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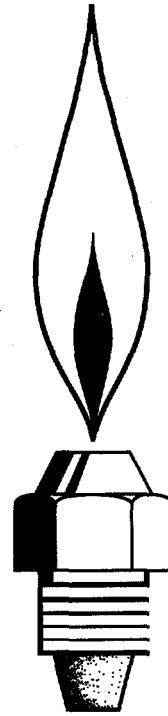
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## PROCEEDINGS OF THE 1996 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP

Held at  
BROOKHAVEN NATIONAL LABORATORY  
UPTON, NEW YORK 11973  
March 28 - 29, 1996

July 1996



Roger J. McDonald

MASTER

Sponsored by the  
OFFICE OF BUILDING TECHNOLOGIES,  
STATE AND COMMUNITY PROGRAMS  
UNITED STATES DEPARTMENT OF ENERGY

In cooperation with  
PETROLEUM MARKETERS ASSOCIATION OF AMERICA



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**ENERGY EFFICIENCY AND CONSERVATION DIVISION  
DEPARTMENT OF APPLIED SCIENCE  
BROOKHAVEN NATIONAL LABORATORY  
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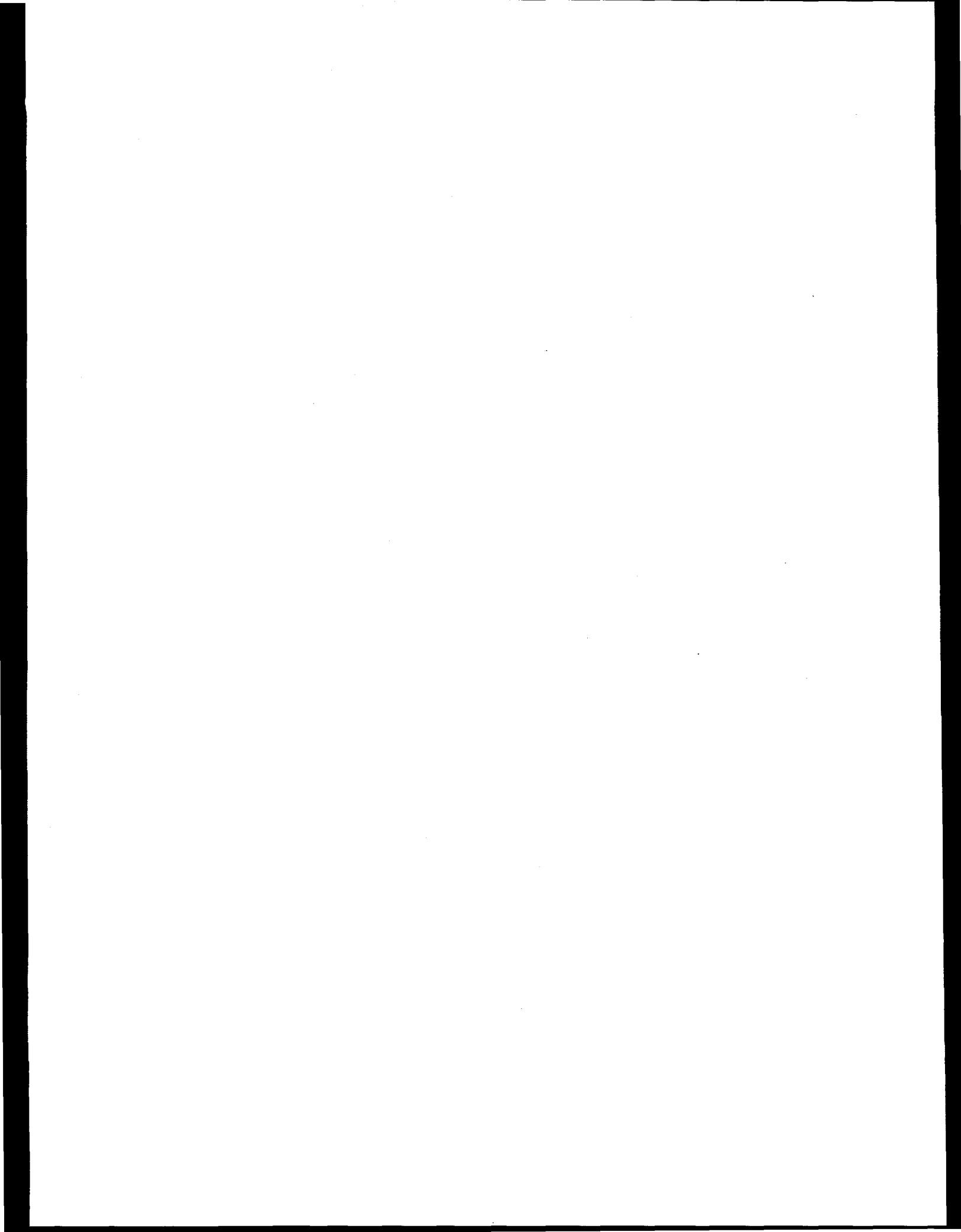
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## ACKNOWLEDGMENTS

The 1996 Oil-Heat Technology Conference and Workshop was attended by 177 participants and was a large success thanks to the hard work of many people. The editor of this report would like to thank the authors for their efforts and splendid cooperation in submitting papers promptly and in the word processing format requested. This made the our conference report staff very happy.

There are several individuals which contribute a great deal to the oil-heat research program at BNL. The BNL authors wish to jointly acknowledge the significant and important contributions of our laboratory staff: Yusuf Celebi (Staff Engineer and Laboratory Manager) and Gang Wei (Associate Staff Engineer). There would be no results to report on without their professional efforts and dedication to the research effort.

The high quality of the 1996 Oil-Heat Conference and Workshop advanced preparations, the smooth operation during the meeting, and the efficient post meeting effort in preparing the proceedings for publication is all due to the professional efforts of the BNL Conference-Coordinators: Arlene Waltz, and Francine Donnelly. The Editor greatly acknowledges their hard work and effort to make this conference more successful each year.



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## EXECUTIVE SUMMARY

### 1.0 Introduction

This report documents the Proceedings of the 1996 Oil Heat Technology Conference and Workshop, held on March 28-29 at Brookhaven National Laboratory (BNL), and sponsored by the U.S. Department of Energy - Office of Building Technologies (DOE-OBT), in cooperation with the Petroleum Marketers Association of America.

This Conference, which was the tenth held since 1984, is a key technology transfer activity supported by the ongoing Combustion Equipment Technology (Oil-Heat R&D) program at BNL, and is aimed at providing a forum for the exchange of information among international researchers, engineers, manufacturers, and marketers of oil-fired space-conditioning equipment. The objectives of the Conference were to:

- o Identify and evaluate the state-of-the-art and recommend new initiatives for higher efficiency, a cleaner environment, and to satisfy consumer needs cost-effectively, reliably, and safely;
- o Foster cooperation among federal and industrial representatives with the common goal of sustained national economic growth and energy security via energy conservation.

The 1996 Oil Technology Conference comprised: (a) four plenary sessions devoted to presentations and summations by public and private sector industry representatives from the United States, and Canada, and (b) four workshops which focused on mainstream issues in oil-heating technology.

### 2.0 Plenary Sessions

The highlights of the plenary session are derived from 14 formal presentations addressing:

- DOE/BNL/NORA Research and Development Cooperation;
- Oil Burner Technology Development;
- Oil Heat Fuel Technology - Private Sector R&D; and
- Canadian Oil Heat R&D Status and BNL Venting, Controls Project Updates

#### 2.1 DOE/BNL/NORA Research and Development Cooperation

Paper 96-1: DOE/NORA/BNL Oilheat Research Agenda Development

The National Oilheat Research Alliance (NORA) has been formed and is currently working to establish a Congressionally approved oilheat check-off program to provide funding for research, education, training, safety, and marketing to benefit the U.S. oilheat industry. NORA will be presenting this program to the Congress for its consideration and approval in the coming year.

It will follow the same path as the National Propane Gas Association which is currently working on obtaining Congressional approval of a propane check off program that has already attracted over 120 co-sponsors in the House of Representatives.

An effort to define the basis of a joint U.S. Department of Energy (DOE) and Oilheat industry (marketers) program for future oilheat equipment research and development will be conducted during FY 1996. At the request of NORA representatives, BNL will coordinate the development of a research agenda addressing three categories of activities, research appropriate for DOE support only, research appropriate for NORA support only, and research appropriate for co-funding by both organizations. This will also serve to update a prior oil-fueled research plan developed for DOE ten years ago which has been the road map for DOE's very successful Oil Heat R&D program at BNL.

It is recognized that the future organization of DOE may be somewhat different than it is today and that NORA is just now being established. The research plan that results from this task will be designed to be useful both to DOE and NORA to be used independently and jointly depending on the future nature and structure of both organizations.

#### 96-2 : Oilheat Manufacturers Association (OMA) - Update

##### OMA's Perspective on the Challenges Before Us

Our industry must undergo a major paradigm shift if we are to prosper. We must change our "Fix it when it breaks" mind set to "Fix it so it won't break." Our main focus must be to improve Oilheat reliability. We have entered the era of the 100,000 mile tune-up. Meeting this challenge will require the best efforts of everyone in the industry from researchers, scientists, and engineers to manufacturers, dealers, sales people, installers, and service technicians.

Last year was a very exciting year for the Oilheat Industry. National Oilheat Research Alliance (NORA), Petroleum Marketers Association of America's (PMAA) Technician Certification, and the Oilheat Manufacturers Association (OMA) with its Oilheat Advantages Project were all started.

OMA was established in 1995 and recruited 28 founding members for the association and has successfully brought about many accomplishments during the year and is looking forward to the upcoming challenges and projects that are now in progress. By being deeply involved with the process of change, we are able to have a voice in shaping the future. It is much easier and cheaper to act to help direct changes than to react to them once they have been made. We continue to look for more ways that we can help grow the oilheat market share and increase oilheat equipment sales.

### 96-3: PMAA's Silver/Gold National Technician Certification Program - Update

There is no better time than now to be in the oil heating industry. Two Examples:

National Oil Heat Research & Development Alliance (NORA) - An idea that was brought to light by Jack Sullivan of New England Fuel Institute (NEFI), here at Brookhaven National Laboratory (BNL), at the 1995 Oil Heat Technology Conference.

The Oil Heat Technician Certification Program. Don Allen, Chairman, PMAA Heating Fuels Committee, has been a great facilitator in bringing industry groups together to develop a program enabling technicians to succeed in our industry.

In the oil/comfort business today, we can either become a full-service company staffed with the top technicians and also offer quality products and state-of-the-art technology, or we can have our company become the "bottom feeders" - the discounters that have nothing to give customers in added value.

The Oil Heat Technician Certification is valid for five years. Recertification or renewal can be accomplished by completing 40 hours (5 credits) of continuing education programs through the Industry Associations.

The advantages for oil heat dealers, technicians and customers are many. As a company in the comfort business, we must decide if we can afford to stand still or become part of a new revitalized industry moving into the 21st century with programs like NORA and Oil Heat Certification. That is our question, and we must either survive or fail with our answers.

### 2.2 Oil Burner Technology Development

#### 96-4: Market Assessment for the Fan Atomized Burner

Brookhaven National Laboratory has developed a fan atomized oil burner (FAB) for residential applications which has as major distinguishing characteristics (1) the ability to fire at down to 0.25 gph, about half the lower limit of conventional burners, and (2) reduced fouling of heat exchangers due to ability to operate at lower excess air. Additional benefits include higher efficiency, reduced emissions, and lower electricity requirements.

This study examined the market potential for the burner in residential space- and water-heating applications. Data gathering for the study included examination of demographic and shipment data and a telephone survey of oil heat industry participants including burner manufacturers, system manufacturers, oil marketers, association representatives, researchers, and others. The major findings of the study are as follows:

- The FAB's low input capability allows development of oil-fired room heaters and wall furnaces, a new market area for oil heat.

- Among conventional oil-fired products, furnaces will benefit most from the burner's low input capability due to (1) their quick delivery of heat and (2) they are more prevalent in warmer climates and smaller homes.
- The greatest potential for increased product sales or oil sales exists in the use of the burner with new products (i.e., room heaters). Sales of boilers and direct-fired water heaters are not likely to increase with the use of the burner.
- Acceptance of the burner will be dependent on proof of reliability. Proof of *better* reliability than conventional burners would greatly accelerate acceptance.

#### 96-5: Part I - FAB Evaluation & Application Trials - AFUE Measurements

An oil burner/boiler efficiency test stand has been set up in the BNL oil heat laboratory which can measure the Annual Fuel Utilization Efficiency (AFUE) of burner/boiler combinations in accordance with ASHRAE and DOE standards. Measurements include both steady state efficiencies and heat-up and cool-down characteristics so that cycling effects can be included in an estimate of seasonal average performance. In addition to AFUE measurements, the direct conversion of fuel energy content to enthalpy increase in the boiler water is monitored. The system is largely automated, with most control functions under computer control and data taken electronically and permanently recorded on disks for future reference.

To date, a retention-head burner and a fan atomized burner (FAB) have been tested in a steel boiler, the latter operating at two different fuel flow rates. The results are presented in detail in the Technical Presentations section of the paper, and verify that the very tight construction of the FAB's fan results in a significant decrease in off-cycle sensible heat losses.

Tests were also performed on a center-flue water heater fired with a conventional retention-head burner and with an FAB. The tests conformed to DOE standard procedures for hot water heaters, and the results are discussed in the Technical Presentations section of the paper.

#### 96-5: Part II - Integrated Heating System (IHS) Development

It has long been the consensus here at the Brookhaven National Laboratory (BNL) and of some associates that the demand for the FAB in the market would be very limited without the development of some new smaller appliances that could capitalize on the FAB assets.

Although it was realized that the market for a small warm-air FAB furnace might exceed that for a low-mass FAB boiler, the boiler prototype was chosen. The low-mass boiler provides the key to the problem of designing an Integrated Heating System (IHS).

The low-mass boiler is the core subsystem that allows the IHS to provide multiple space heating options along with domestic hot water and air conditioning options as well. The FAB low-mass boiler IHS can provide these options.

BNL has determined that operating at reduced excess air reduces fouling resulting from sulfuric acid corrosion. The FAB often produces less CO and deposits less soot at lower O<sub>2</sub> settings. Because of this characteristic, there is a strong motive to operate reliably at very low O<sub>2</sub>.

This IHS boiler has low mass, low water content, low jacket loss, counterflow Hx, and zero off-cycle "stack" loss each of which will contribute to high AFUE and to high output/input efficiency. Detailed testing of the IHS boiler's performance will be conducted at BNL this year and will be reported at the 1997 Oil Heat Technology Conference.

#### 96-6: Fan Atomized Burner Design Advances & Commercial Development Progress

As a part of the Oil Heat R&D program, sponsored by the U.S. DOE, Brookhaven National Laboratory has an on-going interest in advanced combustion technologies. This interest is aimed at: improving the initial efficiency of heating equipment, reducing long-term fouling and efficiency degradation, reducing air pollutant emissions, and providing practical low-firing rate technologies which may lead to new, high efficiency oil-fired appliances. The Fan-Atomized Burner (FAB) technology is being developed at BNL as part of this general goal.

The FAB uses a low pressure, air atomizing nozzle in place of the high pressure nozzle used in conventional burners. Because it is air-atomized the burner can operate a low firing rates without the small passages and reliability concerns of low input pressure nozzles. Because it uses a low pressure nozzle the burner can use a fan in place of the small compressor used in other air-atomized burner designs. High initial efficiency of heating equipment is achieved because the burner can operate at very low excess air levels. These low excess air levels also reduce the formation of sulfuric acid in flames. Sulfuric acid is responsible for scaling and fouling of heat exchanger surfaces.

Currently, the FAB concept is being commercialized by Heat Wise, Inc. in a cooperative program involving New York State Energy Research and Development Authority, BNL, and the Department of Energy - Office of Building Energy Research. Under this program, Heat Wise, Inc. is developing a commercial version of the burner, will obtain a certification listing, and begin to market the burner. BNL is providing technical support to Heat Wise, Inc. and continue to advance the development of the burner.

#### 96-7: Field Tests - Low Input, Side-Wall Vented Boiler

The Fan Atomized Burner (FAB) was developed at Brookhaven National Laboratory as part of the Oil Heat Combustion Equipment Technology Program to provide a practical low-firing rate technology leading to new, high efficiency oil-fired appliances. The first field trial of a prototype unit was initiated during the 1994-95 heating season. This paper presents the results of the second year of testing, during the 1995-96 heating season.

The field tests enable the demonstration of the reliability and performance of the FAB under practical, typical operating conditions. Another important objective of the field test was to

demonstrate that the low input is adequate to satisfy the heating and hot water demands of the household. During the first field trial (1994-1995) it was shown that at a maximum input rate of 0.4 gph (55,000 Btu/hr) the burner was able to heat a home with over 2,000 square feet of conditioned living space and provide adequate supply of domestic hot water for a family of six. The test site is located in Long Island, N.Y.

During the second field trial additional data were obtained to compare the efficiency of the FAB, under different modes of operation, with other heating system arrangements using two different type of boilers and commercially available burners. The results are summarized in this paper.

Also discussed in this paper is the bin analysis that provides local, seasonal information on the total load in Btu/hr on the heating system with the outdoor temperature. With this information the electricity used by the FAB and the electric cost for its operation over a heating season can also be calculated and compared with that of a conventional heating system.

## 2.3 Oil Heat Fuel Technology - Private Sector R&D

### 96-8: Laboratory Tests of Sludge-Control Additives

Laboratory "jar" tests compared eleven different fuel oil and diesel fuel sludge-control additives. Factors studied included 1) ability to disperse and prevent buildup of sludge deposits on surfaces, 2) ability to protect steel from corrosion, 3) ability to inhibit growth and proliferation of bacteria, and 4) ability to disperse water. Results varied greatly, and it was found that many commercial products do not do what they claim. It is concluded that fuel retailers should not believe manufacturers' claims for their additive products, but rather should test such products themselves to be sure that the benefits of treatment are real. A simplified form of the procedure used here is proposed as one way for dealers to do such testing.

### 96-9: Premium Performance Heating Oil - Part 2 Field Trial Results

Limited field trial results of a heating oil additive package developed to minimize unscheduled maintenance indicate that it achieves its goal of keeping heating oil systems cleaner. The multifunctional additive package was developed to provide improved fuel oxidation stability, improved corrosion protection, and dispersency. This combination of performance benefits was chosen because we believed it would retard the formation of sludge, as well as allow sludge already present to be carried through the system without fouling the fuel system components (dispersency should keep sludge particles small so they pass through the filtering system). Since many unscheduled maintenance calls are linked to fouling of the fuel filtering system, the overall goal of this technology is to reduce these maintenance calls.

Photographic evidence shows that the additive package not only reduces the amount of sludge formed, but even removes existing sludge from filters and pump strainers. This "clean-up" performance is provided trouble free: there was no reported indication that nozzle/burner

performance was impaired by dispersing sludge from filters and pump strainers. Qualitative assessments from specific accounts that used the premium heating oil also show marked reductions in unscheduled maintenance.

#### 96-10: Field Performance of a Premium Heating Oil

As part of ongoing research to provide quality improvements to heating oil, Mobil Oil together with Santa Fuel, Inc. conducted a field trial to investigate the performance of a new premium heating oil. This premium heating oil contains an additive system designed to minimize sludge related problems in the fuel delivery system of residential home heating systems. The additive used was similar to others reported at this and earlier BNL conferences, but was further developed to enhance its performance in oil heat systems. The premium heating oil was bulk additized and delivered to a subset of the customer base. Fuel related, unscheduled service calls were monitored in this test area, as well as in a similar baseline area that did not receive the premium heating oil.

Overall, the premium fuel provided a 45% reduction in the occurrence of fuel related, unscheduled service calls as compared to the baseline area. Within this population, there was a reduction of 38% in systems with 275 gallons tanks, and 55% in systems that had >275 gallon tanks showing that the additive is effective in the various configurations of residential oil heat systems. In addition, photographic documentation collected at two accounts supported this improvement by clearly showing that the equipment remained cleaner with the premium heating oil than with regular heating oil. Based on these results, a full marketing trial of this new product has been initiated by Mobil and Santa Fuel, Inc. during the 1995-1996 heating season.

#### 2.4 Canadian Oil Heat R&D Status and BNL Venting, Controls Project Updates

##### 96-11: Canadian R&D on Oil-Fired Combustion Systems

This paper describes R&D presently being conducted on oil-fired space and tap water heating systems by the Advanced Combustion Technology Group, CCRL/ERL/CANMET, in Ottawa, Canada.

The presentation focused on R&D activities at CCRL in support of the Canadian Oil Heat Association (COHA) and on the energy policy initiatives of Natural Resources Canada. Progress was reported on activities to develop suitable oil-fired integrated systems to satisfy the low energy demands of new homes. The utilization of fuzzy logic-based control strategies to optimize the efficiency and emissions performance of integrated space/water heating systems including fan coils for a complete range of old and new North American housing was discussed.

Additional activities discussed in the presentation were related to the development of appropriate seasonal efficiency standards for complex integrated space/water heating systems, as

well as an evaluation of alternative sidewall venting technologies and their implications for seasonal energy efficiency.

#### 96-12: Chamberless Residential Warm Air Furnace Design

Chamberless warm air furnaces do not use any type of combustion chamber. The high static retention head burners which are now commonly used in residential heating applications are capable of operating without the support of a conventional combustion chamber. Indeed some are capable of operating without a target wall or other flame support devices and with intermittent ignition. First listed in the mid-1980's, high efficiency residential chamberless furnaces employing these burners have been installed under rental programs and by heating contractors in Canada for 10 years. Due to their simple design they require little set up time, low maintenance and infrequent cleaning. They are popular with installers and homeowners alike.

Cost reduction is an incentive for developing chamberless appliances. The elimination of the combustion chamber, target walls and even thermal shielding removes many components. This can dramatically reduce heat exchanger manufacturing cost. Further cost reduction comes from the absence of supporting hardware and the reduction in the number of heat exchanger openings. Simpler heat exchangers enable the manufacturer to tailor the exchanger more closely to the furnace application and to reduce tooling and fabrication cost. Since the mounting and operational security of the combustion chamber is no longer relevant, often the same heat exchanger can be used in a variety of orientations with little or no adaptation. These also translate into cost and weight saving. This paper is an introduction to the concept of designing residential warm air furnaces without combustion chambers.

#### 96-13: Development of the Lined Masonry Chimney Oil Appliance Venting Tables

This paper describes the development of the lined masonry chimney venting tables from the output of the Oil Heat Vent Analysis Program (OHVAP). These new tables are different than the prior format, offered in the Proceedings of the 1995 Oil Heat Technology Conference and Workshop, Paper No. 95-04. Issues expressed by representatives of the oil heat industry at last year's conference during the Venting Technology Workshop resulted in subsequent discussions. A full day meeting was held, co-sponsored by BNL and the Oilheat Manufacturers Association (OMA), to address revision of the format of the venting tables prior to submission to the National Fire Protection Association (NFPA) Standard 31 Technical Committee. The resulting tables and text were submitted to NFPA during the first week of October, 1995. Since then minor changes were made reflecting the addition of data obtained by including intermediate firing rates (0.4, 0.65, and 0.85 gph) not included in the original tables which were developed in increments of 0.25 gph. The new tables address the specific question, "If remediation is required, what is the recommendation for the sizing of a metal liner and the appropriate firing rate range to be used with that liner?" In the Appendix of this paper, the reader will find the full text and tables of the proposed revision to the new NFPA Standard 31, Appendix F.

## 96-14: Development of a Two-Color FQI

The Flame Quality Indicator (FQI) concept was developed at Brookhaven National Laboratory as a simple device which could be used to monitor oil burner flames and indicate when a problem was starting to occur. Fault situations which could be identified by the FQI include: fouled nozzle, increased or decreased excess air, blocked air inlet or flue, and use of low quality oil. The basic concept of the FQI is quite simple. A conventional cadmium sulfide photocell is used to measure the amount of light emitted from an oil burner flame when the appliance is fully warmed-up. The measured amount of light is compared to a set point, established during burner tune-up. If the two intensities differ by more than a set range, a "service required" signal is produced.

The amount of light which is emitted from an oil burner flame depends upon the amount of "soot" or carbon in the flame, the size and shape of the flame, and the flame temperature. The quality of a flame is practically judged by the amount of soot which it is producing and for this reason it is necessary to eliminate effects of other parameters. Temperature is expected to be the most important of these. Flame temperature is affected by the type of combustion chamber into which it is fired, firing rate, and also the firing history. When a burner has been off for a long time and it is just fired, the flame temperature is lower than when it is running in steady state. The FQI eliminates effects due to the chamber environment by establishing a set point for each specific appliance. The transient temperature effects are accounted for by examining the flame brightness only at a single time during the firing cycle.

BNL is currently involved with the development of a two-color approach to the monitoring of flame quality. The basic concept involved is the measurement of both flame temperature and total amount of light emitted to allow a more direct estimate to be made of the amount of soot being produced and so the flame quality. The objective is to develop a more sensitive measurement which may be more universally applicable. This paper provides a summary of BNL's approach and results to date in this project.

### 3.0 Workshop Sessions

The conference attendees divided into four workshop groups addressing specific subjects:

- A. Oilheat Research Agenda Forum
- B. FAB Commercialization, Applications, and Product Development
- C. Fuel Quality, Storage & Maintenance - Industry Discussion
- D. Application of Oil Heat Venting Tables, NFPA 31 Standard

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

## GROUP A: OILHEAT RESEARCH AGENDA FORUM

The Oilheat Research Agenda Forum was attended by fourteen industry representatives including marketers, equipment manufacturers, and researchers. Part of the time was spent discussing general research objectives and their relative priority ranking based on the opinions of those present following an exchange of ideas and viewpoints. The chairman also entertained thoughts and suggestions for discussions on specific research topics recommended by the participants at the workshop.

In the area of diagnostic devices, discussions keyed in on the need for these type of tools and that they need to be easy to use, easy to maintain, accurate and useful. The most important oil diagnostic tool, the smoke spot pump sampler, is an example raised by the group that cries out for dramatic modernization. The concept of an automatic smoke spot measuring device with an auto-reading digital output was proposed. Such a device would, at the push of a button, replace the ten strokes currently required for sampling the flue gases and the effort required to remove the filter paper and compare it to the standard smoke spot index card. The device if designed properly might also be useful for transient smoke level determinations leading to the diagnosis of problems related to start-up and shut-down problems like nozzle afterdrip. Tools for chimney diagnostics is another area for consideration. These would help determine the condition and check for proper functioning of the venting system. It was also suggested that another useful tool for the oilheat representative in the field would be an electronic notebook. A device for storing all sorts of useful information from how to tune and adjust heating systems based on the exact, heat exchanger, burner, nozzle, control set-up in front of the technician in the basement, to what the options for domestic water are available, at what trade-offs, for the sales person to use while visiting the designers office while specifying a system for a brand new home yet to be built. It could include diagnostic procedures, sizing information, cost estimating information, pipe and ducting information, etc. The key would be to develop a good friendly interactive user interface that makes it easy to get the information with out a lot of hassle.

System reliability was another topic discussed and brought the group's focus to fuel quality, sludge in fuel systems, and how to deal with the problems associated with sludge. One idea suggested was that a fuel system component or sub-system should be devised to either identify and warn of fuel sludge conditions prior to the sludge causing operational problems, or one that would detect and remove the sludge before the fuel filter, thus preventing it from getting to the burner components and causing problems. It was suggested that the fuel sludge problem be attacked on a very broad basis starting with the fuel as it leaves the refinery and ending at the consumers oil burner. A commitment was made to follow-up in this area by developing a research plan that would in a comprehensive manor address the issues of fuel sludge. This will include many facets like fuel quality issues, fuel handling, fuel contamination, fuel stability, viability of fuel treatment options, storage and transportation concerns, and environmental sensitivities.

Venting combustion products from oil fired equipment was addressed from several viewpoints. Although BNL was recognized for its past significant accomplishments, currently several issues remain with the industry. Resolving these issues related to side wall venting and sealed combustion

systems will be critical to the future viability of the industry in promoting the benefits of oil heat in certain markets, for example conversions of electrically heated homes and multi-family housing units that could greatly benefit from the lower comparative costs associated with oil heat. The effort to continue modernizing codes and standards along with the education of code compliance officials is an ongoing need. The integrity and safety of modern oil heating systems which do not rely on traditional chimney technology for venting, needs to be documented. The group also tackled the issues related to back-drafting and odors as related topics in this area. The group proposed research be included to investigate ways to minimize oil heating related odors including the fuel itself as well as the combustion products. Concepts for fuel odor neutralization or masking would help improve the overall image of oilheat.

Discussions on the topic of safety and issues related to the levels of carbon monoxide formation associated with oilheat systems evolved from the discussion of combustion products and odors. The group felt that, with the growing popularity of carbon monoxide detectors in the residential marketplace, the oilheat industry needs to be prepared for the eventual customer inquiry triggered by the CO alarm sounding, no matter what the cause. The oil industry needs to know what levels of CO can be generated by oil-fired heating equipment under various different operating conditions. They also need information on what other CO sources can trigger the alarms and how to deal with the customer when the oil unit is clearly found not to be the source. This indicates a research need in generating, obtaining, and/or compiling documentable data concerning oilheat appliances and all other sources of CO in the home environment. Then development of programs for educating oilheat industry representatives concerning CO should follow.

Developing a clearing-house for information related to oilheat is very important to the future of the industry. In this electronic age the group embraced the concept of using the Internet as one form of providing information but certainly not the only one. The oilheat industry has a good message to convey to its current and potential future customers. The key is making the message clear, easy to understand, and to support statements with documentable facts. This is where an information clearing-house is important. The clearing-house can provide a lucid single point source of reliable information which is pre-formatted for use, information that is accurate, and information that is documented beyond challenge. Even with the electronic highway there will be a steady need for printed information on the part of the industry and its customers for some number of years into the future.

Another NORA function that was suggested was that there is a continuing need to have a truly independent source address and access new technology developments. It was this independent third party analysis of efficiency benefits provided by BNL back in the late nineteen seventies and early eighties that was the foundation of the success of the flame retention head burner in the marketplace. If in the future this type of effort continues it will provide the basis for future substantiation of energy efficiency or environmental enhancement claims related to oilheat innovations.

New equipment innovations were also discussed at the workshop. These included a project to access the opportunities for developing multi-function appliances which might combine cooling

technology or electric power generation with an oilheat source. The group felt it was premature to discuss the specific merits of one concept or another as most were unfamiliar with the technologies involved. There was a strong level of interest in seeing such a program element included in the long term plans for NORA, although its immediate priority might be comparatively low. There was even greater interest in seeing integrated heating systems (based on currently available or emerging technology concepts) included. This includes the whole idea of integrated appliances, starting with a clean sheet of paper and looking at oilheat not as individual components but as a system supplying energy services in terms of space heating, hot water, air filtration and conditioning, the whole heating, ventilation, air-conditioning system, interfaced with the house system, wrapped up in one design.

In looking at prioritization of the various research areas reviewed by the group the categories fell into traditional lines. The group tended to give the highest priority to items that appear to have the potential for the most immediate benefit for the industry. These included fuel related research to resolve issues associated with sludge, better diagnostic tools, information related projects, and systems integration of available technologies. The non-traditional areas with longer range opportunities like oil-fired cooling technology and co-generation fell into lower priority classifications. The plan for developing the research agenda for NORA/DOE is to hold several more workshops of a similar nature at major industry meetings throughout the country during 1996. This workshop session was an important start to the process and will be used as a foundation to build upon during the planning process.

#### GROUP B. FAB COMMERCIALIZATION, APPLICATIONS, AND PRODUCT DEVELOPMENT

This workshop dealt primarily with the Fan Atomized Burner (FAB), the new burner that is under development at BNL. The group started talking about some of the applications that had been discussed in the past and probably were the initial applications that were thought of at the time the burner was selected for development. The group was very diverse and included: boiler manufacturers, furnace manufacturers, wholesalers, government people, engineers, installers and retailers.

With respect to the applications that had been talked about in the past, there was a discussion about the FAB being applied to a retrofit of electric heated homes and there was some interest in that. There was also an interest in small room heaters to compete with the smaller gas units that are on the market. There was some reservation voiced by a number of people as to the noise level of these units; how would it compare to a gas unit, would it be like an air conditioner or a unit in a hotel, and this certainly would have to be addressed if that market were to be pursued.

Instantaneous hot water heaters was another suggestion, similar to the European units that are out there. Units with small heat input rates with no storage capacity. This type of point-of-use water heater technology is an option that could be pursued with a small clean burning oil unit like the FAB.

Small furnaces for the mobile home market is another possibility for the burner. A high efficiency, clean burning, compact, small foot-print warm air oil furnace could readily be marketed to the mobile home industry.

All of these different markets are niche markets, something outside the mainstream of the oil-heat industry's core product lines. The workshop group did discuss the possibility of a large volume market that would take advantage of some of the strong points of the burner. Specifically, instead of limiting the burner to a maximum of 0.6 gallon per hour, make a burner that could be widely marketed in larger firing capacities. The rationale for this would be what makes this burner special, it has large orifices and can fire down to those smaller sizes. As heard during one of the technical presentations earlier today, they were able to eliminate 45% of the oil-line problems, but that still leaves about 55% of them out there. Perhaps a burner with a large orifice that is capable of passing contaminants that normally now would plug a nozzle, could help bring down that 55%. So, there seemed to be a lot of interest, especially on the part of the installers, in a burner that they could install in a typical 1.0 gallon per hour job that would be less susceptible to nozzle contamination. Could the FAB technology be translated into that larger gallonage? That is for the researchers to determine. But, if it can, it would appear to open a much wider market than what currently exists.

The topic of discussion naturally went around to through-wall venting and positive-pressure firing because this burner can fire positive pressure. There were some questions as to whether that type of market should be pursued because some of the organizations that write standards, specifically those who have not accepted this type of venting, are lagging behind in the development of the technology. This is obviously a handicap in the early stages until it is accepted by the national standard making organizations.

#### GROUP C. FUEL QUALITY, STORAGE, & MAINTENANCE - INDUSTRY DISCUSSION

Approximately 25 participants attended this workshop. The discussion focused on topics that have concerned the industry in the past, specifically, fuel sulfur content, sludge, potential uses of fuel oil additives, red dye required on tax-exempt distillate oil, and cold flow characteristics. In terms of sulfur, there is generally a more aggressive push by the industry for low sulfur content as a standard in heating fuel.

With the widespread use of fuel oil additives many oil distributors still question their effectiveness on reducing service requirements. Initial discussions and questions centered on the Mobil/Santa Fuel field test results on an additive's performance (refer to papers 96-9 and 96-10 given during this morning's session). The only way to measure performance is to obtain a baseline of service information from your customer database and actually "count" the changes with your use of the additive. Not only can additives be evaluated and monitored in this way, but generally this is a good approach to look at the performance and reliability of all heating equipment parts. Overall, there was much interest in this cooperative field study conducted by these two companies.

Could BNL help to develop a standard for a high-performance fuel? Would it be advantageous for the industry to have a fuel that already contained additives upstream in the distribution system or leave additive treatment to individual oil dealers? For those who currently use additives, some participants were interested in seeing BNL test different brands, evaluate and report the results by product name as in "Consumer Reports." It seems, however, that the more appropriate role of BNL would be to develop standards and test methods, acceptance criteria, evaluate current fuel quality standards by performing tests with combustion appliances, and possibly to organize the procedures for field studies. For example, BNL could be involved in cooperative efforts with the industry to provide the methods for evaluating additive performance. The industry could provide the customer base (population pool) for actual testing and the personnel for collecting data related to specific additives of interest. BNL could subsequently do the statistical analyses of the data. BNL could also help to evaluate nonchemical solutions to today's current fuel-related problems.

There was also some interest in testing the effects of red dye used in heating fuel on combustion and equipment performance. It appears that neither EPA nor the dye manufacturer have done any testing on its effects with oil heating appliances in terms of emissions and equipment performance. It was noted that BNL will be conducting some limited tests in cooperation with a burner manufacturer to look at coking of the burner head with diesel fuel, with and without the red dye. Some participants also suggested that we look at filter plugging tendencies and emissions.

The overall plan to improve fuel quality and heating system performance reliability by the oil heat industry is evolutionary. In light of the potential opportunities offered by NORA, the industry needs to begin to identify the specific problems, measure its impacts, and decide what is needed in terms of research goals.

#### GROUP D. APPLICATION OF OIL HEAT VENTING TABLES NFPA 31 STANDARD

The group first addressed the utility of the Oil Heat Venting Tables developed at BNL for NFPA 31, Appendix F. The consensus was that, in general, the tables offer good information but are inadequate in their present form. In terms of interpolation, since the tables only go to 25 feet, individual runs are necessary. The tables should be expanded to include 35 and 50 foot chimneys. The limitation to 8 by 8 clay flues should be opened up with a concentration on the higher firing rates and larger flue tile sizes. Common venting should be pursued through the use of the existing tables. BNL should develop the necessary procedures for securing useful information regarding the successful operation of common vented appliances from the existing tables. The Gas tables, while complicated, provide useful information about multiple elbows, effects of chimney offsets, altitude, etc. The BNL tables may be too simplified to resolve field encountered problems. Metal chimneys and power venting remain open issues and should be pursued.

The group next addressed the issue of field experience regarding masonry chimney performance and documentation of same. They suggested BNL pursue the use of the BNL chimney survey form. The product warranty form may offer opportunities to gather information about equipment

operation. BNL should use the OHVAP program to develop benchmark flue gas temperatures (appliance and vent exit) for equipment and chimneys. The field data has been sparse with little information regarding the appliance operation. So far, the chimney sweep industry has supported the reporting while little has been obtained from the oil heat industry.

The group then discussed the ability to resolve field problems within chimneys by installing metal liner systems. Various viewpoints and opinions were expressed. "There appears to be no concrete evidence of any real problems associated with liners: no hard evidence, too much hear say,." "Metal liners appear to work and last." "Not enough information is documented on the application of metal liners in oil-fired appliances."

The last question addressed by the group was, what remaining venting issues of concern to the oil heat industry have not been covered by BNL's work? The ASHRAE large chimney recommendations ASHRAE Handbook (Chapter 31) were not examined except in checking chimney draft. BNL should examine the application of larger flue tile sizes, such as 8 by 12 and 12 by 12. The issues associated with flue gas dilution and draft control are not clearly resolved where the relative value of whole house energy conservation and drying of the chimney are concerned. There are opportunities for integration of the chimneys (venting system) and the equipment. The lack of "integrated" heating system designs needs a start through BNL guidance. Integrated packages can pose some real field problems in terms of parts availability. Standardization within the industry may become essential. The application of the existing tables are centered around the decision to re-line. The question remains to be answered; "Is the chimney sound or not?" The chimney used in OHVAP is idealized in terms of leakage. There has been an increase in the application of oil fired forced air systems. This is probably driven by the related need for a ducting system when air-conditioning is also desired. The "new" proposed oil fired technology (chillers, heat pumps, etc) will need to be addressed in terms of venting requirements. BNL should generate "rules of thumb", diagnostics, and a slide-rule related to venting needs. The issues of clay liner characterization, alternative liner materials, exterior chimney water proofing, and improved diagnostic methods were all generally accepted. The table revisions are limited to the NFPA revision cycle, but BNL reporting of new information will continue as a Technology Transfer Task.

#### 4.0 DOE/BNL Perspective

The 1996 Oil Heat Technology Conference and Workshop 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. In the future, NORA will provide an opportunity to greatly enhance and expand the scope of these activities for the mutual benefit of the oil-heat consumer and industry.

From a technical perspective, BNL has taken fundamental approaches to identifying and characterizing combustion phenomena that influence the 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 that may transcend technical considerations. The Oil Heat Technology Conference and Workshop, along with the use of a technical advisory group comprised of representatives from various facets of the oil heat industry, helps provide targeted planning of the research and development effort to enhance market acceptance while satisfying energy conservation and environmental program objectives.

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, testing, and evaluation of novel components, subsystems, and systems. The arrangements for access encourage technical interaction with BNL scientists and engineers and 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 facility's 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 1996 Oil Heat Technology Conference and Workshop was held on March 28-29 at Brookhaven National Laboratory (BNL) under sponsorship by the U.S. Department of Energy - Office of Building Technologies (DOE-OBT). The meeting was held in cooperation with the Petroleum Marketers Association of America (PMAA). One hundred and seventy-seven (177) people were registered and participated at the conference.

The 1996 Oil Heat Technology Conference, which has been the tenth held since 1984, is a key technology transfer activity supported by the ongoing Combustion Equipment Technology program at BNL. The reason for the conference is to provide a forum for the exchange of information and perspectives among international researchers, engineers, manufacturers and marketers of oil-fired space-conditioning equipment. They have provided a channel by which information and ideas are exchanged to examine present technologies, as well as helping to develop the future course for oil heating advancement. They have also 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 specific objectives of the Conference are to:

- o Identify and evaluate the current state-of-the-art and recommend new initiatives for higher efficiency, a cleaner environment, and to satisfy consumer needs cost-effectively, reliably, and safely;
- o Foster cooperative interactions among federal and industrial representatives for the common goal of sustained economic growth and energy security via energy conservation.

### Special Addresses

Introductory remarks were provided by James Davenport, Chairman, Department of Applied Science, BNL, who welcomed the assembly on behalf of Brookhaven National Laboratory. Dr. Davenport emphasized BNL's commitment of advancing oil heat technology and to effect technology transfer to the private sector. Dr. Davenport concluded his address by congratulating the organizers and welcomed the participants of the Conference. Lou Divone, Deputy Assistant Secretary of Energy, Office of Building Technologies, State and Community Programs, then presented welcoming remarks on the behalf of the U.S. Department of Energy. John Huber, Government Affairs Counsel, Petroleum Marketers Association of America (PMAA), followed by welcoming the participants on behalf of PMAA and then introduced the Master of Ceremonies, Don Allen, current Chairman of the PMAA Heating Fuels Committee. Mr. Allen presented the Keynote Address on behalf of Mr. John Santa, NORA Steering Committee Chairman and President of Santa Fuels, Inc., who suddenly fell ill two days before the conference. The text of the DOE Opening Remarks, PMAA Opening Remarks and the Keynote Address regarding the important interactions between the U.S. Department of Energy, the Oil Heat Industry, and BNL follows.



## Lou Divone's Opening Remarks

Acting Deputy Assistant Secretary  
Office of Building Technologies  
Office of Conservation & Renewable Energy  
U.S. Department of Energy

The Department is very pleased to have sponsored ten Oil Heat Conferences and we will be delighted to support the eleventh. Normally, I have a somewhat "stock" speech regarding energy, DOE's programs, the importance of energy and environment to the Nation, etc. with a slight tailoring to each particular audience but, today I am not going to do that. I am going to go directly to two key issues that affect this group. The main one being the budget and how it is going to affect this program, and some of you may already be aware of that.

Anyone that works for a large organization has a Job Description and it defines the dozen or so things that they are supposed to be responsible for and then the last item is other duties as assigned. Mine continues on and it has things like kamikaze pilot and standing target, these sorts of things. Today, I will be the standing target because the budget situation is not good at all. I find that kind of strange but I wanted to go into it with you. This has been one of the most successful programs that we have had and we are very proud of it. We are very proud of the researchers here at BNL and we are very proud of the state and industry groups that have worked cooperatively together to get some of the successes that we have had in the past. Jim Davenport mentioned the Flame Retention Head Burner; that was commercially available back in the 1970's, but it was not going anywhere. BNL's involvement, DOE's support and, in spite of the fact that oil prices have increased by 380% during the 1970's and early 1980's, not much was happening and it was because of that support the performance validation that BNL did, the information and training programs, that a lot of the market barriers that may have prevented the technology from achieving the significant penetration were overcome. And, as Jim Davenport has mentioned, the technology has probably saved more oil and affected the related environmental and balance of trade and other issues associated with it, probably more than any other DOE supportive innovation, saving of over six billion gallons and saving consumers over \$6 billion dollars and saving the affects over the environment. Unfortunately, a lot of people do not believe that. Certainly, our Congress does not believe it; they don't think DOE ever does anything. In fact, we have even had hearings about a week or two ago going through the claims for various R&D programs and their past successes. That particular item was one of the ones that they picked on. Why wouldn't it have happened anyway? Why was there a need for Federal Taxpayer's money to go into it? Couldn't it have been done by the Private Sector by themselves? There are a lot of people who don't believe in the public-private partnerships that we are trying to work on, and they certainly don't believe some of these claims. Now, you can argue sure that some of this would have happened anyway - depends on which industry, depends on what's going on in the marketplace, depends on a lot of things, but there are many times, I think that this is a classic one, where a small amount of federal investment tied in with the industry, tied in with information and training programs, can make a major difference, and we think it has. The Flame Quality Indictor (FQI) is another one. Winner of an R&D 100 Award, Popular Science Award, and a bunch of others, and all of the other work going on can really make a difference. In the DOE

program we believe help the fuel oil industry remain competitive. And before the energy price shocks of the 1970's, there were about 15 million homes heated with oil. It declined in the 1970's and early 1980's and then stabilized in the mid-1980's at about 12 million and it remains at that level. And we think in part that it is due to improved technologies hitting the marketplace and improved information that allows the oil industry to remain competitive. I am not going into all the R&D that currently is going on; you will be hearing about that during today and tomorrow. I think that this kind of a meeting is important. It is a chance for you to see what's going in those areas, but much more important it is a chance for us and other industry people to find out what really is going on in the marketplace; what the real needs are, and what the real issues are. And it also gives you a chance to network and talk among yourselves in terms of what the policy issues are and the direction you feel your own company and the industry, as a whole, should be going in. Then we get down to the nitty-gritty, and that is the Budget. As you know, the pressure to reduce the budget deficit is intense. Many worthwhile programs are being cut or eliminated. While the Department has requested just under \$1 million for this program in FY 1996, we are still living under a Continuing Resolution. We anticipate that they are going to extend that, so we don't have to get furloughed and we think we will probably end up with one for most of the year. It is a very awkward situation to be in and makes planning wonderfully simple - you just do it day to day, but I think we will probably get through 1996 OK.

The 1997 Budget is where the issue is. The 1997 Budget was released last week and there are no funds for the Oil Heat Program in 1997. There are a number of you that have been around in the past and saw this happen - both in the mid-1980's and in the early 1990's - and it is happening again. There is an old saying about sausages taste great but you don't want to watch them being made. Certainly, this fits into the same kind of situation. The Administration has, in fact, an extremely strong support for Energy Efficiency & Renewable Energy Programs. In fact, we are requesting considerable increase in funds in the face of a Congress which cut our budget request in 1996 and the Administration is still going back and asking for increases because they feel that energy is fundamental to our environment, is fundamental to our economy and it is trying to push energy efficiency and renewables, which are a key part of that equation. But, at the same time, the pressure to end up with a balanced budget in the not too distant future is enormous and the prioritization process has been severe. And, it is in the course of that, that the increases are primarily for major deployment programs that can have major impacts in a nationwide sense. Many R&D Programs, longer term implications, or that tackle smaller, overall national energy goals ends up suffering as the budget gets tighter and tighter and that is what has happened here. Regardless of that, and regardless of how it all turns out, I want to thank the researchers at BNL for doing some incredible work with even in the day of good times with only relatively modest amounts of money, and to thank the industry for their contributions and their steadfastness in the course of the roller coaster that we go through all the time, and the PMAA for their recognition that an energy efficiency environment and profitability in their own companies all tie together, and that private and public partnerships can work.

## Introductory Remarks

John Huber  
General Counsel  
Petroleum Marketers Association of America

I have been here several years now, in the 1990's, probably starting in 1991 I have come up to every conference. Each conference shows some new exhibits, new technology and new advances. On behalf of PMAA, I want to first welcome everybody here to the conference; we are a sponsor of this conference and very proud of it. We, at PMAA, believe that fuel oil will continue to have a critical role in the nation's energy. As Mr. Divone indicated, we have held pretty tight at 12 million homes over the past several years. We think we can maintain that market share for a long time too, and plan to. I think that's what everybody here is designed to do and that is what we in the industry have been working very aggressively to at least maintain that market share. We would, in fact, like to see it grow a little bit, quite a bit if possible.

There are a couple of developments that have happened within PMAA that we are particularly proud of over the last one-two years. Don Allen, who has been working within PMAA, and many other members who have been working on committees to endorse and really work hard to take the advances and technology that is coming out of BNL and put it on the street, which is where the DOE wants it and where we want it too. Don Allen came up with the idea a couple of years ago, in conjunction with the Oil Heat Manual that was being prepared by BNL to do a certification as a way to force demand for knowledge and that program has been very successful and, as Roger Mc Donald (BNL) has indicated, twelve of our states have indorsed that program and I continue to hear from our other state associations throughout the country indicating an interest in it; whether it be in Minnesota, Wisconsin, Ohio or Indiana, people wanting to have a program where they can start bringing new technology out into the field and make it work. So, I think that Don Allen and the work of PMAA has really served as an impetus to those types of developments.

The other thing that I think has been an interesting development, which Don will give a great deal of interest in and a long spiel about is NORA, the National Oilheat Research Alliance. One of the concerns of the industry has been how DOE would treat this program in the long-term future; as the budgets got increasingly tight that they might jettison this program. So, the industry came together essentially at this conference last year and said we really have to take an aggressive look and see if we can start planning for our long-term future. Could we develop a funding mechanism that would allow to plan for our future to do the necessary R&D both long-term and in applied research. All of that recognizes how important BNL has been to the industry. And, the industry has been working very aggressively to examine whether that is possible and doable. We think that it is possible and doable, however it is going to take us several years to get there, which is unfortunate and I think that our real concern we have in this industry now is that if DOE lets this program disappear in the near-term, a lot of the research that has been going on, a lot of the institutional memory that can serve the industry in the long-term will get lost in the shuffle and that is a strong concern to PMAA at this point. We think that the industry is trying to develop a way to pick it up and if it lapses in October of 1996, which would be what no funding would do, there will not be that pickup. Now, certainly

we at PMAA, including all the people in this room, all our state associations and all of our members, will have to work very aggressively to insure that handoff is allowed to occur. This is as Mr. Divone indicated a troubling budget year. We have not had the opportunity to finalize the budget for this program. It has been tied to a lot of other issues, We have a Congress which has not been able to finish up the Appropriations Bill in this area; the Department of the Interior and the related agencies which this fits with that. We do hope that it gets resolved in the near-term, next week, or maybe next month so that we can at least finish this year up with some standing. However, there is going to be some strong pressure for FY 1997 to get that bill resolved pretty quickly, so we will need an aggressive push by the end of spring, through our Congressional contacts, to insure that we do get funding for FY 1997. I think that this has been one of the strongest programs for DOE. As Mr. Divone indicated, it has been good for energy security, has been good for the environment and has been good for the consumer. When you get those three things going together, it is a win-win-win for everybody. It has easily paid for itself in savings to the consumer. The concern that we have with national security in oil imports has certainly benefitted from the program that has sharply reduced the amount of oil that we need to burn in this country and in the northeast, which is one of the main importing regions. And, clearly when we discuss this with Congressmen they really understand how vital the program is. I think that is going to be the challenge for us over the next year, the next several months, and in the years to the future, until we can really provide for ourselves to make sure that they understand how vital this is to us.

Roger Mc Donald indicated that Don Allen is going to do an extended presentation on NORA, so he requested that I be fairly short and I will do that. But, I do think that on behalf of PMAA we are very proud of the work that Roger and his technicians and scientists and engineers have done here. They have done a lot of advances that have benefitted the industry. They really have been very helpful to us; laid the groundwork for the industry to keep moving forward into the future and we very much appreciate that.

Keynote Address  
John Santa, President  
Santa Fuels  
NORA Steering Committee Chairman

(Presented by Don Allen for John Santa)

A year ago, almost to the day, Jack Sullivan got up on the stage here and called this industry out. He said that if we don't get our act together and figure out a way to fund adequately Oil Heat Promotion, Oil Heat Education, Oil Heat Research and development, we were just kidding ourselves; thus, was born NORA. NORA is an alliance composed of you and everyone in this industry and oil heat enthusiasts who are determined to change the paradigm in which our industry has operated for the last 30 years. The time is now. I want to show you a video that hopefully will ask and answer the questions that, perhaps, you have. At the conclusion of the video, we will sum things up.

*[Selected Text from NORA Video Presentation]*

NORA, the National Oil Heat Research & Alliance. An idea whose time has come. Let me take you on an adventure into the art of the possible, toward a fairer, more equitable method of funding oil heat promotion, education, research and development. I am Bob Hedden. I represent the Oil Heat Manufacturers Association on the NORA Steering Committee. I am sure you join me on detesting the idea that ours is a mature or declining industry. NORA is a check-off program. It can take us back to a vital, growing industry. It promises to expand our market share, enhance research, and improve public perception of oil heat. Ask yourself, "How much longer can we rely on the voluntary generosity of the increasing number of contributing marketers today to defend our industry?" NORA will require that everyone reaping the benefits of healthy oil heat industry invest in building its future.

Check-off programs were first established for the agriculture industry in the 1930's. They have grown and prospered ever since. Today, there are over 150 local and national programs working to improve their industry. No doubt you are familiar with many of them, like this one. *"There are places in every town where you can find a great meal. Tonight at Joe's Grill, for instance, you can find Lemon Herbed Steak, while over at Caparelli's they are serving Savory Steak and Pasta. On the menu at Chez Ralph's there is Honey Dijon Stir Beef Fry and the Chef's Special at Arlene's Place is a Beefy Chili Mac. To enjoy fine dining like this, all you need is 30 minutes or less and you have a table at one of the best Steak Houses in town. Beef - it's what's for dinner!"* Beef - it's what's for dinner, has had a dramatic effect on the public's perception of beef. From a time-consuming weekend luxury meal to a speedy convenient to prepare weekday dish. Purchase intent is up to 12% and people with a positive attitude toward beef are up 50%.

*"Life moves pretty fast. Sometimes you have to tell yourself stop, look around, this is the good stuff. This is the fabric of our lives. This is cotton."* Cotton, the fabric of our lives, has increased awareness by 22% and sales by 14%. Since establishing the program in 1975, cotton's market share has grown from 34% to 53%.

These check-off's are voluntary programs, started and run by the industries that fund them. Regulations are self-imposed. Industry members administer the programs, government involvement is restricted to the passing legislation that enables the check-off to be established and laying out the guidelines under which it operates. The program's creation and design are voluntary but once the laws are passed, participation is mandatory. For instance, the Beef Board collects a mandatory fee of \$1 per every cow processed.

The Oil Heat industry has been shrinking for the last twenty years, despite the fact that Oil Heat is the best space and water heating option. The decline in oil heat and corresponding increase in electric and gas heat is due to the tremendous promotional spending by the utilities. The Gas Research Institute's (GRI) and Electric Power Research Institute's (EPRI) mandatory programs similar to check-off programs raise over \$750 million annually to support their industries' activities. Congress is considering creating a propane check-off. That will leave oil heat as the only space and water heating option without mandatory industry promotional funding.

The NORA bill will authorize and facilitate a program to enhance research and development, education and communications in the oil heat industry for the benefit of the industry, its consumer and the general public. Oil heat is an important commodity, relied upon by some 12 million American families as an efficient, economic energy source for commercial, residential space and water heating. Oil heat equipment's incredible efficiency reduces fuel consumption making oil heat very economical. The production, distribution and marketing of heating oil and equipment plays a significant role in the U.S. economy. However, only limited federal resources have been made available for oil heat research and education efforts to the detriment of both the industry and its 12 million customers. The cooperative development, self-financing and implementation of a coordinated national oil heat industry program for R&D, safety, consumer education, energy conservation, environmental protection and industry training is necessary. It is important for the welfare of the oil heat industry, the general economy of the U.S. and for the millions of Americans who rely on oil heat for commercial, residential space and water heating.

NORA started as the Oil Heat Promotion Steering Committee. From the outset, this volunteer group has sought to be inclusionary, open to any and all compassionate oil heat advocates. Over 30 industry leaders serve on the committee. These enthusiasts represent wholesalers, dealers, oil heat associations, and equipment manufacturers. They come from all over oil heat country. At the last count, 21 states were represented.

The Steering Committee's purpose is to get the law and the referenda needed to create NORA passed. At this point, the committee will disband. The law will create the alliance and specify how members will be selected. The proposed law calls for qualified industry organization to select the members of the alliance. The alliance will consist of 61 members. Each of the states with heating oil sales will have one representative. Ten oil heat marketers will be appointed as Members-at-Large. Twenty-one members will represent the wholesale distributors of dyed distillate. Six public members will be selected. They can be significant users of oil heat, members of the oil heat research community and representatives of other groups knowledgeable about oil heat. Alliance members shall receive no compensation for their services or expenses from NORA, except the public members who, upon request, may be reimbursed for their reasonable expenses related the participation in NORA meetings. It is anticipated that the alliance will set up an Executive Committee of 21 members to oversee day-to-day operations. Alliance members shall serve 3-year terms and may not serve more than two consecutive full-terms.

An oil heat check-off is an old idea. It has been rattling around the industry for years. Now it appears to be an idea whose time has finally come. NORA started with an informal conversation between Jack Sullivan, the CEO of the New England Fuel Institute (NEFI) and me in March of 1995. Jack then made the bold proposal that launched NORA at the BNL Oil Heat Technology Conference on March 22, 1995. The first Steering Committee was at the NEFI Convention in June. We have met at least once a month ever since. In July, we hired Patton & Boggs, the same firm that is working on the propane check-off to help us. In November 1995, we approved the draft legislation and a potential budget. Since then, we have been working to spread the vision of what NORA can be, gaining industry support, raising money to pay for shepherding the bill into law and we have started the legislative process.

We must mount a major legislative campaign to draft and pass a bill by both Houses of Congress and the President. Without government approval, NORA could not be mandatory and attempting to start it could be in violation of anti-trust laws. We need the government to get it started but that is where their involvement will end. NORA will be totally funded and run by members of the oil heat industry. Once the bill is passed into law, two industry referenda must be held. Two-thirds of all wholesale distributors of dyed distillate, weighted by volume and two-thirds of oil heat retail marketers, weighted by volume, must approve the plan in order for the alliance to be created.

We need you to help us share the vision and spread the word to other retail marketers and wholesalers. We will also call on you to reach out to your Congressional Representatives. The more Congressional Co-sponsors we are able to sign on the bill, the better its chance of passing. With everyone working together and putting all of our effort into this important project, together we can ensure a bright future for the oil heat industry!

*[End Selected Text from NORA Video Presentation]*

Since Bob Hedden came down to Virginia in late January to produce that video, and by the way he also wrote the copy, two notable things have happened. Number one, the PMAA which, although it is becoming certainly an oil heat trade association, still represents by and large a lot of motor fuel jobbers who sell a lot of things except heating oil, that organization approved totally, unanimously of this bill. The second thing that has happened since we have produced this video in January is that the propane check-off program is moving forward with great anticipation of success. The lobbying firm of Patton & Boggs expects the propane check-off bill to become law this year. What this means is the time for NORA is now. There is absolutely no excuse for this industry not to succeed in this effort, unless you and I don't roll up our selves and help. At present, we have raised \$175,000, thereabouts, from states as far away as Washington, to North Carolina, to Maine. We are going to need additional funds, additional talent, and additional support from everyone in this industry to have NORA become a reality. So, the point of this presentation today and I am sure that John Santa would have said it more eloquently, is for each of you in this room to please become involved. If you are a manufacturer, or you represent a manufacturer of oil heat equipment, you need to become an advocate of NORA and go back to your Board of Directors and write a check. If you are a supplier, a wholesaler, a seller of heating oil to people like myself, you need to go back to your company and get them involved and write a check. And, if you are a dealer you probably are because you are the enthusiast of oil heat, the people who come here to BNL. So, on behalf of John Santa and the NORA Committee, we appreciate what has happened and appreciate the roll BNL has taken in this effort because the idea began right here almost a year ago when Jack Sullivan got up and made his remarks.

Introductory Remarks - Day Two  
Don Allen  
PMAA Heating Fuels Committee Chairman  
President, E. T. Lawson & Son, Inc.

As I was going over what I was going to say, in the week's past and also this morning, I kept coming up with the same theme, and I was reluctant to present the theme, and as I reviewed the printed collections of what was presented here in year's past, I still came up with the same theme. So, I feel like I am in front of friends and I feel that I can present the theme. Basically, the theme is that, as an oil marketer, it appeared to me in looking back over past actions in my company that we did not have a clue as to what was happening in the oil heat industry. I can say this in front of you all.

As I looked at what was happening here at BNL and what we were doing as a company, I became more and more convinced that we did not really know in the past what we were doing. In the 1970's, for those of you who don't go that far back, we were faced with two crises in the mid-East and a resultant quintupling in oil heat prices. We, as a company, like many oil heat distributors in the nation reacted to these events by becoming obsessed with operational efficiency. What that meant is that we started removing customer services that we had built up over decades. However, here at BNL, people had a greater vision. They realized that what was needed was an inexpensive retrofit device to reduce fuel consumption. Thus was born the Flame Retention Head Burner and savvy marketers throughout our nation installed millions of these units and saved our industry. We had another chance in the 1980's to get it right and we did not do it. As you recall, gas was de-controlled beginning 1980 and it was phased in over five years. We, as a marketer in Virginia, decided the appropriate strategy was to diversify. So, we got into everything but oil heat. However, other savvy oil heat marketers in this nation decided to use the technology that had been developed here at BNL, with modern - yes they were modern - fuel efficient oil heat systems. These systems were so efficient that, at the time, we had 10-12-14% AFUE advantages over the other fossil fuel appliance. And savvy marketers in the mid-Atlantic and Northeast installed millions of these units and saved our industry. So, I am going to try to change and learn. Here we are in the 1990's and yesterday we heard about NORA, a BNL idea, the National Certification for Oil Heat Technicians, a BNL idea, the Fan Atomized Burner, a BNL idea, and today we are going to hear about fuel quality. Bob Hedden appropriately laid out the vision for us in that we need to create a new paradigm for the oil heat service rather than, "Be right over there." when it breaks. We need to create a system that does not break and BNL, through their advanced technology and R&D, is leading the way. So, what I want to say to Roger McDonald here at BNL is that on behalf of the industry as Chairman of the Heating Fuels Committee we want to thank you and your staff for keeping the light of oil heat burning bright and, perhaps, all around it from the start. And, it is our hope that through NORA that we can adequately fund the visions that you all have here, because I personally believe that with those visions adequately funded the future of oil heat is bright.

## Technical Presentations

Fourteen formal presentations were made during the two-day program, all related to oil-heat technology and equipment, covering a range of research, developmental, and demonstration activities being conducted within the United States and Canada, including these topics:

- DOE/NORA/BNL Oilheat Research Agenda Development
- Oilheat Manufacturers Association (OMA) - Update
- PMAA's Silver/Gold National Technician Certification Program - Update
- Market Assessment for the Fan Atomized Burner
- Part I - FAB Evaluation & Application Trials - AFUE Measurements  
Part II - Integrated Heting System (IHS) Development
- Fan Atomized Burner Design Advances & Commercial Development Progress
- Field Tests - Low Input, Side-Wall Vented Boiler
- Laboratory Tests of Sludge-Control Additives
- Premium Performance Heating Oil - Part 2 Field Trial Results
- Field Performance of a Premium Heating Oil
- Canadian R&D on Oil-Fired Combustion Systems
- Chamberless Residential Warm Air Furnace Design
- Development of the Lined Masonry Chimney Oil Appliance Venting Tables
- Development of a Two-Color FQI

## Workshop Sessions

The object of the workshops was to allow an open forum for the researchers, equipment manufacturers, and marketers, and other members of the oil-heat industry to discuss relevant issues in the oil-heat industry that relate to ongoing research or might impact future research directions. Attendees were provided with a list of discussion topics prior to the workshop sessions (see Section III).

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

- A. Oilheat Research Agenda Forum
- B. FAB Commercialization, Applications, and Product Development
- C. Fuel Quality, Storage & Maintenance - Industry Discussion
- D. Application of Oil Heat Venting Tables NFPA 31 Standard

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

## Combustion Equipment Technology Laboratory

Conference participants were welcome to visit the BNL combustion research facilities and witness equipment demonstrations of some of the advanced oil-fired heating systems under development at BNL (see Figure 1). The equipment demonstrated included the BNL FAN-Atomized Low-Firing-Rate, Low-Emission Oil Burner, the BNL Integrated Heating System (IHS) Mini-Boiler, the BNL Flame Quality Indicator, demonstrations by two different manufacturers that have designed Flame Quality Indicators under non-exclusive patent licenses, and side by side boilers installed for long term comparison tests of mechanisms to reduce fouling in heat exchangers. BNL also provided numerous visual displays based on prior and ongoing research related to Oil Heat R&D.

## Closing Session

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

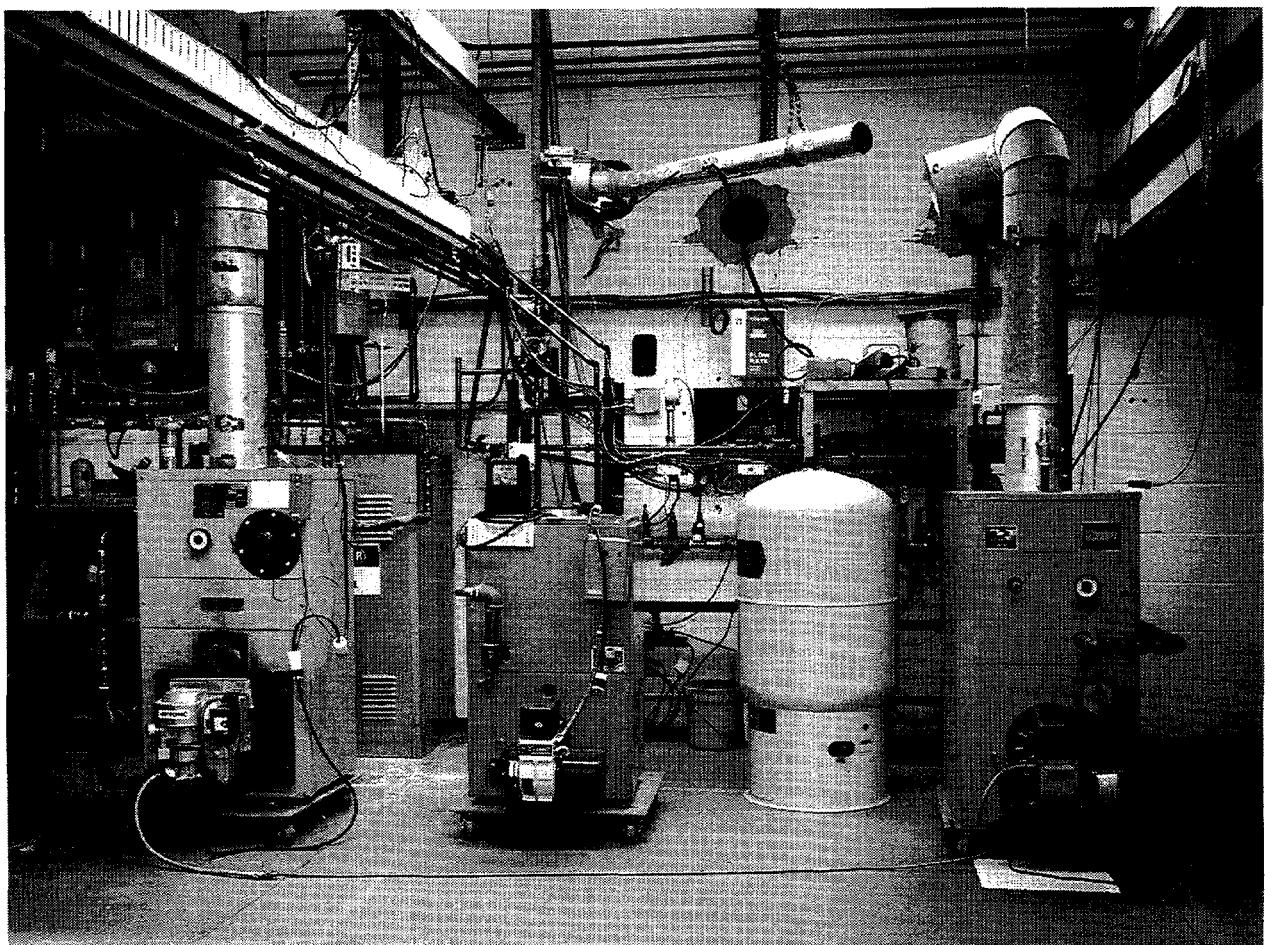


Figure 1. Heating Equipment Being Tested at the CETL.



## **II. TECHNICAL PRESENTATIONS**



**DOE/NORA/BNL OILHEAT  
RESEARCH AGENDA DEVELOPMENT**

Roger J. McDonald  
Senior Program Manager  
Brookhaven National Laboratory  
Department of Applied Science  
Building 526  
Upton, New York 11973-5000

and

John Batey  
BNL Consultant  
Energy Research Center, Inc.  
35 Fawn Rd.  
Easton, CT 06612



**DOE/NORA/BNL  
RESEARCH AGENDA DEVELOPMENT**

**Roger J. McDonald  
Brookhaven National Laboratory  
Department of Applied Science**

**&**

**John E. Batey  
Energy Research Center, Inc  
Easton, CT 06612**

## **I. Introduction/Background**

The National Oilheat Research Alliance (NORA) has been formed and is currently working to establish a Congressionally approved oilheat check-off program to provide funding for research, education, training, safety, and marketing to benefit the U.S. oilheat industry. NORA will be presenting this program to the Congress for its consideration and approval in the coming year. It will follow the same path as the National Propane Gas Association which is currently working on obtaining Congressional approval of a propane check off program that has already attracted over 120 cosponsors in the House of representatives.

An effort to define the basis of a joint U.S. Department of Energy (DOE) and Oilheat industry (marketers) program for future oilheat equipment research and development will be conducted during FY-1996. At the request of NORA representatives BNL will coordinate the development of a research agenda addressing three categories of activities, research appropriate for DOE support only, research appropriate for NORA support only, and research appropriate for co-funding by both organizations. This will also serve to update a prior oil-fueled research plan developed for DOE ten years ago which has been the road map for DOE's very successful Oil Heat R&D program at BNL.

The objective of the oil heat equipment research program is to develop the technical basis for new equipment and operating strategies based on improved understanding of oil-burning fundamentals. The program will continue to provide the oil-fueled equipment industry with the basis for developing a new, high tech generation of equipment and the oil distributors and equipment installers and consumers with improved knowledge of how best to install and operate such equipment.

Every effort will be placed on seeking the broadest national representation of the oilheat industry in the development of the research agenda. BNL will work to obtain extensive input from the private sector through a series of workshops and formal and informal surveys. Workshops will be coordinated to take advantage of those major industry associations sponsoring trade shows and conferences during 1996. These include the 1996 BNL Technology Conference in March, the Atlantic Regional Energy Expo 96 in April, and the 1996 NAOHSM Trade Show in May. Regional

workshops will also be held as needed in those parts of the country more distant from the Northeast and Mid-Atlantic locations where the major trade shows are usually held. All sectors of the industry will be included representing manufacturers, marketers, and service technicians. The effort will involve liaison with all key industry associations including PMAA, NEFI, NAOHSM, OMA, and of course NORA. BNL will of course involve the members of the existing BNL Oil Heat R&D Technical Advisory Group in seeking additional input in the process.

It is recognized that the future organization of DOE may be somewhat different than it is today and that NORA is just now being established. The research plan that results from this task will be designed to be useful both to DOE and NORA to be used independently and jointly depending on the future nature and structure of both organizations.

## **II. Project Plan**

Specific work sub-tasks for developing this multi-year plan include the following:

### *Task 1. Needs Assessment*

Review the current state of technology and obtain recommendations from oil heat equipment manufacturers and fuel marketers about priorities for oil heat research and new equipment. This activity includes:

- a. meetings with key oil heat associations including PMAA, oil heat manufacturers association and other groups;
- b. direct mailing of questionnaires to oil heat companies and associations; and
- c. meetings at various oil heat conferences

### *Task 2. Develop Preliminary R&D Plan*

The preliminary plan will be based on continuing research programs at Brookhaven and equipment manufacturers, and the results of Task 1, develop a list of potential oil research areas. Consult with industry groups concerning expanded research areas to be included based on future funding from the NORA. Research areas may include: combustion and burner development, heat exchanger advances, control systems and advanced diagnostic tools, venting system advances and recommendations, improved efficiency domestic hot water systems, integrated heating, water heating, and space cooling appliances, oil-fueled cogeneration and heat pumps, and education and technology transfer activities.

### *Task 3. Perform Preliminary Cost-Benefit Analyses*

Perform cost-benefit analyses that include efficiency improvement, potential impact on national fuel use, probability of commercialization, and cost to develop and implement. Develop preliminary list of prioritized research areas.

#### *Task 4. Oilheat Industry Review of Preliminary Research Plan*

Distribute the prioritized preliminary plan for review by a wide range of oil heat companies and associations that include equipment manufacturers, fuel oil marketers, service associations, and regional, state, and national associations. Collect and review comments and suggested priorities and develop a final research plan.

#### *Task 5. Produce Final Report*

The final report will summarize the multi-year plan, activities to be completed with U.S. DOE assistance, research to be completed with industry funding, joint projects and a plan for completing the work and coordinating efforts with NORA. These efforts may include demonstration projects that can accelerate the market acceptance of new oil heat technologies.

### **III. DOE/NORA/BNL Example Projects -- New Technology Developments**

#### *Oilheat 2010 Home*

A home, perhaps several, designed as a visitors center to demonstrate environmentally clean energy efficient oilheat technology options as they exist today, in the near term as they are emerging into the marketplace, and as they will be in the future. The home would serve the industry in three ways: as a consumer information center, a public relations center for dealing with the news media, and a test bed for demonstration of new technologies in oilheat as they are developed.

#### *Remote Command Diagnostic/Service Adjustment Oil Heat Appliances*

Furnaces, boilers, and water heater systems designed with on board diagnostic capabilities and feedback controls for adjusting the appliance from remote service center sites. These **smart** systems would use sensors to detect service-related problems, communicate data and information to the remote service center, and upon command from the service hub, adjust themselves to correct the problem; thus eliminating the need to send technicians out into the field when a small remote adjustment would suffice. The **system** would incorporate a built-in microprocessor for detection, communication, and correction activation mechanisms based on variable speed motors and actuators.

#### *Green Oil Appliances*

New concepts in oil burner and heat exchanger system designs hold the promise of ultra-low environmental emissions, maximum efficiency, and minimum size. These units sized to match modern energy efficient house designs can be packaged as wall hung mini-furnaces or boilers reducing the need for special equipment rooms. These units would be designed with sealed combustion systems using outside air for combustion and directly venting the combustion products through the wall.

### *Oilheat Cogeneration*

The advanced development of oil fueled systems that produce heat and electric power. In addition to the engine driven concept as currently marketed by Intelligen Inc. other alternative systems can be envisioned. One unique possibility is the use of Alkali Metal Thermal to Electric Conversion (AMTEC) currently being developed by Ford Scientific Laboratories. AMTEC is a heat driven process that generates electric power.

### *Oil Fueled Thermal Heat Pump*

Thermally driven heat pumps fueled with gaseous fuels are currently emerging in the residential marketplace. These systems provide cooling as well as heating and are based on thermal absorption cycles. They function in a somewhat similar fashion as air-conditioners and electric heat pumps but without needing a motor driven compressor. The units need heat to drive the thermodynamic cycle and this heat could come from an oil burner just as easily as from a gas burner. The only requirement will be that the burner operates very cleanly.

### *Oil-Powered Air-Conditioning*

The same technology used in oil fueled thermal heat pumps can also be applied in developing air-conditioning systems fueled by oil. Another alternative would be engine driven systems given that the emissions of such a small oil fueled engine be keep very clean.

### *Oil Cooking Ranges and Appliances*

Cooking equipment can be developed and marketed based on the use of small compact clean burning oil combustion systems. Prototypes of these mini-burners have all ready been developed and demonstrated for use in military feeding systems.

### *Decorative Oil Lighting and Fireplace Systems*

To date very little research has been directed at developing decorative oil lighting technologies. However one unique prototype system has been designed and demonstrated by firing fuel oil (No.2) that provides a light emission quality equal to or better than a liquid fueled camping lantern which relies on the use of its own special fuel.

## **IV. DOE/NORA/BNL Example Projects -- Enhancement of Current Technology**

### *Customer Services & Support Topics*

- Field Diagnostics Smart Tools and Repair Guidelines
- Smart House Compatible Oilheat Systems
- New Oilheat Construction Field Planning Guidance
- Training Video Series To Compliment New Advanced Oil Heat Manual

### *New Materials and Design Guidance for Oilheat Systems*

- New Refractory Materials and Designs to Resolve Burner/Heat Exchanger Compatibility Issues
- Corrosion Resistant Non-Metallic Vent Systems and Heat Exchangers
- New Design Approaches That Merge Combustion and Heat Exchange Components from the Start of the Design Process
- Develop a Heat Exchanger Design Handbook Combining In One Source Information Needed to Design New Oil Equipment

### *Fuel Related Topics*

- Long Term Effects of Low-Sulfur (0.05%) Heating Fuel on Equipment, Components, and Fuel Quality
  - Benefits and Concerns: Cleaner Heat Exchangers?  
Long Filter Life? Lubricity Issues ? Pump Failures?
- Fuel Degradation Research
  - How fuels degrade over time and how to prevent it.
- Fuel Additives Studies
  - Field studies performed in cooperation with marketers using significantly large numbers of homes to evaluate and identify the effects of various additives and/or products on tank related problems such as sludge, water, biological growth, and corrosion.

## **V. Program Resources and Management**

### *Management Structure*

The current Oilheat R&D Program is one of several key elements of the Office of Equipment and Appliances Program which is in the Office of Building Technologies, State and Community Programs (OBT) in the Department of Energy. A decentralized management plan is used in OBT, whereby the technical resources of the national laboratories are used for program management functions and performing research, while program direction and policy-making is the responsibility of DOE/HQ.

Brookhaven National Laboratory (BNL) has program management responsibilities for the oilheat equipment research. BNL can and has issued Requests for Proposals, evaluated proposals, executed contracts and monitored contractor performance, and otherwise performed the bulk of the interaction with other research institutes, universities, and manufacturers. It has also performed a

variety of in-house research that it is best suited to do, and coordinated technology transfer on work done in-house and by others. Finally, Brookhaven continually interacts with DOE/HQ, serving as the primary information channel for program control as well. This activity is typical for OBT and other DOE research programs.

#### *DOE/BNL Management Approach*

The oilheat equipment technology program outlined here will be planned and managed to complement private sector initiatives. Operationally, this means maximizing industry involvement, with BNL serving in management, testing, and research roles, and universities providing critical knowledge and fundamental research as well. Industry involvement is important for three reasons. First, industry is the appropriate place for hardware-intensive research, and many of the technical questions to be answered about oil-fired equipment involve working with hardware. Second, transfer of technology to industry is far more effective if industry is involved with the work from the beginning, either performing research or observing and providing feedback. In this program, each research area will include work on transferring the technology, starting in the early stages. Finally, there are a great many codes and standards applicable to oil-fired equipment, many of which can even affect applied research decisions. Manufacturers, who are well aware of these issues, help in generating awareness of such institutional and market factors.

BNL involvement currently covers the full range from basic research to doing tests on conceptual hardware. Most important, though, is the lab's role as research managers: making sure the right projects are being done, and by the right people. In this program this role is especially important, as much of the technological advancement will be borrowed from related fields, including both basic research fields and even work done on gas heating equipment. BNL has the unique ability to work across fields in this way, and to make this approach effective.

#### *Resources*

This NORA/DOE/BNL Program will develop a large number of improvements to current capabilities in oil-fired equipment and its use. Some of the planned improvements should be completed within two years; others will take longer. The eventual goal of the program, one or more complete new equipment concepts, should take 5 to 8 years. All work is expected to take place within a funding scenario of approximately \$5 million per year in real dollars. Funding on specific research elements is expected to shift somewhat as various stages on the various elements progress and trade off against one another.

#### **VI. Summary**

The funding from NORA for oil heat R&D is an important opportunity to rapidly advance oil heat technology so that oil marketers and equipment manufacturers can increase their share of the home heating market. R&D funded by the oil industry has not existed for more than 30 years, while the gas and electric industries conducted extensive research programs over the past two decades. Gas powered equipment has advanced significantly over that period and now includes gas-fired heat pumps, pulsed combustors and other important innovations. The oil heat industry now has the

opportunity through NORA to effectively compete with gas and electricity by advancing oil heating technologies.

BNL needs help from oil marketers, equipment manufacturers, and service associations over the next four months so that we can complete an effective multi-year research plan. You can help by reviewing and commenting on proposed research objectives and projects, recommending new projects, returning questionnaires about research priorities, attending planning workshops, and supplying any other input to help guide this planning process. This research plan can lay the foundation for a successful multi-year equipment development program to advance the future of oil heating in the U.S. far into the future.

**Figure 1**

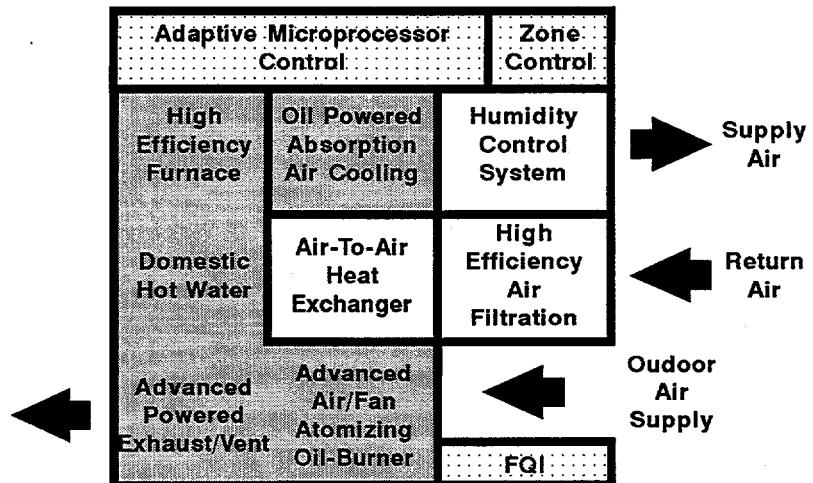
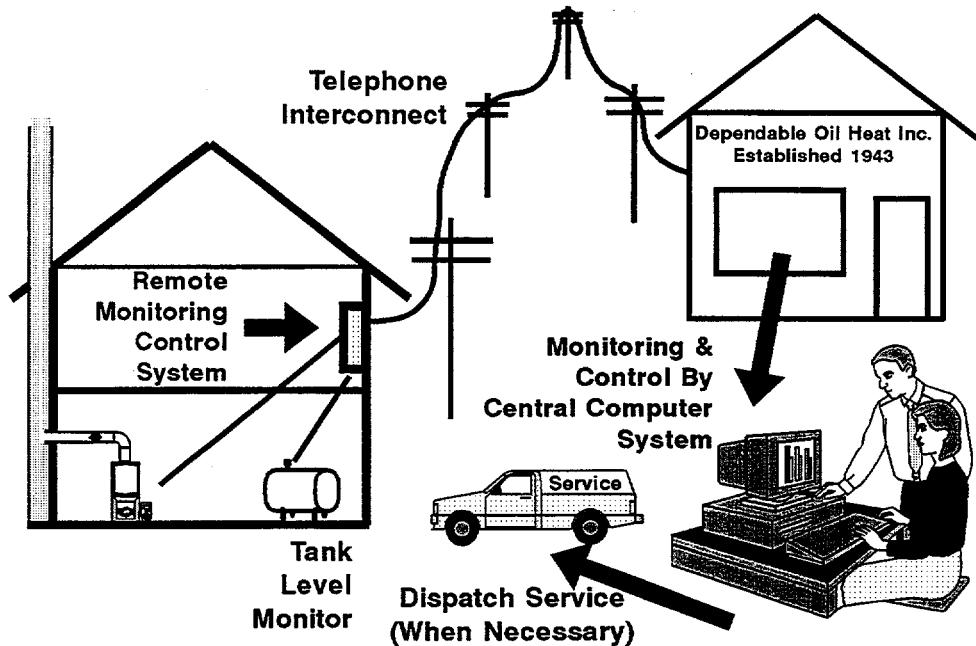


# **Oilheat 2010 Home(s)**

- \* Visitors/ Information Center
- \* Media Reception/News Briefs
- \* Technology Demonstration
- \* Field Trials / Measurements
- \* Today's Oilheat Options
- \* Emerging Technology
- \* Oilheat in the Future 2010

## Figure 2

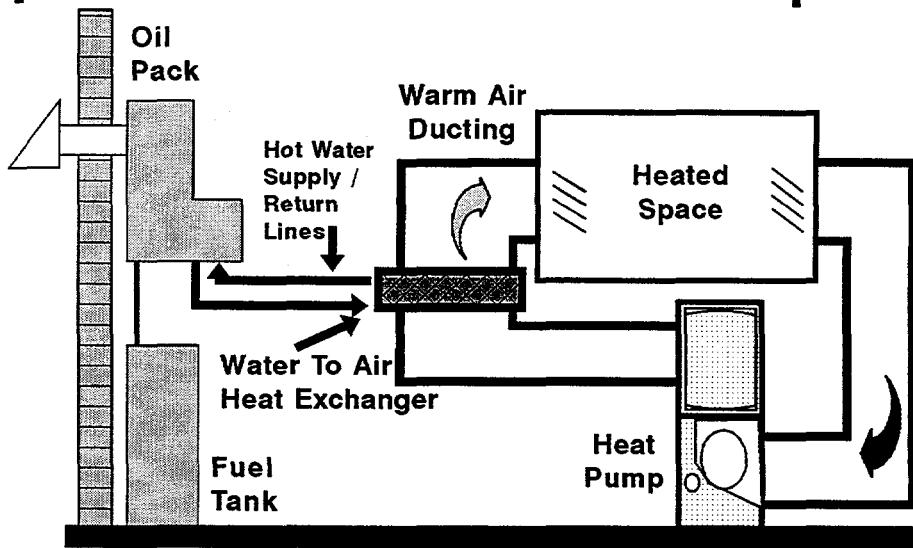
### Heating System with Remote Monitoring / Control



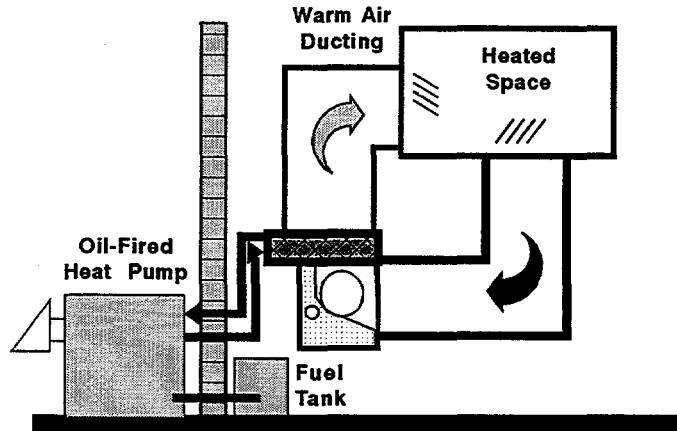
### Schematic Of Integrated Oil HVAC System

## Figure 3

## Figure 4 Oil-Assisted Heat Pump



## Figure 5 Oil-Fired Absorption Heat Pump



### Thermal Absorption Cycle Heat Pump

- Thermal Energy Drives System
- Use Oil To Provide Heating & Cooling
- Gas Fired Units Near Market Ready
- Break 100% Efficiency Barrier
- Oil Powers Absorption Process
- Air or Ground Loop Supplies Heating & Cooling Source/Sink

**OIL HEAT MANUFACTURERS ASSOCIATION (OMA) - UPDATE**

Robert Hedden, President  
Oil Heat Management Services  
RD#1, Andrus Drive  
Pawlet, VT 05761



## OILHEAT MANUFACTURERS ASSOCIATION (OMA) - UPDATE

### OMA's Perspective on the Challenges Before Us

Our industry must undergo a major paradigm shift if we are to prosper. We must change our "Fix it when it breaks" mind set to "Fix it so it won't break." Our main focus must be to improve Oilheat reliability. We have entered the era of the 100,000 mile tune-up. Meeting this challenge will require the best efforts of everyone in the industry from researchers, scientists, and engineers to manufacturers, dealers, sales people, installers, and service technicians.

The good news is that we have already started down this road. Last year was a very exciting year for the Oilheat Industry. National Oilheat Research Alliance (NORA), Petroleum Marketers Association of America's (PMAA) Technician Certification, and the Oilheat Manufacturers Association with its Oilheat Advantages Project were all started. I have had the honor of being deeply involved in all of them and I can assure you they will profoundly affect our industry for the better. You will be hearing about NORA and the Technician Certification from others. It is my job to tell you about OMA. So far, we have had a very good year.

### Some of OMA's Accomplishments for 1995

- Established and organized our association, recruited our 28 founding members.
- Contributed to the research for the Energy Information Agency's energy comparison study titled *Reducing Home Heating & Cooling Costs*.
- Involved ourselves in the great fuel dyeing debate, working with other groups gained a significant reduction in dye concentrations from IRS original request.
- Helped build an Oilheat Industry Coalition to respond to the Department of Energy's (DOE) proposed oil-fired water efficiency standards.
- Working with the Environmental Protection Agency (EPA) to get Oilheat's particulate number reported in AP-42 revised downward, to better reflect new clean-burning Oilheat equipment.
- The Oilheat Advantages Project, Marketing the Advantages Books, Brochures, & Overheads.
- Presented the Oilheat Advantages Seminar 20 times to over 2,000 oil dealers and builders.

- Serve on PMAA's Oilheat Technician Certification Committee, working to improve education and quality of Oilheat Technicians. Involved in the formation of NORA.
- Working with Brookhaven National Laboratory (BNL) on their Venting Technology Project, Chimney Tables, and recommendations to the National Fire Protection Association (NFPA).

### **Upcoming Challenges and Projects in Progress**

- Continue to disseminate the information in the Oilheat Advantages.
- Update the Advantages as needed.
- Legislation and Regulations Oversight.
- Chimney and Venting Issues, continue to work with BNL.
- DOE, water heater efficiency issue.
- Reach out to State Associations to offer our input on equipment related issues.
- Continue to research carbon monoxide and the sick house syndrome.
- Continue to research, NO<sub>x</sub>, SO<sub>x</sub>, and other emissions.
- The lack of lined chimneys in Oregon and Washington, the building inspector's discovery that we require liners, and the effect on equipment sales in that area.
- Working to change EPA's Energy Star Program that currently includes heat pumps, but not Oilheat equipment.
- International Association of Plumbing & Mechanical Officials' (IAPMO) new requirement that all tankless coils installed west of the Rockies be double wall, and their recommendation that their code be adopted nationally.
- Serve on a new standing committee for PMAA on Applied Research and Development. It will serve as an interface between DOE, EPA, BNL, NORA, OMA, the Oilheat dealers and their associations.
- Serve on PMAA's Oilheat Conference Committee.

I am pleased to report that we seem to be winning more than we are losing. Our biggest victory has been our work with BNL on the chimney and venting issue. Together we have crafted a compromise everyone can accept.

By being deeply involved with the process of change, we are able to have a voice in shaping the future. It is much easier and cheaper to act to help direct changes than to react to them once they have been made. For example, by serving on the Technician Certification Committee we were able to insure that Manufacturer's Education Programs are credited toward the continuing education required of technicians to keep their certification. By serving on the NORA Steering Committee, we were able to stop them from levying a fee on heating equipment sold.

We are still struggling with Energy Star, the Oregon Building Inspectors, oil-fired water heater efficiencies, IAPMO's double wall tankless coils, and EPA's notion of Oilheat particulate emissions in AP-42. OMA is represented on NFPA, NORA, PMAA's Technician Certification, Oilheat Conference, and Applied R&D Committees. The Advantages Materials continue to sell briskly. The Advantages Seminars are still in demand. We continue to look for more ways that we can help grow the Oilheat market share and increase Oilheat equipment sales.



**PMAA'S SILVER/GOLD  
NATIONAL CERTIFICATION PROGRAM - UPDATE**

Robert Boltz  
PMAA Education Committee Chairman  
Vincent R. Boltz, Inc.  
45 Guilford Street  
Lebanon, PA 17046



## **PMAA'S SILVER/GOLD NATIONAL CERTIFICATION PROGRAM - UPDATE**

**Robert Boltz**  
**PMAA Education Committee Chairman**  
**Vincent R. Boltz, Inc.**  
**45 Guilford St.**  
**Lebanon, PA 17046**

There is no better time than now to be in the oil heating industry.

Two Examples:

National Oil Heat Research & Development Alliance (NORA) - An idea that was brought to light by Jack Sullivan of New England Fuel Institute (NEFI), here at Brookhaven National Laboratory (BNL), at the 1995 Oil Heat Technology Conference.

At the same conference during the discussion groups, national oil heat certification was revived.

Oil heat technician certification is a process whose time has come.

We are living in one of the most exciting times in history.

The information age has put us in an era of improved technology as well as improved equipment.

With this fast change in technology and equipment, we have the challenge of finding new technicians as well as upgrading current technicians to service and install this equipment.

**The Oil Heat Technician Certification Program** is just the vehicle we need to do this.

Don Allen, Chairman, PMAA Heating Fuels Committee, has been a great facilitator in bringing industry groups together to develop a program enabling technicians to succeed in our industry.

In the oil/comfort business today, we can either become a full-service company staffed with the top technicians and also offer quality products and state-of-the-art technology, or we can have our company become the "bottom feeders" - the discounters that have nothing to give customers in added value.

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The Certification Program is based on two training publications:

1. **The Oil Heat Technician's Manual** that provides effective guidance on basic design, safety and repair of oil heat equipment (Silver Certificate).
2. **Advanced Oil Heat - A Guide to Improved Efficiency** by BNL that provides the latest information on efficiency advances and equipment upgrades (Gold Certificate).

The criteria for Silver Certification are:

1. Minimum of three years experience as an oil heat technician,
2. Minimum of 100 hours of training, and
3. Passage of a test, based on the PMAA (formerly PMEF) Oil Heat Technician's Manual, given by a PMAA Proctor.

The criteria for Gold Certification are:

1. Completion and passage of the National Silver Certificate Program,
2. Minimum of five years experience as an oil heat technician,
3. Minimum of 120 hours of training, and
4. Passage of a test, based on the PMAA Advanced Oil Heat - A Guide to Improved Efficiency given by a PMAA Proctor.

Certification is valid for five years. Recertification or renewal can be accomplished by completing 40 hours (5 credits) of continuing education programs through the State Association.

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Realizes higher profits through better trained technicians, e.g., fewer callbacks.

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Knows the right choice was made in choosing fuel supplier.

As a company in the comfort business, we must decide if we can afford to stand still or become part of a new revitalized industry moving into the 21st century with programs like NORA and Oil Heat Certification.

That is our question, and we must either survive or fail with our answers.



**MARKET ASSESSMENT FOR THE FAN ATOMIZED OIL BURNER**

Detlef Westphalen  
A.D. Little, Inc.  
Acorn Park  
Cambridge, MA 02140-2390



# Market Assessment for the Fan Atomized Oil Burner

Detlef Westphalen  
Arthur D. Little, Inc.  
20 Acorn Park  
Cambridge, MA 02140

## Abstract

The market potential for the fan atomized burner (FAB) in water and space heating applications was examined. The major findings of the study are as follows.

- The FAB's low-input capability allows development of oil-fired room heaters and wall furnaces, a new market area for oil heat.
- Among conventional oil-fired products, furnaces will benefit most from the burner's low input capability due to (1) their quick delivery of heat and (2) their more prevalent use in warmer climates and smaller homes.
- The greatest potential for increased product sales or oil sales exists in the use of the burner with new products (i.e., room heaters). Sales of boilers and direct-fired water heaters are not likely to increase with the use of the burner.
- Acceptance of the burner will be dependent on proof of reliability. Proof of *better* reliability than conventional burners would accelerate acceptance.

## Introduction

There are nationally about 12 million homes heated with oil. The residential oil heat market is regionally concentrated in the Northeast, with additional local concentrations in the Southeast and, to a lesser extent, the Pacific Northwest. The market for conventional oil burners and oil-firing products is dominated by replacement, which accounts for about 80% of sales. The most important products are central furnaces, boilers, and direct burner retrofits (direct-fired water heaters represent about six percent of burner sales).

This study examines the market and energy-savings potential for the fan-atomized burner (FAB). The most important distinguishing characteristics of the FAB are (1) its ability to fire reliably down to 0.25 gph (as compared with 0.5-0.6 gph for conventional oil burners, and (2) a design which eliminates the small nozzle flow passages used in pressure-atomized burners which are a prime cause for nozzle clogging and misfiring.

## Target Markets

### Existing Houses

Identification of the target markets for FAB products among existing homes was based on the 1993 Residential Energy Consumption Survey (RECS) data collected by the Energy Information Administration (EIA). Table 1 below summarizes heating system types by housing type for the Northeast and Southeast regions of interest.<sup>1</sup>

The sum of oil heat residences reported in the table is somewhat less than the total of 12 million mentioned above. This is due to the following factors: (1) the RECS survey includes a nationally representative sampling of about 7,000 households, which may not give an exact estimate of the number of oil heat accounts, (2) only Northeast and Southeast regions are included and (3) apartments are not included. The table is intended to show relative sizes of important household types.

**Table 1: Heating Systems in Existing Residences (thousands)**

		Northeast			Southeast			
		Heating System	Single Family	Condo	Mobile Home	Single Family	Condo	Mobile Home
Oil	Hydronic/Steam	2,763	369	10	338	*	*	
	Warm Air	1,787	85	181	820	*	67	
Baseboard	Furnace	60	*	*	1,555	212	433	
	Heat Pump	363	28	*	3,144	278	47	
	Baseboard	549	66	*	549	*	82	
Propane and Kerosene	Hydronic/Steam	7	*	*	*	*	*	
	Warm Air	122	*	237	397	*	327	
	Room Heater	56	*	*	515	*	*	

Source: DOE/EIA "Residential Energy Consumption Survey", 1993, Raw Data

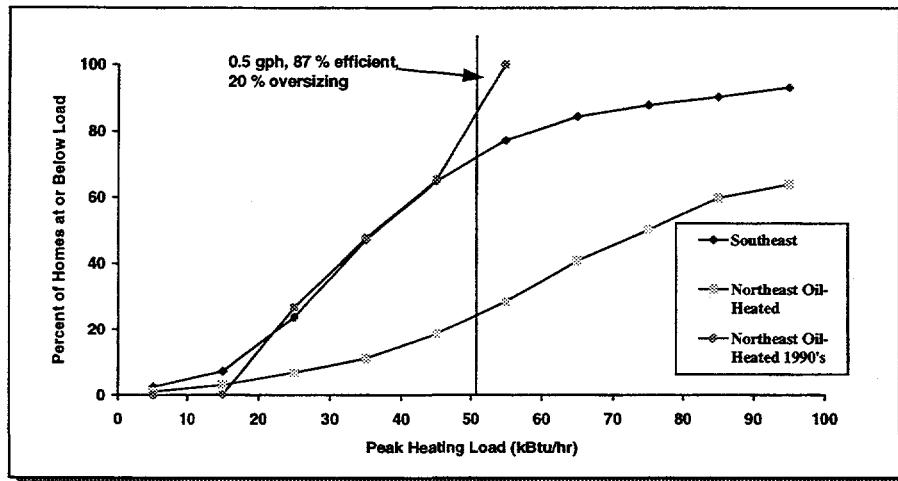
\*Insignificant numbers of these residence types reported

### Low Heating Load Houses

About twenty percent of existing homes in the Northeast and about seventy percent in the Southeast can be heated with a burner with less than 0.5 gph firing rate (20% oversizing is assumed). Furthermore, about 85% of new Northeast houses and nearly all new Southeast houses can use such a burner.

<sup>1</sup> Northeast includes Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, and Pennsylvania. Southeast includes Delaware, Maryland, D.C., Virginia, West Virginia, North Carolina, South Carolina, Georgia, and Florida

Figure 1 below shows distributions of houses based on heating load. Distributions are presented for existing houses and 1990's houses in the Northeast which are heated with oil, and for all types of Southeast houses.



Note: Includes only single-family houses

**Figure 1: Low Heating Load Houses**

The heating load distribution curves were calculated based on raw data of the 1993 RECS and on building descriptions and heating load calculations developed by Lawrence Berkeley Laboratory (LBL).

### New Construction and Additions

Current annual rates of the new construction markets are summarized in Table 2 below. For this table, construction for the entire South census region is presented. About two thirds of this construction is associated with the Southeast area discussed above.

The market for renovation of homes is approaching that of new construction in value. In some cases, additions to existing houses are heated by separate heating systems. This presents an opportunity for an oil-fired room heater based on the FAB.

Estimates of housing additions in oil-heated homes include 23,000 annually in the Northeast (about 9,000 of these are in houses with warm air heating). In the South there are about 7,000 additions in oil-heated houses (5,000 of these are in houses with warm air heat). The estimates are based on value of residential new construction and value of housing additions.

**Table 2: New Construction Markets**

		Northeast			South		
		Single Family	Multifamily Units	Mobile <sup>3</sup> Home	Single Family	Multifamily Units	Mobile <sup>3</sup> Home
New Construction	Natural Gas <sup>1</sup>	61	9		214	15	
	LPG <sup>1</sup>	1	-		41	3	
	Oil	34	*		2	*	
	Electric Heat Pump <sup>2</sup>	14	1		214	*	
	Electric Other <sup>2</sup>	2			33	24	
	Other Fuels (Kerosene, Coal, Wood)	1	*		3	<0.5	
	Total	113	11	16	507	74	174

Source: U.S. Dept. of Commerce "Characteristics of New Housing: 1994," July 1995; adjusted as noted

\*These data are not reported in the source due to inadequate sample size

<sup>1</sup> Gas heating reported by the reference includes propane. Split of gas heated residences into NG and LPG is done assuming that 2% of these residences in the Northeast are 16% of these residences in the South are propane. Reference 8 reports that 2% of gas heated homes in the Northeast are LPG and 16% in the South are LPG.

<sup>2</sup> Numbers of heated residences are reported separately from numbers of homes with heat pumps. It is assumed that the number of gas heat pumps is negligible. The numbers of residences with heat pumps is subtracted from the total number of electrically-heated residences to determine the number of "electric others" residences.

<sup>3</sup> New construction mobile homes all have central furnaces, but data for energy types is not available.

## System Applications

Table 3 shows the appropriate matching of oil fired equipment types with various applications.

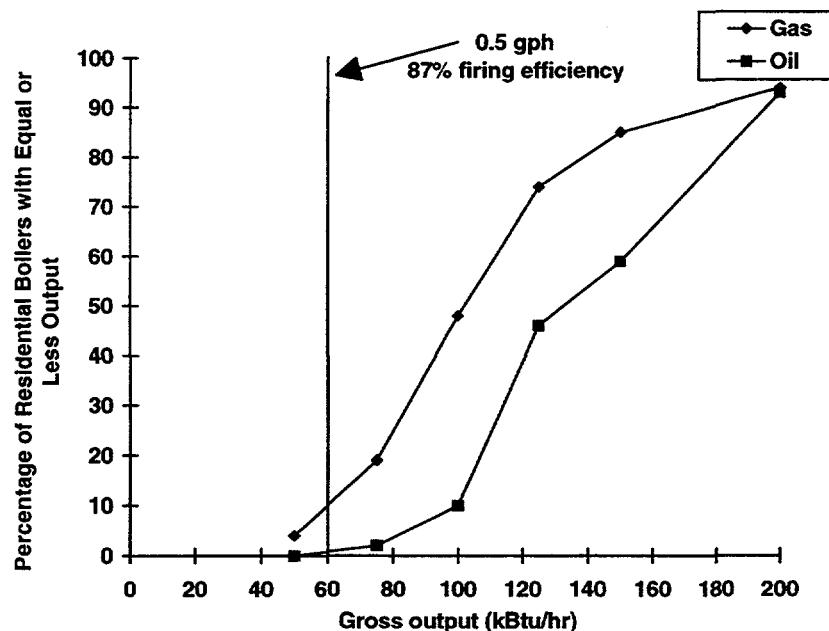
**Table 3: FAB-Based Systems: Equipment match for Target Applications**

	Application	Boiler	Central Furnace	Room Heater	Notes
New	New Construction	X	X	X	Boilers for larger homes in the Northeast; Central Furnaces for smaller homes in the Northeast, Southeast homes, and Mobile homes; Room Heaters for condos and some small single family houses
	Additions			X	Applicable where extension of an existing warm air system is difficult
Replacement	Hydronic/Steam	X			Regional concentration in New England and eastern New York
	Warm Air		X		Regional concentration in the Mid-Atlantic and Southeast
Conversion	Baseboard	X		X	Room Heater reduces first cost of conversion
	Furnace		X		
	Heat Pump		X		Best opportunities amongst heat pump heated homes in colder areas
LPG/Kerosene	Hydronic/Steam	X			
	Central Furnace		X		
	Room Heater			X	

## Boilers

Regionally, hydronic and steam systems are concentrated in New England and parts of the Mid-Atlantic region which are further North and East (Long Island, for instance). Not many boilers are sold in new homes because of the increasing trend for installation of central air-conditioning. The exception is larger homes which combine radiant floor heat with a central HVAC system which heats using a hot water coil.

The most popular size oil boiler has about a 1 gph firing rate. The need for low-input boilers can be assessed by examination of sales of low-input gas boilers. The size distribution of gas boilers sold in the years 1992 through 1995 is shown in Figure 2 below. About 11% of the boilers are in the FAB target range representing less than 0.5 gph input of oil. This percentage is half as much as the percentage of the homes which were estimated to be in this target range (22%--see Figure 1). Even if a low-input oil burner were available, this 11% level would not likely be matched by oil boilers because oil boilers are much more frequently used for water heating than gas boilers.



Source: I=B=R Division of GAMA, "Cast Iron Boiler Shipments"

Figure 2: Boiler Sizes - Shipments for 1992 through 1995

## Central Furnaces

Central furnaces are the most ubiquitous heating system type, even in oil heat homes. Regional concentrations of homes with oil-fired central furnaces are in the Mid-Atlantic and Southeast states ranging from New York to North Carolina. Furnaces are more popular in regions further South because the homes in these regions are more likely to have central air-conditioning. The installation of central air-conditioning has become

more prevalent, even in the more northerly regions. Central furnaces are also more common in smaller houses. For instance, heating systems in mobile homes are primarily furnaces.

The predominance of furnaces in warmer regions and smaller homes means that oversizing with conventional burners should be more of an issue than for boilers. There are significant numbers of central furnaces sold which are rated for a 0.5 gph firing rate (in many cases installers increase firing rate to avoid nozzle clogging problems), and the most popular furnace size has a fuel input of about 0.75 gph. Furthermore, the direct delivery of heat to the space with a furnace makes this application more compelling for a low-input burner. Heat delivered to the space by a boiler can be moderated by the radiator capacity.

### **Direct-Fired Water Heaters**

Direct-fired water heaters are not likely to benefit as much from the FAB's attributes as are the space heating products. The smallest direct-fired water heaters have input of 0.75 gph. Water heaters need high input for quick recovery of water temperature.

### **Room Heaters**

The FAB burner's low input capability makes possible the development of room heaters, a new market area for oil heat. Such a product has the potential for significantly reducing the cost of electric conversion, one of the more important growth markets for oil heat. Conversion to oil heat for these homes typically involves installation of boilers with hydronic baseboard radiators. Availability of a room heater would eliminate the need for baseboard radiators, piping, a circulator pump, and expansion tank. The costs for a boiler installation and for a room heater installation are compared in Table 4 below.

**Table 4: Example Cost Comparison for Electric Conversion**

<b>BOILER</b>		<b>ROOM HEATER</b>	
Boiler Installed <sup>1</sup>	\$3000	Two Heaters Installed <sup>2</sup>	\$3,000
Metal-Wall Chimney Installed <sup>1</sup>	\$1200	Direct Vent Kits Installed (2) <sup>1</sup>	\$2,000
Fuel Tank Installed	\$300	Fuel Tank Installed	\$300
Hydronic System (Installed) <sup>1</sup>	\$8000		
<b>TOTAL</b>	<b>\$12,500</b>		<b>\$5,300</b>

<sup>1</sup>Based on discussions with a Northeast Region Oil Marketer

<sup>2</sup>Cost installed \$1,500 per heater, based on costs of vented kerosene and oil-fired equipment (end-user equipment cost assumed to be 80% of list price), additional cost premium for FAB burner \$200, and installation labor of \$50/hr for 4 hrs per heater. List prices of similar heaters as indicated below.

Fuel Type	Input (Btu/hr)	List Price	Manufacturer
Kerosene	40,000	\$1298	Toyotomi
kerosene	22,000	\$962	Toyotomi
Oil	30,000	\$1377	Franco-Belge
Oil	22,500	\$999	Franco-Belge

The savings for an electric conversion using a conventional boiler are compared to those for a conversion using a room heater in Table 5 below. Due to reduced conversion costs, the payback period for the room heater approach is significantly better than for the conventional boiler approach.

**Table 5: Energy Cost Savings for Electric Conversion (Conventional Boiler vs. Two Room Heaters)**

	<b>Electric Baseboard</b>	<b>Conventional Boiler</b>	<b>Fab Room Heater</b>
Firing Rate (gph)		0.6	2x0.3
Delivered Heat (MMBtu) <sup>1</sup>	56	56	56
Efficiency (%)	100	83 <sup>2</sup>	87 <sup>2</sup>
Heating Energy	16,410 kWh	482 gal	460 gal
Burner Wattage <sup>3</sup>		320	2 x 160
Burner on-time during 6-mo. heating season (%)		18	17.5
Burner Electricity (kWh)		252	245
Unit Energy Costs <sup>4</sup> :			
Fuel Oil (\$/gal)		\$0.90	\$0.90
Electricity (¢/kWh)	9.4¢ <sup>5</sup>	11.4¢	11.4¢
Total Energy Costs:			
Fuel Oil		\$434	\$414
Electricity	\$1543	\$29	\$28
Total	\$1543	\$463	\$442
Savings		\$1080	\$1101
Cost for Conversion		\$12,500	\$5,300
Simple Payback (years)		12	5

<sup>1</sup>Typical annual load for a New York house constructed in the 1950 through 1970's time period with 1200 sqft floor area (Reference 2). Specific total load is 47kBtu/sqft and specific peak load is 30Btu/sqft./ hr.

<sup>2</sup>Source: Brookhaven National Laboratory - these are AFUE estimates rather than true system efficiencies

<sup>3</sup>Source: Personal communication with Dr. Bola Kamath, president, Heatwise, Inc., 2/21/96

<sup>4</sup>Source: Department of Energy/Energy Information Administration, "Household Energy Consumption and Expenditures 1993", October 1995

<sup>5</sup>Electric rate is lower for electrically-heated homes due to special all-electric rates.

A room heater can also be used for some house additions in which expansion of the existing heating system is difficult. The room heater is the FAB-based product concept with the best potential for increasing the sales of oil-fired equipment. With the conventional equipment types (boilers, central furnaces, and water heaters) the use of FAB would not provide enough added end-user benefits to result in significant increase in equipment sales, except in the case of a low-input furnace.

### Market and Energy Savings Estimates

Besides low-load houses, electric conversion, and house additions, the target markets for FAB are other existing oil heat houses, houses in the major oil-heat regions which are not heated with natural gas, and new construction.

An optimistic marketshare scenario for the FAB would involve capture of 10% of the market for conventional applications after an initial introduction period of five to ten years. In addition, sales of FAB room heaters in electric conversions may result in

additional sales representing 50% of the current rate of electric conversions. Such a scenario, involving about 70,000 annual FAB sales, would result in annual primary energy savings increasing at a rate of about 0.75 trillion Btu per year.<sup>2</sup> About one-third of these savings is associated with the conventional applications, where FAB would be compared with conventional oil burners. The other two thirds represents using FAB in place of resistance electric heat in electric conversions. The primary energy savings is much greater for each electric conversion because of the inefficiency of electric heat.

## **Conclusions**

The FAB burner would have the greatest potential for increasing the oil heat account base and reducing primary energy usage when used in a room heater targeted at electric conversion. Among conventional heating products, central furnaces would benefit most from FAB.

## **References**

- (1) Department of Energy/Energy Information Administration, "1993 Residential Energy Consumption Survey", Raw Data
- (2) Lawrence Berkeley Laboratory for Gas Research Institute, "Multi-Family and Single-Family Heating and Cooling Requirements", 1991, 1992
- (3) U.S. Commerce Department, "Characteristics of New Housing 1994", July 1995
- (4) Department of Energy/Energy Information Administration, "Housing Characteristics 1993", June 1995
- (5) Department of Energy/Energy Information Administration, "Household Energy Consumption and Expenditures 1993", October 1995
- (6) U.S. Commerce Department, "Expenditures for Residential Improvements and Repairs", C50/95-Q2, November 1995
- (7) Construction Review, Winter 1995
- (8) U.S. Commerce Department, "Value of New Construction Put in Place", C30, Nov/Dec 1995

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<sup>2</sup> Savings are based on burner performance estimates of Brookhaven National Lab

**PART I**

**FAB EVALUATION & APPLICATION TRIALS  
AFUE MEASUREMENTS**

Richard W. Leigh, Ph.D.  
Brookhaven National Laboratory  
Department of Applied Science  
Building 526  
Upton, NY 11973-5000

**PART II**

**INTEGRATED HEATING  
SYSTEM (IHS) DEVELOPMENT**

Len Fisher, P. E.  
BNL Consultant  
RR# 1, Christian Hill  
Colrain, MA 01340



**Part I**  
**FAB Evaluation & Application Trials**  
**AFUE Measurements**

**1. Introduction**

An oil burner/boiler efficiency test stand has been set up in the BNL oil heat laboratory which can measure the Annual Fuel Utilization Efficiency (AFUE) of burner/boiler combinations in accordance with ASHRAE and DOE standards. Measurements include both steady state efficiencies and heat-up and cool-down characteristics so that cycling effects can be included in an estimate of seasonal average performance. In addition to AFUE measurements, the direct conversion of fuel energy content to enthalpy increase in the boiler water is monitored. The system is largely automated, with most control functions under computer control and data taken electronically and permanently recorded on disks for future reference.

To date, a retention-head burner and a fan atomized burner (FAB) have been tested in a steel boiler, the latter operating at two different fuel flow rates. The results are presented below, and verify that the very tight construction of the FAB's fan results in a significant decrease in off-cycle sensible heat losses.

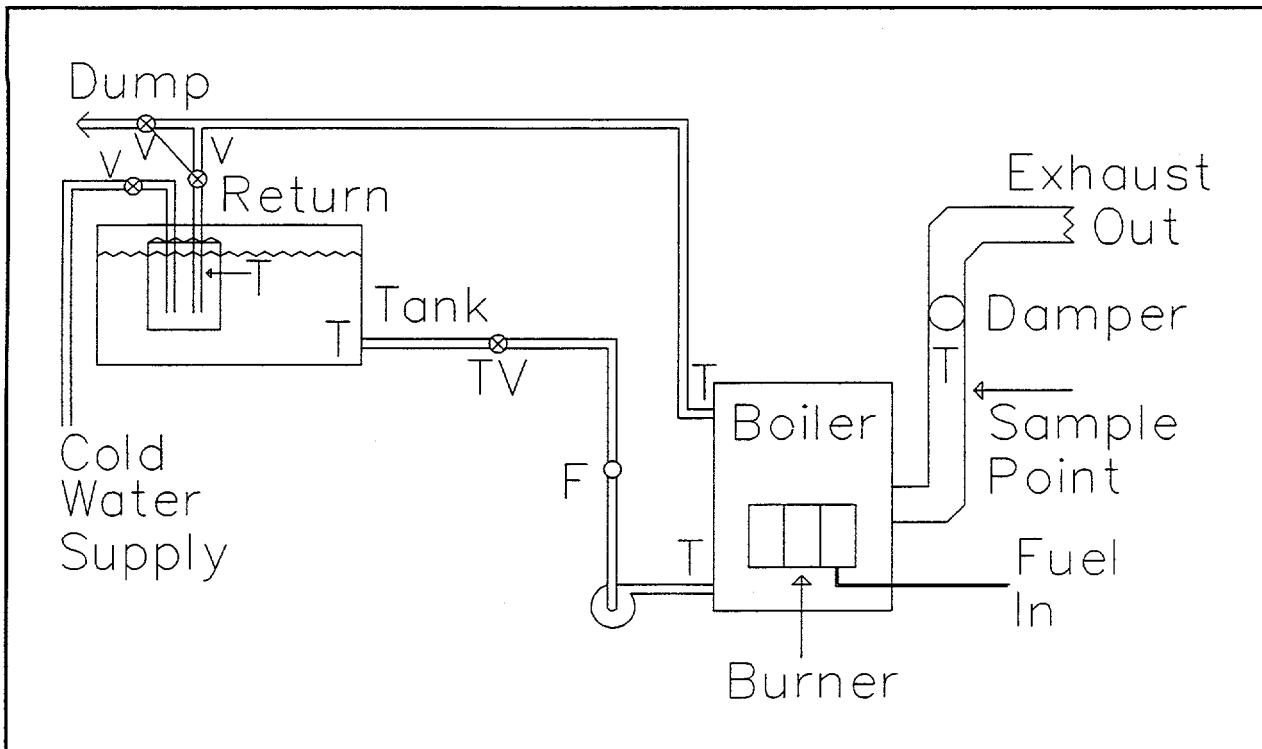
Tests were also performed on a center-flue water heater fired with a conventional retention-head burner and with an FAB. The tests conformed to DOE standard procedures for hot water heaters, and the results are discussed below.

**2. AFUE Test System Design**

The system was designed around the current DOE standards for the energy consumption of furnaces.<sup>1</sup> For the single firing rate boilers we are currently examining, this DOE standard is identical to the current ASHRAE standard.<sup>2</sup> This Annual Fuel Utilization Efficiency (AFUE) standard is based on the measurement of thermal losses up the flue and estimation of coincident infiltration and additional stack losses to determine steady state efficiency. Examination of the cool-down and heat-up performance of the system allows calculation of likely cycling losses, which are then combined with the steady state efficiency to give the AFUE.

In addition to the quantities required for the AFUE measurement, the system measures both the enthalpy increase in water passing through the boiler and boiler fuel consumption to arrive at an independent estimate of steady state efficiency. Since after allowing for jacket losses this should agree with the AFUE measure of efficiency, comparison provides an independent check on the accuracy of the experiment.

Physically, the system is straightforward, and is sketched in Figure 1. Electrically operated valves are indicated by "V", the hand operated throttling valve by "TV", the flowmeter by "F" and several key temperature measurement points by "T". "Sample Point" shows where the flue gas is sampled during tracer gas measurements, and "Damper" indicates the position of the barometric damper.



**Figure 1: AFUE Test Apparatus.**

Water is supplied to the boiler at 120-124°F from a large tank. A flowmeter and throttling valve allow control of the flow. The returning water (at 140-146°F) is either delivered to a small tempering tank within the larger storage tank (if the water in the tempering tank is below a preset temperature) or is dumped to waste (if the tempering tank is above a higher preset temperature). When the level in the large tank drops below its equilibrium value, a level switch opens a valve which introduces cold water into the tempering tank. Under this control scheme, the temperature of the water from the large tank is stable to better than one degree Fahrenheit once equilibrium has been reached.

The data-taking system is automated, with a dozen temperatures, the water flow rate, flue draft, CO levels and other parameters monitored by a Molytek data logger and periodically dumped to and stored in a computer. The computer also ensures that operating parameters, such as input water temperature, remain within specified limits by operating the valves discussed in the previous paragraph. The software was written at BNL in Basic.

The AFUE condition for steady-state operation requires that the temperature of water leaving the boiler vary by less than four degrees over a thirty minute interval. After this condition has been satisfied, the various steady state temperatures and other data are stored for later analysis. The system is shut off and transient behavior after shutdown is monitored, including temperatures and, using tracer gas techniques, gas flow through the burner and stack. After a specified delay, the burner is re-fired and heat-up data is taken. The data is then analyzed following the specifications in

the standard, using either a spreadsheet constructed at BNL or a Fortran program ("AFUEBF") obtained from the DOE.

### 3. Initial Burner/Boiler Test Results

The results reported in this section were carried out using a boiler with a hot (semi-insulated) combustion chamber surrounded by a steel water jacket offering substantial heat transfer surface to the hot gasses. The temperature of the gasses was then measured in the insulated flue pipe. Above that point, a barometric damper regulated the draft and a stack pipe led out to a masonry chimney. No stack damper or other draft control was present.

The first test involved a standard retention head burner. It drew 0.792 gallons per hour of #2 oil. After the system was warmed up, the air was re-adjusted to ensure a smoke reading between zero and one and after the steady state criteria was met, the data displayed in Table 1 were obtained. Because AFUE procedures assume that jacket losses from the boiler amount to one per cent, the AFUE steady state efficiency should ideally be one per cent higher than the fuel energy to water enthalpy efficiency. Since we in fact found the latter to be higher than the AFUE steady state efficiency, there is a 1.9% discrepancy between the two estimates of steady state efficiency. There are several possible causes for this discrepancy, and we are searching for the critical ones.

Table 1: AFUE Results for Retention Head Burner in Steel Boiler.

Burner:	Retention Head	Boiler:	Steel
Conditions:	Standard fuel flow; Smoke less than 1.0		3/4/96
			1
<b>Steady State Operation</b>			
Flue Temp:	354 °F;	Room Temp:	76 °F
Fuel Flow:	0.79 gph;	Draft:	0.023 in. H2O
Flue O2:	4.3 %	Flue CO2:	12.4 %
AFUE Steady State Efficiency (Effyss)=		86.7 %	
Fuel energy to water enthalpy efficiency =		87.5 %	
Discrepancy after 1% jacket loss =		-1.9 %	
<b>Transients following shut-down:</b>			
Volumetric flow at	163 °F =	3.37 cfm	
Off-cycle sensible heat loss:		0.60 %	
Annual Fuel Utilization Efficiency (AFUE) =			85.4 %

The actual AFUE will (normally) be lower than the steady state efficiency due to transient losses as the system cycles off and on. The effect of these losses is calculated from transient temperatures measured during cool-down and heat-up, and from measurement of the amount of air

drawn through the burner by residual draft. This measurement is carried out by injecting a detectable tracer gas, in our case carbon monoxide ("CO"), into the boiler at a known rate. The concentration of CO measured in the flue by sampling and calibrated infra-red spectroscopy then indicates the mass flow through the burner and flue. The result is converted to volumetric flow at the flue temperature at the time of the measurement and presented near the bottom of Table 1.

Also shown is the "Off-cycle sensible heat loss". This is the fraction of input energy which escapes up the flue during the off cycle due to the flow of room air through the hot boiler. It is not a large number, but is presented here for contrast with the FAB results below. Finally, the AFUE itself, calculated from the above measurements, is found to be 85.4% for this burner/boiler combination. The particular boiler we used has not been tested by public laboratories in tests we are aware of, but our result is comparable to those published<sup>3</sup> for similar combinations.

The second test, with results reported in Table 2, is of the FAB, set to operate at minimum fuel flow, which is less than one-half that of the retention head burner. The steady state efficiency is (by either measure) much higher, but this apparently good news must be taken with a grain of salt, since we were firing the boiler at a much lower rate, so high efficiency is expected, along with condensation in a chimney, which would not be at all desirable.

Table 2: AFUE Results for FAB in Steel Boiler, Minimum Firing.

Burner:	FAB	Boiler:	Steel
Conditions:	Minimum fuel flow; Atomizing air at 9" water column	3/08/96	
			3
<b>Steady State Operation</b>			
Flue Temp:	179 °F;	Room Temp:	77 °F
Fuel Flow:	0.35 gph;	Draft:	0.019 in. H2O
Flue O2:	2.6 %	Flue CO2:	13.7 %
AFUE Steady State Efficiency (Effyss)=			91.2 %
Fuel energy to water enthalpy efficiency =			92.6 %
Discrepancy after 1% jacket loss =			-2.4 %
<b>Transients following shut-down:</b>			
Volumetric flow at	146 °F =		0.464 cfm
Off-cycle sensible heat loss:			0.16 %
Annual Fuel Utilization Efficiency (AFUE) =			90.1 %

Although it might be possible to use this configuration in a system employing sidewall venting, such an innovative application would require more research than we have done to date. Here our purpose in presenting the result is to focus on particular improvements in the transient behavior.

Table 2 shows that the volumetric off-cycle flow\* has dropped by a factor of seven compared to the retention head burner in Table 1. This is primarily because the air intake orifices on the FAB are smaller than those on the retention head burner, impeding the passage of draft-driven air and lowering the off-cycle sensible heat losses from 0.60% to 0.16%. Due to the lower flue and stack temperatures, the draft was also somewhat lower, 0.019 inches water column for the FAB as compared to 0.023 inches for the retention head burner.

The last run to be presented here is described in Table 3 and shows that the decrease in flue temperature is only marginally involved in the decrease in volumetric flow and in off-cycle sensible heat loss. Here the FAB was operated at the maximum fuel flow possible while still maintaining adequate air pressure for atomization, resulting in increased temperatures. The steady state efficiencies are slightly lower, as would be expected from the higher firing rate, and the volumetric flow rate is slightly higher. However, the off-cycle sensible heat loss has fallen as a per cent, and is essentially the same in absolute terms, since the total thermal power has increased by about 25%.

Table 3: AFUE Results for FAB in Steel Boiler, Maximum Firing.

Burner:	FAB	Boiler:	Steel
Conditions:	Maximum fuel flow; Atomizing air at 8.2" water column	3/11/96	1
<b>Steady State Operation</b>			
Flue Temp:	211 °F;	Room Temp:	76 °F
Fuel Flow:	0.44 gph;	Draft:	0.019 in. H2O
Flue O2:	2.4 %	Flue CO2:	13.9 %
AFUE Steady State Efficiency (Effyss)=			90.5 %
Fuel energy to water enthalpy efficiency =			87.9 %
Discrepancy after 1% jacket loss =			1.6 %
<b>Transients following shut-down:</b>			
Volumetric flow at	150 °F =		0.522 cfm
Off-cycle sensible heat loss:			0.13 %
Annual Fuel Utilization Efficiency (AFUE) =			89.5 %

These initial results from our AFUE test bed indicate that the FAB has a distinct advantage in lower off-cycle losses resulting from its constricted air entrance passages.

#### 4. FAB Firing of a Center-Flue Hot Water Heater

Earlier in this program efficiency studies were completed with a center-flue water heater fired with a conventional retention head burner (baseline) and the Fan-Atomized Burner (FAB). The

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\* Again, for the FAB, the flue gas mass flow has been converted to volumetric flow at the flue temperature at the time of measurement.

AFUE testing procedures apply only to boilers and furnaces, not to hot water heaters, so here, all tests were done in accordance with DOE standard procedures for oil-fired water heaters<sup>4</sup>. The test is in many ways similar to the AFUE tests, except that cool (56-60°F) water is supplied, consistent with the normal usage of a hot water heater. The purpose of these baseline tests was to verify our testing procedures by making a preliminary comparison with the manufacturer's listed performance data, and to estimate the potential performance of the FAB in this application.

Table 4 below lists the most important performance parameters as measured and also as listed for this appliance. As-tested here under the baseline conditions we only approximated the manufacturer's specified conditions. The retention head burner, used at the rated firing rate (.75 gph) was not the burner listed by the manufacturer. In the baseline tests burner excess air was set at 50%. In tests with the FAB the firing rate was 0.37 gph and excess air was set at 10%.

Table 4: Summary of Water Heater Test Results

	As tested with retention head burner	As listed with retention head burner	As tested with Fan Atomized burner
First hour rating (gal)	118	134	75
Recovery efficiency (%)	78.0	80.0	89.7
Standby loss (Btu/hr)	810	-	714
UA (Btu/hr F)	12.2	-	10.1
Energy Factor	.58	.63	.67

The retention head burner did not perform up to its listed specifications in our tests. We expect that the differences are due to the differences in the burners used, high excess air in the case of our retention head burner tests, and possibly some inaccuracies in our procedures. Comparison of test results for the retention head burner and the FAB indicate that while the low firing rate has reduced the first hour capacity by some 36%, it has increased efficiency so as to offer more than 10% fuel savings. Again, these results should be regarded as preliminary and tentative; the primary purpose of the baseline tests was to shake-down our test methods.

## 5. Future Directions

These boiler and water heater tests have been done as part of our ongoing effort to evaluate appliance efficiencies and the benefits in efficiency which might be realized with low and/or two stage firing rates, especially with the FAB. Having gained some confidence in our ability to measure appliance efficiency accurately, we will now move forward to measure several more burner/boiler combinations. The results will be presented in reports, and will be used to inform our analyses of the FAB's commercial potential and to guide future technical research.

**References:**

1. "Uniform Test Method for Measuring the Energy Consumption of Furnaces", Code of Federal Regulations, 10CFR Ch. 11, Pt.. 430, Subpt B, App.. N (Jan 1, 1995).
2. "Method of Testing for Annual Fuel Utilization Efficiency of Residential Central Boilers and Furnaces", ANSI/ASHRAE 103-1993, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1791 Tullie Circle, Atlanta GA 30329 (1993).
3. "Consumer's Directory of Certified Efficiency Ratings", Gas Appliance Manufacturer's Association (GAMA), PO Box 9245, Arlington VA 22219 (April 1995)
4. "Uniform Test Method for Measuring the energy Consumption of Water Heaters", Code of Federal Regulations, 10 CFR Ch. 11, Pt.. 430, Subpt B, App.. E (Jan 1, 1995).



## Part II

### Integrated Heating System (IHS) Development

#### An Ultra Low Mass Boiler for the Fan Atomized Oil Burner

**Len Fisher, P. E.  
BNL Consultant  
171 Ed Clark Road  
Colrain, MA 01340**

The **Fan Atomized Burner (FAB)** has been tested in boilers, furnaces and water heaters that were designed for firing rates from 0.75 to 1.10 gph. It has demonstrated excellent performance at low excess air:

- Firing rates = 0.25 to 0.70 gph
- O<sub>2</sub> = 1.0 to 3 %
- CO = 20 to 50 ppm
- NOx = 30 to 80 ppm
- Smoke No. = 0

Of course these appliances exhibited very high efficiencies at the lower inputs. Stack temperatures ranged from below 300° to about 450° F with high CO<sub>2</sub>. But such low input rates would not often meet the demand for which the units were designed and rated.

It has long been the consensus here at the Brookhaven National Laboratory (BNL) and of some associates that the demand for the FAB in the market would be very limited without the development of some **new smaller appliances** that could capitalize on the FAB assets. Appliances such as:

- Small efficient warm air furnaces
- Compact, efficient low-mass boilers
- High Energy Factor water heaters
- Other (new) types of appliances

Direct venting or sealed combustion would increase the sales of any of these and would facilitate electric heat replacements for which low inputs would usually be essential.

#### Why a low-mass boiler?

Although it was realized that the market for a small warm-air FAB furnace might exceed that for a low-mass FAB boiler, the boiler prototype was chosen. The low-mass boiler provides the key to the problem of designing an **Integrated Heating System (IHS)**.

The low-mass boiler is the **core subsystem** that allows the IHS to provide **multiple space heating options** along with **domestic hot water** and **air conditioning** options as well. The **FAB low-mass boiler IHS** can provide these options:

- Space heating using conventional baseboards or iron radiators
- Heating with radiant in-floor tubing distribution
- Heating with hydronic flat steel wall panels (European)
- Heating with warm air supplied to ducts using a fan-coil unit
- Cooling with the A-coil mounted on the fan coil unit
- Domestic hot water using an indirect water heater storage tank subsystem

### **The First Low-Mass Boiler Prototype**

The **design criteria** for this development were:

- Low mass and low water content to minimize off-cycle losses
- Low jacket loss to minimize on- and off-cycle losses
- Match the combustion chamber to the flame req. for low CO
- Design airtight for forced draft through a small vent pipe
- Utilize counterflow heat transfer for maximum effectiveness
- Attenuate and isolate combustion noise
- Strive for a wall-hung capability
- Low cost
- Ease of service
- Low maintenance

The **general specifications** (see Figure 1):

• Length x diameter	32.5" L x 10"D
• Weight, material	Under 100 lb., steel
• Water content	<<1.0 gallon
• Orientation	Horizontal
• FAB position	Front end
• Exhaust vent	2" S.S. pipe, back end
• Return tapping	3/4" NPT, bottom, rear
• Supply tapping	3/4" NPT, top, front
• Forced draft at	~0.2 to ~0.5" w.c.
• Heat exch. mode	Counterflow
• Input range	0.25 to 0.35 gph #2 oil
• Estimated output	31 to 43 MBH

The potential **marketing success factors** for an IHS FAB low-mass boiler are:

- Low firing rate range
- Low cost
- Low mass; low water content
- **High AFUE, and high overall efficiency (see Fig. 2 and Ref. 1.)**
- Direct venting; no inducer
- Very quiet
- Easy to clean; longer cleaning intervals = reduced maint. costs
- Low electric watts further reducing cost of operation
- Variable ratings; one nozzle and burner spec.
- Can replace electric heat systems
- Can provide low cost domestic hot water with a storage heater
- Can provide warm air heating option with a fan-coil unit
- Can provide a central cooling option with an A-coil + fan coil
- Applicable to new small homes and many southern homes
- Attractive to wholesalers: stimulates sales of all IHS subsystem products

Figure 2. shows the performance characteristics of two typical types of oil fired boilers operating in the field today plus a conservative estimate of the new BNL low mass boiler with the fan atomized burner.

The lowest curve represents an old dry base unit with a relatively high off-cycle jacket loss and an old open head burner that allows air to flow freely through the boiler during the "off" cycle. To sustain these two losses the burner must run about 5% of the total time without any useful output from the boiler. ( See the lower left corner. ) At steady state this unit just reaches 70% efficiency which means that the on-cycle jacket loss plus the flue loss add up to 30%. ( See the upper right end of the lowest line. ) At 15% "on" time, which is about the seasonal average in the U.S., this unit would have an overall efficiency of only 58%.

Part of this inefficiency is the result of the firing rate of the burner which is (also typically) about 2x that required for the design heating load. If the firing rate were reduced by 50%, the average fractional "on" time would double to 30% while at the same time the steady state efficiency would increase appreciably. At 30% on time the curve shows 67%, but with the lower stack temperature it would likely go well over 70 or even 75%. Of course with a tankless coil in the boiler, again typical, this lower firing rate would be inadequate for showers or baths.

The intermediate performance curve represents an old but more recent wet base unit with a flame retention head burner. Note that this unit starts producing useful output at about 2.5% "on" time as the result of the lower off cycle jacket loss and the lower air flow rate through the flame retention burner during the off-cycle. It also has a higher steady state efficiency, having a lower stack temperature and a lower jacket temperature. At the 15% "on" time this would have a seasonal

efficiency of 74% and if the typical 2x overfiring input rate were reduced to 1x the average "on" time would go to 30% and the seasonal efficiency would increase to well over 80% as would the steady state efficiency.

The top curve represents a conservative estimate of the BNL FAB-low mass low input boiler-burner unit demonstrated here. With its very low jacket loss and its 300F gross stack temperature the steady state efficiency could be nearer 88%. The outlet water temperature rise was timed at 0.5F/sec so that the required "on" time is essentially zero when the unit delivers useful heat. With the very low water content of ~.42 gallons it would take very little time to purge the boiler's heat into a zone at the end of a cycle. This would reduce the off-cycle loss to zero. But even without that purge the burner average on time would typically be near 30% at which point the annual efficiency would be at the steady state value of 86%.

### **Future plans**

BNL has determined that operating at reduced excess air reduces fouling resulting from sulfuric acid corrosion (Reference 2.) The FAB often produces less CO and deposits less soot at lower O<sub>2</sub> settings. Because of this characteristic, there is a strong motive to operate reliably at very low O<sub>2</sub>.

Figures 3, 4, and 5 show that by reducing the excess air the fouling rate of a boiler or furnace is reduced; not increased as has been assumed all these years until recently. The sulfuric acid created by the generation of SO<sub>3</sub> when excess air is present, not only reacts with the boiler to form iron sulfate scale, but at the same time it increases the rate which soot collects on that fouled surface.

The FAB burner has the propensity to remain at zero smoke even at or very near zero O<sub>2</sub>. By using a brushless DC motor that is electronically commutated, it is possible to trim the motor speed using pulse width modulation with the permanent magnet (PM) DC motor or, in the case of the switched reluctance (SR) DC motor, by using frequency modulation. The speed trim (O<sub>2</sub> trim) would respond to a signal from an O<sub>2</sub> sensor or another signal analogous to excess air. This would simultaneously optimize efficiency while minimizing fouling and with proper combustion chamber geometry, could minimize CO with low NOx.

By using the FAB with this low mass boiler design there is a potential to build a very clean low cost unit with a very low cost of operation and maintenance.

Ways to automatically control the O<sub>2</sub> should be investigated. The use of coatings on the heating surfaces to reduce fouling should be investigated. CO and NOx reduction efforts will continue. A low-high-low FAB boiler version will be considered. Low sulfur fuel has now been clearly demonstrated to reduce fouling. Efforts to promote the use of low sulfur (.05%) fuel for heating will be recommended.

This IHS boiler has low mass, low water content, low jacket loss, counterflow Hx, and zero off-cycle "stack" loss each of which will contribute to high AFUE and to high output/input efficiency. Detailed testing of the IHS boiler's performance will be conducted at BNL this year and will be reported at the 1997 Oil Heat Technology Conference.

REFERENCES:

1. J. E. Batey, T. W. Allen, R. J. Mc Donald, R.J. Hoppe, F.J. Salzano, and A. L. Berlad, Direct Measurement of the Overall Efficiency and Annual Fuel Consumption of Residential Oil Fired Boilers, BNL 50853, January, 1978.
2. T. A. Butcher, Ph. D., Yusuf Celebi, and George Wei Fouling of Heat Exchanger Surfaces, BNL Paper No. 91-4.

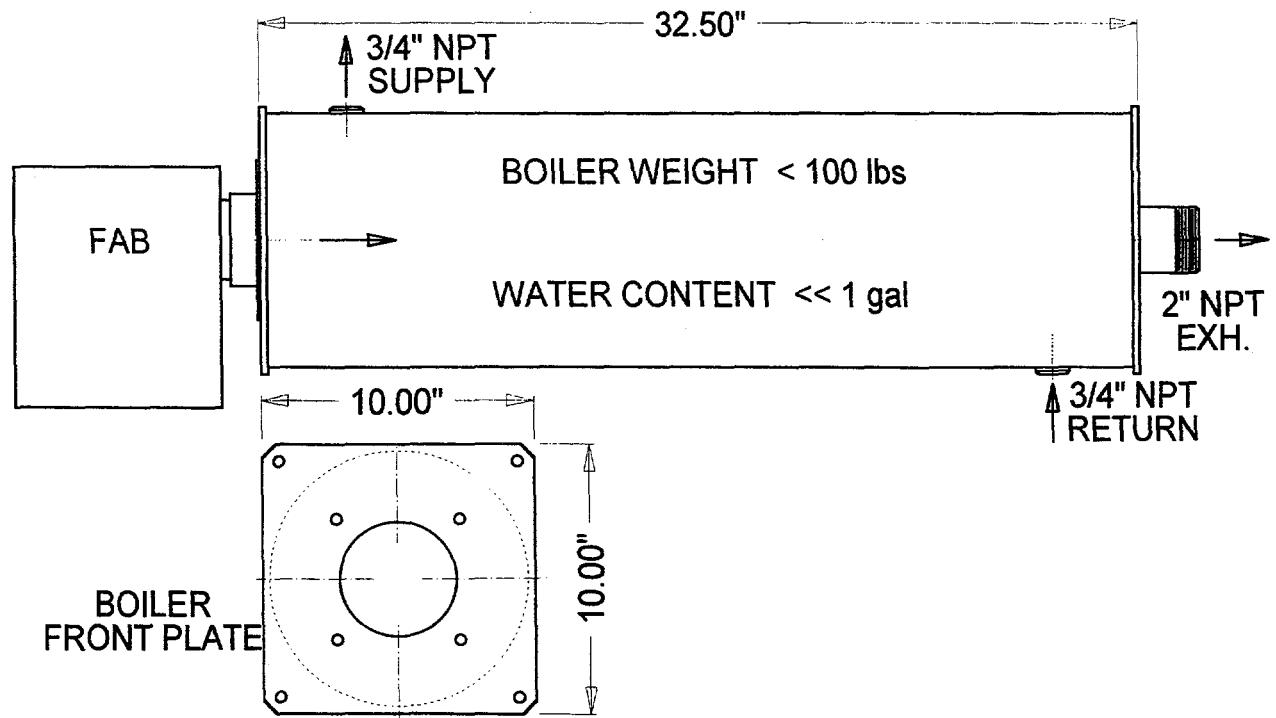


Figure 1. Ultra Low Mass Boiler for the FAN Atomized Oil Burner

## BOILER COMPARISON

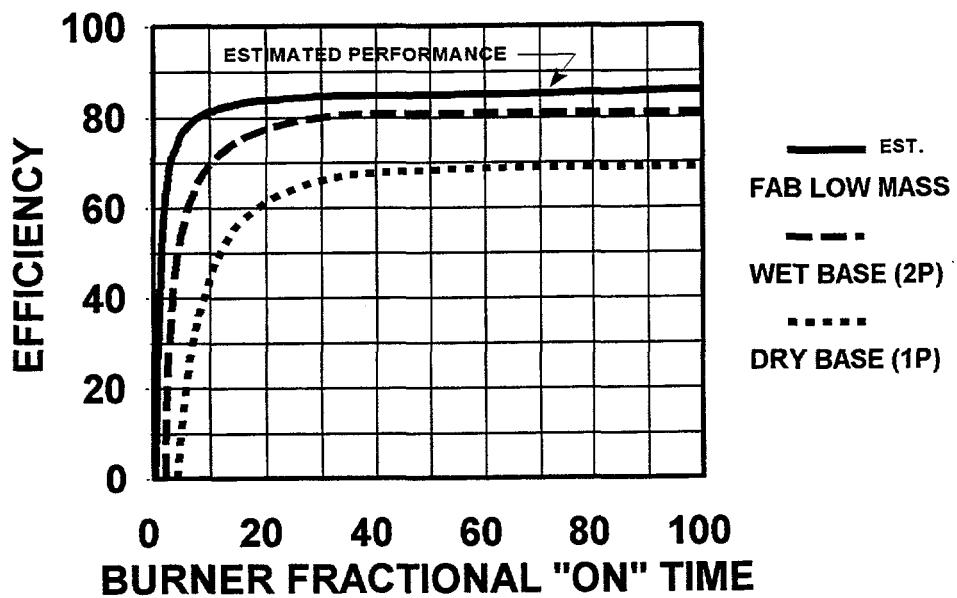


Figure 2. Overall Efficiency vs. Burner Fractional "ON" Time

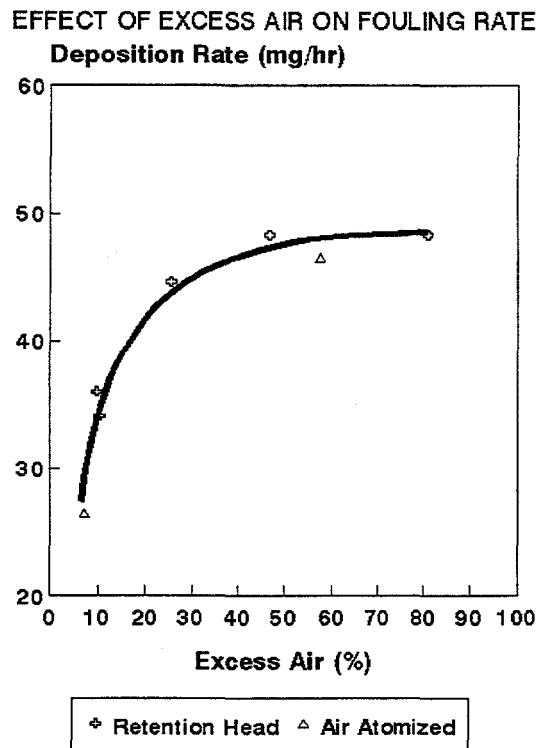


Figure 3. Effect of Excess Air on Iron Sulfate Rate

EFFECT OF EXCESS AIR ON SOOT RATE  
Non-Sulfate Deposition Rate (mg/hr)

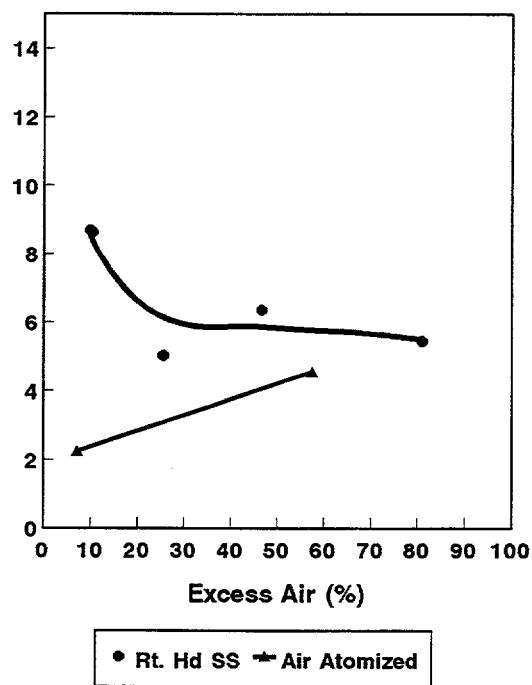


Figure 4. Effect of Excess Air on Soot Rate

EFFECT OF EXCESS AIR ON IRON SULFATE RATE  
Iron+Sulfate Deposition Rate (mg/hr)

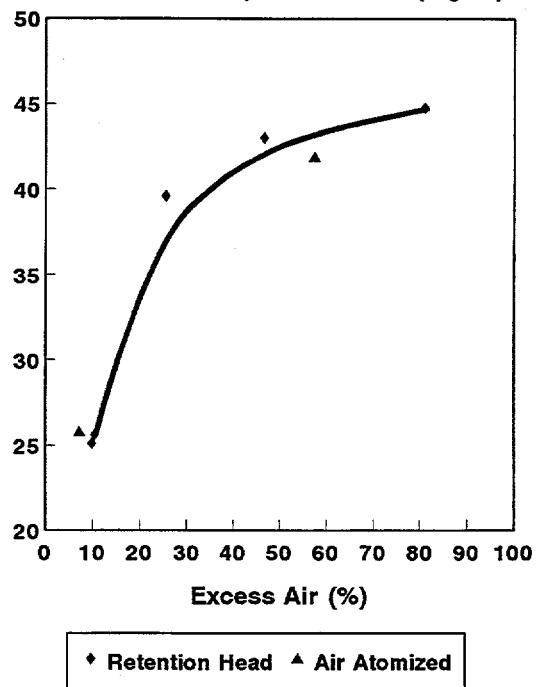


Figure 5. Effect of Excess Air on Fouling Rate

**FAN ATOMIZED BURNER DESIGN ADVANCES & COMMERCIAL  
DEVELOPMENT PROGRESS**

Bola Kamath  
Heat-Wise, Inc.  
Whiskey Rd.  
Ridge, NY 11961

and

Thomas A. Butcher, Ph.D.  
Brookhaven National Laboratory  
Department of Applied Science  
Building 526  
Upton, NY 11973-5000



## Fan Atomized Burner Design Advances and Commercial Development Progress

Bola Kamath  
Heat Wise Inc.

Thomas A. Butcher  
Brookhaven National Laboratory

### **Brookhaven Development Goals**

As a part of the Oil Heat Research and Development program, sponsored by the U.S. Department of Energy, Brookhaven National Laboratory (BNL) has an on-going interest in advanced combustion technologies. This interest is aimed at: improving the initial efficiency of heating equipment, reducing long term fouling and efficiency degradation, reducing air pollutant emissions, and providing practical low-firing rate technologies which may lead to new, high efficiency oil-fired appliances. The Fan-Atomized Burner (FAB) technology is being developed at BNL as part of this general goal.

The Fan-Atomized Burner uses a low pressure, air atomizing nozzle in place of the high pressure nozzle used in conventional burners. Because it is air-atomized the burner can operate at low firing rates without the small passages and reliability concerns of low input pressure nozzles. Because it uses a low pressure nozzle the burner can use a fan in place of the small compressor used in other air-atomized burner designs. High initial efficiency of heating equipment is achieved because the burner can operate at very low excess air levels. These low excess air levels also reduce the formation of sulfuric acid in flames. Sulfuric acid is responsible for scaling and fouling of heat exchanger surfaces.

### **The BNL Fan-Atomized Burner Prototype**

Progress in the development of the Fan Atomized Burner at BNL has been reported at earlier Oil Heat Conferences and in a BNL report [1-4 ]. Important design improvements which have been made in the FAB prototype during the past year include: modifications to the nozzle internal passages which lead to smaller oil film size and better atomization and ignition, use of a solenoid fuel pump, and use of a back pressure type fuel regulator. Figure 1 is a schematic of the current version of the BNL prototype burner. Air at the required pressure is provided by a 5 inch diameter plastic blower driven by a brushless DC motor at high speed. At the nozzle the required fuel pressure is less than 1 psi. The electric solenoid fuel pump is used in combination with a bypass type pressure regulator (typically set at 7.5 psi) and a metering orifice to deliver the required amount of fuel to the nozzle. The control being used has interrupted ignition and provides programmable pre- and post-purge.

As a result of the improvements made internally to the nozzle the atomizing air pressure required for good combustion performance is lower. In the current BNL prototype, air pressure is about 8

inches of water although combustion testing has been done at lower pressures. Figure 2, for example, shows the results of combustion tests with the burner over a range of air pressures.

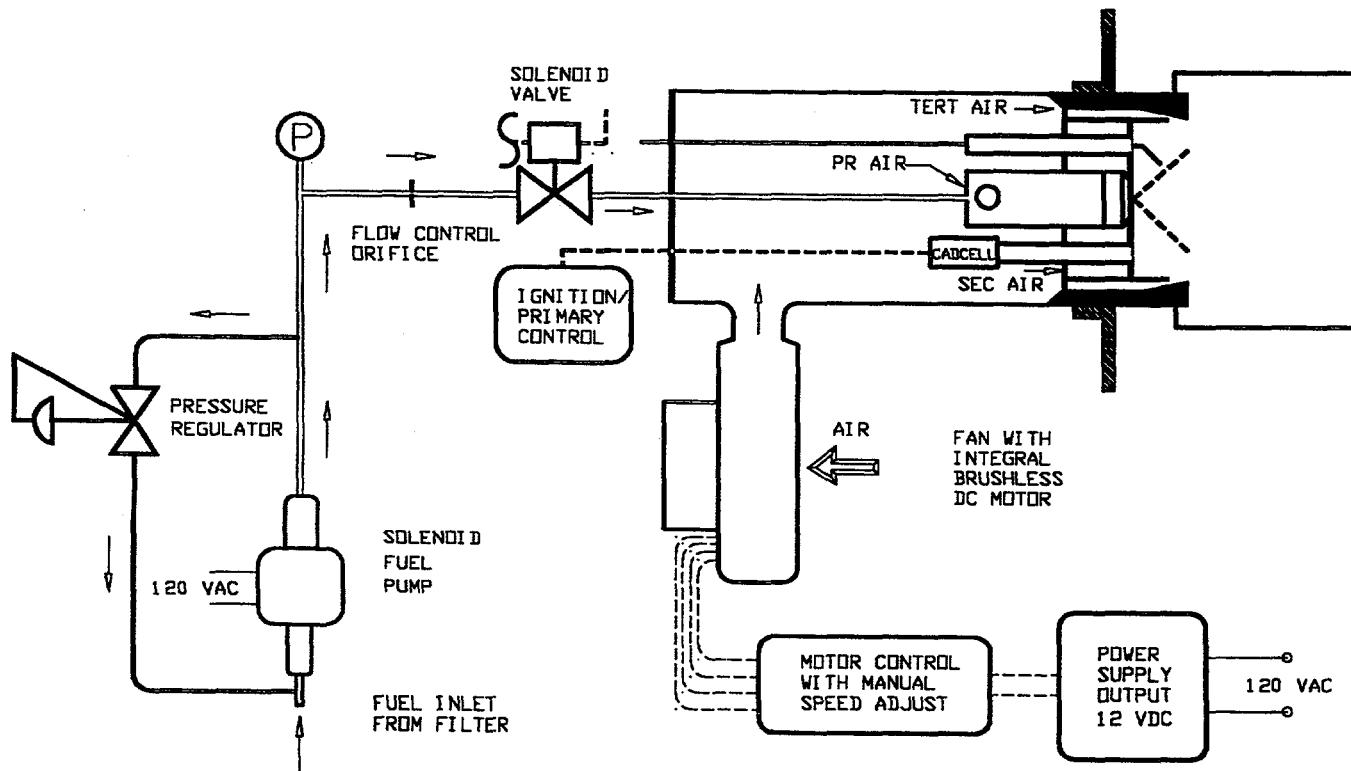


Figure 1. Schematic of BNL prototype burner system.

The solenoid pump currently being used has a dry lift capability of about 8 feet and a large enough flow capacity to allow rapid removal of air during installation. A disadvantage of this type of pump, relative to a conventional fuel pump, is the effect that a fuel line filter partial plug has on firing rate. As the inlet fuel filter starts to become blocked, a conventional pump will maintain nearly the same firing rate to a higher level of inlet vacuum than with the FAB prototype system. A major advantage of the BNL prototype system is low electric power consumption - about 80 watts, compared to 180-230 watts with a conventional retention head burner.

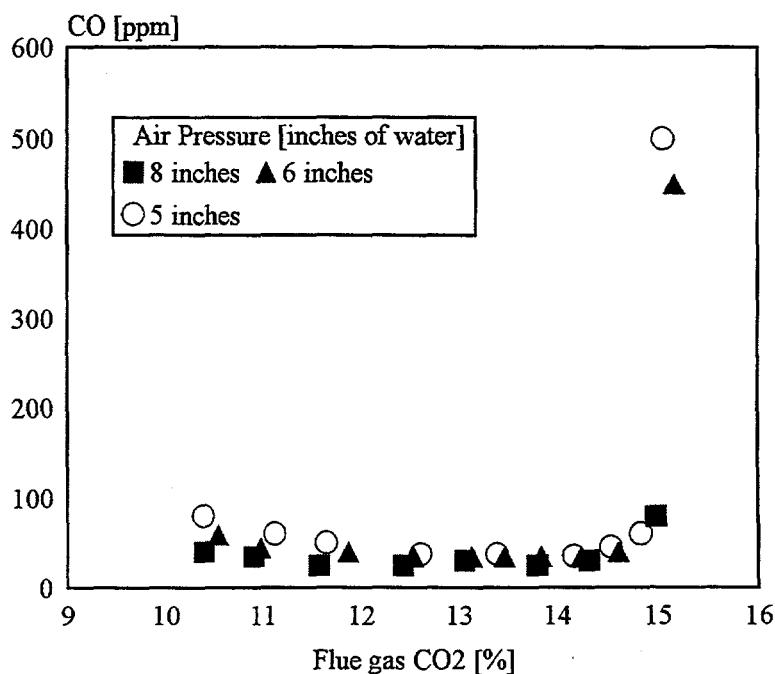


Figure 2. Effects of FAB air pressure on CO/excess air relationship. Steel boiler, all tests at 0.35 gph, smoke number = 0 for all conditions except very highest CO2

## Commercialization Program

Currently the FAB concept is being commercialized by Heat Wise, Inc. in a cooperative program involving New York State Energy Research and Development Authority, BNL, and the Department of Energy - Office of Building Energy Research. Under this program Heat Wise is developing a commercial version of the burner, will obtain a certification listing, and begin to market the burner. BNL is providing technical support to Heat Wise and continue to advance the development of the burner.

## Heat Wise Commercialization Approach

Heat Wise, Inc is a start up manufacturing company that has been producing oil burners for over 6 years. Heat Wise places a strong emphasis on research and development, in order to offer the consumer environmentally safe, fuel efficient burners.

Heat Wise has taken the following steps to commercialize this technology in cooperation with New York State Energy Research and Development Authority (NYSERDA) [5]. The first and foremost goal of this effort is to make this technology complimentary with existing oil heat technology. The conventional pressure atomized burners listed currently start at 0.5 GPH. Some burners are listed at 0.4 GPH for #2 fuel oil. However, there are a few hot air furnaces listed to fire at 0.5 GPH, and they end up using Kerosene or 0.6 GPH nozzles in the field. There is a clear need to use #2 fuel oil in the field below 0.6 GPH. Therefore, Heat Wise decided to go below these firing rates and start with a design target of 0.25 GPH to 0.65 GPH.

The burner had to look as conventional as possible, with as many standard parts as possible, so that the cost of this burner would not be objectionable for an O.E.M. market (who alone can bring this technology to the market place). An in depth evaluation of all available parts was done by Heat Wise with the main priority seen as the burner housing. In studies at BNL it had been concluded that the pressures required for this burner concept could not be achieved with a regular burner fan housing. Therefore, all the BNL tests were done using a brushless D.C. motor, which could generate 5" to 10" W.C. pressure. Yusuf Celebi's (from BNL) recent work with nozzle fuel distributors showed the importance of establishing an upper limit on hole size

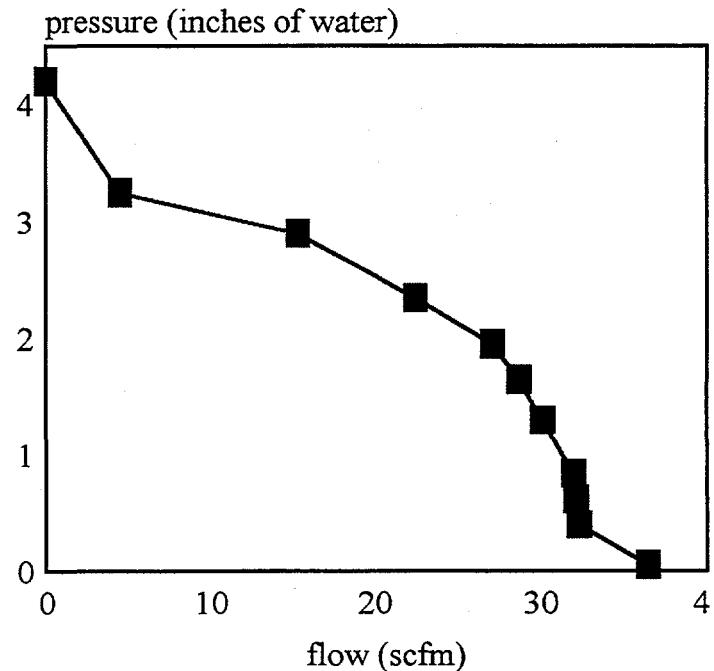


Figure 3. Fan performance curve - Heat Wise BK-1 burner.

and number of holes. Heat Wise worked with these set limits, first with a Heat Wise BK-1 burner housing. Fig.3 shows the basic performance curve for this fan (unthrottled inlet). It is a steep curve, which is hardly influenced by changes in draft [6]. Heat Wise used this housing and a modified version of BNL's FAB burner head and fired the burner using a gravity feed for oil flow by a 7' high day tank (3PSI). The results obtained are shown in Table 1.

Table 1. Test Results BNL FAB Burner Head Combined with BK-1 Burner Fan

Firing rate (gph)	Blower pressure (inches water)	CO (ppm)	Oxygen (%)	CO <sub>2</sub> (%)	NO <sub>x</sub> (ppm)
0.20	3.5	27	1.6	14.4	38
0.20	3.5	31	3.1	13.4	39
0.20	3.4	21	6.9	10.5	30
0.24	3.45	141	0.4	15.4	32
0.24	3.5	101	0.6	15.2	30
0.24	3.5	71	1.6	14.5	44
0.24	3.4	175	1.7	14.4	37
0.24	3.35	65	7.2	10.3	25
0.30	3.3	90	1.2	14.7	45
0.30	3.3	90	1.2	14.7	45
0.35	3.3	153	1.0	14.9	46
0.35	3.3	243	1.1	14.8	35
0.35	3.25	226	2.7	13.6	41

The above results were encouraging and follow the chemistry of NO<sub>x</sub> and SO<sub>3</sub> to achieve cleaner combustion with oil heat. After collecting enough data, Heat Wise will publish articles on this subject. A 0.20 GPH flow rate was achieved, a dream of burner manufacturers around the world, using mostly conventional items. These items include: 3450 RPM, PSC motor which has been accepted in the field [7], a regular transformer, and a regular safety control. The aim is to get the lowest auxiliary power needed to fire this burner at very low firing rates. A gravity pressure of 3 PSI was relied upon to deliver the fuel. At 0.35 GPH, air supply decreased and CO began increasing. Although these CO readings are comparable to standard oil burners, the goal of Heat Wise was to stay below 50 PPM of CO for all applications. Further tests have supported this trend and in most situations, the burner stayed below 50 PPM of CO. After the 1994 death of tennis great Vitas Gerulaitis from CO poisoning, consumer awareness has created a huge industry for CO detectors.

False alarms by these detectors remain a problem for manufacturers and listing agencies, such as U.L. [8]. Heat Wise is collecting data on this subject, which will benefit the oil industry's understanding of CO.

In laboratory tests, it was possible to reach nearly stoichiometric combustion results with 15% CO<sub>2</sub> and less SO<sub>3</sub> formation, which causes less corrosion of the boiler [9,10]. Also we could fire the burner with 10% + CO<sub>2</sub>, which is what most oil service managers like to see in the field. After establishing the lower limit of our own set standards, it was possible to concentrate on reaching higher firing gallonage.

Two more burner housings were selected for evaluation. These were modified to deliver between 5 and 10 inches of water maximum static pressure. Both these housing were packaged with standard parts, except for the nozzle. The nozzle used in the BNL prototype has been modified to the manufacturing goals of Heat Wise to be competitive in the market place with standard nozzles. Fig. 4 shows the fan performance curve from one of these housings, which has been finalized.

One general complaint about oil burners is the noise factor. Heat Wise concentrated on this subject, and determined that an outside air supply attachment, with an air filtering device, would greatly reduce noise. The results from these studies speak for itself. The burner is quieter than conventional oil burners. The air is filtered and only clean air is obtained for combustion. However, to achieve high combustion efficiency and reduction of flue products (like CO, NO<sub>x</sub>, and SO<sub>3</sub>), this burner cannot be forced to work with laundry lint, animal hairs, and dirt from basements.

We now have a burner that can fire from 35,000 BTU and up, filling a very important gap in the oil industry. This product is the result of a joint effort by Heat Wise and Dr. Tom Butcher and his associates, especially Yusuf Celebi and Len Fisher.

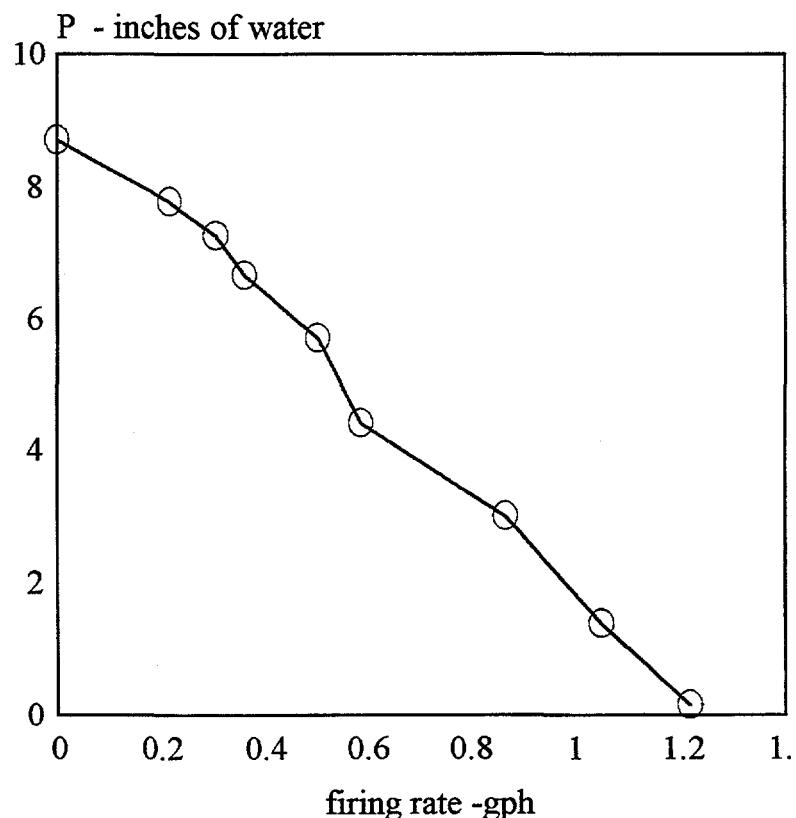


Figure 4. Pressure/flow curve for fan used in Heat Wise burner. Flow expressed in terms of equivalent oil firing rate assuming nominal excess air.

## Future Plans

In future activities BNL will continue to improve the burner head design for specific applications, support Heat Wise, and pursue the development of a two-stage version of the burner. With a two-stage burner both very high efficiency and high capacity can be attained with boilers and furnaces currently on the market. Heat Wise is planning for a 100 unit limited production run prior to the 96/97 heating season and will market the burner on a limited basis.

## References

1. Celebi, Y., Butcher, T., Gang, W. Research in oil burner design and emissions control. Proc. of the 1990 Oil Heat Technology Conf. and Workshop, Upton, N.Y., May 21-22, 1990. BNL 52284, November 1990.
2. Butcher, T., Celebi, Y. and Fisher, L. The Fan-Atomized Burner - status and application testing. Proceeding of the 1994 Oil Heat Technology Conference and Workshop, Upton, N.Y., March 24-25, 1994. BNL 52430, April 1994
3. Butcher, T., Celebi, Y. and Fisher, L., The BNL Fan Atomized Burner system prototype, Proceedings of the 1995 Oil Heat Technology Conference and Workshop, Upton, N.Y., March 22-23, 1995. BNL 52470, April 1995.
4. Butcher, T. Advanced oil burner for residential heating - development report, BNL Informal report 62077, September, 1994.
5. McDonald, R. Brookhaven and NYSERDA launch research project with Heat Wise. BNL Press Release, July 1995.
6. Kamath, B.R., New fan concept improves burner performance, Fuel Oil/ Oil Heat and Solar Systems Magazine, October 1982.
7. Nelson, D. The basics of single phase motors, Fuel Oil News, p. 39, Jan. 1996.
8. Kamath, B.R., Fuel Oil and Oil Heat, 50, 43, Jan. 1991.
9. How oil heat can remain more efficient than gas. Fuel Oil and Oil Heat, Sept. 1992.
10. Butcher, T. and Celebi, Y. Fouling of Oil-Fired Boilers and Furnaces, Proceedings of the 1993 Oil Heat Technology Conference and Workshop, Upton, N.Y., March 25-26, 1993. BNL 52392, September, 1993.

**FIELD TESTS - LOW INPUT, SIDE-WALL  
VENTED BOILER**

W. L. Litzke, Thomas A. Butcher, Ph.D., and Yusuf Celebi  
Brookhaven National Laboratory  
Department of Applied Science  
Building 526  
Upton, NY 11973-5000



## 1. INTRODUCTION

The Fan Atomized Burner (FAB) was developed at Brookhaven National Laboratory as part of the Oil Heat Combustion Equipment Technology Program to provide a practical low-firing rate technology leading to new, high efficiency oil-fired appliances. The development of the burner design and results of application testing have been presented in prior oil heat conferences over the past several years. This information is also summarized in a more comprehensive BNL report<sup>1</sup>. The first field trial of a prototype unit was initiated during the 1994-95 heating season<sup>2</sup>. This paper presents the results of the second year of testing, during the 1995-96 heating season.

The field tests enable the demonstration of the reliability and performance of the FAB under practical, typical operating conditions. Another important objective of the field test was to demonstrate that the low input is adequate to satisfy the heating and hot water demands of the household. During the first field trial it was shown that at a maximum input rate of 0.4 gph (55,000 Btu/hr) the burner was able to heat a home with over 2,000 square feet of conditioned living space and provide adequate supply of domestic hot water for a family of six. The test site is located in Long Island, N.Y.

During the second field trial additional data were obtained to compare the efficiency of the FAB, under different modes of operation, with other heating system arrangements using two different type of boilers and commercially available burners. The results are summarized in this paper.

Also discussed in this paper is the bin analysis that provides local, seasonal information on the total load in Btu/hr on the heating system with the outdoor temperature. With this information the electricity used by the FAB and the electric cost for its operation over a heating season can also be calculated and compared with that of a conventional heating system.

In the FAB the oil is atomized with air supplied by the burner's fan. A single fan is used to provide all of the air for this burner. The air is delivered at a pressure of about 8 inches of water. Some of this air goes through the nozzle, atomizing the fuel; the remainder passes around the nozzle providing air into the flame zone to complete combustion. The nozzle is designed to provide a very small oil film for good atomization and ignition. The burner uses a solenoid fuel pump, and a back-pressure type fuel regulator. Air at the required pressure is provided by a plastic blower driven by a brushless DC motor at high speed. The control being used has interrupted ignition and provides programmable pre- and post- purge. For the complete details of the design of the most recent version of the FAB prototype refer to the accompanying paper (Paper No. 96-6) of these proceedings.

## II. DESCRIPTION OF TEST SITE

The test site is a one-family home located in Long Island, N.Y. Shortly before the start of the initial field trial in 1994, an addition to the existing house was completed that included a family room over a new basement. With this addition the house has a total of approximately 2,000 square feet of conditioned space. The layout of the test site during the 1995/1996 heating season is essentially the same as that used for the 1994-95 heating season. Before setup for the field test began the home

heating system consisted of a dry-base steel boiler (Repco) approximately 17 years old with a conventional retention head burner. Originally firing at 0.85 gph this had been downfired by the homeowner to a 0.65 gph nozzle operating at 130 psi. This system is chimney vented. Performance measurements with this system were made to compare with the FAB test system. For the purposes of these tests, this old system will be referred to as the baseline system. The new, test heating system was installed in the new basement and consisted of a compact, side-wall vented, commercial hydronic boiler (Thermo Dynamics), coupled with an insulated 40-gallon indirect hot water storage tank. This unit was operated with forced venting, an induced draft fan was not used. Combustion air was drawn from within the basement. The storage tank has an internal heat exchanger and was installed as a priority zone. Data was taken with this new test system with the FAB and another modern conventional retention head burner (Beckett AFII), firing at 0.75 gph. In the case of the FAB, pre- and post- purge periods were controlled by the primary control and both were set for 15 seconds. In the case of the retention head burner a separate post purge control timer was used, set for 1 minute of post purge following the manufacturer's recommendations. A summary of the operating conditions of each of these systems is found in Table 1. A series of valves and switches were arranged to allow for simple switch-over from one heating unit to the other to satisfy the home's heat and domestic hot water demands.

System Description	Steady State Stack Temp (°F)	Excess Air (%)	Power Consumption (watts)	Steady State Efficiency (%)
<u>Baseline</u> Repco boiler (#1), retention head burner 0.65 gph	450	60.5	200	82.3
<u>FAB</u> in Thermo Dynamics boiler (#2), 0.35 gph	300	15	75	88.7
<u>Retention Head</u> in Thermo Dynamics boiler (#2), at 0.75 gph	450	34.5	200	84.1

Table 1. Description of heating systems tested in the field.

### Instrumentation

The main components of the field test system consisted of precision, positive displacement fuel meters to monitor the oil consumption, and Btu meters to measure the amount of energy provided to the hydronic system for heating, and from the storage tank to the domestic hot water system. Thermocouples were installed to measure the temperature of the stack, vent, indoor/outdoor air, water supplying the storage tank, and throughout the heating zones. A datalogger was installed

to continuously record the stack and water temperature to the tank. This gives information on when the burner is on and when there is a hot water demand.

All of the Btu meters installed for the field test were initially calibrated prior to installation. However, the field data showed that the Btu meter readings appeared to be consistently low when efficiencies were calculated using this information. It was determined that the configuration of the water supply piping and the installed Btu meters affected its measurements. Btu meters have an internal temperature sensing device, a remote temperature sensor probe, and a flowmeter. To evaluate the source of the apparently low readings the Btu meters were returned to the laboratory for recalibration. This included the installation of these field test meters into a boiler test system with exactly the same piping configuration as that found in the field with the Thermo Dynamics boiler. The meters were installed on the return-side to the boiler. By measuring the actual mass flowrate of the circulating water and the temperature difference between the supply and return side of the boiler the energy delivered was calculated and compared with the Btu meter reading. A correction factor was then generated for all efficiency calculations.

### **Modes of Burner Operation**

On the new test boiler system both the FAB and retention head burners were tested in two modes of operation - with and without constant circulation. Under normal operation, without constant circulation, the heat distribution is controlled with a priority controller to satisfy the water temperature within the storage tank first before heating the zones of the house. With constant circulation one of the heating zones is always left open so that, when the burner is not cycling, the excess heat in the boiler is purged into this zone. This becomes "useful" heat and is measured by the Btu meter. Effectively, this helps to minimize the standby losses associated with the burner off-cycle.

## **III. RESULTS**

### **Bin Analysis**

In a bin analysis, the heating season is divided into 5 degree temperature "bins" and efficiency, total on-time, fuel use, and electric power use in each bin are analyzed separately. Results in each bin can then be added to determine season totals.

To do this analysis engineering weather data was obtained for the local area at Suffolk County/Westhampton Beach, New York<sup>3</sup>. This data contains information on the number of hours observed for each outdoor temperature range, or bin, over the entire year. Each bin consists of five-degree intervals, for example 30-34°F is the temperature range for one of the bins. Figure 1 shows the distribution of annual outdoor temperatures for the test site area. The annual hours is plotted as a function of the mean temperature of the associated bin. This information was used to calculate typical heating degree days, and make energy consumption estimates for the test site.

The total energy demand for heating the test home and providing domestic hot water depends on the outdoor temperature. Field measurements for energy usage were obtained from the Btu meters for both supplies. Local weather data was obtained for the 1995-96 heating season to

determine the correlation of energy use with degree hours. Figure 2 shows the amount of heat delivered to the baseboards as a function of degree hour, and based on this correlation we have determined that 614 Btu/deg.hr is needed for heating.

For the domestic hot water requirement in the bin analysis we assumed a typical water usage of 63 gallons/day, and that the water supply is heated from 60°F to 135°F. Measurements at this site showed that these are quite representative. This gives a constant load of 1642 Btu/hr and is independent of the outdoor conditions.

Using the bin analysis, as described above, we calculated the total average energy used as a function of outdoor temperature for a typical heating season. Using the mean temperature for each bin the average load associated with it was determined and the results are plotted in Figure 3. These results show that for a moderately sized home with average heating and water usage, the maximum amount of energy needed is about 40,000 Btu/hr at the coldest temperatures.

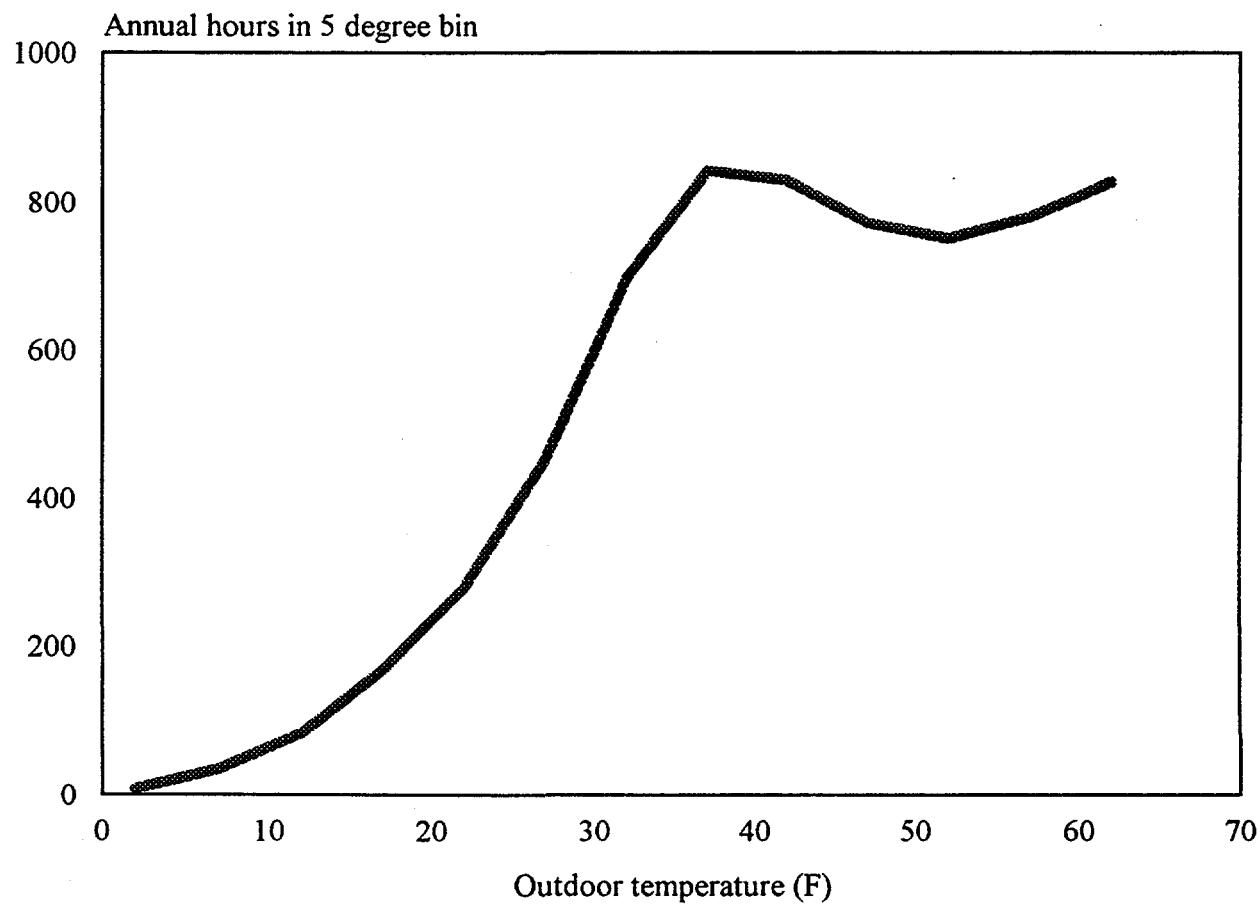
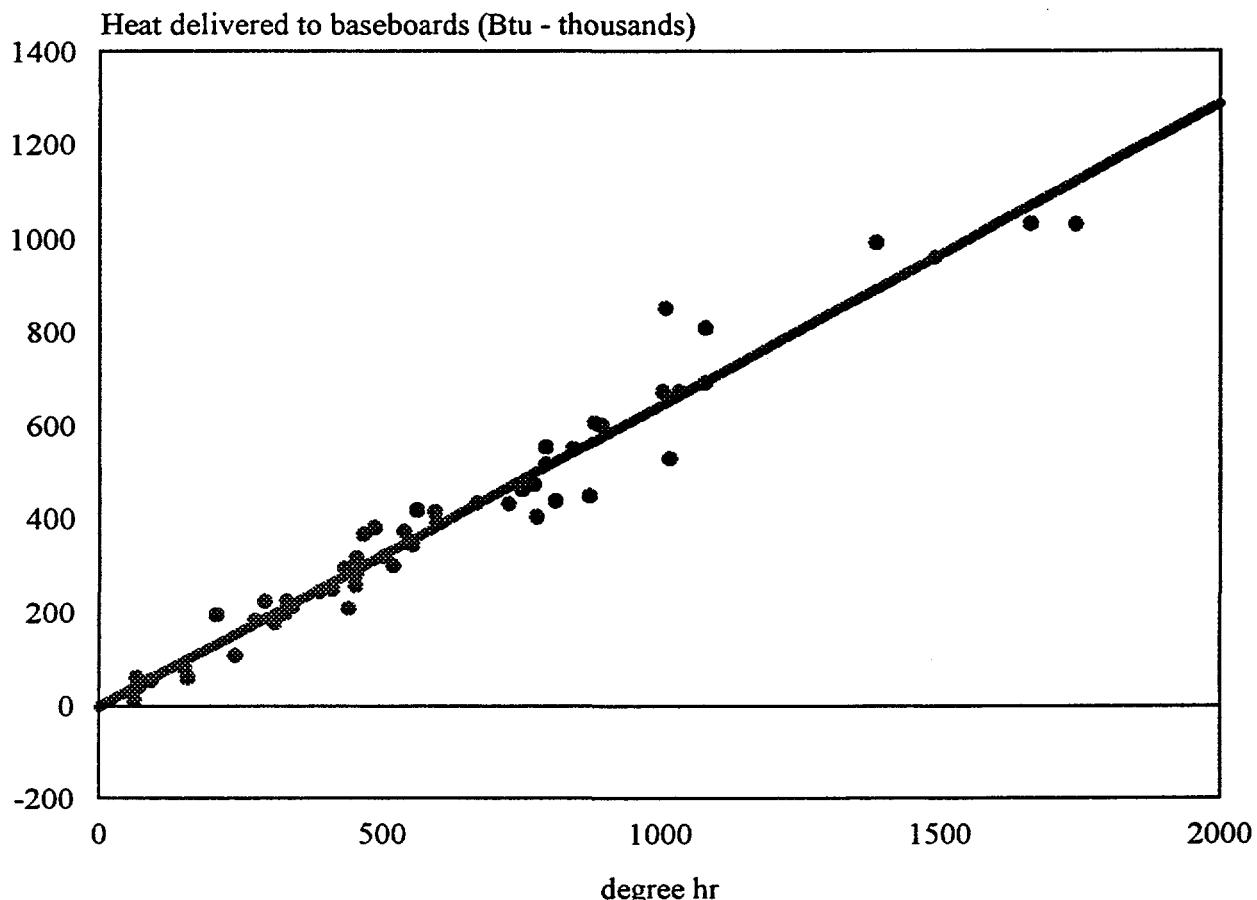


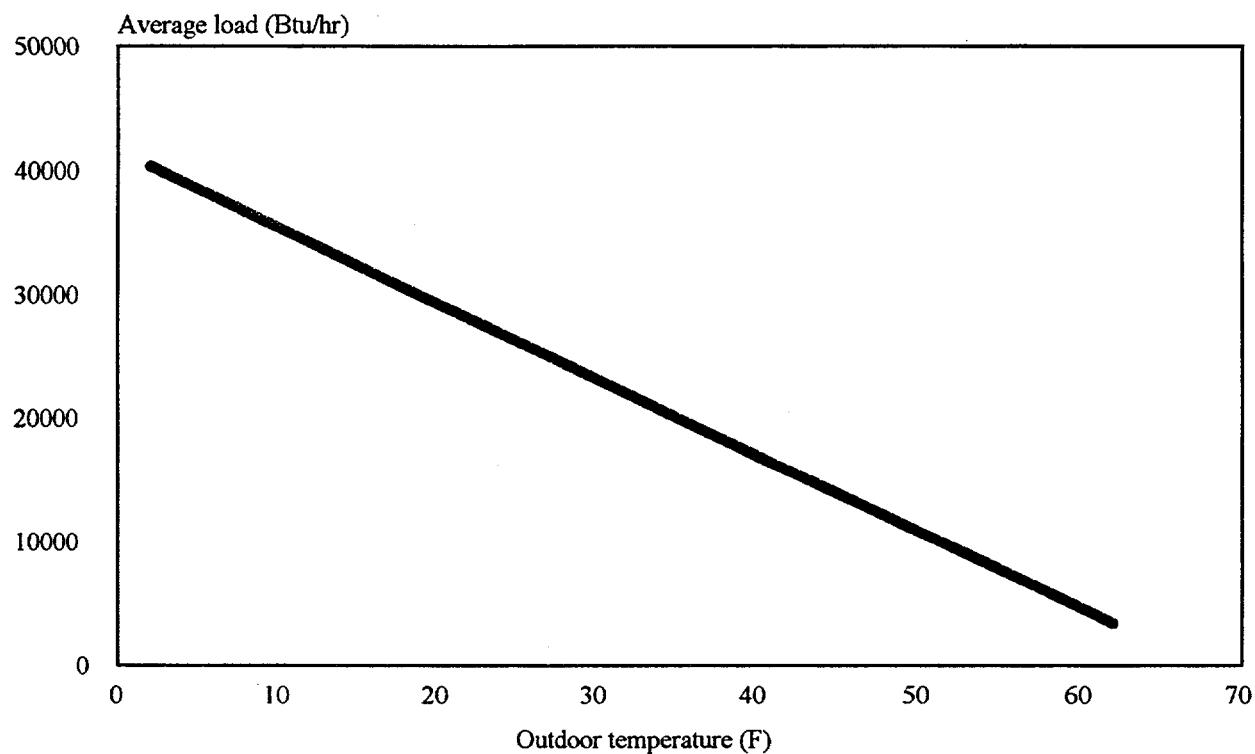
Figure 1. Bin data of annual hours in outdoor temperature range.



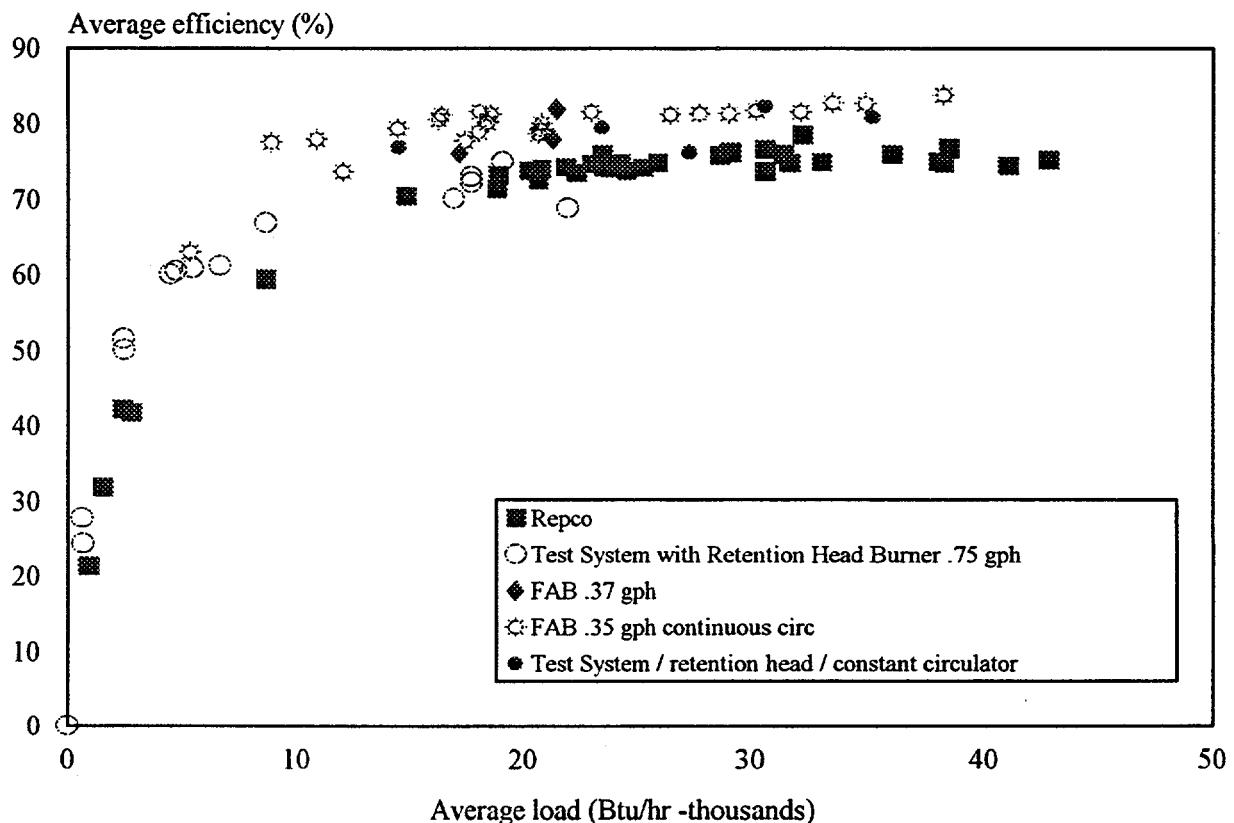
**Figure 2.** Field test results. Correlation of heat delivered to baseboards with outdoor temperatures.

### System Efficiency

The efficiency of the heating system was determined by the ratio of the energy delivered to the baseboards and hot water tank, as measured with the Btu meters, and the amount of energy consumed as measured by the fuel meter. System efficiencies were calculated for five systems: baseline system in boiler #1 (Repco); FAB in boiler #2 with and without constant circulation; and flame retention head burner in boiler #2 with and without constant circulation. Figure 4 shows the average system efficiencies as a function of average load for each case. As the load decreases the efficiencies drop markedly. In general, the baseline system was the least efficient. At the higher loads, between 18,000 to 38,000 Btu/hr, the baseline system had an efficiency of about 75% and the FAB averaged 82%, the efficiency of the retention head burner with constant circulation was very close to the FAB and averaged about 80%. The mode of operation of the system with the FAB, with or without constant circulation, does not appear to be make much difference. For the test system with the retention head burner the data shows an improvement with constant circulation, particularly at the intermediate loads.



**Figure 3.** Average total energy consumption for heating and domestic hot water as a function of outdoor temperature.



**Figure 4.** Average efficiency of different test system configurations as a function of load.

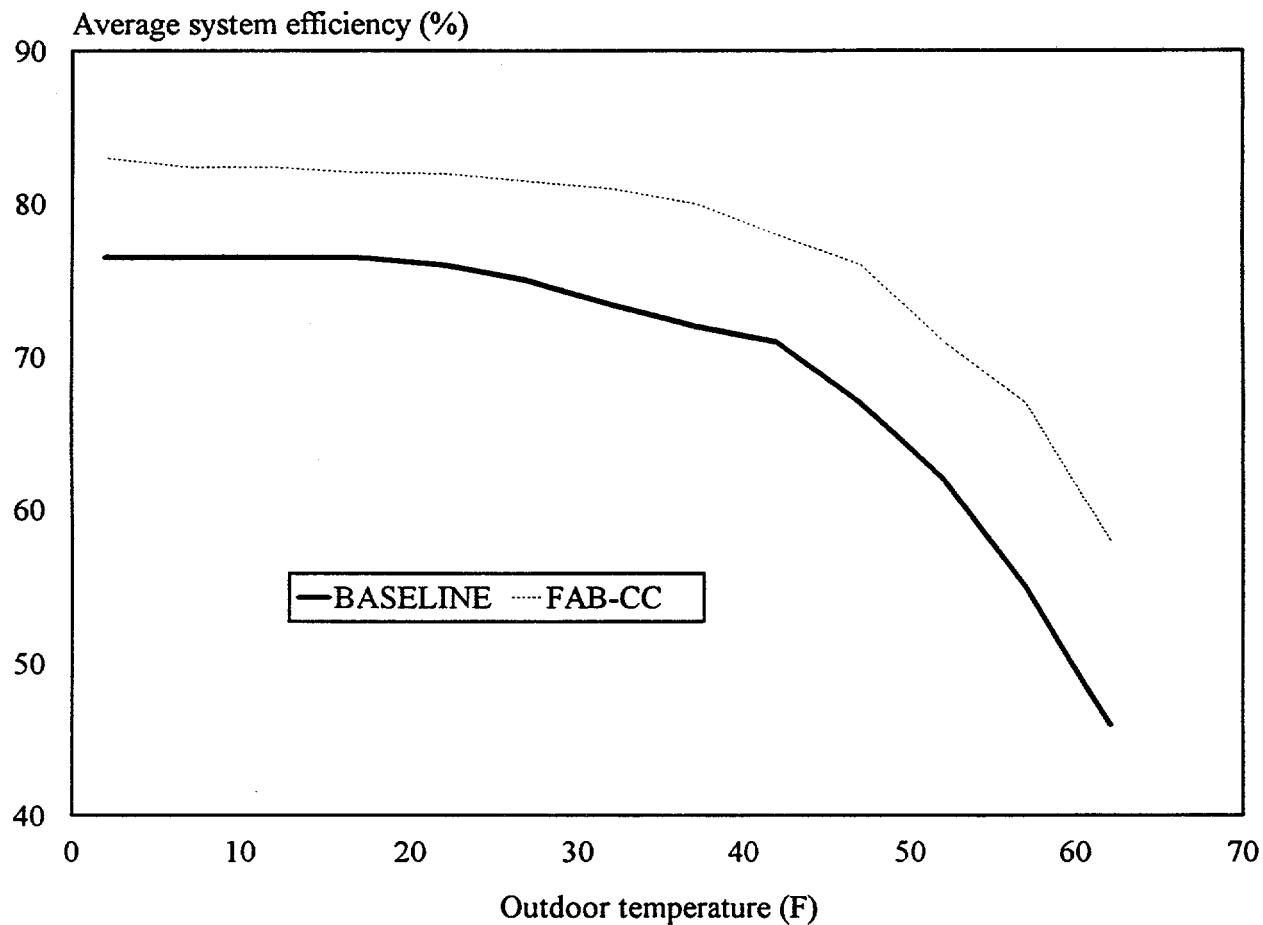
The average system efficiency with respect to the outdoor temperature is shown in Figure 5. Data for two systems are presented - the baseline system and the FAB with constant circulation. This provides a practical representation of the effects of heating system operation with ambient conditions. Notice that for both systems the efficiencies are at the highest levels below 35°F and drop rapidly above this temperature. The maximum efficiency measured for the baseline is 77% and for the FAB is 83%.

The system efficiency consists of both heating and domestic hot water system contributions. A look at these separate components shows that the efficiency of the latter is much lower than the first. Table 2 shows the values calculated for four modes of operation - FAB with and without constant circulation, and the flame retention head burner (Beckett AFII) with and without constant circulation. The calculations were made for specific time periods when there was a large heat demand and very little domestic water usage. The values for each mode of operation varies somewhat since the efficiency is dependent on outdoor ambient conditions. Apparently, the off-cycle losses associated with the hot water storage tank contribute to the low efficiencies and, as a result, reduces the overall system efficiency. For low outdoor temperatures the FAB fires for very long periods of time and the heating efficiency approaches a steady state efficiency close to 87%.

Date	FAB-NCC	FAB-CC	AFII-CC	AFII-NCC
11/15/95	76.8			
11/16/95	81.9			
11/22/95		77.5		
11/23/95		86.7		
1/15/96				79.3/30.4
1/15/96				77.3/29.6
1/16/96			84.8/13	
2/1/96		86.2/5.4		
2/3/96		83.3/43.6		
2/6/96		84.7		

CC-constant circulation; NCC-no constant circulation

Table 2. Analysis of efficiency contributions for heating/domestic hot water.



**Figure 5.** Average system efficiencies as a function of outdoor temperature for baseline heating system and FAB with constant circulation.

#### Fuel and Electrical Energy Consumption

Using the bin analysis and system efficiency results as a function of load, the total fuel usage and electrical energy consumption were calculated for the typical heating season. The information required is the total hours observed for each bin, the total average load for each bin from Figure 2, and the system efficiency associated with that load from Figure 3 to obtain the heat input needed to meet the load. This gives the total gallons of fuel input over a typical heating season. The following equation was used:

$$\text{Total fuel input (gal)} = \text{Avg. load } \left( \frac{\text{Btu}}{\text{hr}} \right) * \frac{\text{Total hours in bin (hr)}}{\text{Efficiency} * 140,000 \left( \frac{\text{Btu}}{\text{gal}} \right)}$$

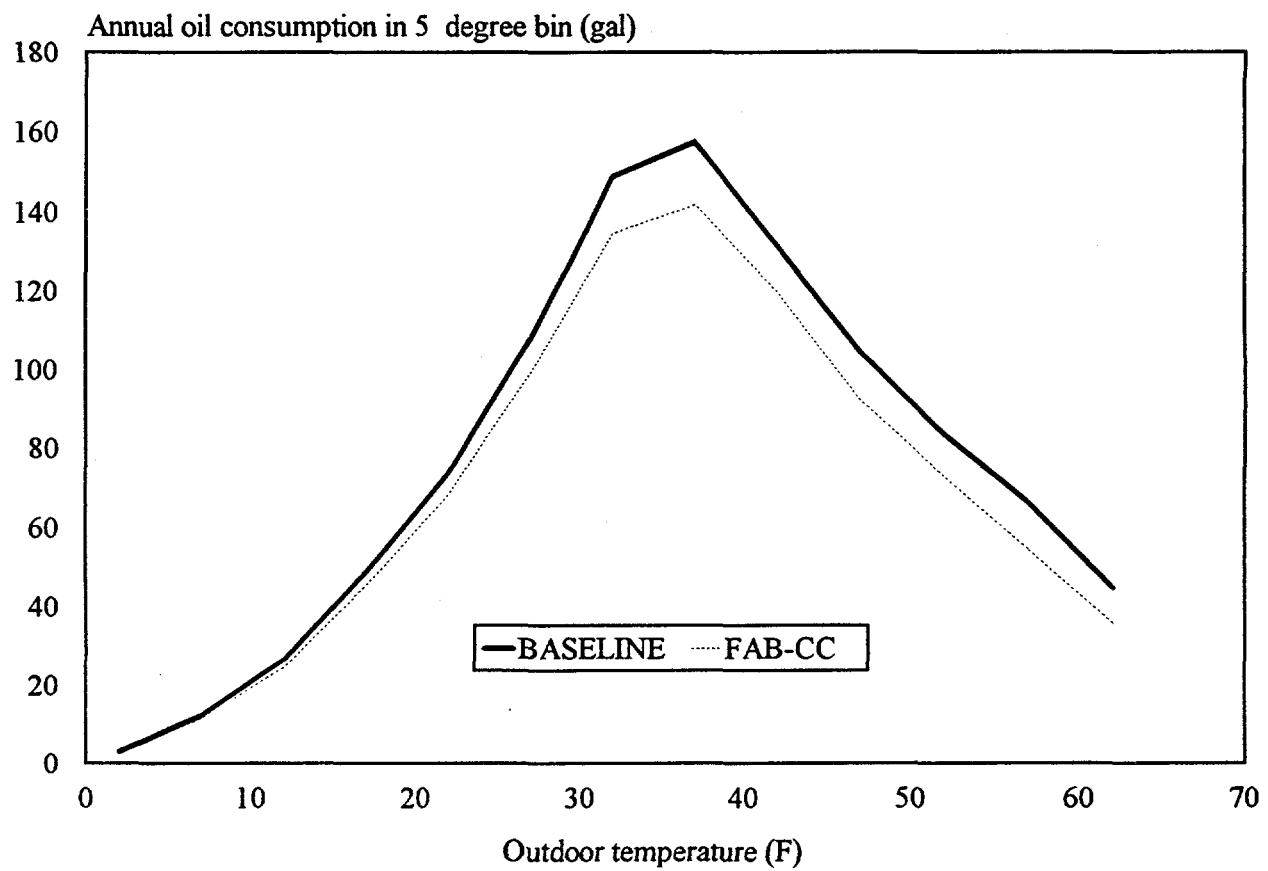
Figure 6 provides the amount of oil consumed with respect to the outdoor temperature. For this region the ambient temperature ranges between 29°-39°F most of the time, and as such, the greatest amount of fuel is used during this time. Also for this period the baseline system uses a relatively greater amount of oil than the FAB. Maximizing heating system efficiency during operation under these ambient conditions would be the most effective improvement.

Given the burner firing rate, the fuel input, and burner power consumption, the electrical energy needed and costs to operate the FAB were calculated and compared with that of the baseline system's retention head burner. The power consumption is 75 watts and 200 watts, respectively. The FAB was firing at a rate of 0.35 gph and the retention head at 0.65 gph. Over one heating the FAB requires a total of 193 kw-hr as compared to 310 kw-hr for the baseline retention head burner. With the local utility rate of \$ 0.15 /kw-hr this corresponds to \$29 versus \$47, a savings of 38% when operating with the FAB.

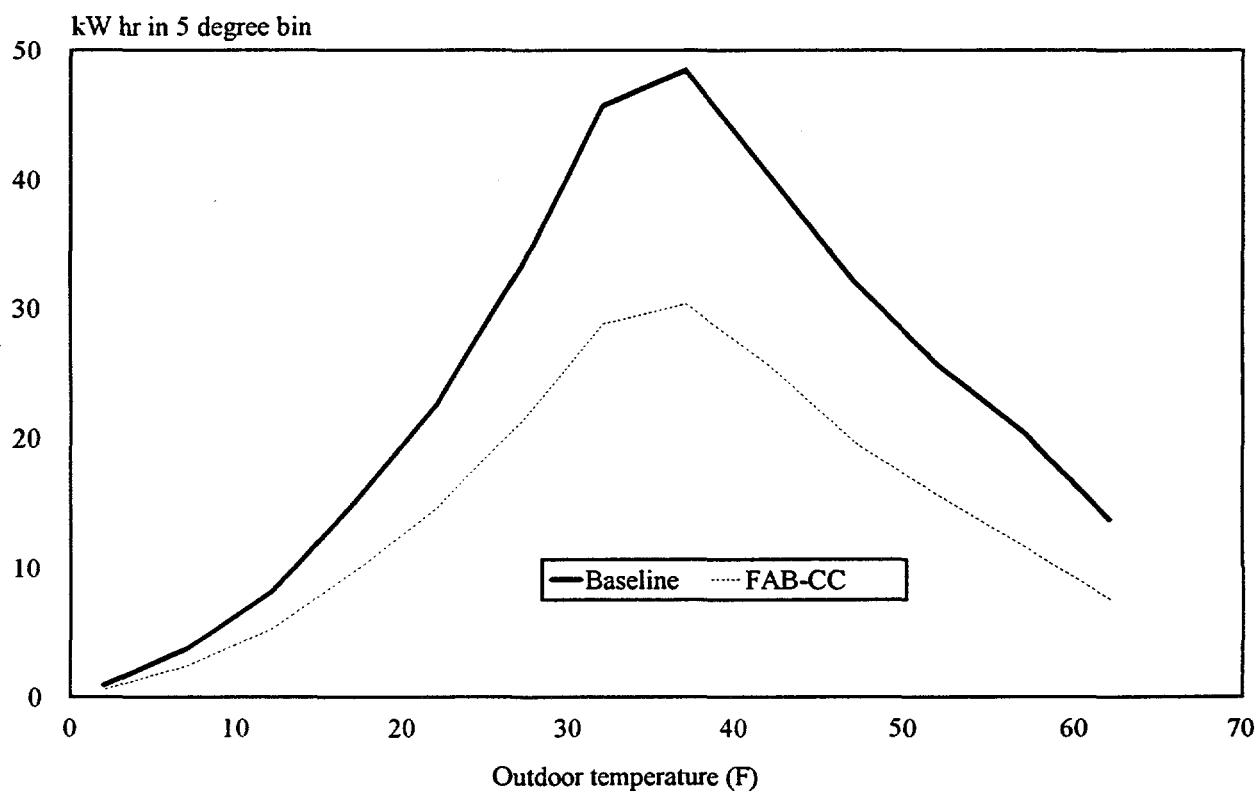
Figure 7 shows the electrical energy consumed with respect to outdoor temperatures for the baseline heating system and the FAB with constant circulation. Similar to the oil consumption data in Figure 6, the electric use peaks at about 35°F. Again, the reason for this is that for this region the temperature averages about 35°F most of the time. In general, the electric use for the baseline system is significantly higher than the FAB system.

### **Burner Cycling Patterns**

As the field data shows burners tend to operate with greater efficiency at higher loads. Generally, this is true because the burners are cycling less frequently, and efficiencies approach steady state efficiencies. With the low input rate of the FAB burner that matches closely with the house energy load, the FAB cycles much less frequently than the typical retention head burner. An analysis of the cycling frequency of the FAB with constant circulation and the retention head burner (Beckett AFII) with constant circulation, operating under similar outdoor temperatures, shows that the FAB cycles about 83 % less than the retention head burner.



**Figure 6.** Annual oil consumption as a function of outdoor temperature for the baseline system and FAB with constant circulation.



**Figure 7.** Annual electric use as a function of outdoor temperature for the baseline system and FAB with constant circulation.

IV. REFERENCES:

1. Butcher, T., Advanced oil burner for residential heating - development report, BNL Informal report 62077, September 1994.
2. McDonald, R., and Celebi, Y. Field Testing the Prototype BNL Fan-Atomized Oil Burner. Proceedings of the 1995 Oil Heat Technology Conference and Workshop, Upton, N.Y., March 22-23, 1995. BNL 52475, April 1995.
3. Facility Design and Planning ENGINEERING WEATHER DATA, Departments of the Air Force, the Army, and the Navy, 1 July 1978.



**LABORATORY TESTS OF SLUDGE-CONTROL ADDITIVES**

Robert E. Tatnall, P. E.  
MIC Associates, Inc.  
10 McCarthy Rd.  
Chadds Ford, PA 19317



## **Laboratory Tests of Sludge-Control Additives**

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MIC Associates, Inc.  
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### **ABSTRACT**

Laboratory "jar" tests compared eleven different fuel oil and diesel fuel sludge-control additives. Factors studied included 1) ability to disperse and prevent buildup of sludge deposits on surfaces, 2) ability to protect steel from corrosion, 3) ability to inhibit growth and proliferation of bacteria, and 4) ability to disperse water. Results varied greatly, and it was found that many commercial products do not do what they claim. It is concluded that fuel retailers should not believe manufacturers' claims for their additive products, but rather should test such products themselves to be sure that the benefits of treatment are real. A simplified form of the procedure used here is proposed as one way for dealers to do such testing.

### **INTRODUCTION**

Service problems caused by sludge in residential oil heat systems are a continuing problem to fuel oil dealers. Not only do they rob the profitability of contract service programs for those dealers who offer service contracts, but they also create ill will among customers who lose heat when problems occur. Customers who continue to experience such operating problems tend to blame the "quality" of the fuel oil being delivered, and will eventually switch to another dealer or to an alternate type of heating system. For all of these reasons, it is in the best interest of fuel oil dealers to eliminate service problems caused by fuel contamination and sludge.

The causes of sludge formation, and the problems associated with sludge, have been discussed in a previous paper.<sup>[1]</sup> These include corrosion of storage tanks and other metal components of fuel handling systems, plugging of filters, strainers, fuel lines and nozzles. Partially plugged nozzles result in poor and erratic combustion, which, in turn, shows up as excessive noise and vibration during furnace operation, excessive sooting of the combustion chamber, and mechanical failures of fireboxes and internal components due to the vibration. The plugging of fuel lines and nozzles can sometimes cause systems to shut down entirely. Finally, because sludge itself contains a lot of water, sludge deposits in outdoor lines can freeze in cold weather, blocking flow and causing what is often erroneously presumed to be "gelling" of the fuel itself.

To deal with problems caused by sludge, as well as the water which enters fuel storage tanks and is essential for the growth of sludge, chemical suppliers offer a variety of fuel additives. The dilemma for fuel dealers, however, is that they have no good way to know whether or not these additives really *do* any of the things they claim to do.

In the previous paper<sup>[1]</sup>, three different sludge-control products were compared in test systems with and without free water layers. Testing as described in that paper would be one way for dealers to compare products. Some dealers, however, have said that they feel that such testing is too ambitious for them to do themselves. What is needed, therefore, is a test method for comparing sludge-control additives that is both easy and inexpensive to run. This paper describes such a test. It also describes the results of this test on eleven commercial products, ranging from bottled products sold for treating automotive diesel fuel tanks, to bulk chemicals offered for turning heating oil into "premium" heating oil. The eleven products tested have one thing in common: they all claim to control contamination and sludge problems.

This study looked at only a fraction of the many commercial additives available on the market. It was not intended to produce a "consumers' guide" to fuel additives, but rather was designed to show fuel dealers what to expect if they decide to evaluate such products *themselves* before deciding which ones to use.

## EXPERIMENTAL PROCEDURE

A. Setup: One-quart, "mayonnaise" jars were used – a total of twelve for this program. Into each jar was placed 50 ml tap water (about 1½ ounces), and the jars filled to within about 5 cm (two inches) of the top with clean diesel fuel. No. 2 fuel oil could have been used, but diesel fuel was chosen because it was more conveniently purchased in small quantities as needed for this test.

B. Inoculation and Pre-Incubation: The first phase of the testing consisted of inoculating each jar with biologically active sludge and then giving that sludge a period without treatment to allow it to acclimate to the new situation and reach peak activity.

Fuel oil sludge was taken from a laboratory stock which came originally from a fuel oil terminal near Pittsburgh, PA. This "culture" is maintained at room temperature in a one gallon glass jug which has a water layer of about 2½ cm (1 inch) depth and the balance diesel fuel, with approximately 60% of the fuel being drawn off and replaced monthly. 100 ml of sludge was drawn from the fuel/water interface using a glass pipette, taking care to collect as much "solids" as possible. This was placed in a blender along with 150 ml tap water, and the mix homogenized aggressively at the highest speed setting for about a minute. This blended material was then dispensed equally into the twelve jars – approximately 20 ml of "sludge soup" per jar. The jars were then loosely capped and placed in a light-tight box.

Every four weeks, most of the fuel was drawn out of each jar, taking care not to remove any water or sludge, and replaced with fresh diesel fuel. Transfer of fuel out of and into the jars was done using a battery-powered kerosene pump, as readily obtained at most hardware stores. The reason for periodically replacing fuel was twofold: 1) since it is not known what fractions of fuel oil are used by the bacteria and other microorganisms present, periodic replacement of much of the fuel assured that whatever small fraction was usable by them would not be depleted over the course of the experiment, and 2) since this test was partly to see whether additives are capable of dispersing sludge and water, periodic replacement of the fuel would allow any such dispersed materials to be gradually removed from the system. In both respects, periodic removal ("use") and replacement of fuel mimics what happens in residential fuel storage systems.

C. Chemical Treatment: At week twelve, after the fuel had been drawn down and replaced for the third time, the jars were labeled for the various additives to be tested – one jar being left untreated as a control, eight receiving treatment by various additives sold for treating fuel oil, and three being treated with commercial diesel fuel additives. The eleven additives are listed by test code numbers in Table I, along with their advertised claims regarding sludge and contamination control issues. Those additives intended for use in treating fuel (heating) oil were coded with the letter "F" (F1, F2, etc.). Those sold for treating diesel fuel systems were given codes starting with a "D".

All of the products tested were used at the doses recommended by their suppliers (except as described below). Those recommended doses, and the equivalent amount used to treat one quart in these tests, are also shown in Table I. The test jars were treated a total of eight times, with treatments spaced at four-week intervals.

A few of the products' instructions recommended treating "badly fouled" systems at double the normal dose the first one or two times, then using normal doses thereafter. Other product labels did not mention this. In order to treat all products equally, it was decided to apply all treatments at twice the normal dose shown in Table I not just the first time, but for the first four treatment periods, and then use normal doses for the last four periods.

For the first four treatment events, the following protocol was used. First, fuel was drawn out of each jar to just above the top of the corrosion coupons. Each jar was the dosed with it's respective additive, using twice the amount shown for a "normal" dose in Table I. The jars were then immediately refilled with fresh fuel, loosely capped, and placed in a light-tight box.

The protocol was changed for the last four treatment periods. After drawing out most of the fuel, each jar was treated at the recommended "normal" dose rate indicated in Table I, and the jars were capped and put back into

the box without adding fresh fuel. After one week, the bottles were again topped up with fuel and put back into the box.

Treatment chemicals were added using glass pipettes fitted with thumbwheel pipetters as shown in Figure 1. After each dose was dispensed, the pipette was flushed twice with clean diesel fuel before using for the next product. This was for the purpose of minimizing cross-contamination with different products.

**D. Corrosion Coupons:** Three days after making the first additive treatment, a corrosion coupon was placed in each jar. These coupons were formed from 0.5 mm (.020") thick, cold-rolled AISI type 1015 carbon steel sheet, which was sheared into pieces 7.6 cm by 5.1 cm (3" X 2"), and then bent in the middle as shown in Figure 2. Each coupon had a sequential number stamped in its upper inside corner so as to keep straight which coupon had been in which jar. Each was also cleaned with acetone and weighed (to the nearest 0.001 gm) just prior to being placed in a jar. The coupon shape assured that one leg would stand up through the water phase, the water/fuel interface, and into the fuel phase.

The temperature of the room in which these tests were carried out ranged from a low of 57° F and a high of 80° F during the test period.

## RESULTS

At the conclusion of the tests, the fuel was again drawn out of all jars down to just above the top of the corrosion coupon. Factors observed or measured included the following:

- A. General appearance of jar surfaces and sludge at interface.
- B. Nature and amount of material adhering to coupons.
- C. Extent and amount of corrosion (weight loss) of the coupons.
- D. Numbers of microorganisms in the interface materials and in the water phases.
- E. Relative amounts of water and sludge remaining in each jar.
- F. Degree of dispersion or cohesiveness of the sludge.

Some of these factors, such as general appearance of the jar and sludge layer, were noted but were not considered germane to the key issue — i.e. *operating problems* alleviated by the various treatments — and so were not weighed in the final product ratings. Other factors, including sludge buildup on the coupons, amount of corrosion, and degree of dispersion or cohesiveness of the sludge were considered critical to the issues of sludge-control, and so were scored from 0 to 10, with a score of "2" being essentially similar to the untreated case, a score of "0" indicating performance significantly *worse than* the control, and "10" implying perfect performance in that particular regard.

**A. General appearance of jar surfaces and sludge at interface:** The sludge layer at the fuel/water interface varied in appearance, from bulky and "cottony" in appearance, to a thin, flat layer almost looking like an "oil slick." Figure 3 shows two treated jars alongside the control, with both the control and F3 jars showing a thick, cottony sludge layer, while the F1 jar typified the thin, "oil-slick" appearance. By contrast, Figure 4 shows jar F5, which exhibited a heavy coating of some sort on the walls of the jar in the fuel phase. While not apparent in these black and white photographs, the sludge layer in THIS jar F4 is a very light tan, while the sludge in all other jars was either a dark brown or black.

All of these things are mentioned simply to point out that the outward *appearance* of the various jars differed at the end of the test. As will become apparent, however, outward appearances mean little, and treatments that change color or texture of the sludge do not necessarily translate to comparable differences in sludge control or corrosion protection.

**B. Nature and Amount of Material Adhering to Coupons:** Unlike the outward appearance just described, the actual amount of sludge and corrosion product adhering to the coupon surface probably relates directly to operating problems such as fouling of lines, strainers and nozzles.

To evaluate this parameter, each coupon was lifted with a tongs from its jar and rinsed lightly with clean diesel fuel to remove any non-adherent slime. The evaluation was made simply by visual observation, and the coupons with deposits attached are shown in Figure 5. The coupons were photographed near a mirror so as to show a portion of the back side along with the upper bottom surface and the front side of the vertical leg.

Of particular interest in this inspection and rating was the buildup near the fuel/water interface, as that was believed most indicative of "sludge" accumulation, while other surfaces in the water phase are likely to be more indicative of corrosion product buildup (Corrosion is judged separately below.).

Of the eleven treatments tested here, only one fuel oil additive (F1) performed well in this aspect of the test, showing only a small spot of attached sludge on the back side. Treatment F4 had a heavy film of slime on all surfaces exposed to the water phase, but little additional buildup at the interface, and so was judged to be somewhat better than the control in that regard. Two of the diesel treatments (D1 and D2) showed significantly less buildup than did the control, though much more than did F1. All other treatments performed poorly in this aspect of the testing, and some showed significantly more buildup of material than did the control. The scores assigned each treatment are shown in Table III.

C. Extent and amount of corrosion of the coupons: As with deposit buildup on surfaces, corrosion caused by fuel contamination is a serious operating concern, and protecting against such corrosion should be a basic requirement for sludge-control additives.

The coupons were cleaned by scrubbing with a "Scotchbrite" pad and abrasive cleanser to remove all of the slime and most of the underlying corrosion product. They were then placed in inhibited 10% hydrochloric acid at room temperature just long enough to remove the remaining black corrosion product. Each was then rinsed with water, followed by acetone, dried, and weighed. Weight loss was calculated based on the original weights.

Scoring for this phase was based on the following percentage weight loss: less than 0.1%, or roughly 20 mg (the amount likely from cleaning of the coupon alone) = 10, less than about 0.5% = 8, less than 1% = 6, less than 1.5% = 4, less than 2% = 2 (the control lost 1.9%), and more than 2% = 0. Again, the scores are shown in Table III.

D. Numbers of microorganisms in the interface materials and in the water phases: As sludge formation is primarily a biological process, one way to prevent it might be to kill or limit the activity of microorganisms in the fuel and water phases. Though none of the products tested claim to be biocides, we decided to see whether any had a significant effect on the numbers of viable organisms. If so, it would also be interesting to see whether such biological control correlates with actual problems such as those discussed above.

10 ml of material was drawn up with a glass pipette from the water/fuel interface in each jar, including as much "solid" material (sludge) as possible. These samples were diluted to 100 ml with filter-sterilized, buffered water, and shaken vigorously to disperse the solids. Each diluted sample was tested for total bacteria counts, as well as for yeast and mold counts, using Difco Laboratories' "Hycheck" devices. In addition, 10 ml of water was drawn from the bottom of each jar, diluted to 100 ml, and tested for total bacteria counts only. The results are summarized in Table II.

E. Relative amounts of water and sludge remaining in each jar: Some of the products tested make strong claims about dispersing or removing water from fuel. Because some water is bound to get into all fuel storage systems eventually, and because its presence is essential for biological activity leading to sludge formation, we decided to see whether any of these particular products actually had removed significant quantities of water from our jars. At the same time, we were curious as to what effect the additives had on the total amount of sludge solids after the eight treatments.

After removing all of the remaining fuel phase from each jar with a pipette, the remaining water and sludge was poured into 50 ml centrifuge tubes and spun to separate the solids from the free water. Because the jar contents exceeded 50 ml, this was done in two stages, with 20 ml of free water removed from each tube after the first

centrifuge run. The tubes were transparent and graduated, and so the volume amounts of solids were estimated as well as the remaining free water. The results are shown graphically in Figure 6.

There was one mishap during this process: tubes representing jars D2 and D3 lost fluid from their tops at the end of the final spin. As a result, the amount of solids in the bottoms of those two tubes could be accurately estimated, but the amounts of water and floating solids could not. The amounts for these tubes as shown in Figure 6, therefore, represents only what remained after these losses.

F. Degree of dispersion or cohesiveness of the sludge: Unlike the simple *quantity* of sludge solids, the stickiness and cohesiveness of the sludge mass is believed to relate directly to operating problems. Sludge that is sticky will tend to adhere to tubing, strainers and nozzles and eventually lead to flow problems. Sludge that is "clumpy" or cohesive implies a large amount of undispersed slime binder, and is more likely to blind filters and strainers than will unbound, dispersed solids.

To evaluate the relative degree of dispersion of the sludge solids by the various additive, the contents of each centrifuge tube were dumped into a small kitchen strainer, and then washed with five tube-fulls (250 ml) of tap water. Solids that are dispersed should be washed easily through such a strainer, whereas those that are still bound by slime are more likely to remain on the strainer. During this process, certain samples showed a marked tendency for solid clumps or particles to stick tenaciously to the walls of the centrifuge tube and resist removal by the five subsequent rinses of the tube. Those samples were noted as being "sticky."

To score these important parameters, the following guidelines were used: The control jar left what was judged to be a "moderate" amount of solids on the strainer, and this material was not particularly sticky. A score of "2", as before, implied performance roughly the same as the control. Samples which showed significantly more material remaining or greater stickiness were scored "1" or "0," depending on degree. Samples which showed measurably less material than the control and no stickiness were scored "4", "6", or "8", again depending on degree of improvement. None of the samples showed a complete lack of material retained, so none was awarded a perfect "10". These scores, again, are reflected in Table III.

## DISCUSSION

Several issues were addressed in this study, some which are believed central to the proposed function of sludge-control additives, and some that may or may not be truly important. An attempt has been made to focus on the issues that really lead to operating problems: plugging of lines, filters strainers and nozzles and corrosion of tanks and other metallic parts in the system.

Sludge-control additives are based largely on dispersants designed to break down the slime binder that makes sludge stick together and to system components. Inhibiting corrosion in the presence of water and sludge is another matter, requiring the additive to first penetrate the sludge or water layer, and then lay down a protective film on the metal surface. The simple test used here is one way to judge a product's ability to accomplish both tasks.

The first phase of this study, which consisted of observing the appearance of the sludge layer in the jar, showed that some of the products tested had a significant effect on the color or texture of the sludge. It later became apparent, however, that these changes were sometimes meaningless, and had no correlation with things that really matter. Treatment F5, for example, had the most dramatic effect on the sludge color, turning it from a dark gray/brown to a pale tan – yet this treatment achieved the lowest scoring (together with F6) among the eleven products tested, and was worse in every important regard than no treatment at all. From this we deduce that a treatment should not be judged simply by putting some sludge in a jar, adding the chemical, and looking for visual changes. The other lesson demonstrated here is that sludge-control additives, even effective additives, do not make a contaminated system instantly "clean" or "pretty."

Looking at the sludge and corrosion product buildup on a metal surface, such as the steel corrosion coupons used here, is probably a much more meaningful observation. Much of a typical oil heating system is fabricated of

steel, and iron (steel) surfaces are well known to be attractive sites for attachment of microorganisms and growth of biofilms and slime (i.e. "sludge"). If a particular treatment in this test allows such things to occur unchecked, then there is good reason to suspect that similar fouling and corrosion would occur in the presence of that additive in a real operating system. It is interesting to note that, in this regard, only four of the eleven products tested were better than no treatment at all — and three products actually made things noticeably *worse*.

The results of the corrosion aspect of this study were also quite disappointing, with only five of the products tested showing any corrosion inhibition at all — and protection quite marginal in three of those cases. This is in spite of the fact that nearly all of the products specifically claim to inhibit corrosion. With only one exception (D3), it was the same products that had prevented buildup of "stuff" on the coupon that also inhibited corrosion. This is probably due in part to the fact that the iron oxides resulting from corrosion tend to enhance binding of "stuff" to the steel surfaces and also contribute bulk to those attached deposits. In any case, it appears that product effectiveness in these two aspects generally go hand in hand. Again, five of the eleven products actually appeared to *accelerate* corrosion vs. no treatment at all. This is not necessarily surprising, as many chemicals can be assimilated by microorganisms and turned into corrosive species such as acids. In any case, it would be a serious mistake to use a treatment product which actually increases corrosion tendencies in a system.

The next aspect of this study dealt with determining the relative numbers of viable microorganisms in the various jars following repeated treatment. While the actual levels of activity indicated should be taken with a grain of salt — as biological testing of environmental systems such as these is notoriously difficult and results usually inconsistent — it is readily apparent that *all* of the jars, whether or not they were treated, contained lots of biological activity. This study shows, however, that control of the numbers of microorganisms is not necessarily required in order to control sludge-related problems.

The measurement of water and sludge solids remaining in the jars likewise does not necessarily measure the ability (or lack of ability) of these treatments to prevent operating problems. In fact, many will argue that distinct water layers such as that built into these tests are a worst-case scenario, and only occur in some underground tanks. As demonstrated in the referenced earlier paper<sup>[1]</sup>, however, the sludge buildup and corrosion problems observed in these tests will occur in systems without discrete water layers as well as in systems which do have such a water layer.

As for water dispersion or removal by these additives, it was observed that, within the limits of our experimental accuracy, none of these products appeared to eliminate a significant amount of water over the course of eight months and eight treatments.

The whole subject of water dispersion in distillate fuels is very complicated. Some so-called water dispersing chemicals will in fact disperse *minute* amounts of water in fuel, but will do the exact opposite if a *lot* of water is present. Some of the same functional chemicals used as water dispersants, therefore, are also sold as fuel "dehazers," and used to *separate* water and fuel at the refinery. It is very misleading, therefore, to expect such additives to handle all levels of water with equal effectiveness. The results of this study support the philosophy that measurable water layers in fuel tanks should be pumped or siphoned out, and fuel additives should not be counted on as a "magic" quick fix.

The problem for the fuel oil dealer is that he does not routinely monitor the level of water in customers' tanks. Many tanks, in fact, are installed in such a way as to make this impractical. From the dealers' standpoint, therefore, it is **most important** that accumulated water, if present, not cause corrosion of that tank or create operating problems in that customers' system. That is what this study was designed to assess.

As for the estimated volume of sludge *solids* observed in the various jars, it is apparent from Figure 7 that the total amount in the jars, adding the bottom sediment to the floating solids, was approximately the same in nearly every case as with the untreated control. The one notable exception to this was jar F4, which had roughly twice the total volume of solids as did all other jars (keeping in mind that D2 and D3 *may* have had more than reported in Figure 7 — some being lost in the centrifuge.). In a real operating system, unlike this static test, there is periodic stirring of the tank contents when it is refilled. This would tend to suspend the solids, so that some of

them can be drawn into the lines and be trapped by the filter. Whether this is good news or bad news depends on whether or not the suspended sludge is lumpy and sticky, or whether it is dispersed into small, harmless particles.

The last aspect of this test program looked at the effect of the various treatments on the stickiness or cohesiveness of the sludge solids. As discussed earlier, this is an attempt to quantify the sludge "conditioning" effect. It was disappointing to find that, of these eleven commercial products, only two were effective in breaking up the sludge and dispersing the slime binder. It was equally disappointing that six of the eleven actually made matters worse in this regard than did no treatment at all.

If this test program had been for the purpose of selecting products to use in actual operating systems, the total scores as shown in Table III would lead to the conclusion that only one fuel oil treatment (F1) is worth considering, and one diesel treatment (D1) stands out from the other two. (While D2 had a similar total score to D1, its terrible performance in the stickiness/cohesiveness test would, in our eyes, make it a poor second choice.)

Hopefully, these results will convince fuel oil dealers to test some sludge-control additives themselves. If so, it is probably not necessary to follow all of the steps discussed above. The basic idea of putting fuel and a little water into jars, adding a small amount of sludge, then treating jars with different products, is easy to carry out and easy to interpret. It should be remembered to always include bare steel "coupons", though they do not have to be fancy or weighed. Fouling and corrosion are easy to spot, and it's easy to tell an effective treatment from a poor one. Such a test should also include an untreated jar, so that it is apparent how the various treatments compare to an untreated case. After all, it is discouraging to think that one might be spending money for a treatment that is not very good, but it would be *doubly* discouraging to think that one is spending that money for a treatment that does more harm than good!

## CONCLUSIONS

1. This study shows that there are sludge-control additives that will effectively disperse sludge, make it non-sticky, and generally not likely to cause operating problems in residential heating or diesel systems.
2. There are also additives that effectively protect metals against corrosion in contaminated fuel systems.
3. There are even more products on the market, however, that do neither of the above, and, in fact, make matters worse than no treatment at all.
4. Users, including fuel oil dealers, should run some sort of tests — perhaps like the ones described here — to determine which products actually do what they claim.
5. None of the eleven products tested here removed measurable amounts of water from fuel. Large amounts of water in fuel tanks should be removed by pumping or siphoning it out.

## ACKNOWLEDGEMENT

Corrosion Testing Laboratories, Inc. provided the facility for manufacturing and preparing the corrosion coupons, and also for their cleaning, weighing and analysis of results of that phase of the study.

## REFERENCE

1. Tatnall, R.E. "Proper Use of Sludge-Control Additives in Residential Heating Oil Systems," in: *Proceedings of the 1995 Oil Heat Technology Conference and Workshop*, ed. Roger J. McDonald, Brookhaven National Laboratory, Upton, NY: 1995.

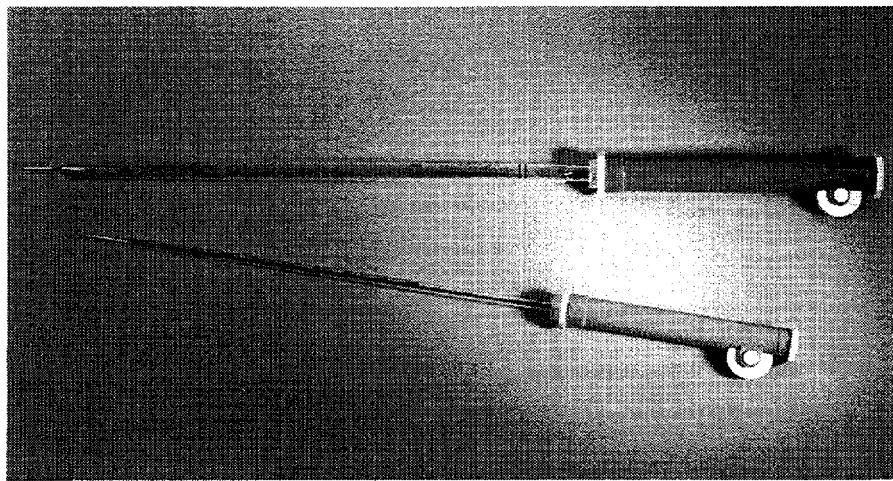


Figure 1 - The pipettes used for adding chemicals to the jars, shown with thumbwheel pipettors. These are available from most laboratory supply houses.

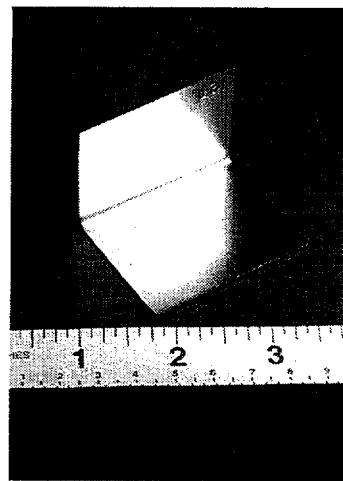


Figure 2 - One of the steel corrosion coupons before the start of the test.

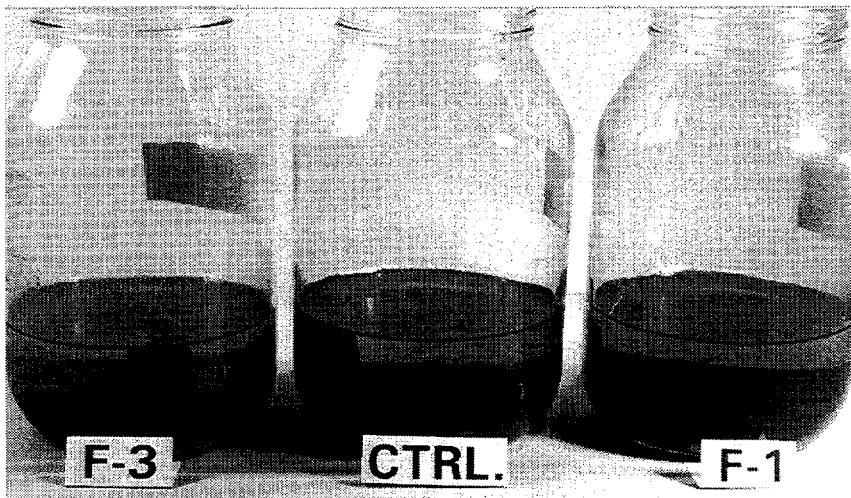


Figure 3 - Three of the jars at the end of the test. The jar on the left typifies a thick, "cottony" sludge layer, while the jar on the right has a thin, "oil-slick" layer at the water/fuel interface.

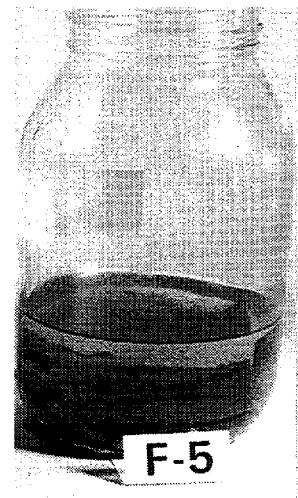


Figure 4 - This shows jar F5, whose sludge is a pale tan. The sludge in all other jars is dark brown or black.

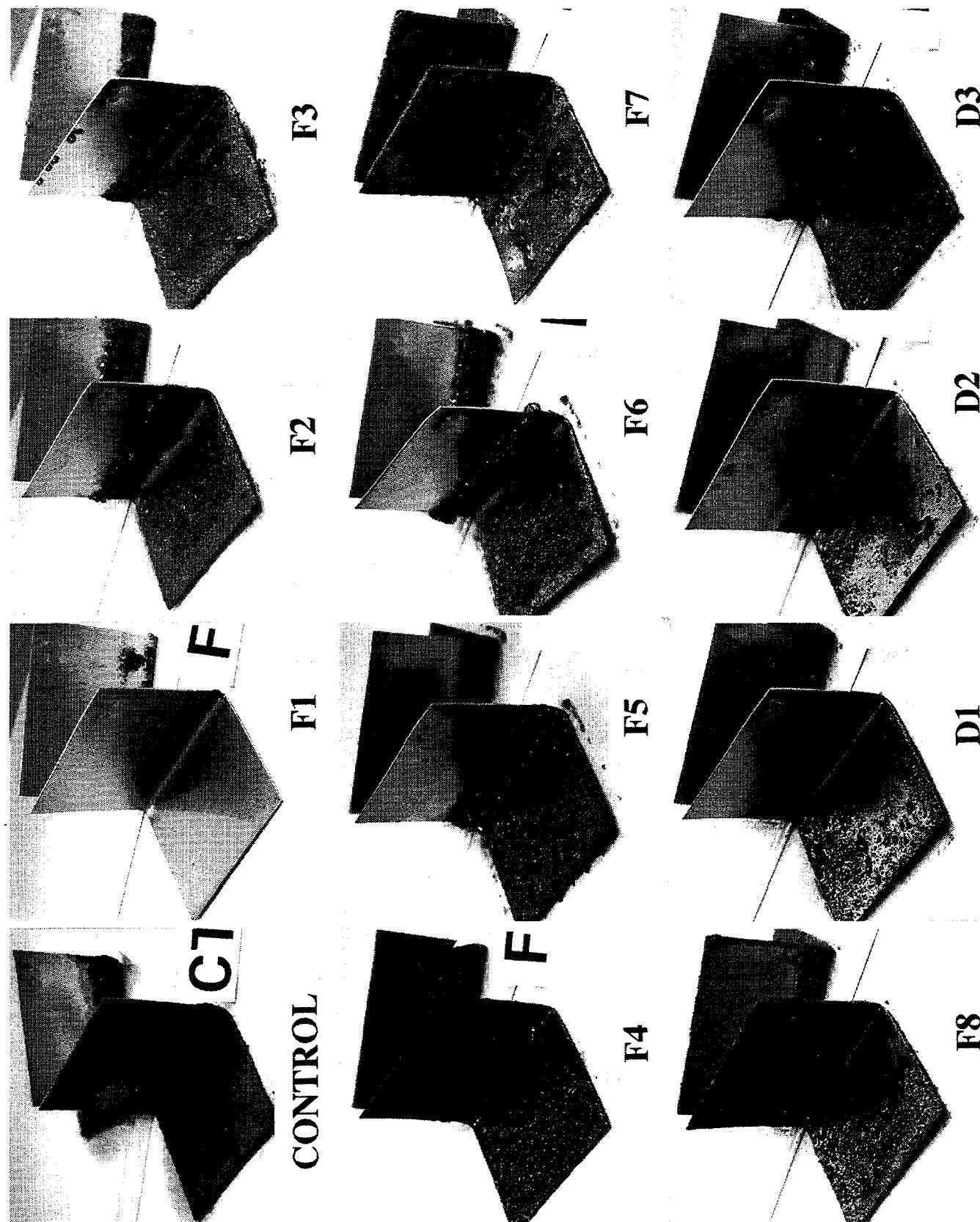


Figure 5 - Composite view of corrosion coupons just after removal from their jars at the end of the test.

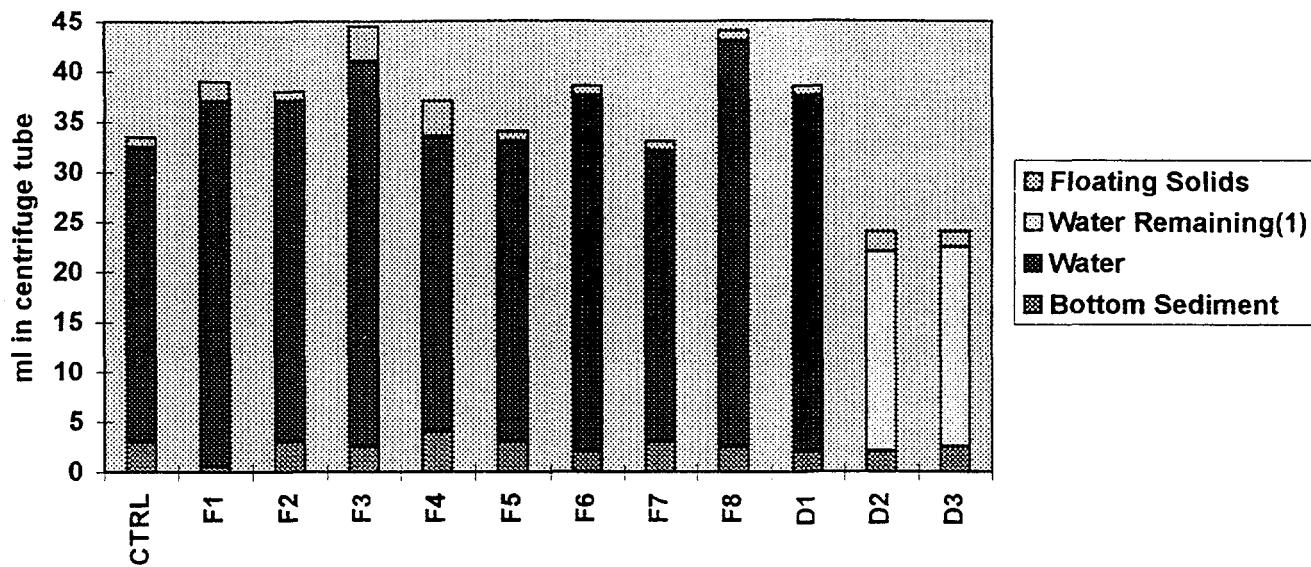


Figure 6 - Schematic representation of the materials remaining in the centrifuge tubes. Note (1): D2 and D3 indicated water and floating sludge quantities shown represent the amounts left after some was lost in handling.

TABLE I  
CLAIMS AND RECOMMENDED DOSES FOR THE PRODUCTS TESTED

I. Product Claims (Related to Sludge)	Test Treatment Code:										
	F1	F2	F3	F4	F5	F6	F7	F8	D1	D2	D3
Disperses or Removes Sludge	X		*	X		X		X	X	X	
Prevents (or Inhibits) Sludge Formation	X		X		*		X	X			
Cleans Nozzles or Removes Gum	X	X	X	*		X		X	X	X	X
Disperses or Removes Water		X	X	X			X	X	X	X	**
Inhibits Corrosion	*	X	X	X		X	X	X	X	X	
II. Recommended and Test Doses:											
Recommended Treatment Ratio 1: (1)		2200		14,000	1100	2000	5000				
Ounces to Treat "x" Gallons (2)	8-300	16-275	16-275	16-250					12-20	12-50	12-50
Recommends Double Dose First Time				X						X	
Test Dose - ml to treat 1 quart (3)	0.296	0.430	0.430	0.473	0.068	0.860	0.473	0.192	4.440	1.778	1.778

Notes:

- (1) Dose at 1 part by volume to \_\_\_\_ parts fuel (e.g. "2200" means add 1 gallon treatment per 2200 gallons fuel)
- (2) Package of \_\_\_\_ ounces treats tank of \_\_\_\_ gallons capacity (e.g. 8-300 means that an 8 ounce bottle treats a 300 gallon tank.)
- (3) Treatment used in this test for one quart. Doubled this amount for first 4 treatments.

\* This benefit implied but not stated.

\*\* Claims to "separate" water and fuel - not to remove or disperse water.

**TABLE II**  
**MICROBIOLOGICAL CONTAMINATION LEVELS AT END OF TEST**

NATURE & LOCATION:	Test Treatment Code:											
	CTRL	F1	F2	F3	F4	F5	F6	F7	F8	D1	D2	D3
	Total Bacteria - Water Phase	high	med.	med.	med.	med.	low	med.	med.	med.	high	med.
Total Bacteria - Interface	TNTC	TNTC	high	TNTC	med.	low	med.	med.	med.	high	med.	high
Yeasts - Interface	low	low	med.	?	med.	low	high	high	high	low	med.	high
Molds - Interface	neg.	high	med.	TNTC	neg.	high	high	med.	med.	neg.	high	low

Notes: All results are on samples diluted 10:1. TNTC means too numerous to count (i.e. very high).

"?" means may be present, but other types of colonies are obscuring surface of test device.

**TABLE III**  
**PRODUCT SCORES IN THREE CRITICAL CATEGORIES**

CATEGORY:	Test Treatment Code:											
	CTRL	F1	F2	F3	F4	F5	F6	F7	F8	D1	D2	D3
	Buildup at Interface	2	8	0	2	4	0	0	2	2	6	6
Corrosion (Wt. Loss)	2	10	0	0	4	0	0	0	2	4	8	6
Cohesiveness/Stickiness	2	8	2	2	0	1	1	1	2	6	1	0
<b>TOTAL (of possible 30)</b>	<b>6</b>	<b>26</b>	<b>2</b>	<b>4</b>	<b>8</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>6</b>	<b>16</b>	<b>15</b>	<b>8</b>

Notes: "10" is a perfect score. "2" means equal in performance to untreated control.

"0" means total failure in that category (worse than untreated control.).



**PREMIUM PERFORMANCE HEATING OIL - PART 2**  
**FIELD TRIAL RESULTS**

Steve M. Jetter, Dennis Hoskin, and Warren R. McClintock  
Mobil Oil Corp.  
Marketing, Refining, & Chemical Technical Center  
P. O. Box 480  
Paulsboro, NJ 08066-0480

and

Cliff Messick and Bill Messick  
Messick Fuel Supply, Inc.



## Premium Performance Heating Oil - Part 2

### Field Trial Results

Steven M. Jetter, Dennis H. Hoskin, Warren R. McClintock - Mobil Oil Corporation  
Cliff Messick, Bill Messick - Messick Fuel Supply, Inc.

### **Abstract**

Limited field trial results of a heating oil additive package developed to minimize unscheduled maintenance indicate that it achieves its goal of keeping heating oil systems cleaner. The multifunctional additive package was developed to provide improved fuel oxidation stability, improved corrosion protection, and dispersency. This combination of performance benefits was chosen because we believed it would retard the formation of sludge, as well as allow sludge already present to be carried through the system without fouling the fuel system components (dispersency should keep sludge particles small so they pass through the filtering system). Since many unscheduled maintenance calls are linked to fouling of the fuel filtering system, the overall goal of this technology is to reduce these maintenance calls.

Photographic evidence shows that the additive package not only reduces the amount of sludge formed, but even removes existing sludge from filters and pump strainers. This "clean-up" performance is provided trouble free: we found no indication that nozzle/burner performance was impaired by dispersing sludge from filters and pump strainers. Qualitative assessments from specific accounts that used the premium heating oil also show marked reductions in unscheduled maintenance.

### **Introduction**

Residential oil heat systems have long experienced problems related to fouling of the fuel system. One source of this fouling is sediment formed from fuel oxidation and tank corrosion that accumulates in the tank eventually plugging fuel filtration devices. This causes poor burner performance and/or burner shut-down resulting in an unscheduled service call. The usual corrective action taken is to replace the fouled parts. The sediment/sludge problem that exists in the fuel system is not addressed until maintenance needs are so frequent that tank cleaning or replacement is justified. We believe that carefully designed fuel additives can address the root problem leading to reduced unscheduled maintenance.

Therefore, several years ago we began a program to develop additive packages that are effective in minimizing the formation of sediment, as well as dispersing sludge already present in systems to prevent filter plugging. Results of laboratory tests on some of the better candidate additives were presented at a previous OilHeat technology conference<sup>1</sup>. This laboratory testing concluded that the additives developed could significantly enhance fuel oil oxidative stability, dispersency, and

corrosion performance and that this performance should lead to reduced unscheduled service calls. To determine if laboratory results translate to field performance, a limited field trial was conducted with Messick Fuel Supply using the Mobil PHO Package. The test comprised four groups of burners with 4-5 burners in each group. Groups received either the Premium or the "regular" heating oil product and the burners started the test either freshly cleaned or "as is (dirty)" in these combinations:

Group 1 Premium Clean	Group 2 Premium Dirty
Group 3 "Regular" Clean	Group 4 "Regular" Dirty

In addition, the rest of the customers received the premium heating oil, although no specific data was collected or available on them. The test was conducted during the time period February 1994 through April 1995, to include a full year's operation. The fuel was bulk additized at the terminal rack. The test burners were inspected prior to the start and at the end of the test period. The inspections included sticking the tanks to estimate sludge accumulation, estimating soot accumulation on heat exchangers, measuring efficiency, and examining (documenting photographically) filters, nozzles, and pump strainers. When assigning groups, historically problematic accounts were given preferential consideration to receive the premium heating oil whenever possible.

## Results

From this testing, four items could be evaluated. The first is a qualitative assessment of the ability of the premium fuel to keep the fuel system clean based on service records of problem accounts in group 1. The second is a direct assessment of fuel system clean-up performance based on photographic documentation in groups 2 versus 4. The third is a qualitative assessment by the Messicks on the overall performance of the additive in the general customer population in reducing fuel related service calls. The fourth is a determination if changes occurred in burner efficiency, soot accumulation, and tank sludge levels. Appendix A includes all of the data that was collected on the burners in this test.

The results of the above analysis are:

1. Two accounts with a history of service problems in Group 1, had no service calls during the 13 months operation on PHO. In these accounts, the fuel system parts remained very clean through the end-of-test evaluation (see Figure 1). In one severe, problem account where service had been required every six weeks for several months prior to introduction of the premium heating oil no service was required for the entire 13 months that the account used the premium heating oil. At the end of test evaluations, Cliff commented "Pump Strainer Definite Improvement,

Filter Amazing!" when the parts were removed.

2. All four burners that were in group 2 showed noticeable improvements in the cleanliness of fuel filters and pump strainers after operation on the PHO, while the four burners in group 4 showed no improvement or degradation in the fuel system cleanliness after operation on "regular" heating oil. Figures 2 and 3 show the photographic evidence of this clean-up performance. In group 2, although the filters and strainers are visibly cleaner, the nozzle appears to be dirtier after operation on the premium fuel. This is believed to be due to an accumulation on the nozzle of very fine material removed from the filter and strainer during the burner operation on premium fuel. None of the accounts that showed this behavior exhibited any indication that performance was in anyway impaired by this fine material on the nozzle. We expect that if left in service, eventually the fine material would be further dispersed so that it would pass through the nozzle and be burned.
3. The Messicks indicated that they did not have nearly as many fuel related problems while using the PHO. They were pleased with the performance of the PHO. They reported that large reductions in problems were seen in high volume and problematic accounts. Specific mention was made of a greenhouse complex where several hundred gallons of heating oil are used weekly during the spring. Cliff felt the premium heating oil had reduced fuel related service problems at the complex by about 70% versus the previous year.
4. No trends in burner efficiency, soot accumulation, or tank sludge levels were observed in this testing.

## Conclusions

From this field test, the following conclusions can be made:

- A fuel formulation showing improved laboratory bench test stability, corrosion, and dispersency performance gave improved maintenance experience in field testing.
- The premium heating oil effectively keeps fuel systems of oil-fired burners cleaner.
- The premium heating oil also cleans dirty fuel filters and pump strainers during normal burner operation.
- The premium heating oil effectively reduces unscheduled maintenance requirements in field experience.
- This performance was achieved without any adverse affects on the burner due to removing the sludge from the fuel system.

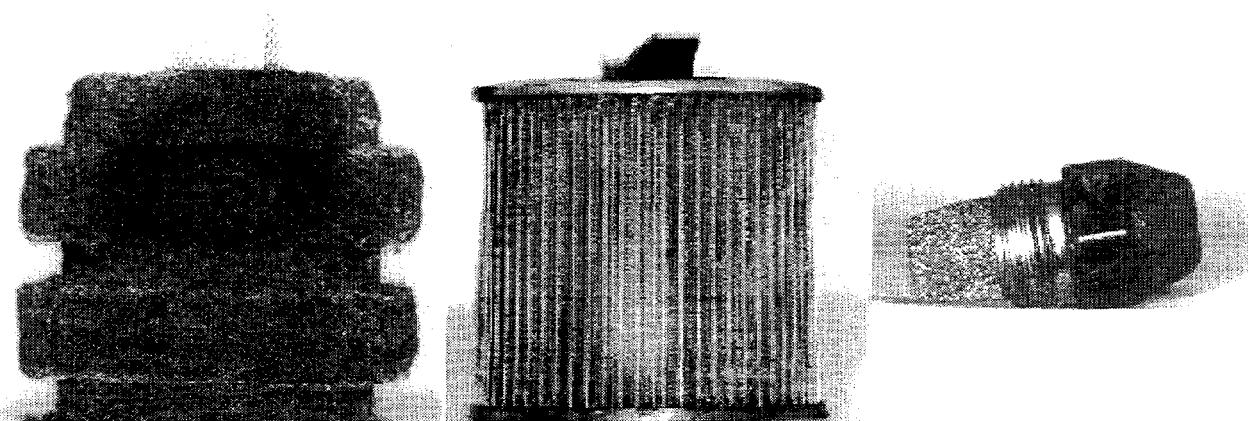
## Other Work

In addition to this work, a new additive was developed to provide a better cost versus unscheduled maintenance requirement performance. This additive was tested in a field trial during the winter of 1994-1995 where the focus was a quantitative determination of the reduction in unscheduled service calls with its use. The results of this field trial are reported in the accompanying paper (joint paper Mobil Oil Corporation and Santa Fuel, Inc.).

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<sup>1</sup> Hoskin, D., McClintock, B., Esposito, F., Trout, R., and Martenak, T. Premium Performance Heating Oil, Paper 94-9. Proceedings of the 1994 Oil Heat Technology Conference and Workshop, BNL-52430, April 1994.

**Group 1, Burner 2**

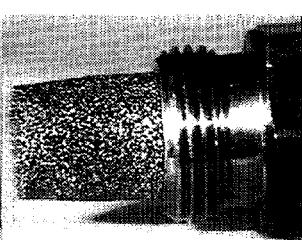
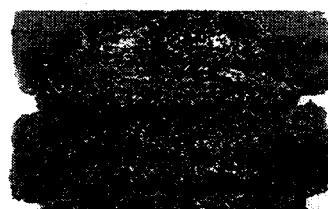


Parts removed after *13 Months* operation on Mobil Premium Heating Oil. Account had a history of service calls for dirty filter, strainer, and nozzle replacements every *6 weeks*. These parts are in near-new condition with respect to cleanliness.

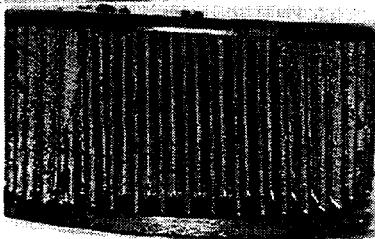
**Figure 1: Example of Keep-Clean Performance of Premium Oil Additive**

### Group 2, Burner 3

Start of test

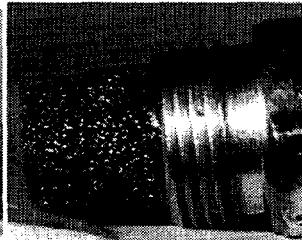


End of test

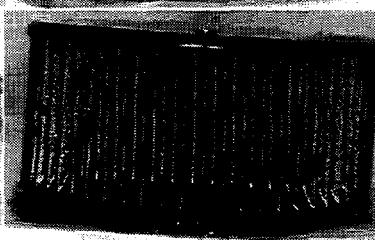


### Group 2, Burner 4

Start of test



End of test

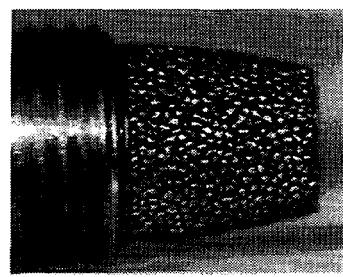
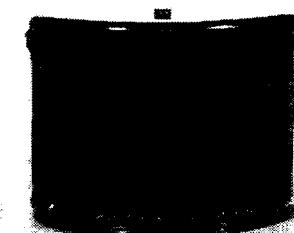
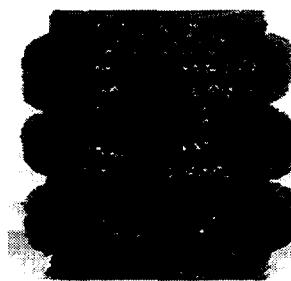


Parts listed as end of test are the same parts as start of test parts after 13 months operation on Mobil Premium Heating Oil. These parts have clearly been cleaned during this operation on the premium fuel.

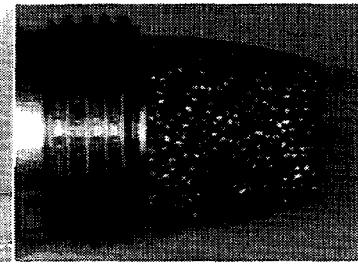
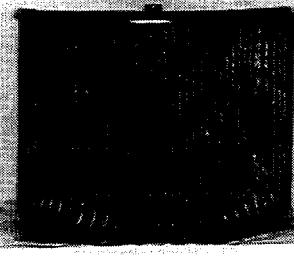
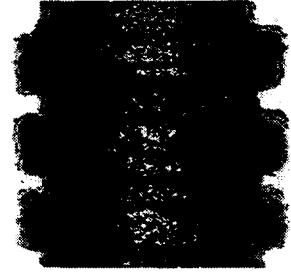
**Figure 2: Examples of Clean-up Performance of Premium Heating Oil**

### Group 4, Burner 1

Start of test

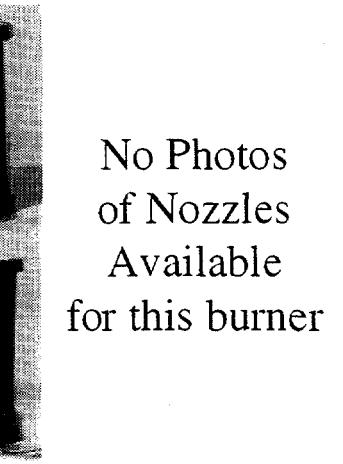
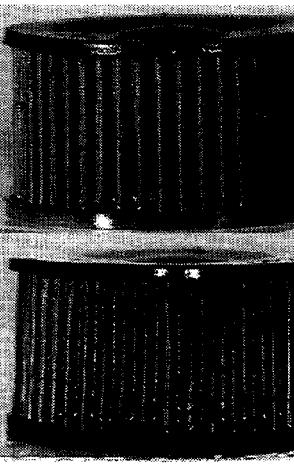
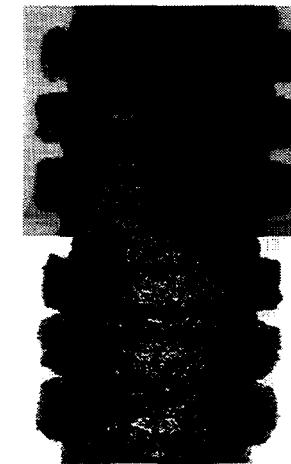


End of test



### Group 4, Burner 4

Start of test



End of test

No Photos  
of Nozzles  
Available  
for this burner

Parts listed as end of test are the same parts as start of test parts after 13 months operation on Regular Heating Oil. These parts have clearly remained dirty during this operation on regular heating oil.

**Figure 3: Examples of performance of Regular Heating Oil**

## Appendix A - Raw Data From Field Trial

Group	1	1	1	1	1	1	1
Burner #	1	2	3	4	5		
REG/PRE	PREMIUM	PREMIUM	PREMIUM	PREMIUM	PREMIUM		
NOZZLE	150 X 80 X W	110 X 80 X B	85 X 80 X A	65 X 70 A -PHOTO	85 X 70 A --PHOTO		
FILTER	SMALL 1/7/94	SMALL 2/16/94	SMALL 2/16/94	SMALL/PHOTO - Shared	SMALL/PHOTO - Shared		
PUMP	MINI SUNTEC 1/7/94	J SUNTEC 2/16/94	MINI SUNTEC 2/16/94	MINI SUNTEC/PHOTO	MINI-PHOTO		
<hr/>							
<b>Start of Test Evaluation</b>							
DATE TEST	34381	34381	34381	34388	34388		
SMOKE	TRACE	TRACE	TRACE	TRACE	TRACE		
TEMP	450	700	600	700	650		
CO2	7	10	12	11	9		
EFFICIENCY	0.7525	0.7275	0.785	0.745	0.7225		
SOOT	NONE	1/32"	NONE	NONE	NONE		
LAST CLEAN	34341	34279	34383	34389	34389		
TANK SIZE	275	1000	275	275	275		
TANK COND.	GOOD	SOME GRIT	SLIGHT GRIT	GRIT ON BOTTOM	GRIT ON BOTTOM		
SERVICE		12/27/93 NOZ/FILT	FILT/SCREEN	SCREEN & FILT VERY	BURN 4/5 SHARE TANK		
COMMENTS		FOUND NOZ/FILT BAD	TAKEN				
			PURPLE	BAD - PHOTO			
<hr/>							
<b>End of Test Evaluation</b>							
DATE TEST	34836	34822	34822	34836	34836		
SMOKE	None	TRACE	3.5	Trace	8		
TEMP	450	700	590	750	700		
CO2	8	8.5	12	11	9.5		
EFFICIENCY	0.775	0.695	0.785	0.73	0.7175		
SOOT	1/8"	3/32"	0	Trace	1/16"		
TANK COND.	Straight down - slight grit. Off-axis, 2" or more of lightly consolidated particulate.	CLEAN	1" Water - Slight Grit	Grit on bottom	Grit on bottom		
COMMENTS		Pump strainer definite improvement. Filter amazing! (Clean)					

## Appendix A - Raw Data From Field Trial

Group	2	2	2	2	2
Burner #	1	2	3	3	4
REG/PRE	PREMIUM	PREMIUM	PREMIUM	PREMIUM	PREMIUM
NOZZLE	100 X 80 X A--PHOTO	75 X 60 X B--PHOTO	100X80XA--PHOTO	100X80AW--PHOTO	
FILTER	SMALL--PHOTO	NONE	SMALL--PHOTO	SMALL--PHOTO	
PUMP	MINI WEB--NO SCREEN	J SUNSTRAND--PHOTO	MINI SUNTEC--PHOTO	MINI SUNTEC--PHOTO	
<b>Start of Test Evaluation</b>					
DATE TEST	34381	34382	34382	34382	
SMOKE	TRACE	TRACE	TRACE	TRACE	#1
TEMP	650	550	700	500	
CO2	11.5	10	8.5	8	
EFFICIENCY	0.765	0.7725	0.695	0.755	
SOOT	1/8"	NONE	NONE	1/8"	
LAST CLEAN	34016	34316	0	0	
TANK SIZE	275	550	550	550	
TANK COND.	GOOD	UNKNOWN	UNKNOWN	UNKNOWN	
SERVICE					
COMMENTS		SHARES TANK WITH BURNS3/4	SHARES TANK WITH BURNS2/4	SHARES TANK WITH BURNS2/3	
<b>End of Test Evaluation</b>					
DATE TEST	34827	34827	34827	34827	
SMOKE	3	1	1	1	
TEMP	750	550	700	500	
CO2	12	9	8.5	8	
EFFICIENCY	0.745	0.7575	0.695	0.755	
SOOT	1/4"	1/16"	Trace	1/4" in Flue	
TANK COND.	Good				
COMMENTS					Soot in boiler inaccessible

**Appendix A - Raw Data From Field Trial**

Group	3	3	3	3	3
Burner #	1	2	3	3	4
REG/PRE	REGULAR	REGULAR	REGULAR	REGULAR	REGULAR
NOZZLE	135 X 80 X W 2/18/94	110 X 70 X B 2/18/94	100 X 80 X A	135 X 70 X B 1/8/94	
FILTER	SMALL NEW 2/18/94	SMALL 2/18/94	SMALL CLEAN AS NEW	SMALL 1/8/94	
PUMP	MINI SUNTEC--PHOTO	MINI SUNTEC--PHOTO	MINI WEB NO SCREEN	MINI SUNTEC--PHOTO	
<b>Start of Test Evaluation</b>					
DATE TEST	34381	34381	34382	34388	34388
SMOKE	TRACE	TRACE	TRACE	TRACE	TRACE
TEMP	450	450	450	650	
CO2	8	11	10.5	14	
EFFICIENCY	0.775	0.815	0.81	0.79	
SOOT	NONE	NONE	TRACE	TRACE	TRACE
LAST CLEAN	34383	34383	34297	34342	
TANK SIZE	275	275	275	1000	
TANK COND.	GOOD	1/2" WATER	GOOD	UNKNOWN	
SERVICE					
COMMENTS	Filter Slimey and Purple				
<b>End of Test Evaluation</b>					
DATE TEST	34827	34822	34827	34836	34836
SMOKE	2	3	1	Trace	Trace
TEMP	450	450	450	700	
CO2	9.5	12	13.5	12.5	
EFFICIENCY	0.7975	0.825	0.835	0.765	
SOOT	1/16"	TRACE	1/4"	3/16"	
TANK COND.	Good	1/2" Water-1/2" Soft Sludge	Good		
COMMENTS	Filter Slimey				

## Appendix A - Raw Data From Field Trial

Group	4	4	4	4	4
Burner #	1	2	3	4	4
REG/PRE	REGULAR	REGULAR	REGULAR	REGULAR	REGULAR
NOZZLE	135 X 70 X B--PHOTO	110 X 80 X B--PHOTO	110 X 80 X A	85 X 80 X B	
FILTER	SMALL--PHOTO	SMALL--PHOTO	SMALL	MEDIUM	
PUMP	MINI SUNTEC--PHOTO	MINI SUNTEC--PHOTO	MINI WEB NO SCREEN	MINI SUNTEC	
<b>Start of Test Evaluation</b>					
DATE TEST	34381	34382	34388	34388	
SMOKE	TRACE	TRACE	TRACE	TRACE	
TEMP	550	550	700	450	
CO2	11	12	9.5	10.5	
EFFICIENCY	0.7875	0.7975	0.7175	0.81	
SOOT	1/8"	1/16"	TRACE	SOME SCALING	
LAST CLEAN	34033	0	0	0	
TANK SIZE	550	275	275	275	
TANK COND.	UNKNOWN	SOME RESIDUE	SLIGHT GRIT	GOOD	
SERVICE					
COMMENTS					
<b>End of Test Evaluation</b>					
DATE TEST	34836	34836	34822	34822	
SMOKE	Trace-1	3	4	TRACE	
TEMP	600	600	720	390	
CO2	10	11.5	9.5	10	
EFFICIENCY	0.7575	0.78	0.7175	0.82	
SOOT	3/16"	3/16"	1/8"	SAME	
TANK COND.	3/4" Water - Some soft residue	SLIGHT GRIT	GOOD		
COMMENTS					



**FIELD PERFORMANCE OF A PREMIUM HEATING OIL**

Thomas Santa  
Santa Fuels, Inc.  
154 Admiral Street  
Bridgeport, CT 06601

and

Steve M. Jetter  
Mobil Oil R&D Corp.  
Marketing, Refining, & Chemical Technical Center  
P. O. Box 480  
Paulsboro, NJ 08066-0480



## Field Performance of Premium Heating Oil

Tom Santa - Santa Fuel, Inc.  
SMJetter, RPTrott - Mobil Oil Corporation

### **Abstract**

As part of our ongoing research to provide quality improvements to heating oil, Mobil Oil together with Santa Fuel, Inc. conducted a field trial to investigate the performance of a new premium heating oil. This premium heating oil contains an additive system designed to minimize sludge related problems in the fuel delivery system of residential home heating systems. The additive used was similar to others reported at this and earlier BNL conferences<sup>1</sup>, but was further developed to enhance its performance in oil heat systems. The premium heating oil was bulk additized and delivered to a subset of the customer base. Fuel related, unscheduled service calls were monitored in this test area, as well as in a similar baseline area that did not receive the premium heating oil.

Overall, the premium fuel provided a 45% reduction in the occurrence of fuel related, unscheduled service calls as compared to the baseline area. Within this population, there was a reduction of 38% in systems with 275 gallon tanks, and 55% in systems that had >275 gallon tanks showing that the additive is effective in the various configurations of residential oil heat systems. In addition, photographic documentation collected at two accounts supported this improvement by clearly showing that the equipment remained cleaner with the premium heating oil than with regular heating oil.

Based on these results, a full marketing trial of this new product has been initiated by Mobil and Santa Fuel, Inc. during the 1995 - 1996 heating season.

### **Introduction**

Many problems in oil fired residential space heating systems (i.e. poor burner efficiency, puff back, odor, noise, and no-heat) can be caused by fouling of the filters, pump strainers, and/or fuel nozzles during the heating season. One source of this fouling is sludge which forms in the fuel tanks and is carried through the fuel system. Although some sludge formation is due to biological growth, it can also be due to oxidation of the fuel and tank corrosion during fuel storage for extended periods of time in the homeowners tanks. It is clear that a fuel that reduces the occurrence of sludge would be desirable from a quality standpoint. Such a fuel should provide significant reductions in unscheduled service requirements, which will reduce a distributor's service costs, as well as improve the image of oil heat and the distributor in the eyes of customers that don't experience sludge related no-heat problems during the winter. Several years ago Mobil began a program to develop a fuel oil that used appropriate additive chemistries to deliver this sludge-minimizing performance. Additive packages were successfully developed to reduce sludge formation through the oxidation and tank corrosion mechanisms, as well as reduce the likelihood that existing sludge will cause a fouling problem. Laboratory test data on additives of this nature has been presented previously.<sup>1</sup> Although this type of testing has shown that a fuel oil can be made more stable, less corrosive, and modified to allow it to disperse sludge which we believe should significantly reduce service requirements, it does not directly address the effectiveness of the additives at reducing the unscheduled service requirements when the fuel is used in the field.

To address this issue, we partnered with a major distributor that has been active in this area for some years to conduct a field trial on a new, experimental additive that was developed for use in heating oil.

## Field Trial Procedures

The field trial was conducted from December 1994 through April 1, 1995. For this trial, fuel was bulk additized by adding an appropriate amount of additive to the delivery truck prior to filling the truck with fuel oil. This approach was chosen over rack additzation only because the trial was conducted in a single delivery area that was handled by one delivery truck. The additized, premium heating oil was delivered to all accounts in the test area (approximately 400 accounts). A second, similar sized area (geographically close to the test area) did not receive the premium heating oil. This was tracked as the baseline area to normalize the effectiveness results of the premium heating oil. The fuel used in this base area, was the same base fuel with a commercially available sludge-control additive instead of the test additive. This commercial additive was used in both areas in the prior years, thus making the only change from base to test area the use of the test additive. A computerized database of all service/fueling records was utilized to obtain complete fueling and service histories for the baseline and test areas. This data was analyzed to determine the effectiveness of the premium heating oil at reducing unscheduled service in the test area. In addition, 8 accounts in the test area were randomly selected for more detailed analysis. For those 8 accounts, a complete cleaning/tune-up was done at the start of testing and the following information was collected at the start and end of the test period:

- Photographs of Filters, Nozzles, and Pump Strainers
- Burner Efficiency

With the data available, the following analyses were completed:

1. For the overall test, comparison of the control and test area service requirements for the prior two years and the test year to determine if reductions were achieved with the premium heating oil. This direct comparison of the two areas over the 3 years simplifies the analysis as it eliminates the need to normalize the data for the varied weather conditions (this type of normalization could also be done using fuel usage or degree day data). Appendix A includes the detailed procedures used to analyze the data.
2. For the 8 detailed analysis accounts, a direct comparison of the condition of the filter, nozzle, and strainer removed at the start of the test (base fuel case) and those parts removed at the end of testing (premium fuel case). This analysis requires the fuel usage data be examined to determine the amount of fuel which passed through the start and end of test parts, to ensure that relevant comparisons can be made. Burner efficiencies can also be compared for these units.

## Results/Discussion

The results of these analysis are as follows:

1. Figure 1 shows the total number of fuel-related service calls in both areas for the three winter heating periods (Dec. to Mar. for each winter). The first two years (1992-93 and 1993-94) data establish that the two areas service requirements are equivalent and track well based on ambient weather conditions (1993-94 was a colder winter). This information

indicates that this type of comparative analysis is appropriate to eliminate weather effects from biasing the data. Based on this, if the additive is effective, we would expect the test area to have significantly fewer unscheduled service calls compared to the control area during the test year (1994-95). In the test year a 45% reduction in the service calls for the test area as compared to the control area was observed. Based on these results, two additional sub-analysis were performed to be sure that the reduction was truly related to the additive and not a bias in the control area service requirements. The first of these was to determine how many of the service calls in the areas were caused by "long-deliveries". A long-delivery was defined as a delivery that was made later than scheduled (a near run out of oil) which could allow any sludge in the tank to be disturbed more than a normal delivery, which could lead to a plugged filter. This was deemed important because if the delivery driver was sick or behind for some other reason, a large number of long-deliveries could take place in a short period of time. This analysis did not show any bias between the two areas and does not change the final results (two service calls in the base area and one service call in the test area were the result of long deliveries). The second analysis was to look at tank size to determine if there was some influence of larger tanks, which Santa Fuel believed have a higher incidence of problems. The results of this analysis are shown in Figure 2 which shows the expected number and split of service calls based on the historical data compared to the observed data using the premium heating oil. This data clearly indicates that the additive was effective at reducing service requirements in both small (275 gallon) and large (>275 gallon) tanks, with observed reductions of 38% and 55%, respectively.

2. For the 8 accounts studied in more detail, only two could be analyzed in sufficient detail to make valid comparisons. Table 1 shows each account, the data collected, and the reason for each that could not be analyzed.

Account #	SOT Eff.	EOT Eff.	Regular Oil Usage (gals)	Premium Oil Usage (gals)	# of Service Calls	Reason for Exclusion from analysis
523093	76.5	75.3	F: 300 N/S: 680	500	1	None - Analyzed
124911	80	78.5	650	1050	0	None - Analyzed
038752	81.5	82.3	N/A	ND	0	No Historical Data
049924	81.5	85.3	N/A	600	1	Insufficient Historical Data
109439	71	N/A	N/A	N/A	N/A	Furnace Replaced
109439	82.3	78.5	ND	ND	0	2000 Gal Tank, No Del. of Premium
514472	84.5	N/A	ND	ND	ND	EOT Inspection not done. Customer away
013862	77.3	N/A	N/A	N/A	N/A	Did not become Customer

Notes: F = Filter, N = Nozzle, S = Strainer used if a single part was replaced that would cause different fuel usage's for different parts. N/A = Data Not Available. ND = Value Not Determined, since account could not be used for some other reason.

Table 1: Detailed Account Data

The table also shows the fuel usage data for each account for the regular and premium fuel filter, nozzle, and strainer. This usage value represents the total gallons of fuel oil (regular or premium) used by the account while the filters, strainers, and nozzles removed and photographed at the start and end of test were in use. For the two accounts that could be analyzed, the fuel usage for the end-of-test parts are similar or greater than the start-of-test parts. This enables a direct comparison of the start- and end-of-test parts to determine if the additive was effective in keeping the fuel system cleaner. Figures 3 and 4 show the photographs of the filters and pump strainers for these two accounts taken at start and end of test. These figures clearly show that the parts that were exposed to the premium heating oil remained much cleaner than those exposed to regular heating oil, even in the cases where the fuel usage was greater with the premium fuel. This keep-clean performance of the premium fuel is consistent with the large reductions in service requirements in the larger test population.

Although there is some indication that the burner efficiency was decreased during the test period with the premium fuel, there is not a consistent trend of decreasing efficiency, and the magnitude of the change is thought to be within the reproducibility of the test method used to determine efficiency.

## Conclusions

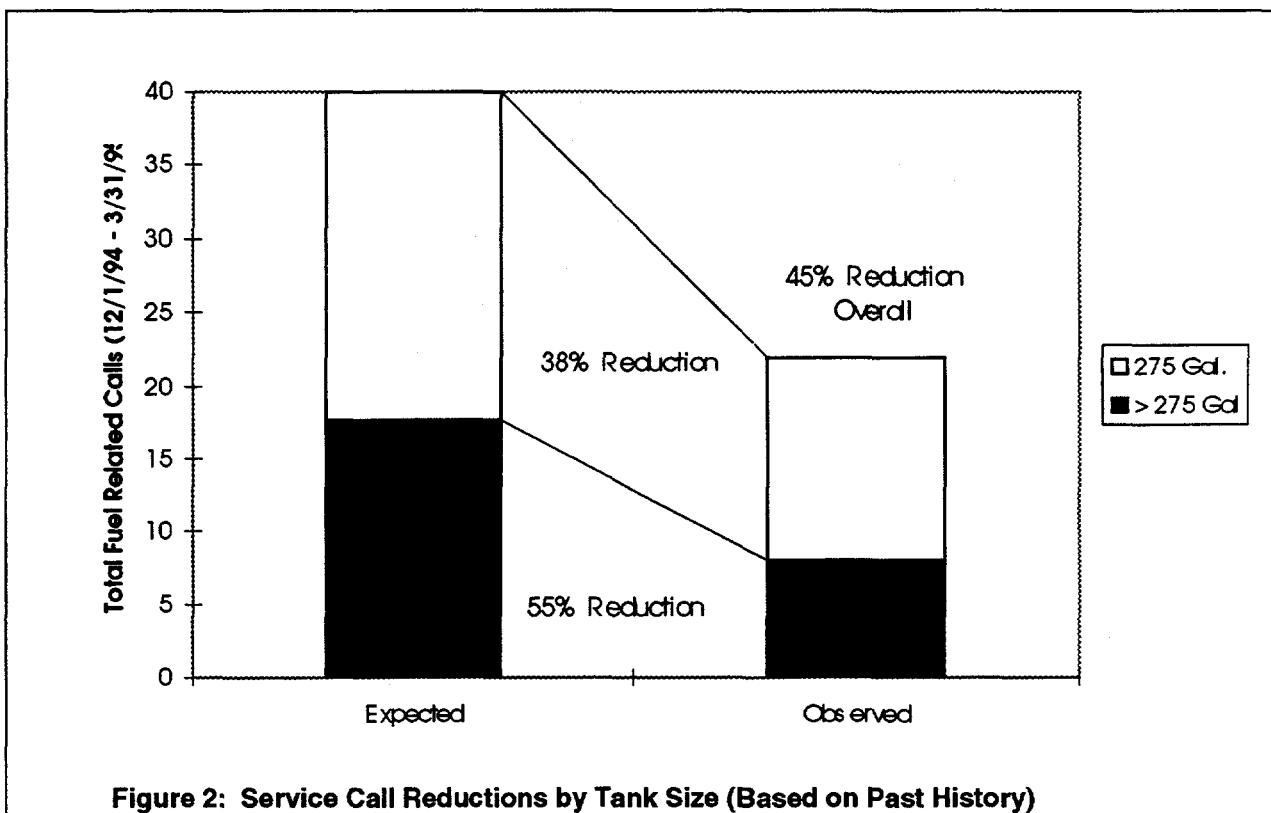
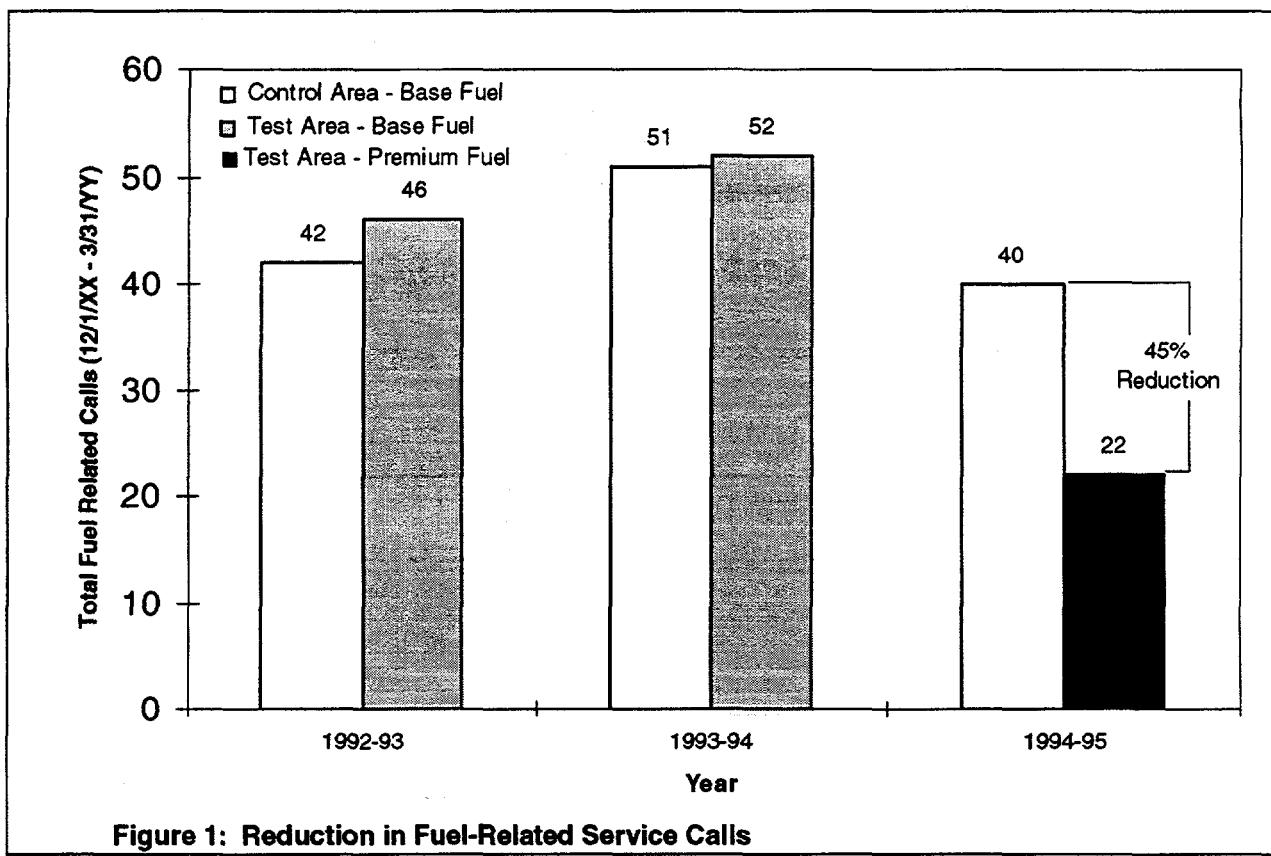
From the field test work that has been completed, it can be concluded that the premium heating oil is capable of providing 45% reduction in fuel-related unscheduled service calls overall (up to 55% reduction seen in some sub-population). The reductions in service are attributed to the ability of the premium heating oil to keep oil burner fuel systems cleaner than a heating oil with a commercial sludge control additive during normal burner operation.

## Future Work

We are currently conducting a full marketing trial of a branded Mobil Premium Heating Oil. This trial is primarily to test the marketing concept of a branded program but will also allow the opportunity to collect more technical data on the additive's performance. If this trial is successful, the product may be introduced, as a Mobil Branded Product, in the winter of 1996/97.

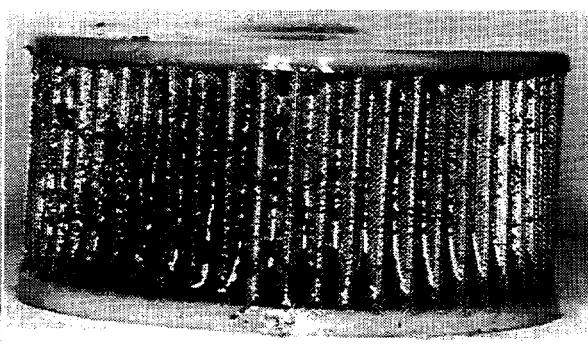
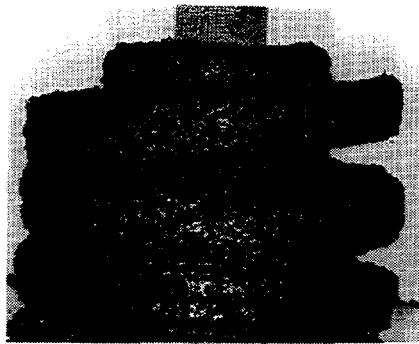
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<sup>1</sup> Hoskin, D., McClintock, B., Esposito, F., Trout, R., and Martenak, T. Premium Performance Heating Oil, Paper 94-9. Proceedings of the 1994 Oil Heat Technology Conference and Workshop, BNL-52430, April 1994.



Fuel Usage

650 Gallons  
Regular Fuel



1050 Gallons  
Premium Fuel

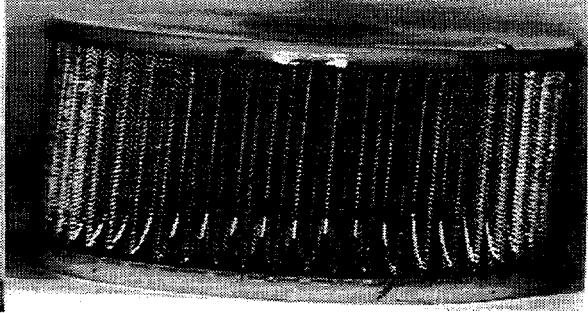


Figure 3: Photographs from Account 124911

Fuel Usage

Filter: 300 Gals  
Regular Fuel

Strainer: 680 Gals  
Regular Fuel

500 Gallons  
Premium Fuel

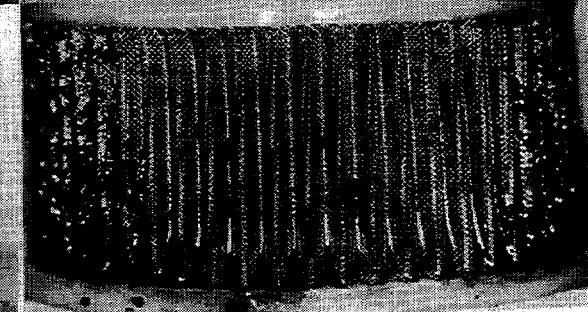
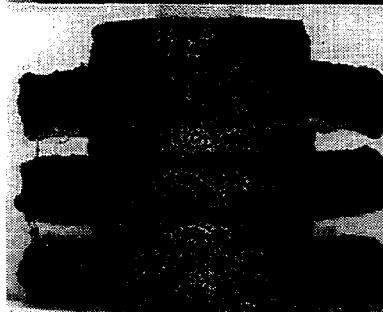


Figure 4: Photographs from Account 523093

## Appendix A - Data Analysis Procedures

The following procedures were used to determine the total number of service calls for the two areas in the field trial. They were used to ensure that comparisons were made on a consistent basis and that only fuel-related unscheduled maintenance calls were considered.

1. Reduce dataset by eliminating calls that were not fuel-related. This was done by keeping only calls in which any of the following parts were used in fixing the burner during the calls:
  - Filter
  - Nozzle
  - Pump Strainer
  - CO2 Cartridge (used to clear a blocked fuel line)
2. Remove calls from the dataset that would not be considered as unscheduled maintenance. The following types of calls were eliminated:
  - Installation
  - Cleaning/Tune-up
  - Fuel Tank Installation
  - Oil Leaks
  - Oil Spills
  - Run out of oil
3. Remove calls that were believed to introduce some bias as follows:
  - Any calls that were from accounts that it could be determined were not Santa customers for the three year period looked at. This would eliminate possible bias from gaining or losing a severe problem account.
  - Duplicate calls that were introduced by a limitation of the database program (multiple records for single service call if more than seven parts were replaced).
4. Eliminate calls that were at an account that had some service performed in the three year period that could cause a step change in the accounts service needs. This also helps to eliminate any bias in the dataset. Calls were excluded if any of the following services were performed on the account in the three year period:
  - Installation (Burner/Furnace)
  - Chamber/firebox replacement
  - Chemical treatment (Biocides, etc.)
  - Pump-out of oil
  - Chimney cleaning
  - Fuel tank installation

The resulting dataset was used for all final analysis from the Field Trial.



**CANADIAN R&D ON OIL-FIRED COMBUSTION SYSTEMS**

A.C.S. Hayden and E. Entchev  
CCRL/ERL/CANMET



## **CANADIAN R&D ON OIL-FIRED COMBUSTION SYSTEMS**

A.C.S. Hayden and E. Entchev

CCRL/ERL/CANMET  
555 Booth Street  
Ottawa, Canada K1A 0G1

for presentation at  
10th Oil Heat Technology Transfer Conference & Workshop  
BNL, March 28-29, 1996

### **ABSTRACT**

This paper describes research and development presently being conducted on oil-fired space and tap water heating systems by the Advanced Combustion Technology Group, CCRL/ERL/CANMET, in Ottawa, Canada.

The presentation will focus on R&D activities at CCRL in support of the Canadian Oil Heat Association (COHA) and of the energy policy initiatives of Natural Resources Canada. Progress will be reported on activities to develop suitable oil-fired integrated systems to satisfy the low energy demands of new homes. The utilization of fuzzy logic-based control strategies to optimize the efficiency and emissions performance of integrated space/water heating systems including fan coils for a complete range of old and new North American housing will be discussed.

Additional activities to be discussed in the presentation will relate to the development of appropriate seasonal efficiency standards for complex integrated space/water heating systems, as well as an evaluation of alternative sidewall venting technologies and their implications for seasonal energy efficiency.

## Introduction

CCRL has been closely involved with technical developments in the oil heating industry since the early 1970's, when it carried out detailed performance analyses (efficiency, emissions, noise, cyclic degradation, etc.) of technical equipment, including burners, furnaces, boilers and water heaters, for the Oil Heat Association of Canada and its successor, the Ontario Petroleum Association.

CCRL has continued to carry out laboratory and field studies to quantify energy losses, efficiency potential and pollutant emissions with residential oil heating systems, and to define suitable new and retrofit technology and strategies to reduce those losses by 20% and more.

In support of this activity, CCRL developed an oil heating efficiency package. CCRL re-defined the servicing programs of a major oil company, to maximize heating efficiency and trained all of their managers and service personnel across Canada. Subsequently, as part of a National Fuel Efficiency Program, in cooperation with all the major oil companies, the independents and the provinces, CCRL wrote the Efficient Oil Heating Manual and trained the majority of the oil servicing industry across Canada in efficient oil heat technology, applied to new, upgraded and existing systems.

CCRL has carried out studies for the Canadian Electrical Association and the Canadian Standards Association (CSA) on the potential problems of venting oil heating systems with add-on electric plenum heaters or heat pumps. These studies defined and initiated a series of actions to improve the venting of combustion equipment in Canada. The result has been a number of new or modified CSA, CGA and ULC standards, as well as the spawning of R&D efforts on venting across North America. Throughout, CCRL has remained a technical consultant to many of these activities.

CCRL has a controlled temperature calorimetric test cell capable of simultaneously running two oil furnaces/boilers. In this cell, the ambient temperature, the temperature of the fuel, and/or the temperature of the returning heat transfer fluid (air, water) can be fixed over a wide range, as well as the imposed draft and the pressurization/depressurization of the test cell. Utilizing this test facility, CCRL has had an on-going program to determine effects of fuel and equipment changes on oil system performance, with particular emphasis on detailed determination of transient start-up, shut-down performance. Continuous measurements are made of all gaseous emissions, soot and temperatures; simultaneously, video recording of the flame character can be made under all operational conditions. Ambient, return air, combustion air and fuel temperatures can be individually controlled, as can the draft and the test cell pressure. Main clients for this work to date have been the major Canadian oil companies, with other work being carried out for environmental regulators, ASHRAE, and specific manufacturers.

A large proportion of CCRL's activities are focussed directly on improving energy efficiency. To this end, CCRL has a High Efficiency Laboratory where advanced fuel-fired heating systems are developed and optimized. In this lab, work is concentrated on integrated

systems performing a range of energy-related applications, and on alternative sidewall venting technologies.

In close association with the Canadian Oil Heat Association (COHA), CCRL is continuing to work to develop more efficient, clean burning, oil heating systems. For the past few years in its high efficiency laboratory, CCRL has been carrying out studies, prototype development and equipment evaluation of a range of combined space/water heating systems, to determine optimal systems for a range of applications. Also being examined is a series of sidewall venting strategies and technologies for oil-fired equipment.

On the industrial scale, CCRL has a pilot scale electric utility boiler and a vertical furnace, both primarily geared to burning low grade fuels and to develop technologies for the efficient reduction of greenhouse gases. The prime clients for this equipment are the large boiler manufacturers and electric utilities. A tunnel furnace and a rotary kiln provide pilot scale facilities for industrial burner development and waste fuel utilization, as well as for the direct simulation of cement and lime kilns. The lab also has pilot-scale bubbling and circulating fluidized bed combustors, for burning coal and industrial wastes.

Significant efforts are being devoted to the computer modelling of flames and combustion processes and to the development of learning-based expert systems for a range of combustion processes. With regards to the expert systems, work is presently underway to apply these concepts to a municipal solid waste incinerator in Vancouver, a soot-blowing system in a large utility boiler in Alberta and for predictive emissions monitoring of gas compressor stations of a major pipeline company and of a dual fuel-fired utility boiler. Similar concepts are being applied to the development of the integrated systems for residential applications.

## **Energy Use in Canada**

The residential and commercial sectors account for 20% of Canada's fossil fuel energy consumption and CO<sub>2</sub> emissions, (nearly all of which is for space and water heating). Energy consumption reductions of 20-39% can be realized by advanced space and water heating systems for new and existing buildings.

Some 25% of the home heating in Canada is from oil-fired systems, with the potential for this figure to grow significantly if it can displace electricity in many presently electrically heated homes. A further market for oil is the presently-electric tap water heating in the majority of oil heated installations in Eastern Canada. However, having a successful venting system which can handle two oil burners simultaneously or independently under Canadian winter conditions is not a trivial problem.

In Canada, with electricity suddenly becoming a less desirable home heating source, both from the consumer's view due to rapidly increasing energy costs, and from the electric utilities' views because of peaking supply problems, oil also has an opportunity to become the energy source of choice in new housing, particularly (but certainly not limited to) in those areas of Canada where natural gas is not available.

One problem, however, is that present burner technology does not allow satisfactory inputs below 0.5 USgph (70 kBtu/h), well above the design requirements for most new housing in Canada (which are coming in at or below 40 kBtu/h), resulting in very oversized equipment, with their attendant inefficiencies and comfort problems. A second driving force is that with lower heat demands, and hence lower annual heating energy bills, the consumer is less and less likely to spend more money on a premium system to supply energy to heat the house.

### **Low Output Oil System for Energy Efficient Housing**

Obviously, one solution to the too-high minimum firing rate of present pressure-atomized oil burners is to design a new burner. This is the route which Brookhaven is following. On the other hand, coupling the problems of lowered heating demand with those of tap water heating leads to a conclusion that combining the two heating functions in a one-burner appliance might kill many birds with one stone, while leading to a very efficient, cost-effective multiple use appliance which could allow oil to increase its share of the marketplace substantially. CCRL is working on alternative solutions to this problem, through the development of advanced integrated space-water heating systems. This is the prime focus of CCRL activity in oil heating at this time.

CCRL has carried out a study to define the options for a low output heating system also capable of supplying tap water heat, evaluating which option has the highest probability of success in the Canadian context.

CCRL has also developed a computer simulator which allows design evaluation and optimization of the most appropriate system(s).

Based on these evaluations and optimization, CCRL is developing design specifications for a low output oil-fired heating system. Efforts are directed towards minimizing the cost and complexity of the final system, while assuring that the goals are achieved.

### **Sidewall Venting**

At the same time, CCRL is examining the appropriateness of sidewall venting technology for integrated systems, as well as stand-alone space or water heating appliances. There is some concern that much of the existing sidewall systems can result in problems under Canada's harsh winter climate and tight housing stock.

Some of these problems are: staining of outside walls; smells in the house; increased furnace sooting or nozzle coking leading to atomization degradation and ignition failure; heating problems with burner components; vent corrosion; inability to operate under changing ambient conditions; or inadequate or converse flow proving. In addition, many installations have large air requirements and commensurate high heat losses, during the on-cycle and during pre- and post-purge operation. CCRL has been given a parallel task to develop an

appropriate modification to the seasonal efficiency standard to reflect the real operation of good sidewall systems.

Systems being examined include single and two stage wall-mounted induced draft fans, a unique "pusher" type induced draft system and forced draft upstream of the furnace.

The strategies developed under this program will also lead to efficient and cost-effective retrofit of electric water heaters in oil-heated homes.

### **Existing Integrated Space/Water Heating Systems (ISWHS) and Their Control Strategies.**

Integrated Space and Water Heating Systems (ISWHS) are a means of providing domestic hot water and space heating requirements of a dwellings using one energy generator (i.e. burner).

Three basic integrated systems are shown in Figures 1, 2 and 3. The energy generator of the system can be an oil-fired water heater or boiler, ideally sized to meet both domestic hot water demands and space heating loads. The space heating loads can be satisfied by circulating the hot water from the generator through a fan-coil unit, a hydronic system or an underfloor radiant system, or some combination thereof. A circulating pump is responsible for moving the hot water through these units and is usually activated by a room (house) thermostat. The burner on-cycle is a function of tank or boiler aquastat setting and the demand.

The current simple control used to manage most storage tank-based systems is to start the burner when the hot water tank temperatures drops below the tank aquastat deadband, and to start the water pump and fan-coil motor when there is a demand for heat as determined by the room thermostat. Some control systems have additional functions, such as giving priority to hot water draw during a combined space\water heating mode. Other functions such as room comfort, absolute tank aquastat settings, water pump speed, etc., have been left to homeowners or service technicians to alter manually.

Because new functions are applied directly to the energy generator, such strategies often cause the burner to cycle more frequently, not be able to satisfy all demands, decrease comfort in the house and sometimes have the system perform in an inefficient manner.

## Fuzzy Logic Control to Optimize Performance

Recently, Fuzzy Logic Control (FLC) has gained a certain degree of popularity due to applications developed for consumers, such as the hand-held camcorder and even washing machines. One of the main advantages of fuzzy logic is that it can allow better control than conventional techniques in complex environments which are characterized by nonlinearities and where the input signals are correlated. At the same time, conventional controllers require a long development time and adjustment to work properly in changing conditions and requirements. Fuzzy logic-based strategies provide continuous control and optimal operation of the system and its components for any combination of the input signals and surrounding environment.

Existing ISWHS have a number of devices which can be controlled directly or can be involved in different types of control strategies. They presently utilize only some of their capabilities, resulting in lower efficiency and system performance and satisfaction than might otherwise be obtained. There is an opportunity to remedy this, producing better performing, more cost effective ISWHS's, by utilizing new more efficient and smart devices. Such devices are capable of being trained and are fully compatible with microprocessor technology. Because of the nonlinearities and nature of the thermal and hydraulic processes involved, the strong influence of the surrounding environment, occupant behaviour, and the necessity of continuous control to gain better system performance, the fuzzy logic approach is very applicable to this kind of application.

Fuzzy logic control offers significant advantages over other control strategies in managing an integrated heating system for improved comfort, energy savings, better system performance and lower emissions. To achieve these goals, the frequency and duration of burner operation, tank temperature levels and circulating fan motor speed will be targeted by the fuzzy logic control strategy.

### Generic Integrated (ISWHS) Systems

Three generic ISWHS have been tested in the Lab under different conditions and operating modes. The first system (System A) consists of low mass boiler, external water storage tank and a fan-coil. The second one (System B) is one with internal double tanks which store the hot water for space and for domestic purposes separately. The third system (System C) is a conventional oil-fired water heater coupled to a fan-coil.

**SYSTEM A** A more efficient oil-fired integrated system, shown in Figure 1, has a low mass boiler fired with a high static burner as the energy generator, coupled to a well-insulated storage tank through an efficient water-to-water heat exchanger.

Intelligent microprocessor controls can allow for maximum boiler efficiency with a significantly reduced number of cycles when coupled with a reversible pumping system. When the thermostat calls for heat, the boiler runs normally, generating hot water for hydronic radiators, or for an efficient fan coil with modulating fan control driven by an

efficient commutating motor. When the house thermostat is satisfied, the burner continues to run instead of shutting off, with the hot water from the boiler being passed through the heat exchanger, sending heat to the storage tank, instead of the house. The next time that the thermostat requires heat, the process reverses and heat is drawn out of the storage tank, across the heat exchanger, and around the house, without the boiler/burner actually operating. Whenever hot tap water is required, it is taken directly out of the storage tank. The number of cycles of the boiler is much less than for a conventional system, the burner runs much longer for each cycle, the boiler operates more efficiently in its heating mode, and the tap water heating efficiency is improved dramatically.

**SYSTEM B** This is an integrated oil-fired space/water unit having an internal double tank in which the hot water for space and for water heating are stored separately. In principle, this system is somewhat analogous to a tankless coil boiler with external water storage.

**SYSTEM C** A conventional oil-fired water heater mated to a properly sized, efficient (commutating motor-driven) fan coil, shown in Figure 2, offers a relatively inexpensive interim step to integrated space/water systems. Care should be taken that scalding-level water does not reach the taps, by requiring a tempering valve before entering the house hot water piping. Long stagnant runs on the space heat side should be avoided. It may be a good idea to install these systems with an efficient water-to-water heat exchanger, to prevent possible contamination of the potable water. There is some concern for the longevity of some systems, if a conventional a water heater now must increase its usage by about a factor of four. Another concern is that the efficiencies of some of these units are lower than for the furnaces and boilers which must meet the DOE 80% seasonal efficiency standard.

### Experimental Procedures

When carrying out performance trials, flue gas analysis was performed continuously using a conditioning train and infrared analyzers for carbon dioxide and carbon monoxide, a paramagnetic analyzer for oxygen and a chemiluminescent analyzer for nitrogen oxides. Data from these analyzers, plus those from flue gas temperature grids and for other required temperatures using ganged CrAl thermocouples are collected and processed by a computer-controlled data acquisition system. The continuous gas sampling train consists of a slotted probe collecting samples across the duct diameter. A dry filter and moisture trap cleaned the sample before it is passed through a chiller and silica gel to remove further moisture, with additional filters to remove particulates immediately before the analyzers.

Systems are tested using both steady state and cycling runs representing peak and normal winter operation for both space and water heating both individually and simultaneously, and with only domestic hot water draws representing summer, with no space heating requirement.

Additional tests are performed to estimate the influence of such system parameters as tank temperature setting, mass flow rate, burner input rate and circulating water and fan control variations on the efficiencies and emissions.

CCRL has previously shown that a significant proportion of the emissions of incomplete combustion products - carbon monoxide, hydrocarbons and particulates - are produced during the transient combustion conditions at start-up and shut-down. There are no effective transient increments to the emissions of carbon dioxide and nitrogen oxides, except in highly unstable combustion conditions.

CCRL has also shown that, for condensing warm air systems, shorter cycles tend to increase efficiency, while for non-condensing systems, the reverse is nearly always true. For condensing systems based on tap hot water generators, the relationship is more complex, and is very much total system dependent.

For integrated systems with an integral water storage tank, burner cycles and burner on-time depend primarily on the water tank thermostat setting and the mode (space or water heating) of the system.

During the space heating mode, the higher the tank thermostat setting, the more rapidly the burner cycles and the shorter the burner on-time per cycle.

One interesting result is the effect of fan coil operation on oil burner cycling frequency. Running a lower circulating fan speed results in a 28% lower burner on-time, but effectively the same burner off-cycle. This would indicate that to supply the same amount of heat to a residence, the system would actually have to cycle more with the lower fan speed, resulting in an increase in transient emissions.

The three systems were tested under three basic modes: space heating, water heating and combined space/ water heating, using both steady state and cycling runs representing peak and normal winter conditions. In addition tests for estimation the influence of mass flow rate, temperature settings and outdoor conditions were performed.

The test results can be integrated and described as follow:

1. The burner cycles every 2-4 min for a period of 1.5-2.5 min during space heating mode for system A and B and every 5-6 min for a period of 3.5-4.5 min for system C. The high boiler supply temperature 80C provides the house with plenum air of 55-60C as the heater supply plenum air with 40-45C.
2. The burner operation during water heating mode depends on tank volume, temperature setting and amount of the draw . Morning water draw schedule caused the burner to come on two times for a period of 7 and 10 min (system A), five times for a period of 2 min (system B) and two times for a period of 7-7.5 min (system C).
3. Combined space/water heating mode caused drops of the plenum temperature to 35-40C for system C and 50-55C for systems A and B.
4. During large draws, more than 60L, all three systems are not able to handle relatively constant plenum air temperatures as the temperature drop is between 5-10C.

5. The performance of the blower motor has a significant influence on system performance. The use of two speed motor coupled with appropriate strategy can reduce the burner cycles approximately by 5-10% and the use of an ICM motor with start and stop delay can reduce the burner cycles by 10-15% .
6. By using two or multi speed water circulating pumps, the quality/quantity control can be applied in a range of ways offering possibilities for even better management of the system performance.

### **Principles of Fuzzy Logic**

Fuzzy Logic or "continuous" logic was found by Lotfi Zadeh in 1960's. It differs from conventional (bivalent) logic in the area where the information can be part of two events at the same time and also by the type of inference process.

Fuzzy logic is a methodology for problem solving, with applications in information processing and controls. By using it, we are able to explain linguistic intersections in terms which a microprocessor can easily understand.

Fuzzy logic provides a systematic interpretation of fuzzy rules, where fuzzy rules are in the form:

**If the room temperature is cool, run the ICM motor fairly high**

A system based on fuzzy rules is regarded as a mechanism for generating signals at its output nodes in response to signals received at its input nodes.

The description of input variables are done by membership functions. By definition, a fuzzy set  $Y$  in space  $X$  is characterized by a membership function such that for any point  $x$  in  $X$ , there is a number between 0 and 1.

Labels are associated with the input and output variables. They are linguistic descriptions of fuzzy sets such as, for example, hot, cold, very warm, cool, etc.

The inference process is the internal mechanism producing non-fuzzy output values from fuzzy rules for given input values. It involves three steps: fuzzification, rule evaluation and defuzzification. Fuzzification is the process of translating real values of input variables to the grades of its input labels. Rule evaluation is the process of obtaining the grades of output labels from input grades. Defuzzification is the translation of output grades to a non-fuzzy output of real output variables.

These characteristics make the application of fuzzy logic very suitable for processes involving system complexity (multi-use or multi-driven, etc.), nonlinearity and uncertainty, or a range of degrees of conditions and satisfaction, yet using inexpensive control chips.

or a range of degrees of conditions and satisfaction, yet using inexpensive control chips. Many consumer products made primarily in Japan are incorporating it to improve operational performance and efficiency.

## **Fuzzy Logic Control for Integrated Systems**

A generic ISWHS suitable for developing a fuzzy logic strategy contains a single stage oil burner firing into a boiler or an efficient tank heater, a variable speed blower motor, a differential room thermostat and tank aquastat.

### **Variable speed blower motor control**

By modulating the warm air flow rate, more efficient performance of the heating system can be achieved. At the same time, comfort can be increased by avoiding the undershooting and overshooting often seen by conventional warm air systems.

The inputs are fuzzified and labelled as follow:

**Room thermostat temperature deviation**, defined as the difference between the current and desired room temperatures and described by seven membership functions with labels: Negative\_Big, Negative\_Med, Negative\_Small, Zero, Positive\_Small, Positive\_Med, Positive\_Big.

**Run Mode**, which depends on thermostat mode set up and contains three membership functions with labels: Energy\_Saver, Normal and Fast.

The **output** controls the motor rotation and has three membership functions described by five labels Zero, Low, Medium, High and Very\_High.

The **rule base** contains 21 expert rules, giving the conditions and connections among the inputs and the output.

This type of fuzzy logic strategy was verified through a simulator. The result is a 3-D graph describing the current motor speed as a function of changing input values is presented in Figure 3.

### **Burner Control**

A single stage, on-off burner common to most applications is targeted by the controller.

The inputs are:

**Tank temperature differential membership function** determined by five labels: Negative, Zero\_Dif, Positive\_Small, Positive\_Medium, Positive\_Big.

**Room thermostat temperature deviation** as described above.

The **output** is the burner operating stage (On, Off).

The results of the burner control simulation is presented in Figure 4.

### **Tank Aquastat Control**

Homeowners have their own energy usage patterns, as reflected by their water draw schedules (times and magnitudes) and their tank temperature settings. There are some common principles for the tank aquastat setting depending on external and internal conditions. However, there are often simultaneous large demands for space and water heating, particularly on cold Canadian winter mornings.

The on-going control of tank aquastat setting is based on:

**Outdoor temperature** described by five membership functions: Cold, Cool, Zero, Warm, Hot. Figure 5 presents this as a sample representative of a membership function.

**Time of day** consists of six membership functions with labels: Morning\_1, Morning\_2, Day, Evening, Night\_1 and Night\_2.

The **output** is Tank aquastat settings described by five labels: V\_Lows, Lows, Meds, Highs, V\_Highs.

The **rule matrix** consists of 30 rules .

A performance simulation of tank aquastat settings is shown in Figure 6. The temperature level of aquastat settings follows the peak morning and evening usage patterns and depends on outside condition as well.

### **Efficiency Standard for Oil-Fired Integrated Appliances**

There is increased impetus to supply integrated oil-fired systems in the marketplace. While individual oil-fired space heating and tap water heating appliances have CSA standards to measure their specific performance on a seasonal basis, there is no accepted means in Canada for determining the real efficiency of integrated systems when the two functions are combined. There is a concern that the existing ASHRAE standard may over- or underestimate the actual seasonal efficiency of integrated systems, depending on the type. CCRL is committed to develop a standard in CSA format to realistically measure the seasonal efficiency of potential combinations of oil-fired integrated space and tap water heating systems, such that accurate determination of the performance is possible for a range of space and water heating applications.

CCRL is now carrying out a study to define the potential combinations of space and water heating equipment most likely to appear for oil-fired systems. Based on CCRL's extensive experience in the area of integrated systems' performance, as dialoguing with a range of interested parties, CCRL will develop a preliminary draft standard in CSA format to measure the seasonal efficiency of these systems, such that accurate determination of the performance is possible for a range of space and water heating applications. As part of this activity, the present ASHRAE standard will be examined for its suitability. CCRL will then carry out supplementary laboratory trials, following the draft standard. Based on the laboratory results and solicited comments from relevant stakeholders, CCRL will modify the standard. At the same time, CCRL will produce a PC-based computer program to perform the calculations required by the standard.

The final result will be suitable to be called up as the reference means of imposing minimum efficiency levels under provincial and federal energy acts.

### Summary

We have considered the role of and the interactions between the conventional and fuzzy logic control for individual space and water heating applications and, associated with them, overall performance of an Integrated Space/Water Heating System (ISWHS). Obviously, a useful system is one that satisfies its performance requirements and design constraints. Fuzzy logic based control gives the opportunity to manage the operations of ISWHS's during space, water heating and combined space\water heating mode in a continuous manner, while providing optimal performance for the separate requirements. This type of control offers significant benefits to the manufacturers as simple, better and cheaper control, improved performance, simpler implementation, reduced design cost and the potential for enhanced customer satisfaction.

In particular,

1. Efficient integrated space/water systems offer the potential for low heat output, to allow oil to return to new and retrofittable electric heated housing as a preferred energy source, in many areas of Canada.
2. Using fuzzy logic, CCRL is designing integrated system control strategies which can maintain high efficiencies over a wide range of load requirements for both space and water heating.
3. Improvements in cycling control strategies as well as overall systems efficiencies can lead to a major reduction in the emissions of oil-fired appliances, both of conventional "pollutants" as well as greenhouse gas emissions, and alleviate venting problems.
4. CCRL is developing a seasonal efficiency standard for integrated oil-fired appliances which will be applicable to the range of combined space and water heating systems anticipated to be developed for the Canadian market.

5. CCRL is working closely with the Canadian Oil Heat Association (COHA) to advance the technologies and systems available for oil-fired appliances in Canada.

### Selected Bibliography

1. Hayden, A.C.S. and Entchev, E.; Integrated Fuel-Fired Heating Systems to Reduce Emissions and Increase Efficiency; AWMA Paper 95-MP1.01; Annual Meeting of Air & Waste Management Association; San Antonio, Texas; June 1995.
2. Hayden, A.C.S., Lee, S.W. and Jia., L.; Emissions of Oxides of Nitrogen (N<sub>2</sub>O and NO<sub>x</sub>) from Residential Systems; AWMA Paper 93-WA-172.04; Denver, CO, June 1993.
3. Hayden, A.C.S., Braaten, R.W. and Brown, T.D.; Emissions and Energy Conservation in Residential Oil Heating; Journal of the Air Pollution Control Association, Vol. 28, No. 7, July 1978.
4. Lee, S.W. and Hayden A.C.S.; Experimental Program for the Evaluation of Fuel Quality Effects on Burner Performance; ASHRAE Paper SF-86-14 and Transactions, V.86 ASHRAE, San Francisco, January 1986.
5. Preto F. and Hayden, A.C.S.; Performance of Oil-Fired Condensing Systems; Proceedings GRI-CHX2 pp 178-191, 2nd International Symposium on Condensing Heat Exchangers; Columbus, Ohio, April, 1987.
6. Lee, S.W. and Hayden, A.C.S.; The Effects of Changes in Fuel Quality and Burner Technology on Oil Furnace Performance, Paper SL-90-15-2, ASHRAE Transactions V.96 Pt.2, June 1990.
7. Hayden, A.C.S. and Braaten, R.W.; Oil Burner Retrofit to Save Energy and Reduce Emissions, APCA Paper 81-8.1, APCA Annual Meeting, June 1981.
8. Hayden, A.C.S. and Preto, F.; A Condensing System for Combined Space and Water Heating; Proceedings GRI-CHX2, pp 120-132, 2nd International Symposium on Condensing Heat Exchangers; GRI, Columbus, Ohio, April, 1987.

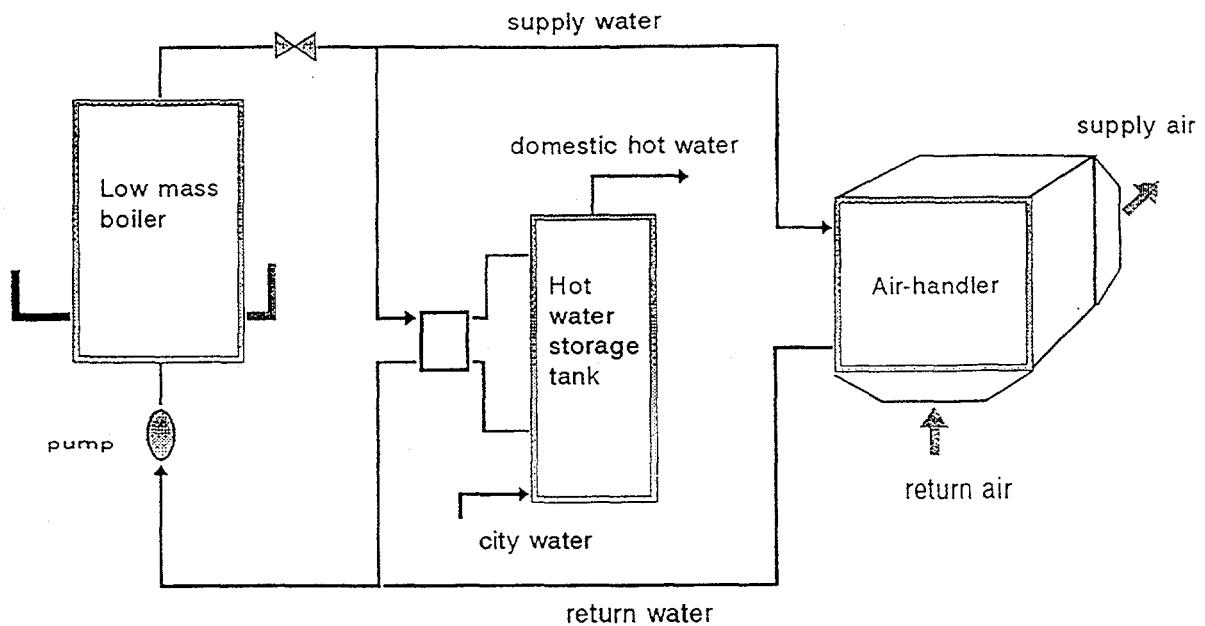


Figure 1. Combined system with low mass boiler and external storage.

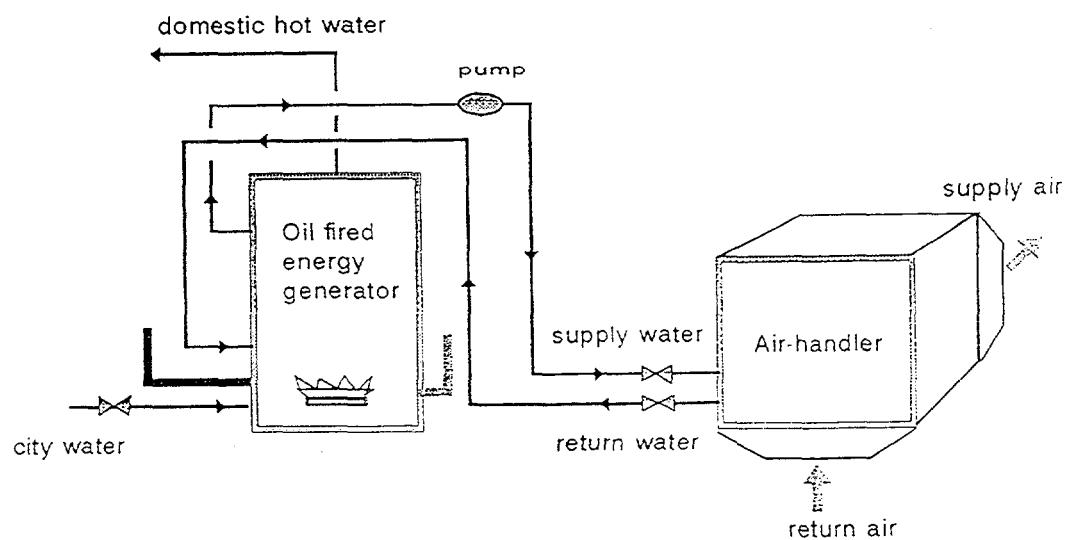


Figure 2. Combined system with large internal direct fired storage.

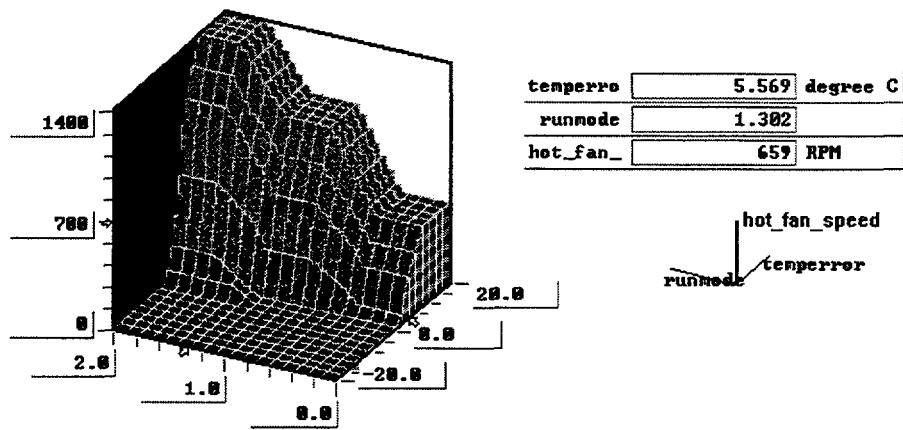


Figure 3. 3-D simulation of the blower motor speed as a function of room thermostat deviation and run mode.

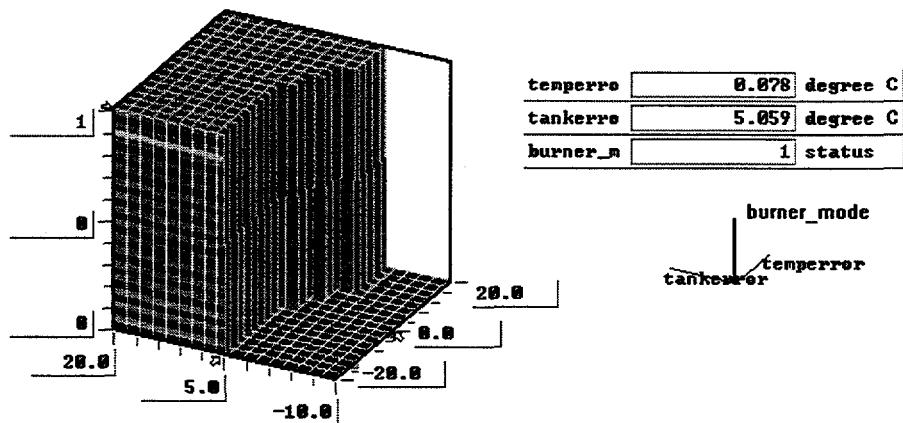
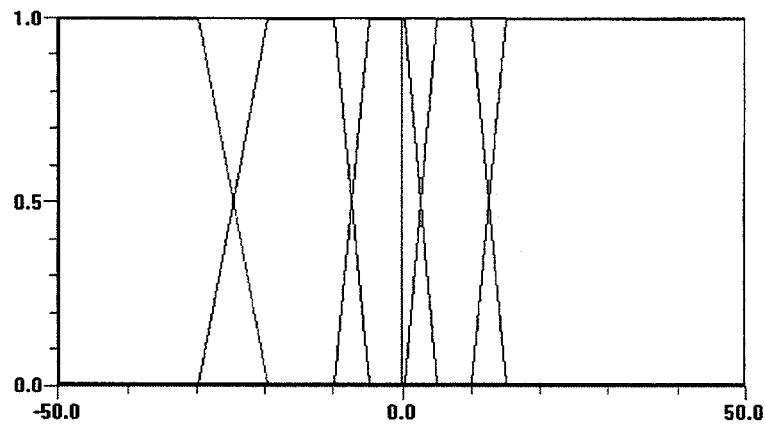


Figure 4. Burner mode 3-D simulation as a function of tank temperature differential and room thermostat temperature deviation.

Variable:  Label:



value	Cold	0.0	Cool	0.0	Zero	1.0
-0.212	Warm	0.0	Hot	0.0		

Figure 5. Membership functions of the outdoor temperature.

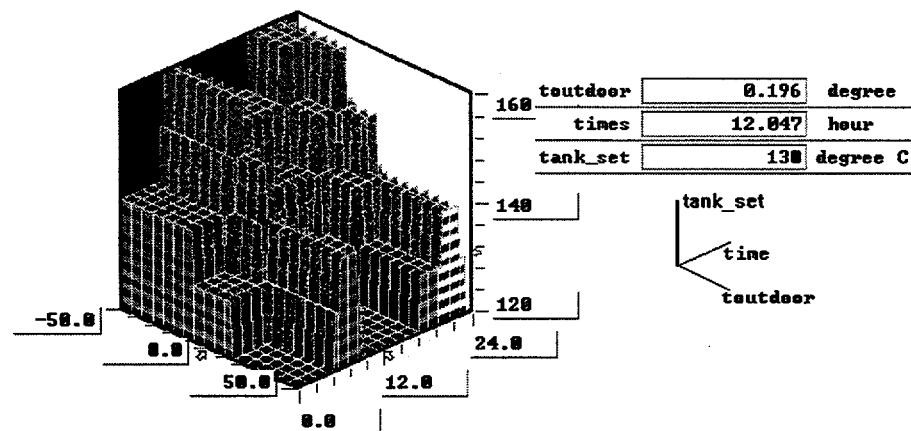


Figure 6. 3-D simulation of water tank aquastat settings as a function of outdoor temperature and time of day.

## **CHAMBERLESS RESIDENTIAL WARM AIR FURNACE DESIGN**

Jeremy Godfree, ACID  
Product Design Consultant  
1169 Pugwash River Road, Pugwash  
NS, B0K 1L0, Canada



## **Chamberless Residential Warm Air Furnace Design**

**Jeremy Godfree, P.Eng, ACID**  
Product Design Consultant  
1169 Pugwash River Road, Pugwash  
NS, B0K 1L0, Canada

10th Oil Heat Technology  
Conference and Workshop  
Brookhaven National Laboratories  
March 1996

### **SUMMARY**

This brief paper is an introduction to the concept of designing residential warm air furnaces without combustion chambers. This is possible since some small burners do not require the thermal support of a combustion chamber to complete the combustion process.

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Chamberless warm air furnaces do not use any type of combustion chamber. The high static retention head burners which are now commonly used in residential heating applications are capable of operating without the support of a conventional combustion chamber. Indeed some are capable of operating without a target wall or other flame support devices and with intermittent ignition.

First listed in the mid 1980's, high efficiency residential chamberless furnaces employing these burners have been installed under rental programs and by heating contractors in Canada for 10 years. Due to their simple design they require little set up time, low maintenance and infrequent cleaning. They are popular with installers and homeowners alike.

Cost reduction is an incentive for developing chamberless appliances. The elimination of the combustion chamber, target walls and even thermal shielding removes many components. This can dramatically reduce heat exchanger manufacturing cost. Further cost reduction comes from the absence of supporting hardware and the reduction in the number of heat exchanger openings.

Simpler heat exchangers enable the manufacturer to tailor the exchanger more closely to the furnace application and to reduce tooling and fabrication cost. Since the mounting and operational security of the combustion chamber is no longer relevant, often the same heat exchanger can be used in a variety of orientations with little or no adaptation. These also translate into cost and weight saving.

Burner performance is maintained by the improved design of the high static burners. A burner/nozzle combination properly matched to the combustion zone of the heat exchanger gives combustion readings similar to those of its chambered counterpart. There is evidence that NO<sub>x</sub> production is reduced. Thermal support for the flame during the combustion process comes from the heat exchanger wall in the combustion zone.

The chamberless design allows more uniform surface temperatures and, in the radiant combustion zone, more complete usage of the heat exchanger surface because the combustion chamber does not shield the heat. Temperature problems associated with combustion chamber openings, such as intense radiant heat damage to the heat exchanger or the burner end cone assembly, are reduced. Nozzle after-drip caused by residual radiant heat at shut down is much less likely.

Nozzle angle and spray type are important as the burner no longer has the support of the combustion chamber to finish the combustion process. The nozzle matches the combustion air flow to the combustion zone inside the heat exchanger to ensure that the flame is properly developed and burns completely.

Circulating air patterns, the burner configuration, the flow pattern of the stack gases through the heat exchanger and the internal dimensions of the combustion zone all affect the heat exchanger surface temperature. The rates of heat production inside and its withdrawal from the outside of the heat exchanger by the circulating air are matched to avoid overheating the exchanger walls.

Fast heat up is a tangible characteristic of the chamberless heat exchanger and this leads to the homeowner's frequent perception of "more heat" or "a great furnace". An occasional side effect can be slightly increased flame noise since there is no muffling by the chamber.

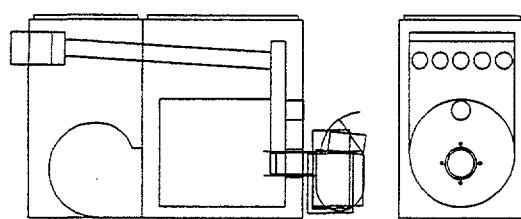
The cheapest and most common heat exchangers are mild steel, though stainless steel could be used where higher heat exchanger skin temperatures are sought. Burner and heat exchanger configurations which necessitate the shielding of the heat exchanger surface are more expensive. Manufacturers warranty terms are the same as those for chambered furnace designs.

Typical warm air furnace inputs range to 1.2 USGPH. There are some small upflow furnaces from 0.5 to 0.75 USGPH and a versatile multiposition unit which can be installed in a horizontal, upflow or downflow position. Depending on the design, like their chambered counterparts, the AFUE's of chamberless oil fired appliances depend on the design and can range from 78% to 86%.

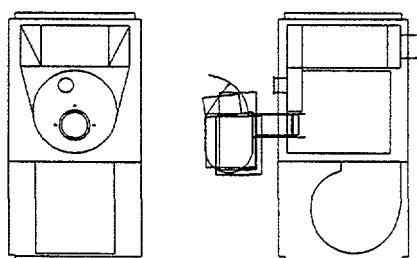
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Jeremy Godfree, P.Eng, ACID, is a product designer specializing in the design and development of heating appliances.

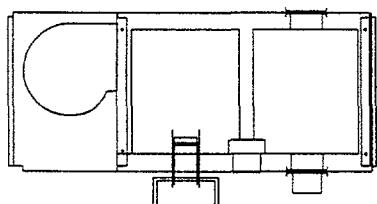
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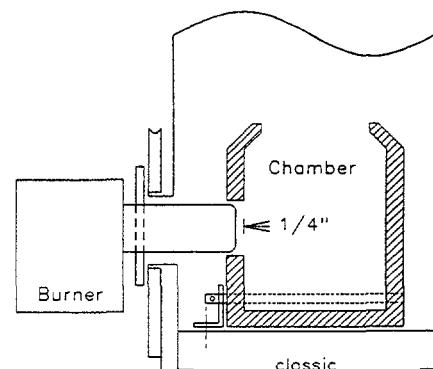
Chamberless Lowboy



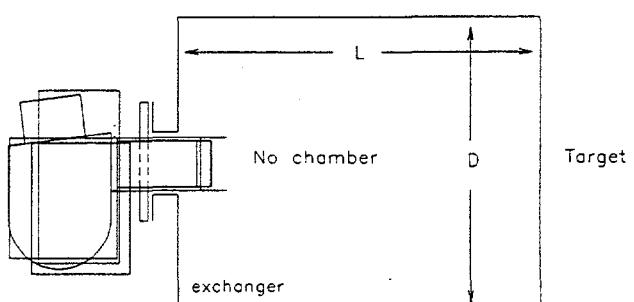
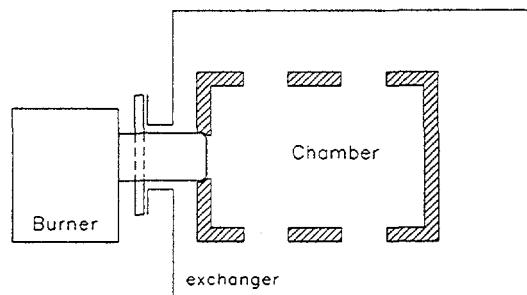
Chamberless Upflow



Chamberless Horizontal



classic



Target

## Chamberless Residential Warm Air Furnace Design



**DEVELOPMENT OF THE LINED MASONRY CHIMNEY OIL APPLIANCE  
VENTING TABLES**

Richard Krajewski, and John Strasser  
Brookhaven National Laboratory  
Department of Applied Science  
Building 526  
Upton, NY 11973-5000



## THE DEVELOPMENT OF THE LINED MASONRY CHIMNEY VENTING TABLES

### **ABSTRACT**

This paper describes the development of the lined masonry chimney venting tables from the output of the Oil Heat Vent Analysis Program (OHVAP). These new tables are different from the prior format, offered in the Proceedings of the 1995 Oil Heat Technology Conference and Workshop, Paper No. 95-4. Issues expressed by representatives of the oil heat industry at last years conference during the Venting Technology Workshop resulted in subsequent discussions. A full day meeting was held, co-sponsored by BNL and the Oilheat Manufacturers Association (OMA), to address revision of the format of the venting tables prior to submission to the National Fire Protection Association (NFPA) Standard 31 Technical Committee. The resulting tables and text were submitted to NFPA during the first week of October, 1995. Since then minor changes were made reflecting the addition of data obtained by including intermediate firing rates (0.4, 0.65, and 0.85 gph) not included in the original tables which were developed in increments of 0.25 gph. The new tables address the specific question; "If remediation is required, what is the recommendation for the sizing of a metal liner and the appropriate firing rate range to be used with that liner?".

In the Appendix of this paper the reader will find the full text and tables of the proposed revision to the new NFPA Standard 31, Appendix F which was recently released by NFPA for public review and comments until April 12, 1996.

### **DEVELOPMENT OF THE TABLES**

The preparation of the input files for OHVAP included the following general geometric configuration information:

(1) Masonry chimneys constructed in accordance with NFPA 211; ie, a clay tile inner liner surrounded by a 0.5 inch air gap, all enclosed with 4 inches of masonry brick. For the cases used in vent table preparation the clay tile was assumed to be standard 8 inch square tile with interior dimensions of 6.75 by 6.75 inches. The chimney heights used in the evaluation were 10, 15, 20, and 25 feet above the breeching.

(2) The connectors are nominally defined as 4, 6, 8 and 10 feet of total straight length. In fact, the single wall (.019 thick) galvanized steel connectors consist of a 1 foot vertical straight section into a standard "tee" containing a barometric draft control. The exit of the "tee" enters a standard 90° elbow which connects to horizontal straight section. This straight section connects to the breech opening in the masonry chimney. For the connectors, two horizontal lengths, 3 and 9 feet, were analyzed and the results

for the intermediate lengths were interpolated.

(3) Where additional metal chimney liners were applied, these consist of 6, 5, and 4 inch diameter smooth stainless pipe with a .019 inch thick wall. The connector, over its entire length, as well as the diameter of the barometric draft control, is held consistent with the diameter of the applied liner. The chimney liners are assumed to be uninsulated (air gap unfilled) and positioned concentric with the inner clay tile of the masonry chimney.

Twelve firing rates were evaluated. These were 0.25, 0.4, 0.5, 0.65, 0.75, 0.85, 1.0, 1.25, 1.5, 1.75, 2.0, and 2.25 gallons per hour. The appliance efficiencies (steady-state) were 80%, 82%, 84%, 86%, and 88%. At a flue gas CO<sub>2</sub> level of 12% the respective flue gas temperatures at the above steady-state efficiencies were 575, 495, 420, 345, and 275° F. Standard boiler time-temperature profiles were used to simulate the appliance cyclic operation with a 10 minute burner "on" period and a 33 minute burner "off" period. Each case run consisted of four cycles with the first three used to condition the vent system and the fourth to store the results of the computations in the output files.

The completion of a run with OHVAP results in the creation of one or two Lotus \*.WK1<sub>(tm)</sub> files. While these files are not considered large in terms of storage, a hard-copy print out of each file would occupy several pages. For this reason, only portions of the output files will be replicated as example figures herein.

The format used by OHVAP for the first part of each output file is arranged in column form as follows:

<u>COLUMN</u>	<u>DESCRIPTION</u>
1	(Cycle) Cycle number
2	(Time) Elapsed time in seconds
3	(Tapp) Flue gas temperature at the appliance (F)
4	(Papp) Flue gas pressure at the appliance (in. H <sub>2</sub> O)
5	(QB) Flow through burner (SCFM)
6	(QD) Flow through draft control (SCFM)
7	(Backflow) Reverse flow in last element (SCFM)
8	BLANK

Depending on the selection for output, whether by Variable or by Element, and the number of elements used, the following arrangement of columns will be recorded starting with column 9. If the output files are created by Variable they will have the following appearance:

<u>COLUMN</u>	<u>DESCRIPTION (ELEMENT 1....ELEMENT I)</u>
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File-1

Tgout1....Tgouti	Flue gas exit temperature (F)
Tl1....Tli	Flue gas side surface temperature of liner (F)
Ps1....Psi	Static pressure (in. H <sub>2</sub> O)

File-2

Tlair1....Tlairi	Air-gap side surface temperature of liner (F)
Acid1....Acidi	Acid condensation (lbs)
Water1....Wateri	Water condensation (lbs)

If the output files are created by Element they will have the following appearance starting with column 9 -

<u>COLUMN</u>	<u>DESCRIPTION (VARIABLE 1....VARIABLE I)</u>
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File-1

Tgout1	Flue gas exit temperature for element 1 (F)
Tl1	Flue gas side surface temp. for element 1 (F)
Ps1	Static pressure for element 1 (in. H <sub>2</sub> O)
BLANK	

Tgouti	Flue gas exit temperature for element I (F)
Tli	Flue gas side surface temp. for element I (F)
Psi	Static pressure for element I (in. H <sub>2</sub> O)
BLANK	

File-2

Tlair1	Air-gap side surface temp. for element 1 (F)
Acid1	Acid condensation for element 1 (lbs)
Water1	Water condensation for element 1 (lbs)
BLANK	

Tlairi	Air-gap side surface temp. for element I (F)
Acidi	Acid condensation for element I (lbs)
Wateri	Water condensation for element I (lbs)
BLANK	

The files used to evaluate the cases needed to establish the venting tables were of the form defined by Variable and only File-1 was used. The criteria used in evaluating acceptability for all cases were based on the vent conditions occurring at the end of the burner "on" period. The acceptable vent system will have:

- (1) a static pressure at the appliance is less than or equal to -0.03 inches of water.
- (2) The inner surface temperature at the exit of the chimney is greater than or equal to 95° F.

The approach taken in generating the venting tables utilized a spreadsheet application, in this case Quattro Pro<sub>(tm)</sub>. This permitted the evaluation of the static pressure at the appliance and the inner surface temperature at the chimney exit at the end of the burner "on" period. This soon proved to be a tedious activity since the results of 1920 computer runs had to be individually evaluated. A portion of a typical output file is shown in Figure 1 below.

CYCLE	TIME	TAPP.	PAPP.	QB	QD	Backflow		Tgout1	Tgout2	Tgout3
	(sec)	(F)	(in wc)	(scfm)	(scfm)	(scfm)		(F)	(F)	(F)
4	0	89.0	-0.019	29.44	5.96	0.00		87.9	84.5	84.1
4	10	135.0	-0.028	29.44	11.16	0.00		130.7	115.6	111.5
4	20	181.0	-0.039	29.44	18.26	0.00		173.5	141.0	134.2
4	30	227.0	-0.047	29.44	24.43	0.00		216.3	162.6	153.6
4	40	250.7	-0.052	29.44	28.05	0.00		238.7	172.4	162.8
4	50	274.3	-0.056	29.44	31.21	0.00		260.9	182.8	172.3
4	60	298.0	-0.060	29.44	34.16	0.00		283.0	192.2	180.9
4	70	304.0	-0.061	29.44	35.42	0.00		288.8	193.7	182.6
4	80	310.0	-0.063	29.44	36.97	0.00		294.6	195.0	184.0
4	90	316.0	-0.064	29.44	37.51	0.00		300.2	198.3	186.9
4	100	318.7	-0.065	29.44	38.60	0.00		302.8	199.8	188.4
4	110	321.3	-0.065	29.44	39.19	0.00		305.3	199.4	188.1
4	120	324.0	-0.065	29.44	39.19	0.00		308.0	201.3	190.1
4	130	325.7	-0.066	29.44	39.61	0.00		309.9	202.7	191.9
4	140	327.3	-0.066	29.44	39.61	0.00		311.9	204.2	193.6
4	150	329.0	-0.067	29.44	40.45	0.00		313.8	205.6	195.2
4	160	330.7	-0.067	29.44	40.87	0.00		315.7	204.6	194.7
4	170	332.3	-0.067	29.44	40.83	0.00		317.5	205.8	196.1
4	180	334.0	-0.068	29.44	41.37	0.00		319.4	207.0	197.4
4	190	334.7	-0.068	29.44	41.37	0.00		320.2	207.7	198.2

**Figure 1 - Typical OHVAP output file (\*.WK1).** This file extends further than what is shown in this figure; column DB (No.107) to the right and downward to row 261.

The solution to this problem was the creation of two spreadsheet template forms, each of which was directed at one of the two nominal connector lengths used in the simulation; 4 and 10 feet long and each with a 25 foot chimney. The nominal 4 foot long connector and chimney system contains 32 elements while the nominal 10 foot long

connector system and chimney contains 38 elements.

The first step in the general procedure used to create the template is to open one of the output files within the spreadsheet application. The values for static pressure at the appliance and inner surface temperature at the chimney exit, among others, is copied with text identifiers to the first available blank column in the screen display. This fortunately is within the view of the first displayed screen for the output files created by OHVAP. Following the procedures for the application, graphs of the element flue gas temperatures, wall temperatures and static pressures are prepared and saved. These graphs, while not used for the evaluation, will prove to be a valuable reference.

In the second step the spreadsheet is then rendered completely devoid of cell values, with headings retained. The now empty spreadsheet is then saved with a name which defines the template. At the time of the save the mouse curser must be located at the first cell of the spreadsheet. Such a template is shown in Figure 2 below.

**Figure 2** - Template form created from OHVAP output file. Contains information on the average flue gas mass flow ratio, appliance and chimney base pressure, and temperatures for the gas and wall at the ends of the connector and chimney at the end of the burner “on” period.

In the third step, combining of each output file in turn into this template will render the static pressure and temperature values immediately available along with the appropriate graphs for reference. An example of the combined spreadsheet is shown in Figure 3 below.

CYCLE	TIME	TAPP.	PAPP.	QB	QD	Backflow	MOFF/MON	Tgout1	Tgout2	Tgout3
	(sec)	(F)	(in wc)	(scfm)	(scfm)	(scfm)		(F)	(F)	(F)
4	0	89.0	-0.019	29.44	5.96	0.00	APP.PRESS.	87.9	84.5	84.1
4	10	135.0	-0.028	29.44	11.16	0.00	-0.07107804	130.7	115.6	111.5
4	20	181.0	-0.039	29.44	18.26	0.00	CHIM.PRESS.	173.5	141.0	134.2
4	30	227.0	-0.047	29.44	24.43	0.00	-0.06136048	216.3	162.6	153.6
4	40	250.7	-0.052	29.44	28.05	0.00	CONN.GAS	238.7	172.4	162.8
4	50	274.3	-0.056	29.44	31.21	0.00	192.6470337	260.9	182.8	172.3
4	60	298.0	-0.060	29.44	34.16	0.00	CONN.WAL.	283.0	192.2	180.9
4	70	304.0	-0.061	29.44	35.42	0.00	144.5417938	288.8	193.7	182.6
4	80	310.0	-0.063	29.44	36.97	0.00	CHIM.GAS	294.6	195.0	184.0
4	90	316.0	-0.064	29.44	37.51	0.00	131.9252319	300.2	198.3	186.9
4	100	318.7	-0.065	29.44	38.60	0.00	CHIM.WAL.	302.8	199.8	188.4
4	110	321.3	-0.065	29.44	39.19	0.00	94.00174713	305.3	199.4	188.1
4	120	324.0	-0.065	29.44	39.19	0.00		308.0	201.3	190.1
4	130	325.7	-0.066	29.44	39.61	0.00		309.9	202.7	191.9
4	140	327.3	-0.066	29.44	39.61	0.00		311.9	204.2	193.6
4	150	329.0	-0.067	29.44	40.45	0.00		313.8	205.6	195.2
4	160	330.7	-0.067	29.44	40.87	0.00		315.7	204.6	194.7
4	170	332.3	-0.067	29.44	40.83	0.00		317.5	205.8	196.1
4	180	334.0	-0.068	29.44	41.37	0.00		319.4	207.0	197.4
4	190	334.7	-0.068	29.44	41.37	0.00		320.2	207.7	198.2

**Figure 3** - By combining the OHVAP output file with the template shown in Figure 3, the required vent system performance evaluation can be made for creating the Venting Tables.

The fourth step in the procedure involves the preparation of a spreadsheet to perform a linear interpolation of the appliance static pressure and the inner surface temperature at the chimney exit for the intermediate nominal connector lengths of 6 and 8 feet.

CHIM.HGT	86% BASE CASE				25 foot chimney			
	DRAFT				TEMPERATURE			
CONN.LN	4	6	8	10	4	6	8	10
FT	FT	FT	FT	FT	FT	FT	FT	FT
0.25	0.049	0.048168	0.046736	0.045	49.7	49.6234	49.4669	49.3
0.4	0.055	0.05413	0.0524	0.050	54.0	53.6870	53.3340	52.9
0.5	0.058	0.056801	0.054903	0.05	57.1	56.5772	55.9845	55.3
0.65	0.062	0.060335	0.058570	0.056	61.6	60.9639	60.3079	59.6
0.75	0.063	0.061535	0.059770	0.05	64.5	63.857	63.124	62.3
0.85	0.064	0.062735	0.060970	0.059	67.4	66.670	65.871	65.0
1	0.065	0.063901	0.062003	0.060	71.9	70.9842	70.0385	69.0
1.25	0.065	0.063801	0.061903	0.06	77.5	77.017	76.484	75.9
1.5	0.064	0.062935	0.060970	0.05	83.1	82.2775	81.4250	80.5
1.75	0.062	0.060868	0.058837	0.056	88.3	87.4442	86.5384	85.6
2	0.059	0.057602	0.055504	0.053	93.2	92.2643	91.2886	90.3
2.25	0.056	0.054102	0.051904	0.049	97.7	96.7643	95.7786	94.7

**"B" CASES**

**Figure 4** - Base case masonry chimney with no metal liner

CHIM.HGT	"B" CASES							
	DRAFT				TEMPERATURE			
	CONN.LN	4 FT	6 FT	8 FT	10 FT	4 FT	6 FT	8 FT
0.25	0.054	0.052834	0.051369	0.049	64.4	62.9281	61.446	59.9
0.4	0.061	0.059501	0.057903	0.056	73.3	72.68	72.01	71.3
0.5	0.064	0.06293	0.0612	0.059	76.1	76.126	76.093	76.0
0.65	0.06	0.066301	0.064603	0.062	83.6	82.8707	82.1314	81.3
0.75	0.06	0.067235	0.065470	0.063	87.0	86.2973	85.5847	84.8
0.85	0.07	0.068168	0.06633	0.064	89.9	89.2773	88.5847	87.8
1	0.071	0.069268	0.06743	0.065	94	93.2973	92.5947	91.8
1.25	0.071	0.069135	0.067170	0.065	98.9	98.4205	97.9110	97.4
1.5	0.070	0.068002	0.065904	0.063	102.8	102.4870	102.1340	101.7
1.75	0.067	0.065201	0.063303	0.061	106	105.8570	105.5140	105.1
2	0.064	0.061968	0.059737	0.057	108.9	108.6536	108.337	108.0
2.25	0.059	0.057302	0.055204	0.053	111.2	111.046	110.813	110.5

**Figure 5** - Interpolation for the "B" cases which define a 6 inch metal liner positioned inside the existing clay tile liner in the masonry chimney.

An entry form is made for each of the vent system configurations and firing rates under evaluation. Once this spreadsheet is prepared, all that is necessary is that the appropriate calculated values for the nominal 4 and 10 foot connectors be entered. The spreadsheet then automatically calculates and displays the respective values for the intermediate nominal connector lengths. Examples of these interpolation spreadsheets are shown in Figures 4 and 5 above.

The fifth and final step is to scan each of the interpolation spreadsheets and pick out the firing rate ranges that satisfy the acceptability criteria for the chimney height, lateral (nominal connector) length, and liner diameter.

## CONCLUSIONS

The transient analysis offered by OHVAP has provided the oil-heat industry with guidance for both lined and unlined masonry chimneys. The techniques applied here can be also applied for developing any broad based interpretation of the program output. This is also true for metal chimneys and power vent applications. The computer runs are time consuming in the setup stages, but once that is accomplished, computer time is expended on an over-night batch run basis and the final interpretive stage goes to completion rather quickly.

## Appendix

PLEASE NOTE! - This is a retyped and corrected version of Appendix F for NFPA Standard 31, Liquid Fuel Burning Equipment contained in the NFPA Technical Committee Reports on Proposals for public review and comment prior to April 12, 1996. Tables F-7(a) through F-7(e) have also been revised to reflect the addition of intermediate firing rates of 0.4, 0.65, and 0.85 gallons per hour to accommodate oil-heat industry needs.

Comments or inquiries should be addressed to: Secretary, Standards Council, National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269-9101. For further information, please contact the Standards Administration Department at (617)-984-7249.

This document will be under consideration at the NFPA Fall Meeting in Nashville, TN, November 18-20, 1996. This material is provided for information only and all official guidance shall reference the provisions contained in the final and approved version of NFPA 31, 1996.

### APPENDIX F - Relining Masonry Chimneys

*This Appendix is not part of the requirements of this NFPA document, but is included for information purposes only.*

**F-1** A tile lined masonry chimney serving an oil-fired appliance should comply with applicable building codes such as NFPA Standard 211, Section 3-2, Construction of Masonry Chimneys. An additional listed metal chimney liner may be needed to reduce transient low draft during start-up and acid/water condensation during cyclic operation. This is particularly true for high-mass masonry chimneys serving oil-fired appliances producing relatively low flue-gas temperature.

**F-2** For masonry chimneys, local experience may indicate how well the construction has withstood the lower temperatures produced by a modern oil-fired appliance. Evidence of potential or existing chimney damage should be determined by visual examination of the chimney and liner. Exterior indicators such as missing or loose mortar/bricks, white deposits (efflorescence) on brickwork, a leaning chimney or water stains on interior building walls should be investigated further. Interior chimney examination with a mirror (or video camera) can reveal damaged or missing liner material. The detailed characteristics of a properly constructed masonry chimney, on which to base the inspection on, are included in NFPA Standard 211 (1992), Chapter 3. The liner must be continuous, properly aligned, intact, and must extend beyond the top of the chimney.

The chimney should also have a clean-out at the base. Any debris collected in the chimney base, drop-leg or connector should be removed and examined for content and source of debris. If any doubt exists regarding the condition of the chimney, examination by an experienced professional is strongly recommended and any problems must be corrected.

**F-3** The physical condition and suitability of an existing chimney must be checked before the installation of a new oil-fired appliance or the upgrade (new burner or reduced firing rate) of an existing appliance. The chimney should be inspected and, if needed, cleaned.

**F-4** The current practice in existing residential oil-fired appliances is to reduce the firing rate, often to levels of 1 gallon per hour or less, for energy conservation purposes. Older oil-fired appliances are being replaced with new models having efficiencies significantly higher than 80%. The resulting reduction in flue gas temperatures will increase the potential for water and acid condensation in the inventory of masonry chimneys serving these appliances.

**F-5** Residential sized heating appliances sold in the U.S. are required to be tested in accordance with the Annual Fuel Utilization Efficiency (AFUE) Test Procedure. This procedure is based on ASHRAE Standard 103-1982. In 1987, the National Appliance Energy Conservation Act (NAECA) was passed into Federal Law by Congress. This law requires that, starting January 1, 1992, for input less than 300,000 Btuh, all boilers and furnaces must have an AFUE of at least 80 percent and 78 percent respectively. Many available oil-fired boilers and furnaces already exceeded these minimum requirements with AFUE values of 82 to 86 percent.

Modern heating appliances meeting these new requirements are being installed as replacements for older systems as well as in new construction. In the replacement of existing older systems, the venting system, largely masonry chimneys, might be oversized and in poor repair. The operational flue-gas temperatures for modern mid- and high-efficiency systems range from 300°F up to about 500°F at the outlet of the unit. These low flue-gas temperatures may be further reduced before reaching the chimney because of heat loss from the connector through dilution when a draft regulator is used. In either case, the resulting available flue-gas temperatures are frequently either insufficient to sustain adequate draft in an older, oversized masonry chimney or permits condensate to form on cold connector and chimney liner walls.

**F-6** After installation of a new oil-fired appliance or upgrade, if no chimney modifications were required at the time of installation, the condition of the chimney must be re-checked after three months and after six months of normal heating appliance operation to verify that the chimney is still in good condition and suitable for continued

use. If any doubt exists regarding the condition of the chimney, examination by an experienced professional is again highly recommended and any problems must be corrected.

**F-7** Results of a computational analysis by Strasser using the Oil Heat Vent Analysis Program (OHVAP), Version 1.0 <sup>[1]</sup> to analyze a series of masonry chimney venting systems indicates that current applications of modern oil-fired heating appliances may have some difficulty in terms of the formation of acid/water condensation within the chimney during winter operation. OHVAP is a transient simulation program written specifically for oil-fired equipment. The simulation uses algorithms modeling flue-gas composition, system pressure, draft control dilution <sup>[2,3]</sup>, system gas-flow, and heat transfer in vent systems serving oil-fired appliances.

These results have been translated into fuel input firing rate (gallons per hour) recommendations in the use of metal liner systems for remediation of troublesome masonry chimney vent systems. The results are shown in the accompanying tables. These tables show appliance steady state efficiency, chimney height and nominal connector length. See section F-9 for specific examples of the proposed application of these tables.

**F-8** The issue of water condensation in masonry chimneys has been documented as are the issues of damage to masonry, mortar and liners in chimneys often due to improper construction. <sup>[4,5]</sup>

**F-9** In interpreting the OHVAP simulation results to develop the recommendations, two criteria for successful system performance are applied at the end of the appliance burner "on" period. These criteria are:

- 1) A minimum available winter-time draft at the appliance of about - 0.03 inches of water column.
- 2) A minimum chimney liner surface temperature at the top of the chimney of about 95° F (water dew point of diluted flue gas).

The tables are derived (by simulation) on the basis of 12% CO<sub>2</sub> but the recommendations are valid for CO<sub>2</sub> levels between 10% and 14%. In addition, a listed insulation system is assumed to surround the metal liner within the chimney. Slightly lower liner temperatures can be expected if no insulation is applied in practice. Field experience and confined efforts in verification analysis using the OHVAP simulation model confirm that liners without insulation are acceptable in most cases with the exception of very marginal conditions.

**F-10** The relined exterior chimney venting tables are included in this Appendix. In order to use the tables, the user must first determine the approximate steady-state efficiency of the appliance being vented. This approximation can be made using one of three methods for a specific appliance. These are; 1) the Flue Loss method, 2) the Heating Capacity method and 3) the Annual Fuel Utilization Efficiency (AFUE) method.

**F-10.1** The Flue Loss method involves the adjustment of the appliance burner for a satisfactory maximum flue gas  $\text{CO}_2$  level (minimum excess combustion air) and a trace to No. 1 smoke (Bacharach scale) after a minimum of 10 minutes of operation. The flue gas temperature is then measured at the appliance exit and the value is used to select the table or tables for use in obtaining the recommended vent size and firing rate. If the measured temperature falls between two tables, examine the recommendations contained in the tables above and below that of the measured temperature. When all measurements are completed the appliance burner adjustments should be checked and readjusted if needed to conform with  $\text{CO}_2$  and smoke level settings as indicated in the equipment manufacturer's specifications.

**F-10.2** The Heating Capacity method involves dividing the appliance heating capacity (usually given in 1000's of Btu per hour) by the input rate (converted to 1000's of Btu per hour) multiplied by 100. This result will provide an approximate steady-state efficiency value for selecting the table or tables used in obtaining the recommended vent size and firing rate.

**F-10.3** The AFUE method involves the determination of the AFUE for the appliance at hand. The AFUE for a particular model of the appliance can be obtained from published annual listings (GAMA, Hydronics Institute) or promotional material provided by the appliance manufacturer. An estimate of the steady-state efficiency can be obtained by adding 1.0 percentage point to the AFUE value of a hydronic boiler and 2.0 percentage points to the AFUE value of a warm air furnace. This steady-state efficiency value can then be used in selecting the table or tables used in determining the recommended vent size and firing rate.

**F-10.4** The following three working examples serve to illustrate the required procedures for evaluating the recommendations offered in the table.

**F-10.4.1** As a first example, assume that an appliance firing 1.0 GPH has an efficiency determined by the AFUE method to be 88 percent ( $\text{AFUE} = 87\text{ percent} + 1.0\text{ percent} = 88\text{ percent}$ ). The total length of the connector is 7 feet, and the chimney is 20 feet high. Locating the proper table, it is determined that the chimney is listed, but the connector length is not, therefore the user must interpolate between the table entries for connectors of 6 and 8 feet long. Looking in the 6 foot connector row it can be seen that only a 5 inch liner will suffice; 6 inches being rated only for higher firing rates of 1.25-2.25 GPH

and 4 inches being rated only for a lower firing rate range of 0.65-0.85 GPH. In the 8 foot connector row only a 5 inch liner will do, as the 6 inch liner and the 4 inch liner are the same as above. In this case the liner size selection is very clear, a 5 inch liner is the indicated choice since both values that bracket the specific characteristics of the working example match.

**F-10.4.2** As a second example, assume that applying the Flue Loss method resulted in a measured flue gas temperature of 523° F after burner adjustment. The firing rate for the appliance is 1.0 GPH. In addition, the total straight connector length is 7 feet into a 22 foot chimney. Note that some of the parameters of the system are not precisely located among the tables. The method that we will employ here is to bracket the system parameters to evaluate an appropriate recommendation. Using a connector/chimney combination of 6/20 at 495° F and 575° F at 1.0 GPH, the recommendations allow for a 4, 5, or 6 inch diameter metal liner. Similarly, for a connector/chimney combination of 8/25 at 495° F and 575° F at 1.0 GPH the same three liner sizes are allowed. In this instance, the choice is clear in that any of the three metal liner sizes would be satisfactory. If the firing rate had been 1.25 GPH, however, the metal liner size choices would have been restricted to 5 and 6 inches due to the high end limit of 1.0 GPH defined under the connector/chimney size of 8/25 at 495° F. On the other hand, if the firing rate had been 0.5 GPH the metal liner choices would have been restricted to 4 and 5 inches due to the low end limit of 0.65 GPH defined under the same connector/chimney combination and flue gas temperature.

**F-10.4.3** As the third example, assume that applying the Heating Capacity method resulted in an estimated steady-state efficiency of 87 percent with a firing rate of 0.85 GPH. In this case, suppose a 4 foot connector is used between the appliance and the chimney which stands 25 feet above the breech. In the table for a steady-state efficiency of 88 percent, the 4 and 5 inch metal liners are shown as satisfactory. In the table for a steady-state efficiency of 86 percent, the 4, 5 and 6 inch metal liners are satisfactory. Based on average values for firing rates between the two tables, the 4 and 5 inch liners should be satisfactory for a steady-state efficiency of 87 percent. In any case, an adjustment of firing rate, an increase of draft, or an increase in the excess combustion air would help serve to bring the system out of any marginal performance condition.

**F-11** In some cases, the relining system performance does not meet either the minimum appliance draft or the minimum liner temperature criteria regardless of treatment. These are shown as "NR" meaning they are not recommended for simple relined chimney venting. In these cases an improvement in system performance can be achieved by using a listed alternative venting system. These alternatives include, but are not limited to, a power-vent (where draft is insufficient) or an insulated factory-built metal chimney (where liner wall temperatures are too low).

## F-12 REFERENCES

- [1] Strasser, J. et al. 1994 "Oil-Heat Vent Analysis Program" (OHVAP), Under development and evaluation.
- [2] Krajewski, R. F. 1994 "Development of Oil Heat Venting Tables", Oil Heat Technology Conference and Workshop, No. 94-15.
- [3] Butcher, T. et al. 1990 "Chimney Related Energy Losses in Oil-Fired Heating Systems: Configuration Effects and Venting Alternatives", BNL-46021.
- [4] Gorden, E. et al. 1990 "Masonry Chimney Inspection and Relining", AGAL Unpublished Topical Report.
- [5] Kam, V. P. et al. 1991 "Masonry Chimneys and Liners", AGAL Draft Topical Report.

Recommended FIRING RATE CAPACITIES and METAL LINER SIZE for Retrofitting Clay Tile-Lined Masonry Chimneys.  
 To Be Used When Field Inspection Indicates Relining is Required. Base Case: Exterior Residential Clay Tile-Lined  
 Masonry Chimney Complying with NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances,  
 subsections 3-2.2 through 3-2.7. Minimum Liner Temperature = 95 Deg. F, Minimum Draft = 0.03 Inches of Water.

Table F-7(a)  
 Steady State Efficiency=88%  
 (12 percent CO<sub>2</sub>, 275 Deg.F Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.75-1.25	0.5-0.85	NR
	6	0.75-1.25	0.5-0.85	NR
	8	0.85-1.0	0.5-0.65	NR
	10	0.85-1.0	0.65	NR
15	4	0.85-2.0	0.65-1.25	0.4-0.65
	6	1.0-2.0	0.65-1.25	0.5
	8	1.0-1.75	0.65-1.25	0.5
	10	1.0-1.75	0.65-1.0	NR
20	4	1.25-2.25	0.65-1.5	0.5-0.75
	6	1.25-2.25	0.75-1.5	0.65-0.85
	8	1.25-2.25	0.75-1.5	0.65-0.85
	10	1.25-2.25	0.75-1.5	0.65-0.85
25	4	1.25-2.25	0.85-1.75	0.65-0.85
	6	1.25-2.25	0.85-1.75	0.65-0.85
	8	1.25-2.25	0.85-1.75	0.65-0.85
	10	1.25-2.25	0.85-1.75	0.65-0.85

NR = Not Recommended

Table F-7(c)  
 Steady State Efficiency=84%  
 (12 percent CO<sub>2</sub>, 420 Deg.F Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.4-2.0	0.25-1.25	0.25-0.65
	6	0.4-2.0	0.25-1.25	0.25-0.65
	8	0.4-1.75	0.4-1.25	0.25-0.5
	10	0.5-1.75	0.5-1.0	0.25-0.5
15	4	0.5-2.25	0.4-1.75	0.25-0.85
	6	0.5-2.25	0.4-1.5	0.25-0.85
	8	0.65-2.25	0.4-1.5	0.25-0.85
	10	0.65-2.25	0.4-1.5	0.4-0.85
20	4	0.65-2.25	0.4-2.0	0.25-1.0
	6	0.65-2.25	0.4-2.0	0.4-1.0
	8	0.65-2.25	0.4-1.75	0.4-1.0
	10	0.65-2.25	0.4-1.75	0.4-1.0
25	4	0.65-2.25	0.4-2.25	0.4-1.0
	6	0.65-2.25	0.5-2.25	0.4-1.0
	8	0.65-2.35	0.5-2.0	0.4-1.0
	10	0.75-2.25	0.5-2.0	0.4-1.0

NR = Not Recommended

Table F-7(b)  
 Steady State Efficiency=86%  
 (12 percent CO<sub>2</sub>, 345 Deg.F Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.65-1.5	0.4-1.0	0.4-0.5
	6	0.65-1.5	0.4-1.0	0.4
	8	0.65-1.5	0.4-1.0	0.4
	10	0.65-1.5	0.4-1.0	NR
15	4	0.65-2.25	0.4-1.5	0.4-0.85
	6	0.65-2.25	0.5-1.5	0.4-0.75
	8	0.65-2.25	0.5-1.5	0.4-0.65
	10	0.75-2.25	0.5-1.5	0.4-0.65
20	4	0.75-2.25	0.5-1.75	0.4-1.0
	6	0.85-2.25	0.65-1.75	0.4-0.85
	8	0.85-2.25	0.65-1.75	0.4-0.85
	10	0.85-2.25	0.65-1.75	0.4-0.85
25	4	0.85-2.25	0.65-2.0	0.4-1.0
	6	0.85-2.25	0.65-2.0	0.5-1.0
	8	0.85-2.25	0.65-2.0	0.5-1.0
	10	1.0-2.25	0.65-2.0	0.5-1.0

NR = Not Recommended

Table F-7(d)  
 Steady State Efficiency=82%  
 (12 percent CO<sub>2</sub>, 495 Deg.F Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.4-2.25	0.25-1.25	0.25-0.75
	6	0.4-2.0	0.25-1.25	0.25-0.65
	8	0.4-2.0	0.25-1.25	0.25-0.65
	10	0.4-2.0	0.25-1.25	0.25-0.65
15	4	0.4-2.25	0.25-1.75	0.25-1.0
	6	0.4-2.25	0.25-1.75	0.25-0.85
	8	0.4-2.25	0.25-1.75	0.25-0.85
	10	0.4-2.25	0.25-1.75	0.25-0.85
20	4	0.5-2.25	0.4-2.0	0.25-1.0
	6	0.5-2.25	0.4-2.0	0.25-1.0
	8	0.5-2.25	0.4-2.0	0.25-1.0
	10	0.5-2.25	0.4-2.0	0.25-1.0
25	4	0.5-2.25	0.4-2.25	0.25-1.25
	6	0.65-2.25	0.4-2.25	0.25-1.25
	8	0.65-2.25	0.4-2.25	0.4-1.0
	10	0.65-2.25	0.4-2.25	0.4-1.0

NR = Not Recommended

Table F-7(e)  
 Steady State Efficiency=80%  
 (12 percent CO<sub>2</sub>, 575 Deg.F Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.25-2.25	0.25-1.5	0.25-0.85
	6	0.25-2.25	0.25-1.5	0.25-0.75
	8	0.25-2.0	0.25-1.25	0.25-0.75
	10	0.25-2.0	0.25-1.25	0.25-0.75
15	4	0.4-2.25	0.25-1.75	0.25-1.0
	6	0.4-2.25	0.25-1.75	0.25-1.0
	8	0.4-2.25	0.25-1.75	0.25-1.0
	10	0.4-2.25	0.25-1.75	0.25-0.85
20	4	0.4-2.25	0.25-2.0	0.25-1.25
	6	0.4-2.25	0.25-2.0	0.25-1.0
	8	0.4-2.25	0.25-2.0	0.25-1.0
	10	0.4-2.25	0.4-2.0	0.25-1.0
25	4	0.4-2.25	0.4-2.25	0.25-1.25
	6	0.4-2.25	0.4-2.25	0.25-1.25
	8	0.5-2.25	0.4-2.25	0.25-1.25
	10	0.5-2.25	0.4-2.25	0.25-1.25

NR = Not Recommended

**DEVELOPMENT OF A TWO-COLOR FQI**

Thomas A. Butcher, Ph.D., and George Wei  
Brookhaven National Laboratory  
Department of Applied Science  
Building 526  
Upton, NY 11973-5000



## Development of a Two-Color FQI

Thomas Butcher and George Wei  
Brookhaven National Laboratory

The Flame Quality Indicator (FQI) concept was developed at Brookhaven National Laboratory as a simple device which could be used to monitor oil burner flames and indicate when a problem was starting to occur. Fault situations which could be identified by the FQI include: fouled nozzle, increased or decreased excess air, blocked air inlet or flue, and use of low quality oil [1-5]. The basic concept of the FQI is quite simple. A conventional cadmium sulfide photocell is used to measure the amount of light emitted from an oil burner flame when the appliance is fully warmed-up. The measured amount of light is compared to a set point, established during burner tune-up. If the two intensities differ by more than a set range, a "service required" signal is produced.

The amount of light which is emitted from an oil burner flame depends upon the amount of "soot" or carbon in the flame, the size and shape of the flame, and the flame temperature. The quality of a flame is practically judged by the amount of soot which it is producing and for this reason it is necessary to eliminate effects of other parameters. Temperature is expected to be the most important of these. Flame temperature is affected by the type of combustion chamber into which it is fired, firing rate, and also the firing history. When a burner has been off for a long time and it is just fired flame temperature is lower than when it is running in steady state. The FQI eliminates effects due to the chamber environment by establishing a set point for each specific appliance. The transient temperature effects are accounted for by examining the flame brightness only at a single time during the firing cycle.

BNL is currently involved with the development of a two-color approach to the monitoring of flame quality. The basic concept involved is the measurement of both flame temperature and total amount of light emitted to allow a more direct estimate to be made of the amount of soot being produced and so the flame quality. The objective is to develop a more sensitive measurement which may be more universally applicable. This paper provides a summary of our approach and results to date in this project.

### TECHNICAL APPROACH

In evaluating concepts for a two-color method of examining flame quality the cost constraints must be considered from the outset. Any device which might be used in a residential burner must be very low in cost. For this reason the idea of making absolute measurements of flame emissivity, which is certainly possible, was abandoned in favor of approximate or relative measures which could be implemented at low cost. To date we have only consider the placement of sensors within the burner air tube, although it is expected that other locations would be more advantageous. Within the air tube sensors are cooled by combustion air but their view of the flame is always partially blocked. Other locations would require the addition of ports in the boiler or furnace.

The discussion of the approach being taken in the BNL development effort best starts with a perfect

emitter, the black body, for which emissivity = 1. Figure 1 shows the emission from a black body as a function of wavelength at two different temperatures. The curves in this figure are derived from the classic Planck's law. A simple two color pyrometer measures the ratio of light intensity at two different wavelengths to determine temperature of an emitting black surface. Figure 2 shows how the ratio changes for two selected wavelengths, again based on Planck's law.

Most surfaces are not perfect black bodies but have lower emissivities. If the emissivity does not depend on the wavelength such a surface is called "gray" and the curve in Figure 2 can still be used to determine the surface temperature.

The application of two color pyrometry to flames requires some approximations. A flame is not a surface but an emitting volume with non-uniform temperature and non-uniform emissivity. It is, however, approximated as uniform for this effort. The emissivity of a flame is not constant but depends upon wavelength and this, in turn, depends upon the size (optical path length) of the flame. If the flame is large enough the emissivity becomes 1.0 at all wavelengths and the flame can be considered as a black body. At the other limit, for small flames typical of residential oil burners the flames may be optically thin, and here, for the spectral range we are studying, the emissivity varies with the wavelength of light as [6]:

$$\text{emissivity} \propto \frac{1}{\text{wavelength}^{0.95}}$$

At a given wavelength, the amount of light emitted varies very strongly with temperature (as  $T^4$ ). For this reason even small changes in flame temperature can have great effects on brightness.

In this development effort the basic approach can be summarized as follows:

1. Using the ratio of light intensity at two selected wavelengths, estimate the apparent flame

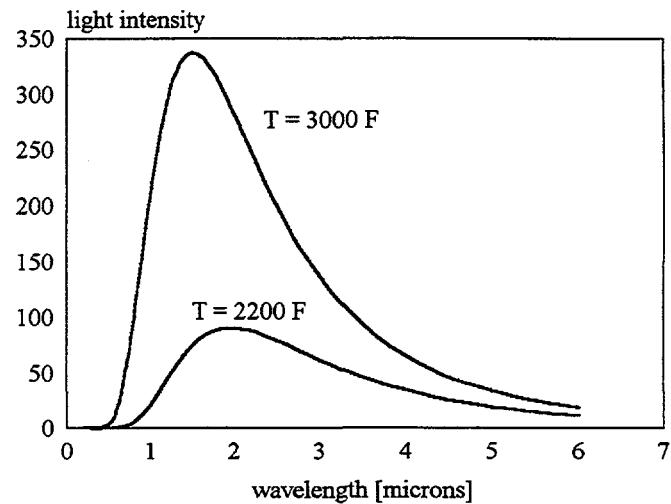


Figure 1. Effect of temperature on light emission from a black body.  
Visible light range is .4 to .7 microns

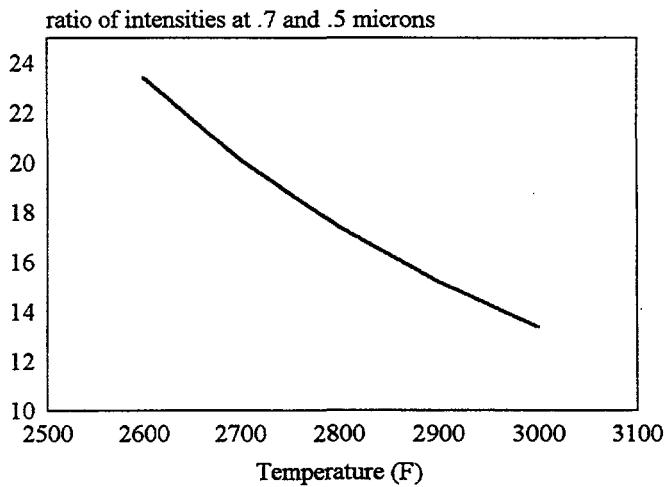


Figure 2. Effect of temperature on the ratio of intensity of light emitted from a black body at two wavelengths - 0.7 / 0.4 microns

temperature;

2. Using the conventional cad cell, make a relative measure of the amount of light being emitted by the flame;
3. Use the estimated temperature, the measured brightness, and the known relationship between light emission and temperature for a black body (Planck's law) to correct the brightness to a constant temperature (selected arbitrarily);
4. This corrected brightness signal is then the input to the two color FQI, which functions like the original, single color FQI.

In step 2, any measure of flame brightness could, of course, be used in place of the cad cell. For example, the output of one of the two sensors used for estimating apparent temperature could be used or the average of the two sensors.

## EXPERIMENTAL

In the experimental work at BNL sensors are being placed into the air tube of a burner to measure the ratio of intensity of emitted light at two different wavelengths and from this flame temperature estimates are made. Two different measurement systems are being used in parallel. In the first method a quartz fiber optic cable is located within the air tube directing light outside to a monochromometer (Oriel Instruments model 77250 1/8 m) which can be manually adjusted for wavelength passed and bandpass. At the outlet side light intensity is measured with a photomultiplier tube. In all work to-date the ratio of intensities at .5 and .54 microns have been studied. Previously, at BNL detailed spectral studies over the visible / near-IR range were made although for a different purpose [1].

In the second experimental method two photodiode sensors were installed on the fuel line assembly and held in place in a machined plastic case. These sensors have integral inlet filters with narrow bandpass. One of these photodiodes has a center wavelength at .5 microns and the other at .7 microns (EG&G Optoelectronics models DFA-5000 and DFA-7000). These are unamplified photodiodes and output is measured in a short circuit mode using a precision electronic current meter.

In testing, both sensor systems were used together. Figure 3 illustrates the mounting of the sensors on the fuel line of a conventional retention head burner, about 3 1/2 inches back from the retention head. The same burner was used for all tests. Prior to combustion testing very careful calibration of both sensor systems was done using a radiant cavity black body calibrator (Graseby Infrared Model IR-564).

## ANALYSIS OF COMBUSTION TEST DATA

Combustion testing has been done to date in a variety of appliances both in steady state and, in some cases, under cyclic conditions. In the steady state testing sensor outputs, resistance of the conventional cad cell used for the FQI, and smoke number are recorded over a very wide excess air range.

With the conventional cad cell and approach which has been used to date in the FQI a fixed voltage (5 V) is applied across the cad cell and an adjustable resistor. At the burner's correct excess air setting the adjustable resistor is trimmed to give 2.5 V across both the cad cell and the adjustable resistor. The voltage drop across the cad cell is used in the FQI circuit. As the excess air is decreased from the set point the amount of soot in the flame increases, the amount of light incident on the cad cell increases, the resistance of the cad cell decreases, and the voltage across the cad cell decreases. The opposite occurs with increasing excess air.

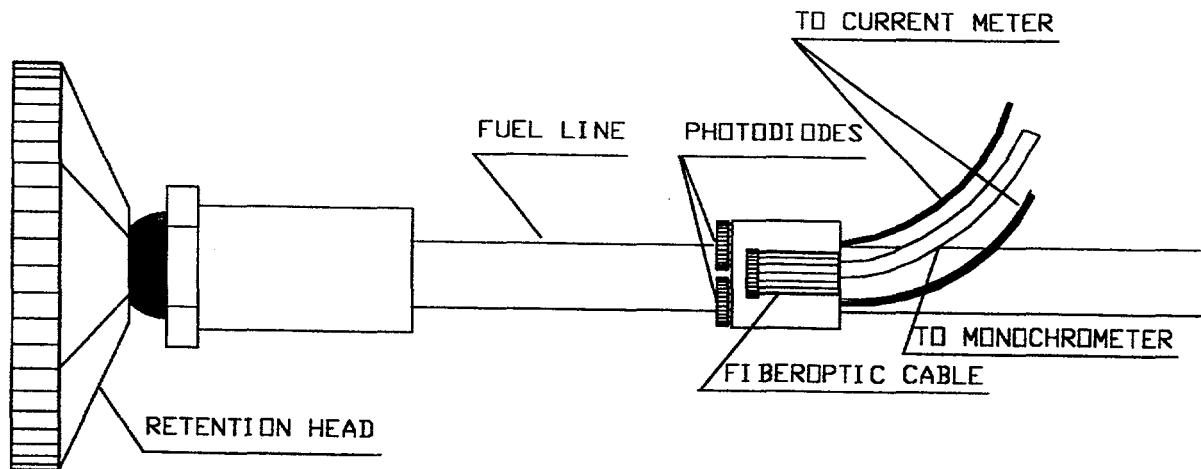


FIGURE 3. ILLUSTRATION OF THE INSTALLATION OF TWO-COLOR SENSORS ON FUEL LINE OF A CONVENTIONAL BURNER

The two-color approach now under development is a modification of this in which the cad cell resistance is corrected for changes in flame temperature. To do this flame temperature is first estimated from the ratio of intensities at the two wavelengths. Next an intensity correction factor is developed based on the ratio of black body emission at the measured temperature to the black body emission at a reference temperature. The reference temperature is arbitrary and is taken here as 2900 F, which is about the mean for the apparent flame temperatures measured to date. The cad cell resistance is then compensated for the change in intensity using characteristic response data for the cell. With this adjusted cad cell resistance, an "adjusted" FQI output voltage is calculated. This concept has not yet been integrated into a complete working circuit system. The adjusted FQI output voltage is simply a calculated value and the approach would need to be implemented using a microprocessor circuit.

## RESULTS TO DATE

Figures 4-9 show the results of the two color approach discussed above in three appliances. Figures 4 and 5 show results for a steel boiler with a horizontal, cylindrical combustion chamber. Apparent flame temperature shows a steady decrease with decreasing excess air in this case. The decreasing flame temperature tends to decrease flame brightness while the increasing soot would increase it. When the FQI voltage is corrected for the flame temperature the result is a signal which is more sensitive to changes in excess air.

Figures 6 and 7 show results for a center flue water heater with a heavy refractory combustion chamber. Here apparent flame temperature peaks in the 30-40% range. At very low excess air levels, where smoke number is increasing sharply, the uncorrected FQI signal becomes less steep while the corrected signal decreases sharply. This is in agreement with measurements of emissions of  $\text{NO}_x$  which is very temperature sensitive and which always decreases as the smoke limit is approached.

Results in a three section cast iron boiler are shown in Figures 8 and 9. Here there is a very sharp decrease in the temperature corrected FQI signal as the excess air is reduced below about 30% and this type of response would provide a better warning of a severe smoking conditions.

## PLANNED WORK

In this area additional studies are planned at BNL to evaluate the effects of sensor location. One of the achievements we would like to realize with the two color system is the ability to have one generic sensor system, with its set point independent of the chamber into which it is fired. To date we have not met this goal. Flame shape varies strongly with chamber variations and the way the light "hits" the current sensor systems also changes. However, relative to the existing, single color FQI the two color approach already offers better sensitivity, especially at the low excess air limits where flame temperature decreases rapidly as smoke increases. The future potential for the commercialization of this technology is totally dependent upon the availability of very low cost sensor/filter systems which can enable the flame temperature to be estimated on a reliable basis. BNL is looking at component options and will be evaluating this question.

## REFERENCES

1. Butcher, T. Performance control strategies for oil-fired residential heating systems. Brookhaven National Laboratory Report BNL 52250, July 1990.
2. Butcher, T. Applications of the Flame Quality Indicator, proceedings of the 1993 Oil Heat Technology Conference and Workshop, Upton, N.Y. March 25-26, 1993. R.McDonald ed., (BNL 52392) September, 1993.
3. Butcher, T. and Wei, G. Field tests on advanced control strategies, proceedings of the 1990 Oil Heat Technology Conference and Workshop, Upton, N.Y. May 21-22, 1990. R.McDonald and J. Andrews, eds., (BNL 52284) November 1990.

4. Butcher, T. Update on the BNL Flame Quality Indicator, proceedings of the 1991 Oil Heat Technology Conference and Workshop, Upton, N.Y. September 30- October 1, 1991 R. McDonald ed., (BNL 523450) July 1992.
5. Sinha, R. Field trials of advanced controls of oil-fired heating equipment, proceedings of the 1991 Oil Heat Technology Conference and Workshop, Upton, N.Y. September 30- October 1, 1991 R. McDonald ed., (BNL 523450) July 1992.
6. Siegel, R. and Howell, J. Thermal Radiation Heat Transfer, McGraw Hill, New York, 1981.

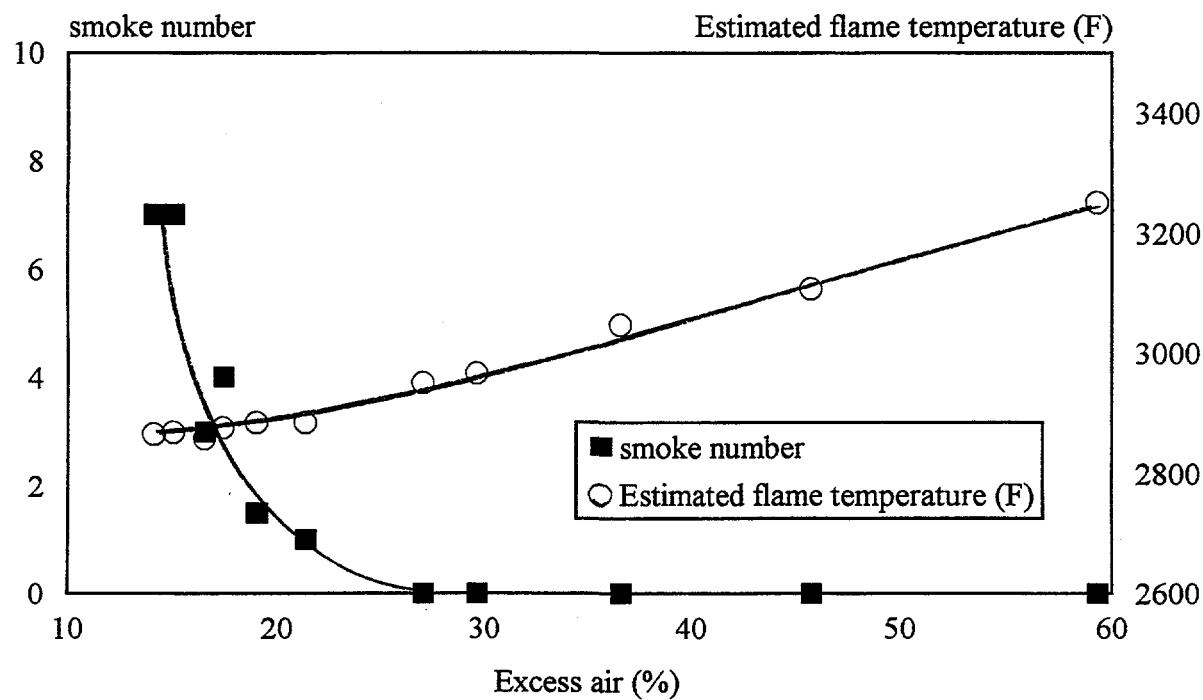


Figure 4. Test results in a steel boiler. Smoke number and estimated flame temperature vs. excess air.

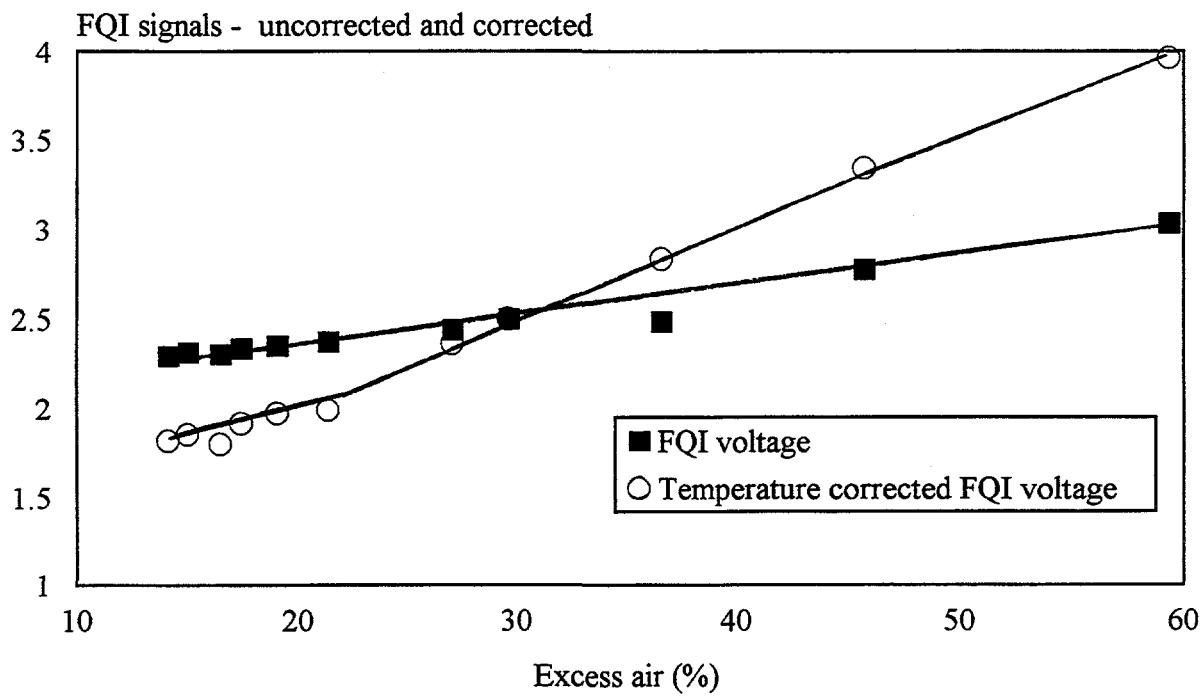


Figure 5. Test results in a steel boiler. Uncorrected and corrected signals vs. excess air.

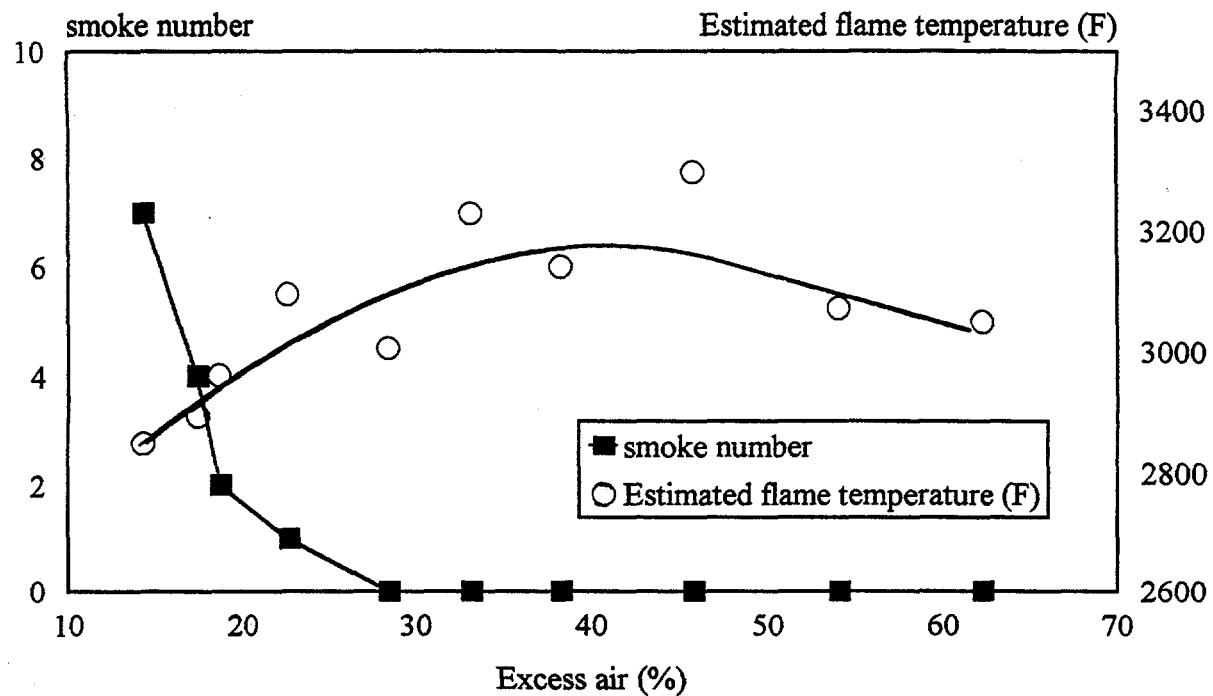


Figure 6. Test results in a center flue water heater. Smoke number and estimated flame temperature vs. excess air.

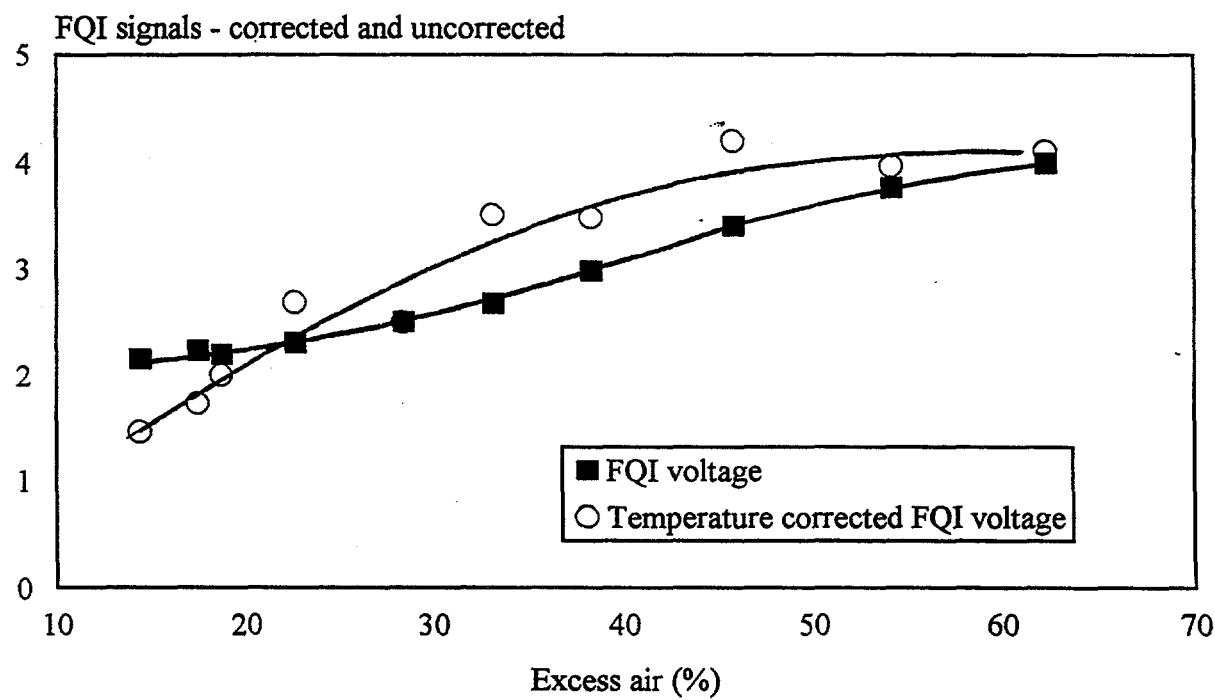


Figure 7. Test results in a center flue water heater. Uncorrected and corrected signals vs. excess air.

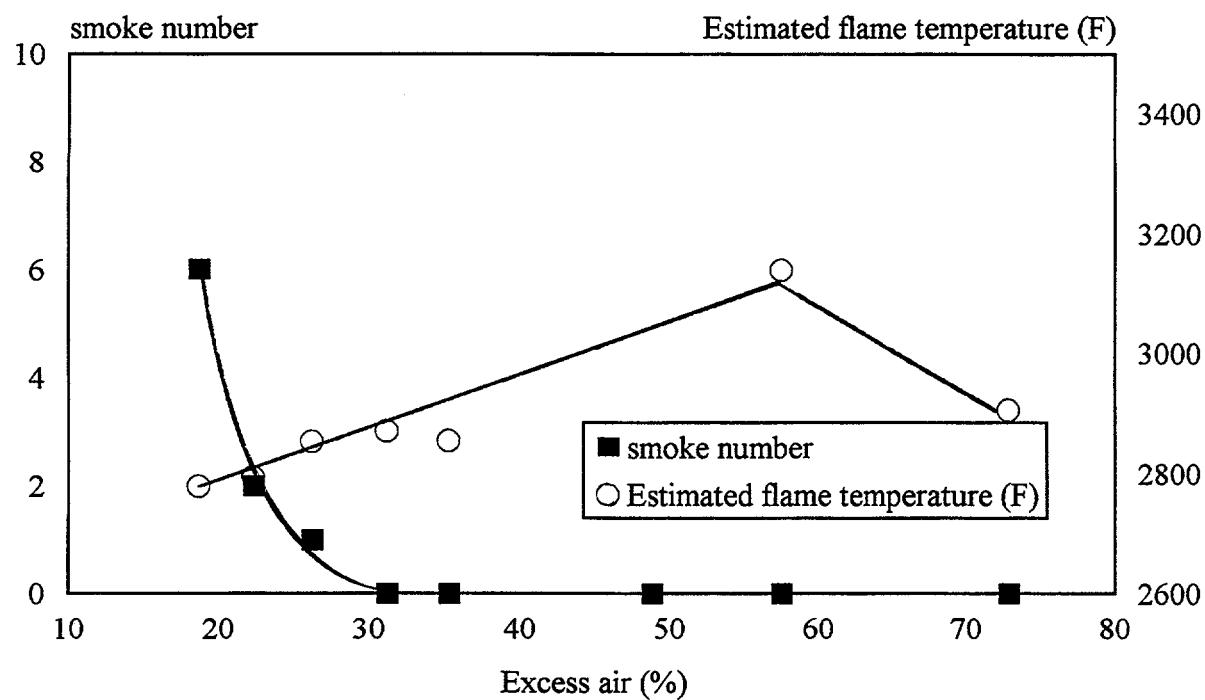


Figure 8. Test results in a cast iron boiler. Smoke number and estimated flame temperature vs. excess air.

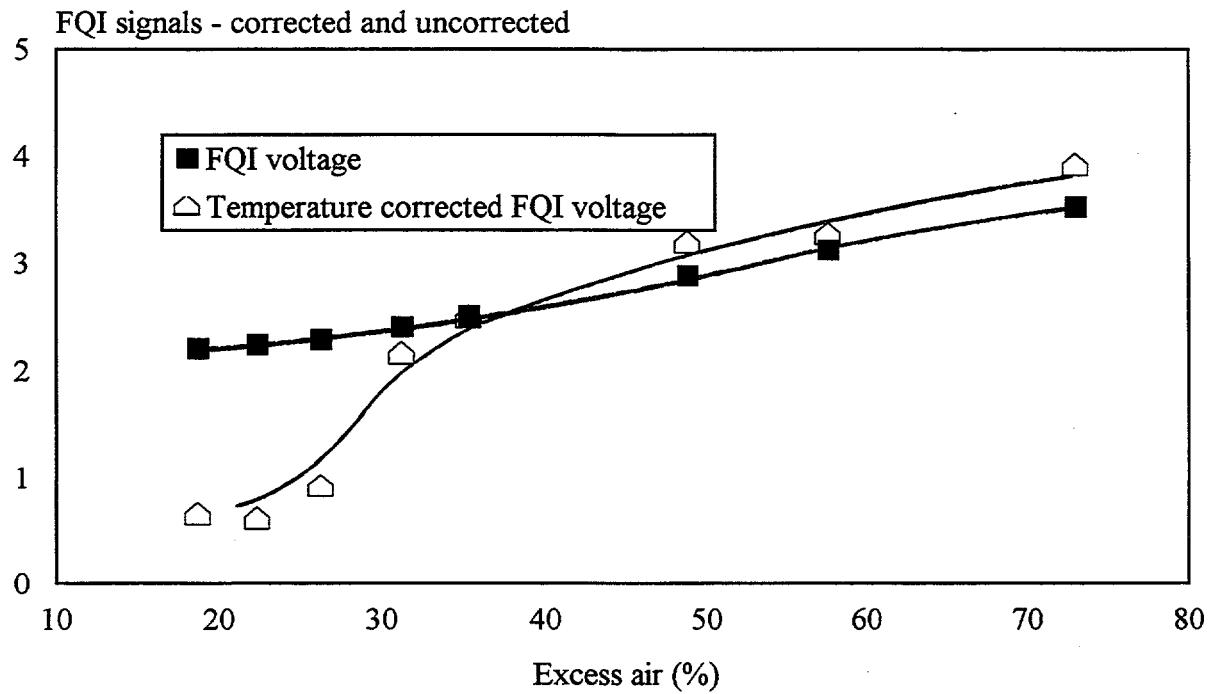


Figure 9. Test results in a cast iron boiler. Uncorrected and corrected signals vs. excess air.



### **III. WORKSHOP SESSIONS**



## **WORKSHOP TOPICS**

**1996 Oil Heat Technology Conference & Workshop**

**Brookhaven National Laboratory**

**March 28 - 29, 1996**

- A: Oil Heat Research Agenda Forum**
- B: FAB Commercialization, Applications, & Product Development**
- C: Fuel Quality, Storage, & Maintenance - Industry Discussion**
- D: Application of Oil Heat Venting Tables  
NFPA 31 Standard**



## GROUP A:

### OIL HEAT RESEARCH AGENDA FORUM

Chairman: John Batey  
Energy Research Center, Inc.

Rapporteur: Roger J. McDonald,  
BNL

*What will the future be like for the oil heat industry ?  
What new technologies will influence oil heat in the future?  
What will occur in the intervening period?  
Do you want to be part of the planning process ?*

If you have ideas, visions, thoughts about the future of oil heat please bring them to the discussions at the Oilheat Research Agenda Forum!

You will be asked to help generate a list of opportunities to review regarding new technology developments. These specific opportunities will then be discussed at the workshop regarding identification of specific research objectives. For example; improved equipment reliability. Then a list of individual research projects will be formed to address the objectives. For example; develop oil burners that are self adjusting like modern engine systems in cars that react to changes in operating conditions to optimize performance. A qualitative effort will be placed on prioritization of opportunities, objectives, and projects based on criteria as cultivated by those present at the forum.

You will also be asked what unresolved issues exist today? Can technology research and development address these issues? If prior attempts have not resolved these issues can they be addressed with more effort or in a different way than has been exercised to date. What areas have not had any attention because no single agency (research, manufacturer, or marketer) has felt the issues were of concern and important as related to the mission statement of that agency or organization.

Bring your ideas, bring an open mind, bring a pen or pencil, and please leave any negative thoughts about the industry's ability to get the job done at the door.

## DISCUSSIONS:

The Oilheat Research Agenda Forum was attended by fourteen industry representatives including marketers, equipment manufacturers, and researchers. Part of the time was spent discussing general research objectives and their relative priority ranking based on the opinions of those present following an exchange of ideas and viewpoints. The chairman also entertained thoughts and suggestions for discussions on specific research topics recommended by the participants at the workshop.

In the area of diagnostic devices, discussions keyed in on the need for these type of tools and that they need to be easy to use, easy to maintain, accurate and useful. The most important oil diagnostic tool, the smoke spot pump sampler, is an example raised by the group that cries out for dramatic modernization. The concept of an automatic smoke spot measuring device with an auto-reading digital output was proposed. Such a device would, at the push of a button, replace the ten strokes currently required for sampling the flue gases and the effort required to remove the filter paper and compare it to the standard smoke spot index card. The device if designed properly might also be useful for transient smoke level determinations leading to the diagnosis of problems related to start-up and shut-down problems like nozzle afterdrip. Tools for chimney diagnostics is another area for consideration. These would help determine the condition and check for proper functioning of the venting system. It was also suggested that another useful tool for the oilheat representative in the field would be an electronic notebook. A device for storing all sorts of useful information from how to tune and adjust heating systems based on the exact heat exchanger, burner, nozzle, control set-up in front of the technician in the basement, to what the options for domestic water are available, at what trade-offs, for the sales person to use while visiting the designers office while specifying a system for a brand new home yet to be built. It could include diagnostic procedures, sizing information, cost estimating information, pipe and ducting information, etc. The key would be to develop a good friendly interactive user interface that makes it easy to get the information with out a lot of hassle.

System reliability was another topic discussed and brought the group's focus to fuel quality, sludge in fuel systems, and how to deal with the problems associated with sludge. One idea suggested was that a fuel system component or sub-system should be devised to either identify and warn of fuel sludge conditions prior to the sludge causing operational problems, or one that would detect and remove the sludge before the fuel filter, thus preventing it from getting to the burner components and causing problems. It was suggested that the fuel sludge problem be attacked on a very broad basis starting with the fuel as it leaves the refinery and ending at the consumers oil burner. A commitment was made to follow-up in this area by developing a research plan that would in a comprehensive manor address the issues of fuel sludge. This will include many facets like fuel quality issues, fuel handling, fuel contamination, fuel stability, viability of fuel treatment options, storage and transportation concerns, and environmental sensitivities.

Venting combustion products from oil fired equipment was addressed from several viewpoints. Although BNL was recognized for its past significant accomplishments, currently several issues remain with the industry. Resolving these issues related to side wall venting and sealed combustion systems will be critical to the future viability of the industry in promoting the benefits of

oil heat in certain markets, for example conversions of electrically heated homes and multi-family housing units that could greatly benefit from the lower comparative costs associated with oil heat. The effort to continue modernizing codes and standards along with the education of code compliance officials is an ongoing need. The integrity and safety of modern oil heating systems which do not rely on traditional chimney technology for venting, needs to be documented. The group also tackled the issues related to back-drafting and odors as related topics in this area. The group proposed research be included to investigate ways to minimize oil heating related odors including the fuel itself as well as the combustion products. Concepts for fuel odor neutralization or masking would help improve the overall image of oilheat.

Discussions on the topic of safety and issues related to the levels of carbon monoxide formation associated with oilheat systems evolved from the discussion of combustion products and odors. The group felt that, with the growing popularity of carbon monoxide detectors in the residential marketplace, the oilheat industry needs to be prepared for the eventual customer inquiry triggered by the CO alarm sounding, no matter what the cause. The oil industry needs to know what levels of CO can be generated by oil-fired heating equipment under various different operating conditions. They also need information on what other CO sources can trigger the alarms and how to deal with the customer when the oil unit is clearly found not to be the source. This indicates a research need in generating, obtaining, and/or compiling documentable data concerning oilheat appliances and all other sources of CO in the home environment. Then development of programs for educating oilheat industry representatives concerning CO should follow.

Developing a clearing-house for information related to oilheat is very important to the future of the industry. In this electronic age the group embraced the concept of using the Internet as one form of providing information but certainly not the only one. The oilheat industry has a good message to convey to its current and potential future customers. The key is making the message clear, easy to understand, and to support statements with documentable facts. This is where an information clearing-house is important. The clearing-house can provide a lucid single point source of reliable information which is pre-formatted for use, information that is accurate, and information that is documented beyond challenge. Even with the electronic highway there will be a steady need for printed information on the part of the industry and its customers for some number of years into the future.

Another NORA function that was suggested was that there is a continuing need to have a truly independent source address and access new technology developments. It was this independent third party analysis of efficiency benefits provided by BNL back in the late nineteen seventies and early eighties that was the foundation of the success of the flame retention head burner in the marketplace. If in the future this type of effort continues it will provide the basis for future substantiation of energy efficiency or environmental enhancement claims related to oilheat innovations.

New equipment innovations were also discussed at the workshop. These included a project to access the opportunities for developing multi-function appliances which might combine cooling technology or electric power generation with an oilheat source. The group felt it was premature to discuss the specific merits of one concept or another as most were unfamiliar with the technologies

involved. There was a strong level of interest in seeing such a program element included in the long term plans for NORA, although its immediate priority might be comparatively low. There was even greater interest in seeing integrated heating systems (based on currently available or emerging technology concepts) included. This includes the whole idea of integrated appliances, starting with a clean sheet of paper and looking at oilheat not as individual components but as a system supplying energy services in terms of space heating, hot water, air filtration and conditioning, the whole heating, ventilation, air-conditioning system, interfaced with the house system, wrapped up in one design.

In looking at prioritization of the various research areas reviewed by the group the categories fell into traditional lines. The group tended to give the highest priority to items that appear to have the potential for the most immediate benefit for the industry. These included fuel related research to resolve issues associated with sludge, better diagnostic tools, information related projects, and systems integration of available technologies. The non-traditional areas with longer range opportunities like oil-fired cooling technology and co-generation fell into lower priority classifications. The plan for developing the research agenda for NORA/DOE is to hold several more workshops of a similar nature at major industry meetings throughout the country during 1996. This workshop session was an important start to the process and will be used as a foundation to build upon during the planning process.

## WORKSHOP TOPICS GROUP B:

### FAB COMMERCIALIZATION, APPLICATIONS, AND PRODUCT DEVELOPMENT

In developing the Fan Atomized Burner concept (or other low-firing rate concepts) what types of new products should be targeted: small space heaters, wall hung furnaces, water heaters, hybrid furnace, small boilers.....

To what firing rate should we limit the FAB? If we proceed with the development of a two-stage burner what should be the rates?

What features inhibit use of oil in new construction?

Can oil compete in small condominium applications?

How much of the market for electric-to-oil conversions is heat pumps vs. resistance?

In electric conversions, how significant is the cost of the hydronic distribution system in the total system. The gas industry is developing "distributed source" products for this market such as direct vented, gas-fired baseboard. Are more innovative distribution concepts needed to improve the position of oil heat?

Has the use of red dye in heating oil caused new maintenance problems?

Should the Oil Heat Industry be more concerned about CO? Is CO well enough understood?

Is the use of sidewall venting expanding in the U.S. market? What combustion issues remain in this area?

Why not interrupted ignition? What are the maintenance implications?

Should the use of low sulfur oil (0.05%) be promoted to become the requirement?

## DISCUSSIONS:

This workshop dealt primarily with the Fan Atomized Burner (FAB), the new burner that is under development at BNL. The group started talking about some of the applications that had been discussed in the past and probably were the initial applications that were thought of at the time the burner was selected for development. The group was very diverse and included: boiler manufacturers, furnace manufacturers, wholesalers, government people, engineers, installers and retailers.

With respect to the applications that had been talked about in the past, there was a discussion about the FAB being applied to a retrofit of electric heated homes and there was some interest in that. There was also an interest in small room heaters to compete with the smaller gas units that are on the market. There was some reservation voiced by a number of people as to the noise level of these units; how would it compare to a gas unit, would it be like an air conditioner or a unit in a hotel, and this certainly would have to be addressed if that market were to be pursued.

Instantaneous hot water heaters was another suggestion, similar to the European units that are out there. Units with small heat input rates with no storage capacity. This type of point-of-use water heater technology is an option that could be pursued with a small clean burning oil unit like the FAB.

Small furnaces for the mobile home market is another possibility for the burner. A high efficiency, clean burning, compact, small foot-print warm air oil furnace could readily be marketed to the mobile home industry.

All of these different markets are niche markets, something outside the mainstream of the oil-heat industry's core product lines. The workshop group did discuss the possibility of a large volume market that would take advantage of some of the strong points of the burner. Specifically, instead of limiting the burner to a maximum of 0.6 gallon per hour, make a burner that could be widely marketed in larger firing capacities. The rationale for this would be what makes this burner special, it has large orifices and can fire down to those smaller sizes. As we heard in a presentation earlier today, they were able to eliminate 45% of the oil-line problems, but that still leaves about 55% of them out there. Perhaps a burner with a large orifice that is capable of passing contaminants that normally now would plug a nozzle, could help bring down that 55%. So, there seemed to be a lot of interest, especially on the part of the installers, in a burner that they could install in a typical 1.0 gallon per hour job that would be less susceptible to nozzle contamination. Could the FAB technology be translated into that larger gallonage? That is for the researchers to determine. But, if it can, it would appear to open a much wider market than what currently exists.

The topic of discussion naturally went around to through-wall venting and positive-pressure firing. There were some questions as to whether that type of market should be pursued because some of the organizations that write standards, specifically those who have not accepted this type of venting, are lagging behind in the development of the technology. This is obviously a handicap in the early stages until it is accepted by the national standard making organizations.

Interest in Carbon Monoxide issues also came up during the workshop. One of the things that was identified is that there are no government standards as to what is an acceptable CO level in the home and the suggestion was made to try to codify that. Another issue put forth for discussion was that there is no instrumentation that measures reliably down in those low ranges that can be readily obtained. Both of these subjects are beyond the scope of BNL to tie down but, something that perhaps is within BNL's capabilities is to get some very easily understandable, easily disseminated information concerning oil burners and the production of CO. Many in the oil heat industry have heard, "Installers say that oil burners do not produce any CO.", and we don't want to necessarily have that marketed to the consumer because that statement taken by itself is not necessarily true. What installers need is good, reliable information, easily understandable by consumers, about the CO produced by oil burners and how that compares with the CO produced by other fuels.



## WORKSHOP TOPICS GROUP C:

### Fuel Quality, Storage, & Maintenance Industry Discussion

**Chairman: Tom Santa  
Santa Fuel, Inc.**

**Rapporteur: Wailin Litzke  
BNL**

#### I. Discussion on fuel quality issues:

- Major fuel-related concerns affecting oil heat industry.
- Consequences of sludge build-up and high maintenance/service requirements.
- How can current field testing of sludge-control additives (Mobil/Santa Fuel, Mobil/Messick Fuel, Others?) benefit the industry as a whole?

#### II. Future Work at BNL:

- What future research areas will benefit the industry?
  - Is there a need to reevaluate current fuel quality standards, such as ASTM D-396?
  - Cooperative field studies between BNL and Industry members.
- Will these areas fit the program goals under NORA?
- Would other projects fit under this program?
  - How about service calls not related to fuel quality, such as CO alarm calls?
  - Is there any interest on establishing industry-wide procedures for response?
  - Interest on separate meeting related to CO?

## DISCUSSIONS:

Approximately 25 participants attended this workshop. The discussion focused on topics that have concerned the industry in the past, specifically, fuel sulfur content, sludge, potential uses of fuel oil additives, red dye required on tax-exempt distillate oil, and cold flow characteristics. In terms of sulfur, there is generally a more aggressive push by the industry for low sulfur content as a standard in heating fuel.

With the widespread use of fuel oil additives many oil distributors still question their effectiveness on reducing service requirements. Initial discussions and questions centered on the Mobil/Santa Fuel field test results on an additive's performance (refer to papers 96-9 and 96-10 given during this morning's session). The only way to measure performance is to obtain a baseline of service information from your customer database and actually "count" the changes with your use of the additive. Not only can additives be evaluated and monitored in this way, but generally this is a good approach to look at the performance and reliability of all heating equipment parts. Overall, there was much interest in this cooperative field study conducted by these two companies.

Could BNL help to develop a standard for a high-performance fuel? Would it be advantageous for the industry to have a fuel that already contained additives upstream in the distribution system or leave additive treatment to individual oil dealers? For those who currently use additives, some participants were interested in seeing BNL test different brands, evaluate and report the results by product name as in "Consumer Reports." It seems, however, that the more appropriate role of BNL would be to develop standards and test methods, acceptance criteria, evaluate current fuel quality standards by performing tests with combustion appliances, and possibly to organize the procedures for field studies. For example, BNL could be involved in cooperative efforts with the industry to provide the methods for evaluating additive performance. The industry could provide the customer base (population pool) for actual testing and the personnel for collecting data related to specific additives of interest. BNL could subsequently do the statistical analyses of the data. BNL could also help to evaluate nonchemical solutions to today's current fuel-related problems.

There was also some interest in testing the effects of red dye used in heating fuel on combustion and equipment performance. It appears that neither EPA nor the dye manufacturer have done any testing on its effects with oil heating appliances in terms of emissions and equipment performance. It was noted that BNL will be conducting some limited tests in cooperation with a burner manufacturer to look at coking of the burner head with diesel fuel, with and without the red dye. Some participants also suggested that we look at filter plugging tendencies and emissions.

The overall plan to improve fuel quality and heating system performance reliability by the oil heat industry is evolutionary. In light of the potential opportunities offered by NORA, the industry needs to begin to identify the specific problems, measure its impacts, and decide what is needed in terms of research goals.

## WORKSHOP TOPICS GROUP D:

### Application of Oil Heat Venting Tables NFPA 31 Standard

Chairman: **Richard F. Krajewski,**  
**BNL**

Rapporteur: **John Strasser,**  
**BNL**

Issues related to the Proposed Venting Tables for Masonry Chimneys:

1. Are the proposed venting tables adequate in interpretation or use?
2. What is the field experience regarding masonry chimney performance?
3. Is the application of metal liners solving the field problems within chimneys?
4. BNL will be completing a few remaining activities related to the oil heat appliance venting project during FY 1997. Are there any existing venting issues of concern to the oil heat industry that have not been covered by BNL's work?

## DISCUSSIONS:

The group first addressed the utility of the Oil Heat Venting Tables developed at BNL for NFPA 31, Appendix F. The consensus was that, in general, the tables offer good information but are inadequate in their present form. In terms of interpolation, since the tables only go to 25 feet, individual runs are necessary. The tables should be expanded to include 35 and 50 foot chimneys. The limitation to 8 by 8 clay flues should be opened up with a concentration on the higher firing rates and larger flue tile sizes. Common venting should be pursued through the use of the existing tables. BNL should develop the necessary procedures for securing useful information regarding the successful operation of common vented appliances from the existing tables. The Gas tables, while complicated, provide useful information about multiple elbows, effects of chimney offsets, altitude, etc. The BNL tables may be too simplified to resolve field encountered problems. Metal chimneys and power venting remain open issues and should be pursued.

The group next addressed the issue of field experience regarding masonry chimney performance and documentation of same. They suggested BNL pursue the use of the BNL chimney survey form. The product warranty form may offer opportunities to gather information about equipment operation. BNL should use the OHVAP program to develop benchmark flue gas temperatures (appliance and vent exit) for equipment and chimneys. The field data has been sparse with little information regarding the appliance operation. So far, the chimney sweep industry has supported the reporting while little has been obtained from the oil heat industry.

The group then discussed the ability to resolve field problems within chimneys by installing metal liner systems. Various viewpoints and opinions were expressed. "There appears to be no concrete evidence of any real problems associated with liners: no hard evidence, too much hear say,." "Metal liners appear to work and last." "Not enough information is documented on the application of metal liners in oil-fired appliances."

The last question addressed by the group was, what remaining venting issues of concern to the oil heat industry have not been covered by BNL's work? The ASHRAE large chimney recommendations ASHRAE Handbook (Chapter 31) were not examined except in checking chimney draft. BNL should examine the application of larger flue tile sizes, such as 8 by 12 and 12 by 12. The issues associated with flue gas dilution and draft control are not clearly resolved where the relative value of whole house energy conservation and drying of the chimney are concerned. There are opportunities for integration of the chimneys (venting system) and the equipment. The lack of "integrated" heating system designs needs a start through BNL guidance. Integrated packages can pose some real field problems in terms of parts availability. Standardization within the industry may become essential. The application of the existing tables are centered around the decision to re-line. The question remains to be answered; "Is the chimney sound or not?" The chimney used in OHVAP is idealized in terms of leakage. There has been an increase in the application of oil fired forced air systems. This is probably driven by the related need for a ducting system when air-conditioning is also desired. The "new" proposed oil fired technology (chillers, heat pumps, etc) will need to be addressed in terms of venting requirements. BNL should generate "rules of thumb", diagnostics, and a slide-rule related to venting needs. The issues of clay liner characterization, alternative liner materials, exterior chimney water proofing, and improved diagnostic methods were all generally

accepted. The table revisions are limited to the NFPA revision cycle, but BNL reporting of new information will continue as a Technology Transfer Task.

#### FUTURE ACTIVITIES:

##### Venting Research Activities for the Remainder of FY 1996

- 1) Review and release of the OHVAP Final Report
- 2) Start "Beta" testing of OHVAP
- 3) Continue and enlarge chimney survey effort.
- 4) Comparison checks with the ASHRAE analysis for large chimneys; issue guidance

##### Venting Research Activities for FY 1997 and Beyond (No Assigned Priority With No Funding Projected)

- 1) Expand the tables to include metal chimneys and power vents; develop new tables
- 2) Expansion of the tables to 35 and 50 foot chimneys; incorporate into tables.
- 3) Examine the effects larger flue tile sizes; incorporate into tables.
- 4) Examine the effects of additional connector elbows, chimney offsets, altitude and less than ideal chimneys; issue guidance.
- 5) Examine the applicability of the existing tables to furnace operation; issue guidance
- 6) Examine the effects of proposed new integrated systems; issue guidance.
- 7) Examine the usefulness of the tables for common venting applications; issue guidance.
- 8) Examine the effects of dilution air on whole house energy conservation and chimney drying; issue guidance.
- 9) Examine the application of "weather proofing" existing masonry chimneys
- 10) Develop the characterization of clay liners and alternative liner materials.



#### **IV. FINAL ATTENDANCE LIST**



Raymond K. Albrecht  
New York State Energy Research  
and Development Authority  
2 Rockefeller Plaza  
Albany, NY 12223

Don Allen  
E. T. Lawson  
4 Ivy Home Rd.  
Hampton, VA 23669

John Andrews  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973

Joe Angello  
Mobil Oil Corp., US M&R  
3225 Gallow Road  
Fairfax, VA 22037-0001

Joan Axelrod  
Mobil Technology Co.  
Billingsport Rd.  
Paulsboro, NJ 08066

Gordon H. Barkell  
Allyn Oil Co., Inc.  
330 W. Merrick Rd.  
Freeport, NY 11520

Bob Barnes  
Barnes Heating & A/C  
678 Nichols Avenue  
Stratford, CT 06497

John Batey  
Energy Research Center, Inc.  
35 Fawn Rd.  
Easton, Ct 06612

Jim Becker  
Thermo-Dynamics Boiler Co.  
P.O. Box 325, Rte. 61, South  
Schuylkill Haven, PA 17972

Drew Behrens  
Dowling Fuel Co.  
Industrial Ave.  
Ridgefield Park, NJ 07660

Vinnie Bertrand  
Heating System Conversions  
PO Box 636  
Agawam, MA 01001

David A. Bessette  
Arlex Oil Corp.  
275 Massachusetts Ave.  
Lexington, MA 02173-4088

Yvon Blais  
Heating System Conversions  
PO Box 636  
Agawam, MA 01001

Carl Bock  
Bock Water Heaters, Inc.  
110 S. Dickinson St.  
Madison, WI 53708-8632

Robert V. Boltz  
Vincent R. Boltz, Inc.  
45 Guilford Street  
Lebanon, PA 17042

Lewis Boyce  
Carlin Combustion Tech, Inc.  
70 Maple Street  
E. Longmeadow MA 01028

Al Breda  
Standard Oil of CT.  
299 Bishop Avenue  
Bridgeort, CT 06607-4005

John Busse  
Burnham Corp.  
PO Box 3079  
Lancaster, PA 17604

Tom Butcher  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973

Dennis Cady  
Webster Heating &  
Specialty Products, Inc.  
999 Industrial Park  
Frankfort, KY 40602-1610

Dave Campbell  
Fuel Oil News  
184 N. Baldwin Hill Rd.  
N. Egremont, MA 01252

Thomas Campbell  
Mestek, Inc.  
260 N. Elm St.  
Westfield, MA 01085

Edward A. Carey  
E. A. Carey HVAC  
RR3, Box 272-9  
Dallas, PA 18612

John Carey  
New England Fuel Institute  
20 Summer St.  
Watertown, MA 02272-9137

Peter J. Carini  
Champion Energy Corp.  
4 Greenwich Office Pk.  
Greenwich, CT 06831

Ken Carr  
J. W. Pierson Co.  
89 Dodd St.  
East Orange, NJ 07017

David Carvalho  
I.C.P.A.  
29 S. Main St.  
West Hartford, CT 06107

Yusuf Celebi  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973

John Chicoine  
Mestek, Inc.  
260 N. Elm St.  
Westfield, MA 01085

Randal Clair  
Agway Energy Products  
6978 NY Rte. 80  
Tully, NY 13159

James Cole  
BETZ Process Chemicals, Inc.  
PO Box 1405  
Blue Bell, PA 19422

Gregory Commins  
Berenklau Oil  
740 Jamaica Ave.  
Brooklyn, NY 11208

Jim Connors  
Mestek  
260 North Elm Street  
Westfield, MA 01085

Lou Correa  
J. W. Pierson Co.  
89 Dodd St.  
East Orange, NJ 07017

Peter J. Cullen  
Carlin Combustion Tech, Inc.  
70 Maple Street  
E. Longmeadow MA 01028

James Davenport  
Brookhaven National Laboratory  
Building 179A  
Upton, New York 11973

John Dicus  
Griffith Consumers  
2155 B Northbridge Ave.  
Baltimore, MD 21226

Bert Disoteo  
Dowling Fuel Company  
Industrial Avenue  
Ridgefield Park, NJ 07660

Lou Divone  
EE-40, FORSTL  
U.S. Dept. of Energy  
1000 Independence Ave SW  
Washington, DC 20585

John Doht  
MCN Distributors  
300 No. Connecting Rd.  
Hauppauge, NY 11788

Robert Dolan  
Castle Oil Corp.  
290 Locust Ave.  
Bronx, NY 10454-2023

Fran Donnelly  
Brookhaven National Lab.  
Bldg. 526  
Upton, NY 11973

Frazer Dougherty  
North Fork Retrofit  
511 Carpenter St.  
Greenport, NY 11944

Nelson Driver  
Driver Heating Oil, Inc.  
PO Box 1765  
Waynesboro, VA 22980

Chuck Dunn  
Weil McLain  
1000 Main St.  
New Rochelle, NY 10801

Thomas Edge  
Heritagenergy  
PO Box 797  
Lake Katrine, NY 12449

E. Entchev  
C.C.R.L./E.R.L.  
555 Booth Street  
Ottawa, Canada K1A 0G1

Norman Ferland  
T-Bird Fuel Co.  
225 Washington St.  
Claremont, NH 03743

Leonard Fisher  
171 Ed Clark Rd.  
Colrain, MA 01340

Don Foreman  
Honeywell  
3660 Technology Drive  
Minneapolis, MN 55418

David H. Forney  
Burnham Corporaton  
P. O. Box 3079  
Lancaster, PA 17604

Dan Fraccalvieri  
Perillo Bros Fuel Oil Co  
9 Murray St.  
Farmingdale, NY 11738

Rodney Freed  
Farm & Home Oil Co.  
3115 State Rd., Box 389  
Telford, PA 18969

Ken Friskey  
Griffith Consumers  
2144 B Northbridge Ave.  
Baltimore, MD 21226

Dennis Frost  
R. L. Leitch Co.  
3173 Solomons Island Rd.  
Edgewater, MD 21037

Isaac L. (Ike) Gadsden  
Fairville Products, Inc.  
302 Robinson La.  
Wilmington, DE 19805-4674

Paul Geiger  
Fuel Oil & Oil Heat Magazine  
389 Passaic Avenue  
Fairfield, New Jersey 07006

Drew Gillett  
33 Holbrook Rd.  
Bedford, NH 03110

Jeremy Godfree  
Product Design  
Pugwash River RR#2  
Pugwash, Nova Scotia  
Canada BOK1LO

Chuck Gratton  
Champion Energy Corp.  
4 Greenwich Office Pk.  
Greenwich, CT 06831

Robert B. Greenes  
Petroconsult, Inc.  
51 Sheldrake Rd.  
Scarsdale, NY 10583

John Griffin  
General Utilities, Inc.  
100 Fairchild Ave.  
Plainview, NY 11803

Eric Grisier  
Bard Manufacturing Co.  
1914 Randolph Drive  
Bryan, OH 43506

Richard Harris  
Carpenter & Smith  
100 Spring St.  
Monroe, NY 10950

Robert Hedden  
Oil-Heat Mgmt Services  
RR#1, Andrus Drive  
P. O. Box 1810  
Pawlet, VT 05761

Paul F. Heinerichs  
Meenan Oil Co., Inc.  
8301 Lansdowne Ave.  
Upper Darby, PA 19082

Thomas Hewitt  
Meenan Oil Co., Inc.  
3020 Burns Avenue  
Wantagh, NY 11793

Brian K. Hills  
Nalco/Exxon Energy Chemicals, LP  
1927 Nolte Drive  
Paulsboro, NJ 08066

Hermann Hinterhaeuser  
Carlin Combustion Tech, Inc.  
70 Maple Street  
E. Longmeadow MA 01028

John Huber  
Petroleum Marketers Assoc.  
of America  
1901 N. Ft. Myer Drive  
Suite 1200  
Arlington, VA 22209-1604

Dale L. Hunsberger  
Suntec Industries  
2210 Harrison Avenue  
P. O. Box 7010  
Rockford, IL 61125

John Hunt  
Meenan Oil Co.  
3020 Burns Avenue  
Wantagh, NY 11793

Everett James  
ThermoProducts, Inc.  
P. O. Box 217  
North Judson, IN 46366

Steve Jetter  
Mobil R&D Corp.  
Billingsport Rd.  
Paulsboro, NJ 08066-0480

Bola R. Kamath  
Heat Wise, Inc.  
590 Whiskey Road  
Ridge, NY 11961

Gowtham Kamath  
Heat Wise, Inc.  
590 Whiskey Road  
Ridge, NY 11961

Kevin Karnis  
Newmac Mfg., Inc.  
P. O. Box 9  
Debert, Nova Scotia B2N4C6

Jack Kayne  
Slant Fin Corp.  
100 Forest Drive  
Greenvale, NY 11548

Edward Kitchen  
Intl. Lubrication &  
Fuel Consultants  
17321 Berkshire Dr.  
Jeffersonton, VA 22724

Tom E. Klassen  
Buderus Hydronic Systems  
50-B Northwestern Drive  
Salem, N.H. 03079

Richard Krajewski  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973

Majorie Krampf  
Fuel Merchants Assoc. of  
New Jersey  
P. O. Box 477  
Springfield, NJ 07081

John Kuebrich  
ARCO  
1801 E. Sepulveda  
Carson, CA 90749

George Kusterer  
Bock Water Heaters, Inc.  
220 Chestnut St.  
Kutztown, PA 19530

Esher R. Kweller  
CE-422, FORSTL, RM. 5H-048  
U.S. Department of Energy  
1000 Independence Ave., SW  
Washington, DC 20585

John Laisy  
R.W. Beckett  
P.O. Box 1289  
Elyris, OH 44036-1289

David Languilli  
Brookhaven National Lab  
Building 902C  
Upton, NY 11973

Steve Lasser  
Energy Kinetics, Inc.  
103 Molasses Hill Rd.  
Lebanon, NJ 08833

Richard W. Leigh  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973-5000

Alan Levi  
Oil Services, Inc.  
P. O. Box 308  
Oceanside, NY 11572-0308

Richard Levi  
Oil Services, Inc.  
P. O. Box 308  
Oceanside, NY 11572-0308

Lindy Lindtveit  
Sid Harvey Corporation  
100 E. Mineola Ave.  
Valley Stream, NY 11580

Walter Lingner  
Petro  
477 W. John St.  
Hicksville, NY 11801

Wailin Litzke  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973

George Lonkart  
McAllister Fuels  
30 Mays Landing Rd.  
Somers Pt. NJ 08244

Robert Lynch  
Energy Matters  
30 Prospect St.  
White Plains, NY 10605

Jim Macaluso  
NALCO/Exxon Energy Chemicals L.P.  
1927 Nolte Drive  
Paulsboro, NJ 08066

John Maniscalco  
N.Y. Oil Heating Assoc., Inc.  
225 W. 34th  
Suite 1202  
New York, NY 10122

John D. Marran  
Energy Kinetics, Inc.  
103 Molasses Hill Rd  
Lebanon, NJ 08833

Roger Marran  
Energy Kinetics, Inc.  
103 Molasses Hill Rd.  
Lebanon, NJ 08833

Thomas Matyjakowski  
Dunkirk Radiator Corp.  
85 Middle Rd.  
Dunkirk, NY 14048

Bob McAllister  
McAllister Fuels  
30 Mays Landing Road  
P.O. Box 185  
Somers Point, NJ 08244

W. R. McClintock  
Mobil Oil  
Fairfax, VA

Roger McDonald  
Brookhaven National Laboratory  
Building 526  
Upton, NY 11973

Richard C. McElwee  
Weil-McLain  
500 Blaine Street  
Michigan City, IN 46360-2388

Edward McPhail  
Cheshire Oil Co.  
Marlboro Street, P.O. Box 586  
Keene, NH 03431

Richard G. Mohrfeld  
Mohrfeld Inc.  
24 Lees Avenue  
P.O. Box 427  
Collingswood, NJ 08108

Frank Mondsini  
J. W. Pierson Company  
89 Dodd Street  
East Orange, NJ 07017

Judith Monks  
Mohonk Oil Co.  
24 Canaan Rd.  
New Paltz, NY 12561-2804

Joseph Monks  
Mohonk Oil Co.  
24 Canaan Rd.  
New Paltz, NY 12561-2804

John Morris  
Ethyl Corporation  
330 S. 4th Street  
Richmond, VA 23219-4304

Jerry Moskowitz  
Carpenter & Smith, Inc.  
P.O. Box 686  
100 Spring Street  
Monroe, NY 10950

Reza (Ray) Mossavi  
GSW Water Heating Co.  
599 Hill Street West  
Fergus, Ontario NIM 2X1  
Canada

James Murray  
R.S. Leitch Co.  
Operations Manager  
P.O. Box 120  
3173 Solomons Island Road  
Edgewater, MD 21037

David Nasner  
Main Brothers Oil Co., Inc.  
1 Booth Lane  
Albany, NY 12205

David Nelsen  
Kurz Oil  
38 Sintsink Drive East  
Port Washington, NY 11050

Rainer Ober  
Baerenklau Oil Co.  
740 Jamaica Ave.  
Brooklyn, NY 11208

John Orr  
National Combustion Co., Inc.  
104-07 180 St.  
Jamaica, NY 11433

Tony Ogborn  
Canadian Standards, Assoc.  
178 Rexdale Blvd.  
Rexdale, Ontario  
CANADA M9W1R3

Chris J. Perillo  
Perillo Bros. Fuel Oil Corp.  
9 Murray St.  
Farmingdale, NY 11735

F. A. Pettigrew  
Ethyl Corp.  
P.O. Box 2158  
Richmond, VA 23218

Frederick Phillips  
Clean Burn Inc.  
83 South Groffdale Road  
Leola, PA 17540

Victor Piano  
Dowling Fuel Co.  
Industrial Avenue  
Ridge Field Park, NJ 07660

Joseph Pihanich  
Boyestown Furnace Co.  
156 Holly Road  
Boyestown, PA 19512

Tony Polvino  
Sun Company  
Sunoco Retail Heating  
4041 Market St.  
Aston, PA 19014

Gary E. Potter  
Agway Energy Products  
6978 NY Rt. 80  
Tully, NY 13159

Roger Prevost  
Quality Equipment Sales  
690 Harleysville Pk.  
Lederach, PA 19450

Fernando Quintero  
NYC Housing Authority  
250 Broadway - Room 2705  
New York, NY 10007

Steven Rakvica  
Dunkirk Radiator Corp.  
85 Middle Road  
P.O. Box 32  
Dunkirk, NY 14048

Earl Rightmier  
Utica Boilers, Inc.  
2201 Dwyer Ave.  
Utica, NY 13501

Andrew Rudin  
Insight Technologies, Inc.  
1150 Walnut Ave.  
Bohemia, NY 11716

John Ryan  
Heritagenergy  
P.O. Box 797  
Lake Katrine, NY 12449

Thomas Santa  
Santa Fuel, Inc.  
154 Admiral Street  
P.O. Box 1141  
Bridgeport, CT 06601

Jim Scheibein  
Grace Oil Co.  
P. O. Box 239  
101 E. 5th Avenue  
Wildwood, NJ 08260

Hos Scheibein  
Grace Oil Co.  
P.O. Box 239  
101 E. 5th Avenue  
Wildwood, NJ 08260

Daniel A. Schildwachter  
Fred M. Schildwachter & Sons, Inc.  
1400 Ferris Place  
Bronx, NY 10461

George Schultz  
Fuel Oil News  
38 Foley Avenue  
Edison, NJ 08820

Kevin Scully  
Laco Service Fuel  
170 E. Lincoln Avenue  
Valley Stream, NY 11580

Clint Shurtleff  
New England Inst. of Tech.  
2500 Post Rd.  
Warwick, RI 02886

Dave Signore  
Ambler Coal Co., Inc.  
250 N. Main Street  
Ambler, PA 19002

Mark A. Skolnik  
Mobil Oil Corp.  
3225 Gallons Road, Rm. 7A915  
Fairfax, VA 22037

Pat Smolenski  
Long Island Lighting Co.  
1393 Veterans Hwy.  
Hauppauge, NY 11788

Paul Sohler  
Crown Boiler Co.  
3633 I Street  
Philadelphia, PA. 19134

Eric Spek  
Riello Canada Inc.  
2165 Meadowpine Blvd.  
Mississauga, Ontario  
L5N 6H6 Canada

William Spencer  
Parrsboro Metal Fabricators  
P.O. Box 637  
Parrsboro, Nova Scotia  
Canada, BOM 1SO

Channing Starke  
Technical Director  
Hydronics Institute Div. of GAMA  
35 Russo Place  
Berkeley Heights, NJ 07922

Gabriel Stefania  
Baerenklau Co.  
740 Jamaica Avenue  
Brooklyn, NY 11208

Jeff Stembridge  
Delavan Fuel Metering Products  
P.O. Box 969  
Bamberg, SC 29003

John Strasser  
Brookhaven National Laboratory  
Bldg. 526  
Upton, NY 11973

Greg Taillefer  
Carlin Combustion  
70 Maple Street  
East Longmeadow, MA 01028-2744

Masoud Tamjidi  
Fulton Boiler Works  
Port & Jefferson Streets  
Pulaski, NY 13142

Michael Tartaro  
New York City Housing Authority  
250 Broadway - Room 2705  
New York, NY 10007

Robert Tatnall  
MIC Associates, Inc.  
10 McCarthy Rd.  
Chadds Ford, PA 19317

Subbu Thenappan  
Bock Water Heaters  
110 S. Dickinson Street  
Madison, WI 53703

Bill Thiel  
Fuel Merchants Assoc., of NJ  
66 Morris Avenue  
P. O. Box 477  
Springfield, NJ 07081

Charles Thomas  
New England Fuel Institute  
20 Summer St.  
Watertown, MA 02172

David Thomas  
BCF Management Co.  
P.O. 381  
371 Circle of Progress  
Pottstown, PA 19464

Erik Titland  
Materials & Energy  
512 Idlewild Road  
Bel Air, MD 21014

Roger Triplett  
Honeywell Inc.  
1985 Douglas Drive N.  
Golden Valley, MN 55422

Jeff Trieb  
Tjernlund Products, Inc.  
1601 Ninth St.  
White Bear Lake, MN 55110-6794

Rick Trout  
Mobil Oil Corp.  
14 Old Auburn Rd.  
Derry, NH 03038

Victor J. Turk  
R.W. Beckett Corp.  
P.O. Box 1289  
Elyria, OH 44036-1289

Todd Tuthill  
T. L. Tuthill Heating Serv, Inc.  
P. O. Box 2013  
Jamesport, NY 11947

Martin M. VanAdelsberg  
Lawrence J. Dove Assoc.  
MVA Engineers Assoc.  
625 Stetson Road  
Elkins Park, PA 19027-2524

Joseph Vassallo  
Santa Fuel  
154 Admiral St.  
Bridgeport, CT 06610

Harry Wallace  
J.W. Pierson Co.  
89 Dodd Street  
East Orange, NJ 07017

Arlene Waltz  
Brookhaven National Lab.  
Bldg. 526  
Upton, NY 11973

Joel Watts  
Yankee Oilman Magazine  
P. O. Box 37  
Beverly, MA 01915

Gang Wei  
Brookhaven National Lab.  
Bldg. 526  
Upton, NY 11973

Mark A. Wensel  
Peerless Heater Company  
Spring & Shaeffer Streets  
Boyertown, PA 19512

Detlef Westphalen  
Arthur D. Little, Inc.  
20 Acorn Park  
Cambridge, Massachusetts 02140-2390

John Winiczei  
Winpro, Inc.  
50 Verdi Street  
Farmingdale, NY 11735

Jason T. Wise  
Wise Oil & Fuel Inc.  
741 Race Street  
Cambridge, MD 21613

William L. Wise  
Wise Oil & Fuel Inc.  
741 Race Street  
Cambridge, MD 21613

Edward Wisniewski  
Wayne Power Burners  
149 Truxton Rd.  
Dix Hills, NY 11746

Chris Wong  
GSW Water Heating Co.  
599 Hill Street West  
Fergus, Ontario NIM 2X1  
Canada

Richard Zaweski  
Meenan Oil  
3020 Burns Ave  
Wantagh, NY 11793

