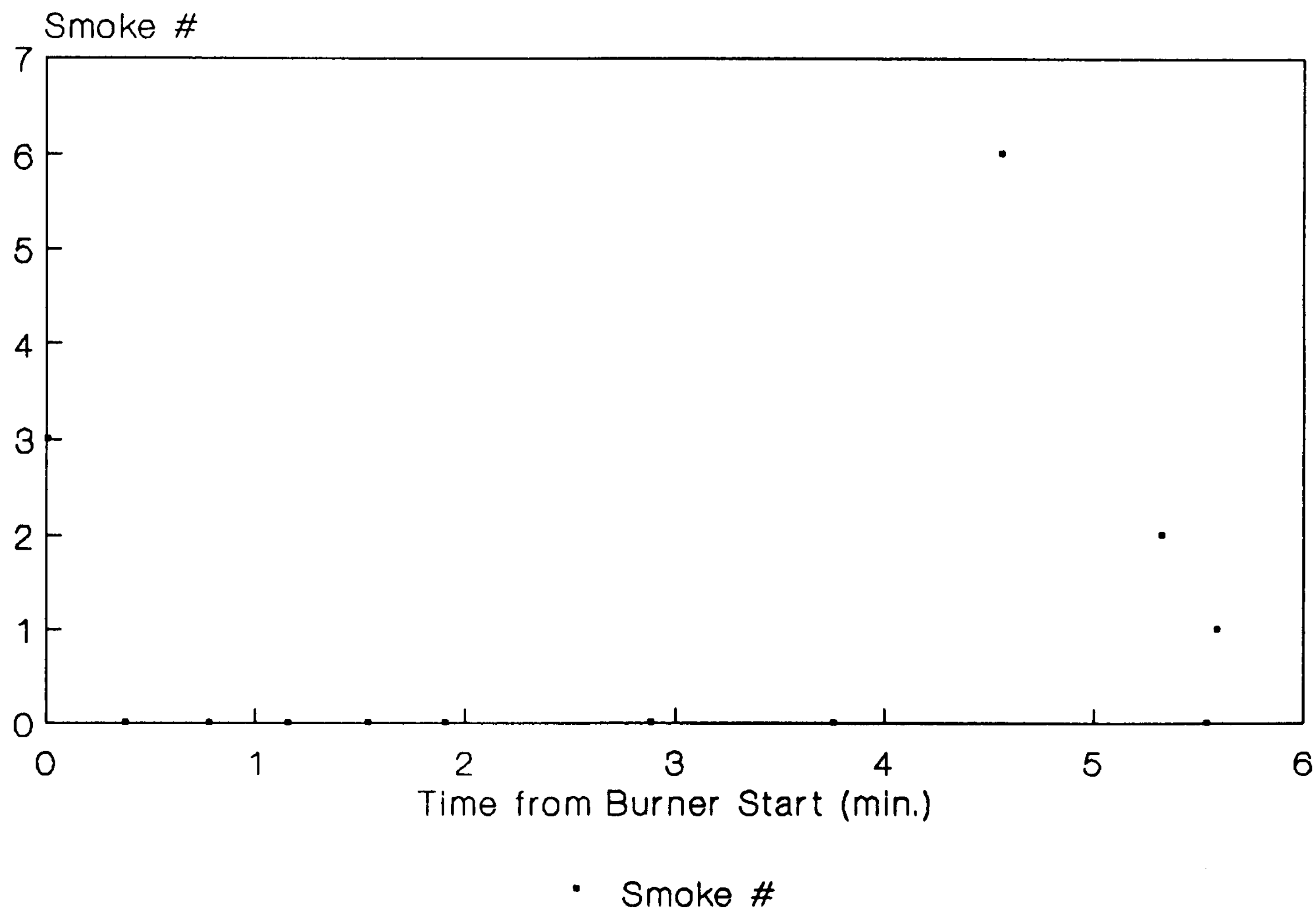

Figure 4-8. Transient Smoke Emissions of a Retention Head Pressure Atomized Burner.

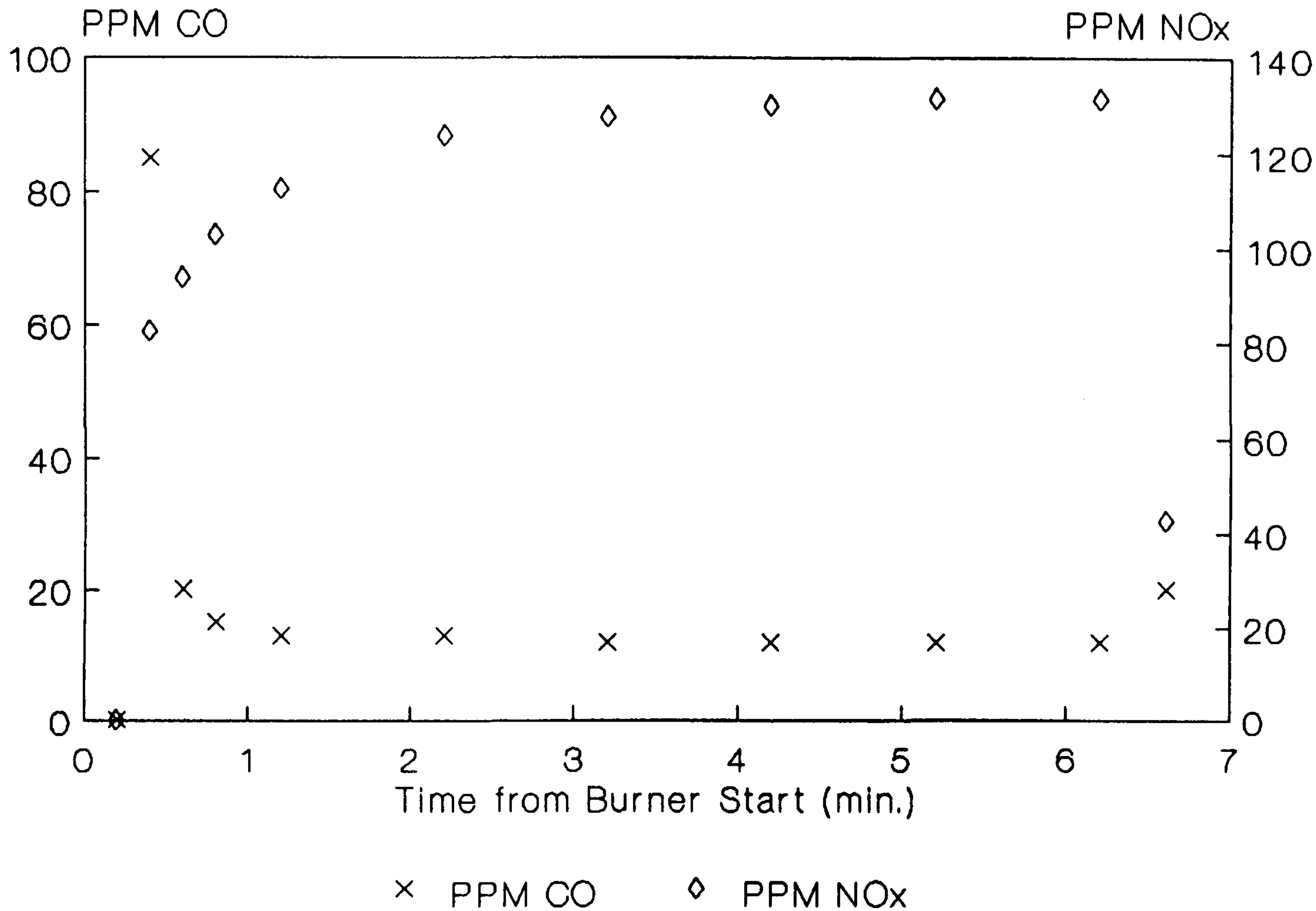

Figure 4-9. **Transient CO and NO_x Emissions Performance of a Retention Head Pressure Atomized Burner.**

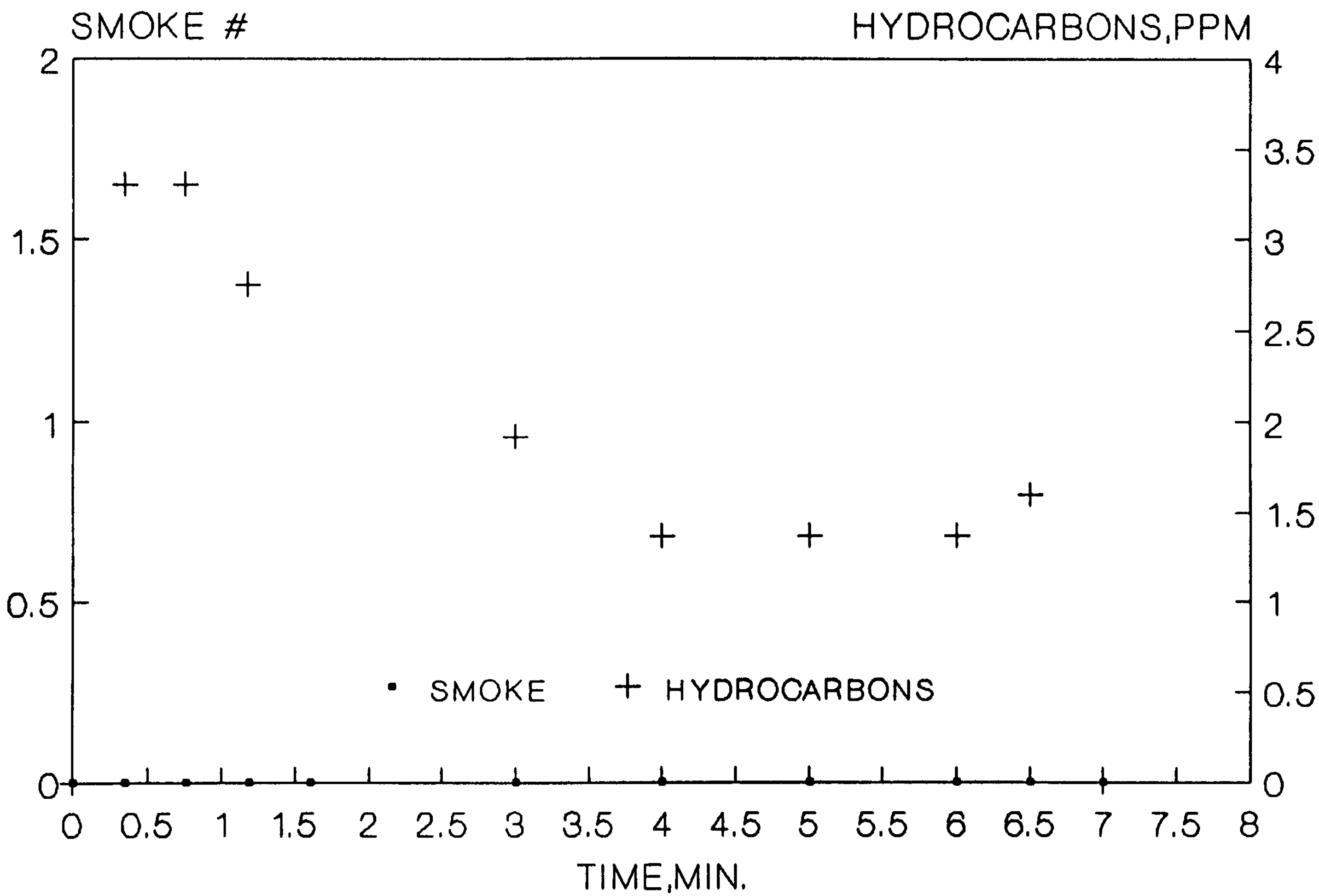

Figure 4-10. Transient Smoke and Hydrocarbons Emissions of the BNL Burner.

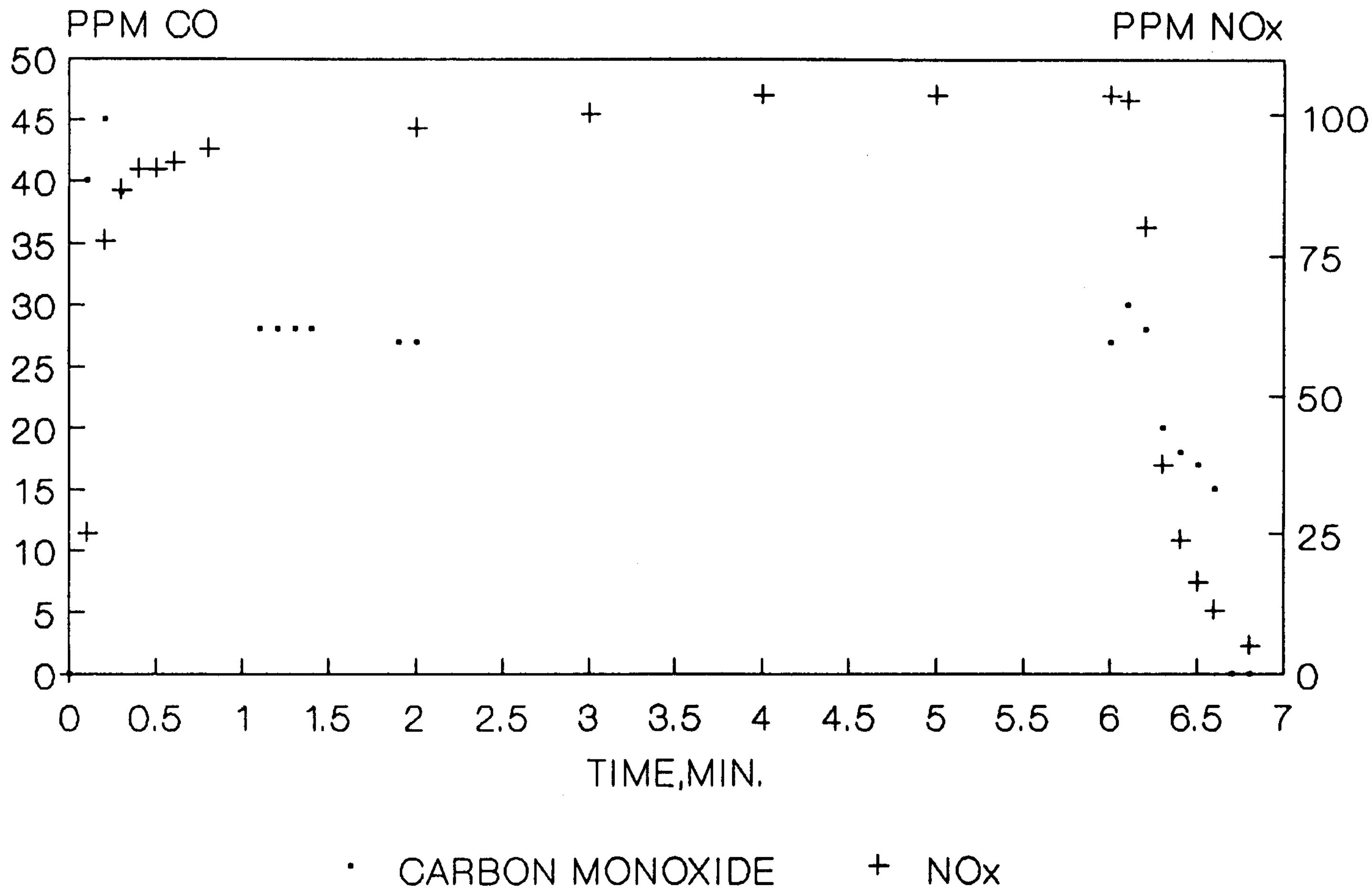

Figure 4-11. Transient CO and NO_x Emissions Performance of the BNL Burner.

Paper No. 89-4

OIL-FIRED HEATING TECHNOLOGY FOR THE ARCTIC

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Background

Canada Mortgage and Housing Corporation(CMHC) is a crown owned corporation whose mandate is to promote the construction of new houses, the repair and modernization of existing houses, and the improvement of housing and living conditions. As part of its business activities, CMHC has established a comprehensive research and development program to help meet its mandate. This paper will discuss some of the technical challenges faced by builders and designers of CMHC's social housing units in Canada's Arctic and sub-Arctic climates with regards to oil-fired heating systems, and some of the CMHC sponsored research and demonstration projects currently underway to evaluate alternative solutions.

The Arctic and sub-Arctic regions of Canada generally fall in a region defined by two territories, the North West Territories and Yukon Territory. The degree days in this region range from 8000DD(Celsius) to 10000DD(Celsius) with some regions experiencing 2 1/2 % design temperatures in the order of -40C to -50C. The population in this region is made up primarily of native indians scattered in approximately 100 communities. The housing market in these regions is largely social housing units built to house the native population(a small private sector market does exist). The Northwest Territories Housing Corporation(NWTHC) and the Yukon Housing Corporation(YHC) are the prime delivery agents for these social housing units, on behalf of CMHC. Approximately 400-500 units are built each year with an installed base of about 4000 units.

Since the housing corporations are generally the largest builders in the north, most of the attention for improved oil-fired systems has been focussed at this market. Furthermore, most of the oil-fired appliances are located in the Northwest Territories

In the north the dominant heating fuel is oil, costing between 30 to 40c/L on average, but reaching as high as 50c/L in remote communities. Electrical rates can exceed 50.0c per kWh. Natural gas is generally unavailable and propane is seen only in limited use in urbanized area.

Figure 1 shows average annual consumer expenditures for oil in Canada. Consumer expenditures on oil for space and hot water use in the Northwest Territories are almost twice the national average, in the order of $1500 dollars per year. Thus, despite the comparatively small market, the north offers the greatest opportunity for savings thru improved oil-fired heating technology.

Design Loads in the Arctic

In recent years the housing corporations in the north have implemented a multi-year plan to improve the quality of their housing stock. The corporations have adopted many aspects of Canadas' R2000 program, resulting in highly energy efficient housing units. Typical housing design specifications are shown in Table 1.

Although basements are constructed, they are generally limited to a small private sector market in more urbanized areas (Yellowknife, NWT and Whitehorse, Yukon). In remote areas, units are constructed above ground.

Floor areas are typically in the order of 1000 sq ft. The units are tight, requiring some mode of forced ventilation. Ventilation rates are typically in the 0.5 ACPH or less. The end result is design space heating loads for these units that are typically in the range of 30,000 to 40,000 BTUH.

THe NWTHC has adopted hydronic heating using indirect water heating in many cases as the preferred mode of heating. Conventional systems currently available on the market are rated from about 70,000 to 100,000 BTUH, sized to handle the peak capacity for both space and water heating. The impact of achieving low design space heating loads has resulted in conventional oil-fired systems that are significantly oversized relative to the design space heating load of the house. The result is less efficient operation of the furnace or boiler due to short cycling for most of the heating season. To compound this problem, the unit never reaches steady state operation. This results in lower stack temperatures, colder chimneys(all chimneys are interior A-Vents but as much as 3 to 4 feet is exposed above the roof line), increased potential for condensation and ice accumulation in the chimneys, and in the long term, accelerated deterioration of the chimney liner. In some cases, the efficiency of the heating system are artificially adjusted down to promote longer heating cycles.

The net result, however, is an installed and future base of oil-fired heating units that are unable to operate optimally, resulting in increased and unwarranted heating costs to the consumer.

Impediments to Change

In relative terms however, the Arctic market is still small for most of the larger manufacturers of oil-fired heating systems. Because of the many remote sites served by the NWTHC, a reliable heating system with a proven track record, a reliable source of parts and a well established, reliable service program are much higher priorities to NWTHC than improved system efficiency. These factors have served as the largest impediment to creating the requisite demand for improving the overall oil-fired heating technology in the Arctic and sub-Arctic regions of Canada. As a result, larger manufacturers are simply not prepared to upgrade the technology for such a small, potentially high risk market, and those manufacturers who are willing to provide improved technology cannot break into the market because of the concern by the housing corporations that the technology is unproven in the Arctic.

Thus, the philosophy becomes one of "If it is not broken, don't change it".

Alternative Solutions: CMHC Demonstration Projects

CMHC has and continues to fund practical studies to evaluate alternative oil-fired heating solutions for the Arctic.

The goal of this program is to stimulate the industry on the benefits of improved oil-fired systems and establish confidence in the newer technologies by demonstrating these systems in the Arctic environment.

The focus has been targeted at the social housing units in the Arctic since on an individual basis, there is a greater opportunity for real cost savings in this region, given the longer heating season.

Emphasis was placed on boiler technology since this form of heating is the preferred choice by the housing corporations.

CMHC's initiatives in the north as they apply to heating are diverse. Studies cover a broad range of topics including thermal comfort, energy efficiency, life cycle cost and market acceptance.

A recent study conducted in Yellowknife, NWT was commissioned to provide more definitive data on the merits of forced warm air systems and hydronic system installed in an Arctic environment. In addition to a conventional oil-fired boiler and a conventional down draft oil furnace, two other systems were evaluated. These were a domestic hot water tank as a combination hot water and space heating appliance and a hybrid system which utilized hydronic coils inserted in a forced air recirculating system. The hybrid design was developed to satisfy the need for a forced ventilation system required in tighter houses and still enable the use of a hydronic or boiler unit. Hydronic systems are finding themselves at an economic disadvantage compared to forced air systems in tight houses.

Figure 2 shows schematics of each of these systems.

Each of these units were monitored with a sophisticated data acquisition system for approximately one year.

The findings of this study are still being analyzed. Table 2 shows some of the preliminary findings. In summary, the domestic hot water tank as a combination space heating and water heating appliance appears to be a cost effective approach to heating. Long term reliability of the system is still needs to be resolved. Taking into account the need for a ducted ventilation system would probably put this system on par with a forced air system. Conventional boiler systems are on par with forced air systems in terms capital and operating costs, if one neglects the need for ventilation. Add in the cost of ductwork for ventilation, and the hydronic system is clearly more expensive than forced air. The hybrid system is an example of an approach to combine the attributes of the boiler and provide a ducted ventilation system. The cost increment, approximately $1500, is probably representative of the cost of providing and boxing the ductwork.

However, capital cost alone are not the deciding factor in choosing a hydronic or forced air system. Ease of zoning, integrated hot water(only one burner), better zone control, less potential for drafts, lower electrical power consumption and the ability to install the hydronic runarond after the the interior finish is complete are some of the advantages proponents of hydronic systems cite over warm air systems. The debate is still not over and the choice of one system over another will depend on a combination of technical, cost and market acceptance factors. However, studies such as this are essential to provide designers and consumers with adequate data to make an informed choice.

This year a more focussed study is underway to identify and evaluate energy efficient oil-fired boilers that can potentially reduce the fuel consumption of housing units in the Arctic. In searching out improved boiler systems, a list of attributes that were considered important to both CMHC and the housing corporations was developed. These attributes are summarized in Table 3.

Three demonstration projects are currently underway, each of which addresses some of the desired characteristics listed in Table 3. The three projects are:

1. System 2000 manufactured by Energy Kinetics and installed in Dawson City, Yukon

2. Domestic Hot Water tanks as combination hot water and space heating appliances located in Yellowknife, NWT.

3. Worcester Combi-Boiler manufactured by Worcester Engineering in UK. Proposed to be demonstrated in Yellowknife, NWT in 1989/90

Demonstration Project #1: System 2000 Installation

The first project currently underway is the System 2000, manufactured by Energy Kinetics. The unit is shown in Figure 3.

The System 2000 was chosen for several reasons. These were:

- Its ability to maintain high efficiency for a range of demand loads. AFUE equivalent was 87% compared to traditional boiler systems which were delivering about 78%.
- Side wall venting. The System 2000 offered an opportunity to assess the potential for side wall venting in the Arctic climate
- Approved for use in the U.S with an established reputation in the American market. This would facilitate approval in Canada.
- Manufacturer support to demonstrate the system in the Arctic

The output of the system was much higher than the design heat load currently being observed in Arctic housing. However, since the design philosophy behind the System 2000 claims to maintain high efficiency to as much as four times the design heat load, it was agreed that if the performance of this system could be substantiated, it would overcome some of the oversizing problems without having to use lower output burners. Installing the unit in a small, energy efficient unit would test the manufacturers claims. This system is installed and is serving an R2000 duplex in Dawson City, Yukon. The duplex affords an opportunity to evaluate the system over a range of demand loads.

The system has been operating since October of 1988. Detailed monitoring is being conducted until March of 1990 to assess the performance of this system in an Arctic environment. Data is stored on a hard disk on site and downloaded on a regular basis to a host computer located in Yellowknife, NWT.

Figure 4 shows the flow, temperature and status sensors that were installed on the System 2000.

Demonstration Project #2: Domestic Hot Water Tanks as combination space heating and hot water appliances.

The second system being evaluated is the hot water tank as a boiler. This is a follow up to an earlier study discussed above. Again, simplicity in installation, low capital cost and compact size are the primary attributes of this system. Evaluating the long term reliability of this type of system is one of the objectives of this demonstration project. A schematic of this system was shown in Figure 2.

Several of these systems are currently installed in Yellowknife, NWT. A study was commissioned to dissect three such units that have been in service for approximately 5 years and inspect these systems for premature deterioration. Two of the systems were dissected and preliminary inspection did not reveal any indications of premature deterioration. A third unit is being shipped to the original manufacturer for more detailed analysis of the liner and anodes.

Demonstration Project #3: The HEATSLAVE Combi-Boiler

The third system being considered is the Worcester HEATSLAVE manufactured in England. Figure 5 is a diagram of the HEATSLAVE. During the product search it was found that in North America, boilers and furnace outputs were constrained to a lower limit of about 60,000 to 70,000 BTUH. Investigations in Europe revealed the availability of much smaller output systems in the order of 30,000 to 40,000 BTUH. The system selected for evaluation was the HEATSLAVE Combi-Boiler manufactured by Worcester Engineering in England. This unit satisfied several characteristics outlined in the plan including:

- small, compact size
- the hot water tank and boiler are integrated into a single unit(no external storage tank)
- side wall venting
- sealed combustion.
- Output in the range of 30,000 to 40,000 BTUH

The system is currently being evaluated by CSA for approval in Canada. Detailed monitoring in the Arctic is planned following CSA approval.

Conclusions

At the technical level, one of the primary goals at CMHC's is to improve the quality of its housing stock through carefully planned and responsive research programs. The initiatives currently underway in the area of oil-fired heating in the north is one of many such activities.

CMHC is not in the business of marketing products, rather it is the goal of CMHC to:

- Demonstrate improved technology under real life conditions
- Provide sufficient data to end users to allow them to make a more informed choices on equipment and materials.
- Stimulate and encourage the industry to improve their products in response to the needs of various regional markets.
- Establish confidence in the performance of new products in an Arctic Environment

The projects commissioned by CMHC over the last few years in the area of oil-fired heating in the north are intended to address these goals.

The benefits of this program extend beyond the north to many other oil dominated regions of Canada including many of the northern and Atlantic provinces. In addition to new energy efficient housing, improved oil-fired technology will benefit a rapidly emerging renovation industry, many of which are still served by oil-fired equipment.

Figure 1: Residential Oil Heating Expenditures

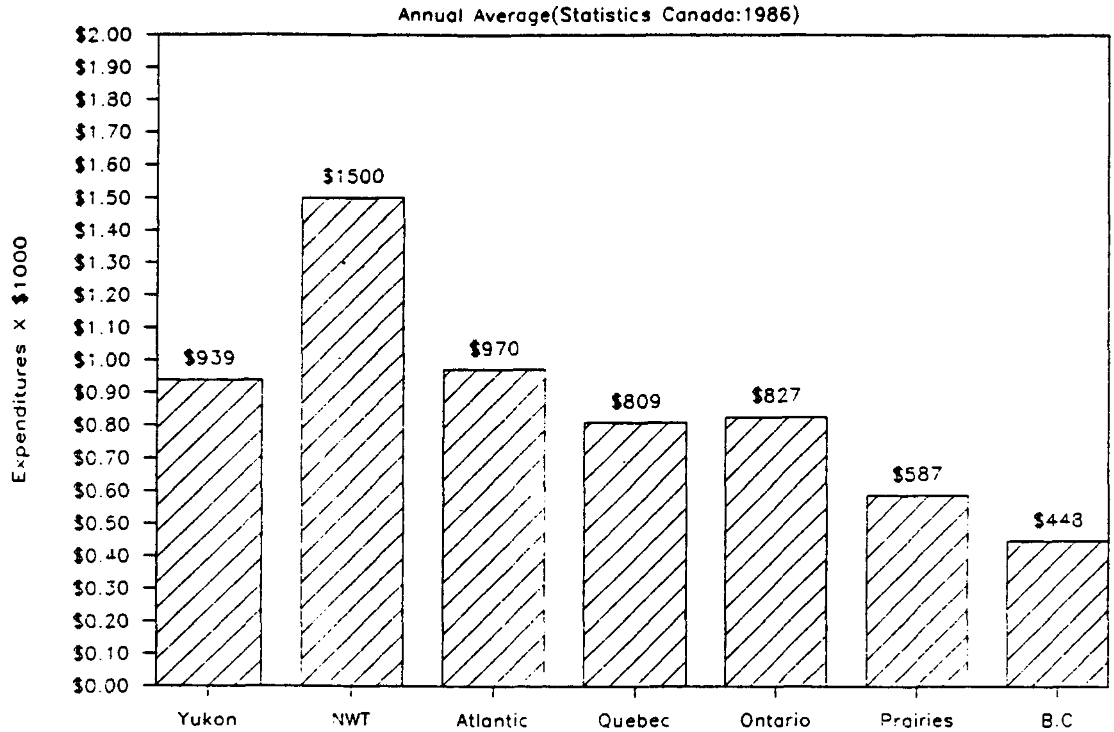


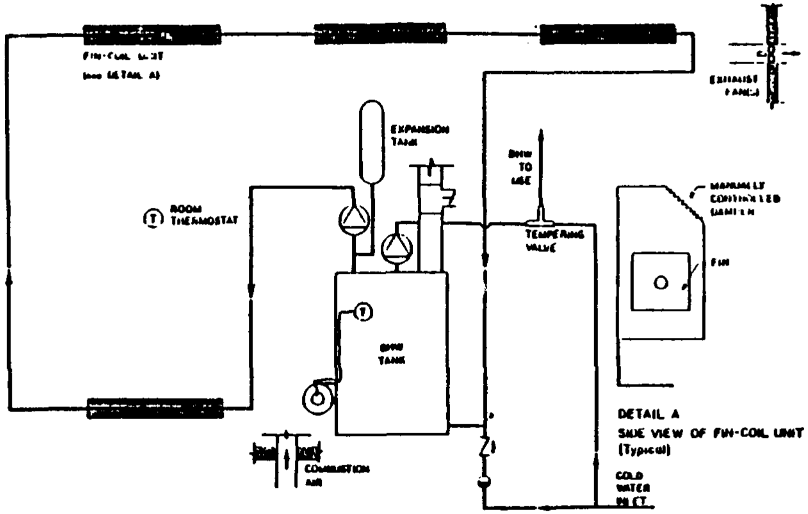
Table 1: Typical Insulation Specifications for NWTHC Housing Units

Exterior walls	R-27
Ceilings	R-60
Exposed Floors	R-33
Basements	R-30
Doors	R-12
Glazing	Triple

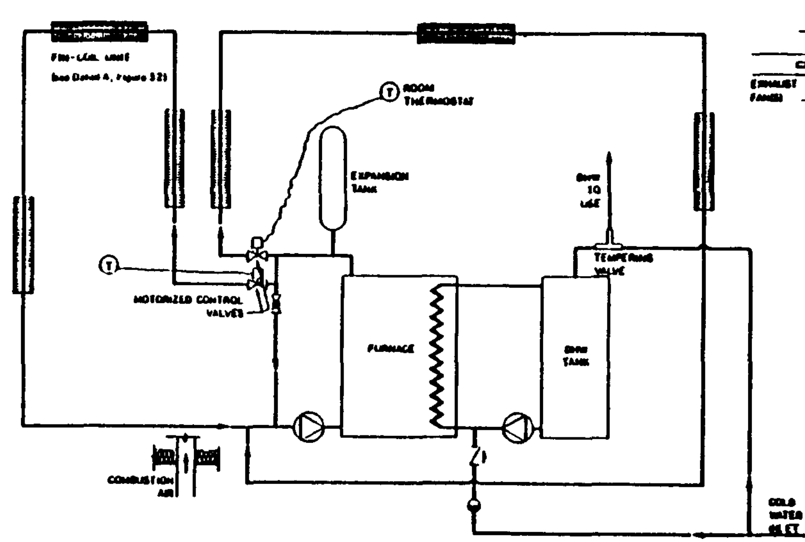
Table 2: Latham Island Alternative Heating Solutions

	Heating Appliance	Heat Distribution	System Capital Cost (incl. DHW)	Power Requirements	Unit Temperature Profi Minimum	Average	Maximu
System 1	DHW tank for space and water heating	Hydronic runaround Single Thermostat	$6,000	86 kWh/month	22+-2	27+-3	33
System 2	Down Draft Forced Air Furnace	Ducted Distribution Single Thermostat	$7,100	78 kWh/month	18+-8	30+-3	34
System 3	Conventional Boiler	Hydronic runaround Single Thermostat	$7,200	65 kWh/month	15+-5	27+-1	34
System 4	Hybrid System	Ducted Distribution Two Zones	$8,500	195 kWh/month	13+-8	27+-3	33

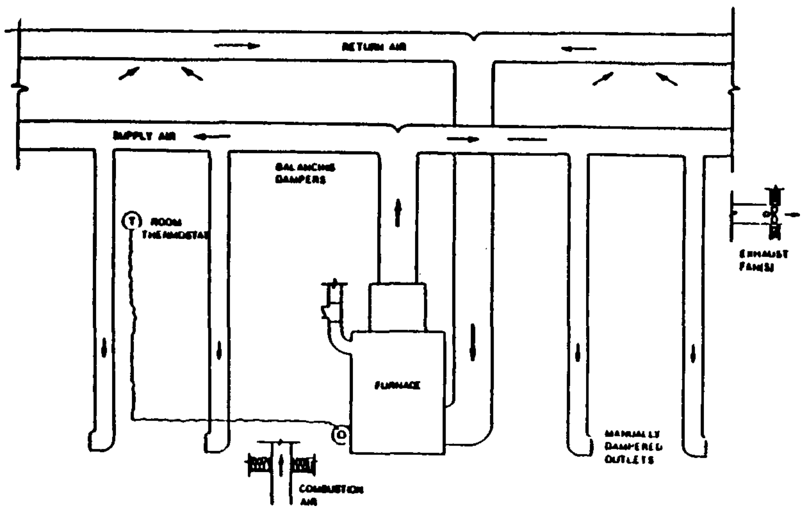
1. Unit Temperature profiles are averaged from data collected in November 1986 and January 1987. Sensors were located in bathrooms, living rooms and bedrooms The +- range reported in the above table represents the range of temperatures observed in each unit



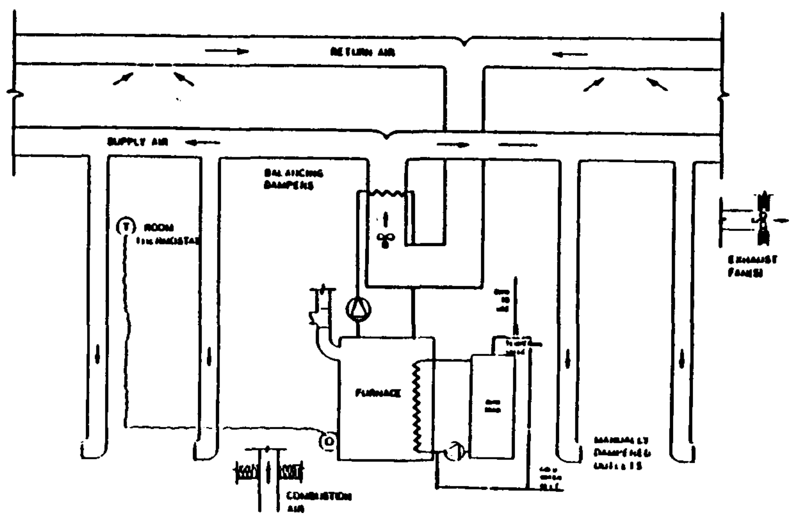
Domestic Hot Water Tank as a combination Hot Water and Space Heating appliance



Conventional Boiler System with indirect Hot Water Heating



Conventional Forced Air Furnace



Hybrid System

Figure 2: Alternative Heating Systems

Table 3: Characteristic for Improved Oil-fired Heating in the North

Characteristic	Criteria	Reason
Increased system efficiency	A minimum AFUE of 80%. Preferably above 85%.	Reduce Energy Bills
Efficient lower output burners	Gross output in the range of 30,000 to 40,000 BTUH	Improve cycle efficiency Reduce potential for condensation in chimneys
Smaller, more compact size.	2 feet X 2 feet X 4 feet Instantaneous or semi-instantaneous hot water systems.	Floor space is a premium.
Ease of installation use and maintenance.	Few controls, easy access to heat exchanger, standard parts, simple diagnostic procedures	Few skilled maintenance staff. Long down time unacceptable
Side wall venting	Reliable, low power draft inducing fan	Eliminate ice build up on the exposed top portions of the chimney Eliminate capital cost of chimney.
Sealed combustion		Alternative to automatically actuated combustion air dampers which were prone to freezing shut.

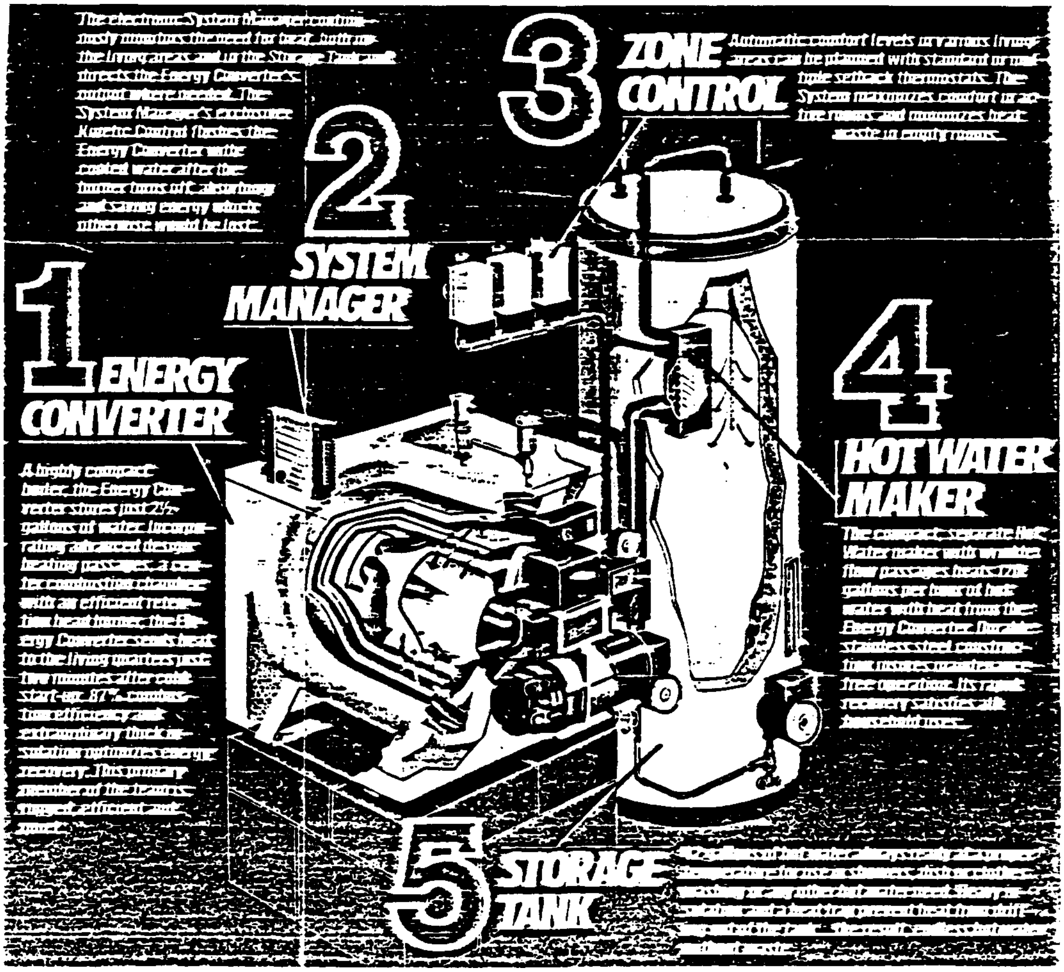


Figure 3: System 2000

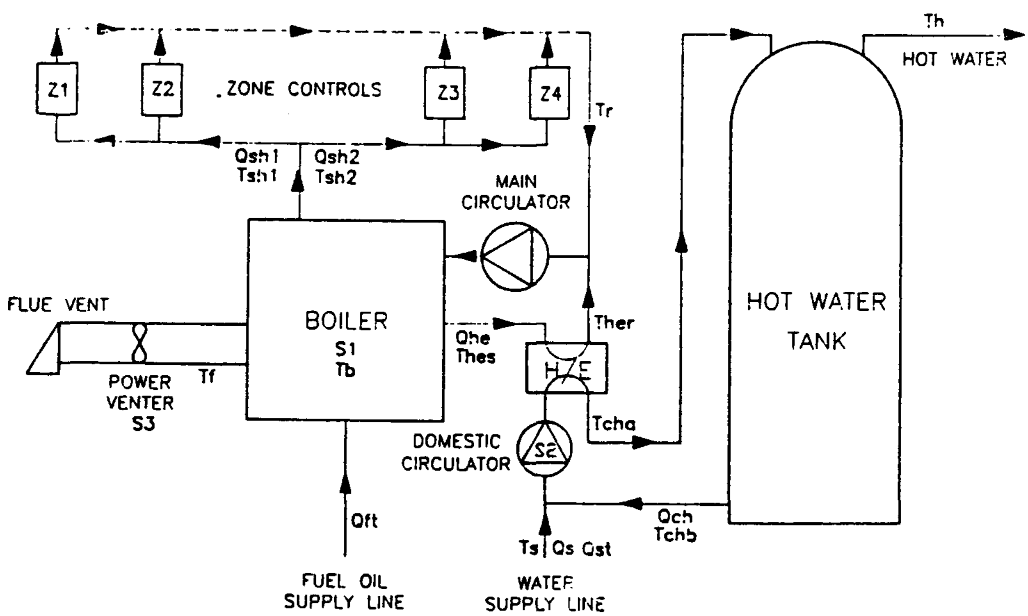
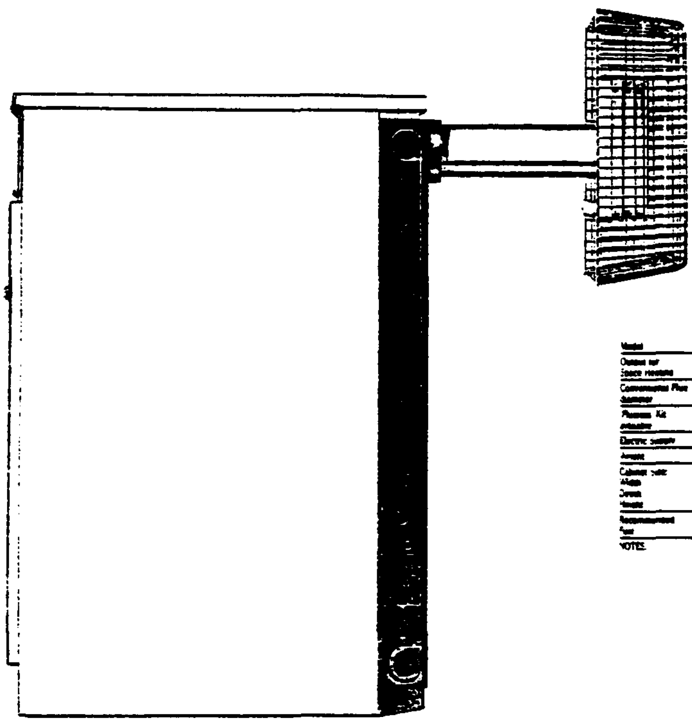
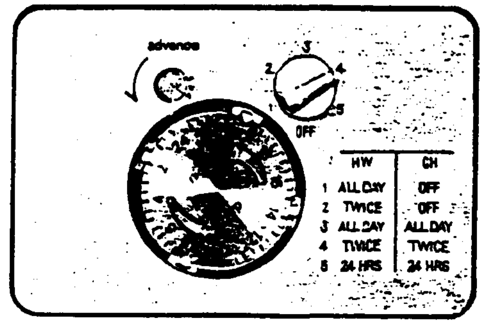


FIG. 4 SYSTEM 2000 SENSOR POSITIONS

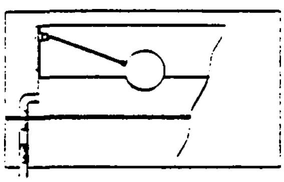


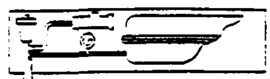


Model		[illegible] 12 14	[illegible] 15 19	[illegible] 20 25	[illegible] 26 32	[illegible] 30 45	[illegible] 45 73
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible] flue diameter	[illegible]	100 (4)	100 (4)	125 (5)	125 (5)	150 (6)	175 (7)
[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Electric supply	V Hz	240 50	240 50	240 50	240 50	240 50	240 50
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cabinet size Width	[illegible]	432 (17)	432 (17)	508 (20)	510 (20)	[illegible]	610 (24)
Depth	[illegible]	559 (22)	559 (22)	616 (24.25)	650 (25.6)	[illegible]	876 (34.5)
Height	[illegible]	840 (33)	840 (33)	840 (33)	900 (35.4)	915 (36)	915 (36)
[illegible]		[illegible]					

NOTES. [illegible]

OPTIONAL CLIP-ON FEED & EXPANSION CISTERN & CABINET ASSEMBLY (BF & RSF MODELS ONLY)





OPTIONAL CLIP-ON SEALED SYSTEM & CABINET ASSEMBLY (BF & RSF MODELS ONLY) (CF MODEL SUPPLIED AS STANDARD WITH PRE-PLUMBED SEALED SYSTEM COMPONENTS)

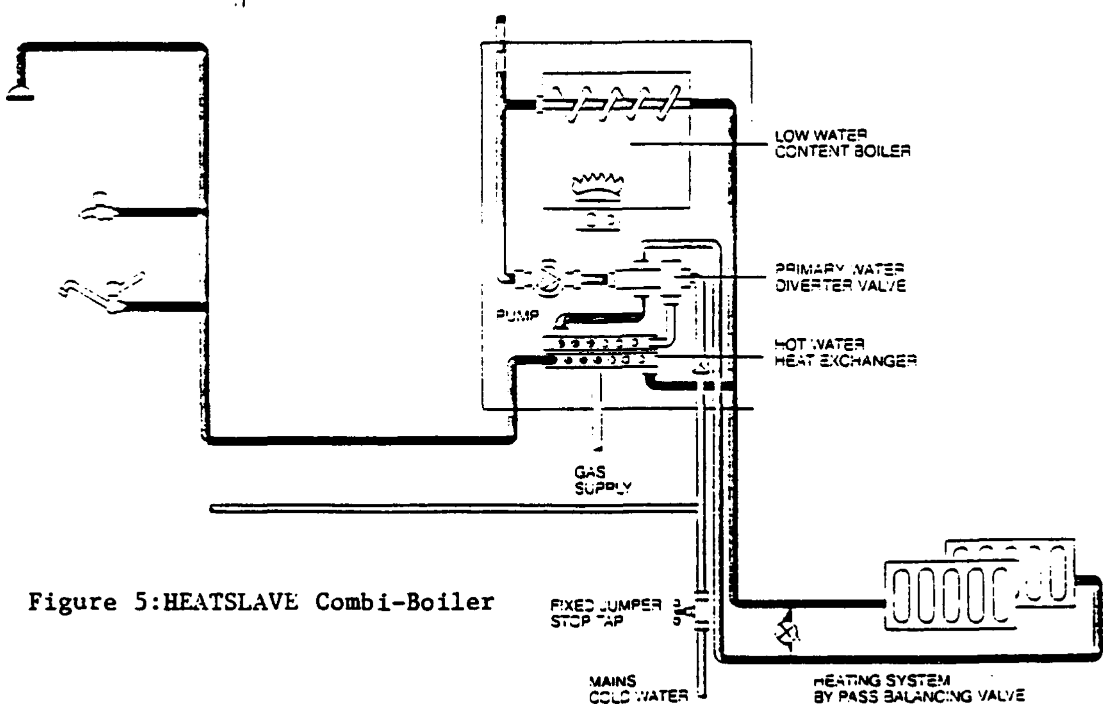


Figure 5:HEATSLAVE Combi-Boiler

Paper No. 89-5

A COMBUSTION SYSTEM FOR BURNING FUEL OIL WITH HIGH EFFICIENCY AND LOW POLLUTANT EMISSION

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THE COMBUSTION SYSTEM

In combustor technology soot-free combustion is a general aim, when hydrocarbon fuels are involved. Efficiency considerations, reliability in operation and environment protection aspects head for near-stoichiometric soot-free combustion.

Soot formation commonly occurs, when vaporization and combustion of the fuel proceed simultaneously in the same location, i.e. burning fuel droplets do exist in the space, where combustion takes place. Owing to the very high temperature in the proximity of the surface of a burning droplet, considerable percentages of fuel vapor undergo cracking, because the vaporization rate and the mixing rate is low, so that the fuel remains under high temperature condition for rather a long period. One of the products of cracking is acetylene, which, as is well known, tends to form soot on burning with limited air supply. Consequently, combustion in the presented process has been arranged in such a way that vaporization of the fuel droplets occur at moderate temperatures within the mixing tube (Fig. 1).

At these temperatures the cracking rate is very small. In the mixing tube the flow velocity is kept above the flame propagation speed. Hence, the combustion can only proceed further downstream. Droplet burning cannot occur, if the vaporization process is completed, before the flow reaches the flame front.

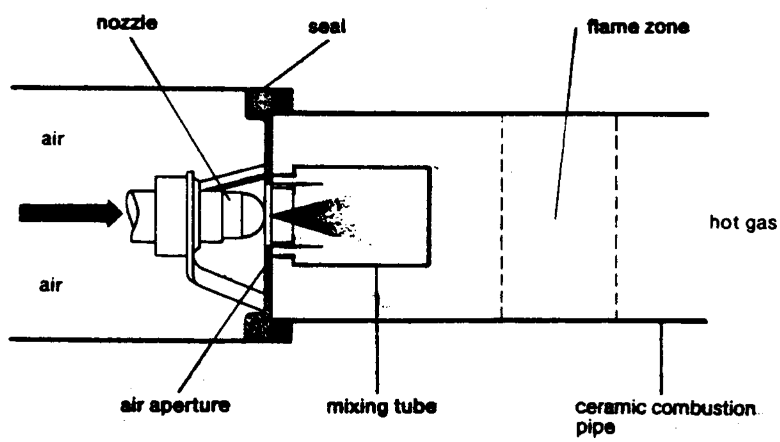

Fig. 1: Scheme of the combustion system

The energy required for evaporation is supplied by a hot gas recycle flow as well as by thermal radiation of the mixing tube wall which is at a temperature of about 1150 K. The mixing tube is made from nonscaling steel or ceramic material. The recycle flow enters the mixing tube through windows in its upstream end. The position and their cross-sectional measure effect the quality of the combustion process.

Momentum transfer between the primary fuel/air and the recycle flow as well as the enlargement of the cross-section at the exit of the mixing tube exert a slowing down effect on the flow velocity so that the flame front can establish itself downstream from the mixing tube. Owing to the practically complete vaporization of the fuel ahead of the flame front, the flame is soot-free and blue.

As can be seen from Fig. 1 the combustion process is enclosed within a flame tube of a definite volume, an important condition for stable combustion. The flame tube is fabricated from ceramic material (SiC).

The recycle flow of the hot gases, essential for the correct operation of this system, is driven by the primary air flow. In order that this process may occur it is necessary to build up and maintain an underpressure in the annular space between the flame tube and the mixing tube (about .3 mbar). This can only be achieved, when the gas flowing out of the flame front seals the upstream annular space from the surroundings. Otherwise cool flue gas may be sucted into the recirculation region, by which, if it happens, the flame starves out and combustion is interrupted. According to the laws governing the mixing of jets the flow field expands from the mixing tube outlet, at an angle of 10 degrees, toward the flame tube wall, as confirmed by photographs taken with a quartz flame tube set-up. With a mixing tube of 35 mm in diameter and 59 mm long the required length of the flame tube having 76 mm in diameter is about 175 mm, in order that the outer edge of the jet mixing zone may get in contact with the flame tube wall.

Experimental investigations showed that a flame tube length of 150 mm prevented flame stabilisation after ignition, whereas a length of 175 mm resulted in unstable operating conditions under which an initially well-shaped flame shrunk within about 3 s and ultimately died. A flame tube length of over 200 mm produces stable combustion under any conditions even though there are between six and eigth holes, approximately 10 mm in diameter, in the flame tube wall, roughly half way downstream.

As by the diverging flow pattern downstream of the mixing tube the gas flow has a considerable momentum loss mainly in the region of its circumference. So its plugging effect against the underpressure in the recirculation annulus vanishes, if the flame tube diameter Df becomes too wide. The following, empirically established equation

```
Df <= 11.5*SQR(moil/(1 - Ptot,abs^(-.286 ))^.5 )
```

may be applied for the calculation of the necessary flame tube diameter in mm, when the oil flow rate moil is expressed in kg/h and the absolute total pressure of the air flow $P_{tot,abs}$ in bar.

As by the flame tube the burner has its own combustion chamber (or fire-box), it is almost independent of the type of the furnace, it is matched with. So it is with the shape of the fire-box, if its volume does not become too small. The quality and stability of combustion is not influenced by the furnace geometry and type, as has been experienced.

In Europe this combustion system is on the market since 10 years with increasing success. More than 200000 burners are in operation in home heating installations.

POLLUTANT EMISSION CHARACTERISTICS

Basically the pollutant emission is the lower the better the degree of energy use in the heating equipment is. Therefore the "rocket burner" - as this system is named in the market - delivers the best possible, because it is sootfree and can therefore be operated close to stoichiometric air/fuel ratio.Besides this it is best, because its air metering port is not fouled by soot or dust, as there is no soot and the passages are wide without narrow slits. So it maintains its high effiency degrees over years of operation, as we experienced. We want to highlight this aspect, as it is of great importance for fuel consumption and pollutant emisson quality.

In areas of dense population remaining heat in the flue gas, water generated by combustion and sulfuroxides may be immissions that raise problems. Therefore it is favourable that a burner with soot-free combustion is suitable for being operated in condensing furnaces that also have the capability of flue gas desulferization. In DLR such equipment has been development to a status that it can be applied in the field. It further reduces fuel consumption and pollutant emission by lower fuel consumption and desulferization.

Emission levels produced by combustion characteristics are demonstrated by plotting the content of species in flue gas over fuel/air ratio from a burner fired steady state. This is what Fig. 2 shows. The diagram contains the content of CO_2, CO, C_nH_m, soot, NO and O_2. The values have been measured with a burner of 22 kW performance fired into a wet furnace having 23 kW capacity.The measured values are compared to those values that would be observed, if the burner has an even mixture distribution of air and fuel and the flue gas will be cooled down very slowly, so that thermodynamic reaction equilibrium is achieved. This may show how good the burner comes close to physically given limits.

Fig. 2 shows a hatched area of fuel/air ratio which can be covered during burner operation due to atmospheric pressure variations. Normally the burner ist adjusted to 14% CO_2 content in the flue gas to admit for high pressure situations.

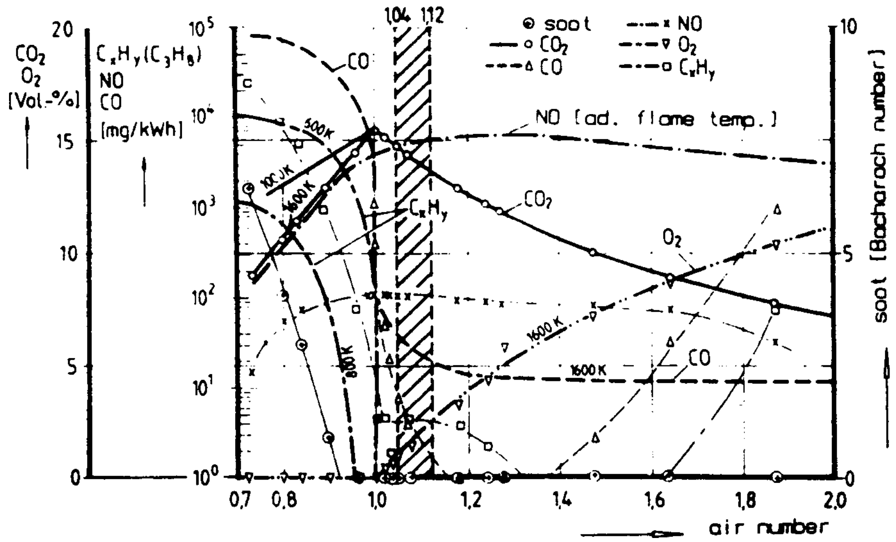

Fig. 2: Flue gas species content versus air/fuel ratio.

In the range of the "operating window" and stationary burning conditions soot emission is zero, as Fig. 2 shows. Unburnt hydrocarbons are lower than 3 mg C3H8/kWh, carbonmonoxide shows values between 2 and 10 mg/kWh and NO-values are just underneath 100 mg/kWh. This is well below those limits that are fixed by emission control laws of the Fed. Rep. of Germany. The burner is awarded to contribute to protect natural environment.

Comparing measured and equilibrium values of the individual species, one may see, that this burner reaches almost the given theoretical limits, besides with NO, where fortunately the reaction rates are such slow, that considerably less NO can be generated in the furnace than theoretically could be possible.

Besides those with firing steady-state investigations on the emission profiles during burner ignition and shutdown have been done. Here mainly unburnt hydrocarbons and carbonmonoxide raise their values for a short time of period. But considering the intermittent operation mode of such burners during application, the overall emission of such installations considerably raises above stationary values. Especially at shutdown design modification are seen that can improve the emission characteristics. The investigations are still underway.

The NO EMISSION has three sources. The first one arises from the content of nitrogen containing substances in the fuel oil. According to our measurements this amounts to a portion of about 50 mh/kWh NO in the flue gas. The second one is the fuel rich combustion of the oil, for example in burning sprays, where, besides soot, NO is formed via cyanogen containing reaction branches. This type of combustion does not take place in the "rocket burner", as there is no fuel rich burning. This is one of the reasons, why this type of burner has so low NO emission rates compared to flame retention head burners. The effect of fuel rich combustion on NO emission can also be seen by the fact, that the natural gas burning version of this burner system just has a NO emission value of 38 mg/kWh.

The third source for NO is the oxidation of nitrogen by oxygen under high temperature. Here the reaction rate strongly depends on temperature, as Fig. 5 shows. Cooling of the flue gas by the furnace immediately after combustion occurred, only allows about 40 to 50 mg/kWh NO to be generated in this burner, while without cooling of the gas a content of 5250 mg/kWh might be possible to be reached.

Though the NO emission values of this burner type are already low, we are still looking for means of improvement. Remembering the emission portion attributed by the nitrogen compounds contained in the fuel oil, there is a margin of about 40 mg/kWh of Zeldovich-NO that can be removed, if appropiate means will be found.

The first means of influencing the NO formation that was studied was changing the temperature of the recirculating combusted gas by drilling holes into the flame tube, so that by the furnace cooled flue gas could be sucked into the recirculation zone of the burner (Fig. 3). The ratio of the bore cross section to the cross section of the entrance of the recirculation area was varied to increase the part of cooled recirculated gas. As Fig. 4 shows, this resulted in strongly decreasing the emission level, sloping off with high ratios, because suction pressure across the wall drops with increasing bore cross section. But the reduction achieved by this means amounts to about 35 mg/kWh, which for wet

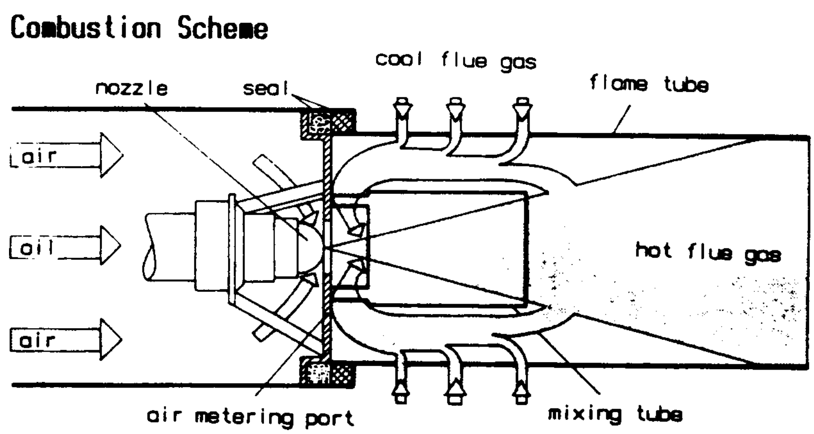

Fig. 3: Burner with flame tube holes for NO formation studies.

furnaces with cold furnace walls and 20,5 kW capacity is almost the Zeldovich-NO share of the emission.

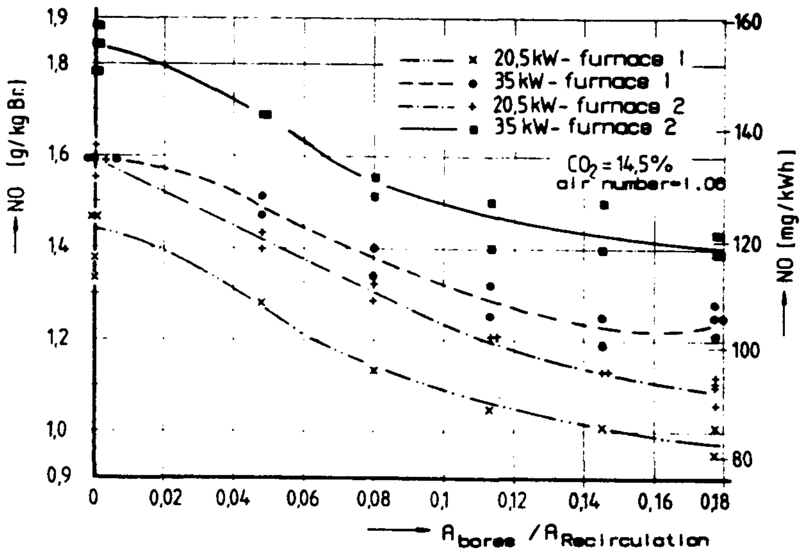

Fig. 4: Variation of NO emission by cooling recirculating gas.

In these investigations the burner performance and the furnace type were varied. The furnaces were overloaded with a 35 kW

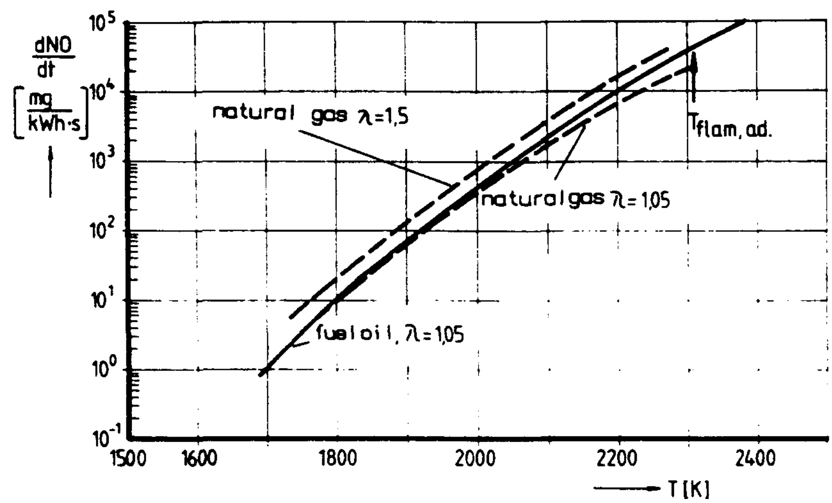

Fig. 5: NO formation rate versus temperature.

burner, which reduces the cooling rate of the flue gas in the furnace. This raises the emission level. But while furnace 1 has a watercooled jacket adjacent to the burnt gas, furnace 2 has a so-called "hot furnace" having an uncooled steel insert which the burner is firing into. This also reduces the cooling rate of the flue gas and raises the NO emission. This is well in accordance with theory which predicts higher formation rates, if the residance time of the burnt gas at higher temperature is increased.

Looking at the formation rates for NO, when fuel oil or natural gas is burnt, the curves teach that in a given period of time only one tenth of Zeldovich-NO is generated, if the temperature of the gas is lowered by about 120 K. This points onto decreasing the combustion temperature or raising the cooling rate of the burnt gas for reducing NO emission. The question is, which means is more effective. This has been studied theoretically (Fig. 6).

In a simplified model we assume that the flue gas leaving the reaction zone flows at a velocity of 6 m/s and is cooled down from the initial temperature of 2200 K by 1 K/mm. Applying the information of Fig. 5 to this model gives the NO formation rate versus time as shown in Fig. 6. Integrating the formation rate over time delivers the overall emission of NO which is given in figures in Fig. 6 too. The same treament has been applied to models where the initial temperature is 2000 K with 1K/mm decay resp. for 2200 K temperature at the beginning and 2 K/mm decay. The result is that a decrease of the peak temperature by 200 K is by far more effective in reducing the NO emission level than doubling the cooling rate in the gas flow. For peak temperatures

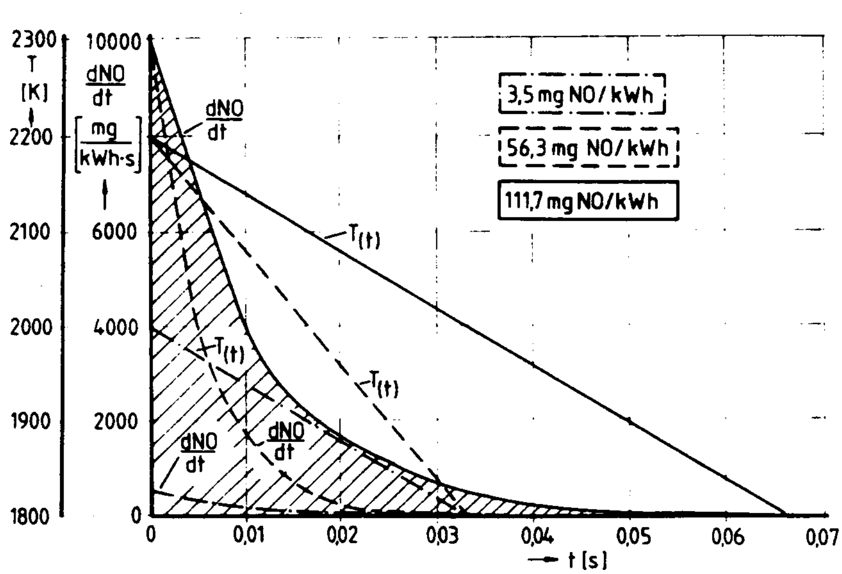

Fig. 6: Calculated NO formation rates and NO emission in a model burner.

of only 2000 K almost no Zeldovich NO is formed under these burner conditions.

These theoretical results are emphasized by data gained in hot firings with the "rocket burner" (Fig. 7). There the air number has been varied between 1.08 and 1.38 which means decreasing combustion temperature. The results of these firings show that flue gas recirculation inside the burner and low combustion temperature can be combined to end up with no Zeldovich NO, because those about 45 mg/kWh NO at the lowest point just correspond to the portion that is formed from burning the nitrogen compounds in the fuel oil.

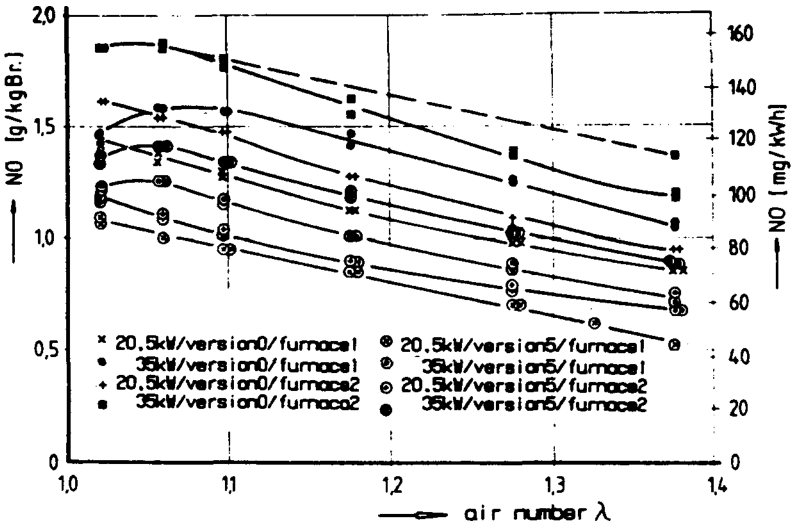

Fig. 7: NO emission over air number

The effect of faster cooling of the flue gas has been proven by reducing the swirl of flue gas in the flame tube. Thus the Zeldovich NO could be lowered by about 25 %, as swirl increases the residence time of the gas in the hot temperature regions.

The investigations show that there is still some space for reducing NO emission by development of burner technology.

Concerning <u>CO EMISSION</u> Fig. 2 has shown that even close to the stoichiometric point the emission values are low. This is mainly due to the fact that in this combustion system the conditions for chemical reaction of the fuel with air to complete combustion are well organized. But this also postulates that the air flow entering the combustion zone is symmetrically distributed. Burner fans normally do not fulfill this condition, as Fig. 8 shows, where on the left side the stagnation pressure of the air flow at the air metering port exit is plotted for an uncorrected burner system. Applying guiding vanes in the air flow a short distance downstream of the fan exit (Fig. 9) improves the distribution pattern considerably (Fig. 8). As Fig. 10 shows, this improvement shifts the near-stoichiometric raise of the CO emission somewhat closer to the stoichiometric point. This is of importance, if the burner is to be operated at small air numbers.

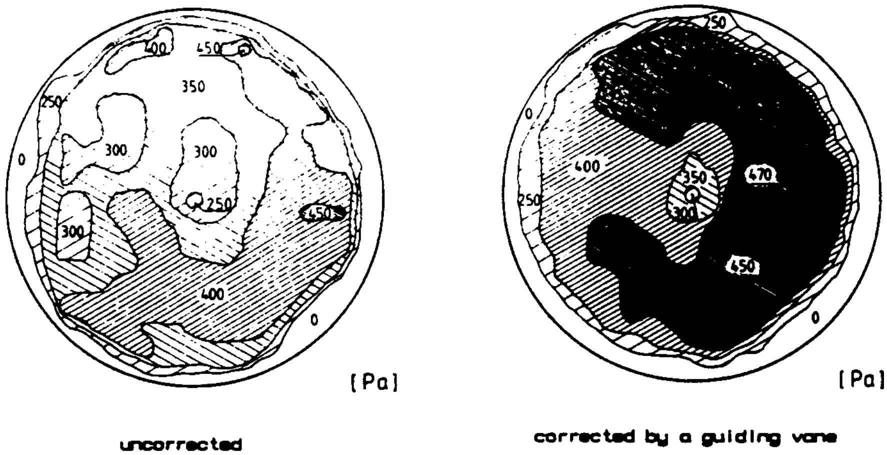

Fig. 8: Distributions of stagnation pressure in the air metering port.

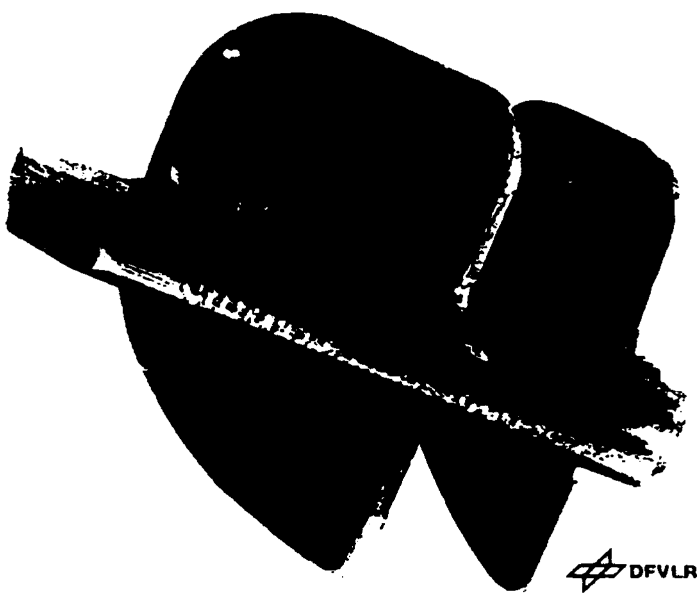

Fig. 9: Guiding vane for flow correction.

Combustion noise sometimes is felt to be a pollutant. This combustion system had the disadvantage to generate some more noise than conventional burners do. So we started an investigation and technology program to reduce the combustion noise of this burner

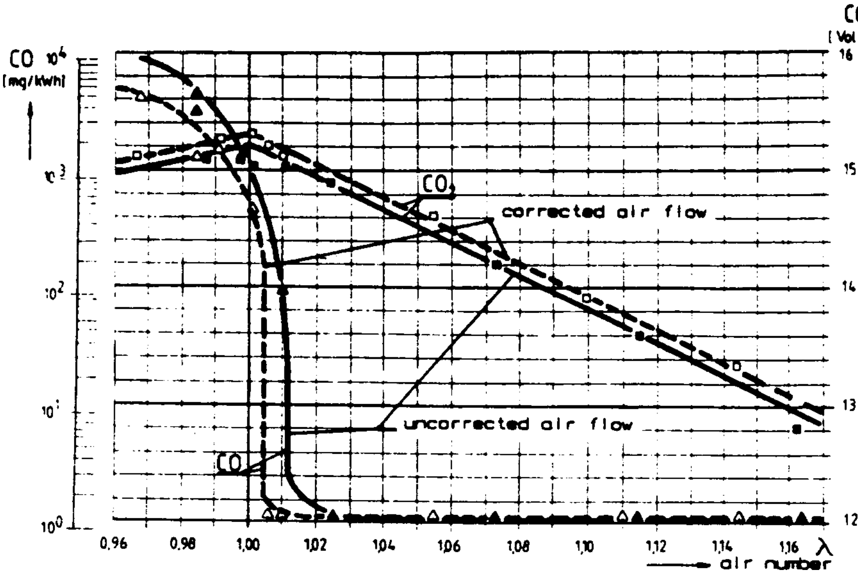

Fig. 10: Compound concentration in the flue gas for corrected and uncorrected air flow.

type. The noise source found is the turbulence initiated at the edges of the air metering port which then spreads in the region where air flow and recirculating flue gas mix. The intensity of the pressure turbulence increases as the flow progresses further downstream. As in this burner type the flame is located a fair distance downstream the air metering port, the noise level is raised. The flame acts as an amplifier of pressure turbulences which are sensed as noise. To reduce the noise level we felt it necessary to modify the system so that the turbulences will be damped down a short distance before the flow enters the flame. This is done by adding a tube section downstream of the known mixing tube and dividing the air flow into several streams which

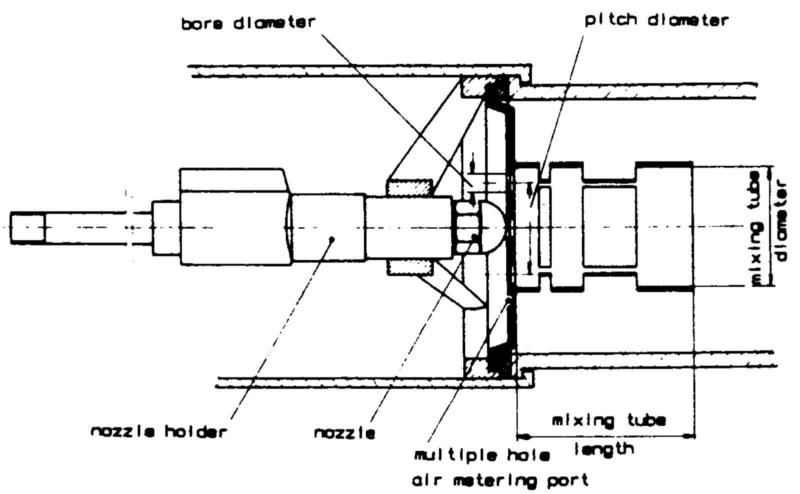

Fig. 11: Burner head system reducing combustion noise.

are located close to the mixing tube wall. The appropiate modification is shown in Fig. 11. Fig. 12 demonstrates how the noise level reduction can be improved by increasing the pitch diameter of the holes in the air metering port so that the air flow comes closer to the tube wall. The design modification resulted in noise level reductions of 8 to 10 dBA, which is more than necessary to fulfill the demands.

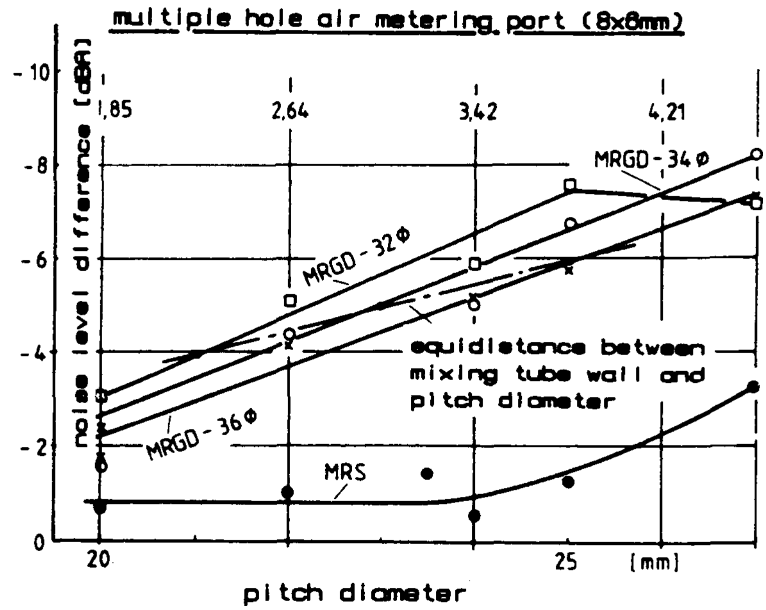

Fig. 12: Noise level reduction compared to series version of the burner versus pitch hole diameter of multiple hole air metering port.

PERFORMANCE RANGE

The broadest application of this burner type as far as production numbers are concerned lies in the range between 17 and 35 kW. More than 200.000 burners have been sold during the past ten years with an increasing tendency, also because other manufactures have started to apply the "Rocket Burner" in prefabricated units of furnace and burner. The burners are now sold up to a performance of 120 kW.

Improvements of house insulations have raised a demand of performances at and below 10 kW. This cannot be covered by conventional swirl atomizers, as the slot dimensions in the nozzle become too small. Analysis of atomization techniques led us to realize small mass flow atomization via bypass swirl nozzles which are also useable to design burners with variable performance. This way prototyp burners have been operated down to about 5 kW performance. A burner prototyp variable in performance in two stages of 9 resp. 25 kW has successfully been operated in long-term runs. The pollution relevant values of the two performance stages are listed in the following table.

Performance	9 kW	25 kW	
CO2	14,1	14,1	Vol.-%
Soot	0	0	Bacharach No.
CxHy	2	4,2	mg C3H8/kWh
CO	5	6	mg/kWh
NO	84	97	mg NO/kWh

If the performance is to be increased beyond about 120 kW, again there is the problem of finding the appropriate atomization tool. To achieve the necessary fineness of the spray with swirl nozzles the feed pressure is to be raised as massflow increases. It fast climbs up to values beyond 100 bar which pumps cannot withstand for long-term operation. Here we switched over to air assisted atomization. The components of the combustion system become proportionally larger. The emission values are as with smaller performances. Only the NO emission raises to about 220 mg/kWh, if the burner performance holds values of 200 to 800 kW.

SUMMARY

DLR has developped a blue-flame combustion system for natural gas and No. 2 fuel oil which has been successfully introduced into the market in Europe since ten years. Due to the fact that this combustion system operates absolutely soot-free the fuel energy can be used most efficient. Also the pollutant emission values that are achieved with this system are very favourable.

Additional research in the meantime brought further improvemnets, mainly concerning NO formation and combustion noise reduction.

By prototype testing it has been shown that this system is able to work within the performance range of less than 10 kW and up to 1 MW as well as it can be operated with performance staging by a factor of 2.5.

As the flue gas of this burner is soot-free, this system is specially suited to be combined with condensing furnaces and for desulferization. Technology development in this field has also been done by DLR.

Paper No. 89-6

EMISSIONS CHARACTERISTICS OF MODERN OIL HEATING EQUIPMENT- COMBUSTION TEST FACILITY RESULTS

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ABSTRACT

Over the past 10 years there have been some very interesting developments in oil heating. These include higher static pressure fans, air atomization, low heat loss combustion chambers, condensing furnaces, and lower firing rate nozzles. The current data base on the emissions characteristics of oil-fired residential heating equipment is based primarily on data taken in the 1970's. The objective of the work described in this paper is to evaluate the effects of recent trends on emissions.

Detailed emissions measurements have been made on a number of currently available residential systems selected to represent recent development trends. Some additional data was taken with equipment which could be considered to be in a prototype stage including a prevaporizing burner and a retention head burner refit with an air atomizer. Measurements include NO_X, smoke numbers, CO, gas phase hydrocarbons, and particulate mass emission rates. The systems were evaluated both in steady state and cyclic operation.

Emissions of smoke, CO and hydrocarbons were found to be significantly greater under cyclic operation for all burners tested. Generally particulate emissions were about 4 times greater in cyclic operation. Air atomized burners could be operated at much lower excess air levels than pressure atomized burners without producing significant levels of smoke. As burners get better, either through air atomization or prevaporization, there is a general trend towards producing CO at lower smoke levels as excess air is decreased. The criteria of adjusting burners for trace smoke may need to be abandoned in favor of adjusting for specific excess air levels.

INTRODUCTION

Air pollutants emitted by residential heating equipment include CO, NO_X, SO_X, particulates (soot), and very small quantities of gaseous unburned hydrocarbons. The basic emissions patterns for residential heating equipment were established in the early 1970's primarily through a field study and follow up laboratory study done by Battelle Columbus Laboratory under the sponsorship of the American Petroleum Institute (API) and the Environmental Protection Agency (EPA) [1,2]. The primary purpose of that work was to establish the contribution of residential heating to the national emissions inventory. Since that time there have been a few tests of some selected equipment done by different groups including some by BNL [3,4,5]. Most of the equipment which has been tested like this has been novel and most of it is not at present on the market. The equipment which is currently on the market or close to being on the market has changed since the early 1970's. In the Battelle field study for example a large portion of the burners tested were non-retention head burners.

In this paper results are presented of emissions tests done with a number of oil heating units selected as being typical of modern equipment or representing a recent development trend. The primary purpose of this work was to provide a benchmark of what oil equipment can do today and what the effects of some of these recent trends are on emissions.

EQUIPMENT SELECTED FOR STUDY

Table 1. lists the equipment which was selected for testing along with a two letter code for each unit. This two letter code is used throughout the results presentation.

The first unit (CR) is a conventional retention head burner with a low static pressure fan (1" water max- R.W. Beckett Corp. Model AF). The second unit (HS) is a newer retention head burner with a higher static pressure fan (3" static) and a flat retention head design (Beckett AFG L1 head, MB ATC). The feature which was of primary interest in the case of this burner was the high static pressure, which has been shown to reduce startup smoke peaks [6]. Unlike some models of this burner the unit tested did not have an inlet air shutoff device.

Unit #3 is another retention head burner with a high static fan and a flat style retention head. The unit also includes a brief combustion air prepurge and an automatic soot control system (Riello- "Mectron" 3M). The fourth unit (AT) is an air atomized burner currently marketed in Europe [7]. This is a very unique system which uses the externally atomized "Babington" nozzle. [8,9] The system firing rate can be adjusted easily during firing by changing the flow rate to the atomizers with a simple screwdriver adjustment.

Units 1 to 4 and units 7 and 8 are all burners only (without heat exchangers) and tests with these units were done by firing into a cast iron boiler (Peerless). Unit 5 (LM) included both a burner and boiler (System 2000, Energy Kinetics). This is a low mass boiler designed to be purged after each firing cycle. From an emissions point of view this unit was of interest because of its unusual combustion chamber design, which is arranged so that there is no direct radiant load on the flame. The flame cannot "see" any cooled surfaces directly. The burner used in the tests is a high static retention head burner (Beckett AFG F3 head, no air damper). To isolate the effects of the chamber on emissions some tests were done with the chamber removed. In this case the burner fired into a completely cold (water backed) enclosure.

The sixth unit (CF) included a retention head burner (Wayne Home Equipment Model HS) firing into a condensing warm air furnace. An induced draft fan is incorporated, which provides a post purge of 5 minutes. Unit #7 is a prevaporizing burner which is currently in a prototype stage. This unit was submitted to BNL for this program by Foster Miller Associates Inc. Some of the early development of this burner was sponsored through BNL [10]. More recently its development has been sponsored by The New York State Energy Research and Development Authority 9who requested the unit be submitted to BNL). This unit has the capability of firing oil at rates as low as 0.1 gph with a clean, blue flame.

The final unit tested (AA) is a conventional retention head burner which was modified at BNL to have an air atomizing nozzle (Delevan Corporation Siphon Model). The interest in this case was to provide a preliminary evaluation on the benefits which could be realized with the improved atomization. The atomization performance of the nozzle included in this burner is described in another paper at this conference [11].

As shown in table 1. most of the burners were tested at a firing rate of 0.5 gal./ hr.. The high static retention head burner (HS) was also tested at a firing rate of 1.0 gph to provide some evaluation of the effect of firing rate. The low mass boiler/burner unit was tested at 0.85 gph which was selected based on the manufacturers specifications. The firing rate of 0.5 gph was selected for most tests for two reasons. First, at that rate there is overlap between the firing rate capabilities of all of the burners. The second reason is simply the continuing interest at BNL in the development of lower firing rate systems.

EXPERIMENTAL

The basic test plan which was followed for each of the units tested is described in the following steps:

1. With the burner firing in steady state, CO, NO_X, smoke number, and gaseous hydrocarbons (HC) were measured as a function of excess air.

2. The excess air was then set to a level 10% greater than the level which produces a smoke number of 1. A zero smoke number was achieved in this manner with all systems on an equal basis for comparison.

3. With the burner operating in steady state at the excess air level set in step 2 the particulate emission rate was measured.

level set at 50%.

The steady state emissions of NO_X are shown in figure 3. For unit HS higher steady state NO_X levels are shown at the 1 gph firing rate. This is most likely due to increased flame temperatures at the higher firing rate. For the case of the low mass system (LM), removal of the combustion chamber significantly reduced the measured NO_X emissions. It is interesting to note the NO_X levels for the prevaporizing burner (PV), which are high relative to those measured for the other burners at the same firing rate.

In figures 4 and 5 typical transient emissions of CO, HC, NO_X, and smoke are shown for one retention head burner. This general trend was observed for all of the units with some exceptions. Figure 6 shows a comparison of the startup and shutdown smoke numbers for all of the units tested. The two air atomized burners tested and the prevaporizing burner did not produce any smoke transients. The retention head units (LM and CF) showed a startup smoke transient, but no shutdown transient. Note that in both cases a fuel solenoid valve was used. In the case of the air atomizing burner (AT) the startup peak of HC was much longer in duration although typical in magnitude. The effect that this might have on heat exchanger fouling is uncertain. The highest emission peaks for both CO and HC were observed in the case of the low mass unit (LM) with the combustion chamber removed. Here the peak emissions were 10 times greater than observed in other systems. Note that this is not how the system is built by the manufacturer. A lot of effort went into design of the chamber and it is an integral part of the system when shipped by the factory.

The particulate emission rate for all of the units in both steady state and cyclic tests is shown in figure 7. In all cases the cyclic emissions are significantly greater than those measured during steady state, on the average 4 times as much. The lowest cyclic particulate emission rate was observed with the air atomizing burner (AT) at the increased excess air level. In cyclic tests the highest particulate emissions were realized for the low mass system (LM). It seems likely that this unit suffered more during the time required to warm up the chamber than other systems. When this unit was operated at an excess air level similar to the other retention head burners at 0.5 gph (50%) the cyclic particulate emission rate was found to be among the lowest measured. Particulate emission tests have not been done to date with the prevaporizing burner because of concerns over the ability of this prototype to run reliably over the required test duration.

CONCLUSIONS

In general the emission rates for particulates were found to be low for all systems, on the order of 0.2 to 0.6 lbs. /1000 gal. in cyclic operation. This could be compared to the average result found in the Battelle field study of 2.5 lbs./1000 gal. It might be expected that the field study would produce higher emission than would be obtained under controlled laboratory studies. Still the present results indicate that under proper conditions modern retention head burners can operate cleanly. The results of the Battelle study are currently used by the EPA to assess the relative contribution of residential oil heating equipment to the national inventory of emissions, which to

4. At the same excess air level the burner was operated in 5 minute on/ 15 minutes off firing cycles. The emissions of CO, NO_X, HC and smoke were measured as a function of time from the burner start.

5. At the conditions set in step 4 particulate emissions were measured over cyclic operation.

In addition to the above tests some tests were done with one retention head type burner (LM) and one air atomizing burner (AT) at a higher excess air level than set in step 2 above. This was done simply to evaluate the effects of operating these systems at these increased excess air levels.

The particulate emission rate was measured using a modified EPA method 5, which essentially involves pumping a part of the flue gas through a preweighed filter. Each particulate emission rate test required about two days of sampling to ensure that an adequate sample mass was obtained and to ensure that the sample was representative. Each test was done twice and repeatability was generally very good. In the cyclic tests the particulates sampling system was started about 30 seconds before the burner started and was operated for about 30 seconds after burner shutdown.

Flue gas oxygen for excess air determination was measured using a paramagnetic analyzer. Carbon monoxide was measured using an infrared analyzer and a chemiluminesence analyzer was used for NO_X. Hydrocarbons were measure using a heated Flame Ionization Detector (FID) type analyzer. All of the analyzers used were manufactured by Beckman Instruments.

RESULTS

Figure 1. shows the excess air at the set point defined in step 2 above. This could be considered as the first figure of merit for comparing different burner systems. For burner HS figure 1 shows that a reduction in firing rate from 1.0 top 0.5 gph requires an increase in the excess air. This is a typical result due in part to the lower air velocities at the lower firing rate. At 0.5 gph all of the retention head burners tested in the cast iron boiler (CR,HS,RF) require essentially the same excess air. All of the air atomized burners which were fired into the same boiler could be operated at much lower excess air levels. The burner fired into the low mass boiler could also be operated at lower excess air levels, due to both the higher firing rate and the combustion chamber used. Figure 1 shows the excess air set point for this system with the chamber removed which illustrates how much lower the excess air setting can be with this unit when using the chamber. The retention head burner which was fired into the condensing furnace could also be operated at fairly low excess air levels.

Figure 2 shows the steady state CO emissions for all of the units tested. In every case the CO emission levels were very low. It is interesting to note the relatively high CO, however, for the case of the low mass boiler with out a combustion chamber. For units LM and AT results are included for the setpoint excess air levels as shown in figure 1 and a higher excess air date is not a major concern of the EPA..

The use of advanced air atomizing burners can lead to significant additional reductions in particulate emissions if these are operated with modest excess air levels.

Overall, cyclic operation still contributes most of the particulates which are emitted, and improving this cyclic performance may hold the greatest opportunity for realizing even cleaner systems in the near future.

Without a combustion chamber higher transient emission levels of HC and CO are realized, but reduced NO_X. The impact that higher HC transients may have on heat exchanger fouling is not known.

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Table 1 Equipment selected for study

1.	CONVENTIONAL RETENTION HEAD	.5 GPH	(CR)
2.	HIGH STATIC RETENTION	.5 & 1.0 GPH	(HS)
3.	RETENTION WITH FEATURES	.5 GPH	(RF)
4.	AIRTRONIC	.5 GPH	(AT)
5.	LOW MASS/ HIGH REFRACTORY	.85 GPH	(LM)
6.	CONDENSING FURNACE	.5 GPH	(CF)
7.	PREVAPORIZING	.5 GPH	(PV)
8.	AIR ATOMIZED	.5 GPH	(AA)

Figure 1. Excess air at the set point

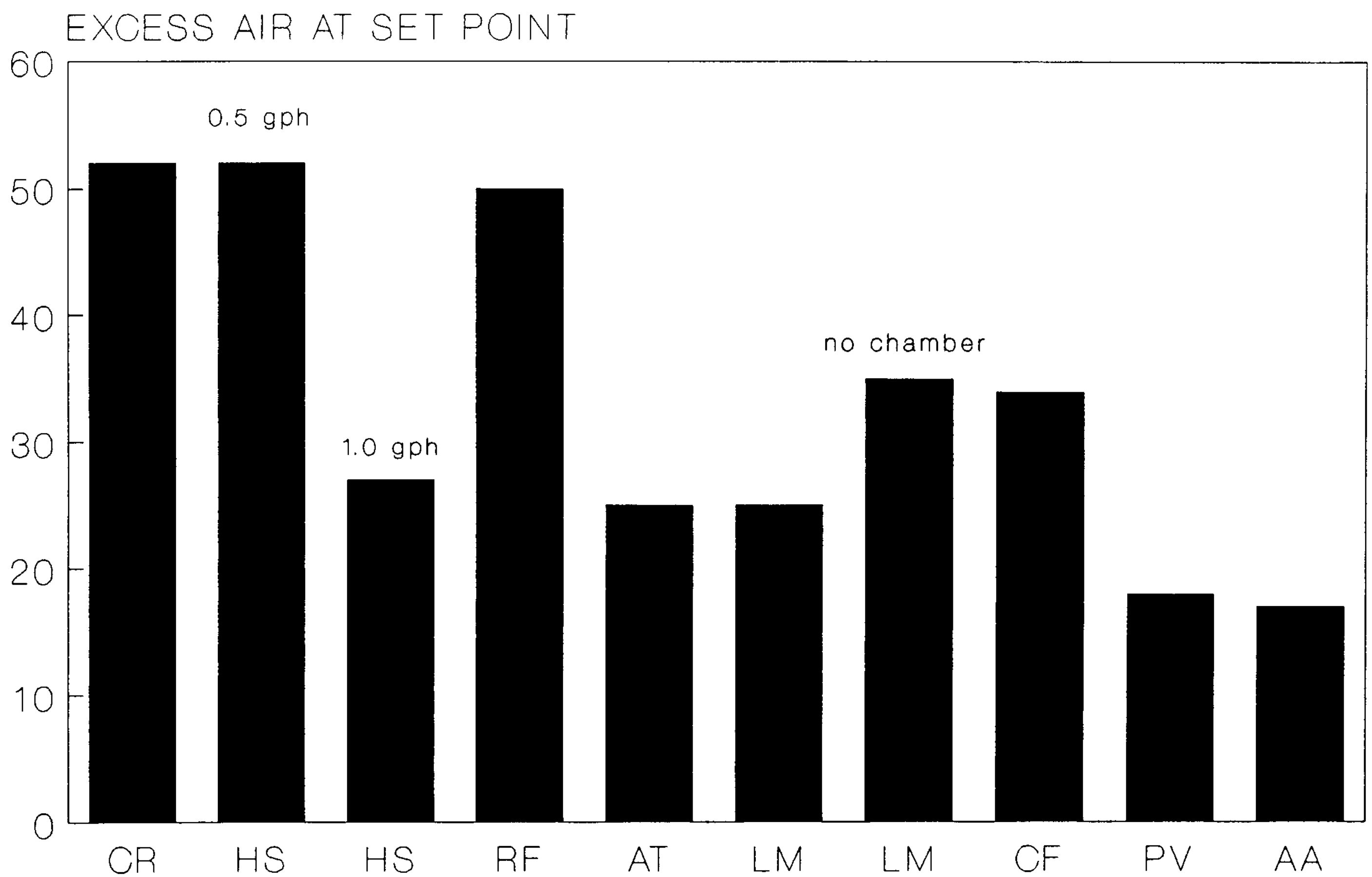


Figure 2. Steady state CO

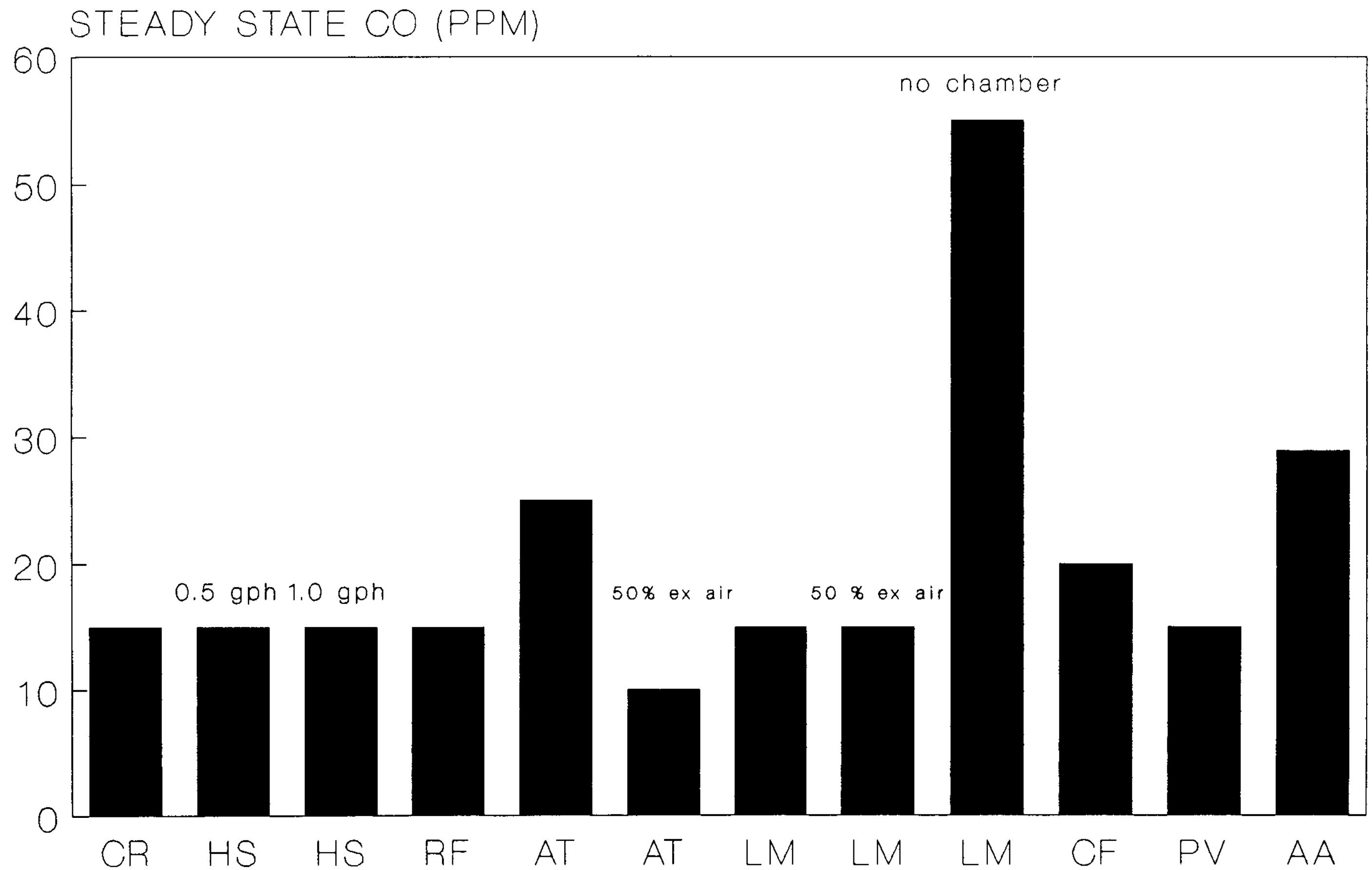


Figure 3. Steady state NOx

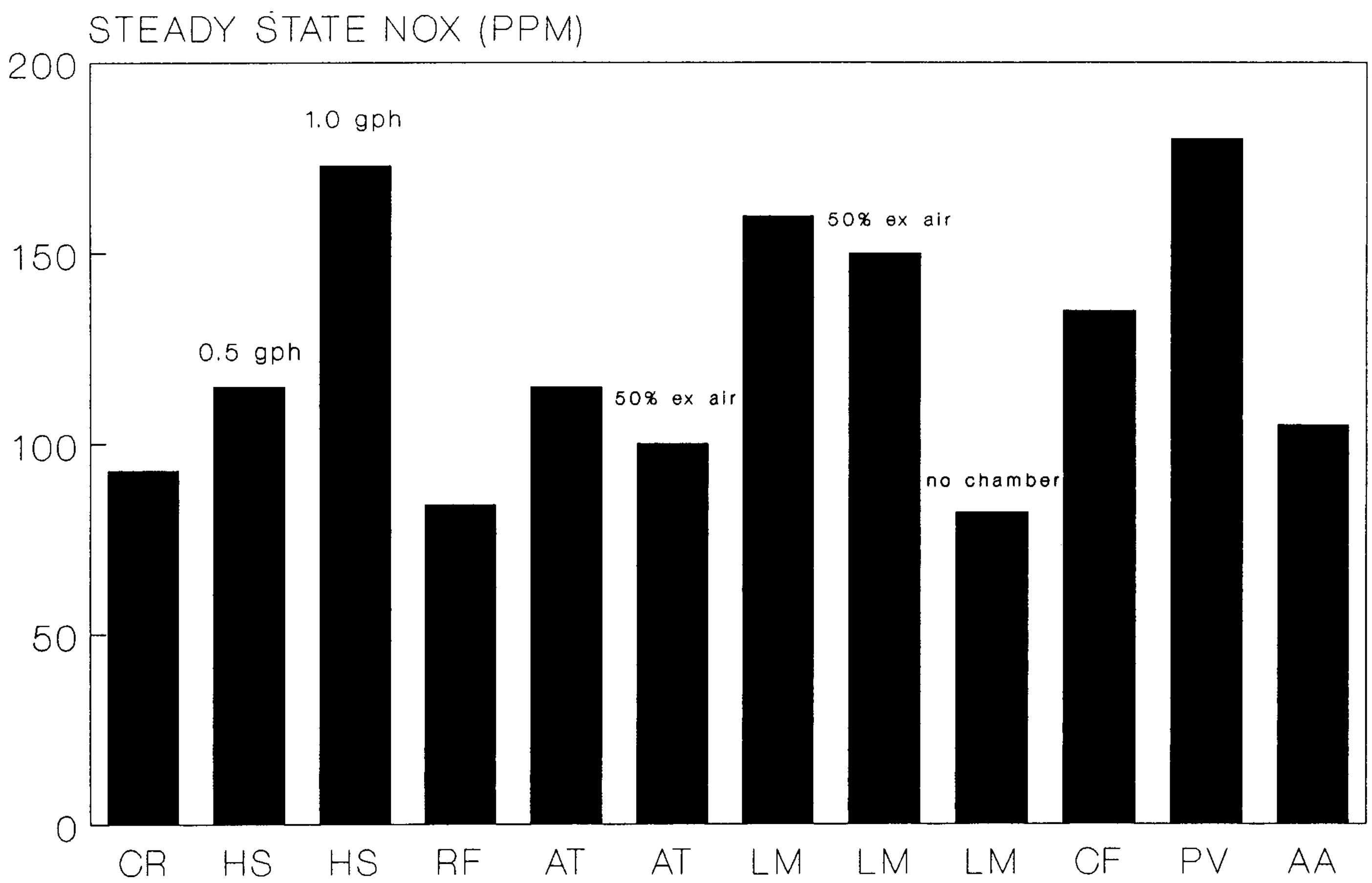


Figure 4. Transient smoke and HC.(LM)

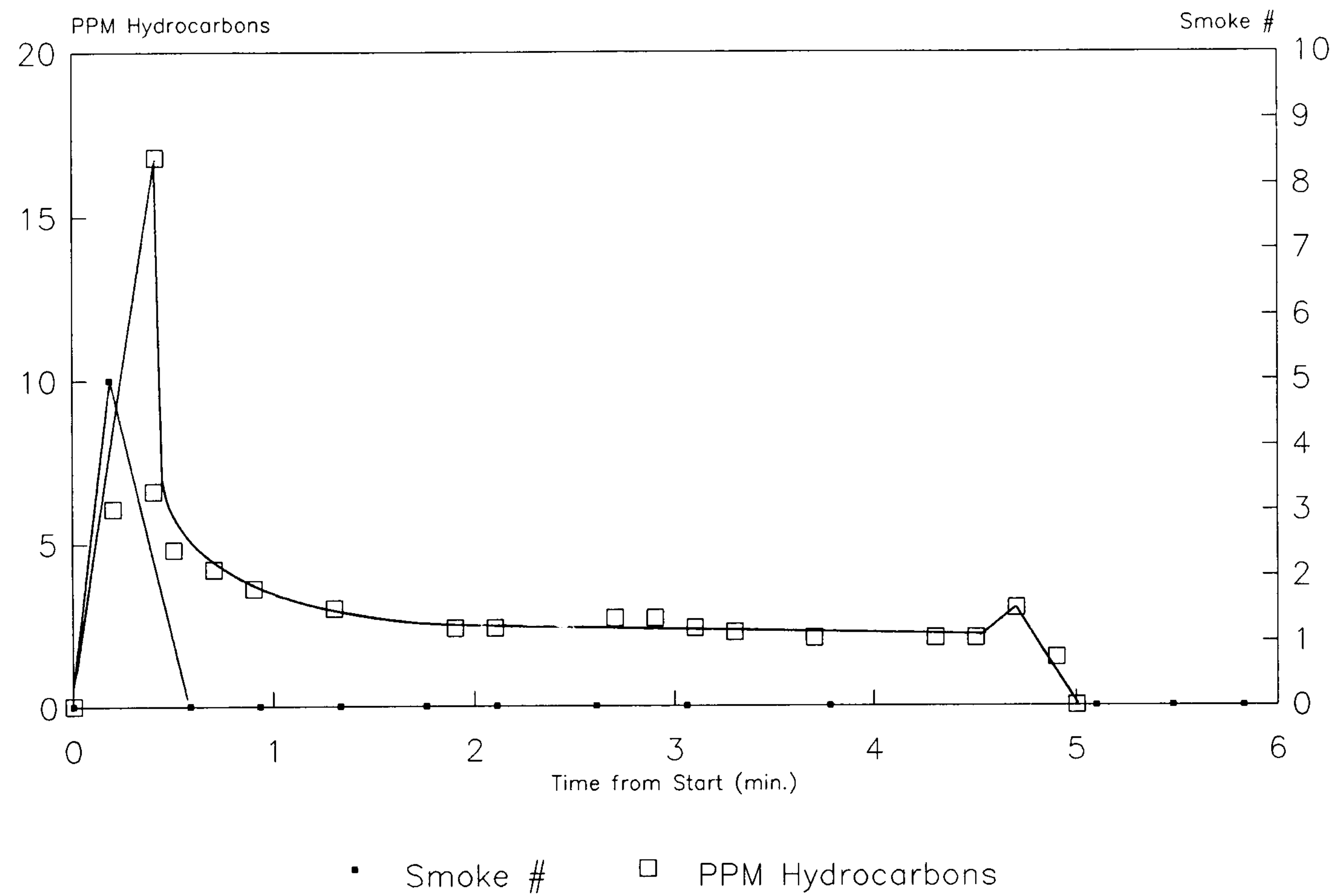


Figure 5. Transient CO and NOx-unit LM

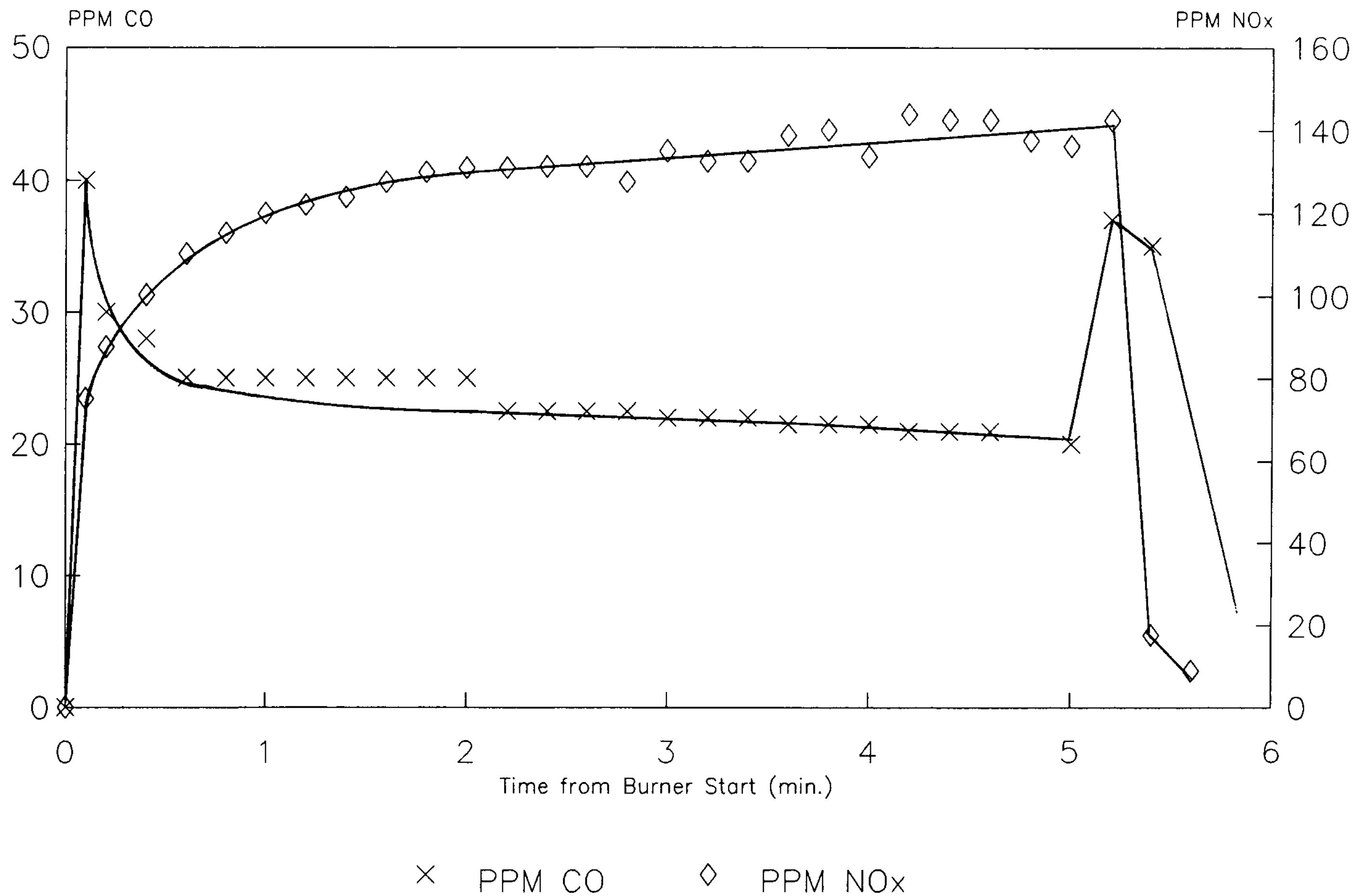


Figure 6. Transient smoke numbers

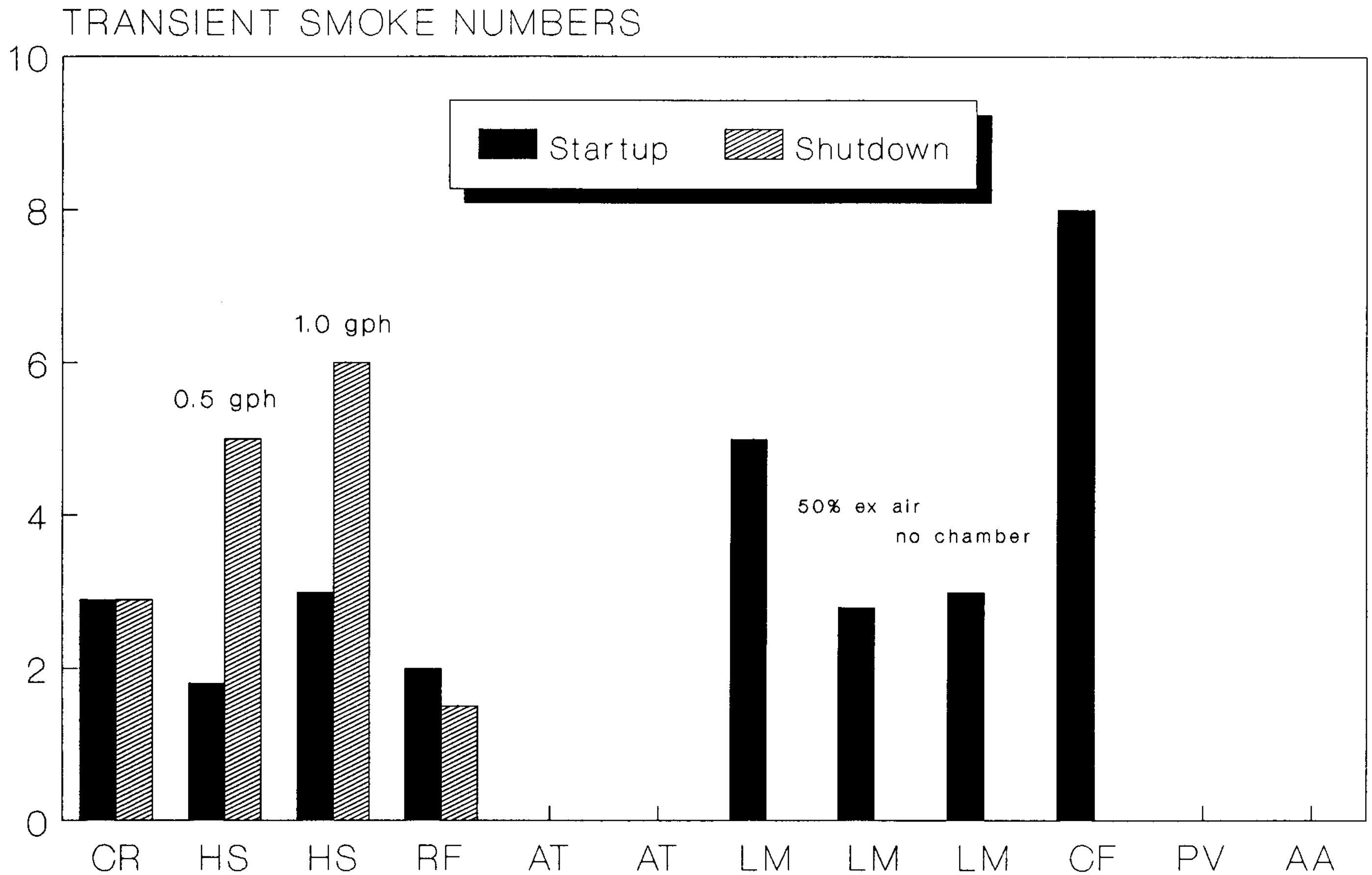
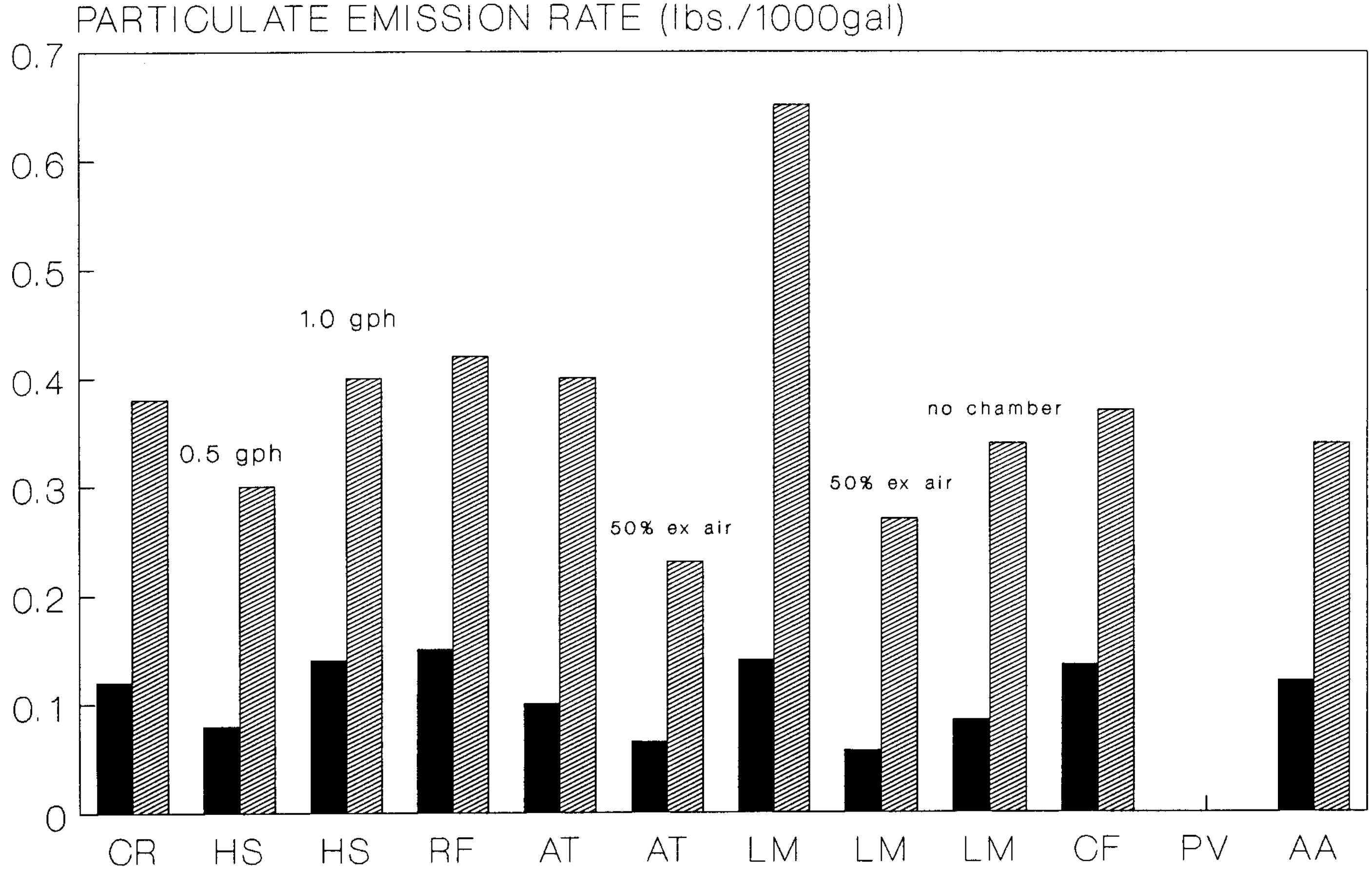


Figure 7. Particulte emission rates



Paper NO. 89-7

New York State Energy Research and Development Authority

Oil Burner Research Program

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This presentation described the research activities of the Building Systems Group within the New York State Energy Research and Development Authority. The Building Systems Group funds research projects in the subject areas of HVAC and lighting. Such projects typically develop or demonstrate advanced technologies that increase energy efficiency in buildings. Many of the projects are conducted in cooperation with participating manufacturers located in New York State. This presentation also described prospective program opportunities for research funding during the coming year as would be applicable to the oil heat industry.

This presentation also included a description of an ongoing project to develop a blue flame oil burner with low firing rate capability. The oil burner design incorporates internal combustion gas recirculation to vaporize and mix oil with combustion air prior to burning. The fuel/air mix then passes through and burns on a stamped sheet metal flameholder. The burner flame is similar (short and of blue color) in appearance to the type of flame observed with premix power gas burners that use flame holders.

The described oil burner design enables low firing rate operation by using the heat of recirculated combustion gases to vaporize fuel oil. While this aspect of the burner operation has not been studied in detail yet, it is our understanding that the burner therefore does not require as fine atomization as conventional oil burners. Combustion starts in conventional burners before vaporization and mixing of fuel with air has been completed. Very fine atomization is therefore required to minimize the presence of remaining liquid droplets within the combustion zone and to thereby reduce the formation of soot. Since the blue flame burner developed under this project distinctly separates the vaporization and mixing process from combustion, fine atomization is not absolutely necessary for soot reduction. The purpose of atomization in the described burner is rather to reduce the residence time required for vaporization and to enhance the mixing of vaporized fuel with combustion air. Smaller fuel droplets can obviously reduce the time required for vaporization and can therefore enable the burner to use a shorter vaporization and mixing chamber. This effect can provide the burner with greater geometrical design flexibility to meet typical burner size design requirements for oil-fired boilers and furnaces.

In addition to its low firing rate capability, the described oil burner design is also applicable to conventional residential and commercial size ranges. Based upon a revised design concept that has been established after field testing of the original prototype model burner, no physical size or firing rate limitations are apparent. The burner design therefore offers an advantage of broad size application not afforded presently by other advanced oil burner technologies.

The described oil burner (Figure 1) has been tested recently at Brookhaven National Laboratory and shows promising environmental performance characteristics relating to emission of soot and carbon monoxide. Further environmental testing of the burner by Brookhaven National Laboratory is anticipated. It is expected that the burner will exhibit especially low nitrogen oxide (NO_x) emissions once it is coupled to a furnace or boiler that takes advantage of the capability of the burner to operate without a large combustion chamber.

Further testing of the burner is planned by Utica Boilers, Inc. (the original joint manufacturing sponsor) of Utica, New York and Fulton Boiler Works, Inc., of Pulaski, New York. Discussions have also begun regarding potential sponsorship by the Energy Authority of advanced environmental testing and commercial size burner field testing within the near future.

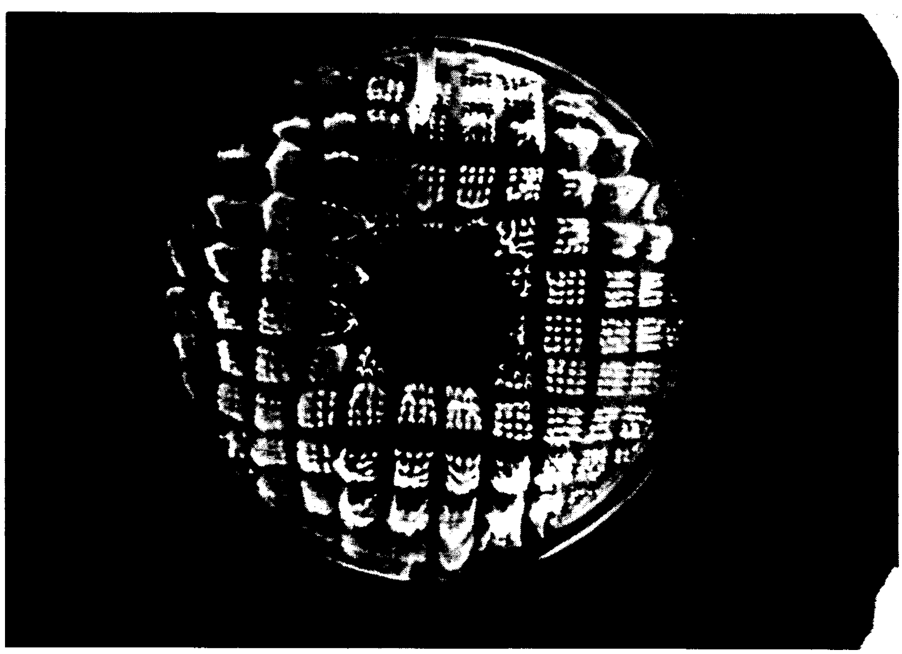

Figure 1. Prototype Blue Flame, Exhaust Gas Recirculation, Oil Burner

Paper No. 89-8

APPLYING THE BEST TECHNOLOGY TO ASSIST LOW-INCOME HOUSEHOLDS: OILHEAT RETROFIT PROGRAM

Mark Hopkins
Alliance to Save Energy

Summary

The Alliance to Save Energy conducted a research and technology transfer program to determine the effectiveness of installing flame retention oil burners in state low-income weatherization programs. Seventeen states implemented programs to install flame retention burners in oilheat systems; over 18,000 burners were installed and 1,500 energy auditors and heating contractors were trained. The program involved state conservation programs, national laboratories, equipment manufacturers, oilheat contractors and dealers, and community action agencies which weatherized homes. The program was supported by a cooperative agreement with the U.S. Department of Energy's Existing Building Efficiency Research Program and Weatherization Assistance Program.

The Alliance program demonstrated that installing these burners is an effective conservation measure (20 percent average improvement in steady-state efficiency (SSE); 16 percent average energy savings) in low-income programs. Recently, we have conducted a field study of the longevity of these energy savings by assessing retrofits installed five years ago. We found systems lost one-third of their SSE over a five year period. However, even with the loss, flame retention burners are still cost-effective to install.

Background

The first weatherization program started at a small community action agency in Maine in response to the 1973 OPEC oil embargo. The price of oil, Maine's primary home heating fuel, rose dramatically, and poor families couldn't afford heating costs. A local agency responded by installing conservation measures in homes to reduce the cost of energy.

Weatherization programs typically install weatherstripping, ceiling insulation, and storm windows. To assess the effectiveness of weatherization, the National Bureau of Standards (NBS) conducted the Optimal Weatherization Research Program in the early 1980's that found "significant increase in savings when mechanical as well as architectural options are installed." Unfortunately, state and local weatherization managers did not have any program procedures to guide the installation of mechanical measures. About the same time, Brookhaven National Laboratory conducted a small field test of one promising option - the flame retention oil burner.

Flame retention burners are high-efficiency burners that can be used to replace older, less efficient burners in oilheat systems. Retention burners are capable of hot gas recirculation within the flame, which uses less air to achieve combustion. This produces a hotter flame and hence better heat transfer, making it possible to achieve an efficient 80+ percent steady-state efficiency level. These burners also allow nozzles to be downsized and reduce off-cycle losses because they restrict the amount of air that can pass through the burner when the system is not operating.

This paper discusses an oilheat retrofit program the Alliance operated from 1982 until 1987 to help state weatherization programs install flame retention burners. It also summarizes our field study of the longevity of retrofit savings.

Alliance OilHeat Retrofit Program

In 1981, the Ford Foundation, and later the Standard Oil Company, funded the Alliance To Save Energy and the Institute for Human Development, which operated an oilheat retrofit program in Philadelphia, to develop and field test procedures for installing flame retention burners. A program approach was developed and pilot tested through training programs for heating contractors and energy auditors.

In 1983, two offices at DOE -- the Existing Building Efficiency Research Program and the Weatherization Assistance Program -- funded the Alliance to provide training and technical assistance to state weatherization programs to install oilheat retrofits in low-income homes. The program, entitled "Applying the Best Technology to Assist Low-Income Households," but generally referred to as the "Retrofit Program," was conducted by a team that included the Alliance, Oak Ridge and Brookhaven National Laboratories, and the Institute for Human Development (later replaced by the Corporation for Ohio Appalachian Development). Projects involved other organizations such as state conservation offices, oil contractors and dealers, and community non-profit groups.

Several evaluations of oilheat retrofit programs were conducted during the early 1980's; a review and analysis of these were done. Past evaluations varied in quality and used different methods to determine savings. Savings ranged from 11 percent to 22 percent. Two major factors influenced savings - retrofits of boilers tended to achieve higher savings than those of furnaces, and the lower the initial steady-state efficiency of the system, the greater the potential savings from a burner retrofit.

A model plan for a state retrofit program and the necessary forms to administer a program were prepared. Program procedures were developed and states were provided with contacts in the equipment industry. Procedures included diagnostic tests, performance standards, a fixed fee for service, and training for technicians.

About 75 training workshops on oilheat retrofits were conducted for 1,500 community energy auditors and heating contractors. States were encouraged to develop their own training capabilities. Minnesota, Wisconsin, Ohio, Washington, Massachusetts, New York, and Pennsylvania continue to provide training opportunities in various ways. Manufacturers of burners, also provide training programs for heating contractors.

A training manual entitled "Technician's Manual: Low-Income Oilheat Retrofit Program" was developed for use in training sessions. The manual was reviewed by state energy and weatherization offices, trade associations, national laboratories, and private businesses. The manual explains the features used in the retrofit program, provides basic information about oil heating, the flame retention burner, and troubleshooting, and discusses other conservation options for oilheat systems. Importantly, the manual allows states to conduct their own training workshops. Over 950 copies have been disseminated; it is currently available from the Alliance.

Seventeen states were assisted in implementing programs to install flame retention burners in weatherized homes. Several of these programs were large-scale projects involving the installation of thousands of burners. Participating states installed over 18,000 burners.

Program procedures developed by the Retrofit Program were successful in allowing state weatherization programs to institute burner retrofits into their low-income conservation programs. Most states with a large concentration of oilheat homes now install burners in their weatherization program. Further, the oilheat industry has now adopted the flame retention burner as the industry standard; all new systems include high efficiency burners.

Longevity of Energy Savings: An Inspection and Analysis of OilHeat Systems Five Years After Retrofit

Previous studies have estimated the short-term improvement in efficiency that results when an oilheat system is retrofitted with a flame retention burner. In nearly all cases retrofit brings a system's steady-state efficiency (SSE) up to 80 percent or more, close to that of a typical new heating system. Questions remained, however, as to the long-term benefits: Would the high level of efficiency achieved by retrofit remain in effect? Or would systems revert to their inefficient, pre-retrofit levels? How would a loss of efficiency affect the long-run economics of the retrofit option?

The Alliance to Save Energy studied the field performance of oilheat retrofits installed five years ago. The purpose was to assess the longevity of energy efficiency improvements resulting from the retrofits.

The study took place during the winter of 1987-88 in two states-- Maine and Wisconsin--which had conducted oilheat retrofit programs in 1982. To conduct the study we inspected 61 heating retrofitted systems. The systems were tested for SSE and smoke level, and major components were inspected. Service histories were compiled by inspecting records of both homeowner and heating contractors and interviewing. Additionally, clients and service personnel were interviewed regarding their service practices and attitudes.

Key findings were as follows:

- The retrofits initially improved steady-state efficiency by 20 percent, corresponding to expected savings of 16 percent in fuel consumption. Actual savings could be greater due to reduction of off-cycle losses, which we have not estimated.

- About one-third of the initial gain in steady-state efficiency was lost over five years. Almost all systems, however, are still performing well above their pre-retrofit levels.

- Despite some loss of efficiency over time, oilheat retrofit remains, in our judgment, a cost-effective conservation measure.

- Retrofitted systems are seldom maintained according to recommended practices. Air filters are likely to be dirty, clogged, or missing. Systems are cleaned and tuned infrequently, if ever.

- Many service technicians tune systems without the aid of efficiency measurement instruments. The likely result is that systems do not get tuned to maximum efficiency.

- The vast majority of retrofitted heating systems met the program goal of providing at least five years' service beyond the date of retrofit and are likely to continue in operation for many years.

Based on the findings of the field research, we draw several conclusions and recommendations. At current fuel oil prices, retrofits offer about a 12 percent return on investment after adjusting for declining efficiency, and they pay back their initial costs through energy savings in about six years. We therefore recommend that states continue to offer oilheat retrofits in their low-income weatherization programs.

The financial merits of retrofit are fairly sensitive to the price of oil and the initial cost of the retrofit. If oil prices rise above current levels (about 80 cents per gallon), the returns rise sharply; the returns drop, on the other hand, if the cost of retrofit rises above the $500 benchmark. Program managers, therefore, need to evaluate the costs and benefits of retrofit as economic conditions change.

Questions remain about the rate of degradation of efficiency and the ability of routine service to minimize degradation. Given certain limitations of our data, we were unable to distinguish between unavoidable efficiency loss from unfortuantely poor service practices. While regular service appears to be correlated with improved performance, more frequent testing, inspection, and collection of service records over a longer period is needed to establish definitive conclusions. Also unknown is whether proper cleaning and tuning alone could restore previously-retrofitted systems to the high efficiency levels that were recorded immediately after retrofit.

We recommend that standards be established for training of heating system technicians and for servicing of retrofitted systems. We also recommend that state conservation programs educate retrofit clients about the importance of changing filters and obtaining proper service. Finally, we suggest that states consider using a portion of fuel assistance payments once standards are developed, to help low-income consumers obtain periodic cleaning and tuning of their retrofitted oilheat systems.

Paper No. 89-9

PRESENTATION TRANSCRIPT

POWER SIDEWALL VENTING OF OIL FURNACES

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It is a privilege to be invited to participate in this 1989 Oil Heat Technology Transfer Conference and, hopefully, I can transfer some information about the power sidewall venting of furnaces. First, I would like to say a little about Thermo Products. Thermo Products is our Company name. Thermo Pride is the tradename under which we market our products. We are a closely held Company - 43 years old this year. We manufacture a complete line of oil, gas and wood/coal forced air furnaces. Oil furnace capacities range from 56,000 to 320,000 Btu/hr output. We also manufacture split-system air conditioners in the two-to-five ton capacity range. We have two factories .. our main factory, Engineering, and Administration is located in Indiana, and our second Plant in North Carolina. We distribute out of those two factories eleven regional warehouses that are spread around the roughly 35 States in which we do business. We sell on a direct-to-the-dealer basis; rather than through the wholesale distributor, and we have approximately twenty representative that are out in the various territories calling on dealers.

The subject we are covering, of course, is Power Sidewall Venting and the question that first comes to mind is why did Thermo Products decide to become involved in this particular endeavor. About three or four years ago, we started receiving input from several of our representatives and dealers asking for a product that would allow them to use oil furnaces in homes that were currently heated by electricity. Obviously, the cost of electricity was the motivating reason. Improved efficiency was also an issue, due to the fact that you do not experience the heat losses normally occurring in a chimney with sidewall system. New construction, with space limitation, certainly was another key factor in favor of sidewall venting and increasingly, as more efficient products with lower stack temperatures are coming onto the market, chimney problems have become more evident and sidewall venting offers an alternative. Having attended the prior two BNL Conferences, I found that there was a lot of interest ... particularly at the last conference about this topic. That, more or less, was our final deciding factor in going ahead and taking a hard look at this program.

Before discussing, in detail, the development process, I want to show about a 3-1/2 minute segment of a 17 minute video which we mandate that any dealer who purchases his first power vent system must see. We mandate this to insure an awareness on the part of the contractor of the primary installation requirements. This short segment will give you an idea of the components that make up our system and the sequence of the systems operation. I have to admit that there is a 30 second commercial at the beginning. The video basically continues on into considerable detail about the specific installation requirements which are, of course, spelled out in the Installation Manual. At the end of the video, we touch upon UL; and that is going to be a major focus of the presentation. You should note that we are offering an entire package, and that entire package is UL listed. The package consists of the sidewall termination, the power venter with the inducer fan and pressure switch, all of the controls that go with it; relays, electric wiring harness, and for those applications where a person needs to go up into the floor joist area; we have an optional 45 degree joist adapter.

(VIDEO TAPE SEGMENT WAS PRESENTED)

What were the reasons for going to UL for Certification? We wanted the fullest confidence from a safety standpoint because of this new technology. We also felt that, from our own standpoint, the standpoint of the dealer and particularly the homeowner, it was important that we obtain this type of national recognition. In addition with UL being a well known agency, we felt that there would be much less problem at the local inspector level in terms of acceptance of this type of product. Lastly; with our oil furnaces all being UL listed, it was very compatible to be working with UL on this particular product.

As I have stressed, the package is a complete system. We noted several years ago when we first started this project that some of the competition did have a UL or a National Agency recognition on a particular component (perhaps the inducer or the vent hood itself), but not really on the complete package. We found that there is such a wide range of variability in the field in terms of the home, the construction, the type of clearances that are required, that dealers very commonly would not be aware of exactly what components they did or did not need to provide a system that would work correctly. We felt the best way to proceed therefore was to obtain a complete package certification and then the dealer had just an "install it type situation"; rather than being faced with a number of decisions and uncertainty about something he may have been unfamiliar with.

One of the first needs was to define exactly what we wanted our system to consist of and identify the basic residential Btu capacity range of primary interest. In our case, that was from roughly a half-gallon (or 56,000 Btu/hr output) on up to 150,000 Btu/hr output. We determined that a 30' vent length would probably be the maximum that would be required in terms of the venting distance from the furnace and, as it turned out, we needed to have a minimum of 2' distance. Knowing the Btu capacity and the vent pipe distance that we were dealing with allowed the determination of the inducer blower requirements and its' CFM capacity. The last thing we had to do was, of course, define what we wanted in the way of clearances which it was decided was 0" clearance through the wall for the vent hood, a 4" clearance on the adaptor through the joist space, and 9" clearance from the power venter and all the vent pipe leading from the furnace to the power venter.

Next; we started a test program which took place over the winter of '87 and '88 ... although some of our furnaces had been out in the field for a year before connected to sidewall vent systems and were working very well. We set up a cycle test program and initially what we were looking for was any soot and combustion problems. We purposely ran very short cycles to simulate many starts and stops. We were aware, of course, of the soot spikes on the front and tail end of the combustion cycle and we were searching for any problems related to venting through the sidewall. We also were looking for any discoloration problems on the exterior walls where the vent hood was attached and mechanical problems that might develop, particularly with the motor bearings, regarding life expectancy of the inducer. These tests were all passed. We very purposely ran poor combustion for about a 2-3 week period .. trying to force some exterior wall discoloration.

We mounted a vent hood on a inside corner of a factory wall which pointed in the direction of the prevailing wind. There was a lot of circulation and wind disturbance in that area and, as I said, we purposely ran very poor combustion but could not force any discoloration to occur. Another test concern that we addressed was inducer noise problems. The inducer itself is positioned right adjacent to the vent hood leading out of the home. That location very well could be underneath a bedroom or an area that is lived in a lot and so, consequently, we were concerned about noise. We really did not find that there was a problem, however, we do recommend in our instructions that the dealer install an isolating buffer to cut down on any vibration transmission problems.

Reverse flow, flue products coming in instead or going out, after the cycle is complete was definitely a concern of ours and we did in fact find that we did have a problem. We attributed it primarily to the Plant (test site), because the factory is operating under a very negative pressure condition due to exhausting related to the welding and paint operations. We found that we could overcome this problem completely by going with outside combustion air, and I am going to discuss that further in a moment since it turned out that there was more to that subject than we initially thought.

With the test work having been completed, being satisfied with the results of the cycle testing at the factory and from the field observations that we made, we then approached Underwriters. Initially, we approached them from the standpoint of receiving a listing that would allow our product to be used as a generic type of retrofit device; to be used not only with our product but with any brand furnace already in the field. There was not and is no standard developed by UL for the power sidewall venting of oil fired equipment as such and, consequently, once we had defined to them what we wanted to do they identified three different existing UL standards that they would draw from in terms of designing our test program. One was the oil fired central furnace standard; another was a standard on draft equipment and the third was on chimneys. Specifically, they took various sections or paragraphs from those standards in designing their program. The bombshell to us was that they also came back and said that, in order to obtain a generic type approval, we would have to pass temperature tests that would go up to the 1300^{0}F range. Obviously, 1300^0 was beyond all realm of possibility and was not realistic. UL's feelings were that with the age of some of the equipment out in the field .. some very old burners, concerns about safety problems .. i.e., if a limit switch failed and a burner continued to run; you could see such extremely high temperatures. It became apparent to us when we tried to do testing at that level, and actually had trouble simulating those high temperatures, that to achieve the 0" clearance requirement through the wall would have required a tremendous amount of insulation and cooling to enable the system to handle those temperature levels through the vent pipe. Basically, we backed off from that approach. It became evident that the best way to proceed was to offer our package strictly with our own UL listed Thermo Pride furnaces, because we knew what our stack temperatures were .. UL knew what they were, and it just made a lot more sense to go that route. I might mention that even though our UL listing is with our own furnace line that does not mean that our system cannot be used with another brand product .. a furnace .. or a boiler. However, it is UL certified only for use with UL Thermo Pride oil furnaces. In our case, the top temperature to be addressed was 650^{0}F. Our furnaces operate with a stack temperature of 400-425^0 so 650^0 obviously provides a good cushion for failures. I might mention that 650^0 basically explains why we have an 8" diameter outer pipe on the vent hood. We have a 4" pipe through the center and then a combination of insulation and air for cooling purposes to provide the 0" clearance where it passes through a combustible wall.

The UL test program itself addressed several issues. Of course, electrical, which is the big thing with UL, flue temperatures, clearances, the 10,000 cycle life on all of the electrical controls and then they did a 40 mile/hr wind test, and here they were looking for our ability to maintain proper combustion under those extreme conditions. These tests were all passed. I would mention, for the benefit of any other manufacturer that might be considering going to UL, that I really do not see UL developing a standard for this product because there are relatively few oil fired furnace manufacturers in the business. If everyone of them decided to develop their own product like this, then there might be enough demand for the development of a standard but, more likely, UL is going to listen to what you want to do. You tell them what your product consists of, what you want it to do and so on. They will then come back and pick and choose from existing standards (and/or specify other tests) that they deem appropriate and define a program that you will then have to pass.

Having them completed the UL program this last Summer of 1988, we actually went to market in September. We currently have several hundred systems out in the market and approximately half used to joist adapter...in other words, are going directly out through a sidewall. In many cases, it is just a masonry basement wall. The other half go up through the joist area because they don't have the ability to be vented directly through the wall. There is a minimum of 18" clearance, by the way, between the vent hood outlet and the ground level. Our dealer cost for this package is $280...the vent hood, the inducer, controls, electric wire harness package, etc. There is an additional cost of $35 for the dealer who wants the joist adapter. The ballpark total is around $300 in hardware. The dealer still has to provide the links of galvanized pipes, screws and some other minor items that are locally available. A $300 dealer cost doubled to $600-700 would equal the approximate installed cost. Again, it is substantially below what the cost would be of constructing a masonry type chimney, and especially in a home where you are taking living space to do so.

We have surveyed several of our dealers to find out where the installed systems are being used. We were told originally why they wanted power sidewall venting, but what in fact has really been happening with the installed units? In fact, most systems have been going into electrically heated homes; homes where there were no chimneys. We have also had several cases where they have gone in where there was wood heat in the home. An interesting comment, by one dealer, was that one homeowner had to put in this system because the wood furnace or stove and its' by-products of creosote had completely destroyed the existing chimney. This sidewall system gave them another alternative. Some systems have been used in new construction, and particularly modular homes. One of our larger dealers made a comment that, while he has used several of them, he would not use sidewall venting if he had a good chimney in place. In other words, he would not consider using the sidewall venting if a conventional chimney was available.

What has been our field experience? This is a good news/bad news situation. The good news is that there have been virtually no installations questions, and I think this has been partially a result of the video. We also have an excellent set of instructions. We have had no product component failures. There have been no reports of discoloration; although we had one case where there was a clogged nozzle that did cause some discoloration. In that case, the dealer was notified by the homeowner right away, solved the combustion problem and was able to clean off the soot outside...so there was really no major occurrence there. We have had essentially no problems as far as local authority acceptance is concerned; with one exception, that being in Massachusetts. We did go to the State Fire Marshall and provide copies of our UL tests. We now are labeling products going into that State and have provided the approximately 350 Fire Chiefs with instructions on the product.

The bad news side?...Really there have been two primary issues that have been brought up. One has to do with odor problems and the other has to do with melted pump couplings. I want to stress that these incidents probably involve no more than about a half-dozen or ten situations out of several hundred. There have been a couple of these that have been rather trying to fully resolve. We find that reverse flow is a much greater problem than we thought; especially in extremely tight homes. As the system operates, it is exhausting air out of the structure. Initially, we recommended that the dealers bring in outside air for combustion purposes but we did not mandate it. Obviously, a number of dealers did not and, in cases where they did not and again in very tight homes, the system is essentially pulling the house into a negative condition during the operation cycle. Once the post-purge period was complete, there could still be some pressure equalization going on and so any residual heat or products in the system were drawn back into the burner where they could leak out. As I mentioned, in a couple of cases we had melted pump couplings. We also find that a phenomena called "dynamic wind loading" can occur in extremely tight homes. The whole house acts almost as a chimney and if you have the wind circulating around the house it can create a negative condition inside. Again, this works against a system that is drawing its' combustion air from within the home. We have now changed our installation requirements with regard to outside combustion air. We now mandate that the dealer bring the combustion air in directly to the furnace that is used with sidewall venting. Essentially, we are recommending that the dealer close off all the louvers on the inside of the burner compartment and bring his outside air into that compartment so he can continue to use the air bands on the burner to adjust the air setting for combustion purposes.

In bringing the combustion air in, we are recommending that the dealer locate the combustion air pipe no closer than 4' from the exhaust vent hood but on the same side of the home...because, it is necessary to have the same pressure environment for both pipes; rather than having one on one side of the structure and the other on the other side where you can have a strong positive and a strong negative pressure at the same time. Such an arrangement would not work well at all. Another change that we will bring out shortly will be a longer time period post-purge delay. The version that we are currently including in the package has a 2-minute post-purge period. Again, this has worked fine in the vast majority of situations, but we feel that we need a longer time and so we are looking at about a 5-minute control now. Keep in mind that only outside air will be used for combustion purposes, and even though the system will post-purge for a longer period you are not going to be exhausting heated air out of the home.

The last procedure that we are encouraging the dealers to follow is to install some type of an equalizing device for the home (a pressure balancing device) because so many of these homes are very tight. Even with a closed loop (so to speak) for your combustion air and the exhausting of the flue products, there is a need for a device which you can tie into the duct system that will allow the house to maintain an equalized pressure at all times. We feel that equalized pressure in conjunction with outside combustion air and the longer post-purge period should solve the problems of odor or melted couplings.

Again, I would like to thank BNL for the invitation to present information about Thermo Pride's power vent system...and thank you for your attention!

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CANADIAN RESEARCH ON OIL-FIRED COMBUSTION APPLIANCES

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INTRODUCTION

This paper will describe principles and the research and development presently being conducted on oil-fired space and water heating appliances at the Canadian Combustion Research Laboratory (CCRL), to improve draft and chimney performance, minimize indoor air pollutants and develop higher efficiency equipment.

CHIMNEYS, DRAFT AND COMBUSTION PERFORMANCE

For most combustion appliances, the primary mechanism for the generation of the flow up a chimney is natural draft, due to a temperature and pressure difference between the appliance and the top of the stack. Some of the newer appliances replace or augment this natural draft by mechanical means.

Over their lifetime, chimneys are often called upon to exhaust the combustion products from a number of different fuels. Canadian houses built prior to the early 1950's typically had a coal-fired furnace, operating relatively inefficiently at high excess air and high particulate levels. Then conversion to oil took place, with increases in efficiency and decreases in excess air and particulates. More recently, an upgrading of the burner efficiency, with reduced firing rate and reduced excess air may have occured. Throughout this progression, there are general reductions in mass flow through the chimney, furnace exit and chimney base temperatures, and particulate loadings.

This has resulted in condensation and corrosion of existing chimneys, poor draft, poor combustion performance and even spillage of the combustion products into the house (1).

WHAT CONDITIONS DOES A CHIMNEY SEE?

Complications arise when attempting to generalize as to what temperature and quantity of mass the chimney must handle.

Under steady state conditions, for conventional oil-fired appliances, the amount/rate and temperature of combustion products generated by the appliance itself are fixed within narrow limits, depending on the excess air level, the firing rate and the amount of heat exchange surface.

Effect of Furnace Cycle Length

In fact, central heating appliances only very rarely reach steady state. Rather, they operate in varying periods of on-off cycling operation, whose length depends primarily on ambient outdoor temperature and the thermostat setting. There is a finite time for a furnace to reach equilibrium and the flue gas temperature to reach its maximum value. This can be as long as fifteen minutes for a high thermal mass, large heat exchange surface oil furnace.

Recognizing that the majority of installed furnaces were oversized for the home heat demand, a problem exaccerbated by the retrofitting of insulation and the sealing of homes, firing rate has generally been reduced in recent years, with a commensurate reduction in flue gas temperature (3).

Effect of Dilution Air from Oil Furnace/Boiler

An additional complication is the amount of dilution air required by the furnace through the barometric damper. This air, brought in to mix with the flue gas downstream of the heat exchanger proper, takes no part in the actual combustion or heat exchange process, nor in the supply of heat to the house. Rather, it is designed to isolate the burner from outside pressure fluctuations and to minimize the spillage of combustion products into the house. Depending on the specific installation, this dilution air can be anything from 0 to 1 to 10 times the amount of air actually required by the burner for combustion. The dilution air can be the major influence on the temperature at the base of the chimney and on the mass flow of combustion products through the chimney.

Figures 1 shows the amount of dilution air required for one oil heating system, instaalled with a conventional burner. The excess air before dilution , as indicated by the higher CO_2 curve, is about 100%, stabilizing rapidly within the first two minutes. However, the flue gas temperature before dilution takes a much longer time to reach equilibrium.

Excess air after dilution rises to 860%. The chimney base temperature decreases in a similar fashion, falling by 71%.

Chimney Location

Chimney location can be a major factor in poor draft, flue gas condensation and chimney degradation. In some areas (2), as many as 95% of the masonry chimneys are on outside walls, with three sides exposed to the cold ambient.

In many new two-storey homes, chimneys are often set in the poorest location from the point of view of draft development, exposure and condensation potential. Often a family room is built behind the garage, with only a single floor. Convention dictates that a fireplace should be situated in this room, fixing the location of the doubled-flued chimney. Eddys off the higher two-storey main roof can lead to subsequent draft disruption. This in turn can cause poor combustion on start-up and can even cause, in some cases, such as shown in Figure (2), poor combustion over the entire operating cycle, with significant potential for sooting and for flue gas spillage.

To cure the problem, the chimney is often extended, with four walls exposed. This is the case of a non-essential appliance (the fireplace) driving the location and operation of the essential appliance (the furnace), to the detriment of the latter.

Similarly, if an additional chimney is to be constructed in an existing dwelling, as for a wood stove, that chimney should be built within the house structure, if possible. If the stove is located in the basement recreation room, present practice is to go immediately outside the house and up the outside wall with a prefabricated metal chimney. Such an installation could not be worse for draft, condensation and creosote. The house often behaves as a better chimney than the chinmey itself, so that start-up performance is poor, often resulting in backdrafting and spillage of the combustion products into the living space, as well as high levels of soot deposition onto the heat exchanger.

Table 1 shows the falacy of these strategies. If we have a chimney with an exit temperature of 150F and a height of 10 feet, the draft developed is a very marginal 0.012 " H_2O. To double the draft to 0.025, the chimney height must be doubled, assuming no more temperature loss!

On the other hand, Keeping the temperature within the system only 50F higher by better insulation and/or a higher chimney base temperature will also give us 0.025.

Getting the 0.05 draft that many servicemen would like would require the height of the chimney to be quadroupled, again with no temperature loss, an effective impossiblility. The same draft increase can be obtained by keeping the chimney gas temperature at only 300F.

Potential for Condensation in the Venting System during Furnace Operation

It is difficult to predict the probability of flue gas condensation in any specific installation, without actual measurement of the dilution effect. This is due to the unpredictable level of the dilution air and its effect on the water dewpoint of the flue gas. Figure 3 presents field test results from a number of homes where dewpoint is plotted against furnace exit temperature. No correlation is readily visible, with the highest (40oC) and the lowest (11oC) both occuring at furnace exit temperatures in the range of 270oC.

Two major driving forces for condensation in a venting system are the dewpoint of the gas stream and the inside surface temperature on the conduit through which the gas is passing. To determine the former, measurement should be made of the flue gas temperature and the excess air (by CO_2 or O_2), after the dilution device.

The composition of the flue gases is primarily carbon dioxide and water vapour, with small amounts of carbon monoxide, soot, nitrogen oxides, sulphur dioxide and even partially burned hydrocarbons also present in varying quantities. If the temperature on the inner surface of the venting system in contact with the flue gases is below the dewpoint of the flue gas, water vapour will condense on the surface, bringing with it small amounts of the other products to yield a slightly acidic condensate. The higher the hydrogen content of the fuel and the lower the amount of dilution air the higher the dewpoint and the more likely condensation is to occur. Figure 4 shows thee effect of excess air on dewpoint for four fuels. Comparing natural gas and No. 2 oil at stoichiometic, natural gas has a dewpoint of 58C, while No. 2 oil has a dewpoint of 48C. At 100% excess air, this falls to 47C and 37C, respectively.

Similarly, the lower the quantity of flue gas (mass flow) for the same chimney cross-section, the lower the velocity, the longer the residence time for the gases in the stack, the cooler the gases become and the greater the potential for condensation.

Chimney Damper Equipped Appliances

A chimney damper is a device, coupled to the thermostat, which closes off the flue when the combustion appliance is not operating, in an attempt to save energy. For installations where a fossil fuel-fired water heater is coupled to the same flue as a chimney damper-equipped furnace or boiler, little overall energy may be saved, as the developed draft may actually increase losses through the water heater.

If fitted to an appliance which has its own flue, it may lead to increased cooling of the chimney, promoting condensation and freeze-thaw cycles which could damage the chimney structure.

At the same time, the heavy mass of stagnant cold air in the chimney from the long off-cycle can make the generation of draft difficult. This can disrupt start-up combustion performance, causing sooting and puffing and resulting in significant amounts of flue gas spillage into the house at the beginning of each cycle.

Techniques to Maintain Elevated Chimney Flue Gas Temperatures

Inside Chimneys

Efforts should be made in new housing to locate chimneys inside the house structure, reducing flue gas heat loss and keeping flue walls much warmer, reducing and even eliminating condensation/deposition, while dramatically improving draft.

New Liners for Chimneys

Many masonry chimneys are oversized for their present application. An effective way to bring the chimney back in line with the new flow rate is to reline the chimney, reducing the cross-sectional area. For oil furnaces or wood stoves, a stainless steel liner, either smooth walled sectional or flexible continuous, and insulated with stabilized vermiculite, generally results in superior performance. Indeed, the improved thermal performance and significant reductions in flue gas heat loss may even allow smaller cross-sections than might be required with conventional flues.

Double Walled Flue Pipe

As has been shown, chimney temperature is one of the most important factors in the generation of draft and for avoidance of condensation/deposition. Many combustion appliances lose a considerable amount of heat from the single walled flue pipe connecting the appliance to the chimney. If double walled pipe with a stainless inner liner was used instead, gas temperature loss would be reduced, raising the chimney base temperature substantially. At the same time, inner flue temperatures would be high so that there would be no chance on condensation/corrosion in the flue pipe.

However, the above argument does not hold true for vented double wall pipe, which typically has some 30 2" long slots around the circumference at the beginning and end of each section, to allow reduced clearances. These vented slots set up convective heat transfer, and remove heat from the inner liner and flue gas. The chances of condensation are increased dramatically, as evidenced by the Whitehorse woodstove field trial. At the same time, the flue gas temperature is actually lowered more than even for single wall flue pipe, so that the chimney base temperature is lower, and draft, etc., is even poorer.

INDOOR AIR QUALITY

Increased interest in energy conservation, changes in airtightness, appliance design and building materials, along with fuel switching, have all combined to potentially raise the level of pollutants in the indoor environment, resulting in increased concern for indoor air quality.

At the same time, with homes being made tighter, combustion appliances are having an increasingly difficult time receiving adequate air to operate safely and properly. Spillage of incomplete combustion products or even chimney flow reversals can result in significant amounts of carbon monoxide and other toxic combustion products being exhausted into the house.

Combustion appliances generally require air both for the combustion process itself and for dilution. The dilution device, (the draft hood on a gas system or the barometric damper on an oil system), is located downstream of the furnace heat exchanger and takes no part in the combustion or heat exchange processes. It is primarily designed to isolate the combustion system from outside pressure fluctuations. However, it does represent the major air requirement of the heating system, 2 to 10 times the air required for combustion (3).

New oil-fired combustion systems, either under development or just reaching the market place, offer the potential of eliminating the dilution device and forcibly exhaust the combustion products either with a fan or a series of powerful combustion pulses. Such appliances, with their high efficiency and low air demand, are well suited to the low energy consuming homes of today, while significantly reducing the chance for combustion spillage into the house.

Combustion Appliance Performance

Because houses are being made tighter, combustion appliances are having an increasingly difficult time receiving adequate air to operate safely and properly.

The various combustion systems found in Canadian homes have dramatic differences in their air requirements. This has implications for efficiency of fuel use, where cold outside air infiltrates the house, is heated up to room temperature and then is immediately exhausted up the chimney. More importantly, it raises serious questions of the ability of tight housing to supply that air, with implications for the health of the inhabitants.

Central furnaces/boilers fired by oil have two distinct air demands - for combustion and for dilution. The combustion air is brought into the appliance at the burner, mixed with the fuel, ignited and burned; the excess air and the combustion products pass through the heat exchanger before venting. The dilution air is brought in through the barometric damper, downstream of the furnace proper, after the heat exchanger, and is used primarily to isolate the burner from changing outside conditions.

Appliance Air Requirements

Over the course of a typical Canadian heating season, a central furnace will only be on for from 15% to 25% of the time, depending on the degree of furnace oversize. Obviously, the furnace is on the least during the spring and fall periods, and the longest during the coldest portion of the winter, usually in January.

However, to determine the appliance air requirements, the unit must be treated as if it is on continuously. This is because when the appliance is indeed running, it absolutely needs its air at that particular time, in order to ensure safe and efficient operation.

Conventional Oil Burner A conventional burner with a 0.85 USgph nozzle, a typical firing rate for Canadian conditions, will have combustion air requirements of about 65 m3/h, with an additional dilution air requirement of 195 m3/h.

Flame Retention Head Oil Burner The more efficient flame retention head burner, developed as a retrofit kit by CCRL (4), has a 25% lower combustion air demand, and a steady state efficiency improvement from 72% to 80%, on average (5). The combustion air requirement is reduced to 44 m3/h, but the dilution effect remains the same. If the burner is fitted with a delayed action solenoid valve, which allows the burner fan to run to establish draft before ignition, back puffing of pollutants into the house can be eliminated.

Efforts are now under way by CCRL to develop a mid-efficiency oil furnace which will eliminate the dilution air requirement, and allow the furnace steady state and seasonal efficiency to be increased to 90%, without condensing the combustion products. As well as for new appliances, the concept may be suitable for retrofit in existing oil furnaces, resulting in fuel savings of 30% or more, relative to conventional burners. The combustion air requirement for such a unit should be 37 m3/h or less.

Table II presents a summary of the air requirements of the various residential combustion equipment discussed, in terms of the number of air changes per hour and actual air flow rates, for a typical Canadian house. For the purposes of this paper, the typical house was taken to be a bungalow with a full basement, having a total internal volume of 498 m3. The measure of air tightness of a house is most often given in terms of air changes per hour, the air change being the total volume of air present in the house. To get some appreciation of what the number means, 0.5 air changes/hour are considered necessary by many groups to ensure that there is no long term build-up of contaminants for indoor air pollution. Some of the new, tight homes require forced ventilation systems (air-to-air heat exchangers) to achieve this level.

Conventional oil furnaces/boilers are seen to have air demands on the same order as the half air change rate of many tight houses. As such, they offer potential problem sources for spillage of combustion products, or even flow reversals in adverse circumstances, unless steps are taken to alleviate the problem.

Even worse, the fireplace has a potential air demand nearly three times that of a moderately tight house. How can this inefficient appliance not be expected to interfere with the operation of other air-breathing equipment?

The upcoming higher efficiency oil appliances and small "airtight" wood stoves have no significant air demand and thus mate well with the lower energy consuming, tighter houses of today and tomorrow.

Starving combustion appliances for air, or forcing spillage or even flow reversal can result in exhausting the combustion products, including toxic carbon monoxide, directly into the house environment. Homeowners should be made aware of the symptoms of CO poisoning - headaches, extreme lethargy, dizziness and nausea. If they experience such symptoms, they should immediately act to open doors/windows to the outside, and even leave the dwelling. Afterwards, they should consider the following recommendations to alleviate the problem.

Non-Combustion Air Demands

Air change in a house is required to remove odours, humidity or the long term build-up of pollutants. As well, air is exhausted from the house as required for other specific applications, like cooking, showers or clothes drying. Air-to-air heat exchangers may be used to supply fresh air to the house at an energy advantage.

Some residential electrical appliances, such as BBQ ranges, clothes dryers, central vacuum systems and bathroom exhausts have powerful fans which exhaust air from the house. In a tight house, or one with marginal draft, due to poor chimney construction, location, deterioration or misuse, these air-exhausting appliances can be the driving force which causes combustion appliances to backdraft or spill combustion products into the house.

One type of electric cooking appliance, the BBQ range, has massive air requirments, which, for tight housing, can only be met by its own specific air supply. The intermittent use, high flow and high moisture content of a clothes dryer exhaust also precludes its use with the house air-to-air heat exchanger. One solution is to duct outside air directly to the dryer. For cold winter temperatures, the moisture content of the incoming air will be very low and may actually aid the drying process. Central vacuum systems also exhaust large quantities of air and may pose problems for tight housing. Care should be taken in using any of these appliances while combustion appliances are operating in the house, unless provision is made for outside make-up air.

OIL FURNACE ADVANCES

There is potential for significant reductions in energy consumption by improving the efficiency of residential oil-fired heating systems. This potential has been only partially realized to date in Canada.

New developments are yielding more efficient oil furnaces, often with positive venting of combustion products and potentially no dilution air requirement, most of which may be safer and from 10% to 20% more efficient than even the flame retention head burner systems, or as much as 37% more efficient than conventional oil or gas furnaces.

Mid-Efficiency Furnace

The mid-efficiency furnace eliminates the barometric damper, with its large air requirement. It may have an induced draft (ID) fan, located downstream of the furnace proper, which pulls the gases from the furnace and propels them up the stack, or a very high pressure drop burner with a properly baffled furnace, allowing the burner to withstand any presuure fluctuations transmitted from the top of the stack. At the exit of the appliance there needs only be a small opening, so the unit also operates as if it had a chimney damper on the off cycle. It can improve the seasonal oil furnace efficiency to about 90%, without condensing. Fuel savings of this mid-effiiciency furnace would be from 15% to 25%, relative to a conventional furnace, depending on the furnace design. Most of this type of appliance design should yield savings closer to the high end, and seasonal efficiencies on the order of 85-88%.

Compared to a flame retention head-equipped furnaces, savings would be at least 10%, even though the steady state efficiencies for the two technologies, and even those from the AFUE could appear to be almost the same.

Additional benefits are reduced reliance on natural draft, much lower total air requirements and a safety shutoff in the event of flue blockage or reversal. Knowing the exact quantity and temperature of flue gas to be delivered to the chimney base allows proper sizing of the chimney to ensure adequate capacity, with little danger of condensation in the system.

Indeed, with this type of technology it may be possible to eliminate the chimney altogether, and exhaust the gases out the side wall of the house. Presently, some new furnace systems are doing this, while still maintaining a certain dilution air through the barometric. If the latter can also be eliminated, possibly by diluting with outside air at the wall exhaust point, the true potential of the mid-efficiency unit will be realized.

Hydrogen Content of Fuels

Number 2 oil and natural gas both contain hydrogen which, on combustion, forms water vapour, tying up energy in the form of latent heat. In comparison to oil, natural gas has twice the hydrogen content, making its flue gases much more moisture-laden than oil; hence the requirement for a chimney liner on conversion to gas in order to avoid condensation, damage and even ice bridging in masonary chimneys. This results in the fixed "hydrogen loss" of about 12% for conventional gas-fired units and accounts for the fact that such equipment has a lower efficiency than a similar oil-fired unit, which has a hydrogen loss of only about 6%. As seen previously on Figure 4, the dewpoint of natural gas is also much more conducive to condensing than that of oil.

Condensing Oil Furnace

A further, possibly less-desireable development is a condensing oil furnace, either new or retrofit. This type of furnace makes a conscious effort to recover some of the latent heat described above, by condensing some of the moisture from the flue gases in an additional heat exchange section.

This additional surface, made out of stainless steel, or plastic with a water spray, lowers the furnace exhaust gases below their dewpoint, regaining the latent heat contained therein. Because the flue gas temperature is so low with any condensing furnace, no chimney is required. Combustion products are merely vented through an outside wall with a plastic pipe and condensate sent to the drain. This furnace can be even 5-10% higher in terms of efficiency than the ID fan type described previously, if it can eliminate the need for a dilution device.

For most condensing furnaces, contrary to conventional furnaces, the shorter the cycle length, the more water is condensed (ref. 4), due to cold furnace walls, and the higher the efficiency. However, due to reheating/reevaporation of the condensate stored within the unit in some appliances, this gain in short cycle operation is not always realized (6).

This type of furnace generally has a seasonal efficiency very similar to its steady state efficiency, with negligible transient effects.

Some condensing oil systems use two vents, maintaining a conventional chimney and along with a plastic pipe out the side wall of the house, both open at the same time. With this type of system, there is a strong possiblity of the flue gases bypassing the water spray condensing system and going straight up the chimney. The barometric damper is also kept, so that the additional dilution air lowers the dewpoint even further, making it even harder to condense the flue gases.

In any case, with oil containing much less hydrogen, the potential for efficiency improvements by condensing the flue gas is much lower than for gas - the dewpoint is lower, so you have to work harder to condense less. Also, with much higher sulphur levels, the condensate is more corrosive, so that any condensing heat exchanger for oil must be even more corrosion resistant. The fact that oil combustion also produces a certain amount of soot, which can concentrate the acidic condensate at certain points on the heat exchange surface, makes things even more difficult. Thus a condensing furnace may be less attractive with oil. However, both the mid efficiency and condensing oil furnaces offer major efficiency advantages over conventional existing appliances, much more than can be seen merely by the differences in their steady state efficiencies, or even the AFUE's, at least in some cases.

FUEL QUALITY

For the past few years, CCRL has been carrying out a detailed research program on the effects of changing fuel quality on burner performance. The study has focused on fuels with higher aromatic content and ones with increasing viscosity, to ensure maximum use of the crude oil barrel (7). In Canada, an increasing amount of crude is coming from the ALberta Tar Sands. By its nature, the oil has a much higher aromatic content, making it potentially more difficult to burn. Also with the increasing demand from diesels for middle distillate fuel, there is strong pressure to increase viscosity. A similar driving force is the greater availability of heavier crudes on the world market.

The goal of the work at CCRL is to produce an index of burnability which will enable refiners to blend satisfactory fuels. Experiments to date indicate that higher than standards viscosities (>3.6) can be used if the aromaticity is kept low; similarly, if aromaticity levels of 45% are desired, the viscosity must be kept low. Other work is concentrrating on defining a more suitable and effective technique to be used by refiners to measure/characterize aromatic fractions in middle distillates.

At the same time, a new technique has been developed to measure the aromatic content of fuels accurately. It is presently being considered for adoption as a National Standard by the Canadian General Standards Board (CGSB). This technique will enable refiners to more accurately control their streams and to optimize middle distillate produuction and use.

Their is an increasing need for oil-fired systems to be able to utilize cleanly and efficiently wide variations in conventional fuel properties - and fuel supply temperatures, especially with the use lower firing rates, which are potentially more susceptible to problems.

SUMMARY

The problem of chimney design and sizing is seen as a complex one; one in which the environment cannot be exactly defined. Thus even making a good new chimney for a specific appliance has some degree of uncertainty.

There are more complications in the field, where a wide variety of non-code chimneys, deteriorated chimneys or chimneys not suited to their present use exist in large numbers. These can often be repaired/converted into suitable installations with an insulated stainless steel liner, while the use of unvented double wall flue pipe can improve performance by keeping flue gas temperatures high.

The chimney obviously should be suited to the appliance which is feeding it. Ideally, the temperature at the chimney base should be known, as should the mass flow through the chiminey. In practice, only for non-dilution air appliances can these be fixed with certainty.

Conventional oil furnaces/boilers are seen to have air demands on the same order as new tight houses. As such, they offer potential problem sources for indoor air quality problems, due to spillage of combustion products.

Even worse, the fireplace has a potential air demand nearly three times that of a moderately tight house. This appliance must be isolated from the home enviroment through tight fitting glass doors and an outside air supply directly into the combustion chamber.

Changes in burner/furnace technology offer still further reductions in fuel consumption by improving combustion performance, reducing off-cycle losses, eliminating the need for downstream infiltration of dilution air and increasing dramatically the steady state efficiency with more heat exchange surface. The most promising of these improvements is the mid-efficiency oil furnace, without dilution air. The low air demands of this design coupled with its powered exhaust capability promises to remove the oil-fired appliance from consideration as a source of indoor air pollutants.

It is possible to consider using a heating fuel of higher viscosity or higher aromaticity, providing other fuel characterisitics are controlled.

Any improvements in efficiency which are achieved by reductions in flue gas temperature and/or elimination of diilution air must be accompanied by changes to the venting system, to ensure adequate draft and to prevent condensation/corrosion.

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TABLE I. Effect of Temperature and Height on Chimney Draft

CHIMNEY EXIT TEMPERATURE	DRAFT ("H2O) AT DIFFERENT CHIMNEY HEIGHTS		
	10 ft	20 ft	40 ft
150F (65C)	.012	.025	.050
200F (93C)	.025	.050	
300F (149C)	.045		

TABLE II. Air Demands for Residential Combustion Appliances.

Appliance	Air Requirement			
	Combustion m3/h	Dilution m3/h	Total m3/h	AC/h
Conventional Oil	65	195	260	.52
Retention Head Oil	44	195	239	.48
High Efficiency Oil	37	-	37	.07
Conventional Gas	51	143	194	.39
ID Fan Gas	44	-	44	.09
COndensing Gas	29	-	29	.06
Fireplace	680	-	680	1.4
Airtight Wood Stove	17	-	17	.03

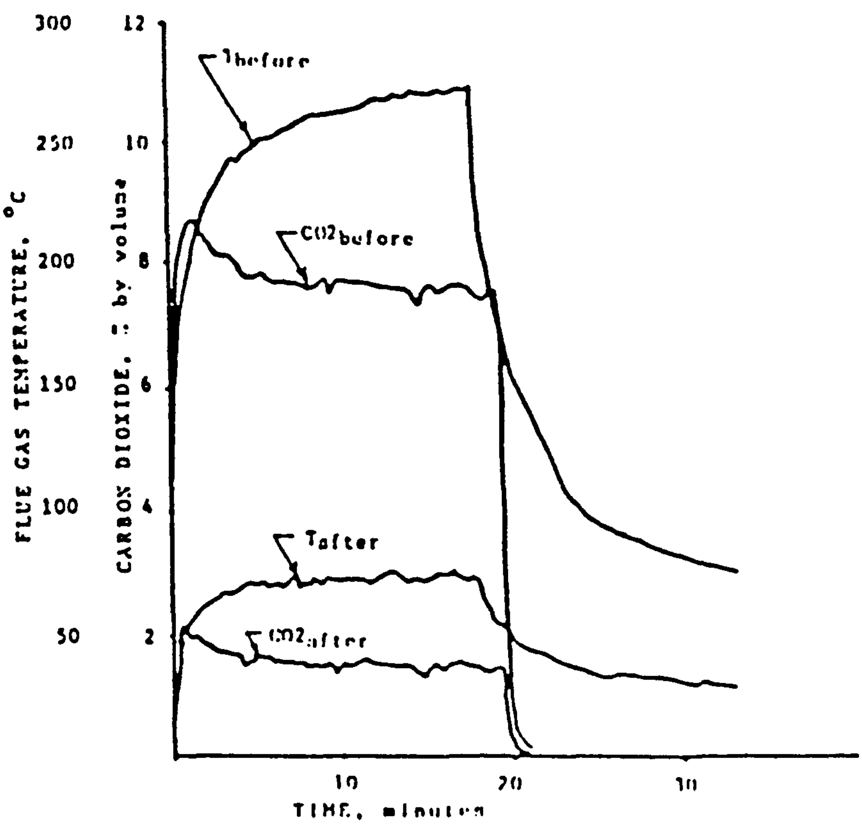

Figure 1. Flue gas parameters from a residential furnace, before and after dilution, House A.

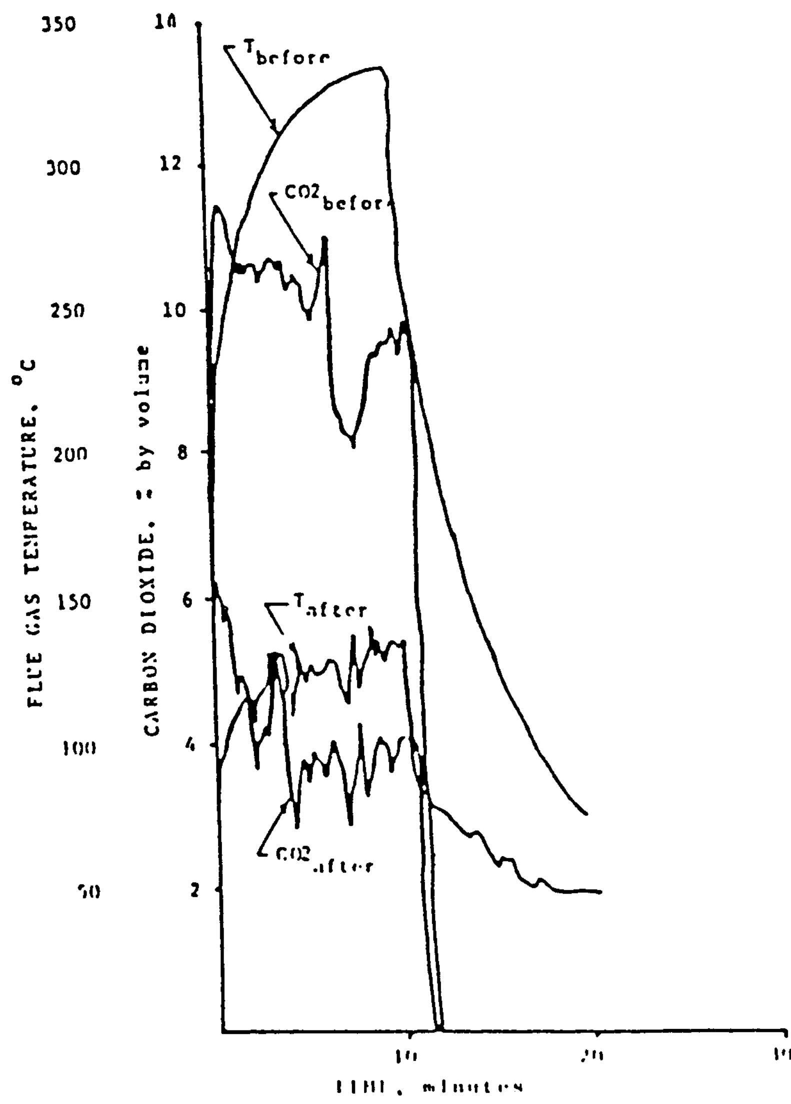

Figure 2. Flue gas parameters from a residential furnace, before and after dilution, House B.

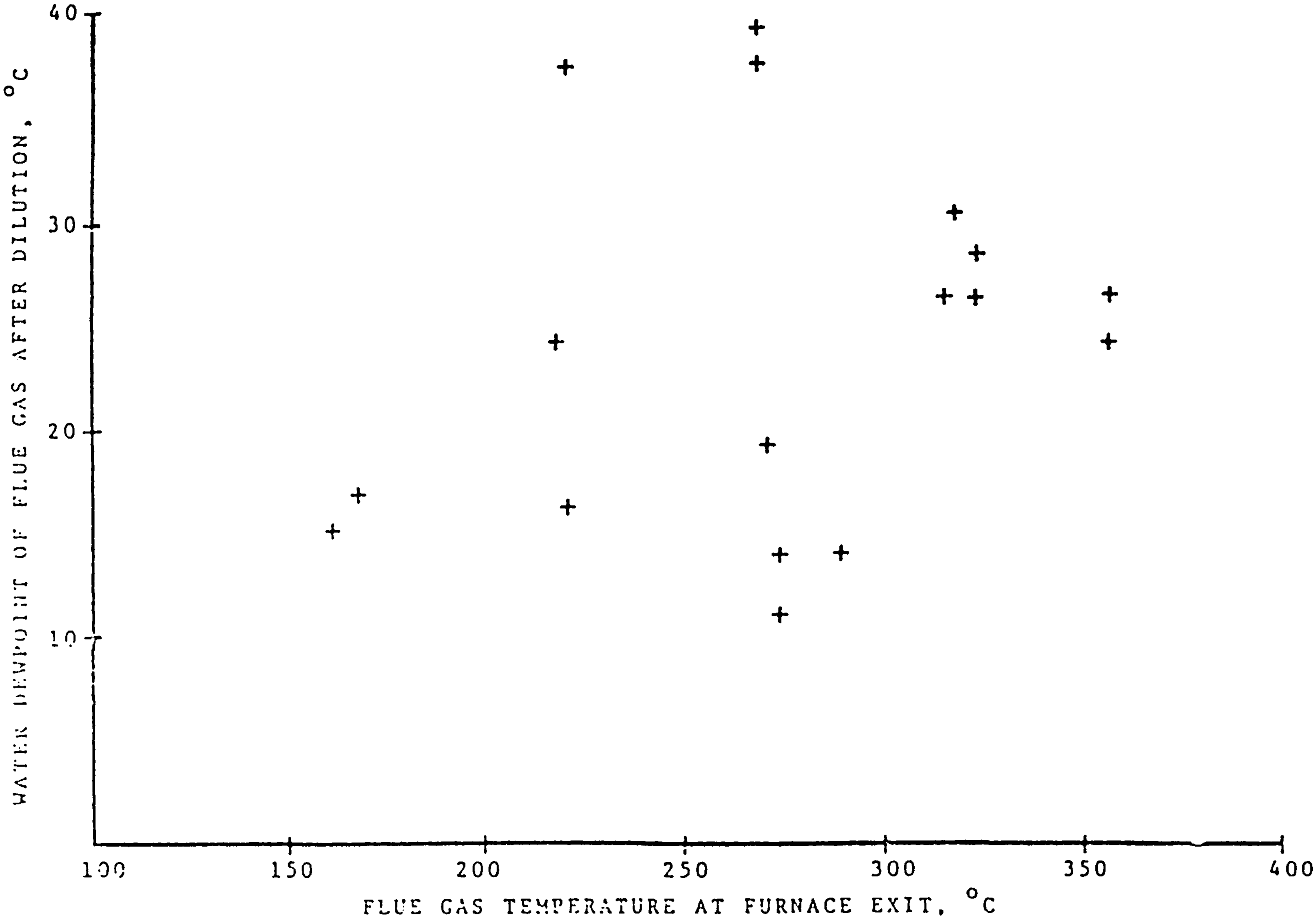

Figure 3. Variation in water dewpoint at chimney base with furnace exit temperature, for a number of oil-fired furnaces in the field.

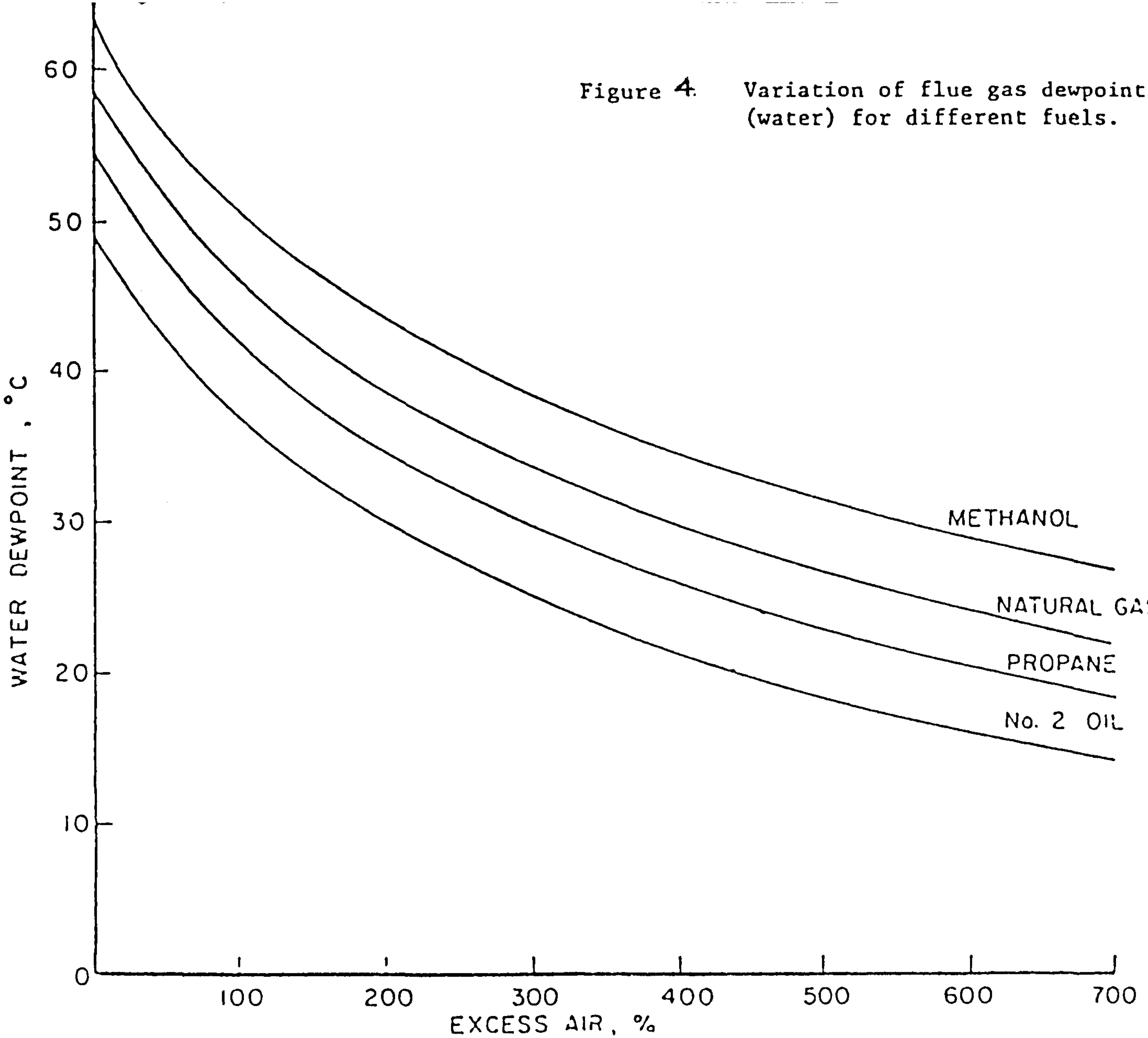

Figure 4. Variation of flue gas dewpoint (water) for different fuels.

Paper No. 89-11

SAFE VENTING AND THE HOUSE AS A SYSTEM

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INTRODUCTION

Energy conservation in the residential heating market is one of the most appropriate methods to reduce the use of fossil fuels and extend the life of the known North American fossil fuel reserves. The other benefit, is the reduction of combustion by-products that are produced and then injected into the atmosphere. The drive for energy conservation has not been without it's problems relative to indoor air quality. Indoor air quality problems can best be addressed by designing the vent systems to specific heating loads and the conditions under which they are expected to perform. Understanding "The House As A System™", where the building envelope, the mechanical systems and the occupants of the home, are treated as parts of a comprehensive system, will provide a logical approach to improving indoor air quality.

NATURAL DRAFT VENTING

Natural draft venting is the most common venting method presently in use for wood fuel fired heating appliances. Natural draft venting is used by the majority of North American heating manufacturers who design, test and receive approvals for their heating appliances. They do so based on the assumption that the chimney or vent will perform as intended - complete the combustion process and the removal of all the combustion process by-products safely into the atmosphere.

When the chimney or vent fails to provide the heating appliance with proper designed combustion gas flow characteristics, two undesirable reactions are set in motion during every heating cycle. They are:

- The combustion process will become destabilized, the flame temperatures or heat production will not be optimized and the heating appliance will fail to produce efficient heat transfer to the distribution medium (air or water); and,
- The vent system will not remove all the combustion by-products and a portion of the by-products will be spilled into the residence, either through the draft control devices or leaky vent connections. Spillage out the front of a fireplace or an air-tight stove when the doors are open is another factor to be considered. The level or proportion of combustion by products spilled, will be in a ratio relative to the degree of fault in the vent system or chimney and the free area of the leakage available.

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*The House As A System is the registered trademark of Synergon, Inc.

ESSO PETROLEUM CANADA RESEARCH: Service Call Analysis

Early in 1981, Esso had instituted a field evaluation program to determine the cause of an increase in service calls from it's residential home heat customers. Using computer data from a national customer base of 250,000 residential customers, all the customers who had service plans that included annual conditioning service, selected replacement parts for the combustion device, and service labour were isolated. This represented an average across Canada of 52% of the total customer base. The study was initiated in January 1981 and the data base was for the years 1970-1980. The period from 1970-1973 showed no change or deviations from the normal 1:2 call per customer per year ratio.

The call ratio shifted and from 1973 to 1980, the ratio changed from 1.2 calls to 1.7 calls per year. Selective sampling of the service calls indicated that there was not a direct increase in the total value of parts installed but the labour portion alone was escalating.

The Esso situation with service calls paralleled the findings of a study completed in the United States for the National Association of Oil Heat Service Managers, where over 40% of all service calls were combustion related.

Their research confirmed that independent service contractors who maintained their own service plans in cities outside major metropolitan areas were also experiencing similar service call frequency changes.

Venting System Evaluation and Testing

Esso followed up this initial research by setting up an evaluation process for problem homes that were identified by dealers as having more than two service calls per year in instances where flame retention head burners and blue flame combustion appliances had been installed. The evaluation process included a complete mechanical system assessment, a confirmation with the customer of energy retrofit measures taken, and a heat loss calculation. The energy consumption was tracked from delivery records and a three year minimum history was analyzed. The energy consumption was correlated to the degree days from local weather data for a basis to determine the optimum energy input for the customers residence. The vent system was analyzed and a field temperature profile was completed with a minimum of four points monitored for temperature until the heating appliance reached steady state combustion levels or five minutes of operation, which ever was relevant. All field vent temperatures were taken in the centre of the flue gas column in the chimney.

Generally, the drive for residential energy conservation had resulted in manufacturers producing more compact higher efficiency heating appliances. The higher efficiency heating appliances resulted in three basic changes to achieve increased efficiency levels.

- Smaller volumes of flue gases are always produced with higher efficiency appliances (eg. 10% CO2 [50% excess air] to 13% CO2 [10% excess air] = 28% reduction). Wood burning air-tight appliances can actually be operating with a negative air supply.

- Lower temperature flue gases are always produced with higher efficiency appliances. However, the dewpoint temperature increases (see Table I).

- Smaller volumes and lower temperature flue gases equate to lower flue gas heat content. The smaller volumes produced release heat to the exchanger surface at an improved rate (see Table II).

  The result of these changes is that lower heat content, based on lower mass does not provide adequate temperature differentials to establish vent system draft required by the heating appliance.

Case Study: Airtight Home

In January 1982 Esso encountered a very sobering situation where a Toronto resident who had, over a period of five years, taken numerous steps to reduce energy consumption in his home, had succumbed to carbon monoxide poisoning.

The old oil heating appliance was replaced with a modern Econoblue furnace during the 1977-1978 heating season. In 1980, the consumer had the attic insulated under the Canadian Home Insulation Program. Also in 1980, the existing windows were replaced with triple glazed thermopane fixed sash windows on the main floor and new windows retrofitted over the basement windows. In addition, the inside sill plate on the foundation wall was plastered with mortar to seal any cracks.

The consumer also practiced additional energy conservation measures by turning the thermostat down (night setback) to 55°F at night and during day time operation when absent from the residence or on vacation. The annual energy consumption was reduced from 998 U.S.G. to 451 U.S.G.

The normal outdoor design temperature for Toronto is 0°F. However, in January 1982, the outdoor temperatures reached -20°F and, the combined temperature and windchill factor equated to -40°F for two consecutive nights. The masonry chimney froze over (frost was observed by a neighbour around the decorative tile cap) and the by-products were spilled out the barometric draft control and reingested into the heating appliance combustion process. The heating appliance went from 13% CO_2 by test, to the opposite side of the stoichiometric combustion curve and the production of CO in excessive quantities was evident.

Simulated tests were conducted by investigators from the Ontario Coroners Office, Metropolitan Toronto Police-Homicide Division and the Ontario Government Fuel Safety Branch. It was found during this investigation that the house was under negative pressure of (-0.04 in. W.C.) during normal operation. The heating appliance could operate for ten consecutive minutes and on shutdown, the cold outside air would pour back down into the residence through the masonry flue and out the barometric draft control.

The heating appliances was working in an environment where the actions of the air movement inside the residence plus high moisture levels (over 65% relative humidity by test) contributed to the vent system failure.

On-Going Esso Research: Field Test Results

Esso's field test results indicated that predicting the performance parameters of the vent system, was impossible in the field. The Service Technicians indicated that when they completed their service function and tested the heating appliance performance, their results were in line with normal appliance operation. The consumer would still complain of fumes and odors and erratic performance at other times, but this was not a constant problem.

The results of the field evaluations of over 200 residential fossil fuel fired heating appliances installations proved, overwhelmingly, the following:

- By-products of combustion were being spilled on ignition and until adequate draft was established in the vent system;

- Destabilization of the combustion process and back pressure on burners was occurring;

- Heating appliance combustion performance was intermittently affected by the changes in air pressure inside the residence;

- Heating equipment combustion performance was effected by the vent system being subjected to a reversal with high return air suction pressure in the air distribution system at the heating appliance;

- High levels of relative humidity inside the residence plus lower dilution air temperatures injected into the vent system, raised the dewpoint temperature and decreased the vent exit temperatures;

- High levels of relative humidity inside the residence, where off cycle draft was available until the vent system returned to zero draft or reversed, kept vent liner surfaces moist and cold;

- Flue gas exit temperatures in the centre of the flue gas column never exceeded 105°F even when the outdoor temperatures where above 32°F, the heating appliance was above 80% combustion efficiency.

- Unacceptable vent draft, less than -0.01 in. W.C. did not allow a significant amount of dilution air to enter the dilution device, which increased the dewpoint temperature and reduced the volume of air to carry the moisture produced in the combustion process into the atmosphere;

- Vent connections in cool basement areas or cool utility areas, even with effective lengths that meet the existing codes, would radiate heat from the vent connection surfaces lowering flue gas temperatures 100°F to 200°F between the heating appliance and the chimney base; and,

- The variable that effected vent system performance inside residences and contributed to poor indoor air quality and combustion performance, would have to be addressed with an engineered vent system designed specifically for the heating appliance.

Sample test results are found in Table III.

THE HOUSE AS A SYSTEM™

The ability of a Service Technician or Installer of any heating appliance to solve problems with heating systems or wood burning appliances, must be in conjunction with a knowledge and understanding of the House As A System™ concept.

Esso had an unrealistic expectation level that their Service Technicians could solve any problem with heating systems **when they had not been appraised of the interaction of the other major components of the house.**

Let's review the House As A System.

The House As A System™, which is technique for explaining how a house (or any building) works, developed and promoted by our consulting firm since 1982, must be introduced at this point in my presentation. For example, knowledge of air flow is extremely important since air carries heat, moisture and many other substances (eg. spilled combustion pollutants) throughout the house. Combustion pollutants include: carbon monoxide, carbon dioxide, nitrogen oxides, hydrocarbons, sulphur dioxide, particulates and moisture.

The video that I am about to show you, presents a colourful overview of our House As A System technique. The first part deals with the basic building science principles. The second part presents a short series of problems and solutions that will illustrate the value of systems thinking.

Air Exchange

There is a constant exchange of air between every house and the air outside. This air exchange is the result of two different processes: ventilation and air leakage.

Ventilation is controlled air exchange. It is provided by bathroom and kitchen exhaust fans, dryer vents and all other mechanical devices that exhaust or draw air into the house.

Air leakage, on the other hand, is uncontrolled air exchange. It occurs as air flows through gaps around window frames, under doors, around electrical outlets and through many other small cracks and openings in the building envelope.

Exfiltration refers to the flow of air from inside the envelope to outside the house. Infiltration refers to the flow of air in the opposite direction, from outside to inside.

Air Pressure

Air leakage occurs only when there is a difference in air pressure between the inside and the outside of the house. In other words, even if there is a hole through a wall, no air will flow through the hole unless there is a pressure difference. The air pressure on one side of the wall must be higher than on the other side.

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*The material outlined above is to be presented by video (i.e. not delivered verbally) during the presentation.

Air pressure is related to the concentration of air in a space. The air pressure is greater in one space than in another if there are more air molecules in an equal volume. The air pressure in a fixed space will drop if air is sucked out, or rise if air is pumped in.

The flow of air, like the flow of heat, always tries to establish a balance. The flow of air will continue from a high pressure area to a low pressure area until a balance is achieved -- that is, until the pressure in both areas is the same.

Pressure Effects

Differences in air pressure cause movements of air. What then, causes differences in air pressure?

Pressure differences between the inside and the outside of a house are caused by four pressure effects: the stack effect, the flue effect, the ventilation effect and the wind effect.

The Stack Effect. When air is heated it becomes lighter and rises. During winter, heat is almost continually fed into the building. The result is an upward flow of air in the house.

As air flows upward, pressure builds in the upper parts of the house until it is higher than the air pressure outdoors. Since air flows from high pressure to low pressure, air leaks outward (exfiltrates) from the upper floors.

The upward flow of air, of course, draws air out of the lower parts of the house. Here, the air pressure drops. Air leaks into the building envelope from outside (infiltrates) where the air pressure is higher.

The overall result is an upward flow of air in the house, with exfiltration occurring upstairs and infiltration occurring downstairs -- the stack effect.

Somewhere between the extreme upper parts of the house and the extreme lower part, there is a point where the pattern of air flow changes from exfiltration to infiltration. Here there is no difference between the indoor air pressure and the outdoor air pressure. This can be pictured as a flat surface cutting across the house and dividing it into two parts -- one with high pressure and one with low pressure, relative to the outdoors. This dividing surface is known as the "neutral pressure plane".

The Flue Effect. The flue effect occurs in all houses with an open chimney flue connected to a furnace, boiler, domestic water heater, fireplace, wood stove, or any other fuel burning appliance.

Combustion gases, which are very hot and have a low density, rise rapidly up the chimney flue creating a strong upward draft. This draft sucks air out of the house, reducing the indoor air pressure. Air will then have a tendency to infiltrate into the house from outside, where the pressure is higher.

The flue effect is strong only when there is a strong draft up the chimney. When combustion stops, the flue cools down and the draft weakens. The neutral pressure plane, in other words, rise and falls with each cycle of the furnace.

The Ventilation Effect. Most houses have a number of mechanical devices that exhaust air. Common examples are bathroom fans, kitchen range fans, dryer vents, and central vacuum systems. Where operated, these devices expel air from the house and reduce the indoor air pressure.

This ventilation effect is similar to the flue effect. It leads to a reduced indoor air pressure and a tendency for air to infiltrate into the building envelope.

As described above, the neutral pressure plane tends to rise whenever the indoor air pressure is reduced. The neutral pressure plane, therefore, rises whenever mechanical exhaust devices are turned on, and falls whenever they are shut off.

When a house is operating normally, with the furnace cycling and the various ventilation devices being used intermittently, the stack effect, flue effect and ventilation effect may at times combine together to create a powerful exhaust of air out of the house. The combined effect is strong enough to overcome the high pressure build up in the upper part of the house by the stack effect. The indoor air pressure even in the upper floors is reduced to the point where air is drawn inward through all parts of the building envelope. The neutral pressure plane under these conditions rises above the upper ceiling level.

The Wind Effect. When wind blows against a house it creates a pocket of high pressure pushing against the windward side of the house, and a pocket of low pressure pulling outward on the leftward side. Air tends to infiltrate on the windward side and exfiltrate on the leeward side.

The Air Flow

It is very important to recognize that the four pressure effects, and the pressure patterns they create are not fixed, they are constantly changing. During any 24 hour period, each part of the house will be exposed to pressures of varying strength and direction as combustion systems cycle, mechanical exhaust equipment is turned on and off, and the winds change in speed and direction.

The overall air flow pattern in a typical house with an oil or natural gas heating system is represented here. Natural infiltration dominates in the lower part of the house, while natural exfiltration dominates in the extreme upper part. Air is exhausted mechanically by the chimney flue and exhaust fans; the neutral pressure plane rises and falls as the furnace cycles and the fans are turned on and off. This basic pattern is distorted whenever winds blow.

ESSO RESEARCH: Laboratory Testing of Venting Systems

To confirm the field test results, presented earlier, Esso built a natural draft masonry chimney at their Sarnia, Ontario Combustion Research Laboratory, to the standards outlined in the National Building Code. The masonry chimney was built in the spring and prepared for operation and tests in the fall of 1982 and winter of 1983.

The clay tile liner was sealed and grouted to ensure a continuous column. The base and cleanout door were sealed with the cleanout door inside the heated area. The heating appliance used was a Clare manufactured 100 O.H.B. with an Aero manufactured flame retention head burner. The heating appliance was dismantled and a new solid steel burner mounting plate was manufactured, and a solid gasket and sealant was used to ensure the burner would not pull any dilution air into the combustion zone during the operating cycles. The vent connection (7" diameter) was installed with a Field barometric regulator and the effective length of the vent connection was less than 10 feet. During all tests the draft regulator was set to produce an over fire draft of -0.02 in. W.C. the burner smoke test was 0 to a trace, CO_2 was 10% minimum and the oil flow rate was adjusted by pressure to compensate for any deviations. The nozzles were flow rated, spray angle tested and the oil spray pattern verified. Flow rated nozzles allowed for only minor increases (less than five pounds) in pressure to achieve rated input. The system was thermocoupled to a direct readout computer input recorder capable of taking temperature readouts at 20 second intervals and continuous combustion flue gas analysis.

The following test points were thermocoupled for readout: Indoor and outdoor ambient, oil temperature before pump, after pump and at nozzle; heating appliance exchanger; warm air supply, return air supply, furnace exit (breach), after dilution device before entry into vertical masonry chimney; and masonry chimney at selected locations both on the clay tile surface and the centre column of the flue gas travel. The flue gas exit temperatures were measured a minimum of 18" inside the top clay tile liner.

The tests were always set for a minimum of ten minutes of combustion process and were set up under both day time and night time cycles, and from cold starts with 12 hours off to stimulate night set back operating conditions.

ESSO RESEACH: Laboratory Test Results

Lab tests verified the field temperature test results in the vent system. Lab conditions ensured that the heating appliance was operating under optimum conditions and the in-home variables that contributed to the venting problems were eliminated. Test temperature profiles are shown in Table IV. Laboratory testing of the venting system found the following results:

- The masonry and clay tile liner surface temperatures and the flue gas temperatures, were always below the acid dewpoint before the flue gases had reached the midpoint of the vent system. Condensation was always evident on the clay tile liner at various levels with the lower input rate showing the condensation taking place down to the midpoint of the vent system.

- Higher levels of surface condensation would take place in residential vents because of shorter combustion cycles and cooler dilution air and more vent surface connection area to radiate heat from the gases produced.

The achievement of assured indoor air quality with all fuel fired heating appliances can best be achieved when the vent system functions properly.

A list of the criteria for a chimney to achieve acceptable results is provided below:

- Vents all combustion products, plus excess air without spillage into the residence;

- Operates under all possible outdoor temperatures at which heating is required up to 21°C (70°F);

- Promotes or permit rapid increase in volumetric flow;

- Does not cause change of flow through any naturally-aspirated combustion device;

- Maintains flue gas temperatures above acid condensation temperatures - even at the flue liner surface;

- Prevents leakage of air into, or gas out of joints;

- Resists acid attacks during warm-up and shut-down;

- Survives with minimum maintenance for several decades;

- Resists wind and other external weight forces; and,

- Resists creosote (solid fuels only).

The draft produced in a vertical vent for combustion products has a direct relationship to the exit temperatures of the flue gases, the outdoor ambient temperature and the vent column sized to contain the volumes of flue gases produced that move upwards in a uniform flow pattern. Table V illustrates the relationship between temperature and height relative to draft.

The exit temperature of the flue gases and height of the vertical vent dictate the maximum draft that will be produced. The draft that can be produced, when correlated to the rate of flow will dictate the amount of combustion gases plus dilution air that can be vented safely in a vent column of a specific diameter.

The control of flue gas exit temperatures is important for the production of natural draft and to prevent undercutting the acid dewpoint and the water dewpoint inside the vent system.

Conclusion: The production of natural draft in Table V can be eliminated if the other forces impacting on the house produce higher levels of opposing pressures.

ESSO VENT LINER AND HOUSE AS A SYSTEM TRAINING PROGRAM

Target Communication's was subsequently engaged by Esso to develop a nation-wide training and education program for their sales and service representative's. Based on our House As A System approach, the completed program comprised student handbooks, instructors guidebooks (complete with acetates and slide shows), two video presentations and a student performance evaluation exercise.
The program featured a program to selectively reline existing masonry chimneys with insulated stainless steel sectional liners. Where the exit flue gas temperatures

The program featured a program to selectively reline existing masonry chimneys with insulated stainless steel sectional liners. Where the exit flue gas temperatures in the centre column had been as low as 65°F after five minutes of appliance operation with outdoor ambient temperature readings of 24°F, the insulated lined retrofitted vent systems produced temperatures over 200°F in the centre column of the flue gas travel after five minutes of combustion.

The stainless steel liners used, although approved for the application, had a significantly high field failure rate from corrosion produced during start up and shut down. Prior to two years of operation being, completed 127 of the 220 installations had to be relined for material failure and it was then decided to change the balance of the installations from sectional assembles to continuous flexible stainless steel liners that were Warnock Hersey tested for corrosion, air tightness and water tightness, plus for other requirements for installation. The original type of stainless steel was 304 and the new selected type was 316 with low carbon and high moly content. For special low temperature application Allegheny Ludlum 294C stainless steel is specified.

Esso field test were also conducted where field installations were completed using higher static pressure burners. The higher static pressure burners, plus known pressure drops or internal resistance in the heating appliance and vent carefully sized for the volumes produced along with the elimination of the air dilution device, showed, where either care was taken to seal all the vent connections or a continuous flexible connection from the heating appliance to the base connection was used, flue gas spillage inside the residence was eliminated. •This method was designated the "Econotech System" for venting.

Esso field test installations with sealed combustion system and insulated vents have proven energy usage for space heating is reduced by a minimum of 25% over previous energy usage of 3200 (845 U.S.G.) litres of less and up to 62% on energy usage of 5000 litres or higher. Similar installations in the eastern United States, (New Jersey, Pennsylvania, Delaware, Maryland) have shown equal or higher fuel use reductions.

CONCLUSION

Armed with a working knowledge of the House As A System™, those involved in the Air Conditioning Industry are well prepared to avoid and solve venting problems. *Systems thinking* will better ensure the health and safety of your customers; reduce service calls; enhance customer relations; reduce your liability; and, guide the implementation of appropriate (integrated) energy conservation measures.

Table I, #2 Fuel Oil
Variation in Water Dew Point Based on Excess Air

TEST		EXCESS AIR	WATER DEWPOINT TEMPERATURE
% CO_2	% O_2	%	
15	1	2	44.4°C - (112°F)
14	2	5	43.8°C - (111°F)
13	3	10	43.3°C - (110°F)
12	4	30	42.7°C - (109°F)
11	6	40	42.2°C - (108°F)
10	7	50%	41.6°C - (107°F)

CO_2 at stochiometric = 15.2%

Calculations are based on dry air for combustion process and dilution

Table II, Combustion Air Volumes

TEST		EXCESS AIR	L.S.	C.F.M.
% CO_2	% O_2	%		
15	1	2	10.6	(22.46)
14	2	5	11.0	(23.40)
13	3	10	11.4	(24.25)
12	4	30	13.9	(29.40)
11	6	40	14.86	(31.5)
10	7	50	15.9 L/S	(33.7)

Based on:

Oil Pressure	6.9 BARS	(100 lbs)
Flow rate	3.8 L.P.H.	(1.00 USGPH)

Table III, Vent System Performance Test Results*

CUSTOMER	HEIGHT	TYPE	TEMPERATURE AT 4 PROBE POINTS			
			BREACH	INLET	TOP	OUTDOOR AMBIENT
LARKIN	8.5 M (28')	0	365°C (690°F)	254°C (490°F)	35°C (95°F)	(35°F)
JOHNSON	9.1 M (30')	1	237°C (460°F)	126°C (260°F)	38°C(100°F)	(33°F)
DAY	5.5 M (18')	0	232°C (450°F)	165°C (330°F)	31°C (88°F)	(30°F)
DILWORTH	9.8 M (32')	0	276°C (529°F)	135°C (275°F)	26°C (80°F)	(28°F)
LIPSHAW	6.1 M (20')	1	232°C (450°F)	182°C (360°F)	34°C (93°F)	(35°F)
BOISVENUE	8.5 M (28')	0	121°C (250°F)	65°C (150°F)	38°C(100°F)	(65°F)
FERGUSON	8.5 M (28')	1	149°C (300°F)	65°C (150°F)	40°C(105°F)	(60°F)
LAPIERRE		1	249°C (480°F)	218°C (425°F)	38°C(100°F)	(28°F)
GOULET	9.1 M (30')	0	321°C (610°F)	221°C (430°F)	32°C (90°F)	(30°F)
SHANNON	6.4 M (21')	0	243°C (470°F)	126°C (260°F)		(28°F)
BISONNETTE	4.9 M (16')	0	304°C (580°F)	144°C (292°F)	18°C (65°F)	(40°F)
WALTERS	7.6 M (25')	0	229°C (570°F)	157°C (315°F)	28°C (82°F)	(25°F)
ROSS	3.7 M (12')	0	343°C (650°F)	257°C (495°F)	35°C (95°F)	(23°F)

TYPE 0 - OUTSIDE 4 SIDES EXPOSED ABOVE ROOF; 1 INSIDE
STEADY STATE TEMPERATURES OR MINIMUM FIVE MINUTES OPERATION
ALL FUELS MASONRY TILE LINED. TOP TEMP. TAKEN 1.2 M (1.5 Ft.) DOWN IN CENTRE COLUMN

Table IV, Test Temperature Profile for Brick Tile Lined Masonry Flue After 10 Minutes of Continuous Operation

FIRING RATE U.S.G.P.H.	.65	.75	.85
BREACH TEMPERATURE	410	455	482
VENT INLET TEMPERATURE	224	230	248
CENTRE FLUE GAS COLUMN			
@ 7' ABOVE INLET	158	120	185
CENTRE FLUE GAS COLUMN	104	111	122
25' ABOVE INLET	82	91	95
OUTDOOR AMBIENT	42	37	42
INDOOR DILUTION AIR TEMP.	68	71	69

STANDARD NORTH AMERICAN FLAME RETENTION HEAD BURNER/OIL HIGH BOY FURNACE

COMBUSTION SET AT 10% CO2; 0-1 SMOKE; -02 OVER FIREDRAFT; T.R. 80°F; PUMP PRESSURE 100 LBS

J.Y. GUTTMANN, P. ENG.
ESSO PETROLEUM CANADA

Table V, How Temperature and Height Effect Vent Draft for Natural Draft

ASSUMPTIONS : CHIMNEY OR VENT IS SIZED TO ACCEPT VOLUMES OF FLUE GAS PRODUCED PLUS DILUTION AIR
: MAXIMUM OUTDOOR DESIGN TEMPERATURE IS 70°F
: FLUE GAS TEMPERATURES ARE RECORDED AS EXIT TEMPERATURE OF THE VENT
: DRAFT IS MEASURED IN INCHES OF WATER

CHIMNEY OR VENT HEIGHT

VENT EXIT TEMPERATURE	3.0 M 10.0 FT	6 M 20 FT	9 M 30 FT	12 M 40 FT
65.5°C (150°F)	0.012	0.025	0.037	0.050
93.3°C (200°F)	0.0.25	0.050	0.075	0.135
149°C (300°F)	0.045	0.090	0.150	0.210

PURDUE UNIVERSITY 1950-1952

Paper No. 89-12

PRESENTATION TRANSCRIPT

OIL HEAT EDUCATION AND TRAINING - THE FUTURE OF THE INDUSTRY

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OIL HEAT EDUCATION AND TRAINING - THE FUTURE OF THE INDUSTRY
TRANSCRIPT

It is indeed a pleasure to be here this morning to talk about a subject that I am very much involved with and I would suspect many of you are very much involved with it. I think it was good to see that Brookhaven when they put together this program included something about training and education because I think we all realized that all of the work that has to be done in the lab in the way of technical advances also has to be followed up with some good education and training on the part of our industry and the part of other organizations to make sure that the equipment once it gets into the field is serviced properly to achieve the satisfaction for the oil heat customer. That is the ultimate goal, I think of all of us is to achieve, a satisfied customer that will coming back to oil heat. Some of the things that I may say this morning are not very technical and not based on graphs and laboratory experiments, but more or less on my observations and conversations with other people that talk with oil heat technicians and manufactures and code writing officials and so I can't really point to any data out of the laboratory for some of my comments and some of my comments are personal opinions. If you share those opinions with me I would be very happy, because this afternoon we will have an opportunity at one of the workshops to kind of put our heads together and talk about this subject. If you don't share the opinions, that is fine too, that is why we have the workshops this afternoon also.

In the little bit of time we have let me just hit some of the areas in training and education that we should all be concerned with and have all been concerned with. It is a very broad field. There are many levels at which we must address these problems and it starts very basically with the home owner, the person that has the oil heat system in their house, or has the potential of having an oil heat system in their house. I think most of you have probably gotten together with your families or friends and when they find out that you have something to do with the heating business they say, "gee I am having trouble with my heating system and I need some advice," and you end up giving some training or education whether you like it or not. And how often have you heard from a neighbor or perhaps your brother-in-law that, "well I am kind of thinking of switching to gas because oil is dirty," or oil is smelly. "There isn't much in the way of good efficient equipment around and oil has had its day." What do you think? This puts you in position of being the educator and being the trainer and trying to convince that person that there is something out there and there is something that oil heat can give him as a customer. In this area we are bombarded with media commercials that are very antagonistic towards the oil heat industry. This area happens to be very heavily oriented towards oil heat. For those of you who are not from areas where oil is as popular I sure you would be surprised if not shocked to hear commercials that say oil heat is a dinosaur. That is the quote that they use. I've seen bumper stickers that say Oil Heat is a Dinosaur. What the people paying for these commercials are trying to convince homeowners and consumers of, is that the day of oil heat has come and gone, and now they should move on to something else. So on this level of the consumer, of the homeowner, or the commercial user there is definitely an education area that must be addressed to try to change that image and continue to present the image of an advancing technology, of a good technology and of a technology that can give them very satisfactory and economincal heating in their homes.

On another level we have the builders. That issue has been alluded here in the last two days and we have to do a good job in educating the builders as to what is available and what is coming on line and what they can expect in the future. Some of the advantages of using oil heat and of using control strategies that allow oil heat to really shine, to really give that builder something that he can sell to the customer. Code officals also must be educated or informed as to what is save, what is the wave of the future in oil industry equipment. Sometimes this is a little difficult to do because the people that sit on these boards have a vested interest. I think we all come across the situations where, for instance, electrical codes will vary greatly from area to area based on which electrical contractor sits on the town board. We have the situation in many areas and in some areas there are no codes, but in areas where there are codes and inspections required, these people must be brought up to date on what is new in the way of oil heat technology.

The burner service technician is another level and that is a level that I will be coming back to very shortly to spend a little time on because that is pivotal to the future of the oil heat industry. How that serviceman relates the customer, his knowledge, how fast he can get in, fix the problem and get out again all has a bearing on whether people will be friendly towards oil heat or will start to look around for alternatives. So we will come back to the service technician. The oil company owner or manager is particularly now an area of concern because it is not like it was years ago. When I first started calling in oil companies 25+ years ago, the most technically qualified guy in the place was usually the owner. There were smaller oil companies and a lot more of them and generally the guy who headed the operation either because he was the owner or he was the top service man had gotten there because of his technical knowledge and the ability to manage men. But he was the guy, that when the servicemen had the problem, they turned to him. He was the guy that went out and held the hand of the customer and got the job going and took care of whatever difficulties there were. Well that is not the case now, you can't go in and talk to Frank anymore. Frank has retired. Frank has sold his business to a much larger oil company and these much larger oil companies, the management, and ownership of these oil companies, in many case have not come up through a technical half. They are oriented towards selling oil which is understandable, and obviously a necessity, but they do not have the appreciation of how important having good technical training and qualified serviceman are, for the ability of them to sell that oil. I've stood at the counter of supply houses with servicemen and talked with them about that, and the expression now is among serviceman, "the management doesn't know which end the flame comes out anymore." In some cases that is true. And I don't mean that derogatory, because certainly the people that run large oil companies are extremely well qualifed businessmen. They have a lot to think about and a lot to consider. Sometimes technical training and training their men gets lost in some of the other considerations. This is definitely an area where we who are involved in technical training and in the technical end of the business must spend some time in educating and informing these people as to how important it is that when that new high efficiency unit gets plunked on the basement floor, that there is somebody there who knows how to install it, and six months or a year or two years from now, that there is somebody there to service it.

And lastly one of the levels that I think education must be entered upon, is that of the politicians. I sure you can all remember in the early 80's when the energy crisis was the big concern. Much more so than today. Even though it is still a problem. Even though we are oriented towards better and better, more efficient units. But it doesn't have the immediacy that it had in the early 80's. In the early 80's the opinion in congress was that natural gas should be used for space heating and oil should be reserved for making plastics, fertilizer, chemicals and so forth. And unfortunately for us that attitude is still held by many people that make policy in this country. So they have to be made aware the there are better alternatives to that 1920 oil burner that they had sitting at home, that there are things that the oil heat industry can do for this country in the way of energy conservation.

Let me go back to the oil heat technician or the oil burner serviceman and talk a little about that. It is my opinion that he is one of the key players in the future of the oil heat business. And if you look at the way oil heat technicians are trained you see that we must do better in the future and must get a little better at what we do if we are utilize the good technology that is being developed. The profile of the average serviceman in this area, and in most areas of the country, and it does vary in different geographic areas, but a typical profile would be somebody who is primary trained by OJT, on the job training. He goes to work for the oil company, possible before he gets out of high-school, during the summer doing clean-ups. He drives an oil truck sometimes, carries heavy parts down the basement for the older gentlemen, lugs the old boiler out and eventually gets to the point where he starts to service on his own. Now in some areas of the country, supplemental to that, there is formalized training in a trade school, or through an organization, and there are some very fine state organizations that are just about totally committed to education and do a very fine job. But that is very spotty. In some areas the education is very good and in some areas it is not as good. So that OJT is still the primary place where the oil heat service technician gets his education. I think you can appreciate that when you go from company to company to company you will find all types of OJT, some is very good if the person doing the training is very good, but some isn't so good. I'm sure we have all run into the serviceman who has 25 years in the business, 25 years of experience that amounts to 1 year of experience and 24 years of repetition, and somewhere along his 12th year he starts training another person who then carries on those traditions. My opinion, you can take it for what it is forth, is based on teaching seminars every year primarily, and talking with guys at the counter at the oil companies and service companies, my opinion is that we must do better in the future in the way of training our servicemen if we are at all to take advantage of what is coming down the road in the way of technical advances. There is a problem today with the existing technology, with basic understanding of wiring, basic understanding of how to troubleshoot a fuel unit, basic understanding of the whole house as a system. It exists today with the basic technology and this meeting has been geared towards the future of technology. And the future technology does not seem any simpler than what existed in the past and what exists in the present. And yet we have the problem right now, in that we as an industry sometimes have left a lot to be desired in the way of training the service technician.

If you look back through the recent history of oil heat after WW-II, we can count many many new technologies that came and went primarily because of lack of trained people and lack of service and some of these were very fine technologies, very fine if they worked properly and were maintained properly. An example, the GE low pressure units, which some people today feel are still among the finest most economical units ever built. They came and went based on lack of proper training and field service. And you can go right down the list, Williams Oil-Matic, Winkler, all these "more sophisticated technologies" things that burned oil better, but somehow fell by the wayside because training wasn't given and reliable service therefore wasn't given to the homeowner, the consumer. So these were pulled out of the field. If you are an oil company or a service company, you are always suspicious of new technologies, no one ever wants to be the first, and sometimes that is not a very forward thinking way of looking at things, but there have been some very good precedents in the history of oil heat that make many people involved in the oil heat service want to stick to that creed. One of the things that makes oil companies and oil heat service companies very reluctant to except new technology is because they have to do a lot of training of their people and its understandable because it is expensive to train.

One of the strong things or strong points of our industry is that it is a free enterprise industry. Being a free enterprise industry means that the companies have to make a profit to stay in business. Oil companies and service companies have been struggling with training their people on the existing technology and sometimes the last thing you need is a new technology, for very practical economic reasons. I can remember in the early 80's talking with owners of oil companies who were being dragged, kicking and screaming, into energy conservation. I talked to them about a flame retention head burner and that it may save their customers 30% and their palms started to sweat, because any time you take and reduce your volume by 30% you don't even make enough to cover your fixed costs. And while they all wanted to hold on to their oil accounts, in the middle of the night when they were all alone they hoped that everybody didn't put in a flame retention head burner, until they could adjust for that 30% reduction in volume and that is understandable. The key to new technology in this business is no different to the key to new technology in any business. You have to develop it, but then when you stand it on the floor there has to be a human factor, someone has to install it and maintain it. And what I submit to you is that what we have to do, before we can move ahead, is come up with some way of better training those people that have to install that equipment and do that service.

Very briefly let me just throw out a few things for you to think about and hopefully this afternoon if you come to the workshop we can kick them around some more. One of the things I thought we could use is a "Bible" in this industry. I've never found a nice big textbook that I could rely upon to be everything I wanted to know about the oil business, but didn't know who to ask. We have a conglomeration of some very fine publications, but we really don't have any one place where it is all pulled together into one textbook and one reference guide, or series of textbooks where oil heat technicians can get the information they need. Some of the most well attended seminars I've every given are in some of the most remote places in this country where guys have 2 and 3 hours and stayed 2 and 3 hours afterwards to get the information, they want the information, they are hungry for the information, but they have no way of getting it. And many times I've been asked, "How did you learn this stuff?," what did you read and unfortunately I don't have a good answer for it. My background is probably similar to many guys backgrounds. My family has been in the oil heat business all their life, I grew up with it and somewhere along the line I absorbed some of it, but that is difficult to tell a guy in Markett, MI, way up in the boonies, that he has to wait 25+ years to absorb some of this stuff. I think we need some kind of combined definitive text on oil heat and I think to go along with that we need a program to utilize that text and here is where organizations and perhaps BNL and perhaps the DOE can be involved with coming up with some national program where we can train people to know the correct story. There are a lot of wivestails and twisting of mother nature out there when you talk to oil heat servicemen. There is a lot of things that they swear by and that they pass on to the people that they, "on the job train," and it is just plain wrong. You need that definitive place where guys can turn for the proper authoritative information and of course support for the state associations and their education training is a key factor in this. I've never been one that has advocated licensing of oil burner servicemen, that kind of stuff goes against my grain, and I must say that my own personal experience, when I go and speak to a group that has either licensing or some kind of certification, I am hard pressed to see the difference in that audience and the audience where anyone can go out and do oil burner service on their own. Whether the education and the license means anything I don't know. My opinion is that is doesn't, and that is strictly my opinion. I'm not saying we license oil burner servicemen, but we give them the tools.

In closing I guess what I am trying to say is that in the oil heat industry we have to be much better than the next guy. When our oil heat servicemen go into a home they have to be better equipped, neater, more polite and better qualified than the next guy. Because once that homeowner decides that they are not satisfied, they have an alternative (to change fuels), and that's the alternative that we in the oil heat industry do not want to see them take advantage of.

Poster Paper No. 89-A1

FLUE GAS DESULFURIZATION IN OIL FIRED HEATING PLANTS
POSTER EXHIBIT PAPER

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INTRODUCTION

Almost one third of the atmospheric sulfur emissions originate from combustion processes. In the northern hemisphere, approximately 50% of sulfur emissions come from human sources. In the winter months, this value increases to nearly 100 %. In West Germany the amount of sulfur dioxide emissions originating from heating oil combustion is 5 %. In built up areas, this increases in the winter months to almost 100 %. The results of sulfur dioxide emissions are acid rain, damage to forests and acidification of land and water.

Practical desulfurization processes were previously only available for power stations and industry. The utilization of the exhaust gas residual heat in oil fired heating plant has been connected with a high corrosion rate due to the sulfur and sulfureous acidity of the condensed water. The German Aerospace Research Establishment (DFVLR) has now developed an effective process for burners in the 10 kW to 3000 kW range. This technique enables 60-99 % of the sulfur to be removed from the exhaust gas and simultaneously reduces fuel consumption by 10-35%.

THE DFVLR PROCESS

During combustion of fuel oil, approximately 3% of fuel sulfur is oxidized to sulfur trioxide (SO_3) and about 97% appears as sulfur dioxide (SO_2). While using the upper calorific value of the fuel, condensate appears in the residual heat exchanger. This condensate absorbs SO_3 from the exhaust, becomes acidic, end can no longer absorb SO_2 (strong acids displace weaker ones).

In our process, the condensate is passed through a neutralization chamber using a circulation pump and is then returned to the residual heat exchanger. The neutralization substance, MgO, raises the pH-value to about 7.5. The weak basic condensate absorbs 60 to 99 % of the SO_2 from the exhaust and is then immediately oxidized by contact with air to nonpoisonous magnesium sulfate (Epsom salt, often present in hard water). The overflow of condensate is diluted in a buffer tank with domestic waste water and directed into the sewage system. The neutralization substance works as a sacrificial anode (no corrosion of the condensing heat exchanger) and as a bonding agent for metallic oxides. Thus, no metals are released in the waste water.

A supply of air to the circulating condensate causes an immediate change of the sulfite ions to sulfate. Thus, no sulfur dioxide can evaporate from the condensate. Measurements of the flue gas and condensate show approximately equal desulfurization rates.

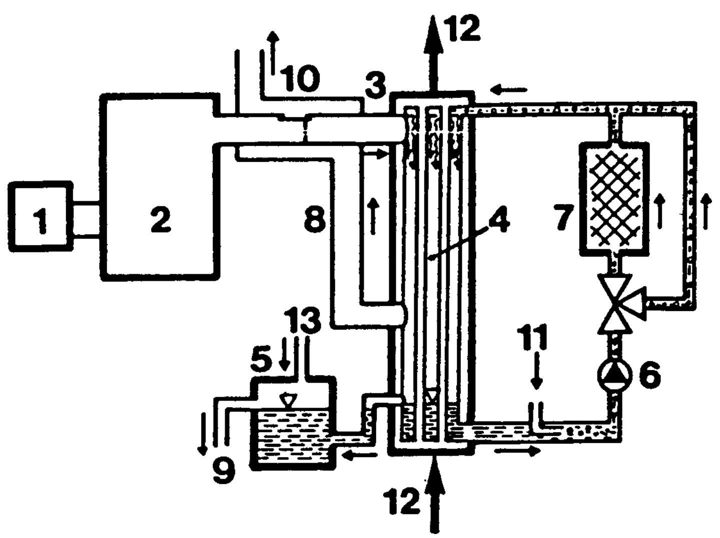
This process extracts the latent heat of vaporization from the water vapor in the exhaust gases. This results in a fuel savings of about 10% for a modern heating system and about 35 % savings in an older one. The DFVLR process is patented in several countries, including in the USA.

APPLICATIONS

Some application of the DFVLR desulfurization process are: under-floor heating, low temperature radiator heating, domestic water heating, swimming pool heating, heat pumps, etc.

Technical questions can be addressed locally to Z. Faragó or to Prof. Dr. W. Buschulte, DFVLR, D-7101 Hardthausen a.K., W.GERMANY. Asking for a US licence contact Mr. U. Henckel, DFVLR Center Cologne-Porz, D-5000 Koeln-Porz 90, W.GERMANY. Any kind of applications questions can be discussed with the German DFVLR Licensee, Mr. G. Schmidt, Ing-Buero Schmidt, Altenkesseler Str. 17, D-6600 Saarbruecken, W.GERMANY.

PRINCIPLE OF THE DFVLR PROCESS



1 burner
2 boiler
3 exhaust before desulfurization
4 flue gas purifier and residual heat exchanger
5 intermediate container for condensate and domestic waste water
6 condensate pump
7 condensate neutralization
8 exhaust after desulfurization
9 condensate and domestic waste water outlet
10 exhaust drier
11 fresh air supply
12 heating return
13 domestic waste water supply

III. WORKSHOP SESSIONS

III. WORKSHOP SESSIONS

GROUP A. Advanced Controls for Oil Heat and Performance Degradation
Chairman: Charles Green
Rapporteur: Tom Butcher

GROUP B. Educational Needs in the Oil Heat Industry
Chairman: Lindy Lindtveit
Rapporteur: Roger J. McDonald

GROUP C. Oil Appliances with Direct Sidewall Venting - Recent Advances and Remaining Issues
Chairmen: Jack Cunningham and John Marran
Rapporteur: John Batey

GROUP D. Future Development of Advanced Oil Heating Equipment and Appliances
Chairman: A.C.S. "Skip" Hayden
Rapporteur: C.R. Krishna

IV. DISCUSSION TOPICS

SUGGESTED GUIDANCE FOR WORKSHOP DISCUSSIONS

1989 OIL HEAT TECHNOLOGY
CONFERENCE AND WORKSHOP
MARCH 27-28 1989

BERKNER HALL
BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NY

CHAIRMEN AND RAPPORTEURS FOR WORKSHOP GROUPS

Group	Chairmen	Rapporteurs
A - Control Strategies	Charles Green	Thomas Butcher
B - Educational Needs	Lindy Linvit	Roger McDonald
C - Venting Technology	Jack Cunningham & John Marran	John Batey
D - Advanced Heating Equipment	A.C.S. "Skip" Hayden	C. R. Krishna & John Andrews

WORKSHOP GROUP A: ADVANCED CONTROL STRATEGIES AND PERFORMANCE DEGRADATION

- Which factors contribute most to calls for service?

  - nozzle fouling
  - ignitor failures
  - draft problems/odor
  - oil pump
  - fuel line blockage
  - circulator/distribution
  - chamber failure

- Which factors contribute most to seasonal efficiency degradation?

  - improper burner adjustment
  - oil quality
  - unavoidable factors
  - partial nozzle fouling mid season
  - poor draft
  - lack of maintenance

- Properly adjusted and installed, are modern retention head burners clean enough, from a service point of view? Consider furnaces and boilers with and without chambers.

- What are the most important benefits that advanced controls could provide?

  - improved reliability (less no heat calls)
  - improved customer confidence
  - faster servicing
  - more accurate air adjustment
  - automatic excess air adjustment
  - would permit burners to be adjusted for lower excess air

- What information should future control systems be capable of communicating to the service organization?

  - oil tank level/fill required
  - draft
  - home temperature
  - flame quality
  - control lock out
  - heat exchanger fouling

o Would advanced control systems which indicate that the burner performance has degraded be useful?

- would create too many unneeded service calls
- would enable service to be performed before no heat situation occurs
- would generate customers through increased attention to heating system.

1989 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP

WORKSHOP GROUP B: EDUCATIONAL NEEDS OF THE OIL HEAT INDUSTRY

- Who needs to be reached by improved educational programs?
    - Homeowners
    - Fuel oil dealers
    - Service technicians
    - Builders and contractors who select equipment
    - Oil heat equipment designers
    - Code officials
    - Others

- What are some of the problems caused by inadequate educational activities within the oil heat industry?
    - Homeowners are unaware of the efficiency advantages of oil heat
    - General lack of awareness regarding newer oil heat equipment options
    - Lack of demand for newer products
    - Other problems

- How can service technicians in particular be educated and trained to improve the quality and efficiency of service for oil-heat equipment?
    - Better training programs
    - Technician certification programs (statewide)
    - Broadened scope of learning to introduce newer, more efficient systems, retrofit options, maintenance procedures, etc.
    - Increase availability of pamphlets, training manuals, brochures, trade magazines, etc.
    - Others

- What type of information is needed?
    - Latest developments in oil heating equipment
    - Installation guidelines for service technicians
    - Results of efficiency test programs (in simplified form)
    - Basic introductory information on efficient operation of heating equipment
    - Practical methods for selecting and installing high efficiency oil heating equipment
    - Other educational needs

- o Who should participate in coordinating a national effort to increase information dissemination and establish educational programs to public groups? What are their roles in supporting this effort?

    - U.S. DOE
    - Private and public research agencies
    - State and regional oil heat associations
    - Independent oil companies equipment manufacturers
    - Other participants

- o As a follow-on activity, volunteers from interested groups and agencies are requested to form a committee for developing action items which support technology transfer goals. This activity will serve to extend key ideas discussed at the workshop, into a working plan for improving education programs.

F10/Topics

1989 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP

WORKSHOP GROUP C: OIL APPLIANCES WITH DIRECT SIDEWALL VENTING - RECENT ADVANCES AND REMAINING ISSUES

- What venting improvements can be considered?
  - Definitions of venting systems
  - Direct vent (through the wall)
  - Sealed combustion (outside combustion air source)
  - Removal of barometric damper in combination with high static pressure burners
  - Induced draft (power venting) or forced draft (high static pressure burner) designs
  - Other features

- What experience currently exists with alternative (without chimney) venting?
  - Marketed products
  - Field installation
  - Laboratory or field test

- What are the technical benefits from improved venting approaches?
  - Reduced fuel use through lower air infiltration induced by the chimney for combustion and draft relief air
  - Reduced off-cycle heat loss from boilers and furnaces
  - Elimination of start-up and shut-down and seasonal transients that affect fuel-air ratio, efficiency and soot deposition
  - Capability for installing high efficiency oil heating systems with flue gas temperatures too low for conventional chimney venting
  - Radon control by reduced basement depressurization
  - Other beneficial features of improved venting techniques

- What technical problems exist regarding alternative venting methods?
  - Safety issues related to new venting methods
  - Wind effects that can vary the fuel-air ratio of the burner
  - Low level exhausting of combustion products and potential hazards
  - Location of vent discharge relative to windows, corners and other building features
  - Installation problems such as installing the vent termination below the snow line
  - Building discoloration by exhaust products
  - The need for specific design and installation guidelines to assure safe and efficient vent operation
  - Building code restrictions that prevent direct venting of oil heating systems
  - Availability of vendor-specified contractor-supplied temperature and corrosion capable materials
  - Other problems - tight structure conditions may cause odor or melted coupling problems after burner shutdown

- What research and development activities are needed for advancing alternative venting methods?

    - Quantification of energy savings produced by improved venting methods based on laboratory and in-field studies
    - Development of evaluation guidelines to assist oil heating equipment installers in venting system selections, especially for high efficiency heating systems
    - Development of oil industry standards to assure safe and effective installation and operation of venting systems
    - Evaluation of improved venting methods for both retrofit and new oil heating systems
    - Other research, design or development activities

- Who should conduct each phase of the research, design and develop activities?

    - Oil Heat Equipment Manufacturers
    - Public Research Groups
    - Oil Heat Associations
    - US DOE/National Laboratories
    - Other Participants

- How can these groups interact effectively to develop practical alternative venting systems?

- How can this technology be transferred most effectively into practice? Who needs to be involved?

    - Oil Heat Equipment Manufacturers
    - Fuel Oil Service Groups
    - Homeowners
    - Code Officials
    - Fuel Oil Marketers
    - Government Agencies: Federal, State, Local

F13/Guidelines

1989 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP

WORKSHOP GROUP D. FUTURE DEVELOPMENT OF ADVANCED OIL HEATING EQUIPMENT AND APPLIANCES

- What further improvements can be made to increase the efficiency of current oil heat systems?

  - higher efficiency components
  - lower firing rate capabilities
  - direct vent systems
  - cleaner operation (reduced soot and boiler fouling)
  - improved diagnostics
  - improved performance control
  - maximized combustion efficiency
  - minimized fuel quality variations
  - other developments

- What problems limit the development or use of new, high efficiency oil heating equipment?

  - fragmented oil heat industry; lack of unified direction
  - market uncertainties
  - lack of consumer awareness and education in new systems
  - lack of standardized equipment efficiency information
  - higher equipment costs
  - service problems
  - outdated building codes
  - other implementation barriers

- What solutions are needed to overcome these problems?

  - cooperative efforts
  - effective technology transfer programs to educate service personnel and inform consumers
  - reliable equipment efficiency information
  - revisions to update building codes
  - other solutions

- What are the roles of fuel marketers, equipment manufacturers, trade associations, and government agencies in solving these problems? What positive actions can be taken to successfully implement each of the above solutions?

- What future R&D activities are required to advance oil heat equipment technology to its fullest potential?

V. WORKSHOP SUMMARIES

GROUP A. ADVANCED CONTROLS FOR OIL HEAT AND PERFORMANCE DEGRADATION

Charles Green
Chairman

Thomas Butcher
Rapporteur

The chairman started the workshop session by polling the participants about the most significant service problems. Three items made up 70% of the responses:

1. Sooting
2. Burner Setup and Service Diagnostics
3. Oil Quality

The remainder of the workshop session focused on these three items.

Sooting

In general the problem of sooting appears to be improving with time although when problems do occur they tend to be sudden and severe. Boilers are getting tighter and the general attitude is that this trend should not go any further.

The efficiency of boilers is becoming less important as a driving force for equipment selection, and reliability is becoming more important. The general opinion, however, is that improved reliability should not be attained at the expense of efficiency.

As burners are being equipped with fans with higher static pressure they are becoming more critical - small changes in the inlet air damper position result in large changes in air flow. This has led to some service problems.

In some cases sooting problems have resulted from substition of nozzles by servicemen. This is in part due to over-rating of the equipment. Manufacturers should provide a list of recommended nozzles over a wide firing rate range. In addition the general quality of nozzles is poor, and performance is inconsistent.

The control strategies which have been developed at BNL could be very useful for improving equipment reliability. The group was generally concerned, however, about unnecessary service calls and involving the homeowner in the process. The service company should be signaled when a consistent trend of performance degradation has been realized.

Burner Setup/Service Diagnostics

The digital test kits for flue gas O_2 measurements are expensive and not generally reliable. The older wet "dumbell" types used to measure CO_2 are considered more reliable. In either case many servicemen still do not use instruments to adjust burner air/fuel ratios. Some service organizations use an incentive system to promote use of instruments but this was seen as an expensive solution. A new technology - like the optical approaches under development at BNL would be a welcome improvement. The addition of a second optical sensor specifically for flame quality evaluation is not seen as a significant concern.

Oil Quality

The general consensus of the group was that more work is needed in this area and specifically in methods of detecting problem oil, methods of detecting tank condition, chemical treatment methods and tank cleaning. This is seen as a very important area which should receive more attention at the Oil Heat Technology Conference. Under the BNL oil heat program evaluation of oil quality in actual home tanks should be done.

Group B. Educational Needs of the Oil Heat Industry

Chairman: Lindy Lindtveit

Rapporteur: Roger J. McDonald

The chairman began the session by having everyone introduce themselves and identifying where they were from. In all, 39 conference attendees participated in this workshop, representing ten different states and Nova Scotia, Canada.

The chairman introduced the workshop topic and requested participants to share some of their own experiences concerning educational techniques used at the local level that might be useful to consider in developing a national program for the industry.

The first person described the use of video training tapes in his own small oil heat business as being very useful. The serviceman takes the tapes home and can review the material, repeating segments that are unclear to him without concern for embarrassment or ribbing from fellow workers. Others in the group thought that video tapes were good training aids, but were not the only key to a good training program. The necessity for hands on learning was stressed. Another comment was that the use of video tapes was helpful in keeping formal training courses on track and reinforced what was learned by other means.

The next topic was the need for a good industry source book, a "bible" that would include material (in chapters) covering everything the serviceman needs to know to perform all facets of his job, as well as a primer on the oil heat industry in general. One person mentioned that the "Burkhardt" book was already available and covered everything. Many others in the group disagreed stating that the book in question did not cover everything and did not include enough detail on many subjects that it did include. This book, "Domestic and Commercial Oil Burners," was first written in 1950 by Charles H. Burkhardt, was last published in 1969 by McGraw-Hill, Inc. As other participants pointed out, the book is a good overview of the oil burner, its systems, and includes very useful information, but it is very dated and is lacking a lot of details that servicemen need to know. It does not touch on any of the newer advances in technology realized during the last two decades.

The next suggestion was that what was needed was a manual, which was made up of separate modules (topics), each of which could be updated independently at any time. The manual would thus be a ring binder with many sections, or a series of volumes on individual topic areas. Certain modules would not be expected to change very much (like basic wiring) while others might require periodic updates as the industry and its technology evolves. Entire new modules may need to be added as new advanced equipment designs become available.

A new topic was brought out for discussion. An individual identified that the industry needs to improve its image to the public and that most certainly involves the image of the service technician, the person the public sees come to his house. The importance of presenting a neat clean appearance (people and equipment) was stressed. It was suggested that a section of the "bible" should cover this area as well as the more technical parts of a serviceman's job. This went as far as suggesting a section on marketing replacement equipment and educating the serviceman on how to handle this situation. How to calculate costs and benefits into the future might also be included. This also led to an aside on the topic of how to recruit new young people into the field of oil heat and oil burner servicing. It was suggested that image was again important and that approaching high schools with a video tape for use during career days or career counseling could be of some benefit in this area. This led to the issue of unions found in some areas and the differential between a trainee (example, $10/hr) compared to a regular serviceman's salary after two years of training (example, $17/hr). The issue being was this sufficient to attract new people into the industry. Several indicated that this was a significant problem.

A representative of an oil burner manufacturer indicated that all these were good ideas, but that the key to good training was a hands on approach. Manuals and video tapes have both good and bad sides and are not sufficient to replace hands on training.

One company representative indicated that it costs each company approximately $12,000 to $15,000 to send one man for training for one month including his salary, training course fees, transportation, and living expenses. The investment in training new service technicians be it "on the job" (OJT) or in a formal training program is very substantial. When that individual becomes qualified and useful to his employer he is under no obligation to stay with that company and is a target for other companies to try to hire away. Another possibility is that the individual may choose to go out on his own and work as job shopper or "lumper." The conclusion drawn by the committee was that the "bible" should also cover the topic of how to attract labor, as well as train them, and how to maintain employee loyalty. The happy employee stays and the dissatisfied employee looks elsewhere. This requires a manager dedicated to education and also to good employee relationships.

One company manager described a technique where each serviceman who is in a training program is asked to teach the rest of the trainees on one particular subject and in so doing becomes a specialist in at least one area (for example fuel pump units). The representative of the Alliance to Save Energy indicated that with the state weatherization programs it is often the service managers that use the training manuals that they have produced and the manager then passes on the information on an as needed basis to the servicemen in the field.

The issue of certification of oil burner technicians by states or some other agency was discussed. The group was split on the pros and cons concerning certification of servicemen. Some thought it gave the industry a good image, that the certified qualification of servicemen was an asset. Others felt that the certification once obtained would create a situation where servicemen would feel no obligation to continue their education beyond the level required for certification.

The chairman concluded the session by stating that the general consensus seemed to favor the creation of an industry "bible" for training purposes and that it should be modular in format and updateable. It also seemed that everyone was in favor of the use of video taped materials to supplement the printed information and that both were needed to do the job properly. As a starting point it was recommended, by several attendees that what educational materials were already available should be cataloged along with information on how to obtain them and this could be distributed to the members of the oil heat community while the process of developing a "bible" was ongoing. This would also be the logical starting point for the development of such a project. BNL volunteered to host a technical advisory committee to further refine the goal and objectives of the activity and to discuss how the acitivity would be supported now and in the future.

The chairman ended the session by asking everyone around the table to identify one key idea, concept, or statement that was important to the future of education within the oil heat industry. The following list contains the responses:

- Use training module approach
- Utilize military sources
- Use an incentive program for servicemen
- Dollar commitment is a key
- Commitment by those in authority
- Make servicemen feel more part of the company
- Use short one hour courses on specific items
- List what is already available in training materials and how to obtain them
- Positive attitude promotion
- Get back to basics/starting at top management level
- Educate the company principles on down
- Servicemen should be able to question principles
- Promote industry careers at the high school level
- Use laboratories and equipment to replicate problems
- Quality time devotion by the companies
- Get solid owner backing for educational activities
- Certification with mandated training
- Use 1989-90 contracts to standardize service and time slots for emergency service rather than 24 hours/day
- Promote the industry with local young people
- Have oil heat institutes work with high schools
- Look at other industries and their training programs
- Establish skill levels and ranking for servicemen
- Update experienced service technicians with retraining
- Develop a national clearinghouse for information
- Use loose leaf format for the "bible" to allow for updating
- Go with certification programs
- Develop better communication links between owners and servicemen on these issues
- Follow-up on these issues is the key!

Group C. Oil Appliances With Direct Sidewall Venting Recent Advances and Remaining Issues

Chairmen: Jack Cunningham and John Marran

Rapporteur: John Batey

The discussions began with a review of definitions for various venting configurations:

- Direct venting is removal of exhaust gases without the assistance of a chimney, and often involves through-the-wall venting of combustion gases.

- Sealed combustion refers to the case using outside combustion air in which the combustion air inlet through the system to the exhaust terminus are air tight.

- Direct exhaust refers to cases in which an inducer fan is removing exhaust gases from the furnace with combustion air supplied from the house.

Sealed combustion was discussed as a means for eliminating off-cycle odor problems, by preventing the spillage of fumes into the furnace room. However, ducting outdoor combustion air to the burner could produce oil ignition problems because of cold air cooling the oil. An alternative is to bring outdoor air into the room, and use the room as an air plenum. The size of the opening for outdoor air supply was also discussed. Another benefit from sealed combustion was reduced fouling of the burner and heat exchanger by lint, dust, animal hair, and other household contaminants. This has been a problem in some houses and can produce a degradation in heating system performance. Also, the use of large attic fans and problems associated with back drafting, was mentioned as a problem that could be reduced by sealed combustion. The attic fan can pull oil combustion odors into the house when conventional (non-sealed) venting systems are used.

The discussions next addressed the types of sidewall venting heating equipment that is now available in the marketplace. The Energy Kinetics System 2000 boiler and the Thermoproducts furnace as manufactured by the session chairmen were mentioned as two examples. No major problems have been experienced with these systems thus far. The exact details of power venting system designs can vary. These include: fan powered exhaust, fan powered supply, and high static pressure burners. Draft can be regulated by controls on the fans (dampers) or by a barometric damper.

The System 2000 has 5 years of field test experience and has been on the market for about 3 years. It is recommended that the negative pressure be set for -0.10 inches water column to leave room for fan degradation. Following the recommended installation instructions is essential. Fuel quality problems have been experienced in recent years, and direct venting needs clean combustion.

When installed properly, direct venting is a low-cost method for installing efficient oil heating units. However, other problems, (such as ignition delays) will become more noticeable than for systems with chimney venting.

Several important notes regarding direct vent systems are:

- o The installer must alert homeowners that their house siding (near the vent) may need to be washed occassionally. But this inconvenience is offset by many benefits.

- o The burner must be properly adjusted using combustion test equipment.

- o Homeowners must be aware that annual servicing is required.

It was mentioned that installation and service practices are difficult to change. Some people will not follow instructions.

One technical problem that has been experienced by sidewall venting systems is the pressure of oil fume odors. If the burner is above the exhaust outlet, a post-purge of the combustion chamber is needed. For some units, a 10 foot vertical rise of the exhaust vent line leaving the unit is recommended. This produces adequate natural draft to reduce odor problems. A 3 to 5 minute post-purge period was mentioned by one manufacturer as being adequate to reduce odor problems. This means running the venting system blower(s) an additional 3 to 5 minutes after the combustion of fuel is stopped.

Alternative venting configurations were discussed next. One method is a 4 to 5 foot high exhaust plenum along the side of the house. This resembles a short chimney constructed of concrete block, with an exhaust port on the side near the top. This can reduce house siding discoloration while providing good exhaust flows. This configuration appears to be aesthetically more pleasing than other alternatives. A second venting method involves installing an exhaust pipe below-ground for some distance from the house. A tile pipe riser can then emerge from the ground to exhaust the combustion gases at a suitable location.

Other experiences with alternative venting systems were discussed. One workshop member indicated that using a barametric draft regulator with power venting can cause a noticeable reduction in the building air. Another attendee discussed a recent problem with a chimney collapse and stack relay failure that formed a potential safety hazard for a conventional chimney venting arrangement. The possibilities of unexpected conditions with power venting systems was discussed. One example was the presence of an oil leak that could create a "pool fire" in the combustion chamber. This could cause a runaway condition with excessively large flames. One workshop session member felt that the "tight" design of modern burners would limit the air flow in such a case, and control the fire to some degree. Redundant safety devices such as pressure and temperature switches connected in series were mentioned as an important consideration for reducing safety problems.

The important advantages of power venting systems were discussed, and the following prioritization was determined:

- o Opens up new markets for oil heat in replacing electric heat and heat pump systems.

- Lowers installation costs by eliminating the chimney.
- Improves efficiency and also lowers operating costs.
- Eliminates existing chimney problems.

Many existing chimneys are 30 to 40 years old, and were not designed for the low flue temperatures associated with efficient boilers and furnaces. This can cause serious problems. Side wall horizontal venting may help in oil heat installations, both in new and retrofit applications.

Proper chimney sizing was discussed as a problem area. It was mentioned that a 6 inch by 6 inch chimney may be adequate for newer heating units.

BNL was mentioned as an important technical resource to help establish venting guidelines for both new and older heating systems.

Another problem that was discussed is that local code requirements are not uniform, but vary from place to place. In New York State the town must pass an ordinance against sidewall venting for the local building department to prevent it. UL listing was discussed as an important step in the code approval process.

Again proper flue sizing was discussed and it was decided that a technical committee is needed to make recommendations concerning venting system sizing and design. Also, it was mentioned that sidewall venting is not appropriate to all installations. However, in many cases it can offer important advantages over chimney venting of combustion products.

The impact of alternative venting systems on indoor air quality was discussed briefly. A workshop member from Canada indicated that sidewall venting is the only viable option for the tight R-2000 houses. Ice formation in the flue, and fine blowing snow were mentioned as two problem areas in Canada.

Finally, the group addressed the need for research and development activities related to power venting oil heating systems. These include:

- Evaluation of efficiency improvement and fuel cost savings;
- Developing reliable systems that do not have unusual servicing requirements;
- Concern for bearing failures used in induced draft exhaust fans.

Group D. Future Development of Advanced Oil Heating Equipment and Appliances

Chairman: A.C.S. "Skip" Hayden
Rapporteurs: John Andrews and C.R. Krishna

This workshop was attended by about 35 people. Topics for discussion included further possible improvements in oil heat systems, problems limiting their development or use, necessary solutions to these problems, appropriate roles of the various groups associated with oil heat, and future research and development needs. Discussion at this workshop focused on the following areas:

High-Efficiency Equipment

The consensus was that the primary need was for a generally accepted classification system that would give guidelines on what boilers and furnaces could be used with what vent systems. Lower limits might be set for flue-gas temperatures for each type of system. Climate was seen to be a factor in setting these lower limits. Available efficiency levels were seen as sufficient; there was not a lot of support for a big push to condensing systems.

Thermal Distribution Systems

There was significant sentiment in the group that thermal distribution systems--ductwork and pipes-- could provide a fertile field, not only for improved energy efficiency, but for oil heat installers to expand their business into a new area. This could be seen as a "tune up" for the heat distribution system; cleaning, adjustment, sealings, and insulating where appropriate.

Low-Firing-Rate Systems

A need was seen for systems that could go below 0.5 gallons per hour input. It was pointed out that with conventional nozzles, few installers will go anywhere near as low as half a gallon an hour, even though that is the lower limit according to the conventional wisdom. After-drip, cracking of the fuel, and coking were seen as inherent problems with conventional atomizers, pointing to the need for a different mode of atomization.

Sidewall Venting

A need was seen for better quantification of the efficiency gains from sidewall venting and sealed combustion. Credible information could serve as a marketing tool for these systems.

On-Line Diagnostics

The need was seen for systems that maintain clean burning characteristics over time. There was discussion whether this should be attained through the implementation of on-line diagnostics or by fail-safe system design to prevent heat exchanger fouling from occurring. On a shorter-term basis, a soot indicator in the combustion chamber was seen as a desirable compromise.

Combined Systems

Systems that serve two different functions were seen as a way to increase oil sales and improve efficiency at the same time. An optimized combined space and water heater was suggested. The idea of oil-fired cogeneration for the home was well received in the group. An oil-fired clothes dryer was also suggested, as was an oil-fired absorption heat pump. The use of a conversion technology such as thermoelectrics to skim a small amount of electricity from the system, which would then be used to run pumps and fans, would provide insurance against electrical outages as well as lower operating costs due to purchased power in conventional systems.

Summary

Several areas where work is ongoing were cited as appropriate, and some new areas were suggested. A real need was seen to get information about recent and ongoing developments in oil heat equipment to the public and to others in the decision chain.

APPENDIX A

CONFERENCE ABSTRACTS

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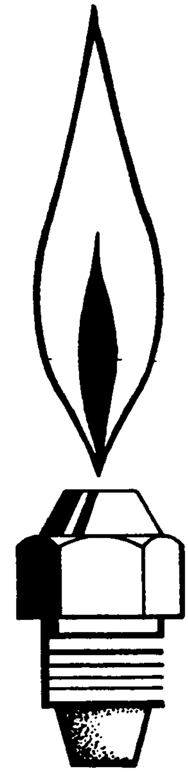
CONFERENCE ABSTRACTS



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BERKNER HALL
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Paper No. 89-1

OIL HEAT RESEARCH AND DEVELOPMENT - PATH TO THE FUTURE

Roger J. McDonald - Program Manager
Combustion Equipment Technology
Brookhaven National Laboratory

ABSTRACT

The Brookhaven National Laboratory, Architectural and Building Systems Division, provides technical and management support to the U.S. DOE - Office of Building and Community Systems in Combustion Equipment Technology (CET) applied to oil heat. The work at BNL was originally started back in 1975 with a program on efficiency testing of unique high efficiency concepts in an effort to accelerate product development and marketing of such equipment to conserve energy in the oil heat energy use sector.

The current program started in 1987 is a direct result of efforts on the part of the oil heat industry asking congress to support Oil Heat R&D for the benefit of the nation, oil heat consumers (totalling approximately 12,000,000 in the U.S.), and the industry.

A multi-year plan for research and development activities was approved by the DOE in 1987 and currently includes projects on:

- Advanced Control Strategies
- Research on Advanced Oil Combustion Equipment
- Oil Appliance Venting Technology
- Technology Transfer, and
- Support of the Combustion Equipment Technology Lab

The plans for the future include activities related to: fuels, fuel quality, and storage; effects of combustion chamber design, oil co-generation concepts (total energy packages); advanced heat exchanger technology; and oil technology education activities within the more general project area of technology transfer.

This paper will serve as an introduction to the work at BNL in Oil Heat Technology as well as set the stage for the technical papers to be presented by the BNL research staff on individual projects included in the program.

Paper No. 89-2

ADVANCED CONTROL STRATEGIES

Thomas A. Butcher
Brookhaven National Laboratory

ABSTRACT

Results are reported of an experimental study of sensors for advanced control systems for residential oil-fired heating equipment. The work has been aimed at a broad range of sensing options including indicators of heat exchanger fouling, fuel/air ratio and flame quality. Output or control options under consideration include local or remote indicators of "service required," tools to aid rapid and accurate air fuel ratio setting, and automatic excess air trim.

It was found that evaluation of the rate of performance degradation due to heat exchanger fouling can be done very simply using the peak flue gas temperature during heating cycles. Tests on low cost oxygen sensors based on zirconium probes showed these to be very useful for the oil heating application. The use of flame optical emissions for control was evaluated by making spectral intensity measurements over the range 200-1100 nm (ultraviolet to near infrared) and broad band emission measurements in both the visible and the infrared. Optical emissions were found to be very useful indicators of flame quality. A simple concept for using optical inputs for burner adjusting and/or indicating service required is described.

Paper No. 89-3

RESEARCH ON FUTURE OIL BURNER CONCEPTS

C. R. Krishna
Brookhaven National Laboratory

ABSTRACT

The reduction in the heating requirements of homes through conservation measures requires development of burners firing at significant lower rates than conventional burners. Both competition with alternate fuels and the increasing awareness of the need for less pollutant emissions require combustion at these lower firing rates to produce much less soot. A previous analytical study indicated that a significant determinant in achieving the development of advanced burners meeting these objectives is the quality of atomization of the fuel oil.

The work reported here compares results of measurements from different types of atomizers and preliminary testing of burners incorporating unconventional atomizers. It is shown that different designs of pressure atomizers can show differing spray drop sizes. It is also shown that air assisted atomizers generally can be operated to give much finer spray drop sizes at both high and low firing rates. Preliminary burner testing results indicate that this improved atomization characteristics does indeed translate into much better transient smoke emissions compared to conventional retention head burners.

OIL-FIRED HEATING TECHNOLOGY FOR THE ARCTIC

Robin Sinha
Canada Mortgage and Housing Corporation

ABSTRACT

Canada Mortgage and Housing Corporation (CMHC) is a crown owned corporation whose mandate is to promote the construction of new houses, the repair and modernization of existing houses, and the improvement of housing and living conditions.

This paper will discuss some of the technical challenges faced by builders and designers in Canada's Arctic and sub-Arctic climates with regards to oil fired heating systems and some of the CMHC sponsored research and demonstration projects currently underway to evaluate alternative solutions.

The Arctic and sub-Arctic regions of Canada generally fall in a region defined by two territories, namely the North West Territories and Yukon Territory. The degree days in this region range from 8,000 DD (Celcius) to 10,000 DD (Celcius) with some regions experiencing 2 1/2% design temperatures in the order of -40C to -50C.

In recent years both CMHC's social housing delivery agents in the Arctic have implemented a multi-year plan to improve the quality of their housing stock adopting many of the design criteria defined by Canada's R-2000 program. The results have been significant improvements in the quality of the housing units. The design space heating load for these units typically range between 30,000 and 40,000 BTUH.

This trend towards energy efficient and R-2000 type housing has now resulted in oil fired systems that are generally oversized relative to the design space heating load of the house. Several problems have manifested themselves as a result of this oversizing. These range from lower efficiency and higher energy cost to accelerated deterioration of chimneys.

Over the past 2 years CMHC has attempted to address this problem by investigating and demonstrating alternative heating systems that offer improvements over conventional oil fired heating systems.

Three approaches to heating with oil are currently being evaluated.

The first is the System 2000, manufactured by Energy Kinetics. This system is installed and is serving an R-2000 duplex in Dawson City, Yukon. Detailed monitoring is being conducted to assess the performance of this system in an Arctic environment.

The second system being considered is the Worcester HEATSLAVE manufactured in England. The system is currently being evaluated by CSA for approval in Canada. Detailed monitoring in the Arctic is planned following CSA approval.

A third system being evaluated is the hot water tank as a combined boiler and domestic hot water tank. Several of these systems are currently installed in the Yellowknife, NWT. An evaluation of the state and condition of these systems is currently underway.

Each of the systems will be assessed for technical merit, cost effectiveness, and appropriateness for the intended market.

A COMBUSTION SYSTEM FOR BURNING FUEL OIL WITH HIGH EFFICIENCY AND LOW POLLUTANT EMISSION

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ABSTRACT

A combustion system with combustion gas recirculation for soot-free combustion of hydrocarbon fuels with air is described. The system itself contains - besides means for air supply and distribution and for fuel supply, atomization and distribution - a mixing tube for the introduction of recirculating combustion gas into the air-fuel-mixture stream promoting fuel evaporation and a flame tube for defining a properly sized reactor space. Certain interrelationships between certain measures of the combustor elements are to be obeyed to achieve proper and stable operation. Special importance for proper functioning was predicted by theory for the maximum droplet size in the fuel spray.

Pollutant emission values of this combustion system are low, even at near stoichiometric operation. Due to its soot-free flame no fouling of the air metering port occurs, so that good burner performance is kept over operation periods of more than two years without maintenance. Special investigations are under way to study the conditions of NO_x - formation in the system, aiming at further reduction of this kind of emission.

Also the mechanism of combustion noise generation has been studied with the result of minor design modifications that are able to decrease noise levels up to 10 dBA.

This combustion system is sold in the market in Germany since 10 years with increasing success. More than 200,000 burners are now in operation in home heating installations.

*Prof. Dr.-Ing., VDI

Paper No. 89-6

EMISSIONS CHARACTERISTICS OF MODERN OIL HEAT EQUIPMENT-COMBUSTION TEST FACILITY RESULTS

Yusuf Celebi, Ruth Coughlan, Tom Butcher,
C.R. Krishna, and Roger McDonald
Brookhaven National Laboratory

ABSTRACT

Over the past 10 years there have been some very interesting developments in oil heating. This includes higher static pressure fans, air atomization, low heat loss combustion chambers, condensing furnaces, and lower firing rate nozzles. The current data base on the emissions characteristics of oil-fired residential heating equipment is based primarily on data taken in the 1970's. The objective of the work described in this paper is to evaluate the effects of recent trends on emissions.

Detailed emissions measurements have been made on a number of commercial systems selected to represent the recent development trends. Some additional data was taken with equipment which could be considered to be in a prototype stage including a prevaporizing burner and a retention head burner refit with an air atomizer. Measurements include NO_x, smoke numbers, CO, gas phase hydrocarbons, and particulate mass emission rates. The systems were evaluated both in steady state and cyclic operation.

Emissions of smoke, CO, and hydrocarbons were found to be significantly greater under cyclic operation for all burners tested. Generally particulate emissions were about 4 times greater in cyclic operation. Air atomized burners could be operated at much lower excess air levels than pressure atomized burners without producing significant levels of smoke. As burners get better, either through air atomization or prevaporization, there is a general trend towards producing CO at lower smoke levels as excess air is decreased. The criteria of adjusting burners for trace smoke may need to be abandoned in favor of adjusting for specific excess air levels.

ENERGY CONSERVATION PROGRAMS FOR OIL HEAT

Raymond J. Albrecht-Senior Project Manager
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ABSTRACT

This presentation describes the research activities of the Building Systems Group within the New York State Energy Research and Development Authority. The Building Systems Group performs research projects in the subject areas of HVAC and lighting. Such projects typically develop or demonstrate advanced technologies that increase energy efficiency in buildings. Many of the projects are conducted in cooperation with participating manufacturers located in New York State. This presentation will also describe program opportunities for research funding during the coming year as would be applicable to the oil heating industry.

This presentation will also include a brief description of a recent project that developed a prototype blue flame oil burner. The oil burner incorporates internal combustion gas recirculation to vaporize and mix oil with combustion air prior to burning. The burner flame is similar to that observed with pre-mix power gas burners that use screen type flameholders. The described oil burner design would enable low firing rates but would also be applicable to conventional residential and commercial size ranges. The burner has been tested recently at Brookhaven National Laboratory and shows promising performance characteristics relating to emission of soot and carbon monoxide combustion.

Paper No. 89-8

ALLIANCE TO SAVE ENERGY'S OILHEAT RETROFIT PROGRAM

Mark Hopkins
Alliance to Save Energy

ABSTRACT

The Alliance to Save Energy conducts a research and technology transfer program to explore ways to improve the efficiency of existing oilheat systems. The program involves the U.S. Department of Energy's Existing Building Efficiency Research Program, state weatherization offices, burner manufacturers and distributors, community action agencies, and local heating contractors and/or fuel oil dealers.

During the past five years, the Alliance has assisted seventeen state conservation programs install flame retention burners on oilheat systems in low-income households; over 18,000 burners were installed and 1,500 energy auditors and heating contractors trained. The program demonstrated that state weatherization offices could improve program performance by installing high-efficiency burners, along with traditional building envelope measures. Based on our efforts, most states with a large percentage of oilheat systems now incorporate retrofits in their low-income conservation programs.

Last year the Alliance undertook a field study of the long-term performance of systems retrofitted with flame retention burners. The purpose of the study was to determine if the performance of the burners continues or degrades over time. Sixty-one homes in Wisconsin and Maine were visited and the systems tested. We found:

- Although retrofits initially improved steady-state efficiency by 20 percent, about one-third of the initial gain in steady-state efficiency was lost over five years.
- Most systems were not maintained to recommended practices and many service technicians do not use testing instruments when tuning a system.

Based on our results we make the following recommendations:

- Training by the oilheat industry should emphasize the importance of using instruments to tune heating systems.
- A portion of low-income fuel assistance payments should pay for cleaning and tuning retrofitted oilheat systems.

Paper No. 89-9

POWER SIDEWALL VENTING OF OIL FURNACES

Jack R. Cunningham
Thermo Products, Inc.

ABSTRACT

The presentation will provide a brief background of the Thermo Products company, its products, and specifically define its oil furnace line and unique features. The demands which prompted the decision to develop a power venting system will be reviewed, specifically: electric heat costs; improved efficiency; new construction/space issues; and conventional chimney condensate problems. The prototype build-up and testing program will be described. The decision to obtain Underwriters Laboratories certification on a complete package versus inducer assembly only will be discussed. The components making up the system will be reviewed. The involvements with Underwriters Laboratories concerning: the lack of a specific test standard and how standards to be tested against were determined; UL listing for Thermo Products only versus use with any other furnace, why, temperature limitations; and the test program will be presented. The product's introduction: when, approximate volume currently installed; and price as a comparison to conventional chimney venting will be included. A review of experiences, feed-back from field installations, including: acceptance by local authorities; odor issues; melted couplings; need for outside combustion air due to tight homes and how to accomplish this; equalization of in-house and outside air pressures, even with outside combustion air; and outside wall discoloration will be addressed. Part of Thermo Products installation videotape will be included in the presentation.

Paper No. 89-10

CANADIAN RESEARCH ON OIL-FIRED COMBUSTION APPLIANCES

A.C.S. HAYDEN, S.W. LEE, F. PRETO AND N. LAIRD
Canadian Combustion Research Laboratory

ABSTRACT

This paper will describe research and development presently being conducted on oil-fired space and water heating appliances at the Canadian Combustion Research Laboratory (CCRL). Activities to be discussed are as follows:

1. Combined space and water heating system performance.
2. Performance of oil-fired condensing systems, including condensate characterization.
3. The effects of variations in conventional fuel quality on combustion performance.
4. Should aromatics also be considered as an essential property?
5. Effects of flue pipe characteristics on performance, including vented and unvented double wall flue pipe characteristics.
6. Advanced design oil heating equipment, for high efficiency, without condensing.
7. Venting requirements of new and existing combustion systems.
8. Potential future R&D requirements.

Paper No. 89-11

THE HOUSE AS A SYSTEM

Harry R. West-Senior Consultant-Mechanical Systems
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ABSTRACT

Energy conservation in the residential heating market is one of the most appropriate methods to reduce the use of fossil fuels and extend the life of the known North American fossil fuel reserves. The other benefit, is the reduction of combustion by-products that are produced and then injected into the atmosphere. The drive for energy conservation has not been without it's problems relative to indoor air quality. Indoor air quality problems can best be addressed by designing the vent systems to specific heating loads and the conditions under which they are expected to perform. Understanding "The House As A System™," where the building envelope, the mechanical systems and the occupants of the home, are treated as parts of a comprehensive system, will provide a logical approach to improving indoor air quality.

™The House As A System is the registered trademark of Synergon, Inc.

Poster Exhibit Paper
Paper No. 89-A1

FLUE GAS DESULFURIZATION IN OIL FIRED HEATING PLANTS

Zoltan Farago
DFVLR, German Aerospace Research Establishment

ABSTRACT

INTRODUCTION

Almost one third of the atmospheric sulfur emissions originate from combustion processes. In the northern hemisphere, approximately 50% of sulfur emissions come from human sources. In the winter months, this value increases to nearly 100%. In West Germany the amount of sulfur dioxide emissions originating from heating oil combustion is 5%. In built up areas, this increases in the winter months to almost 100%. The results of sulfur dioxide emissions are acid rain, damage to forests and acidification of land and water.

Practical desulfurization processes were previously only available for power stations and industry. The utilization of the exhaust gas residual heat in an oil fired heating plant has been connected with a high corrosion rate due to the sulfur and sulfureous acidity of the condensed water. The German Aerospace Research Establishment (DFVLR) has now developed an effective process for burners in the 10 kW to 3000 kW range. This technique enables 60-99% of the sulfur to be removed from the exhaust gas and simultaneously reduces fuel consumption by 10-35%.

THE DFVLR PROCESS

During combustion of fuel oil, approximately 3% of fuel sulfur is oxidized to sulfur trioxide (SO_3) and about 97% appears as sulfur dioxide (SO_2). While using the upper calorific value of the fuel, condensate appears in the residual heat exchanger. This condensate absorbs SO_3 from the exhaust, becomes acidic, and can no longer absorb SO_2 (strong acids displace weaker ones).

In our process, the condensate is passed through a neutralization chamber using a circulation pump and is then returned to the residual heat exchanger. The neutralization substance, MgO, raises the pH-value to about 7.5. The weak basic condensate absorbs 60 to 99% of the SO_2 from the exhaust and is then immediately oxidized by contact with air from the exhaust and is then immediately oxidized by contact with air to nonpoisonous magnesium sulfate (Epson salt, often present in hard water). The overflow of condensate is diluted in a buffer tank with domestic waste water and directed into the sewage system. The neutralization substance works as a sacrificial anode (no corrosion of the condensing heat exchanger) and as a bonding agent for metallic oxides. Thus, no metals are released in the waste water.

A supply of air to the circulating condensate causes an immediate change of the sulfite ions to sulfate. Thus, no sulfur dioxide can evaporate from the condensate. Measurements of the flue gas and condensate show approximately equal desulfurization rates.

This process extracts the latent heat of vaporization from the water vapor in the exhaust gases. This results in a fuel savings of about 10% for a modern heating system and about 35% savings in an older one. The DFVLR process is patented in several countries, including in the USA.

APPLICATIONS

Some applications of the DFVLR desulfurization process are: under-floor heating, low temperature radiator heating, domestic water heating, swimming pool heating, heat pumps, etc.

Technical questions can be addressed locally to Z. Farago or to Prof. Dr. W. Buschulte, DFVLR, D-7101 Hardthausen a.K., W. Germany. Asking for a U.S. license contact Mr. U. Henckel, DFVLR Center Cologne-Porz, D-5000 Koeln-Porz 90, W. Germany. Any kind of applications questions can be discussed with the German DFVLR Licensee, Mr. G. Schmidt, Ing-Buero Schmidt, Altenkesseler Str. 17, D-6600 Saarbruecken, W. Germany.

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