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Roger J. McDonald

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The 1995 Oil-Heat Technology Conference and Workshop was attended by 184 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 1995 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 1995 Oil Heat Technology Conference and Workshop, held on March 22-23 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 ninth 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 1995 Oil Technology Conference comprised: (a) three 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 10 formal presentations addressing:

- o Oil Heat Technology Research and Development;
- o Oil Heat Fuel Technology; and
- o PMAA and OMA - Industry Association Activities Update.

2.1 Oil Heat Technology Research and Development

Paper 95-1: Oil Heat Technology R&D

The goal of the BNL Oil Heat R&D is to reduce residential and small commercial building primary energy use for oil-fired heating systems by 0.30 quad (50 million barrels) annually by the year 2005. The objective is to provide technology advances which allow industry to develop products and adopt practices for cleaner combustion and improved efficiency. A major program goal is the development of low-emission burner and combustion indicator/control options which allow optimal performance to be maintained over the heating season. The objective here is to eliminate the combustion emissions and heat-transfer degradation that is inherent with conventional oil heating equipment. Too often, efficiency gains with today's new oil space heating equipment are not being realized over the long term, because degradation results between annual tune-ups due to formation of soot and scale on heat exchangers. A commercialization plan has been developed to achieve this goal within five years through the development of a unique burner design integrated with new flame-quality and excess-air combustion controls.

Paper 95-2: RotriX "Vortex Breakdown" Burner Turbulence-Stabilized Combustion of Heating Oil

For the past two years, the Viessmann MatriX radiant burner has been made in Europe for low emission combustion of gas. Now, with the RotriX burner, Viessmann has succeeded in its efforts to reduce nitrogen oxide emissions in the combustion of oil. After a successful test period, the RotriX burner is now being introduced to the market. The RotriX oil burner consequently takes into account the mechanisms in the creation of environmental emissions in the combustion of heating oil No. 2, and establishes stable combustion under various operating conditions. Thus, a burner was created with the following features: (1) Heating oil is combusted only after complete vaporization and mixing with combustion air and recirculated flue gases. (2) The flame is not stabilized with a turbulater disk, but a strong turbulating current is created by means of the "Vortex Breakdown" phenomenon, which develops a very stable flame under operating conditions. (3) High internal flue gas recirculation rates lowers the flame temperature to the point where thermal NO formation is reduced to the same low level as in the combustion of gas. Results of the new burner technology include: extremely low emissions of NO_x <60 mg/kWh, and CO <5 mg/kWh at a CO_2 concentration of 14%.

Paper 95-3: Canadian R&D on Oil-Fired Integrated Systems

This presentation described research and development presently being conducted on oil-fired space and water heating systems at the Combustion & Carbonization Research Laboratory (CCRL) in Ottawa, Canada. It focused on R&D activities at CCRL in support of the Canadian Oil Heat Association (COHA); in particular, progress was reported on activities to develop suitable oil-fired integrated systems to satisfy the low energy demands of new homes and to define outstanding issues and recommend solutions relating to sidewall venting, particularly in cold climates.

Additional activities discussed related to the development of appropriate seasonal efficiency standards for oil-fired combustion systems, in support of Canadian federal and provincial policy initiatives. The first activity in this standards area is a determination of the most appropriate measure of seasonal efficiency of complex integrated space/water heating systems. Performance of a range of existing and prototype integrated systems will be examined and their overall performances defined, using heat loss, heat balance and combined methods, for a wide range of cyclic operations and demands. The draft standard may be either a (slight or detailed) modification of the existing ASHRAE standard, or may be a new more appropriate test and analysis procedure, for the range of present and future systems suitable for Canadian applications in both new, low energy housing and in existing housing. The second standards activity is the development of an appropriate measure for the seasonal efficiency of sidewall vented oil-fired appliances.

Paper No. 95-4: The Application of Masonry Chimney Venting Tables for Oil-Fired Appliances

This paper presented an overview of the results of work in developing a set of rational guidelines for the venting of modern oil-fired appliances. The activities included the continued development and completion of the Oil-Heat Vent Analysis Program (OHVAP), Version 1.0 and the interpretation of nearly 2,000 runs in preparing recommendations for presentation in table form. These results were presented in the form of venting tables for the installation of chimney vent systems for mid- and high-efficiency oil-fired heating appliances using masonry chimneys.

A brief description of the OHVAP program was given as well as a discussion of what the program does. Recommendations based on the results of OHVAP are presented in the form of five tables spanning oil-fired appliance Steady State Efficiencies (Eff_{ss}) of 80% to 88%. The assumptions used in the calculations and examples of the computed results are presented as well as a discussion of the rationale for masonry chimney system treatment. Working examples are given with suggested diagnostic approaches for application of the table recommendations.

Paper No. 95-5: The BNL Fan-Atomized Burner System Prototype

Brookhaven National Laboratory (BNL) has a continuing interest in the development of advanced oil burners which can provide new capabilities not currently available with pressure atomized, retention head burners. Specifically program goals include: (1) Ability to operate at firing rates as low as 0.25 gph. (2) Ability to operate with very low excess air levels for high steady state efficiency and to minimize formation of sulfuric acid and iron sulfate fouling. (3) Low emissions of smoke, CO, and NO_x even at very low excess air levels. (4) Potential for modulation - either staged firing or continuous modulation. In addition any such advanced burner must have production costs which would be sufficiently attractive to allow commercialization. The primary motivation for all work sponsored by the U.S. DOE is, of course, improved efficiency. With existing boiler and furnace models this can be achieved through down-firing and low excess air operation. Also, with low excess air operation fouling and efficiency degradation due to iron-sulfate scale formation are reduced. Two-stage firing boilers or furnaces can operate for most of the heating season at the low-firing, high efficiency condition and still retain the high firing rate capability for recovery capacity. The DOE AFUE test procedure allows two-stage firing appliances to use an averaged efficiency with the lower input, higher efficiency conditioning receiving the most weight. In tests at BNL the AFUE setting of a furnace was raised from 79 to 84% with a two-stage firing approach. In addition to improving the efficiency of existing boiler and furnace models it is anticipated that the development of advanced burners can lead to new, high efficiency product concepts. This may include low output furnaces and boilers for selected markets and lower input oil-fired water heaters. Current work at BNL centers on the development of a concept which has become termed the Fan Atomized Burner. In this approach oil is atomized with air supplied by the burner's fan. In other air-atomized burner designs, a compressor is used to provide a small flow of air at 5 to 20 psi to the nozzle for atomization. A fan is also included to provide the remainder of the air required. This secondary air is delivered at a much lower pressure, 2 to 3 inches of water. In the Fan Atomized burner there is only one air supply, a fan delivering air at 6 to 12 inches of water pressure. 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. At last year's Oil Heat Conference the burner head was described in detail and system component options were discussed. Over the past year two prototype system concepts have evolved and these prototypes are now being tested both inside and outside of BNL. In this paper the two current prototypes were described and some performance test results were given. Following this, BNL's current direction in development work and future areas of interest were discussed.

Paper No. 95-6: Field Testing the Prototype BNL Fan-Atomized Oil Burner

BNL has developed a new oil burner design referred to as the Fan Atomized Burner System. Industry representatives at the October 1995 Oil Heat Technical Advisory Group (TAG) meeting reviewed the status of the burner's development. The TAG reviewed and agreed with a suggestion from the DOE and BNL program managers, that to gain the industry's attention and interest in the burner it should be field tested to demonstrate its capabilities under real world operating conditions, not just tested in the research laboratory. The same field tests would, of course, point out and key in on areas that require additional work providing focus and direction to future developmental activities as might be required. The new burner is designed to operate in the capacity range of 0.3 to 1.0 gallon per hour inputting 40,000 to 140,000 Btu per hour to the heating appliance it's used with. The BNL Oil Heat Research and Development program has for over fifteen years presented the industry with the conclusion that the heating load of almost any average sized house could be met with a heating system capacity of less than 70,000 Btu per hour 0.5 GPH. BNL elected to put both its technology and long term opinion about low firing rates to the test by proposing a field test of the new burner in a home with over 2,000 square feet of conditioned living space located on Long Island and do it was a firing rate of 0.3 to 0.4 GPH (40,000 - 55,000 Btu per hour input). The test used a compact high efficiency side-wall vented hydronic boiler coupled with a well insulated 40 gallon indirect hot water storage unit. The hot water storage unit included an internal coil type heat exchanger inside the tank and was installed with a separate circulator and priority switching relay control. The primary objective of the field study as reported was to evaluate and demonstrate the reliable operation of the Fan Atomized Burner. The secondary objective was to establish and validate the ability of a low firing rate burner (0.3-0.4 GPH) to fully staisfy the heating and domestic hot water load demands of an average household in a climate zone with over 5,000 heating-degree days. The field activity was also used to evaluate the practicality of side-wall venting with the Fan Atomized Burner with a low stack temperature (350°F) and illustrate the potential for high efficiency with an integrated heating SYSTEM approach based on the Fan Atomized Burner. The Fan Atomized Burner successfully passed the test by satisfying all heating loads even under the coldest days encountered during the 1994-1995 heating season.

2.2 Oil Heat Fuel Technology

Paper No. 95-7: Fuel Sulfur and Boiler Fouling

Fouling of the heat transfer surfaces of boilers and furnaces by "soot" leads to reduced efficiency and increased service requirements. The average level of annual efficiency reduction as a result of fouling is generally accepted as 2% per year. Improving the efficiency of equipment in the field may be the most important oil heat conservation opportunity at present. Improvements can be realized by reducing fouling rates, promoting lower firing rates in existing equipment, and enabling excess air levels to be set lower without raising concerns about increased service requirements. In spite of the importance of efficiency in the field there is very little data available on efficiency degradation rates with modern equipment, actual field operating conditions (excess air and smoke number settings) and service problems which affect efficiency. During 1993-94 field tests were initiated to obtain such data and to obtain information that would compliment existing and current laboratory work. Experimental work conducted on a bench scale level have included tests with various advanced burners, fuel types, and different operating conditions which have been done at the BNL Rapid Fouling Test Facility. This presentation focused on the field study of fouling effects on ten residential heating systems local to BNL. The fouling rate, efficiency degradation, soot composition, and related service problems at each site were summarized. In addition, the technical difficulties involved with conducting such a field study were also discussed as well as how the findings can serve to enhance future work in this area.

Paper No. 95-8: Proper Use of Sludge-Control Additives in Residential Heating Oil Systems

This presentation discussed various aspects of heating oil "sludge": How it forms, typical problems it causes, how sludge-control additives work, what should be expected of them, and what happens in a contaminated system when such additives are used. Test results from laboratory and field experiments demonstrate that performance of commercially available additives varies greatly. The concept of "end-of-the-line" treatment was described and compared with bulk fuel treatment. A procedure was described whereby a retailer can test additives himself, and thus determine just what those additives will or will not do for his business. Finally, the potential economics of an effective treatment program were outlined.

2.3 PMAA and OMA - Industry Association Activities Update

Paper No. 95-9: PMAA's National Certification Program for Oil Heat Technicians

In response to an initiative proposed at an earlier Oil Heat Technology Conference, BNL developed a project to bring the benefits of its research and development to the oil heated homes of America. PMAA, in conjunction with its member associations, in turn has created a voluntary national certification for oil heat technicians based on this initiative. The text which support these programs are the Petroleum Marketers Association of America's (PMAA's) Oil Heat Technician's Manual, and the PMAA's Advanced Oil Heat - A Guide to Improved

Efficiency. Modern oil heat appliances are clean, efficient, quiet, compact, and long lasting. However, a great deal of the furnace and boiler population is old, inefficient, and not clean. It is up to the management structure of the industry to aggressively replace the old with the new. The best way to do that is by encouraging and supporting the service technicians in the industry to do just that. To deliver this message, PMAA is supporting the silver and gold certification for oil heat technicians. This program was outlined during the presentation along with information to encourage the industry to actively participate.

Paper No. 95-10: Oilheat Manufacturers Association Oil Heat Advantages Project

The newly formed Oilheat Manufacturers Association (OMA) was represented by Mr. Robert Hedden and Mr. John Batey who, for the first time, presented the results of OMA's Oilheat Advantages Project. This project involved the creation and dissemination of a unified, well documented, compellingly packaged Oilheat story. The project involved three steps: The first step was to pull together all the existing data on the advantages of oilheat into a single, well documented engineering report. The second step was to rewrite and package the technical document into a consumer piece and a scripted presentation supported with overheads, and to disseminate the information throughout the industry. And the third step will be to fund new research to update existing information. This step will begin next year. The information will be packaged in the following formats: (1) The **Engineering Document**. This will include all the technical information including the creditable third party sources for all the findings on the many advantages of oilheat. (2) The **Consumer Booklet**. This summarizes all the findings in the Engineering Document in simple language with easy to understand illustrations and graphs. (3) A series of single topic **Statement Stuffers** on each of the advantages. (4) **An Overhead Transparency-Supported Presentation** that can be used by industry representatives for presentations to the general public, schools, civic groups, and service clubs. (5) **Periodic Publication** of updates to the Oilheat Advantages Study.

3.0 Workshop Sessions

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

A. Fuels, Fuel Quality, and Storage - Industry Discussion

B. New Oil Heat Equipment Developments

C. Application of the Oil Heat Venting Tables - NFPA 31 Standard

D. PMAA National Oil Heat Service Technician Certification Program
- Silver and Gold - Industry Role and Future Support

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

GROUP A. Fuels, Fuel Quality, and Storage - Industry Discussion

This workshop session consisted of approximately 30 members from a broad spectrum of the petroleum industry - oil marketing, refining, heating equipment suppliers, fuel additive companies, and trade organizations.

During the initial discussions the chairman raised current issues pertaining to fuel sulfur content, pour and cloud point concerns, and lubricity concerns. Feedback from the participants was sought on these topics in terms of comments or experience with the new low sulfur diesel fuels (0.05%) which had been mandated by the Federal Clean Air Act for use in vehicles since October 1993. This low sulfur content No. 2 diesel has also been available and sold as No. 2 heating fuel in some markets. During that first heating season of 1993/94, **one of the coldest winters** in recent history, oil distributors and other end-users voiced concerns over the difficulties with handling these fuels in terms of gelling and clouding. Significant kerosene blending was needed, as reported, in order for proper handling of the fuels. To date, with the end of the 1994/95 heating season, it is still too early yet to have much information or experience with the use of low sulfur fuels in home heating systems. No additional concerns were brought up by workshop members regarding this issue. BNL tests have clearly shown that the fouling rate of boiler and furnace surfaces can be reduced with lower sulfur fuels. This can enhance the long term stability of high efficiency performance and reduce the maintenance needs for the heating unit. Significantly, because of the wide availability of low sulfur fuels, its cost difference compared with the typical heating fuels has become quite small.

Interest remains on the topic of fuel additives. Specifically, oil companies want to know if additives will help to reduce the overall service needed for their customer's heating equipment or storage tanks. Other common questions include - Which ones work? How do you select an additive? How do you test whether an additive works before investing in a treatment program? Is there an additive that will prevent sludge? Testing of sludge, a major problem in some tanks, can become very expensive; and in some cases little information on the exact causes of sludge buildup can be obtained. Representatives from service companies indicated that at some point they all have used fuel additives and have had mixed results. One major oil distributor has been carefully conducting a field study for the past few years to evaluate different types of additives. No dramatic changes have been observed thus far with a relatively large sample of homes.

One way of addressing some of these questions is to actively involve the industry members to participate in field studies and surveys. Results from laboratory and bench tests can be limited in some applications because the numerous differences in actual field conditions often cannot be duplicated. Clearly, the industry has the capability to effectively evaluate products, methods and new technologies by focusing and combining their efforts in terms of data gathering and reporting on large scale basis. It has been suggested that BNL can play a central role in providing the expertise needed to organize field tests, evaluating methods and procedures, assist with quantifying and analyzing information collected, and serve as liaison among the participants.

GROUP B. New Oil Heat Equipment Developments

During this workshop session, there was lively discussion on developing trends in oil heat technology with an emphasis on issues which may be appropriate for BNL to address. The most significant points raised during the discussions are as follows:

The industry may realize great benefit from the development of variable firing rate/variable output boilers and furnaces. The gas industry is moving forward rapidly in this area. Potential advantages for oil include: higher efficiency, less maintenance, and reduced noise. There are, however, some issues which should be addressed in this area. What are the real efficiency gains associated with variable firing rates, including effects of system losses? With reset controls and integrated appliances, can the same efficiency levels be achieved with fixed-firing rates?

With variable firing rate, there is always a concern about heat exchanger corrosion. If the heat exchanger is sized for good efficiency at high firing rates, low gas temperatures, condensation may occur at low rates. One participant suggested the use of direct contact economizers to provide good efficiency over the entire firing-rate range, while avoiding the corrosion concern.

The industry should continue to pay attention to oxides of nitrogen (NO_x) emissions. It was suggested that BNL do some work on achieving modest NO_x reductions with small changes in conventional burner designs as well as looking at new technology options.

Proposed changes in DOE efficiency regulations are expected to make burner electric power consumption more important in the future. As firing rates decrease, the need to reduce power draw increases.

System noise remains a concern with oil-fired appliances and it was suggested that BNL include noise measurements in their work. Noise concerns can impede the use of some higher efficiency equipment. An example of this is the replacement of an electric hot water heater with an oil-fired unit.

Interest is increasing in side-wall venting. Important issues remain in this area including: post-purge requirements, standards, sealed combustion, and inducer electric power requirements.

It was suggested during the discussions that the oil industry should look for opportunities to integrate with heat pump heating and cooling equipment.

GROUP C. Application of the Oil Heat Venting Tables - NFPA 31 Standard

There were approximately seventeen oil heat industry representatives in attendance at the workshop session. Included in the group were service technicians, marketers, and several equipment manufacturers. The workshop session was structured to allow for industry questions, comments, and follow up discussions regarding the technical presentation on **The Application of Masonry Chimney Venting Tables for Oil-Fired Appliances, Paper 95-4,** which had been presented by the session's chairman the day before. The level of interest was quite intense and many comments and concerns regarding the proposed appendix to the NFPA 31 Standard were discussed.

The comments and concerns voiced at the workshop session will be addressed prior to the final submission of the text and venting tables for the proposed appendix. The tables are intended to provide guidance in making the proper choice when the service person is faced with a chimney that requires relining. They will also be useful in the correct design of venting systems to be installed in new home construction. They are not intended to be the sole criteria for relining an existing chimney that has been operating satisfactorily for many years. The tables will be reformatted to include the current relining information only. Under the existing NFPA 31 Standard, reference is made to NFPA 211 for further guidance on chimneys. This guidance includes a requirement for the annual inspection of chimneys. In the proposed appendix this requirement will be reinforced. In addition, a recommendation will be included to inspect the chimney 3 to 6 months immediately after any equipment modifications, retrofits, or replacements to, or of, the attached heating system.

GROUP D. PMAA National Oil Heat Service Technician Certification Program - Silver and Gold - Industry Role and Future Support

Twenty-six industry participants attended the workshop which began with an overview of the status of the certification program, how it is intended to work, the training and examination requirements for certification, and how it was being organized to serve the needs of the industry. The certification program was the subject of workshop chairman Donald Allen's technical presentation on **PMAA's National Certification Program for Oil Heat Technicians** given earlier in the day. There was a great deal of enthusiasm and interest in the program and several important issues were brought out regarding testing, record keeping, and continuing education.

The workshop discussions provided important information and input for consideration by the PMAA Education Committee which is in the process of developing the protocol for implementing the national certification program for oil heat service technicians. It opened up dialogues with various state associations regarding existing certification and state licensing requirements which must be considered along with the question of grand-fathering individual technicians. Those people who have already proven themselves by obtaining the training, taken exams, obtained several years of field experience, and currently hold a valid state license or certificate will not likely be required to re-test and certify at the silver level. It initiated a review of concerns regarding continuing education and how this might be implemented either nationally or at a state level. It also provided concerns that must be considered regarding local proctoring of exams in those states without strong oil heat association representation. These items will be addressed by the PMAA committee with the help of and other industry representatives involved in the evolution of the national program and will be resolved over the next few months with meetings at the NEFI exposition in June and at the PMAA National Oil Heat Conference in August.

4.0 DOE/BNL Perspective

The 1995 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.

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 again 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 1995 Oil Heat Technology Conference and Workshop was held on March 22-23 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 eighty-four (184) people were registered and participated at the conference.

The 1995 Oil Heat Technology Conference, which has been the ninth 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:

- 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;

- 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 Martin Blume, Deputy Director of BNL, who welcomed the assembly on behalf of Brookhaven National Laboratory. Dr. Blume emphasized BNL's commitment of advancing oil heat technology and to effect technology transfer to the private sector. Dr. Blume concluded his address by congratulating the organizers and welcomed the participants of the Conference. John Huber, Government Affairs Counsel, Petroleum Marketers Association of America (PMAA), then welcomed the participants on behalf of PMAA and then introduced the Master of Ceremonies, Donald B. Craft, current Chairman of the PMAA Heating Fuels Committee. Mr. Craft then introduced the Keynote Speaker Mr. Jack Sullivan, Incoming Executive V.P., C.E.O., of the New England Fuel Institute. The text of John Huber's remarks regarding the important interactions between the Oil Heat Industry and BNL follows.

John Huber's Introductory Remarks
Government Affairs Counsel
Petroleum Marketers Association of America

We have developed a very strong partnership with Brookhaven National Laboratory (BNL) in both co-sponsoring this conference and in helping to implement many of the programs that have been developed by BNL over the years. Probably this year we are most proud of the work that Don Allen and a Sub-Committee of our Heating Fuels Committee has done in conjunction with BNL. That is the Oil Heat Efficiency Manual and Certification Program. For many years, BNL has been working to make sure that the ideas and the strategies that they have developed to make oil heat a clear winner for the future are implemented. They wrote a manual that brings much of the research out into the field in a readily usable fashion. PMAA has published that manual and we have those available for sale. There is a sample of the manual at the Registration Desk if anybody would like to take the time to peruse it. It is very attractive and a very worthwhile book. Don Allen, one of our creative heating oil dealers, like so many of you are, decided that just having a book out there for everybody to read or put on the bookshelf was not enough. We have to make sure that the ideas in that book are really used and really taken advantage of. PMAA should take the next step to force-feed the industry and to give something to the industry to take and utilize. So, he came to us and the Heating Fuels Committee of PMAA and said that we should develop some type of a certification program. There is nothing that makes people feel better about themselves than to be recognized for what they know. A certification program would, therefore, give people recognition and the encouragement to take the knowledge that BNL has and put it into their own minds and then put it into the field so that every oil heat customer would be able to take advantage of that. Don is going to give a presentation on that, so I am not going to completely steal his thunder. PMAA is very proud of the work that he has done and what we have done with this program.

Fuel oil, as you know, has a strong role in the northeast, has a strong role in the northwest and has a role in almost every state in the country. Heating oil is everywhere; it is an important bulk fuel, and it is a fuel that is going to be here for a long, long time. It is a strong industry and is composed of men who are entrepreneurs, woman who are entrepreneurs, people who survive, people who did not just learn that customer service is vital. They have been preaching that for so many years that it is part of the Gospel in the industry. Well, many other industries are just discovering that customer service pays and is important. This industry has always sung that song and will continue to sing that song and, thus, we will always have oil customers. As long as you have customers, there will be a future for this industry. We think that it is a bright future for the oil heat industry. We have made significant progress in reducing consumption for the American consumer of oil through the research here, by service technicians and oil companies preaching conservation and pushing it along so that we are a competitive fuel. We have also shown that emissions from oil heat equipment can be reduced significantly and, therefore, we have not been bothered with much regulation at the federal level. Since we are not a concern to the environment, there is no reason to bother us and to regulate how this industry does business.

BNL, itself, plays a vital role in this industry. For PMAA, BNL has been a partner in almost everything we do, both helping the industry advance and helping us in Washington. The knowledge that is going to be presented here today and that was presented at the last eight conferences is often the groundwork that we need to present to the agencies, to the Congress in Washington, to describe our industry, to show where we are at, to show that we are not a problem, to show that we are a *positive* for America. In nearly every technical paper that BNL has published is contained information that in someway can be used in that effort, so it is vital that this program keep going. BNL has a bright future, too, as far as oil heat is concerned. There is much research that remains to be done, we are not at 100% efficiency in any of the uses of oil heat, but we are going to get there. BNL is going to keep leading the way, making the equipment more and more efficient, making it more and more accessible to the community and making it more and more a worthwhile fuel.

Now, I think many of us are concerned, myself in particular, as to where BNL and its funding is going this year. Everybody knows that the Republicans took Congress with a vow to eliminate agencies, cut federal spending, to get control of the federal deficit, and they have made some preliminary moves in that direction; some very aggressive moves in cutting programs. A program that oil heat dealers are probably most familiar with is LIHEAP, the Low Income Home Energy Assistance Program, $1.4 billion a year. That program is on a death watch I believe at this point. The House of Representatives has zeroed it out. We believe that the Senate will restore it, but not to the level of $1.4 billion. We are hoping that it is only cut in half at the end of the year for 1996, so you can see some of the aggression and this is in the early deficit cutting round. They have gone through a couple of preliminary steps to try to raise money to pay for the earthquake in California, pay for the flooding, pay for some natural disasters, pay for the Haiti invasion, and this is where they are trying to spend and save money on these different programs, and that is where LIHEAP got tagged.

Now, BNL and the funding for this program that PMAA works so hard to get every year is a little uncertain at this time. The process in Washington is that there is a budget bill that has to be presented before anything really happens in the budget game. That is due April 15th, and is supposed to be passed by both the House and the Senate. At that time, we will essentially know the federal pie and basically how big the pieces of pie are for the different agencies and if there will be money in each of those sections for the programs that we support. We don't really know what that is as yet, however, we have gotten some initial signals. The Representative from Ohio, who is the Budget Chairman, when challenged on what type of spending cuts could be achieved and whether a balanced budget is achievable in the future and whether America could get on the glide path to being on a balanced budget by 2002, presented a document last week describing some of the cuts that he would make on behalf of the Republicans that could be done fairly effortlessly and not completely eviscerate government. Let me just read to you what he said about this program and this general program area. Now what he is speaking of is approximately a $700-800 million program and, as most of you probably know, this program here [Oil Heat R&D] gets funded at about one million dollars a year out of Washington. So, we are a small part of that overall budget pie. But he said, "Energy conservation in the U.S. has been, of course, a clear success. In the 1980's, for example, the economy grew one third while energy use remained flat due to market-driven energy conservation. Government spending on energy conservation, on the other hand, has been less successful. Business has incentives to market and customers to buy conservation technology that work well. DOE is left to fund less reliable and less promising technologies. The proposal continues energy conservation funding at $560 million per year, a 27 percent decrease." So, what he is basically saying is that the overall pie of $800 million could be trimmed down to $560 million. Now each of the pie pieces within that big piece of pie would be similarly reduced. In some ways we are probably fortunate that this is a small program and is not attracting major attention. An alternative program, the Oil Exploration and Production program that gets funded at $600 million, he recommended be completely eliminated. So, you see that we are in a troubled time. We have spoken to Congressman Mc Dade about this program early in the session to get a feel about what he thought we would be facing this year. Congressman Mc Dade has been the main benefactor of the program. He has been the person who is most responsible for it, has taken significant effort to ensure that Congress provides the funding for this program every year and he is very proud of that. At every Pennsylvania Delegation luncheon that Congressman Mc Dade has gone to, he always mentions oil heat research and development as something that he has been doing for the marketing and the oil heat industry. So, it is one that he has been paying careful attention to. Now, Mr. Mc Dade is not Chairman of the Appropriations Committee. He would have been, except for some legal problems that he has, however, he is a very significant player in this. Now, in speaking to him, he indicated that this year would be the most problematic year for oil heat that he has had in many years. That we would have to put more effort into it than we have ever had to do before and that it has to be watched very carefully. Depending upon how the pie slices go, it could be in significant trouble. So, that is an important message that we have heard from our main benefactor. This year we have to work harder and more aggressively than we have ever done before to ensure that this program is funded.

Now something else that everybody is probably aware of is that this Congress was a complete shift. It went from Democrat to Republican, has one hundred new members. The last Congress had about one hundred new members, so we have an almost completely new group of men and women in the Congress who are in charge of this funding. Now, each one of them has pledged that they would be closer to their districts, they will listen to the businesses and the people in their home towns. They want to get away from Washington. They want to hear what the people in the field are talking about. Grassroots - the efforts of people in their communities, people in the Congressman's own district writing them, become more and more important. The information age is here and they know they can take advantage in processing information they get from their home state and their home district. So, it becomes very, very important that the people here in this room, people in the oil heat industry, people in the petroleum marketing industry work very aggressively to ensure that we protect this million dollars to ensure that its funding is continued for the next year and that it becomes a very solid item in the budget, and that they recognize how important it is in this industry and how important it will be in the future. That energy conservation in our industry is benefitting from the government and that Congress does not need to eliminate a program that is benefitting each of us.

I hope that everybody here can take a little bit of time and help PMAA move the ball forward. Work with your state associations, work with your company, try to show support for this program. I believe that everybody here recognizes that the BNL program has benefitted them and their company and that they should also try to put something back into it to try to make sure it stays here in the future. With that I will conclude my remarks. I look forward to the next couple of days to hear about some of the advances that will be occurring in this industry and look forward to talking to most of you in the room individually over this period. Thank you.

Technical Presentations

Ten 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, Canada and Europe, including these topics:

- Oil Heat Technology R&D
- RotriX "Vortex Breakdown" Burner Turbulence-Stabilized Combustion of Heating Oil
- Canadian R&D on Oil-Fired Integrated Systems
- The Application of Masonry Chimney Venting Tables for Oil-Fired Appliances
- The BNL Fan-Atomized Burner System Prototype
- Field Testing the Prototype BNL Fan-Atomized Oil Burner
- Fuel Sulfur and Boiler Fouling
- Proper Use of Sludge-Control Additives in Residential Heating Oil Systems
- PMAA's National Certification Program for Oil Heat Technicians
- Oilheat Manufacturers Association Oil Heat Advantages Project

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. Fuels, Fuel Quality, and Storage - Industry Discussion

B. New Oil Heat Equipment Developments

C. Application of the Oil Heat Venting Tables - NFPA 31 Standard

D. PMAA National Oil Heat Service Technician Certification Program - Silver and Gold - Industry Role and Future Support

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 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. In addition, Viessmann Manufacturing, Inc. displayed an operating exhibit of its new "RotriX" oil burner firing into a vertical quartz tube combustion chamber (see Figure 2). This burner was the subject of a technical paper presented later during the conference (Paper No. 95-2).

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.

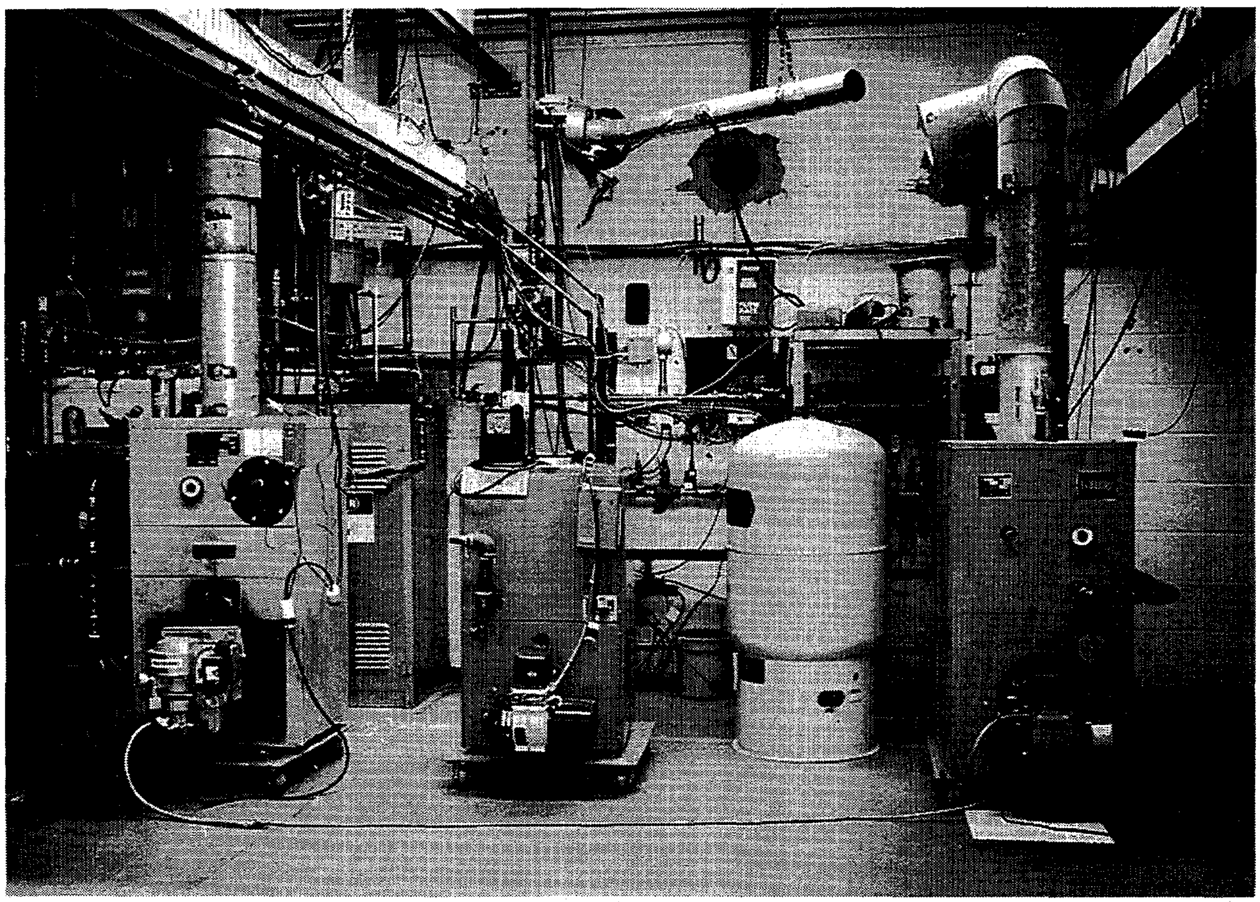

Figure 1. Heating Equipment Being Tested at the CETL.

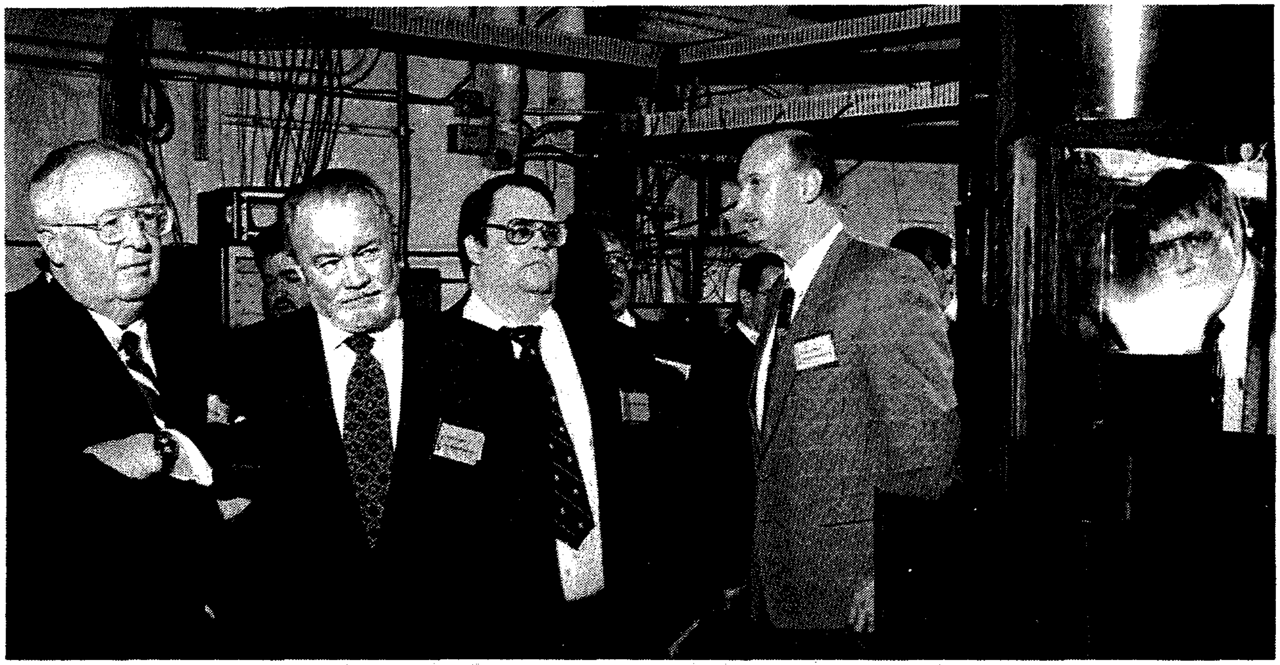

Figure 2. Operating Exhibit of Viessmann Manufacturing, Inc. "RotriX" Oil Burner Firing Into a Vertical Quartz Tube Combustion Chamber at the 1995 Oil Heat Technology Conference & Workshop.

II. TECHNICAL PRESENTATIONS

Paper No. 95-1

OIL HEAT TECHNOLOGY RESEARCH AND DEVELOPMENT

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OIL HEAT TECHNOLOGY RESEARCH AND DEVELOPMENT

Program Definition

The purpose of this United States Department of Energy (DOE)/Brookhaven National Laboratory (BNL) program is to develop a technology base for advancing the state-of-the-art related to oil-fired combustion equipment. The major thrust is through technology based research that will seek new knowledge leading to improved designs and equipment optimization. The Combustion Equipment Space Conditioning Technology Program currently deals exclusively with residential and small commercial building oil heat technology.

Program Goal and Objectives

This program's goal is to reduce residential and small commercial building primary energy use for oil-fired heating systems by 0.30 quad (50 million barrels) annually by the year 2005. The objective is to provide technology advances which allow industry to develop products and adopt practices for cleaner combustion and improved efficiency. A major program goal is the development of low-emission burner and combustion indicator/control options which allow optimal performance to be maintained over the heating season. The objective here is to eliminate the combustion emissions and heat-transfer degradation that is inherent with conventional oil heating equipment. Too often, efficiency gains with today's new oil space heating equipment are not being realized over the long term, because degradation results between annual tune-ups due to formation of soot and scale on heat exchangers. A commercialization plan has been developed to achieve this goal within five years through the development of a unique burner design integrated with new flame- quality and excess-air combustion controls. This five-year commercialization plan is detailed in Figure 1.

Key Products

The current research will be completed when prototypes under development are commercialized and the results are transferred to the oil heat industry. The three hardware products for commercialization are:

- Flame Quality Indicator
- Low Excess Air Burner
- Low Excess Air Control

The other major **key product** is **Technology Transfer** including conferences, training materials, venting guidelines for high efficiency systems, and industry outreach activities. The time table for developing these products is as indicated in Figure 1.

Strategy

The strategy plan for our work on oil-heat research and development is summarized here:

In recent years BNL/DOE's efforts have helped lead the industry in achieving improved furnace and boiler average efficiency rating gains from the mid 70% range in the 1970's to today's average mid 80% efficiency range. This at first appears to bring new equipment progress to a point of diminishing returns; however, the introduction of higher-efficiency furnaces and boilers brings a new set of equipment-related issues to be addressed. The current strategy is to do research with industry involvement in order to resolve the remaining technical barriers to introduction and expanded use of high-performance oil furnaces and boilers, and to maintain that high-performance level over time. Three issues now remain to be resolved.

1. Venting Systems for High-Efficiency Furnaces and Boilers

The new design of higher efficiency furnaces and boilers has introduced two new problems:

- Poorly designed vent systems serving high-efficiency furnaces (in the mid 80% range) are more susceptible to deterioration caused by condensation of combustion gases. The higher-temperature flue gases in older and lower-efficiency furnaces were less likely to drop below the condensation point before exhausting outdoors.

- Side wall venting of new higher-efficiency furnaces and boilers eliminates the need for a chimney. In addition to possible condensation, potential side wall venting problems include discoloration or damage to paint and brick surfaces exposed to combustion products. Current research is addressing these potential problems with the development of a venting model to be used in recommending guidelines for installation. Chimney system guidelines will also included in this effort.

2. High-Efficiency Boilers and Condensing Furnaces

The introduction of higher-efficiency condensing oil-fueled furnaces has proved more difficult than that of condensing gas-fueled furnaces. This is because oil combustion products contain sulfuric acid, in addition to the type of acid condensates found in gas furnaces, and oil furnaces can be susceptible to the buildup of soot and scale deposits, which can easily plug the narrow passages needed in condensing heat exchangers. These are also important issues for the higher-efficiency non-condensing boilers with more restrictive heat exchangers.

3. Degradation in Performance

Oil-fired furnaces do not remain at the same efficiency level that they achieve immediately after initial installation or after annual cleaning and tune up. Changes in combustion (air/fuel ratio) and the subsequent buildup of soot and/or scale on the heat exchanger reduce heat transfer, and efficiency drops gradually over the heating season. Inconsistent servicing and/or neglect in regular service results in reduced operating efficiency. The high-efficiency equipment (including condensing) and efficiency degradation issues mentioned earlier stem from a common underlying problem: soot and scale deposits. These are being addressed in the BNL/DOE program as follows:

Soot Deposition

Soot is the result of incomplete burning. Soot formation in oil burners occurs when external conditions change over the heating season. These changes typically include a gradual buildup of dirt, lint, or animal hair in the air inlet passages to the burner, the buildup of dirt in the oil nozzle, nozzle coking / plugging from after-drip, or sometimes variations in the quality of the fuel oil itself. This unbalances the fuel-oil / combustion-air ratio, which adversely affects the flame quality. This problem is addressed in current research in two areas. First, a flame-quality monitor, which detects and warns of any change in the flame quality before the soot can develop, is being test marketed. This is based on a DOE Patent licensed on a non-exclusive basis to the manufacturer involved. Second, guidelines for maintaining proper fuel-oil quality have been published based on BNL research in the area of fuels, fuel quality, and fuel storage. These guidelines are currently being evaluated by interested fuel oil marketers who are applying the recommendations in the field.

Scale Deposits

Scale deposits begin to form on the heat exchanger almost immediately after the annual heat-exchanger cleaning. Current research has uncovered that the precursor to scale is the formation of sulfuric acid in the combustion products. However, if the burner is operated with very little excess air, then sulfuric acid will not form in quantities that are significant to the fouling process. Laboratory testing has also shown that scale deposits can be reduced significantly when firing with low-sulfur fuels or with conventional fuel oil when operating with very low excess air. This issue is being addressed in two areas:

- BNL is developing a new burner design that mixes air with the oil before burning and operates with very low excess air. As an added benefit the new **Fan Atomized** burner is lower in nitrogen oxide emissions than any oil burner currently on the market. Operating with low excess air also means a higher combustion efficiency. This burner has strong commercialization potential because it operates on low-pressure air (6-10 inches water column) supplied by the combustion air blower instead of requiring an expensive air compressor as used with other air-atomized oil burner designs.

- The development of a new control that sets and holds excess air at a low level and signals any change in the setting is also underway. This control will be the precursor to a burner that self adjusts. Installers currently are very conservative in burner set-up and usually adjust on the high side of the optimum excess-air setting in order to avoid call-backs. Many installers don't use the test instruments needed to establish the smoke and excess air level adjustments properly. Instead they set the burner by the visual appearance of the flame, which invariably results in a non-optimum setting or worse.

Research & Development Plan - Current Status

The current DOE/BNL Oil Heat Research and Development effort is expected to require five years to complete the last two "key products". The Flame Quality Indicator (FQI) is currently being test marketed by two DOE licensed manufacturers and should be ready for the full scale marketing soon. A detailed plan for the commercial development of the Fan Atomized Oil Burner will be completed in 1995. The advanced control system project has not yet progressed to the working prototype stage. Basic flame spectral research has been conducted towards the development of a multi-color detector based combustion control / diagnostic system.

Technology Transfer

Technology transfer to the industry is progressing in three areas:

(1) Development of **Guidelines for Fuel Quality and Fuel Storage.**
These guidelines are now available and include fuel sampling techniques, ways to minimize contamination in handling and storage, ways to safely treat fuel with additives, and a description of the parameters that limit acceptable performance in current heating equipment designs.

(2) **Development of Venting Guidelines** that will eventually be incorporated into an installation code (NFPA 31) for oil heating equipment and in Sections of the ASHRAE Handbook series. This represents a culmination of the prior literature searches and current research. This includes the development of a venting model that is being used to develop vent sizing tables included in the guidelines. The guidelines will also address high-efficiency equipment and side wall venting. This work will be completed in 1995.

(3) **Advanced Oil Heat - A Guide to Improved Efficiency** BNL has developed an efficiency training manual for training service technicians. This guide provides industry representatives with knowledge on how to select, size, properly install, and maintain high efficiency oil heating equipment. In the long term homeowners will benefit by getting real heating comfort and reliability, provided at the lowest price, with the highest efficiency, and the least impact on the environment that is possible. The oil heat industry will benefit from a satisfied and loyal customer base long onto the future. The text was based on over fifteen years of BNL research and development in the field of oil heat technology. To target it for the intended users it was developed with the assistance of a voluntary industry review panel which provided comments and

suggestions as the guide was developed to maintain quality consistent with current industry practices. The end result is a text containing ten chapters and over 140 graphics supporting and highlighting key points.

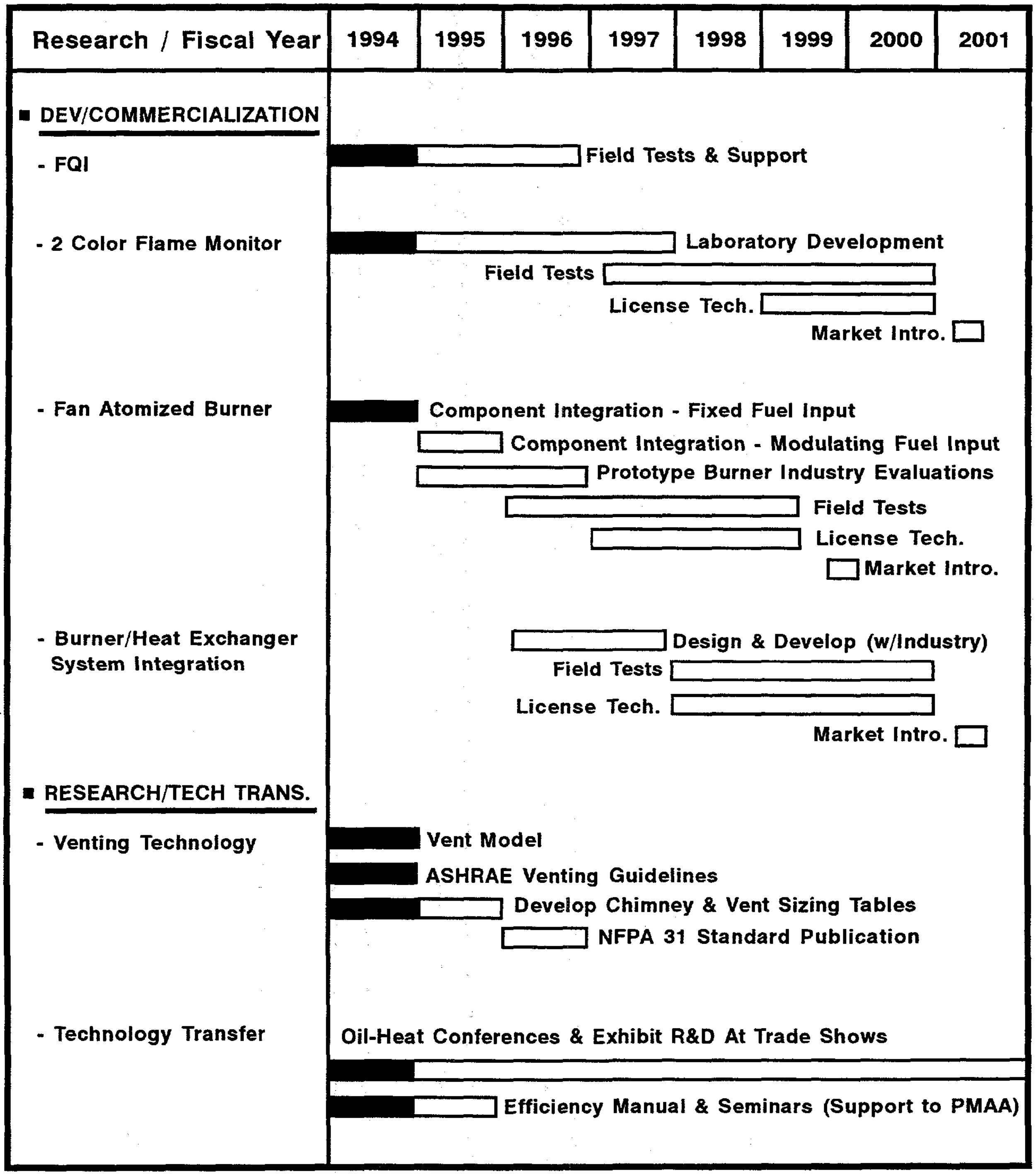
The manual is intended to support industry training programs and the guide has been tested in three pilot training seminars attended by over 80 oil heat industry participants. The Petroleum Marketers Association of America (PMAA) agreed to publish the manual, actively promote its use within the industry, and provide for future revisions when and as needed. PMAA has organized industry support for the project, committed its resources for an initial printing of two thousand copies (completed in January 1995), and established an education committee to develop a voluntary national certification program. This certification will provide formal recognition for those who have benefitted from this advanced professional training. The New England Fuel Institute (NEFI) working with the PMAA Heating Fuels Education Sub-committee has developed a training curriculum and course based on the manual with plans to train 500 students in the first year (1996). Other organizations, for example the National Oil Heat Service Managers Association, are working with PMAA to provide certified training programs based on the new manual.

Industry Evaluation and Future Planning

The oil heat combustion research program and plans are discussed by key members of the oil heat industry at semi-annual meetings of the BNL Oil Heat R&D -- Technical Advisory Group (TAG). The TAG group covers the subjects of advanced combustion systems development, venting technology, and related industry fuel quality issues. Annual oil heat technology conferences allow the BNL research staff and researchers from other countries to present the latest findings of their research to the oil heat industry. Workshops held at these conferences also allow for feedback from the conference participants and helps BNL and DOE refine future research plans accordingly.

Figure 1

BNL OIL-HEAT R&D STRATEGY PLAN



Paper No. 95-2

ROTRIX "VORTEX BREAKDOWN" BURNER TURBULENCE-STABILIZED COMBUSTION OF HEATING OIL

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RotriX oil burner sets standards in low emission combustion

Prof. P. Hofbauer
Dipl.-Ing. Walter Bornscheuer

For the past two years, the Viessmann MatriX radiant burner has been setting the standard for low emission combustion of gas [1]. Now, with the RotriX burner, Viessmann has succeeded to also drastically reduce nitrogen oxide emissions in the combustion of oil. After a successful test period, the RotriX burner is now being introduced to the market.

The RotriX oil burner consequently takes into account the mechanisms in the creation of harmful emissions in the combustion of heating oil No. 2, and guarantees stable combustion under any operating conditions. Thus, a burner was created with the following features:

- Heating oil is combusted only after complete vaporization and mixing with combustion air and recirculated flue gases.

- The flame is not stabilized with a turbulator disk, but a strong turbulating current is created by means of the "Vortex Breakdown" phenomenon, which develops a very stable flame under any operating conditions.

- High internal flue gas recirculation rates lower the flame temperature to the point where thermal NO formation is reduced to the same low level as in the combustion of gas.

Result of the new burner technology: extremely low emissions of NOx < 60 mg/kWh, and CO < 5 mg/kWh at a CO_2 concentration of 14 %.

Theoretical basis

Why flue gas recirculation in the combustion of oil?

In the combustion of gas, the lowering of the temperature in the reaction zone through disengagement of radiant heat represents an ideal measure for the prevention of NOx. This is not possible in the combustion of oil. The reasons for the different methods to achieve low-NOx combustion of heating oil and gas are to be found in the varying material data of the two fuels (Table 1).

Due in particular to the high content of fuel-bound nitrogen, the NOx emissions in the combustion of heating oil with heat disengagement through radiation cannot be as greatly reduced as in the combustion of natural gas. Picture 1 shows the results of a kinetic reaction model calculation of NOx formation in the combustion of oil and gas [2]. Whereas in the combustion of natural gas, under certain marginal conditions, NOx values of < 10 ppm can be achieved through a 15 % heat disengagement, the NOx content in the flue gas, at the same heat disengagement, will still be higher than 40 ppm in the combustion of heating oil No. 2, and this does not even take into account the formation of NO caused by the fuel-bound nitrogen.

The reason for these differences lies in the higher flame temperature of oil, and in the varying reaction kinetics due to the different C:H ratio in heating oil. An increase in heat transfer from the flame is almost impossible in the combustion of oil, since partially, quickly the critical limit of CO creation of 900°C of the gas temperature is undercut very quickly, respectively the temperature of the radiant surface for the necessary radiation is not achievable due to restriction of materials and the chemical balance. Furthermore, a constructive realization of a radiating oil burner could only be achieved by incurring excessive costs, since oil has a distinctly lower ignition temperature than natural gas (Table 1), which moreover lies within the boiling range of the heating oil.

Reduction of the oxygen content in the reaction zone remains as the essential primary measure. Therefore, the principle of flue gas recirculation for the purpose of NOx reduction is applied in the combustion of heating oil. Through an appropriately high flue gas recirculation rate of approx. 50 % (which equals a flue gas mass content of 0,5 in the combustion air), thermal formation of NO can be substantially reduced (Picture 2). The effect of flue gas recirculation is based on two principles:

1. Lowering of the oxygen partial pressure within the flame, thus causing a reduction of the flame temperature.

2. Direct cooling of the reaction zone through the flue gas portion not participating in the reaction (inert flue gas portion).

Principles of flame stabilization

The principles of flame stabilization can be divided into three different categories:

Burner with turbulator disk (yellow flame burner)

The majority of burners utilized in heating technology stabilizes and holds the flame by means of a turbulator disk. The combustion air is directed to a usually slotted disk which also contains the oil nozzle in its surface. This disk causes an increase in the flow velocity, combined with the respective decrease in pressure. Immediately behind the turbulator disk, the velocity decreases again sharply. In this area, the base of the flame is stabilized, aided by a slightly turbulating current which is being created by the slots in the turbulator disk. This principle also allows (primarily at outputs of < 100 kW) recirculation of flue gases for the reduction of NOx to a certain degree. At high recirculation rates, the ignition rate velocity of the mixture drops however, and the flames become unstable and lift off. Therefore, this burner principle has restrictive limits when it comes to the reduction of NOx.

Burner with flame tube (blue flame burner)

In this burner design, a strong axial velocity of the combustion air is created. The fuel is introduced into this combustion air flow by means of a pressure atomizer nozzle, and is vaporized downstream by the recirculating flue gas. The flame stabilizes itself in the flame tube at the point where the ignition velocity and the flow rate attain equilibrium. This combustion process also imposes tight limits in respect to reduction of nitrogen oxide, since the wide range of ignition velocities, increased by varying temperatures, would not be controllable at high flue gas recirculation rates.

Burner with spin-turbulence-stabilized flame

Particularly in large capacity burners and burners for industrial applications, spin-turbulence-stabilized flames have been known for a long time (for instance gas turbines). A tangential introduction of combustion air produces a strong spin turbulence, which allows a precise flame shaping.

The principle of flame stabilization is comparable to that of the burner utilizing a turbulator disk.

If, however, an over-critical spin turbulence is created and directed to a sudden cross-sectional enlargement, the flow profile is changed to an under-critical state [3,4]. An axial flow with a distinct recirculation zone and a vigorous mass transfer is created (Picture 3). This type of velocity, which is to be compared in nature to a tornado, is also called "Vortex Breakdown Phenomenon" and represents an extremely stable state. The differences in velocities created through this effect are so great at the location of the cross-sectional enlargement that flames in a wide range of excess air ratios can be stabilized even at high flue gas recirculation rates.

Construction and function of the RotriX burner

In the RotriX oil burner, Viessmann has adopted the burner principle with turbulence stabilization (which is already being successfully applied by ABB in gas turbine construction [5]), and has developed it further in respect to the application in heating technology.

Internal flue gas recirculation in sufficiently high quantities and a homogenous pre-mixing of fuel and combustion air, with simultaneous vaporization of the fuel, make a combustion with extremely low nitrogen oxide and stable flame possible. The core part of the burner consists of two halves of a cone divided lengthwise, positioned axis-symmetrically transposed to one another. The combustion air, which is first being mixed with flue gas from the combustion chamber through injectors, is introduced through the slots between the cone halves. The supply of fuel takes place by means of an oil nozzle at the tip of the cone (Picture 4). The tangential feed of combustion air / flue gas creates the strong turbulent flow described in Section 1, which at the burner end cone reverses itself into an axial flow with a distinct recirculation zone and there stabilizes the flame [6,7]. The burner consists of the following individual components:

Vaporizer head

Low emissions require a good mix preparation. In addition to the required good vaporization, the angle of the spray plays a central role in the RotriX burner due to the special shape of the burner head. Set at approx. 30°, it assures a homogenous spray preparation without wetting the walls of the cone or directing an actual stream against the walls.

The oil nozzle is double-circumcirculated by combustion air (Picture 5). This enveloping by air has two functions:

1. Cooling of the nozzle, thus ensuring good combustion, even with varying heating oil qualities.

2. Preparation of the fuel spray through partial pre-mixing with combustion air and keeping the spray angle constant.

Combustion air supply and flue gas injectors

The pockets located at the sides of the double cone (Picture 4) form the air supply. The combustion air exits the two air pockets through a large number of orifices and takes on flue gas on the way into the double cone. The entrance channels (mixing zone) in the double cones are made in the form of diffusers. They make possible - in combination with the drilled air exit openings in the form of individual nozzles - the highest possible flue gas recirculation rate, and at the same time a good mixing of the recirculated flue gases with the combustion air. The flue gas recirculation rate is determined through the respective lay-out of the cross sections of the air nozzles, the slot width between air supply pockets and mixing channel, as well as the cross section of the mixing channel itself (Picture 6).

The start-up air mechanism

To achieve the low NOx emissions of < 60 mg/kWH, the RotriX burner requires a high flue gas recirculation rate. If this, however, would already be available right after starting of the burner with flue gases that are still cold, this could lead to an unstable state of combustion. Therefore, the flue gas recirculation rate is decreased during the first 60 seconds by increasing the combustion air supply along the entry channels in the double cone.

This additional air supply briefly increases the excess combustion air supply and thus reduces the start-up emissions of unburned hydrocarbons and CO, and prevents the entry of too large an amount of recirculated, but still cold, flue gases into the mixing channels. The excess combustion air travels through a pipe directly into the burner head. After the starting phase, the pipe is closed by means of a valve (Picture 6) [8].

Test results

The high flue gas recirculation rate causes complete vaporization of the fuel and combustion at a respective low temperature. Therefore, the flame only appears as an extremely low bluish light.

Picture 7 shows the combustion results above the air ratio Lambda. The operating point of the burner lies at an excess air ratio of Lambda 1.13, according to a CO2 content of 13.5 %. The curve shows, however, that the burner can also be operated up to an excess air ratio of Lambda 1.05 (CO2 = 14.5%) and downwards to an excess air ratio of Lambda 1,4 (CO2 = 11%), without any appreciable increase in the CO values. The smoke spot as per Bacharach in the entire range is zero.

Picture 8 shows the start-up behavior of the burner. The start-up mechanism reduces the flue gas recirculation rate within the first 60 seconds and supplies additional oxygen to the combustion process.

Field tests and subsequently installed pilot projects have fully confirmed the expectations placed in the RotriX burner.

The following individuals have collaborated in the development of the RotriX oil burner:

Mr. Gunthard Goerge, Dipl.-Ing.	Construction
Mr. Ruediger Stock, Dipl.-Ing.	Tests

September 19, 1994 BSC/Mje

Table 1: Comparison of material data of heating oil No. 2 and natural gas

	Heating Oil No. 2	Natural Gas
Ignition temperature	approx. 360°C	approx. 640°C
Physical state at ambient conditions	liquid	gaseous
Boiling point	180 - 400°C (multifuel mixture)	- 162°C
Adiabatic flame temperature	2050°C	1950°C
C:H ratio	6,7 : 1	3,0 : 1
Fuel-bound nitrogen	80 - 120 mg/kg	< 5 mg/kg

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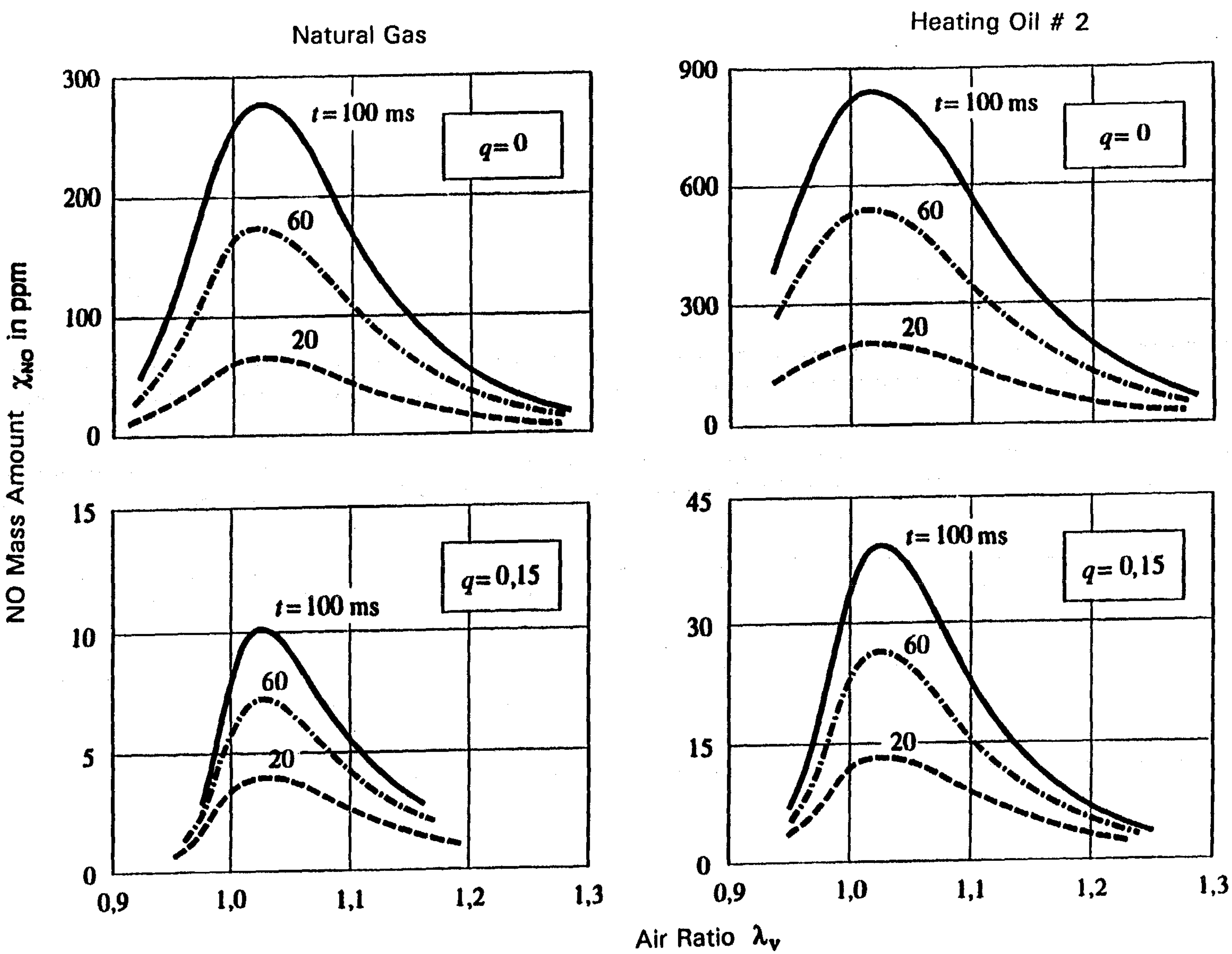
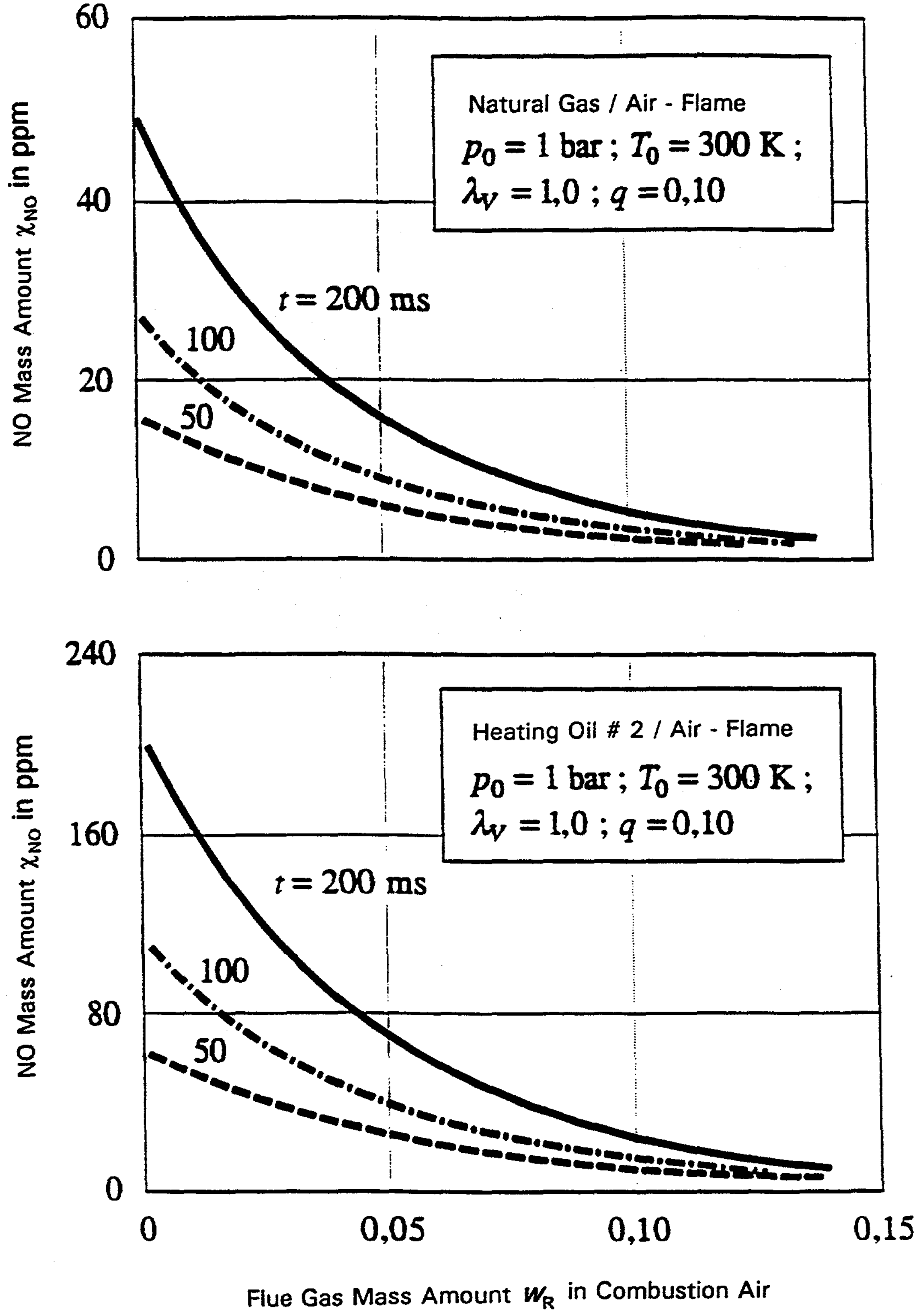
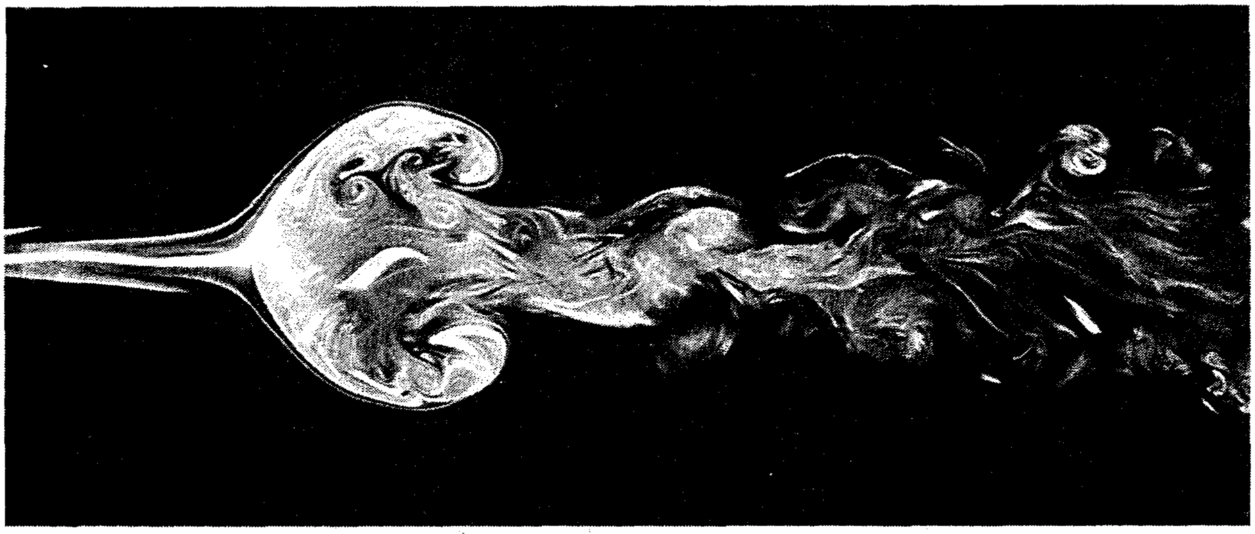


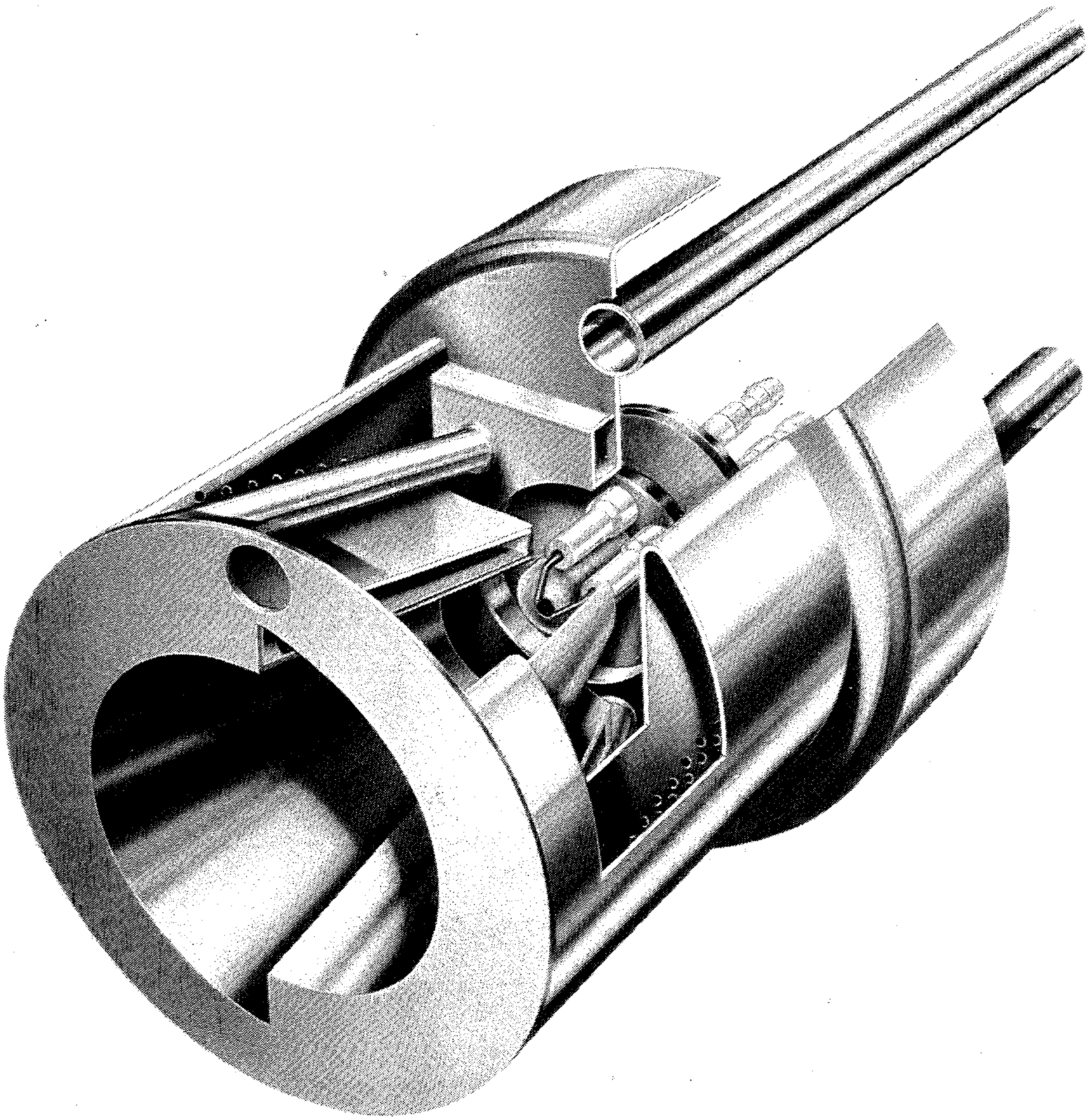
Picture 1: Comparison of the effect of heat disengagement "q" in the combustion of natural gas and heating oil No. 2



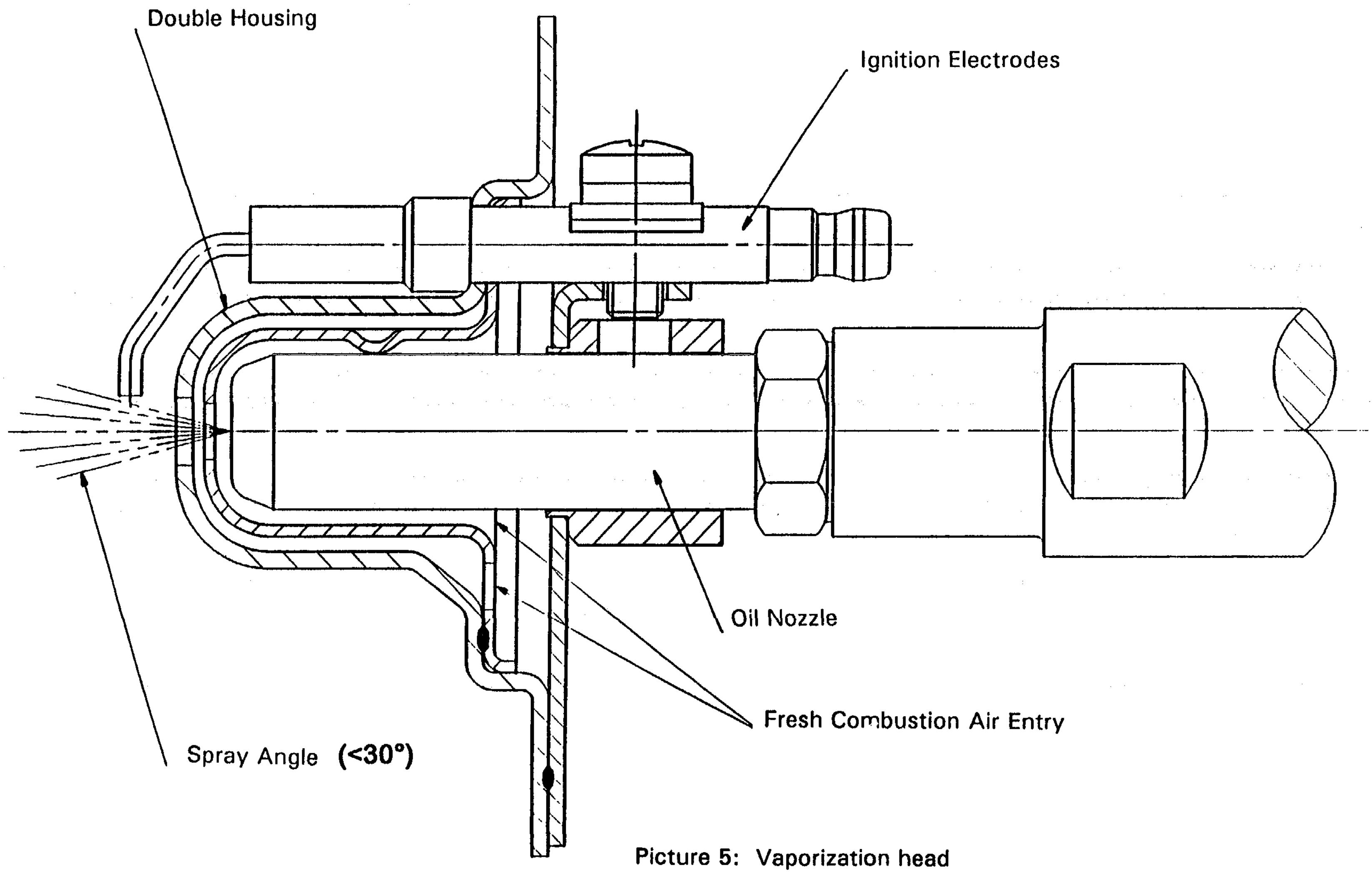
Picture 2: The effect of the flue gas recirculation rate on the formation of thermal NO in a natural gas / air flame and a heating oil / air flame



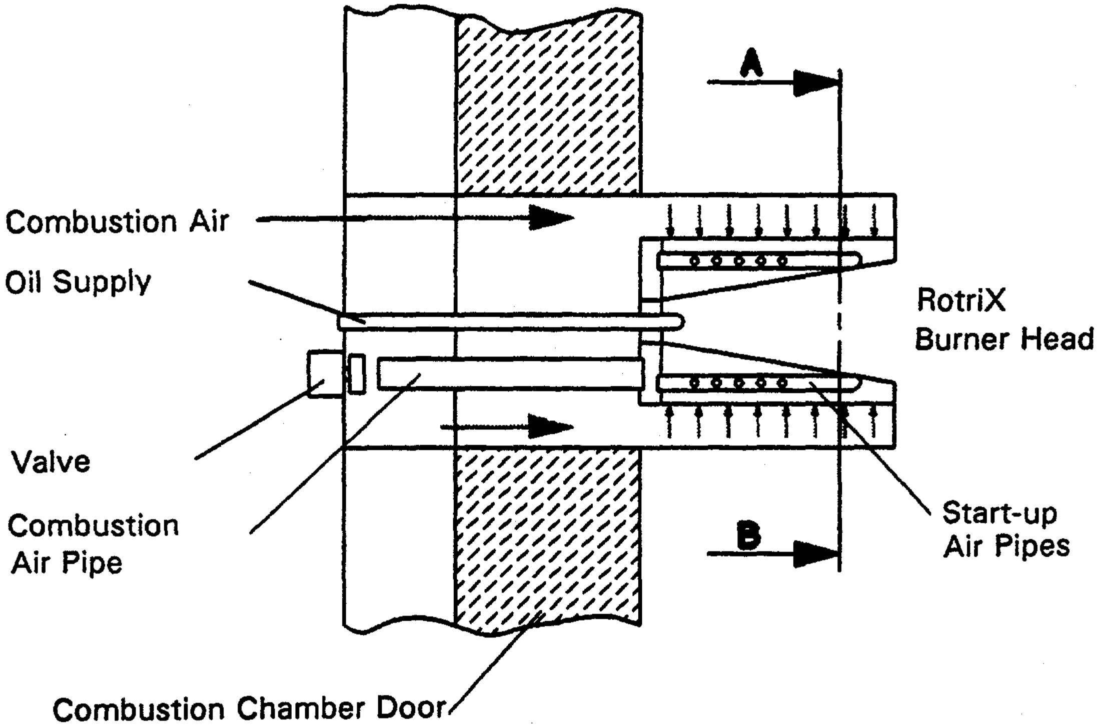
Picture 3: Illustration of the Vortex Breakdown Phenomenon at Reynolds Re_D = 3300



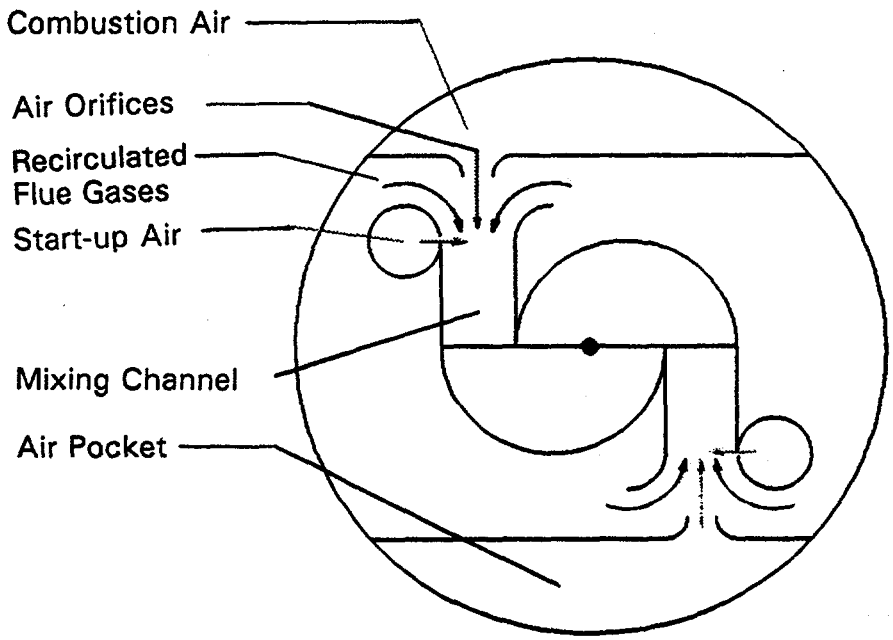
Picture 4: RotriX oil burner



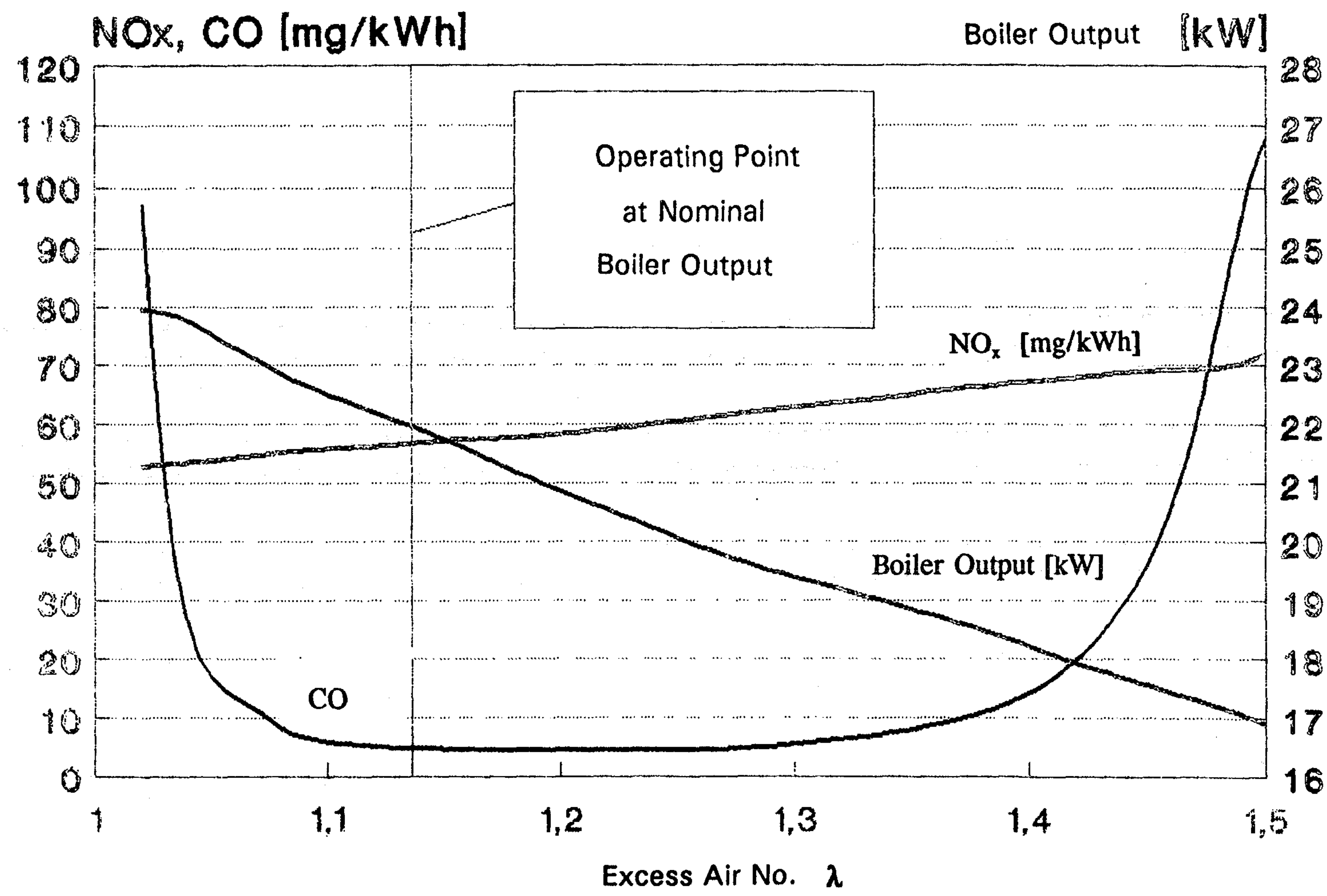
Picture 5: Vaporization head



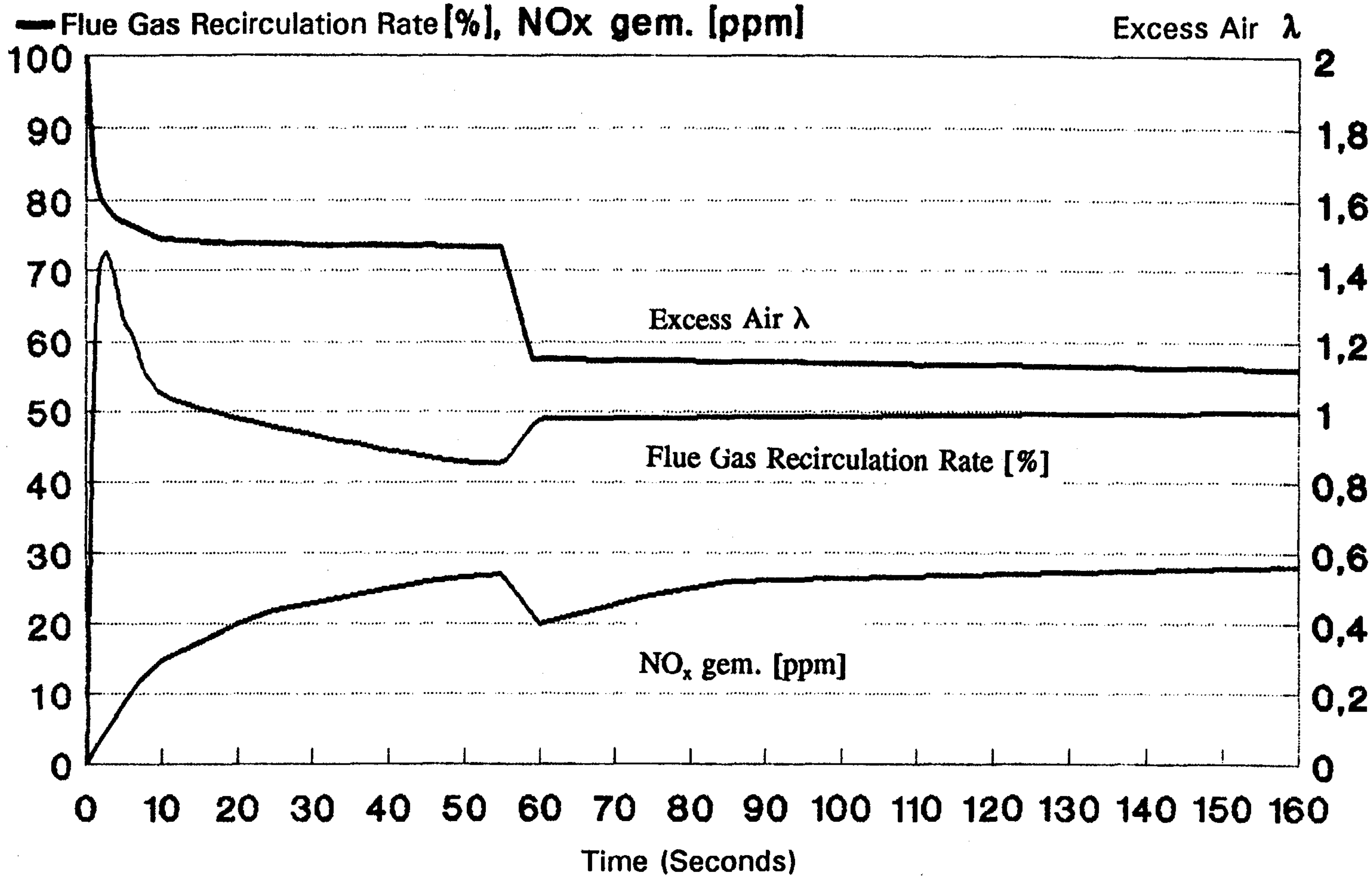
Side View A-B



Picture 6: **Functional diagram of the RotriX oil burner**



Picture 7: Dependency of the flue gas emissions from the excess air for the RotriX burner on a Vitola-biferral-RN



Picture 8: Effect of the starting air mechanism device on the flue gas recirculation rate, excess air ratio, and NOx emissions

Paper No. 95-3

CANADIAN R&D ON OIL-FIRED INTEGRATED SYSTEMS

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Abstract

This presentation will describe research and development presently being conducted on oil-fired space and water heating systems at the Combustion & Carbonization Research Laboratory (CCRL) in Ottawa, Canada. It will focus on R&D activities at CCRL in support of the Canadian Oil Heat Association (COHA); in particular, progress will be reported on activities to develop suitable oil-fired integrated systems to satisfy the low energy demands of new homes and to define outstanding issues and recommend solutions relating to sidewall venting, particularly in cold climates.

Additional activities to be discussed relate to the development of appropriate seasonal efficiency standards for oil-fired combustion systems, in support of Canadian federal and provincial policy initiatives. The first activity in this standards area is a determination of the most appropriate measure of seasonal efficiency of complex integrated space/water heating systems. Performance of a range of existing and prototype integrated systems will be examined and their overall performances defined, using heat loss, heat balance and combined methods, for a wide range of cyclic operations and demands. The draft standard may be either a (slight or detailed) modification of the existing ASHRAE standard, or may be a new more appropriate test and analysis procedure, for the range of present and future systems suitable for Canadian applications in both new, low energy housing and in existing housing.
The second standards activity is the development of an appropriate measure for the seasonal efficiency of sidewall vented oil-fired appliances.

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 of technical equipment for the Oil Heat Association of Canada and its successor, the Ontario Petroleum Association.

It has then continued to carry out laboratory and field studies to quantify energy losses with oil 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. For Gulf Canada, CCRL re-defined their servicing programs to maximize heating efficiency and trained all of Gulf's 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 and maintenance.

In the early 1980's, CCRL carried out studies for the Canadian Electrical Association and CSA on the potential problems of venting modified oil heating systems. These studies defined a series of actions which resulted in a number of new or modified CSA, CGA and ULC standards with respect to venting combustion equipment, as well as spawning R&D efforts on venting across North America. Throughout, CCRL has remained a technical consultant to many of these activities.

Utilizing a controlled temperature calorimetric test cell capable of simultaneously running two furnaces, 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 startup, shutdown performance. Continuous measurements are made of all gaseous emissions, soot and temperatures and 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.

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.

The residential and commercial sectors account for 20% of Canada's fossil fuel energy consumption and CO_2 emissions, (nearly all of which is for space and water heating). Energy consumption reductions of 20-43% can be realized by advanced space and water heating systems for new and existing buildings.

Some 25% of the home heating is 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.

Low Output Oil System for Energy Efficient Housing

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. A further market for oil is the now-electric tap water heating in the majority of oil heated installations in Eastern Canada.

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.

In most Canadian homes heated with oil or electricity, the tap water heating is done electrically, often at very high monthly electricity bills. It is possible to convert these systems to oil-fired water heaters, but the problem is one of high cost for two oil systems, and also how to properly vent two retention head-fired systems. As well, many existing oil-fired water heaters are not terribly efficient, having reasonably high flue gas temperatures, dilution air loss and high off-cycle losses, relative to furnace/boiler technology.

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 will first carry out a study to define the options for a low output heating system also capable of supplying tap water heat, such as by reducing input as per the present BNL activity or by integrating systems in a way to reduce instantaneous heat output significantly, and to evaluate which option has the highest probability of success.

CCRL will develop a computer simulation which will allow design optimization of the most appropriate system.

Sidewall Venting At the same time, CCRL is examining the appropriateness of sidewall venting technology for these 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 also been given a parallel task to develop an appropriate modification to the seasonal efficiency standard to reflect the real operation of good sidewall systems.

Based on these evaluations and optimization, CCRL will develop design specifications for a low output oil-fired heating system. Based on these specifications, a prototype will be constructed and laboratory performance trials carried out to determine conformance with the criteria over a range of space and water heating loads. The design will evolve to obtain optimal performance.

Efforts will be directed towards minimizing the cost and complexity of the final system, while assuring that the goals are achieved.

Finally, on obtaining a suitably-performing prototype, CCRL will define specific design specifications and operational/installation guidelines for such an integrated system. The final technology will be one suitable for installation in new, low energy homes. The goal is to have a unit which will have maximum efficiency for both space and water heating over its entire range of operation.

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

Integrated Systems Presently under Test

SYSTEM A A conventional oil-fired water heater mated to a properly sized, efficient (commutating motor-driven) fan coil, such as shown in Figure 1, 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 mixing valve before entering the house hot water piping. Also 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 contamination of the potable water. There is some concern for the longevity of such systems, with a water heater now being asked to increase its duty by about a factor of four. Also as mentioned, the efficiencies of these systems are generally lower than for the furnaces and boilers which meet the DOE seasonal efficiency standard.

SYSTEM B A more efficient oil-fired integrated system, as shown in Figure 2, has the energy generator as a low mass boiler, fired with a high static flame retention head oil burner, coupled to a well-insulated storage tank through an efficient water-to-water heat exchanger. Intelligent microprocessor controls will 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. If the heating system is hydronic, the boiler water would pass through radiators around the house. If the heating system is forced air, the hot water passes through an efficient fan coil, with modulating fan control driven by an efficient commutating motor. When the thermostat is satisfied, the burner would continue to run instead of shutting off, but the hot water from the boiler is 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 would be required, it is taken directly out of the storage tank. Both the overall operational time and the number of cycles of the boiler is much less than for a conventional system, the boiler operates more efficiently in its heating mode, and the tap water heating efficiency is improved dramatically.

SYSTEM C Another system examined by CCRL for this paper is a commercial integrated oil-fired space/water heating system having an internal double tank which store the hot water for space and for water heating separately. A proprietary sophisticated control system governs the burner operation for customer comfort.

TEST PROCEDURE

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 were processed by a Hewlett Packard 3497A data acquisition system.

The continuous gas sampling train consisted 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.

Four systems were tested using both steady state and cycling runs representing peak and normal winter operation for both space and water heating, and with only domestic hot water draws representing summer, with no space heating requirement.

Additional tests were performed to estimate the influence of such system parameters as tank temperature setting, mass flow rate and burner input rate on the efficiencies and emissions.

Alternate control strategies were applied to obtain higher efficiencies and lower emissions.

Other papers (1-7) have discussed some of the detailed experiments performed on oil-fired systems under a variety of temperature conditions and fuel properties. These have 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 startup and shutdown. There are no effective transient increments to the emissions of carbon dioxide and nitrogen oxides.

Experiments carried out at CCRL have shown that pollutants from gas-fired systems (1,8,9,10,11) are independent of cycling frequency, except where frequency affects system efficiency. For condensing warm air systems, shorter cycles tends to increase efficiency (11), while for non-condensing systems, the reverse is true. For condensing systems based on hot water generators, the relationship is more complex, and is very much 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.

Table 2 shows some interesting effects 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.

Efficiency Standard for Oil-Fired Integrated Appliances

As stated, 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 under-estimate 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

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

In particular,

1. Efficient space/water integrated systems offer the potential for low heat output, to allow oil to return to new housing as a preferred energy source, in many areas of Canada. They also offer the potential for retrofitting electric heated homes, as well as gaining additional oil market in those homes presently heated with oil but using electric water heaters.

2. CCRL is designing integrated systems which can maintain high efficiencies over a wide range of load requirements for both space and water heating, using advanced control strategies.

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, while alleviating potential venting problems.

4. Using the strategies developed to maximize efficiency with integrated systems, retrofitting a water-to-water heat exchanger and storage tank to an oil-fired hydronic system have the potential to act as an effective Demand Side Management (DSM) tool for utilities if the water heating was originally by electricity.

5. 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.

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Table 1. Steady state emissions measurements from integrated appliances.

UNIT	Experimental Measurements - Steady State						
	Input Btu/h	O2 % vol	CO2 % vol	NOx ppm	N_2O ppb	CO ppm	FGT °C
B	103	4.6	11.9	68		20	176
C	103	4.2	12.4	76	262	23	180

Table 2. Effect of heat removal on burner cycling, System B.

Circulating Fan Speed	**Circulating Fan Time (sec)**		**OIL Burner Time (sec)**	
	ON	**OFF**	**ON**	**OFF**
High	300	900	212	988
Low	300	900	212	988
High	Continuous	0	211	137
Low	Continuous	0	152	144

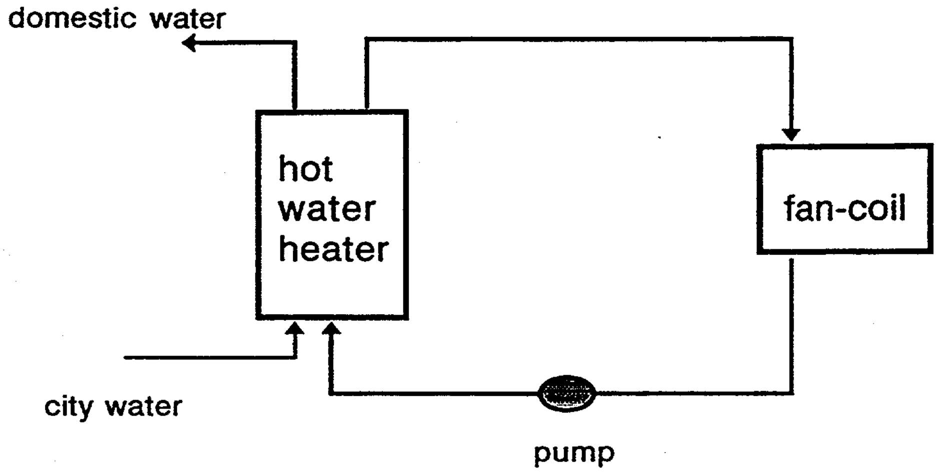

Figure 1. SYSTEM A - Oil-Fired Water Heater with Fan Coil.

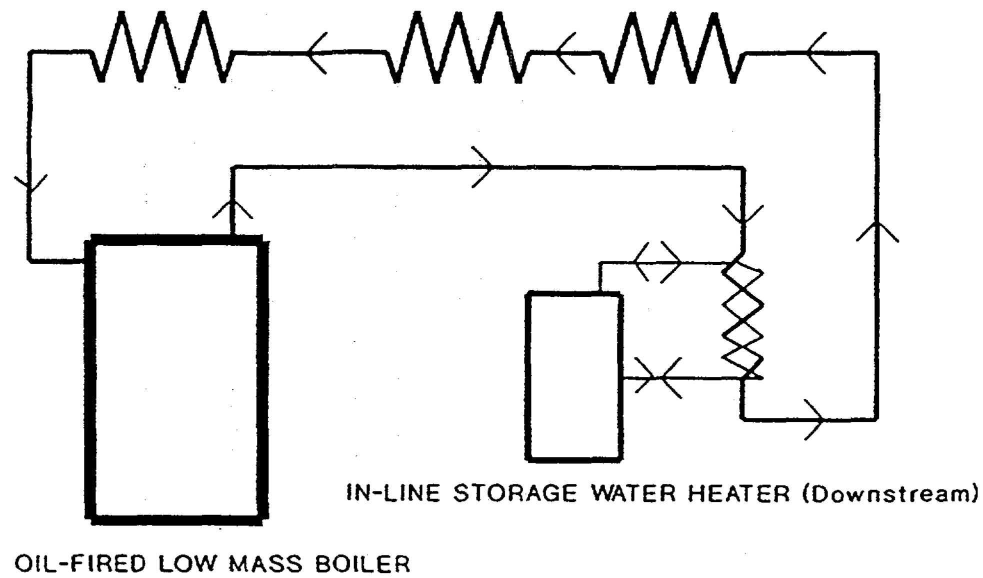

Figure 2. SYSTEM B - Low Mass Boiler having External Storage and Reversible Flows.

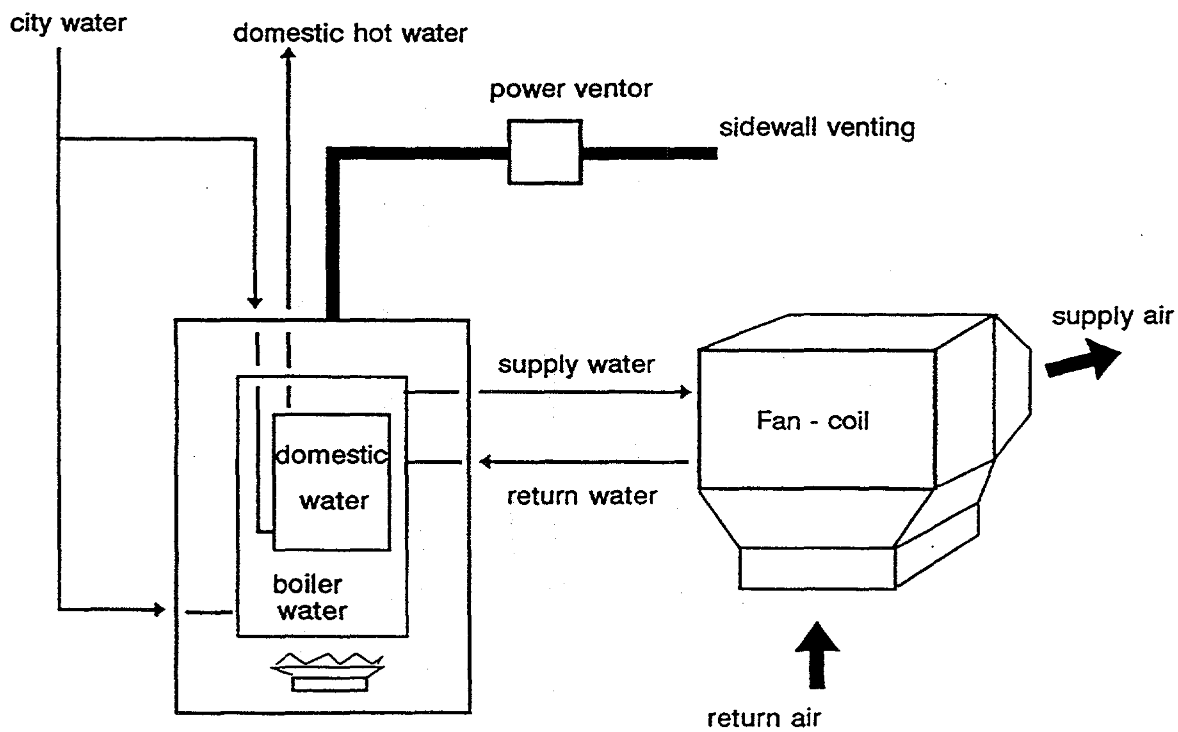

Figure 3. SYSTEM C - Integrated Space/Water Heating System with Coincident Tanks.

Paper No. 95-4

THE APPLICATION OF MASONRY CHIMNEY VENTING TABLES FOR OIL-FIRED APPLIANCES

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THE APPLICATION OF MASONRY CHIMNEY VENTING TABLES FOR OIL-FIRED APPLIANCES

ABSTRACT

This paper presents an overview of the results of work in developing a set of rational guidelines for the venting of modern oil-fired appliances. The activities included the continued development and completion of the Oil-Heat Vent Analysis Program (OHVAP), Version 1.0 and the interpretation of nearly 2,000 runs in preparing recommendations for presentation in table form. These results are presented in the form of venting tables for the installation of chimney vent systems for mid- and high-efficiency oil-fired heating appliances using masonry chimneys.

A brief description of OHVAP is given as well as a discussion of what the program does. Recommendations based on the results of OHVAP are presented in the form of five tables spanning oil-fired appliance Steady State Efficiencies (Eff_{SS}) of 80% to 88%. The assumptions used in the calculations and examples of the computed results are presented as well as a discussion of the rationale for masonry chimney system treatment. Working examples are given with suggested diagnostic approaches for application of the table recommendations.

INTRODUCTION

A major effort within the Oil Heat Venting Program at Brookhaven National Laboratory (BNL) has been the development of the Oil Heat Vent Analysis Program (OHVAP) Version 1.0.[1] OHVAP is a transient analysis program with broad capabilities for studying the behavior of chimney and alternate vent systems serving oil-fired appliances.

The primary purpose for the development of OHVAP has been to develop oil-fired chimney venting tables for oil heat industry manufacturers and installers and to serve as a research tool in support of other oil-fired venting applications. The first phase of this work, the development of venting tables for masonry chimneys, has been completed and is contained in Appendix A of this paper.

In support of the transient program (OHVAP) development and its application, a suitable format for the venting tables has been developed.[2] This format is intended to present recommendations to the user as to the appropriate venting system configuration to be used with a particular oil-fired appliance. The arrangement of the table is such as to provide the user with flexibility in terms of the vent system configuration as defined by various system parameters such as appliance efficiency, firing rate, chimney height and connector length. The base chimney used in the analysis was assumed to be constructed in conformance with the provisions for residential appliances in Section 3.2 of NFPA Standard 211 (1992).[3]

The information included in **Appendix A** of this paper contains recommendations based on a transient analysis of masonry chimneys using **OHVAP Version 1.0.** These recommendations **supersede** any prior BNL releases of information in the form of venting tables for oil-fired appliances and **can be applied in the repair of nonconforming or problem**

chimneys and to new chimney construction. Existing conforming chimneys which are found to be structurally sound and not requiring major repairs to either the chimney structure or the clay tile lining, should be functionally verified by an experienced contractor (or licensed professional as may be required by local jurisdiction) for safe and satisfactory operation. This verification is particularly important when upgraded heating equipment is installed. Heating equipment upgrades can include the installation of a modern retention head burner up to the installation of a complete mid- to high-efficiency heating appliance.

TRANSIENT CHIMNEY VENT ANALYSIS - WHAT DOES OHVAP DO?

OHVAP is a transient program written using algorithms modelling flue-gas composition, system pressure, draft control dilution, system gas-flow, and heat transfer in vent systems serving oil-fired appliances. The program is written in the C programming language and is compiled to operate on 386 class personal computers. The program accepts keyboard input of system geometry, ambient conditions, firing rate, excess air, flue gas temperature profile, and cycle duration to create sets of input files. Calculations of system values are performed in 10 second time-steps over the cycle. The results are stored in output files readily accessible using popular spreadsheet applications.

The program does not model the combustion process or heat-exchange process within the appliance but uses instead, cyclic exit temperature profiles based on the performance of real appliances. The analysis uses the repetition of identical cycles of appliance operation and not the aperiodic operation of real systems under continuously varying building heating loads.

At the present time, the results of the simulations neglect the thermal effects of condensation. The impact of this on liner material temperatures is expected to result in a small under-prediction of surface temperatures for the relatively massive clay liners. This under-prediction may be more significant for metal liners. In order to be conservative, 120^{o} F has been chosen as the minimum acceptable temperature of the surface exposed to the flue gas at the exit of the vent system. This temperature is 20^{o} F above the actual water dew point of the diluted flue gas which is approximately 100^{o} F. This provides a reasonably conservative safety margin for the criterion upon which to evaluate successful operation.

The thermal storage effects in the connector wall and chimney wall sections are evaluated using one-dimensional finite element analysis in the heat transfer across (perpendicular to) the chimney wall elements. The simulation results are based on the behavior of an exterior masonry chimney with heat loss through all faces. These results are considered conservative and are applicable to interior chimneys as well. This very conservative approach reflects an allowance for higher actual heat losses due to: (1) the effects of three-dimensional heat transfer (longitudinal, lateral, and as well as perpendicular to the chimney walls) (2) the uncertain effectiveness of building wall proximity in the reduction of heat flow from any face of the chimney, and (3) the uncontrolled nature of the air temperature surrounding a chimney in a vertical chase within a building.

A more complete description of the OHVAP model and the algorithms used will be published in an engineering report during late 1995 or early 1996.

BASIS FOR CALCULATIONS

Using OHVAP, a series of calculations were made for a wide range of residential heating appliance efficiencies and chimney vent system configurations.

1) The appliances evaluated include those with steady-state stack-loss efficiencies (Eff_{SS}) ranging from 80% to 88% at 12 percent CO_2. The end-of-burn period exit temperature is used to approximate the steady state temperature.

2) The masonry chimneys have heights (above the chimney connector) of 10, 15, 20, and 25 feet. The construction consists of conventional brick masonry followed by a 0.5 inch air gap surrounding a 0.625 inch thick clay tile liner. The clay tile is a nominal 8 X 8 inch liner with a 6.75 X 6.75 inch flue gas passage on the interior.

3) The connectors are assumed to be conventional, single-wall, galvanized pipe. The configuration consists of a vertical rise of 1 foot into a "T" fitting (for a barometric draft control) followed by an elbow into a nearly horizontal run to the chimney breech. For the base case simulations, the chimney is as described in 2) above and has no metal liner, the connector is assumed to be 6 inches in diameter, with total straight lengths (flue-side + stack-side) varying from 4 to 10 feet (see Figure 1). An investigation of the results using 7 and 8 inch connectors revealed only small variances in heat loss and pressure drop as compared to the 6 inch diameter connector.

4) The ambient temperature selected for the chimney is 42° F with all sides exposed. This temperature is consistent with the average exterior ambient temperature used in AFUE evaluations as well as the initial chimney element temperature conditions for the VENT II vent system analysis program for gas appliances. An ambient temperature of 60° F was chosen to reflect the initial connector wall condition and ambient air temperature for a basement installation of the appliance.

   In actuality, the connector and the clay tile liner within a masonry chimney are warmer than the ambient due to heat stored in these elements during preceding appliance cycles. Even with extended burner off periods during night set-back, these elements are warmed indirectly by heat stored in the appliance. **In the analysis, the system is operated through three cycles serving as a preconditioning period with the fourth cycle yielding the results used as a basis for table recommendations.**

5) The largest practical metal liner diameter which can be used inside a nominal 8 X 8 inch (6.75 X 6.75 inch inside dimension) tile chimney liner is 6 inches. The evaluations for the table recommendations use 6, 5, and 4 inch metal liners back-filled with a high-temperature vermiculite material. Connectors used with the lined systems matched the liner diameters, that is, for a treated system using an insulated metal chimney liner, the connector diameter is held consistent with that

of the metal chimney liner. The metal liner is assumed to be smooth and straight in the OHVAP simulations, however, the recommendations may be applied to flexible metal liner materials as well, provided these liner materials are installed fully extended and retained straight as possible within the chimney flue passage to minimize friction loss.

6) The draft control dilution flow is based on the use of a BNL correlation from laboratory test data which reflect dilution flow versus flue gas draft at the draft control location.[4] In the simulation, the flue gas draft (static pressure) at the control location is calculated continuously based on an iterative solution of the vent system conditions with closure on heat transfer, flow and pressure for each time step. The draft control is set at the mid-point of it's adjustment.

WHAT DO THE VENTING TABLES REPRESENT?

The tables contain code letters which prescribe the recommended configuration of specific masonry chimney vent systems based on appliance efficiency, firing rate, chimney height and nominal connector length.

In interpreting the results, 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 120° F.

Where, in the base case **(System A)**, a conventional masonry chimney system was found to fail the above success criteria, treatments are applied to make the system meet those criteria. These treatment options, represented by Systems B, C, and D below, represent solutions applied to the base system using existing technology and are listed in the order of ascending cost and effectiveness.

The following is a list of the systems examined including the base case:

1) **(System A)** - The base case, using a conventional single wall galvanized flue pipe chimney connector and masonry chimney made up of a clay liner, air gap and outer brickwork.

2) **(System B)** - The existing clay chimney liner is retained and relined with a listed 6 inch stainless steel liner, wrapped or back-filled with a listed insulation system.

3) **(System C)** - The existing clay chimney liner is retained and relined with a listed 5 inch stainless steel liner, wrapped or back-filled with a listed insulation system.

4) **(System D)** - The existing clay chimney liner is retained and relined with a listed 4 inch stainless steel liner, wrapped or back-filled with a listed insulation system.

In some cases, the chimney system performance did not meet the temperature criteria regardless of treatment. These are shown as "NR" meaning they are not recommended for simple chimney venting. In these cases an improvement in system performance will require an alternative venting system such as a power-vent or the use of an insulated metal chimney.

In other cases the recommended code letter is accompanied by an "*", indicating the chimney system performance did not meet the minimum appliance draft criteria. In these cases a reduction or elimination of draft control dilution and/or the addition of a power-vent may be required.

Table 1 contains calculated values for chimney liner flue wall temperatures at the exit of the chimney at the end of the burner "on" period for various appliance outlet temperatures and efficiencies. The chimney liner wall temperatures further down the chimney are warmer than the exit. The masonry chimneys within the bold outlined area of the table have liner exit temperatures above the nominal undiluted flue gas water dew point of 120^{o} F. These are based on predictions using **OHVAP Version 1.0** and are provided here for information purposes only. The vent tables in **Appendix A** offer recommendations which suggest the application of an insulated metal liner for the masonry chimney cases outside of the bold outlined area of the table. The recommendations are also valid for listed stainless steel liners without an insulation material back fill provided that these liners are retained as concentrically positioned as possible within the flue passage of the chimney and with sufficient continuous clearance to the adjacent masonry to provide an insulating air gap. Some specific situations requiring the application of these recommendations could include nonconforming or repaired chimneys and new chimney construction.

CONCLUSIONS

In terms of transient operation of exterior masonry chimneys to vent oil-fired appliances, concerns regarding the potential for condensation appear well founded. The transient analysis resulting from OHVAP reveals conditions with the potential for acid condensation in many masonry chimney cases, some of which have been considered to be satisfactory by experience, conventional wisdom, and common practice.

The issue of water condensation in masonry chimneys is well documented as are the issues of damage to masonry, mortar and liners in chimneys.[5,6] While the requirement for a minimum liner exit temperature of 120^{o}F severely reduces the number of apparently successful untreated masonry chimney applications, it is important to note that the criterion offers a considerable margin of safety.

Current trends in firing rates for energy conservation purposes in residential oil-fired appliances are frequently reduced to 1 gallon per hour or less. Based on the OHVAP calculations, failure to meet the criterion set for minimum liner temperature at the exit of the chimney is shown to be the rule rather than the exception. **It must be noted that, though there are many references to specific types of masonry chimney failure, no general failure pattern has been clearly identified with chimneys serving oil-fired appliances.** Therefore, subject to local jurisdiction, properly constructed (conforming) masonry chimneys may be used to serve mid- and high-efficiency oil-fired appliances provided they are initially and annually thereafter, inspected, serviced and verified for safe and satisfactory operation.

REFERENCES

[1] Strasser, J. et al. 1994 "Oil-Heat Vent Analysis Program" (OHVAP, Version 1.0), 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] NFPA. 1992 Standard for Chimneys, Fireplaces, Vents, and Solid Burning Appliances. NFPA Standard 211-1992. National Fire Protection Association, Quincy, MA.

[4] Butcher, T. et al. 1990 "Chimney Related Energy Losses in Oil-Fired Heating Systems: Configuration Effects and Venting Alternatives", BNL-46021.

[5] Gorden, E. et al. 1990 "Masonry Chimney Inspection and Relining", AGAL Unpublished Topical Report.

[6] Kam, V. P. et al. 1993 "Inspection of Masonry Chimneys Used to Vent Gas Appliances", AGAL Draft Topical Report.

TABLE 1 - INNER SURFACE TEMPERATURE OF CLAY LINER (TEMPERATURES SHOWN AT CHIMNEY EXIT)

25 FOOT CHIMNEY, 10 FOOT CONNECTOR					
RATE GPH	SS=88% 275 F	SS=86% 345 F	SS=84% 420 F	SS=82% 495 F	SS=80% 575 F
0.25	54	56	61	64	68
0.5	60	64	69	75	80
0.75	65	74	80	85	92
1	71	79	87	95	104
1.25	77	86	95	105	115
1.5	83	93	103	114	125
1.75	88	100	111	124	136
2	93	106	119	133	146
2.25	98	112	126	141	156

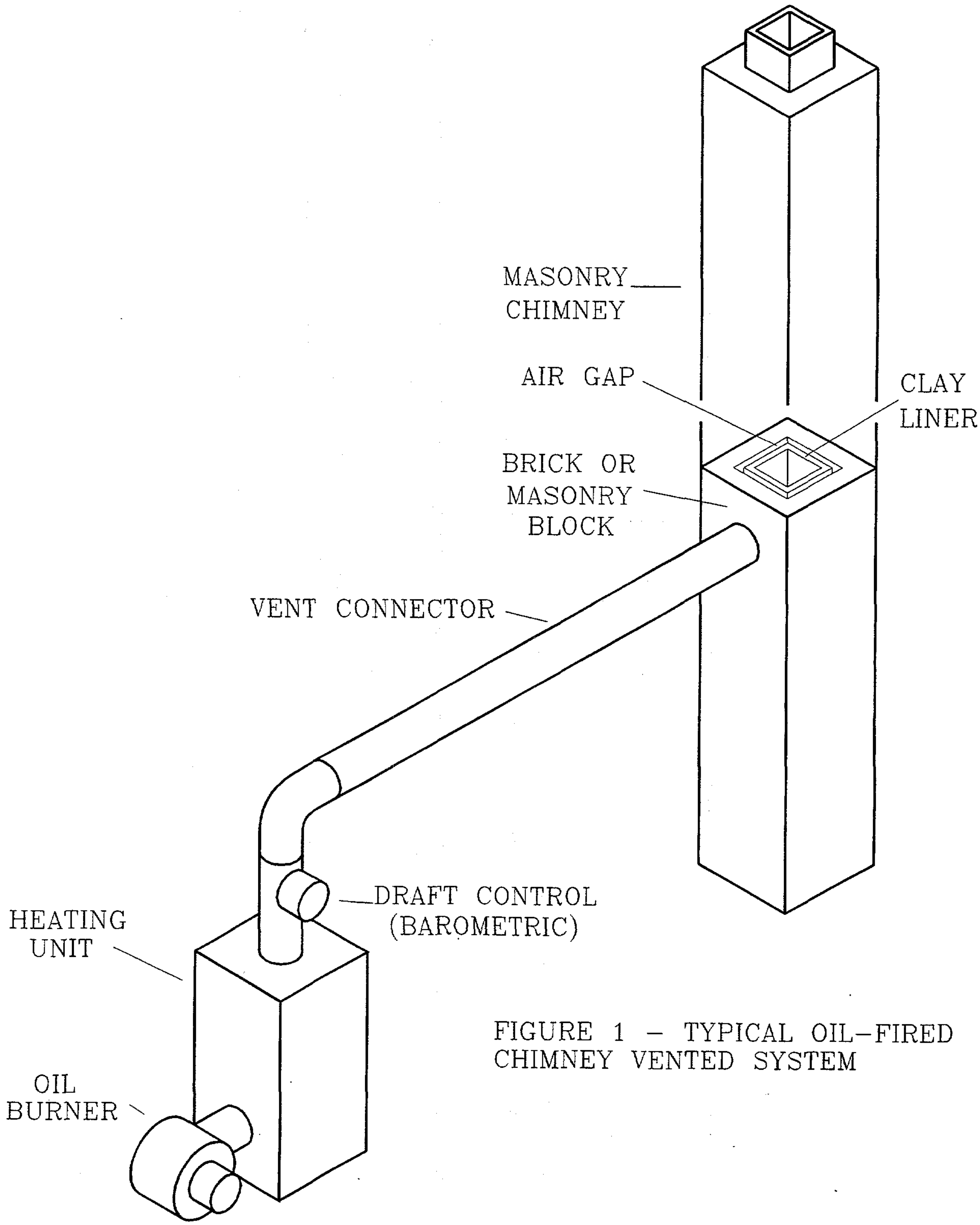

FIGURE 1 – TYPICAL OIL-FIRED CHIMNEY VENTED SYSTEM

APPENDIX A

The chimney venting tables generated using OHVAP Version 1.0 are included in this Appendix. They are provided here for industry use and review of the format and applicability.

USING THE VENT TABLES

Venting an Existing Appliance

A) Adjust the appliance burner for a satisfactory CO_2 level and a trace to No. 1 smoke.

B) Measure the flue gas exit temperature of the appliance at the end of a 10 minute (or longer) burner-on period. It should be noted that although the tables were prepared using 12% CO_2 in the flue gas, the table recommendations are applicable over the range of 10% to 14%.

C) Using the measured appliance flue gas temperature as a reference, enter the appropriate table in **Appendix A**. If the measured flue gas temperature falls between two tables, examine the recommendations contained in the tables above and below that of the measured temperature.

D) Find the applicable firing rate, chimney height, and connector length in the table(s) and read the letter code(s) for the recommended vent system(s). When the measured flue gas temperature falls between two tables and the recommendations above and below are not the same, use the most conservative recommendation. The most conservative recommendation will be the one in which the "worse-case" conditions are assumed to exist in terms of system flue gas temperature. The "worse-case" is the case with the lowest flue gas temperature requiring the most reduction of heat loss from the chimney. The user will then select from the choices the recommendation which meets the "worse-case" requirements.

Example:

Suppose that the flue gas exit temperature from the appliance is measured as 523° F with a firing rate of 1.0 GPH. In addition, the total straight connector length is 7 feet into a 22 foot chimney. Note that each of the parameters for the system is not precisely located in the table. However, by bracketing with the nearest values, a determination of the required venting system can be made. Using a connector/chimney combination of 6/20 at 495° F the recommended code is "B". At 575° F the recommended code is also "B". Similarly for a connector/chimney combination 8/25 is also "B" for each of the flue gas temperature levels. Here the correct choice is clear as being "B". If the firing rate had been 0.75 GPH, however, the choice would have been between "C" at 495° F or "B" at 575° F. In this case the correct choice would have been the most conservative one or "C".

Venting a New Appliance:

A) Evaluate the estimated steady-state efficiency as follows:

(1) Find the Heating Capacity (MBh) of the appliance on the attached nameplate, promotional material or instructions.

(2) Multiply the Oil Input (GPH) by 140 to give the input in (MBh).

(4) Divide Heating Capacity (MBh) found in (1) by the the Oil Input in (MBh) calculated in (2).

(5) Multiply the result obtained in (4) by 100.

(6) For appliances intended to be installed indoors use the value calculated in (5) as the estimated steady-state efficiency. For appliances intended as isolated combustion systems, add 1.7 to the value calculated in (5) to obtain the estimated steady-state efficiency.

B) Using the estimated steady-state efficiency as a reference, enter the appropriate table in **Appendix A**. If the estimated efficiency falls between tables, examine the recommendations of the tables above and below the that of the calculated efficiency.

C) Find the applicable firing rate, chimney height, and connector length in the table(s) and read the letter code(s) for the recommended vent system(s). When the calculated steady state efficiency falls between two tables and the recommendations above and below are not the same, use the most conservative recommendation in the same manner as previously described.

Example:

Suppose that the Heating Capacity of the appliance is 103 MBh and the Oil Input is 0.85 GPH. By multiplying the Oil Input by 140,000 an Input of 119 MBh is obtained. Dividing the Heating Capacity by the Oil Input results in an approximate Steady State Efficiency of 87 percent. In this case, suppose a 4 foot connector can be applied to an existing chimney which is 25 feet above the breech. In the table for a steady state efficiency of 88 percent, the bracketing recommendations for the firing rate are "NR" and "D*". Similarly, at 86 percent efficiency, the bracketing recommendations are "D" and "C". In this case, the most conservative choice will be "NR" indicating that alternative venting should be considered. On the other hand, the application of "D*" might work with a reduction of draft control dilution. If not, the investment already committed in relining the existing chimney could be recovered with the addition of a chimney inducer.

APPENDIX A

CHIMNEY VENTING TABLES FOR OIL-FIRED APPLIANCES

APPLIANCE EXIT FLUE-GAS TEMPERATURE = 275 F GROSS (215 F NET) S.S.EFF.= 88% AT 12% CO2

CHIM.HG	10 FEET				15 FEET				20 FEET				25 FEET			
CONN.LN	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
GPH	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
0.25	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.75	D*	D*	D*	D*	D*	D*	D*	NR	NR	NR	NR	NR	NR	NR	NR	NR
1	C*	C*	C*	C*	C	C	D*	D*	D*	D*	D*	D*	D*	D*	D*	NR
1.25	B	B	C*	C*	C	C	C	C*	C	C	C	C	C	D*	D*	D*
1.5	B*	B*	B*	B*	B	B	C*	C*	C	C	C	C	C	C	C	C
1.75	B*	B*	B*	B*	B	B	B	B	B	B	B	C*	C	C	C	C
2	A*	A*	B*	B*	B	B	B	B*	B	B	B	B	B	B	B	B
2.25	A*	A*	A*	A*	B*	B*	B*	B*	B	B	B	B	B	B	B	B

APPLIANCE EXIT FLUE-GAS TEMPERATURE = 345 F GROSS (285 F NET) S.S.EFF.= 86% AT 12% CO2

CHIM.HG	10 FEET				15 FEET				20 FEET				25 FEET			
CONN.LN	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
GPH	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
0.25	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.5	D*	D*	D*	D*	D	D	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.75	C	C	C	C	C	C	D	D	D	D	D	D	D	D	D	D
1	B	B	B	B	C	C	C	C	C	C	C	C	C	C	D	D
1.25	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C
1.5	A	A	B	B	B	B	B	B	B	B	B	B	B	B	B	C
1.75	A	A	A	A	A	A	B	B	B	B	B	B	B	B	B	B
2	A	A	A*	A*	A	A	A	A	A	B	B	B	B	B	B	B
2.25	A*	A*	A*	A*	A	A	A	A	A	A	A	A	B	B	B	B

APPLIANCE EXIT FLUE-GAS TEMPERATURE = 420 F GROSS (360 F NET) S.S.EFF.= 84% AT 12% CO2

CHIM.HG	10 FEET				15 FEET				20 FEET				25 FEET			
CONN.LN	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
GPH	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
0.25	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.5	C	C	C	C	C	D	D	D	D	D	D	D	D	NR	NR	NR
0.75	B	B	B	B	C	C	C	C	C	C	C	C	C	C	D	D
1	B	B	B	B	B	B	B	B	B	B	B	C	C	C	C	C
1.25	A	A	A	A	B	B	B	B	B	B	B	B	B	B	B	B
1.5	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B
1.75	A	A	A	A	A	A	A	A	A	A	A	A	B	B	B	B
2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2.25	A	A	A*	A*	A	A	A	A	A	A	A	A	A	A	A	A

APPENDIX A (CONTINUED)

CHIMNEY VENTING TABLES FOR OIL-FIRED APPLIANCES

APPLIANCE EXIT FLUE-GAS TEMPERATURE = 495 F GROSS (435 F NET) S.S.EFF.= 82% AT 12% CO2

CHIM.HG	10 FEET				15 FEET				20 FEET				25 FEET			
CONN.LN	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
GPH	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
0.25	D	D	D	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.5	B	C	C	C	C	C	C	C	C	D	D	D	D	D	D	D
0.75	B	B	B	B	B	B	B	B	B	C	C	C	C	C	C	C
1	A	A	A	A	B	B	B	B	B	B	B	B	B	B	B	B
1.25	A	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B
1.5	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B
1.75	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2.25	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

APPLIANCE EXIT FLUE-GAS TEMPERATURE = 575 F GROSS (515 F NET) S.S.EFF.= 80% AT 12% CO2

CHIM.HG	10 FEET				15 FEET				20 FEET				25 FEET			
CONN.LE	4	6	8	10	4	6	8	10	4	6	8	10	4	6	8	10
GPH	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT	FT
0.25	C	D	D	D	D	D	D	NR	NR	NR	NR	NR	NR	NR	NR	NR
0.5	B	B	B	B	B	C	C	C	C	C	C	C	C	C	C	D
0.75	A	A	B	B	B	B	B	B	B	B	B	B	B	B	B	B
1	A	A	A	A	A	A	A	A	B	B	B	B	B	B	B	B
1.25	A	A	A	A	A	A	A	A	A	A	A	A	A	A	B	B
1.5	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
1.75	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
2.25	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

NOTES:

(NR) - NOT RECOMMENDED FOR MASONRY CHIMNEY VENTING. USE INSULATED METAL CHIMNEY OR SIDE-WALL VENT SYSTEM.
(A) - CONVENTIONAL MASONRY CHIMNEY (TILE LINER, AIR GAP, BRICK OUTER)
(B) - CONVENTIONAL MASONRY CHIMNEY WITH A LISTED 6 INCH DIAMETER METAL LINER AND A LISTED INSULATION SYSTEM
(C) - CONVENTIONAL MASONRY CHIMNEY WITH A LISTED 5 INCH DIAMETER METAL LINER AND A LISTED INSULATION SYSTEM
(D) - CONVENTIONAL MASONRY CHIMNEY WITH A LISTED 4 INCH DIAMETER METAL LINER AND A LISTED INSULATION SYSTEM
(*) - INDICATES THAT THE DRAFT AT THE APPLIANCE MAY BE LESS THAN .03 INCHES OF WATER. ADJUSTMENT OF THE DRAFT REGULATOR MAY BE REQUIRED. THE ADDITION OF A DRAFT INDUCER SHOULD BE CONSIDERED.

Paper No. 95-5

THE BNL FAN-ATOMIZED BURNER SYSTEM PROTOTYPE

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THE BNL FAN ATOMIZED BURNER SYSTEM PROTOTYPE

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INTRODUCTION

Brookhaven National Laboratory (BNL) has a continuing interest in the development of advanced oil burners which can provide new capabilities not currently available with pressure atomized, retention head burners. Specifically program goals include:

- Ability to operate at firing rates as low as 0.25 gph.
- Ability to operate with very low excess air levels for high steady state efficiency and to minimize formation of sulfuric acid and iron sulfate fouling.
- Low emissions of smoke, CO, and NO_x even at very low excess air levels.
- Potential for modulation - either staged firing or continuous modulation.

In addition any such advanced burner must have production costs which would be sufficiently attractive to allow commercialization.

The primary motivation for all work sponsored by the U.S. DOE is, of course, improved efficiency. With existing boiler and furnace models this can be achieved through down-firing and low excess air operation. Also, with low excess air operation fouling and efficiency degradation due to iron-sulfate scale formation are reduced. This relationship between fouling and excess air has been discussed in earlier Oil Heat Conference papers.[1,2]

Two-stage firing boilers or furnaces can operate for most of the heating season at the low-firing, high efficiency condition and still retain the high firing rate capability for recovery capacity. The DOE AFUE test procedure allows two-stage firing appliances to use an averaged efficiency with the lower input, higher efficiency conditioning receiving the most weight. In tests at BNL the AFUE setting of a furnace was raised from 79 to 84% with a two-stage firing approach.

In addition to improving the efficiency of existing boiler and furnace models it is anticipated that the development of advanced burners can lead to new, high efficiency product concepts. This may include low output furnaces and boilers for selected markets and lower input oil-fired water heaters.

Current work at BNL centers on the development of a concept which has become termed the Fan Atomized Burner. In this approach oil is atomized with air supplied by the burner's fan.

In other air-atomized burner designs, a compressor is used to provide a small flow of air at 5 to 20 psi to the nozzle for atomization. A fan is also included to provide the remainder of the air required. This secondary air is delivered at a much lower pressure, 2 to 3 inches of water. In the Fan Atomized burner there is only one air supply, a fan delivering air at 6 to 12 inches of water pressure. 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.

Background development work for this burner concept has been presented at earlier oil heat conferences and is now documented in a BNL report.[3] At last year's Oil Heat Conference the burner head was described in detail and system component options were discussed. Over the past year two prototype system concepts have evolved and these prototypes are now being tested both inside and outside of BNL. In this paper the two current prototypes are described and some performance test results are given. Following this, our current direction in development work and future areas of interest are discussed.

DESCRIPTION OF BURNER PROTOTYPES

The two burner prototypes currently under tests could be considered to be a high firing rate version and a low-firing rate version. These prototypes were developed simply to allow evaluation of this burner concept with different system details. It is certainly possible to reconfigure either burner differently, mixing components as desired.

The higher firing rate prototype is illustrated in Figure 1. Air for both atomization and combustion is provided by a brushless DC motor/fan package with integral controller. This control accepts 110V AC power directly and speed control can be either manual (casing trim dial) or electronic (0-10V DC input). The manual speed control is used in this version. The fuel pump being used is identical in appearance and in most of the internals to a conventional oil burner pump. This pump, however, has internal flow metering specifically for delivering fuel to an air atomized burner. Fuel flow rate is controlled by manually adjusting an internal pressure regulator. In the current version of this prototype the fuel pump and motor assembly is not housed with the other burner components but is free standing. All other components are mounted in a case with dimensions: width = 8 inches, height = 12 inches, and depth = 7 inches, not including primary control ignition transformer, and air tube. For the primary control we are using a microprocessor-based recycle control with pre- and post-purge functions. During the pre-purge period both the fuel pump and the fan are on and the fuel pressure just before the solenoid valve rises to the internal pressure on the lift/metering pump (30-40 psi). After the pre-purge period the solenoid valve opens and the pressure stored in the upstream gauge produces a short burst of nozzle fuel flow which aids ignition.

The prototype system illustrated in Figure 1 has been operated over the range 0.3 to 1.0 gph. Relative to other possible configurations this prototype has both advantages and disadvantages. The nearly-conventional lift and metering pump is a familiar component with excellent lift capability and it allows rapid fuel system bleeding on startup. The fan/motor package used in this prototype has a maximum static pressure of about 20 inches of water and a flow capability much greater than necessary for the firing rate range. This fan is larger and lower in efficiency than a fan more correctly sized to the application could be. The use of

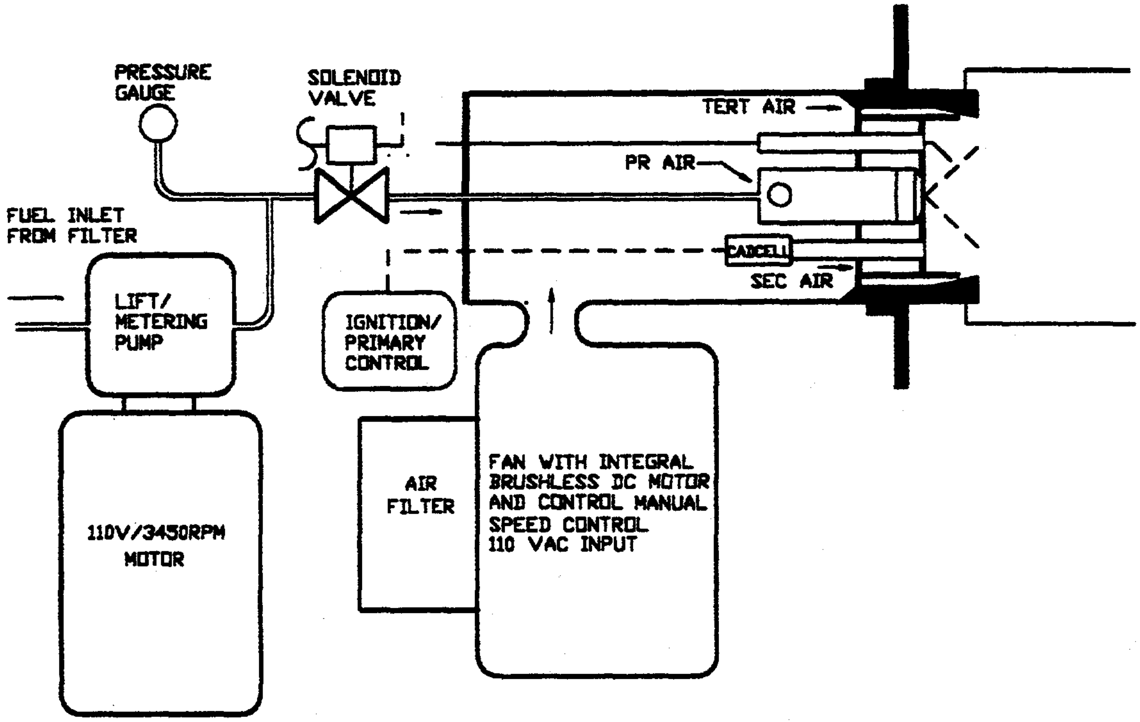


FIGURE 1

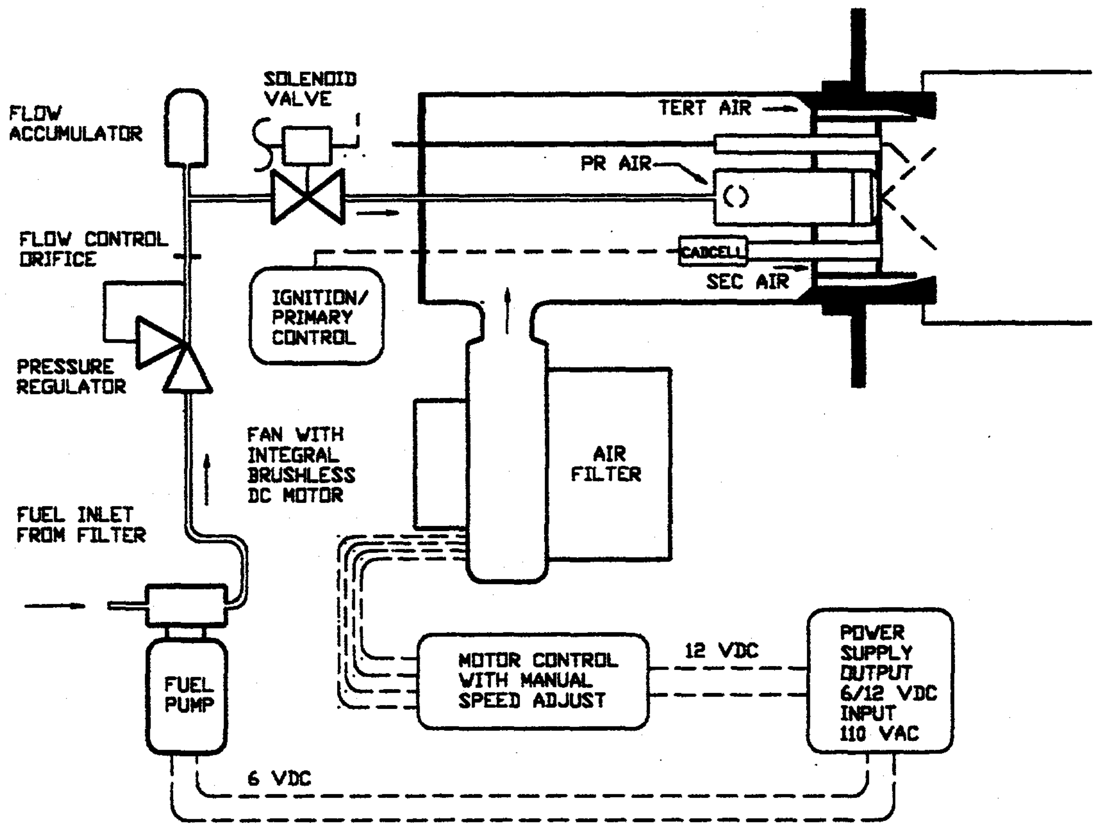


FIGURE 2

separate fuel pump and fan motors is obviously undesirable. Fan speed in this unit ranges from 7,000 to 10,000 rpm and while it may be possible to run the fuel pump at such speeds it is likely that electric power consumption would be excessive.

The second burner prototype developed is illustrated in Figure 2. This unit again uses a brushless DC motor-driven fan but the fan in this case is much smaller. This fan has a plastic housing and blade wheel and develops a maximum static pressure of 11.5 inches of water. This fan is much smaller with a diameter of 5 inches and a height for the fan/motor combination of 3 inches. The control for the brushless DC motor is mounted on a separate circuit board and provides for manual speed control. The capacity of this fan is low and can really only be used at firing rates to 0.4 gph. Input power to the control is 12 V DC. The fuel pump used in this second prototype burner is a small gear pump with a plastic housing and DC motor drive. Overall dimensions of the motor/pump package are 3 3/4 inches x 1 3/4 inches x 2 inches. An external pressure regulator and metering orifice are used to control nozzle fuel feed. As in the case of the prototype system shown in Figure 1 a burner primary control with pre- and post-purge is used. The fuel pump runs during the pre-purge period and fuel pressure is stored in the small accumulator shown in Figure 2. After the pre-purge period the solenoid valve opens and the accumulator pressure is released giving the short fuel flow burst. With both burners the pre- and post-purge periods are 15 seconds.

The DC power for both the fuel pump and the fan are provided from a single power supply incorporating a dual-tap secondary transformer, two bridge rectifiers and a simple capacitor "filter" for each. Primary advantage of this prototype over the higher-range unit include a smaller package size, lower electric power consumption, about 85 watts, and lower estimated cost. Disadvantages include the limited firing rate capacity and limited fuel pump lift capability.

BURNER PERFORMANCE

Application tests with the burner are continuing in a variety of appliances and some were reported during tests at the 1994 Conference.[4] Here, these results will be extended. Figures 3 and 4 show the results of some tests which were done in a two-section, cast iron boiler using the burner prototype with the higher firing rate range. Boilers of this type have very short combustion chamber lengths and a partial refractory covering on the combustion chamber surfaces. For these tests a small piece of refractory blanket was added to the floor of the combustion chamber. At 0.3 gph firing rate the CO is higher than desired but at all other conditions performance is very good. Smoke number which is not shown is zero at all conditions tested. At firing rates below about 0.5 gph the boiler exit temperature (Figure 4) is too low to vent these combustion products using conventional chimney systems as condensation problems would occur. For this reason it is unlikely that the burner would be used in a boiler of this type at such low firing rates.

Figure 5 shows the results of a test series which was conducted using the lower firing rate prototype burner in a center-flue water heater. These tests were all conducted at only one firing rate, 0.35 gph. This appliance has a heavy refractory liner in the combustion chamber. As a results of this the burner can operate at very low excess air levels without producing smoke or CO. The efficiency values shown in this figure are based on stack gas conditions and do not include jacket or off-cycle losses.

BNL FUTURE DEVELOPMENT DIRECTIONS

In future development work at BNL we will be striving to make improvements to the burner design which improve reliability, reduce cost, improve performance, and offer more options for appliance manufacturers in their efforts to develop advanced high efficiency products. We are targeting our work in three specific areas:

1) Reduced NO_x

In all of our performance testing we have tried to configure the burners to get good performance in a very broad range of applications. However, to get optimum performance, both low NO_x and low excess air operation it is really necessary to work with both the burner and the combustion chamber environment. By doing this it is possible to minimize peak flame temperatures (and so NO_x) and at the same time avoid local, very cold surfaces exposed to the flame which leads to CO and smoke production. Our approach to reducing NO_x emissions is to work both with the burner and chamber in selected configurations to provide a combustion system with just enough cooled internal CGR (combustion gas recirculation) to prevent or to greatly reduce thermal NO_x generation. At the same time our approach is to provide a set of system conditions (combustion chamber environment) for oxidizing all fuel completely.

2) Direct Coupled Fuel Unit with Reliable, Electronic Fuel Control

The burner prototypes developed to date have included separate fan and fuel pump motors and it would clearly be desirable to combine these. The difficulty in doing this, of course, is the high fan motor speed. We plan to explore either high speed fuel pump options or a speed reduction drive for the fuel pump. In addition it is planned to continue the development of options for electronic firing rate control. This would allow the development of low cost modulating burner designs. The approach we are taking is the use of an automotive type, pulsed injector. This tiny solenoid valve opens and closes at a frequency of 100 cycles per second. The fuel flow rate is controlled by adjusting the amount of time that the valve remains open each cycle. This has been tested in the past at BNL but not included in burner prototypes because of observed fuel flow rate drift during routine cyclic operation. It is planned to continue development efforts to eliminate this concern.

3) Development of a Two-Stage Burner Prototype.

The present versions of the Fan-Atomized Burner are seen as most attractive at the low firing rate end because of the lack of burners commercially available in this range. As discussed earlier, two stage burners can offer significant efficiency advantages while retaining capacity at the high end. The combination of electronic fuel flow control and the brushless DC fan drive, make the Fan-Atomized Burner a good choice for two-stage firing. Currently our efforts in this area are aimed at evaluating options for changing head position with firing rate. This would allow a turn down ratio of 3:1. The alternative is to keep head position fixed and vary only fan

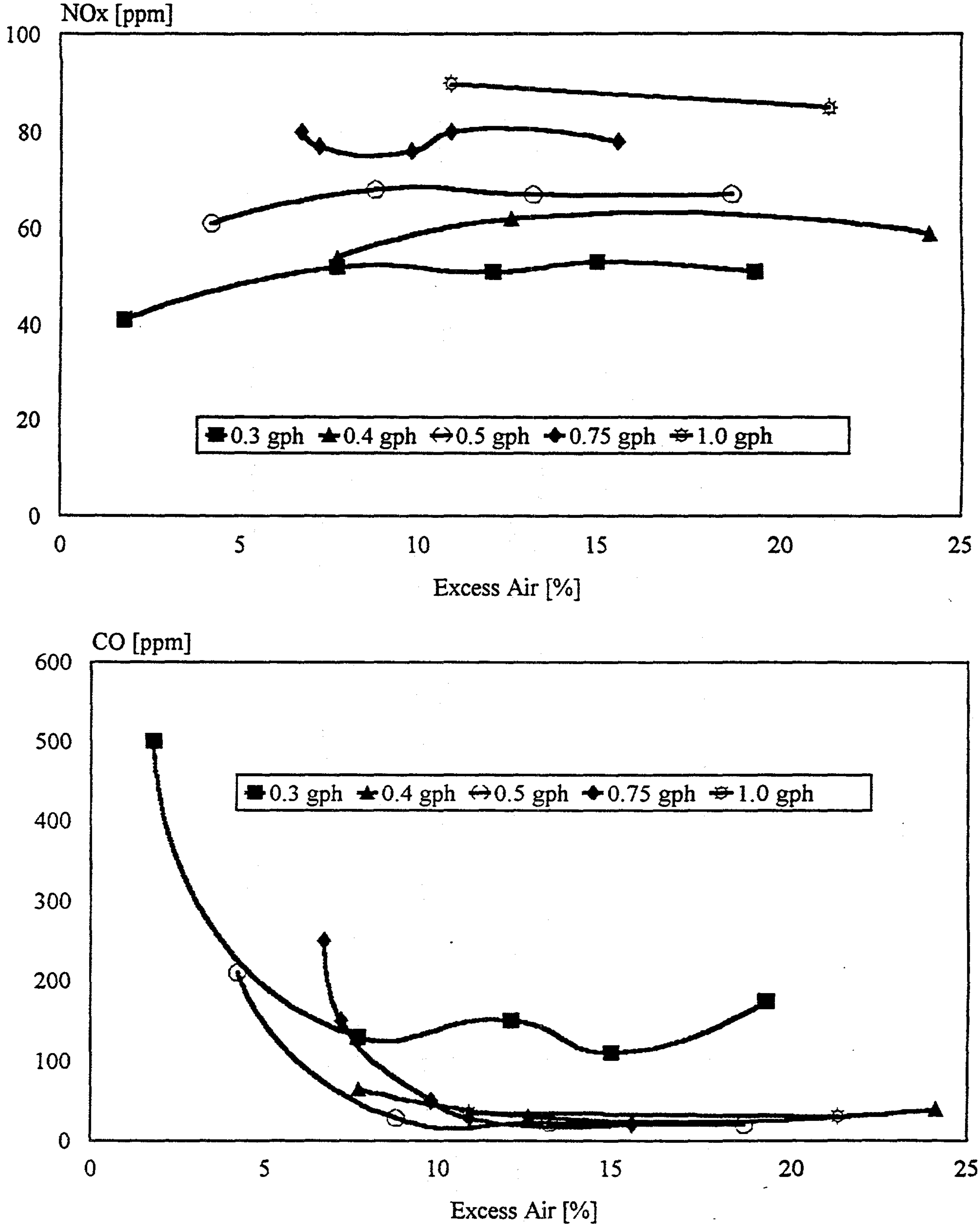


Figure 3. Example performance test results. Tests with Fan-Atomized Burner in two section, cast iron boiler. Effect of excess air on CO and NOx.

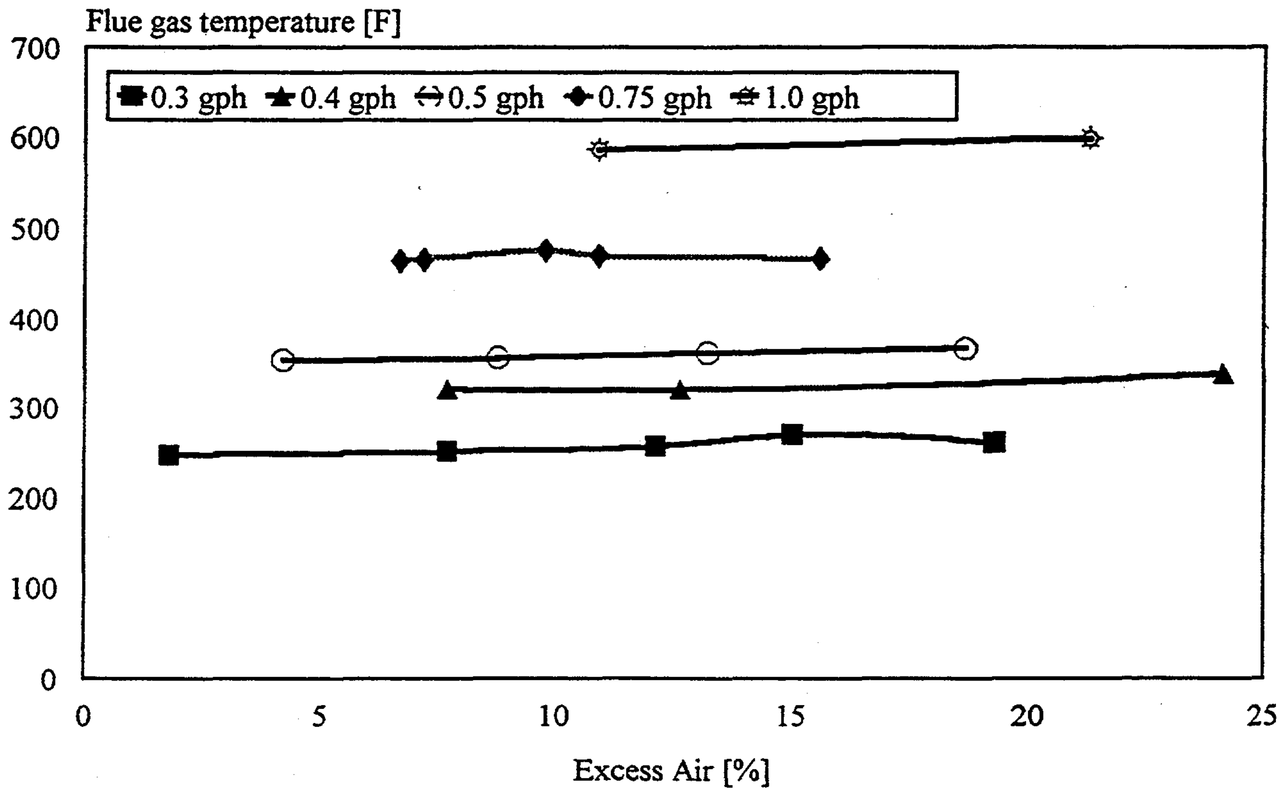
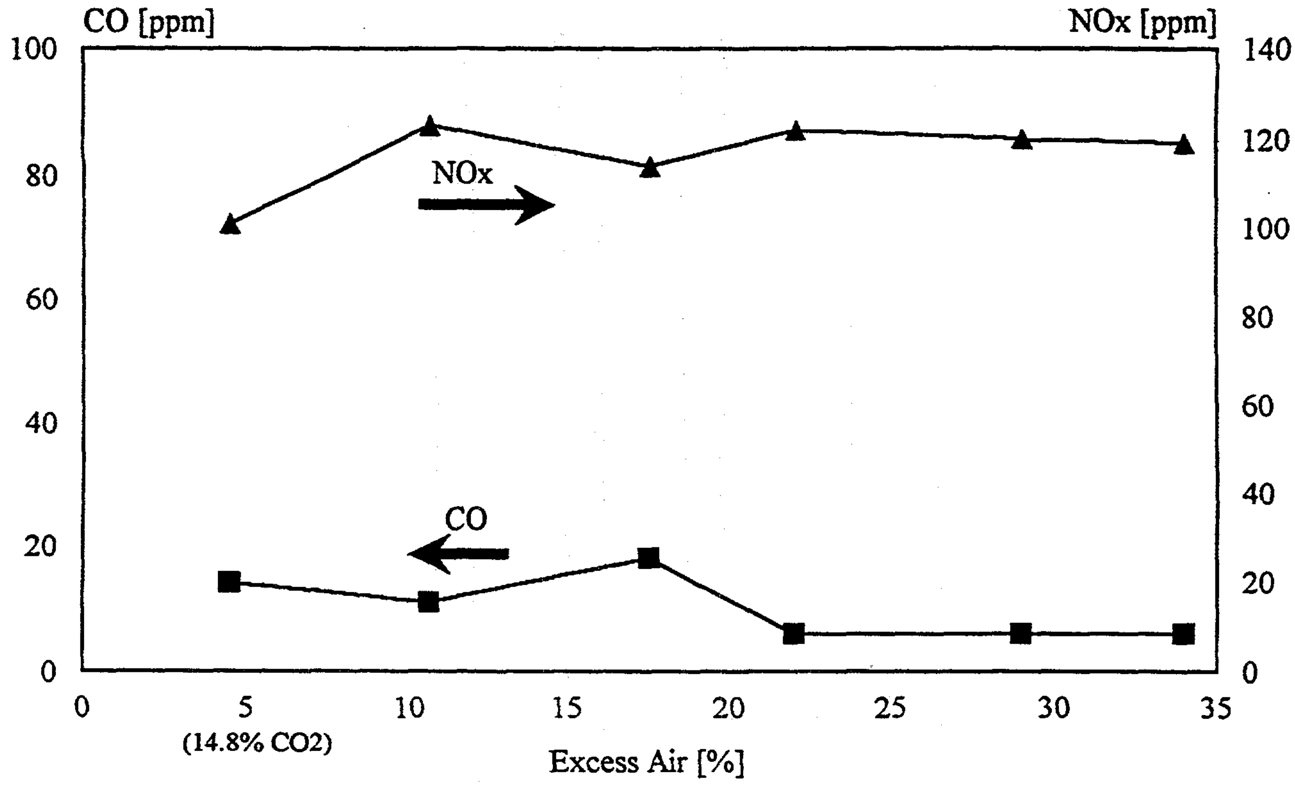


Figure 4. Example Test Results. Tests with Fan-Atomized Burner in two section, cast iron boiler. Gas temperature at the boiler exit.



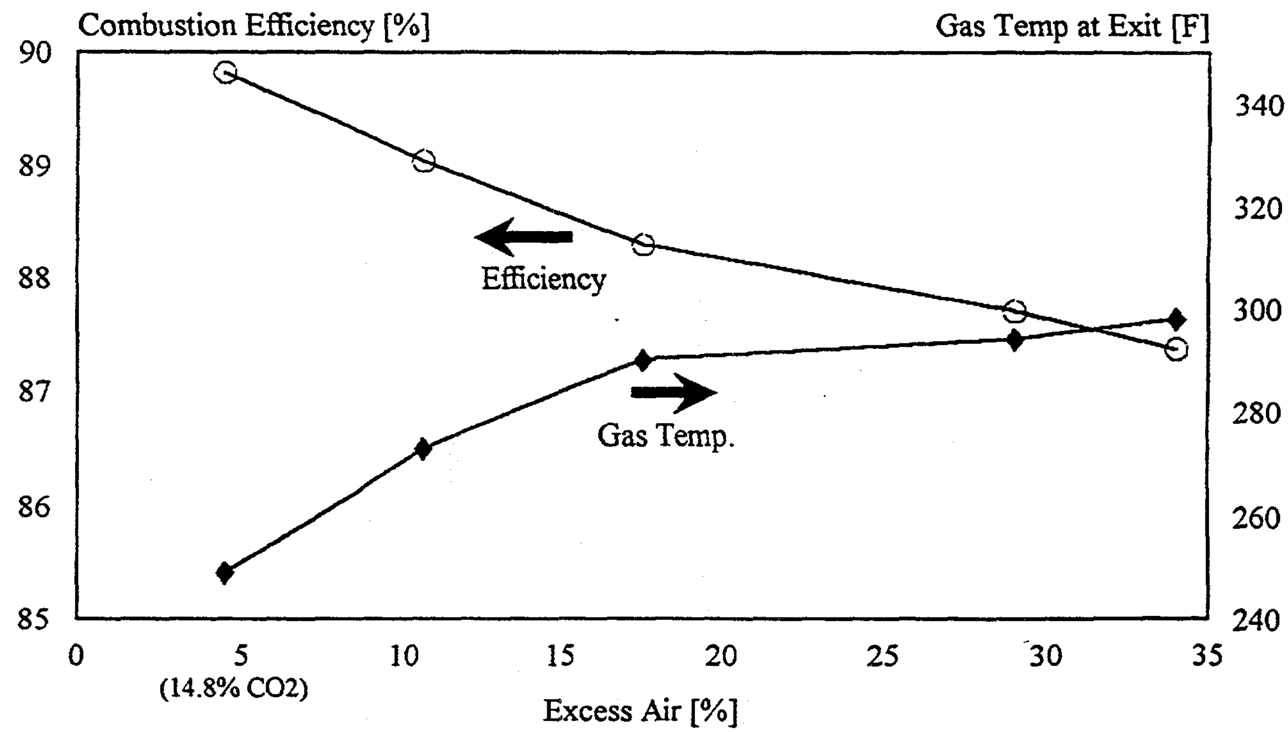


Figure 5. Example performance test results. Tests with Fan-Atomized Burner in center-flue water heater. CO, NOx, gas exit temperature, and combustion efficiency.

speed to change air flow and firing rate. This simpler approach will provide only a very limited turn down ratio (1.5:1). Costs, problems, and advantages of these approaches are being evaluated.

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Paper No. 95-6

FIELD TESTING THE PROTOTYPE BNL FAN-ATOMIZED OIL BURNER

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Introduction

BNL has developed a new oil burner design referred to as the Fan Atomized Burner System. [The burner's design and development are discussed in a companion paper, see paper No. 95-5.]

Industry representatives, members of the BNL Oil Heat Technical Advisory Group, met in October of 1994 to review BNL's latest progress in the ongoing design and development of the new burner system. Presentations were made detailing laboratory performance tests and results, as well as various design options for major components including pumps, blowers, etc. BNL also requested the group to provide comments regarding the commercial potential of the burner and any recommendations for future directions to investigate regarding design options. The group evaluated and agreed with a suggestion from the DOE and BNL program managers, that to gain the industry's attention and interest in the burner it should be field tested. A field test would demonstrate its capabilities under real world operating conditions, not just tested in the research laboratory. The same field tests would, of course, point out and key in on areas that require additional work providing focus and direction to future developmental activities as might be required.

The BNL Oil Heat Research and Development program has for over fifteen years presented the industry with the conclusion that the heating load of almost any average sized house could be met with a heating system with a firing rate input of less than 70,000 Btu per hour (0.5 gph). The new burner is designed to operate in the firing range of 0.3 to 1.0 gallon per hour (gph) equal to 40,000 to 140,000 Btu per hour input. BNL elected to put both its technology and long term stance about low firing rates to the test by proposing a field test of the new burner in a home with over 2,000 square feet of conditioned living space located on Long Island and do it with a firing rate of 0.3 to 0.4 gph (40,000 - 55,000 Btu per hour input). The test system was designed around a compact high efficiency side-wall vented hydronic boiler, see Figure 1, coupled with a well insulated 40 gallon indirect hot water storage unit. The domestic hot water unit was one of the many designs that are available in the marketplace. Its particular design uses an internal coil type heat exchanger immersed in the tank to transfer the heat supplied from the boiler water to the domestic water being heated and stored. It was installed in a separate boiler loop (zone) using a circulator pump to power the boiler water feeding the heat exchanger. The circulator was in turn controlled by a priority switch relay included in a multi-zone relay control installed in the heating system. This multi-zone relay unit also controlled the main circulator with its four zone valves used for the four heating zones located throughout the house.

The primary objective of the field study was to evaluate and demonstrate the reliable operation of the Fan Atomized Burner. The secondary objective was to establish and validate the ability of a low firing rate burner (0.3-0.4 gph) to fully satisfy the heating and domestic hot water load demands of an average household in a climate zone with over 5,000 heating-degree-days. The field activity was also used to evaluate the practicality of side-wall venting with the Fan Atomized Burner with a low stack temperature (300F) and illustrate the potential for very high efficiency with an integrated heating **SYSTEM** approach based on the Fan Atomized Burner.

Test Site

The test was located in Port Jefferson, NY on the north shore of Long Island and owned by one of the Oil Heat R&D staff who volunteered the occupied single family house for the test. Recently affixed to this ranch style home was a modest addition comprised of a family room over a new full basement with a ground entry basement doorway on the back side of a slope on which the home is located. The basement also has two windows on the back wall of the house adjacent to the new doorway, see Figure 2. One window would be used to install the side-wall vent terminal eliminating the need to drill a large and permanent hole through the concrete basement wall.

Experimental Plan

The plan was to be able to switch the house back and forth from the old boiler, a dry base steel unit from the 1960-69 era and subsequently retrofited with a flame retention head burner. A fuel meter was installed to monitor the oil consumption. Two Btu meters were installed to measure the thermal heat outputs produced by the system. The two Btu meters were used to measure the domestic hot water use as well as the energy used to heat the house in the baseboard units. Thermocouples were installed to monitor temperatures at various locations including the venting system. The vent was installed by lowering the top sash of a basement window and installing two metal plates in its place through which the vent terminal unit was mounted with threaded rods, washers, and nuts. This is definitely **not approved** for a permanent installation and was only used in this case after careful consideration keeping safety as the first concern. This experiment was conducted for only one month and was closely monitored on a daily basis by the homeowner, a BNL staff-member assigned to the Oil Heat R&D Project. A carbon monoxide detector was also installed in the equipment area to monitor the test site.

A series of valves and switches were arranged for simple switch-over from one heating unit to the other. This was typically accomplished in less than a minute. Figure 3 illustrates the hydronic switching valves and oil switching valves along with the placement of the Btu meter system that monitored the hydronic heat output to the four zones in the house. The domestic water was switched in same way and monitored with a second Btu meter. The house and its four heating zones were blind with regard to which system was providing the heat required. The Btu meter used is a self contained battery powered unit that measures the water flow through and temperature difference (supply and return) across the hydronic distribution system. The same type of unit measured domestic hot water use by measuring the water flow rate and the difference between the cold water in and the hot water out. Since one Btu is the amount of energy that is require to heat one pound of water one degree Fahrenheit, the Btu flow is calculated by multiplying the number of gallons, by 8.34 pounds of water per gallon, times the temperature difference in degrees Fahrenheit. The Btu meter does this automatically and indicates the running accumulated Btu total on its output display. A computer controlled data acquisition unit was used to measure and log temperature data measured at ten different points. Included were indoor, outdoor, stack, vent, and various water temperatures throughout the piping system.

Performance Results

The system successfully heated the home even on the coldest of nights during the 1994/95 heating season. These included a period of four days with windy nights and the thermometer readings in the single digits followed by day-time temperatures no warmer than 20F. Figure 4 illustrates the stack, supply water, and return water temperature profiles versus time, as measured during the recovery period following a night set-back in house temperature set-point. The data clearly indicates the ability of the 0.4 gph firing rate to satisfy this peak period heating demand. The cyclic pattern of the stack and water temperatures indicates that the burner is being turned on and off in response to the aquastat control. The limiting factor in the heating system's response to the load imposed by the night set-back recovery was the capacity of the baseboard units (heat convectors) to transfer heat into the various zones in the house and not the burners firing rate which was more than adequate to meet this peak demand.

The measured 24 hour period (cyclic) thermal input/output average efficiency data is presented in Figure 5 as a function of average output (load) in thousand Btu per hour units. The results indicate an overall efficiency gain of five to ten percent over the baseline heating system. The efficiency values with the Fan Atomized Oil Burner test system are lower than expected and may be attributed to a problem with the oil flow meter. Problems with the fuel system were persistent throughout the field study causing operational problems with the Fan Atomized Burner. This fuel meter will be replaced with a newly calibrated unit prior to subsequent field studies planned for the 1995/96 heating season.

The flue gas analysis measurements indicated a steady state stack efficiency of 89% with zero smoke, 13.5-14% CO_2, and 15% excess air (nominal) with firing rates of 0.35 to 0.55 as tested. The oxides of nitrogen were below 70 ppm and carbon monoxide in the flue products was less than 15 ppm.

Coking of the combustion head components was also observed and based on prior laboratory results this was not unexpected. During 1995 BNL is tasked and is currently working on refining the design of the combustion head and its components to improve both ignition and eliminate coking concerns. Excellent progress in this area has been demonstrated by laboratory tests. The new modifications to the burner's design will certainly be available in time for the planned 1995/96 field test and are expected to resolve the coking problem observed in the first field test.

Conclusions

The major conclusion of the field demonstration was that the Fan Atomized Burner did successfully heat a typical Long Island home and in addition provided a more than adequate supply of domestic hot water while firing at a maximum input rate of 0.4 gph (55,000 Btu/hr). It was able to meet and maintain the maximum heating loads demanded under design conditions for Long Island, NY with temperatures in the range of 0-10F and with a total of 5,500 heating degree-days per year.

The burner was reliable but, problems were noted with sensitivity to air entrained in the fuel system which caused several automatic burner shut-downs. This is being resolved by refining the design of the burner's fuel handling components.

The burner is extremely quiet during operation. One comment received from the occupants after the test had been concluded was "the noise in the basement is back," meaning the old heating system was again in use rather than the test system equipped with the Fan Atomized Burner. The other post test period comment/complaint was that the domestic hot water was no longer adequate. The family living in the home had experienced a plentiful supply of domestic hot water with the test system even though the burner was only fired at the low-input rate of 0.4 gph. The domestic hot water storage unit working with the boiler and the burner as a **system** had provided a more than adequate reserve capacity for all of the hot water demands including bathing, clothes washing, and dish washer use.

Future Activities

BNL is planning to propose follow-on tests of the Fan Atomized Burner utilizing the same test home during the 1995/96 heating season. The test boiler was left in-place with this in mind. The **field test laboratory facility** concept can be extended to other locations and lends itself to the study of: various **system** issues, multi-function oil-fired appliances, alternative domestic hot water generation concepts, testing side wall venting designs, and new control concepts. In the future BNL will propose expanding studies in the **field laboratory** to include these types of investigations.

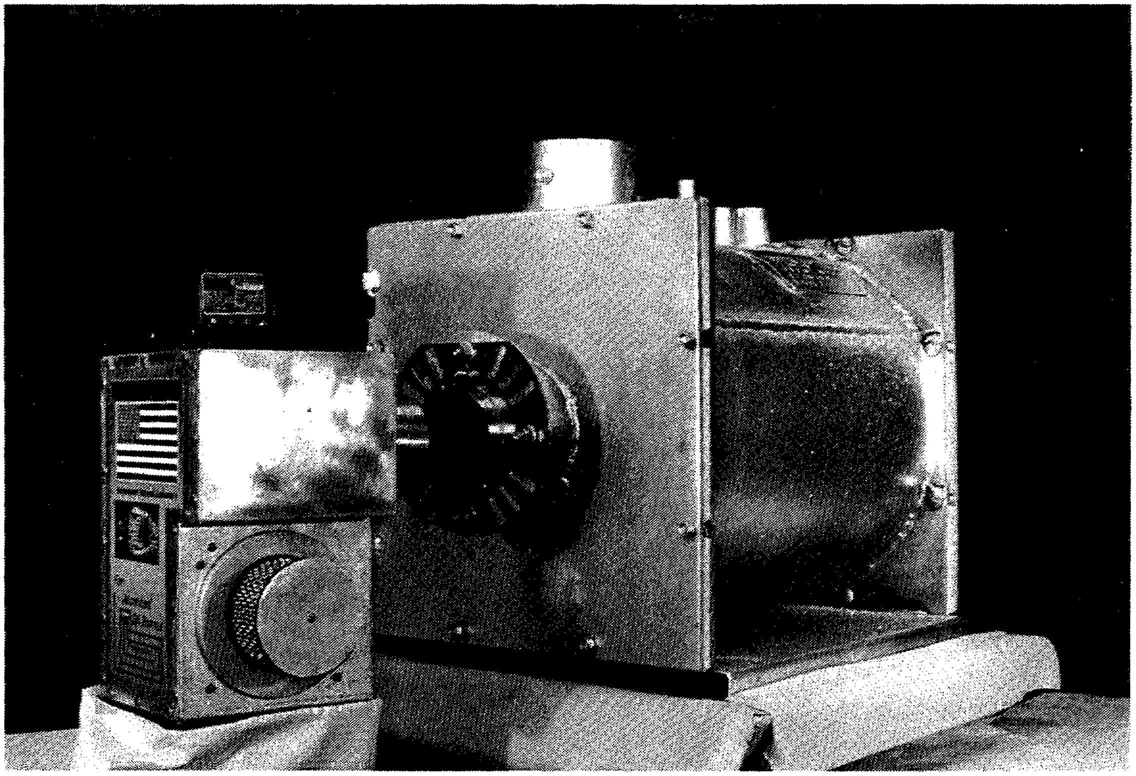

Figure 1
Fan Atomized Oil Burner and Compact Low Mass Direct vent Boiler Selected for Field Test

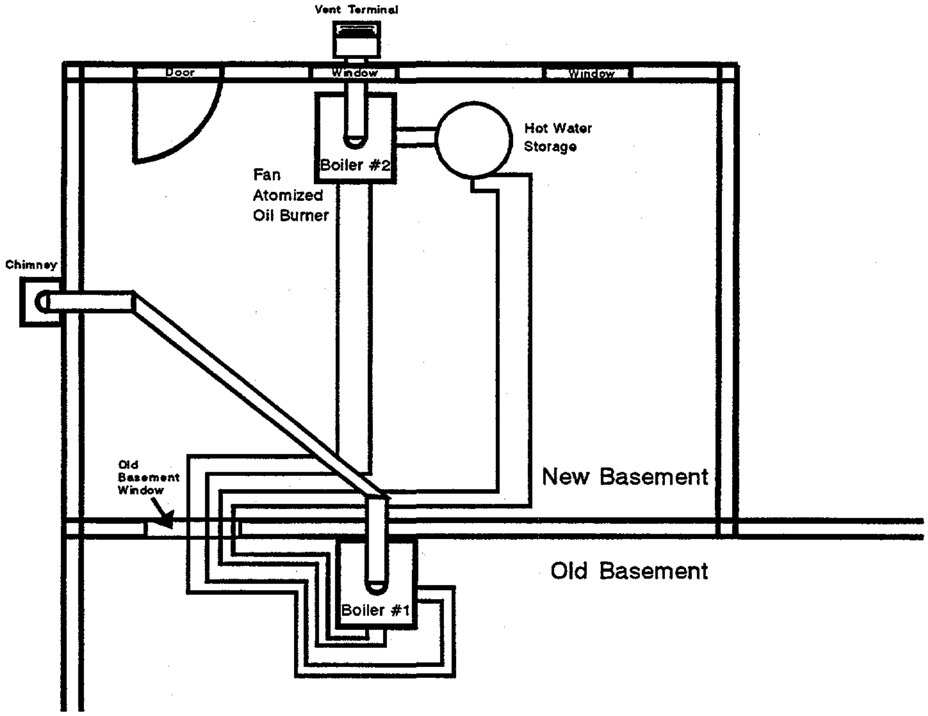

Figure 2 Floor plan layout of test site.

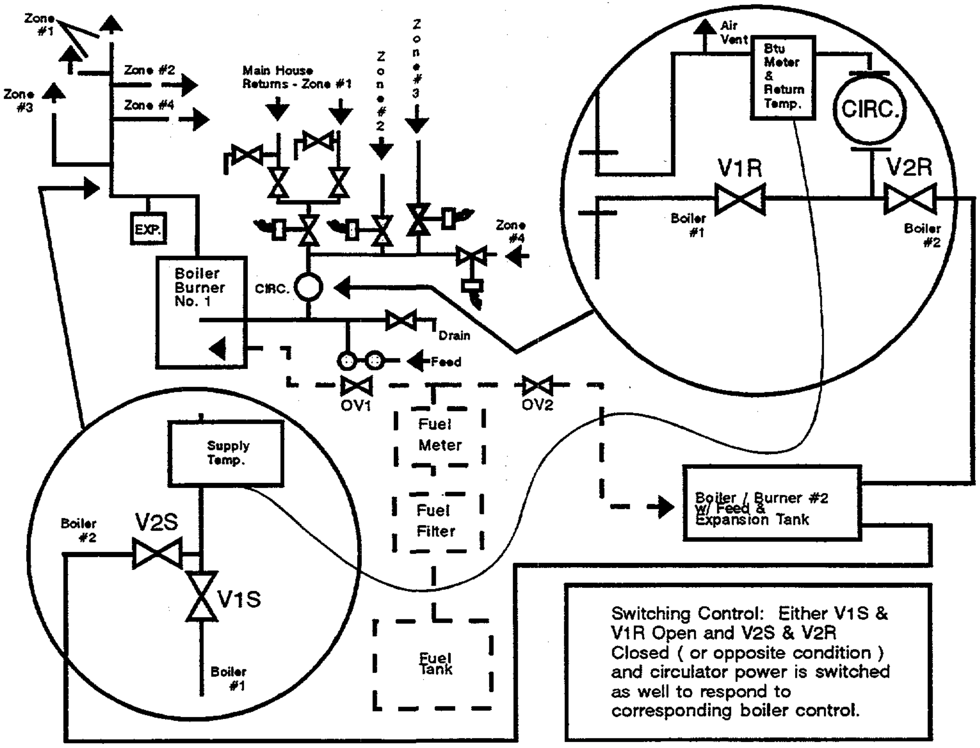

Figure 3 Switching for space heating.

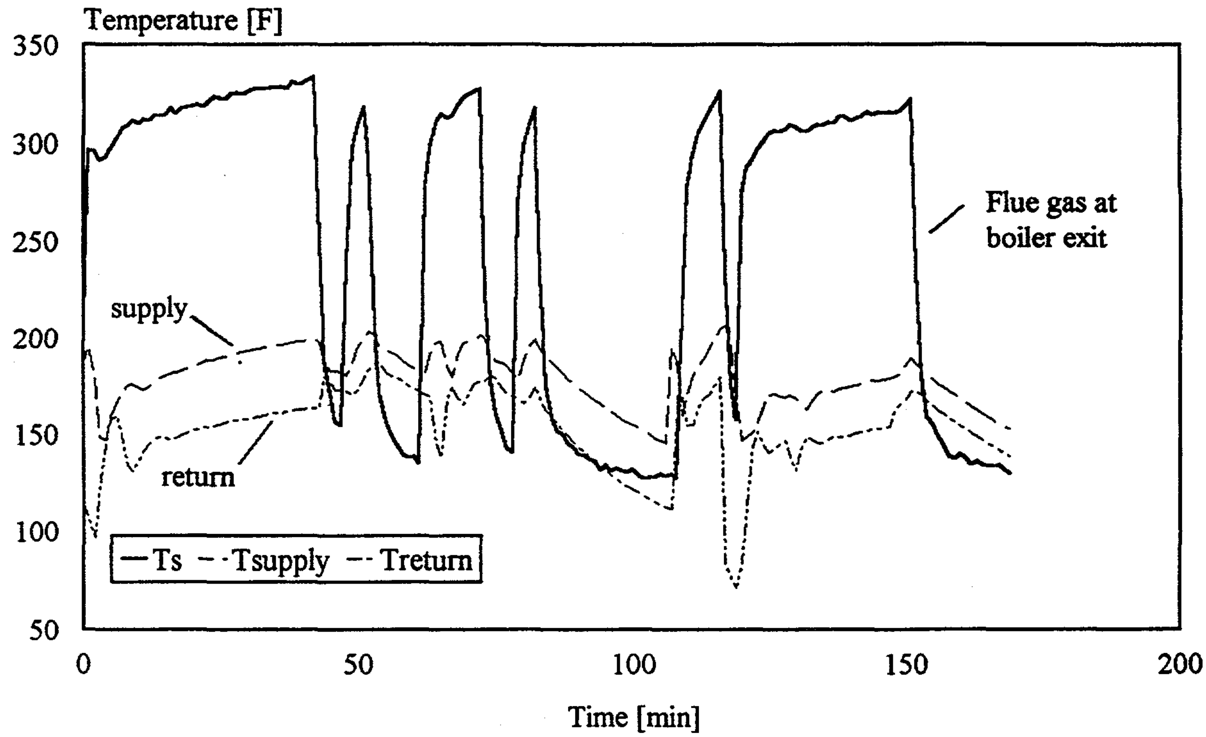

Figure 4. Illustration of Field Test System Response to Heat Call During Recovery From Night Time Setback. FAB at 0.4 gph.

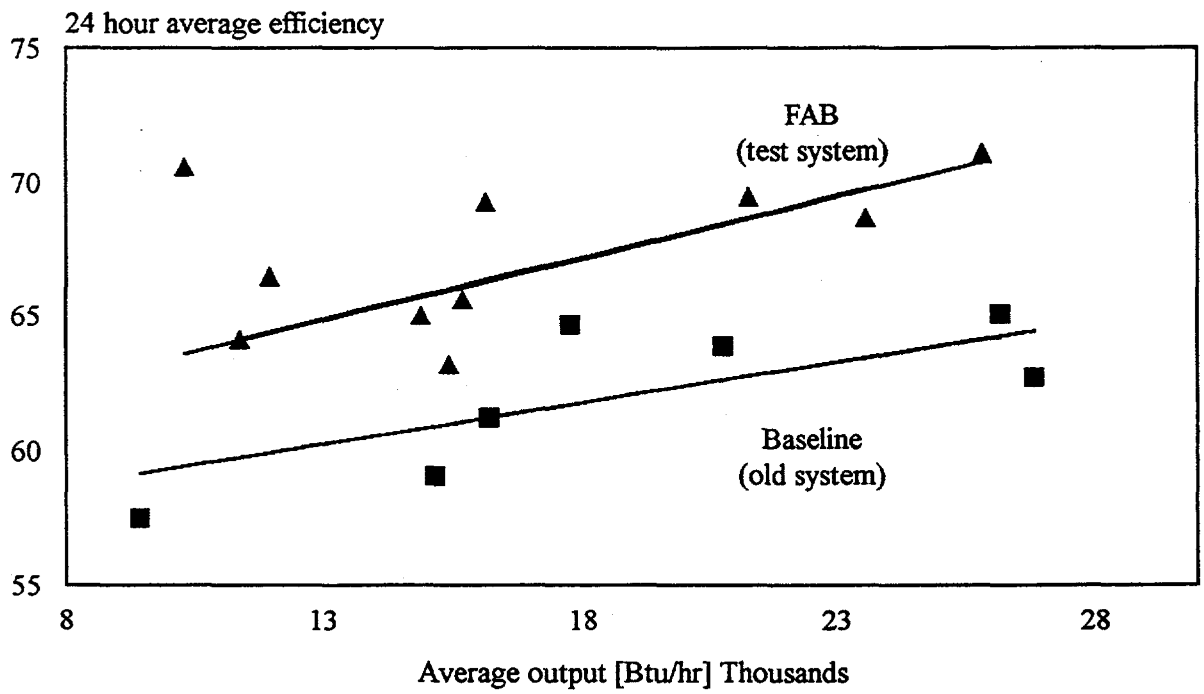

Figure 5. Comparison of Efficiency Over 24-hr Time Periods. Old System and Test System.

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Paper No. 95-7

FUEL SULFUR AND BOILER FOULING

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FUEL SULPHUR AND BOILER FOULING

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ABSTRACT

Fouling of the heat transfer surfaces of boilers and furnaces by "soot" leads to reduced efficiency and increased service requirements. The average level of annual efficiency reduction as a result of fouling is generally accepted as 2% per year. Improving the efficiency of equipment in the field may be the most important oil heat conservation opportunity at present. Improvements can be realized by reducing fouling rates, promoting lower firing rates in existing equipment, and enabling excess air levels to be set lower without raising concerns about increased service requirements. In spite of the importance of efficiency in the field there is very little data available on efficiency degradation rates with modern equipment, actual field operating conditions (excess air and smoke number settings) and service problems which affect efficiency. During 1993-94 field tests were initiated to obtain such data and to obtain information that would compliment existing and current laboratory work. Experimental work conducted on a bench scale level have included tests with various advanced burners, fuel types, and different operating conditions which have been done at the BNL Rapid Fouling Test Facility. This report will focus on the field study of fouling effects on ten residential heating systems local to BNL. The fouling rate, efficiency degradation, soot composition, and related service problems at each site are summarized. In addition, the technical difficulties involved with conducting such a field study shall also be discussed as the findings should serve to improve future work in this area.

INTRODUCTION

Brookhaven National Laboratory (BNL) has an ongoing project in atomization and combustion to study causes of soot fouling as part of the Combustion Equipment Technology Program. Reduced fouling of heat exchanger surfaces is one primary means of cleaner combustion and improved efficiency. The objective of this project is to determine the most important mechanisms that cause fouling and to identify practical methods to minimize the resulting deposits.

Earlier work at BNL has focused on the development of rapid fouling tests which permit fouling deposits to be repeatably weighed and analyzed. Preliminary studies were done using water-cooled stainless steel fouling probes. This was followed by the development of a test which uses temperature-controlled test sections cut from actual boilers and furnaces. This represents a more realistic fouling test than the stainless steel probes. Fouling deposits were formed on these test sections. In this test facility a metered part of the flue gas from a modified, conventional, steel boiler is passed over these small test sections which are maintained at a controlled temperature with water or air. In such a manner, realistic temperature cycles can be simulated. Routine analysis includes total deposit mass, soluble iron and sulfate. Iron sulfate is the principal component of the deposit. In some cases more detailed elemental analysis of the deposit has been done. The typical test period lasting about 24 hours allows for rapid evaluation of many cases.

Studies with the fouling test sections have included cast iron and steel boiler surfaces, and steel furnace sections. The effects of surface temperature, cycling pattern, excess air, fuel sulfur content, additives, and one surface-coating system have been evaluated [1,2]. Side-by-side boiler tests were conducted in 1993-94 in the BNL lab in which two identical boilers were operated under the same conditions to demonstrate, at full scale, the most important findings from tests of the small fouling test sections. Quantitative fouling rate tests in full scale boilers are more difficult because the heat exchanger surfaces are difficult to access for inspection and fouling deposit removal. For this reason these full size boiler tests last much longer. Evaluations of the effects of high and low water temperature (purge mode), fuel sulfur content, and ultra-low excess air operation were evaluated.

Taken together, the BNL laboratory tests and analyses provide important understanding about the mechanism of fouling of boiler surfaces and the following section provides a summary of this. The real magnitude of the efficiency cost associated with fouling, however, can only be evaluated through actual field measurements.

REVIEW OF FOULING MECHANISMS

The mechanisms which can most affect the accumulation of fouling deposits on heat exchanger surfaces include:

1. The condensation of sulfuric acid from the combustion products onto the heat exchanger surface followed by reaction of this acid with iron from the heat exchanger wall to form an iron sulfate scale product;

2. The deposition of carbon-rich soot from the combustion products onto the heat exchanger surface;

3. Corrosion of the heat exchanger by excess oxygen in flue gas.

Sulfuric acid is formed in combustion products directly from sulfur in the fuel. In the flame most of the sulfur from the fuel is converted to sulfur dioxide (SO_2) and exits the chimney without affecting the boiler or furnace heat exchanger surfaces. A small sub-fraction of the sulfur, however, is converted to sulfur trioxide (SO_3) in the flame. After the combustion products leave the flame zone this SO_3 reacts with water vapor to form gaseous sulfuric acid (H_2SO_4).

One important effect of the formation of sulfuric acid is the elevation of the dewpoint. In the absence of sulfuric acid water vapor begins to condense from the combustion products as the temperature is lowered to about 125°F (depending upon excess air - higher excess air = lower dew point). With sulfuric acid in the combustion products the dew point is raised to about 230°F. As the temperature is lowered through this point a concentrated acid/water mixture begins to condense. The concentration of the acid condensed depends upon the temperature, with concentration decreasing as the temperature decreases. For temperatures between 125° and 230°F the condensation rate is very low although the condensate is highly corrosive. Below 125°F the condensation rate increases greatly and the acid concentration is very low.

If the temperature of the surface of a boiler or furnace heat exchanger is between 125° and 215°F (the normal condition in heating boilers) the concentrated sulfuric acid/water mixture will condense on this surface even when the average temperature of the combustion products is much higher. In this case the primary corrosion mechanism is direct attack of the iron by the sulfuric acid to form iron sulfate scale, $FeSO_4 \cdot H_2O$.

With acid corrosion in this way the rate of corrosion and scale formation is primarily limited by the rate at which the acid condenses on the surface. This, in turn, is dependent upon the acid concentration in the combustion products and the local heat transfer rate (higher heat transfer rate = higher acid condensation rate).

For a given combustion chamber and firing rate the amount of acid produced by the flame depends upon the fuel sulfur content and the excess air level. This situation is generally illustrated in Figure 1 which shows the results of some recent measurements made at BNL with a fuel with a normal sulfur level, 0.18%, and a very low sulfur content fuel, 0.03%. With the higher sulfur content fuel measurements were made over a range of excess air settings. With the low sulfur content fuel measurements were made only at a high excess air level. These tests were done using a conventional retention head burner, firing in steady state (no cycling) into a wet-base, steel boiler. Measurements of the flue gas sulfuric acid concentration were made using a standard test method - the controlled condensation technique[3].

The second fouling mechanism discussed above is the deposition of soot on heat exchanger surfaces. In the early 1970's Battelle Columbus Laboratory [4] explored correlations between soot concentration and smoke number. They found that reasonable correlations could be made for a single appliance but a general correlation covering both steady state and cyclic operation could not be found. Figure 2 shows some example results from the Battelle work in steady state.

For the test conditions shown in Figure 1 measurements of soot concentration in the combustion products were also made (at BNL). Results are shown in Figure 3. In Figures 1 and 3 the smoke number = 0 for all tests except the lowest excess air point where smoke number =4. Comparison of figures 1 and 3 shows that at high excess air the concentration of sulfuric acid in the combustion products is higher than the soot concentration. With low excess air, and elevated smoke numbers the opposite situation exists.

The concentration information in Figures 1 and 3 begins to give some idea about the relative importance of acid and soot in the fouling process. It is also necessary, however, to consider the ways that acid and soot diffuse thorough the gas to the surface. Acid molecules are small and can get to the surface by molecular diffusion. Soot particles are relatively large and so have lower diffusivities - by a factor of 10^5. A mechanism which can drive significant amounts of soot to the surface, however, is thermophoresis - the motion of a particle in a

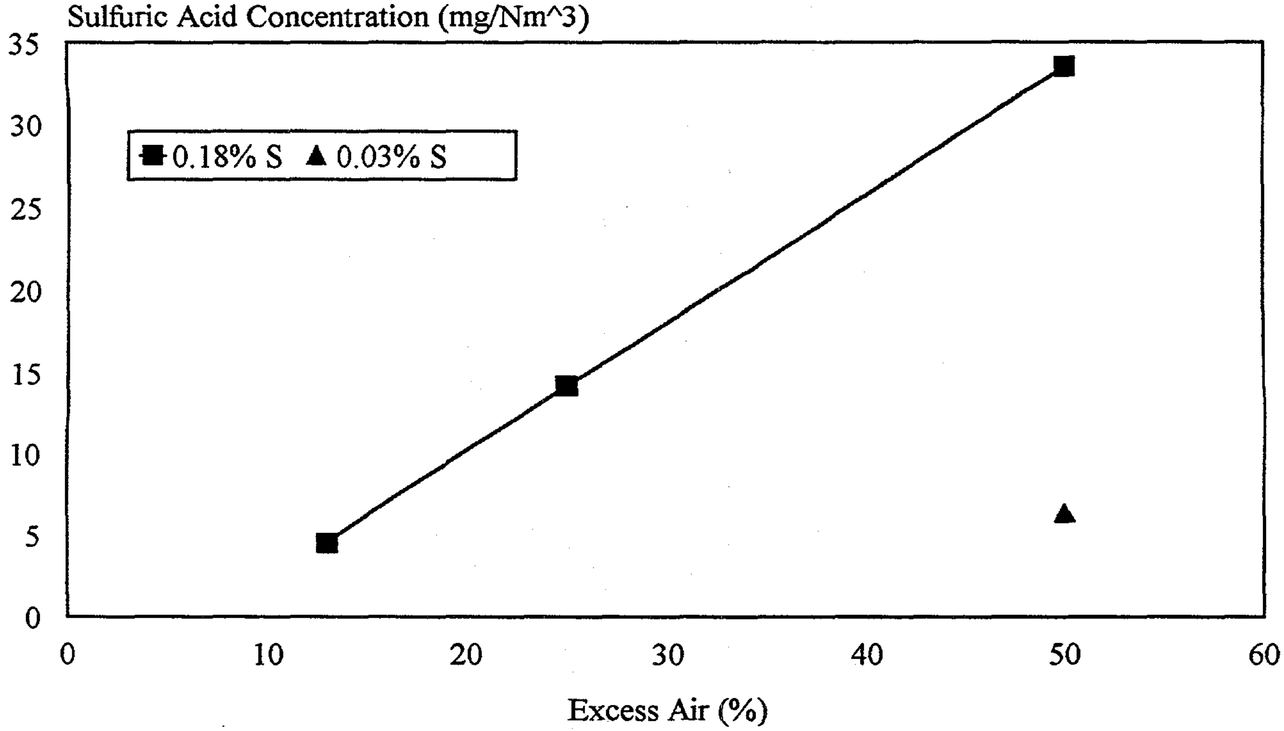

Figure 1. BNL Fouling Test -acid concentration at the test section inlet with normal and low sulfur fuels. Smoke number = 0 for all tests except the lowest excess air. At this condition smoke number = 4.

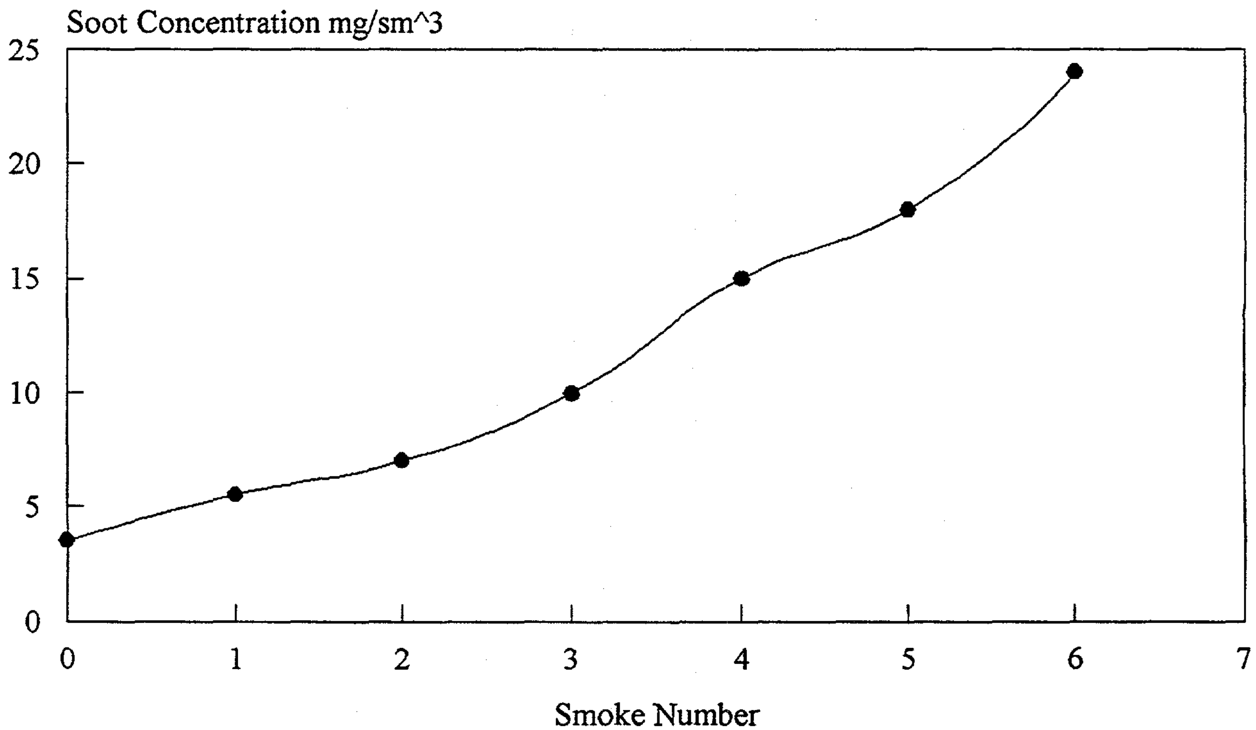

Figure 2. Correlation between smoke number and soot concentration based on Reference 4.

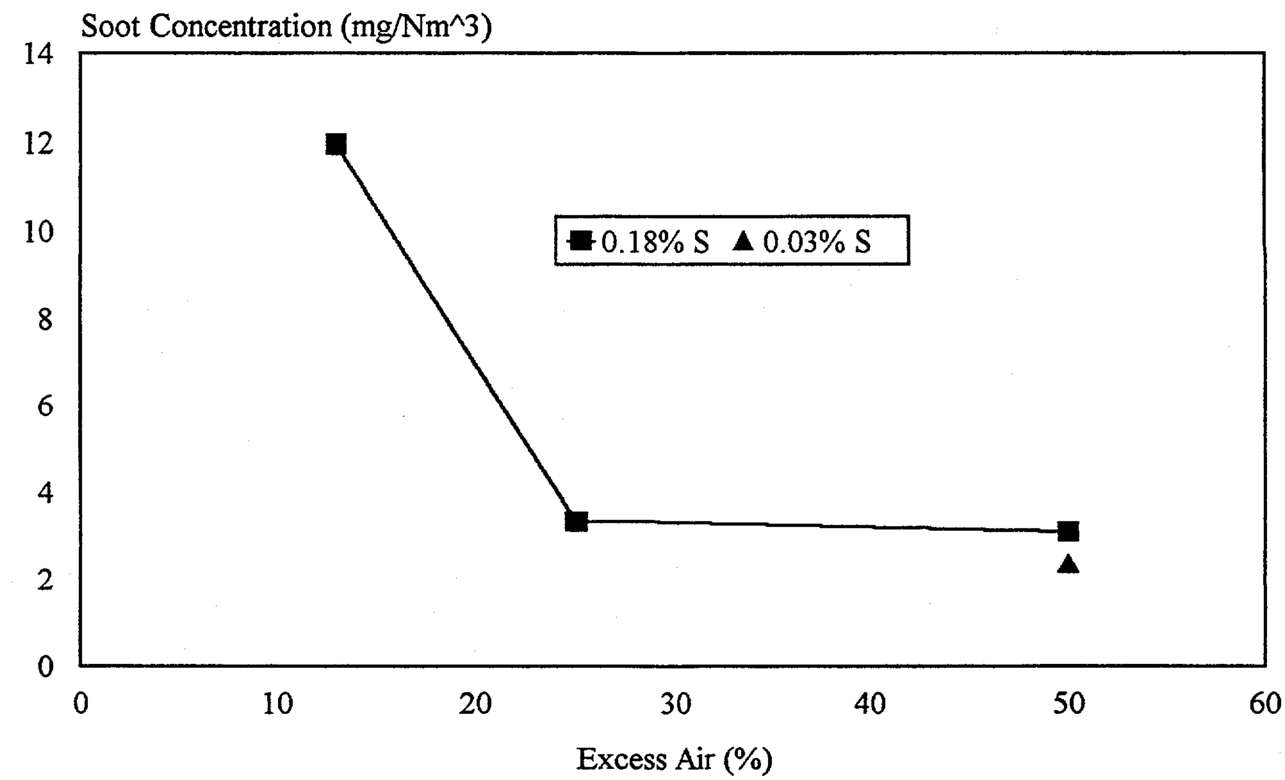

Figure 3. **BNL Fouling Test - soot concentration at the test section inlet with normal and low sulfur fuels. Smoke number = 0 for all tests except the lowest excess air. At this condition smoke number = 4.**

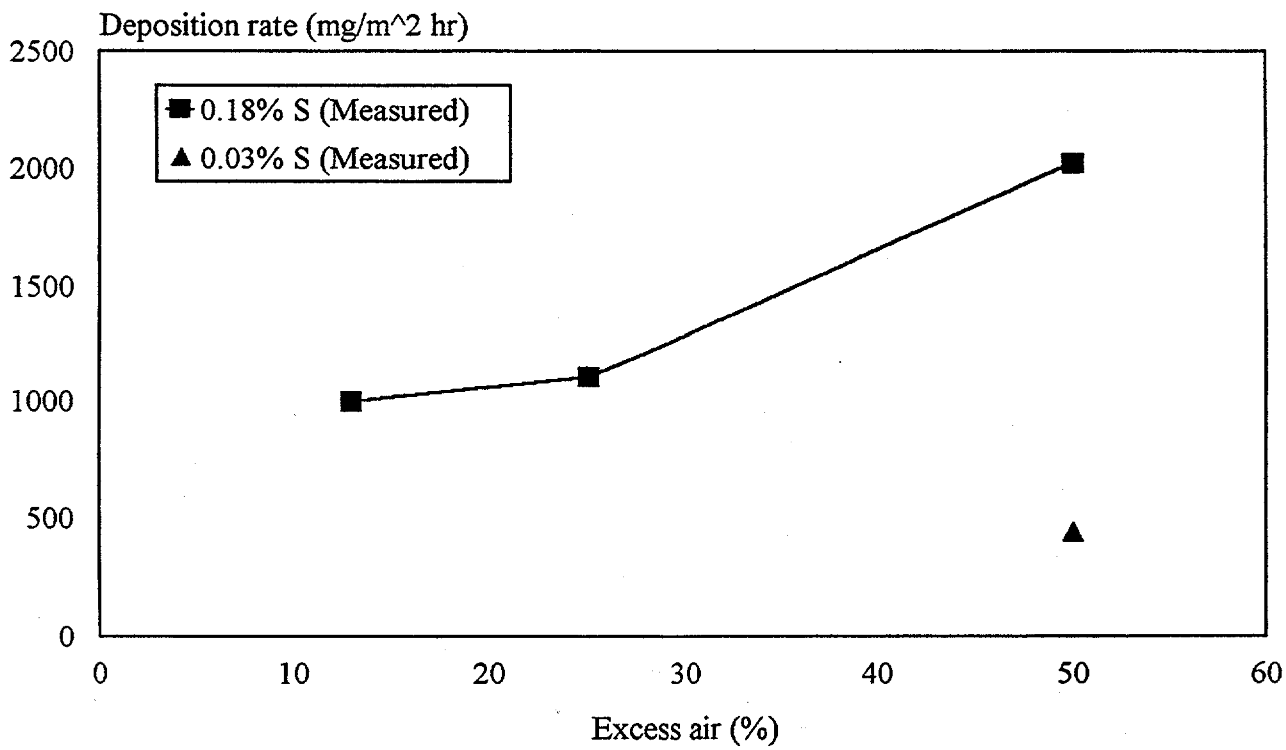

Figure 4. BNL Fouling Test - Fouling rate with low and moderate sulfur fuels. Smoke number = 0 for all tests except the lowest excess air. At this condition smoke number = 4.

temperature gradient. This mechanism leads to cold surfaces (cold relative to the surrounding gas) becoming coated with dust or other particles while hot surfaces remain clean. To further complicate matters, under some conditions the acid may form very small aerosol drops in the combustion products. These drops would have lower diffusivities than the molecules.

Perhaps the best way to evaluate the relative importance of soot and acid in fouling is experimentally and the BNL Rapid Fouling Test Facility has been used for this purpose. Figure 4 shows the results of fouling measurements made simultaneously with the acid and soot concentration measurements of Figures 1 and 3. All of the tests were done in steady state. The trends, reducing fouling with both excess air and fuel sulfur content, suggest the dominance of sulfuric acid in the fouling process. Chemical analysis of deposits removed from the surfaces indicate that nearly all of the material was iron sulfate.

To further evaluate the role of sulfur in surface fouling longer term fouling tests were done using identical, side-by-side cast iron boilers operating in the BNL lab under controlled cycling conditions. One boiler was operated with 0.9% S oil and the other with 0.18% S oil. The viscosity and other relevant properties for the two fuels were the same. After three months of continuous, cyclic operation the boilers were inspected and cleaned. The mass of soot deposit was 3.6 times greater with the higher sulfur fuel. Analysis of deposits removed from these boilers indicates that a little over half of the deposit mass is iron sulfate scale and the remainder is carbon. In comparison to the steady state fouling tests discussed above this is a much greater carbon fraction and it is likely that this results from startup and shutdown soot. This test is now being repeated with 0.18 and 0.03% S fuels and results should be available in April, 1995.

The purpose of the field test program discussed below was to extend the BNL laboratory results to fully realistic conditions. A baseline of information was established as a result of the field testing conducted by BNL during the 1993-94 heating season by which future improvements as a result of changes to fuels, burner types and operating conditions can be measured. This report provides a description of the details and results of this field test.

FIELD TEST STUDY METHODS

Field Test Setup

These field tests were initiated to obtain better information than is currently available on the rate of efficiency degradation due to fouling. This will allow improved estimates to be made of the benefits of current technologies which lead to reduced fouling.

Field measurements were made in ten homes over one heating season. At each home BNL conducted a preseason inspection, cleaning, and recorded a set of baseline measurements. Flue gas temperature trends were monitored for several days before and after the cleaning. Measurements were also made of flue gas oxygen content and draft both in the chamber and in the flue before and after cleaning. One purpose of the careful before and after measurements was to get a preliminary estimate of the efficiency gain with cleaning. In some cases the nozzle was changed and/or excess air was changed during the setup procedure and in these cases a comparison of stack efficiency before and after is not really meaningful. Before cleaning the average flue gas temperature was 593°F and values ranged from 445° to 708°F. During test setup all units were adjusted to operate without smoke as measured by the Bacharach Smoke Scale. The average excess air level was 46% and values ranged from 29% to 64%. For those sites which had the same flue gas oxygen level before and after cleaning the average reduction in gas temperature with cleaning was 50°F, corresponding to roughly a 1.5% efficiency increase. The average pressure drop across the heat exchanger before cleaning was 0.02 inches of water. After cleaning the average pressure drop across the heat exchangers was less than 0.01 inches of water. These sites were monitored on a periodic basis throughout the heating season.

Tables 1 and 2 provide a description of each of the test sites and the measured parameters. The boiler types range widely over most that are commercially available. All sites have conventional retention head burners which fire No. 2 heating oil.

During the heating season BNL was notified by the homeowners of any service requirements at the sites and made inspection visits when unusual circumstances occurred. At the end of the heating season BNL repeated these measurements to quantify efficiency degradation. The heat exchangers were exposed for inspection and carefully cleaned. The total mass of fouling deposit was determined by collecting the material in a fresh pre-weighed vacuum cleaner bag. Seasonal fuel use at each site was also recorded. Data is provided in the next section of the report along with a discussion of the results.

For three of the test sites detailed analyses of the deposits were also done to determine its elemental components and compounds. This information is not only useful for gaining a better understanding of the mechanisms of fouling but has also been used with the results of the BNL lab studies to predict fouling rates.

RESULTS

Stack Temperature Trends

Stack temperatures at each site were tracked throughout the heating season to determine whether fouling rates could be determined by changes, or rises, in the temperatures. Figure 5 shows the maximum observed flue gas temperatures during normal operation for eight of the ten sites. As shown, the changes varied considerably from among the sites. The monitoring began right after the initial cleaning of the boiler.

Table 1. Description of Test Sites

Site	Boiler Type	Heat Exchanger Type	Firing Rate-gph
YC	wet base, steel	horizontal firetube	0.75
TP	wet base, cast iron	pin construction	0.85
JW	wet base, cast iron	pin construction	1.00
BP	wet base, cast iron	pin construction	0.75
CK	wet base, cast iron	pin construction	0.85
RK	wet base, cast iron	pin construction	0.85
TB	dry base, steel	vertical firetube	0.65
LS	dry base, steel	vertical firetube	0.9
MB	dry base, steel	vertical firetube	0.65
WL	dry base, steel	vertical firetube	0.85

Table 2. Baseline Measurements for each Site - Beginning of the Heating Season

Site	Initial peak stack temperature, F	Initial $\%O_2$	Initial Excess Air, %	Pressure drop across heat exchanger in. water
YC	460	6.1	38	0
TP	560	7.9	56	0
JW	571	5.0	29	.025
BP	600	5.0	29	0
CK	477	7.7	54	0
RK	581	7.2	49	0
TB	420	8.3	61	.007
LS	533	6.9	46	.003
MB	685	8.5	64	.02
WL	440	5.7	35	.015

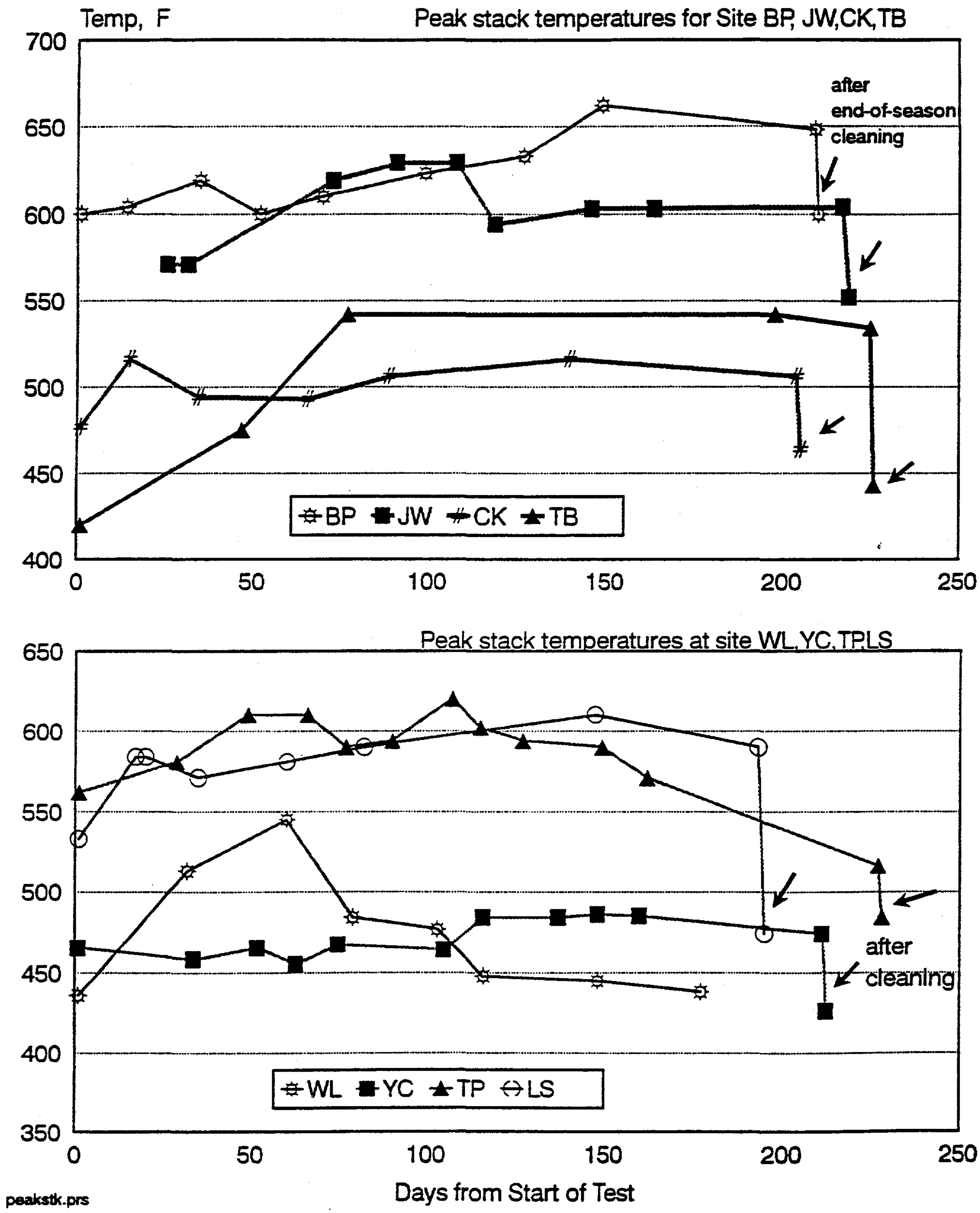

Figure 5. Field Fouling Studies - Peak Stack Temperatures Observed at 8 Sites

Inconsistent trends were observed at two of the sites, not shown, and it is believed that the servicing required in the middle of the season, which included change of nozzle and other components, may have resulted in a sudden shift in temperature ranges. Although it seems that there is a general rise in temperature at the end of the season (before the final cleaning of the boiler) as compared with the beginning, this is not so obvious from the trends. In fact, there is so much fluctuation between the temperature measurements that trying to determine fouling rates from these values was not possible. The variations are about the same magnitude as what we would expect for the efficiency measurement. The fluctuations in temperatures is mostly attributed to frequency of burner cycling, which varies depending on the load requirements throughout the season. For rapid consecutive cycles in which a burner has a short "off" period stack temperatures tend to be higher than for repeating cycles in which there is a relatively long cool down period in between. Temperature measurements would then be dependent on when and how they are recorded.

In some cases, a consistent set of values can be obtained if operating conditions can be controlled. For example, if there is thermostat set-back during the night and only early morning on/off cycles were analyzed the data obtained may show a definite trend. This is the case at Site BP where the burner is essentially shut off overnight and turned on early in the morning. In this case, the boiler load and the operating conditions, such as combustion chamber temperature (essentially cold), are very similar each morning.

End-of-Season Measurements

Cleanup and final inspections were conducted at the end of the heating season. At each site the boilers were opened for photographs and collection of samples for analysis. Table 3 provides the information gathered at each of the test sites. The difference in observed peak temperatures at the beginning of the season after cleaning of the boiler convective sections and at the end of the season before cleaning of the boiler is expressed as ΔTpeak. The average peak temperature rise was 50°F; the average amount of soot collected from each site, excluding that from Site WL, was 134 grams. The pressure drop across the heat exchanger was measured before the final cleaning of the unit; the average was 0.013 inches of water. Fuel use was approximated based on the deliveries made during the season. These results do not show a clear correlation between the amount of soot collected and the stack temperature rise (ΔTpeak), fuel use, or type of heat exchanger.

The most dramatic change during the season occurred at site TB with rise in peak stack temperature of 114°F. After the final cleaning of the heat exchanger the flue gas temperature returned to levels observed at the beginning of the season. No significant change in excess air occurred during the season. Pressure drop across the heat exchanger increased during the season from less than 0.01 inches of water to 0.03 inches of water. The total mass of soot removed from the heat exchanger was 254 grams. The deposits were generally light in color, indicating minimal carbon content.

At site WL measurements at the end of the season were not made because the boiler was found to be severely sooted. Normal procedures called for a set of performance data to

Table 3. End-of-Season Measurements at Test Sites

Site	Peak stack temp at end of season, F	ΔT peak F	Total Soot Deposit Collected (gm)	Season Oil Use (gallons)	Final $\%O_2$	Pressure drop across heat exchanger in.of water
YC	485	25	203	400	6.7	.005
TP	571	11	240	784	7.8	.005
JW	604	33	43	700	6.2	.018
BP	655	55	113	450	4.7	.01
CK	512	35	122	617	7.5	.002
RK	673	92	40	ND	7.8	.015
TB	534	114	254	600	8.2	.03
LS	600	67	108	480	7.8	.01
MB	700	15	80	800	8.2	.02
WL	ND	ND	813	550	ND	ND

ND - No Data

be taken before the final cleaning started. This could not be done since smoke was obviously entering the house from the back-pressured combustion chamber. The homeowner was very surprised and had not noticed anything unusual with the burner prior to the final inspection visit. Upon exposing the heat exchanger sections the unit was found to be totally blocked. The total mass of soot removed was 813 grams and this was very black in appearance, clearly indicating a high carbon content. An analysis of its composition, as discussed later, verifies this result.

Efficiency Degradation

To estimate an efficiency loss due to fouling for each boiler unit it is most useful to look at the temperature difference before and after cleaning of the heat exchanger sections at the end of the season. The reason for this is that operating conditions and other seasonal variations do not change much within the short time span during which monitoring is done. In most cases, temperatures are recorded over a 24-hr period before and after the cleaning. Typical stack temperatures are reported in Table 4 for eight sites. Insufficient information was obtained for two of the sites; as mentioned earlier, measurements at one site could not be obtained because of extreme sooting.

These stack temperatures were carefully selected during similar conditions of normal burner operation. If the burner remains off during a cycle for approximately one hour before the next "on" cycle the boiler can adequately cool down to a steady level. The temperature at about 5 minutes after the burner starts or when it reaches steady state during the next "on" cycle was then selected. These temperature profiles have been found to be very reproducible when compared with those of other similar cycles during the same monitoring period.

Table 4. Efficiency Loss Determination Based on Stack Temperatures Before and After Boiler Cleaning

Site	Stack temp before final cleaning	Stack temp after final cleaning	ΔT after final cleaning	Efficiency loss due to fouling, %
YC	468	406	62	1.9
TP	487	455	32	1.0
JW	589	533	56	1.7
BP	603	563	40	1.2
CK	473	436	37	1.1
TB	502	402	100	3.0
LS	581	456	125	3.8
RK	668	565	103	3.1

The data obtained for all sites indicated that efficiency losses due to fouling ranged from 1% to less than 4% with an average of 2%. These results were derived from testing over one heating season with an initial cleaning of the boilers.

Analyses of Soot Deposits

At three test sites the deposits collected from the final cleaning of the boiler convective sections were analyzed to determine its elemental components using Electron Spectroscopy Chemical Analysis (ESCA), and its dominant compounds using infrared spectroscopy. The results from ESCA are provided in Table 5.

The composition of the deposits at Sites LS and JW are representative of that from a typical boiler with the heating system operating normally without major servicing problems throughout the season. At site WL, as mentioned previously, excessive sooting and blockage of the convective sections occurred at the end of the season . This is clearly indicated by the greater amount of carbon in the deposit taken from this site.

Based upon infrared analysis for all of the listed sites the most dominant compound is $Fe_2(SO_4)_3 \bullet 9H_2O$ in every case. No other corrosion products have been identified highlighting the importance of sulfur in the scale formation process.

Table 5. Composition of Soot from 3 Sites

Weight %	Site WL	Site LS	Site JW
S	3.3	7.2	9.2
C	78.0	53.3	45.9
N	3.0	3.5	5.9
O	15.2	34.4	37.7
Fe	0.5	1.6	1.2

At all of the sites the sulfur/iron ratio is significantly higher than for the iron sulfate corrosion product identified by infrared analysis (0.857). It seems likely that much of the sulfur is present as acid which has not yet reacted with iron from the boiler. If this is the case then the corrosion reaction that takes place to form scale will continue if the deposits remain on the iron surfaces of the heat exchangers even if there is no accumulation of additional deposits. Further tests and chemical analyses can be done to evaluate this hypothesis. A test site can be selected which has a boiler that provides heat to the residence and a separate hot water heater. Some of the deposits can be collected from the boiler at the end of one heating season (during the spring) with the remaining to be collected at the end of that summer. During summertime the boiler would remain idle. If the scaling process continues on the boiler with the residual deposits then a higher iron concentration at the end of summer would be expected.

DISCUSSION ABOUT FIELD TESTING

Field testing can be encumbered with factors that affect data accuracy and should be considered when evaluating the information. From these tests, one of the factors which could lead to error is the measured total amount of soot collected from the boiler heat exchanger sections. Although a great deal of care was taken to remove the deposits the configuration of these sections and its accessibility limited our ability in collecting absolutely all of the materials. The information reported earlier as total soot collected can therefore only provide approximate values from the units. With the small sample of data it is not surprising then a correlation was not found between total soot collected and efficiency degradation.

The numerous factors which may be related to seasonal changes, modes of heating system operation, or the sudden upsets to heating units requiring service calls can make it very difficult to monitor specific trends. For example, as discussed earlier, stack temperatures throughout the heating season are difficult to track because of the variations in the types of firing cycles encountered. As a result, efficiency degradation due to fouling was best estimated based on end-of-season cleaning and temperature change. Problems encountered during the heating season that required servicing included plugged fuel filters, nozzles, and oil accumulation at the bottom of the burner head tube. The most severe problem occurred at Site WL with the blockage of the boiler convective sections in which big differences were observed in terms of soot composition and total amount of soot collected when compared with the other test sites.

FUTURE WORK

Plans for further work during 1995 in the area of fouling include additional evaluation of low sulfur fuels (<0.05% by wt). Most of the fouling tests will be conducted in the laboratory with two side-by-side cast iron boilers over a period of several months. Typical fuel oil with about 0.25% sulfur will be fired into one boiler while low sulfur fuel will be used in the other under the same operating conditions. Prior studies done in 1993-94 have included tests with 0.75 % sulfur oil. Long-term testing over several months will also be conducted with an advanced burner, developed at BNL, using ultra-low excess air and compared with conventional retention head burners. In cooperation with one local oil company a limited field test may also be conducted in which part of their customers will receive only low sulfur fuel oil during the heating season. BNL will support this effort by performing cleanups, testing and analyses of boiler deposits.

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Paper No. 95-8

PROPER USE OF SLUDGE-CONTROL ADDITIVES IN RESIDENTIAL HEATING OIL SYSTEMS

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ABSTRACT

Discussed are various aspects of heating oil "sludge": How it forms, typical problems it causes, how sludge-control additives work, what should be expected of them, and what happens in a contaminated system when such additives are used. Test results from laboratory and field experiments demonstrate that performance of commercially available additives varies greatly. The concept of "end-of-the-line" treatment is described and compared with bulk fuel treatment. A procedure is described whereby a retailer can test additives himself, and thus determine just what those additives will or will not do for his business. Finally, the economics of an effective treatment program are outlined.

INTRODUCTION

In the competitive marketplace of residential heating, oil is portrayed as the "dirty and smelly" alternative to gas and electricity. This image, while largely undeserved, is unfortunately strengthened when oil heat customers have fuel-related problems which lead to poor combustion, plugged filters and oil fumes in the home. Current concerns about corrosion of oil storage tanks add still more incentive for homeowners to consider alternative fuels for new homes — or switch to those alternative heating methods from present oil systems.

Oil dealers are partly at fault for allowing these images to survive. They have typically ignored fuel contamination issues, preferring instead to believe that "only customers who buy oil from our competitors have problems with fuel contamination." Interviews with homeowners have shown, on the other hand, that those customers simply believe that their oil dealers don't care, and either go elsewhere for their service, switch to "more caring" dealers for oil *and* service, or attempt to treat their own problems with store-bought additives.

Unfortunately, fuel additives have earned a bad reputation among retailers, and this has inhibited their use. Many commercial products are offered, some claiming "miracle cures" for all fuel ills. There is an understandable reluctance on the part of dealers to spend money to treat fuel when one's competitors are not doing the same. The cost of such treatments come right off the dealers "bottom line," and do not often justify charging a premium price for that fuel to recover the cost.

The fact is, oil dealers who sell service contracts have an option that is both effective and immediately cost-effective, and that option is targeted "end of the line" treatment with sludge-control additives. This paper presents evidence to that effect.

THE ORIGIN AND NATURE OF SLUDGE

"Sludge" has been seen by every oil service technician, but most believe that it represents some sort of tank bottom contamination that is literally transferred downstream from refineries, pipelines or terminal operations. In fact, this is only partly true. Sludge is the end result of biological contamination of fuel oil, and it actually *grows* in storage facilities. This includes not only upstream bulk storage tanks, but also local distribution tanks and, most importantly, home storage tanks.

One essential factor for growth of sludge is water. All fuel oil storage tanks breath outside air through a tank vent. As fuel is removed from a tank, air containing moisture is drawn in to replace it. When the temperature drops, this moisture condenses in the tank. Because water and fuel oil generally don't mix, and because water is heavier than fuel oil, the condensing water goes to the bottom of the tank. Certain types of bacteria which are commonly found in the environment find their way into the fuel and then into the water droplets. These bacteria "exist" in the air, in the soil, and are almost always detectable in even the cleanest looking fuel. They can exists without growing for very long periods of time — even years — until they find condition suitable for growth. At this point they start to grow and multiply. If conditions are just right, many common types of bacteria double in number every twenty to thirty minutes. At this rate, it does not take long for a large population to grow from just a few organisms. (One single bacterium, doubling in number every 30 minutes, will number over a million cells in just ten hours!)

The bacteria that cause fuel contamination grow in the water droplets but feed off certain fractions of fuel that permeate into the water. They break this fuel down, producing a variety of fuel byproducts, including hydrogen, carbon dioxide, and high molecular weight, carbon-rich residues which make up the black portion of sludge. The bacteria also generate polymers, known as "exopolymers" or "exopolysaccharides," but which most of us simply call "slime." It is this sticky slime that gives sludge its often shiny appearance and slippery feel. It is also the slime that makes particles of sludge stick tightly to fuel lines, filters, and the orifices of spray nozzles. Figure 1 shows sludge growing at a fuel/water interface in a laboratory tank.

This black, semi-solid material we call sludge is actually made up largely of water, with degraded fuel giving it color, body and bulk. The slime fraction is generally less than 5% of the overall weight, and the bacteria cells themselves make up less than .001% of the total weight. Trapped in the sludge may also be a few particles of sand and grit which have found their way into the tank. Finally, biologically-active sludge is corrosive to iron and steel tanks and fittings, and the products of this corrosion also end up in the sludge.

It is thus seen that sludge is a natural product which forms and accumulates in distillate fuel during storage. While its formation can be greatly accelerated either by putting water into a storage tank (actual water layers are apparently rare in heating oil tanks), or by transferring small amounts of active sludge from upstream storage tanks, it will eventually form even without these factors. It is believed that virtually all distillate oil storage tanks which have been in service for a few years or more contain some sludge.

This is not to say, however, that all heating systems fed by these tanks have serious sludge-related problems. If not stirred up, sludge will accumulate on tank bottoms for many years without apparently moving downstream to create operating problems. Two factors seem to cause sludge to become stirred up and suspended in the fuel: low levels in the tank and aggressive refilling of the tank. The latter is fairly commonplace, as most delivery trucks are designed to pump fuel into home tanks at a very aggressive rate of 40-50 gpm. Severe weather, such as the winter of 1994 in the Northeastern U.S., leads to low tank levels. This is because deliveries are delayed by poor road conditions, so many home tanks have unusually low levels when fuel finally arrives. Severe weather conditions also cause low levels in many terminal and retailers tanks, so more sludge is stirred up and transferred to home systems.

PROBLEMS CREATED BY SLUDGE CONTAMINATION

As mentioned above, active sludge is corrosive. Tanks with a sludge accumulation, therefore, will suffer pitting corrosion and eventual penetration from the inside. Other than this, sludge *in the tank* is not a problem. The real operating problems occur when sludge is stirred up, suspended and drawn downstream.

Sludge particles can stick to the walls of fuel lines, grow there and eventually plug off those lines. The same thing happens on filters, where the slime in the growing sludge clogs the filters and causes high pressure drops and starving of pumps. The greatest problems occur, however, as the sludge grows ***through*** the filter and starts to break off and continue downstream. (While the pores of a fuel filter seem very small to us, they are very large to a bacterium. Expecting a fuel filter to stop bacteria and slime might be likened to attempting to keep mosquitoes out with a chicken wire fence.)

Sludge particles which bypass or break off from a filter may accumulate in pumps and cause eventual plugging of the fuel pump. More often, however, their effect is felt first in nozzles, where they partially plug the nozzle orifice and, especially, the small slots in the nozzle which are designed to create the rotating cone of fuel mist required for proper combustion. As the fuel flow pattern is progressively disturbed, combustion efficiency deteriorates until, finally, the fuel is mostly "squirting" into the combustion chamber. The homeowner frequently notices smoke coming from the chimney and, in the latter stages of pluggage, a severe vibration or "rumbling" action in the furnace. The reduced combustion efficiency produces excessive sooting, fouling of the starter electrodes and blinding of the flame detector. Often, these problems are treated by the service technician as mechanical problems without realizing that they are due initially to fuel contamination.

WHAT A FUEL CONDITIONER IS AND WHAT IT DOES

Heating oil conditioners come in a variety of chemistries. What they do (or propose to do) is pretty much the same regardless of the specific chemicals used. All contain one or more dispersants (i.e. detergents) to break up the slime binder of the sludge. Many contain a corrosion inhibitor to help protect tank walls while the sludge is being dispersed. Some contain a biocide to help control bacteria numbers, although biocides can only reach the bacteria after the slime has been dispersed. Some conditioners also contain anti-oxidants to retard fuel degradation (also known as "instability"), although their value *within* a sludge accumulation is questionable.

When an effective sludge-control fuel conditioner contacts sludge, the first thing it does is to start to break down the slime binder. Within minutes the "stickiness" of suspended sludge particles goes away. The breakdown of a large sludge accumulation may take months, but is accelerated by stirring up the sludge in the tank bottom in the presence of the additive. As the sludge binder is broken down, what remains is dispersed small particles of black, degraded fuel. These do not disappear, but rather become suspended in the fuel and eventually pass downstream to become trapped on the filter or, if they pass through the filter, to become burned as fuel. While these tiny particles are suspended in the fuel it takes on a slightly turbid appearance. The transformation from a dirty, sludge-laden tank into a clean, particulate-free (other than sand and grit particles, which remain in the tank bottom indefinitely) tank, will happen eventually, but it may require years and multiple treatments. The key thing is that, as the sludge binder is broken down, particles which do become suspended are not sticky and are usually too small to cause problems.

There is one aspect of the <u>first</u> treatment of a fouled tank that bears understanding and caution. As mentioned above, the sludge breakdown occurs gradually over time. The surfactants in the conditioner, however, are *instantly* effective in keeping materials suspended once they are stirred up. This means that, if a sludge-laden tank is treated for the first time, and that sludge is stirred up just after the chemical has been added but before it has had time to break down the sludge binder, then the tank can remain filled with suspended, intact sludge "globs" for a period of many hours. To make matters worse, such a fouled system most likely has a filter that is also coated with slime and has limited flow capacity. Should the heating system be operated while all this undispersed sludge is stirred up, large amounts of suspended sludge will be sucked into the lines and completely plug the filter. When this happens, the filter is likely to collapse and allow sludge to bypass, and the entire system may become plugged. This has happened in more than one case, and is one reason why dealers are reluctant to use fuel conditioners.

The answer to this dilemma is simple. Simply add the first conditioner treatment either 1) after the tank has been refilled, or 2) at least a week before it is scheduled to be refilled. In the first case, the suspended sludge particles will settle back to the tank bottom before the conditioner has a chance to diffuse throughout the tank contents and provide a suspending capability. In the second case, the conditioner will have had a chance to partially break down the sludge binder, so what will later be suspended is tiny, non-sticky particles which are not likely to cause problems. In addition, the conditioner will have had a chance to be drawn into the filter and start to break down its slime blanket, so the filter will be much more capable of accepting additional particulate loading without serious flow restriction. Several systems, all known to be seriously fouled with sludge, have been treated using these guidelines, and none has experienced operational problems as a result of the treatment.

Once a fouled system has been treated with an effective sludge control chemical, the sludge in that system, while still largely present in some form, will remain "conditioned" for many months. Follow-up treatments within that period, therefore, may be made without concern about timing, as the sludge and filter will have been adequately "conditioned" to prevent problems.

TREATING BULK TANKS VS. HOME TANKS: "END OF THE LINE" TREATMENT

The prevailing proposed scheme in the additives business is to treat bulk oil storage tanks to prevent problems downstream. In fact, many refineries do treat their product with sludge-control additives before it leaves their hands. The problem is, the treatment chemicals generally do not travel far with the fuel, but rather become absorbed into water and sludge residues along the way. Those not so absorbed may adsorb onto the walls of tanks and pipelines. Whatever the reason, treated fuel does not stay effectively treated once it is transferred to another tank. This explains why problems occur in spite of widespread refinery treatment. Because it is not cost-effective to treat fuel at several points along its route, and because *problems* are mostly concentrated at the end of the line in the heating system, it would seem to make the most sense to treat the fuel after it has entered the last storage tank — the home heating oil tank. This scheme is called "end of the line" treatment.

While it would seem at first that bulk treatment is much cheaper than buying re-packaged products sized for treating small tanks (the cost is roughly twice as high per gallon treated by repackaged product vs. drum quantities of additive), experience shows that it requires more than twice the dose to obtain the same benefit if the fuel is treated in the retailer's bulk tank. This, combined with the fact that bulk treatment means the retailer is treating *all* his fuel — including fuel sold to will-call buyers for whom he shares no service responsibility — makes end of the line treatment the more profitable choice in most cases.

EXPERIMENTS

I. Laboratory Test Of Sludge Control

Three five-gallon glass carboys were used as test "tanks" for evaluation of fuel conditioners. As shown in Figure 2, these tanks were placed inside a light-tight enclosure, as testing in the presence of light would significantly affect the biological activity in the tanks. This enclosure was opened only for adding or removing fuel and other monitoring activities.

In the first test each tank was filled with diesel fuel, used instead of heating oil because it is not colored and thus easier to see through for monitoring test results. One tank was left untreated and was the control. The other two were each treated with manufacturers' recommended doses of either of two commercial heating oil conditioners. A small quantity of water was also added to each tank with a syringe. This water was taken from a room dehumidifier, in order to simulate the chemistry of water condensed from the air. The amount of water added to each tank varied over the course of the experiment, from 2 ml initially, to 10 ml near the end of the six month test. Into each tank was also placed a test "coupon" in the form of a bundle of 12d common iron nails tied together with cotton twine. This coupon was intended to provide a significant surface area of iron, known to be an attractive attachment and growth site for bacteria (recall that the test tanks, unlike real fuel storage tanks, were glass) — plus something which could be retrieved at the end of the test to compare relative amounts of fouling and corrosion. These tests were run indoors at ambient temperatures ranging from about 50° to about 80°F.

After one week, one gallon of fuel was drawn out of each tank, and another small dose of water was added. This weekly fuel removal/water addition was repeated over the next two weeks until each tank contained two gallons of fuel. After remaining at this level for another week, all tanks were topped up with fresh fuel to the five gallon level and the two treated tanks again treated with their respective products.

After 3½ months of such testing there was no sign of black sludge buildup, either in tank bottoms or on the nail bundles. At this point, each tank was purposely contaminated with 10 cc of sludge which had been removed from a fuel oil tank in the Pittsburgh, PA area.

After an additional 2½ months' testing with contaminated tanks the tests were stopped and the nail bundles removed. The bundles are shown in Figures 3-5. As shown in Figure 3, a significant amount of sludge grew on the control bundle during this 2½ month period. Also apparent on that bundle were orange-colored deposits at the edges of the sludge buildup, indicative of corrosion of the nails. Figure 4, on the other hand, shows that one of the two products tested (Product A) completely prevented sludge buildup or corrosion. This difference was also apparent in the tank bottoms themselves, with a significant accumulation of black sludge at several areas around the control tank bottom, but only a slight amount of dispersed fine, black particles on the bottom of that treated tank.

As shown in Figure 5, however, the other product (Product X) did not prevent sludge buildup. This third tank also showed a sludge buildup on the bottom very similar in quantity, though somewhat lighter in color, than the control. Clearly, Product A is effective while Product X is not.

II. Laboratory Test With Water Layer

The tests above were resumed, but this time 1 liter of tap water was added to each tank to provide a layer of water slightly less than one inch deep. The new nail bundles also used fewer nails to insure that the entire bundles would sit immersed in the water phase. Product X was not used this time, as it was already deemed to be ineffective, but was replaced with another commercial fuel conditioner. This new product (Product Y) was also selected because it's label claims that it "Totally Disperses Water."

This test was run for a total of forty weeks, using the same protocol as the first test except without weekly addition of water. The depth of the various water layers was checked after 35 weeks, and again at the end of the test. Surprisingly, the water level remained constant throughout the test not only for the control, but also for Product Y (the product which claims to "totally disperse" water). The water level dropped about 30% over this same time frame in the tank treated with Product A, which makes no such claim. To put this in perspective, however, this test represents almost five complete replacements of the tank fuel capacity, plus eight treatments with the chemical, so a 30% removal of the water is not outstanding. Why

Product A did cause some water removal is not clear, as no water droplets were observed to be suspended in that fuel at any time during the test. It is presumed that the surfactants in that product increased the solubility of water in fuel somewhat, whereas the ingredients in Product Y did not.

The nail bundles from this test are shown in Figures 6 through 8. As evident from these photographs, neither of the treatments effectively controlled sludge development nor corrosion in a water layer, although Product A showed less sludge buildup than did the other two examples. This is probably indicative of the fact that the control agents in these products either don't work in water, or that the portion that partitioned into the water phase was simply not sufficient to provide needed protection.

III. Field Test

It is one thing to report laboratory test results, but what really counts to an oil retailer is the reduction of service problems as a result of treatment. To evaluate the benefit on home systems — and to confirm that there would not be negative aspects of a treatment program — a retailer in the Wilmington, DE area agreed to treat the tanks of eight customers who had experienced severe fuel-related problems during the '93-'94 heating season. These eight were also selected because all of them heated water with oil as well, so their oil supply would be used throughout the year.

The initial treatment with Product A was made in early April, 1994. The two months following treatment were unusually cold, so that the heating season extended until the beginning of June. This notwithstanding, only one of the customers had experienced a fuel-related problem after nine months, even though several of the test systems had experienced several fuel related problems in the two or three months immediately preceding treatment. The one problem occurred in a system which had an oversized 550 gallon tank. Not knowing this, the initial treatment was only half of the recommended dose. That system was given a full dose the following September, followed shortly thereafter by a refilling of the tank. Immediately following refilling, plugging of the filter and pump strainer occurred. The filter was replaced and the strainer cleaned out, and no further problems have been reported after another four months. These field tests will continue for a full twelve months, including the heart of the heating season just beginning as of this writing.

THE ECONOMICS OF A TREATMENT PROGRAM

Sludge control treatment can take any of many forms. Just whose fuel gets treated, when, and by whom varies from retailer to retailer. When figuring the economics, however, many retailers struggle to justify adding to their cost for fuel which they sell for the same price as do their competitors who do not treat. A few justify this by selling what they call "premium" fuel at a premium price. This might work for small and medium sized outlets, but generally does not work for larger retailers. The problem lies in attempting to justify the cost of treatment *within the cost of the fuel*. What becomes very easy to justify, however, is treating to *reduce service calls*, and thus increase margins on service contract programs. One such scheme is:

1. Treat *all* systems that are on service contract, and only those ones.

2. Apply treatment once a year, by the service technician, as part of the annual scheduled service.

3. Schedule this annual service to occur either just after a fill up, or at least a week before.

4. Do replace filter elements as usual, but do not replace nozzles as part of the annual scheduled service. (Treated nozzles don't plug. Saves about $1.85 ea.)

5. If a treated system does experience fuel-related problems, treat again as part of that service call.

6. Do not charge a premium for service contracts to cover the chemical cost, but, rather, absorb the cost of treatment in the present contract price.

It is expected that the above scheme, assuming an effective sludge-control treatment is used, will reduce unscheduled, fuel-related problems by at least 90 percent the first year, and higher than that in succeeding years.

Table I outlines the economics of this plan for a retailer who has 5000 service contract customers. Several assumptions are made in this hypothetical case: Annual service contract price of $110, normal scheduled service (without treatment) costs the retailer $60, average unscheduled call (labor only) costs the retailer $40, present (untreated) unscheduled calls average one per customer per season, half of which are fuel-related. These figures are gathered from a poll of retailers and represent fairly typical values. It is also assumed in this particular case that each treatment costs the retailer $4.50.

A TEST SCHEME FOR THE RETAILER

Given the findings above, it would be foolhardy for a retailer to blindly adopt a program based only on the label claims of a fuel additive. The responsible thing is for the retailer to do his own tests — on his own customer base, and with his own cost figures factored in. This is not difficult. The process is:

1. Select a reasonably large group of test customers. They should be picked at random, and should include a representative number who do not have a history of fuel-related problems, as well as some who do. (The cost savings are roughly half for the few customers who have major fuel contamination problems, and half for the larger number of customers who rarely have problems. To treat only serious problem systems, therefore, is to throw away half of the potential savings of such a program.) The larger the number of test customers vs. untreated "controls," the more accurate your test results will be. A good *minimum* number to test is probably around 100 systems per product being tested.

2. Select and obtain the required number of treatments from vendors. These should represent at least two or more different products, unless another friendly retailer has already separated the "good" from the "poor" products available in your area.

3. Treat the test customers in conjunction with their scheduled annual service. It is probably best *not* to inform the customers that they are being treated, as this could bias the results by affecting their actions one way or the other.

4. Keep good records of service calls, both for treated as well as untreated customers. This should include a notation as to whether the problems were fuel related or not.

5. At the end of that heating season, compare numbers of fuel-related service calls for each of the products tested, as opposed to the average number of calls for customers who were not treated. If good records have been kept in past years, also compare problems this season with last season for treated and untreated customers. It is very important, however, that you distinguish between fuel-related and non-fuel-related service calls.

As a general rule of thumb, if there has not been at least an 80% reduction in fuel-related calls with a given treatment (vs. not treated), then the product being used was probably not performing well, and a better product should be sought.

CONCLUSIONS

1. Many operating problems with oil heating systems are due to bacteria and water contamination, which in turn leads to sludge production in the system. This will eventually occur even if only clean fuel is added to that system, but is usually accelerated by seeding the tank with upstream contamination.

2. Effective sludge control additives do exist on the market, as well as some which are *not* effective. The retailer should determine through his own test program which product works best for him.

3. A fuel oil retailer can use such additives without concern for generating additional problems — provided the first treatment of a contaminated system is not made immediately before or at the same time that tank is refilled.

4. In those rare cases where a water layer exists within a heating oil tank, chemicals alone should not be depended on for curing the problem. The water layer should be pumped out, and then an effective sludge-control additive used to clean up the residue.

5. By proper use of <u>effective</u> sludge-control additives, a heating oil retailer can dramatically reduce the number of unscheduled, fuel-related service calls. As a result, a substantial increase in the profitability of a service contract program should be realized.

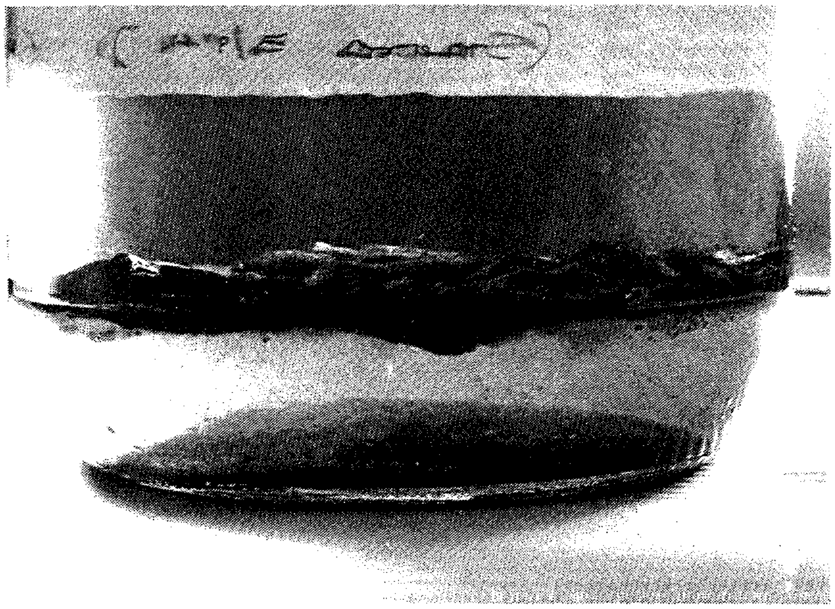

Figure 1. Sludge growing at a fuel (upper layer) and water (lower layer) interface. If this were periodically broken up by stirring, much of the solids would eventually settle to the bottom and form the more familiar "mud like" type of sludge.

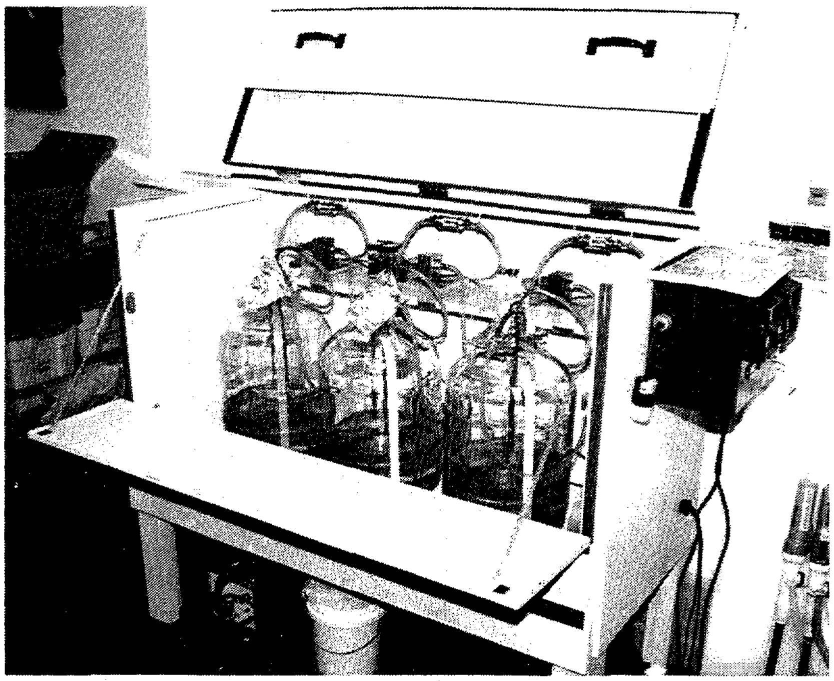

Figure 2. The test setup used to evaluate fuel additives. The enclosure is normally kept closed to exclude light. This picture also shows a recirculation system with in-line filters on each glass "tank," although those were not in use for the tests discussed in this paper.

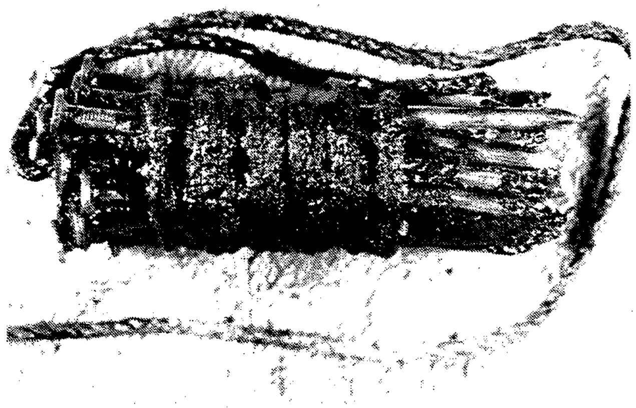

Figure 3. The nail bundle removed from the control (untreated) tank at the conclusion of the sludge-control test. Note the buildup of tarry sludge. Not as visible in this black and white photograph are several areas of orange deposits indicative of corrosion of the nails.

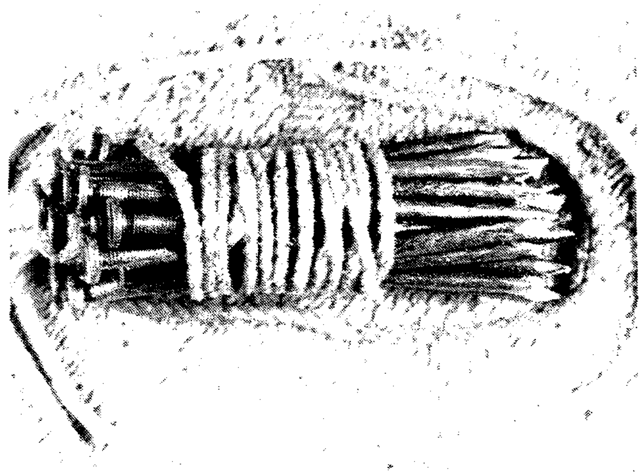

Figure 4. The nail bundle from the tank treated with Product A, exposed for the same test period as the bundle shown in Figure 1. Note the complete absence of sludge or visible corrosion product. This is indicative of an "effective" sludge-control additive.

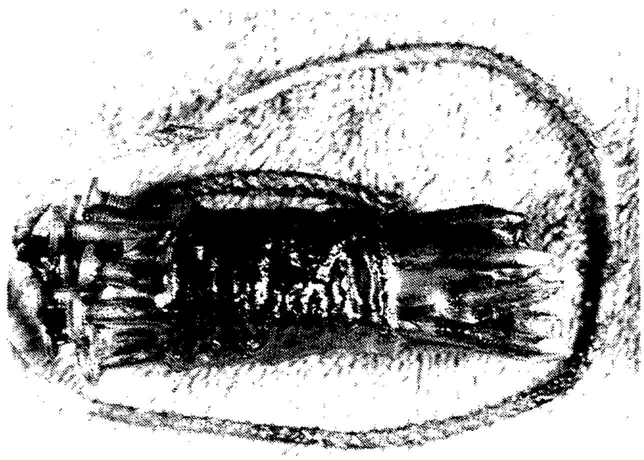

Figure 5. The nail bundle from the tank treated with Product X, from the same test series as Figures 1 and 2. This product is clearly "ineffective" in controlling sludge.

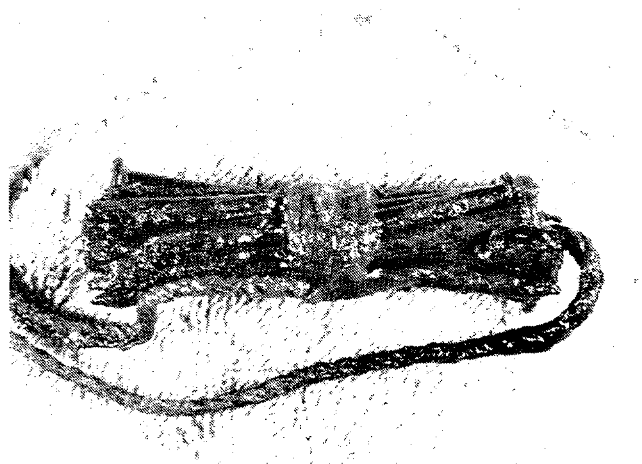

Figure 6. The "control" nail bundle removed from the water layer in the second test. There is considerable buildup of slime and sludge, plus many indications of corrosion of the nails.

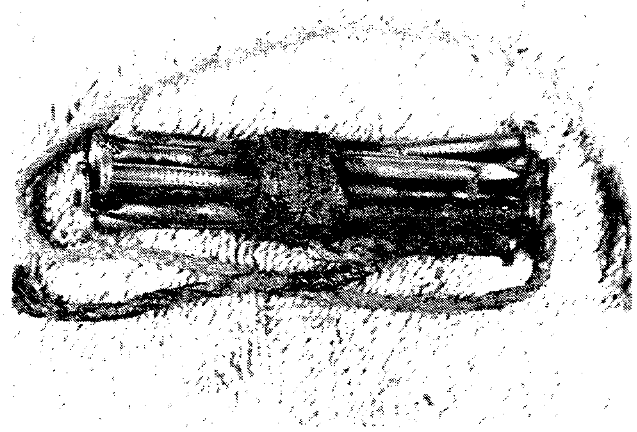

Figure 7. The nail bundle removed from the water layer in the tank treated with Product A. Unlike the case without a water layer (Figure 4), even this product did not completely prevent sludge accumulation in this case — although this is considerably better than the untreated case in Figure 6.

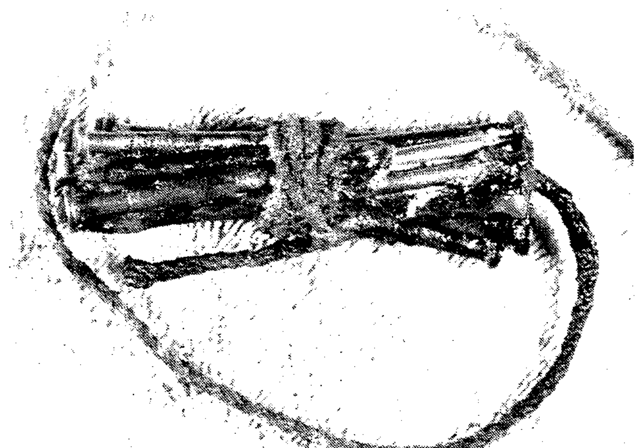

Figure 8. The nail bundle removed from the water layer in the tank treated with Product Y. As with Product X in the first test (Figure 5), this product shows little improvement over the untreated control.

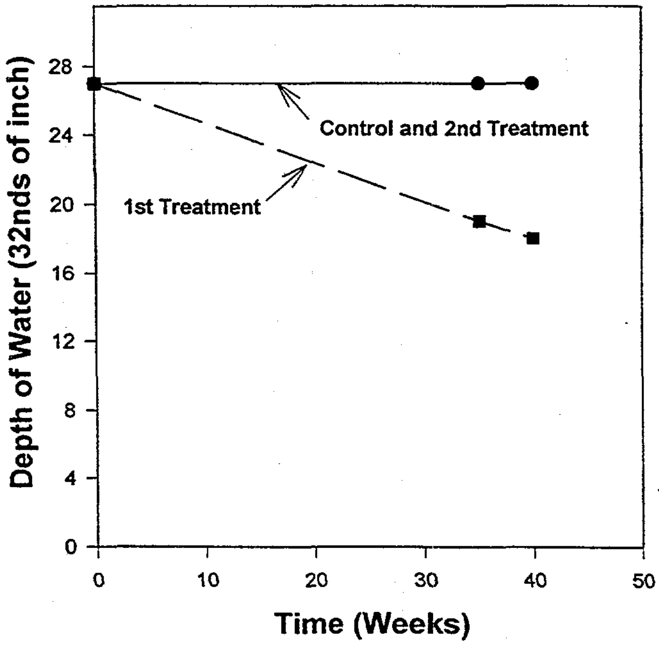

Figure 9. Curves showing the depth of water layer in the test tanks over the course of this 40 week test. Neither the untreated tank nor that treated with Product Y (which claims it "Totally Disperses Water") changed measurably during this test. What these results really show, however, is that chemical treatment alone should not be depended on to remove a substantial water layer.

TABLE I
ECONOMICS OF SLUDGE-CONTROL TREATMENT

	BEFORE TREATMENT		WITH TREATMENT	
COLLECTED FOR 5000 SERVICE CONTRACTS	$550,000		$550,000	
LESS...	No.	COST	No.	COST
SCHEDULED ANNUAL SERVICE	[5000]	$300,000	[5000]	$313,250*
UNSCHEDULED CALLS - NOT FUEL-RELATED	[2500]	$100,000	[2500]	$100,000
UNSCHEDULED CALLS - FUEL-RELATED	[2500]	$100,000	[250]	$11,125**
PRODUCES...				
RETAINED PROFITS - SERVICE CONTRACTS		$50,000		$125,625
GAINS FROM TREATMENT				**$75,625**
AGAINST TOTAL COST OF TREATMENT (NET)				$14,375
NET RETURN ON TREATMENT INVESTMENT				**526%**

* Includes $4.50 ea. treatment cost less $1.85 nozzle replacement cost (eliminated with treatment).
** Includes $4.50 ea. cost of additional treatment.

Paper No. 95-9

PMAA's NATIONAL CERTIFICATION PROGRAM FOR OIL HEAT TECHNICIANS

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PETROLEUM MARKETERS ASSOCIATION OF AMERICA'S NATIONAL CERTIFICATION PROGRAM FOR OIL HEAT TECHNICIANS

ABSTRACT

In response to an initiative by Roger McDonald to bring the benefits of Brookhaven National Laboratory's (BNL) research and development to the oil heated homes of America, PMAA in conjunction with its member associations has created a voluntary national certification for oil heat technicians. The text which support these programs are the Petroleum Marketers Association of America's (PMAA's) Oil Heat Technician's Manual, and the PMAA's Advanced Oil Heat - A Guide to Improved Efficiency.

Committee members responsible for this effort are:

Phil Chisholm, John Huber, Roger McDonald, Don Craft, Doug Woosnam, Paul Heinrichs, Gary Potter, Robert Boltz, George Kusterer, Richard T. Ambrogi, Bob Hedden, Bernie Smith, John Carey, Tim Laughlin, Gordon Bartel, and Dave Nelson.

SUMMARY

Modern oil heat appliances are clean, efficient, quiet, compact, and long lasting. However, a great deal of our furnace and boiler population is old, inefficient, and not clean. It is up to the management structure of our industry to aggressively replace the old with the new. The best way to do that is by encouraging and supporting our service industry to do that is by encouraging and supporting our service industry to do just that.

To deliver this message, the PMAA is supporting the silver and gold certification for oil heat technicians.

INTRODUCTION

In response to an initiative by Roger McDonald of BNL to develop a mechanism by which the applied research and development that is taking place at BNL could be more effectively integrated into the homes of America, the technical committee of PMAA was formed. This committee represents our industry. Its members speak for our national and regional associations, the three largest heating oil companies, the National Association of Oil Heat Service Managers (NAOHSM), and the Oilheat Manufacturers Association (OMA).

This committee is appreciative of the leadership role that Phil Chisholm and PMAA have taken by putting PMAA and its member associations in the forefront of oil heat education. The committee also wishes to recognize the leadership role of Bernie Smith and the New England Fuel Institute (NEFI) in this effort. Additional recognition needs to be given to Dave Nelson and Bob Boltz. Through their efforts, NAOHSM is fully involved.

THE PROGRAM

Certification Requirements:

Silver Certificate:

1) Three Years of Field Experience
2) 100 Hours of Formal Training
3) Passing the PMAA Silver Test - The text being the PMAA Oil Heat Technician's Manual

Gold Certificate:

1) A Silver Certificate
2) Five Years of Field Experience
3) 120 Hours of Formal Training
4) Pass the PMAA Gold Test - The text being the PMAA Advanced Oil Heat Manual

Training and Testing:

For members who wish to schedule training and testing for certification, please contact one of the following:

PMAA: John Huber, 703-351-8000

NEFI: John Carey, 617-924-1000

NAOHSM: Lou Minigiello, 201-939-0963

Training and testing for this program is to be done by proctors as certified by PMAA. At present, there are 15 proctors certified by PMAA to deliver this program. NAOHSM is planning to have certified proctors in all 27 chapters after their convention in May, 1995.

Texts:

The Silver Certificate is based on a text originally developed by NOFI, updated by the Petroleum Marketers Education Foundation (PMEF), and now owned by PMAA. It is called the Oil Heat Technician's Manual. The Gold Certificate is based on a text developed by BNL and now published by PMAA. It is called Advanced Oil Heat - A Guide to Improved Efficiency. Both texts can be ordered from PMAA. The price, including shipping and handling, is $74.95 per text.

Testing and Record Keeping:

PMAA has contracted with Ferris State University (FSU) to handle the testing and record keeping component of this program. For a one-time fee of $15 per test, FSU will generate, mail, receive, grade, and record test results. FSU will also communicate results to all concerned parties.

Revenue Sharing:

The proceeds from manual sales will be apportioned among PMAA and its member affiliates according to present apportionment formulas.

Future Plans:

This entire procedure will be initiated in Tidewater, VA. in April, 1995. The oil dealers in this market will be sending over 95 technicians to two weeks of training and testing as delivered by NEFI. Procedures involving teaching, testing, proctoring, test norms, and apprentice standard verification will be fine-tuned.

Articulation with existing educational efforts is underway. Bob Boltz (NAOHSM), is discussing these issues with those involved with the Pennsylvania State program. John Carey is discussing these issues with those involved with the Connecticut and Massachusetts programs. John Huber is discussing these issues with Fred Sacco of the New Jersey Fuel Merchants Association.

The Oregon Oil Heat Commission and the North Carolina Petroleum Association are studying the program for possible implementation.

Discussion of issues that led to these actions!

Consumer perceptions about oil heat need improvement!

Public perceptions of our industry need improvement. In a realtor survey prepared for the Massachusetts Association of Oil Heat Council in October, 1994, realtors and home buyers perceive that our product costs more than gas, is not as clean as gas, and is not as efficient. This survey is the latest in a long list of market research that gives the same conclusions.[1]

How can this be when we, as an industry, know that, in general, gas and oil cost about the same? In fact, this has been the story since 1985. (See Figure 1).[2]

How can this be when we, as an industry, know that a modern flame retention burner produces the same amount of particulate emissions as a natural gas furnace. (See Figure 2).[3]

How can this be when we, as an industry, have sold and installed furnaces that, on average, exceed the efficiency of gas furnaces significantly? (See Figure 3).[4]

Negative consumer perceptions about oil heat are based on experiences with obsolescent equipment.

Unlike modern oil heat equipment, old oil heat equipment -- equipment that has not been retrofitted with a flame retention burner -- is unclean, inefficient, and prone to break down. (See Figure 3).

Studies have shown that the owners of dinosaurs convert -- market research done by Bob Hedden indicates that over 76% of gas conversions occur where the oil heat equipment is obsolete. In addition, his studies show that over 97% of discount customers have old equipment.[9]

The entire residential HAVC market is faced with increasing obsolescence.

GAMA reports that over 2,000,000 furnaces and over 300,000 boilers are annually at risk of replacement until the year 2000.[8] The reason is increasing age and technological obsolescence. OMA reports that over 10,000,000 gas furnaces have AFUE's of less than 62%.[5]

OMA also reports that there are over 23,000,000 resistance-heated homes in the U.S. and that there are over 30,000,000 electric water heaters in use.[5]

What is to be done?

The answers lie in a management effort to train our companies to believe in our product and replace obsolescent upgraded equipment.

The people who work on our dinosaurs are our technicians. These technicians have the highest credibility of any group in our industry. Over 73% of all equipment leads come from our technicians. However, for years we have failed, as an industry, to aggressively promote equipment upgrades. The time is now to retrain those of us, who in the industry, are patching the dinosaurs -- we must train the technicians to replace the dinosaurs.

Ours is an old industry. There are many proud practices within the service industry. The good technicians have always prided themselves on being able to keep equipment running properly. This is an admirable trait, but management must realize that this strategy will not work with 25 to 65 year old equipment any longer. If we do not replace obsolescent equipment, the utilities will.

The purpose of the National Oil Heat Certification process is to build a cadre of service technicians who are proud to recommend modern oil heat equipment. The focus of the Gold Certificate Program is just that. The committee feels that the service sector of our business will embrace these concepts in their quest for self-pride and recognition.

It is up to the management structure of the over 5,000 heating oil distributors to sustain the management emphasis to successfully implement this program. Hopefully these 5,000 companies can recognize the profitability associated with 1) increased equipment sales, 2) reduced expenses from non-chargeable work to obsolescent equipment, 3) improved account retention from customers with modern equipment, and 4) improved margins that result when the customer base has new equipment.

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4. Sale-Weighted Efficiencies for Central Gas and Oil Furnaces. Data prepared by Energy Research Center, Inc., John Batey from GAMA sources.

5. Oilheat Manufacturers Association report prepared by Bob Hedden.

6. Oregon Oil Commission/1993 Phase I Oil Heat Consumer Benchmark, Table 1.

7. PMAA Marketer Characteristics: Marketer Profile Outlook. Prepared by Ethel Hornbeck, dated October 29, 1994.

8. GAMA statistics as reported by The Air Conditioning Heating and Refrigeration News. April 11, 1994, pg 8.

9. From data prepared by Oilheat Management Services by Bob Hedden.

St	% of Use	1985	1986	1987	1988	1989	1990	1991	1992	1993	Simple Avg.
ME	3	.80	.62	.68	.76	.91	.92	1.08	.97	.84	.84
NH	2	1.04	.78	.86	.91	.95	1.01	.93	.85	.84	.92
MA	11	.99	.81	.88	.92	.94	1.01	1.00	.90	.81	.93
CT	8	.86	.73	.74	.79	.82	.93	.98	.80	.73	.83
NY	19	1.05	.89	.90	.97	.97	1.10	1.17	1.09	.94	1.02
NJ	9	1.03	.89	.93	.98	1.03	1.20	1.22	1.08	1.02	1.04
PA	12	1.11	.93	.93	.98	1.01	1.13	1.17	1.05	.97	1.04
DE	1	1.08	.87	.91	.73	1.00	1.18	1.26	1.14	1.03	1.02
MD	3	1.09	.97	.99	1.07	1.08	1.27	1.37	1.14	1.02	1.12
DC	0	1.05	.90	.94	.96	.96	1.05	1.21	1.15	.90	1.03
VA	4	1.10	.97	.99	1.01	.96	1.18	1.15	1.12	.88	1.06
WI	3	1.11	.89	.91	.91	1.05	1.20	1.18	1.12	.98	1.05
MI	3	1.18	1.03	1.03	1.06	1.20	1.47	1.45	1.37	1.39	1.22
OH	3	1.20	.97	1.02	1.04	1.12	1.35	1.36	1.29	1.13	1.17
Wtd Avg	81	1.04	.87	.90	.94	.98	1.11	1.15	1.04	.94	1.00

FIGURE 1. Ratio of oil to gas prices in major residential oil consuming states weighted by percent of residential heating oil use.

SOURCES: U. S. Department of Energy, Monthly Energy Review, Natural Gas Marketing Monthly, Various Issues.

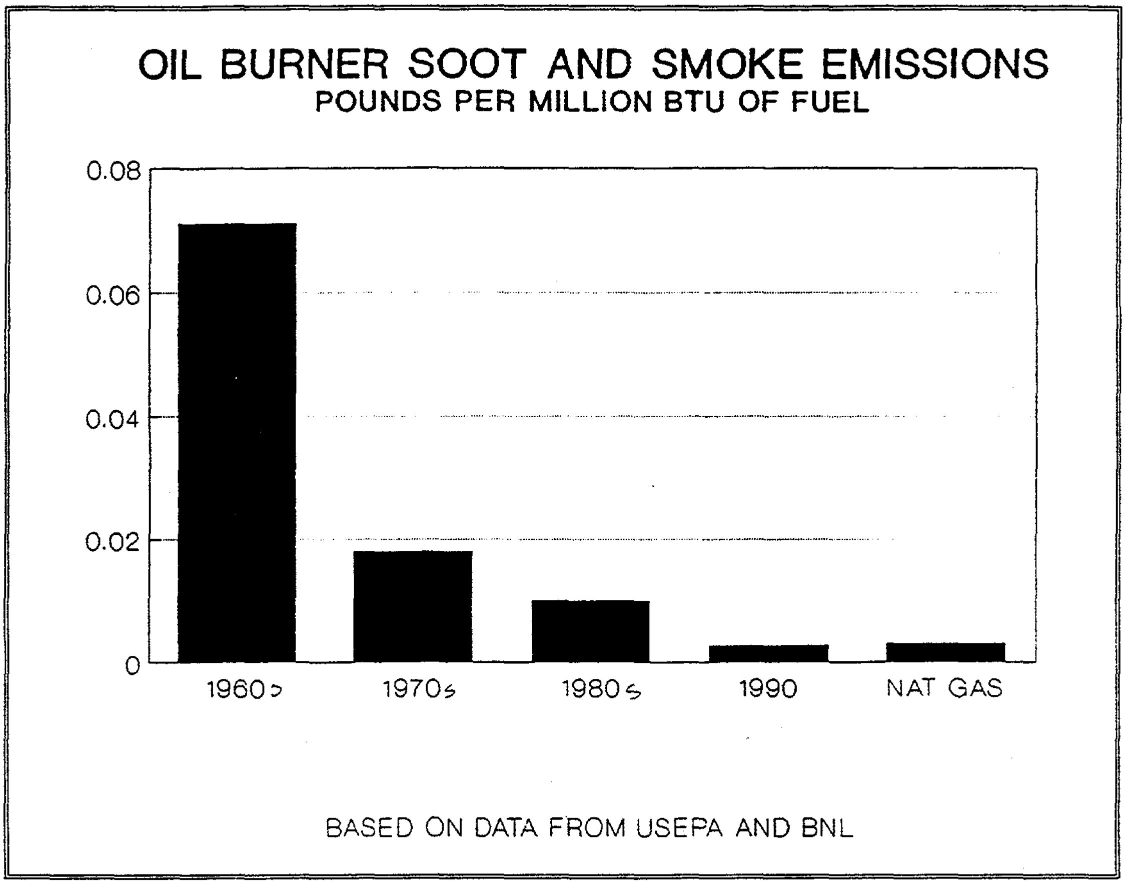
OIL BURNER SOOT AND SMOKE EMISSIONS
POUNDS PER MILLION BTU OF FUEL
0.08
0.06
0.04
0.02
0
1960s
1970s
1980s
1990
NAT GAS
BASED ON DATA FROM USEPA AND BNL

FIGURE 2.

SALES-WEIGHTED EFFICIENCIES (AFUEs)
FOR CENTRAL GAS AND OIL SPACE HEATERS

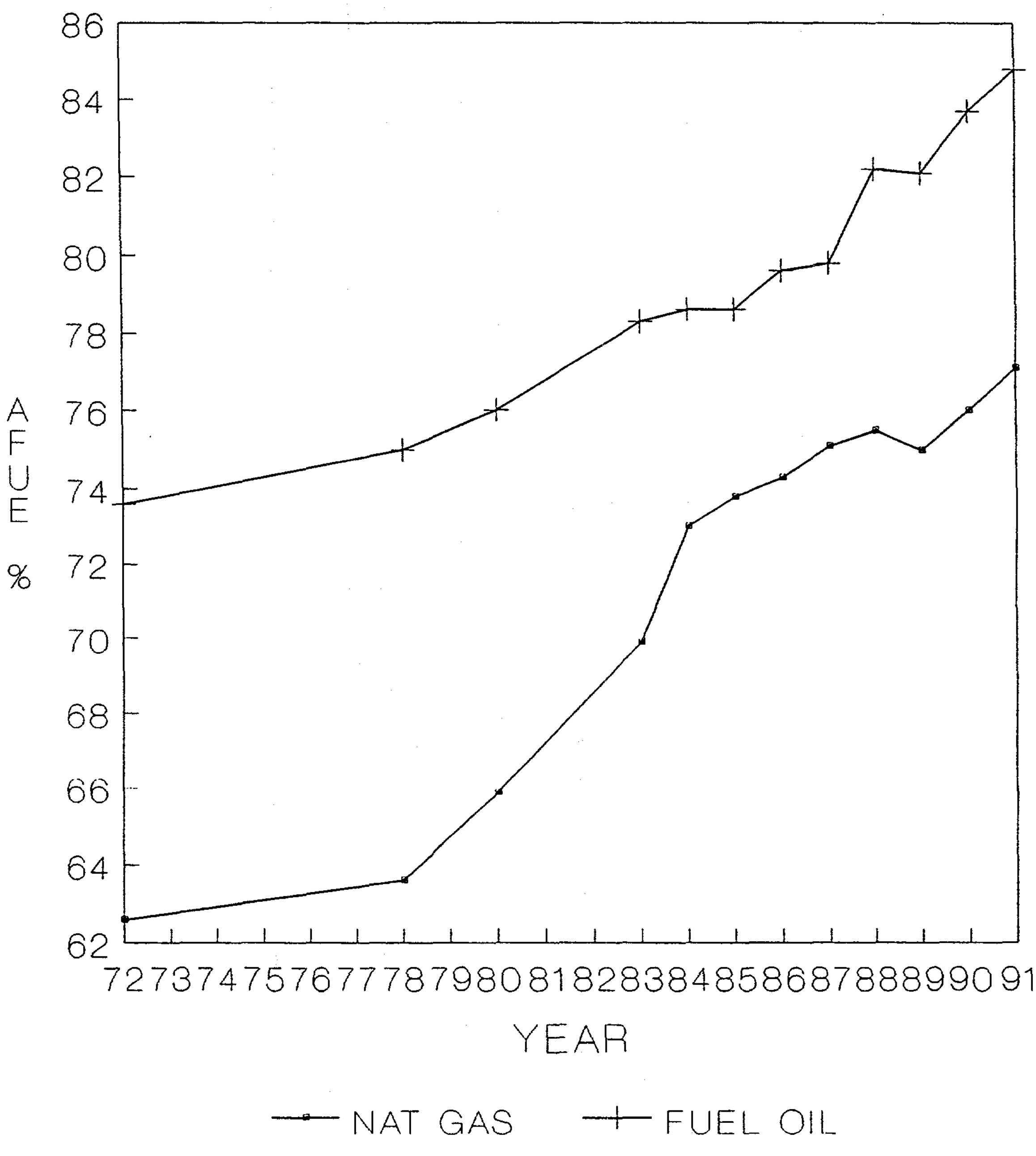

FIGURE 3.

Paper No. 95-10

THE OILHEAT MANUFACTURERS ASSOCIATION OILHEAT ADVANTAGES PROJECT

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and

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The Oilheat Manufacturers Association's Oilheat Advantages Project

Robert Hedden
Oilheat Management Services

The Oilheat Manufacturers Association (OMA) Technical Advisory Committee, John Batey and Bob Hedden continue to make progress on the Oilheat Advantages Project. It is intended to fill a void in our industry. In the last year, we have all found ourselves in at least one of the following situations:

- Engaged in radio debates with representatives of the utilities over the relative merits of various energy sources.
- Trying to convince our customers to upgrade their 40 year old heating system.
- Granting interviews to reporters doing articles on energy conservation options.
- Trying to dissuade customers from disconnecting tankless coils and installing electric water heaters.
- Trying to inspire a heat pump victim to buy an oil-fired hydroair system.
- Trying to sell someone with electric-resistant heat, an oil-fired system.
- Trying to persuade a Builder to put Oilheat in his homes.
- Trying to explain to a local Fire Marshall that a power vent installation is acceptable.
- Trying to keep a State Government from outlawing underground oil tanks.

Frankly, we are attempting to accomplish all these tasks with insufficient information.

When trying to defend and expand our industry, we find ourselves armed with precious little creditable third party proof for what we know to be true - that today's oil-powered equipment produces very efficient, clean burning, safe, comfortable, inexpensive, dependable, environmentally friendly heat. This lack of facts forces us each to tell our own version of the oilheat story - often full of misconceptions, wishful thinking, half truths, and guesses - stretching every shred of evidence we can lay our hands on for all it is worth.

Our industry desperately needs a unified, well documented, professionally packaged, consistent Oilheat Story. This story must be disseminated to everyone in the industry because we all have the opportunity and responsibility to go out and spread the word.

There are millions of electric heated homes in North America that should be heated by oil, millions of electric water heaters that should be oil-fired water heaters. There are over 10 million old atmospheric gas burners with standing pilots running at less than 62% efficiency that could be converted to new oil-fired equipment. At least 50% of the oil equipment out in the field is inefficient, oversized, and obsolete. There are nearly five million non-flame retention burners still in the field; they should be upgraded. In order to sell our wonderful new oil-heat equipment to these vast potential markets, we need the facts in a compelling, easy to understand format.

OILHEAT ADVANTAGES PROJECT

The Oilheat Advantages Project is the Oilheat Manufacturers Association's first project. It involves the creation and dissemination of this unified, well documented, compellingly packaged Oilheat story. The project involves three steps: The first step is to pull together all the existing data on the advantages of oilheat into a single, well documented engineering report. The second step will be to rewrite and package the technical document into a consumer piece and a scripted presentation supported with overheads, and to disseminate the information throughout the industry. And the third step will be to fund new research to update existing information and discover new advantages of oilheat. This step will begin next year. The information will be packaged in the following formats:

- The **Engineering Document.** This will include all the technical information including the creditable third party sources for all the findings on the many advantages of oilheat.
- The **Consumer Booklet.** This summarizes all the findings in the Engineering Document in simple language with easy to understand illustrations and graphs.
- A series of single topic **Statement Stuffers** on each of the advantages.
- An **Overhead Transparency-Supported Scripted Show** that can be used by industry representatives for presentations to the general public, schools, civic groups, and service clubs.
- **Periodic Publication** of updates to the Oilheat Advantages Study.

The following is an outline of the Oilheat Advantages:

I. Oilheat is Efficient

A. Efficiency Definitions

1. Combustion Efficiency
2. Steady State Efficiency
3. Off-Cycle Efficiency
4. Annual Fuel Utilization Efficiency
5. Seasonal Efficiency
6. Electric Heat Efficiency
7. Water Heater Efficiency

B. Historic Efficiency Trends

C. Efficiency of New Equipment

D. Reasons for Equipment Efficiency Differences

E. Efficiency Improvement by Replacing Old Equipment

II. Oilheat is Clean

A. Historic Soot and Smoke Emissions

B. Particulate Emissions from Modern Oil Burners

C. Comparison of Particulate Emissions from Various Sources

D. Oil Burner Smoke as Safety and Adjustment Indicator

III. Oilheat is Best for the Environment

A. Combustion Emissions

B. Air Emissions from Residential Oil Burners

C. Emissions from Various Combustion Sources

D. Comparison of Air Emissions from Oilheat and Electric Heat

E. Environmental Cost Comparisons for Oilheat and Other Sources

F. New Oil Burners Reduce Air Emissions

G. Task Force Studies on Oil Tanks

IV. Oilheat is Economical and Converting to Oilheat Offers Compelling Paybacks

A. Fuel Price Comparisons

B. Excellent Paybacks from Electric to Oil Conversions

C. No Payback for Oil to Gas Conversions

D. Payback Periods for Gas to Oil Conversions

E. Cost Savings for Converting from Electric to Oil Water Heaters

F. Residential Oil and Gas Prices

G. Range of Gas Prices

V. Oilheat is the Fuel of the Future

A. Electronic Control Advances

B. New Burner Advances

C. New Technology Means New Markets for Oilheat

D. Oil Cogeneration

E. Oilheat Conservation Options

VI. Oilheat is Made in America

A. Where Crude Oil Comes From

B. Heating Oil is a Manufactured Product, the Refining Process

C. The U.S. is a Net Exporter of Heating Oil

VII. Oilheat is Safe

A. Oil Does not Explode, It Does not Even Burn!

B. Oil, Gas and Carbon Monoxide - The Big Difference

C. Oil Storage Tanks, Vented Outdoors

VIII. The Oilheat Industry is Vital to the Communities We Serve But Does not Effect our Trade Deficit

A. Oilheat Accounts for 3% of U.S. Petroleum Consumption, less than 2% of the total energy used

B. There are 12 million Oilheated Homes in the U.S.

C. There are over 9,000 Oilheat Companies in the U.S.

D. We Employ over a quarter million people

E. The Oilheat Industry contributes over $8 billion to the economies of the communities we serve

IX. Oilheat is the Choice That Offers a Choice

A. Electric and Natural Gas are supplied by large, unresponsive, bureaucratic monopolies

B. Oilheat is supplied by relatively small, local, or regional, predominately family-owned businesses, that compete fiercely with each other and the utilities for customers' loyalty with low prices, quality service, and value added augmentations

C. Oilheat's Famous "I'll be right over" Service

X. Oilheat is Warm, Comfortable and Reliable

A. Cite various Consumer Surveys that rate Oilheat highest on these intangibles.

III. WORKSHOP SESSIONS

WORKSHOP TOPICS
GROUP A:

Fuels, Fuel Quality, and Storage Industry Discussion

Chairman: **Robert Greenes**
N.Y. Oil Heating Assoc'n., Inc.

Rapporteur: **Wailin Litzke**
BNL

I. Brief discussion on current fuel quality issues including:

- What is the field experience regarding the new low sulfur diesel fuels?
- What are the fuel's pour point and cloud point, and what are the requirements? What to use, additives or kerosene?
- What has BNL done to look at fuel quality?
- What does housekeeping have to do with fuel quality?

II. Future work at BNL

- What changes should BNL make in their R&D program?
- What should be included in next year's program?
- How can the information generated at BNL be used to benefit the oil-heat industry?

DISCUSSIONS:

This workshop session consisted of approximately 30 members from a broad spectrum of the petroleum industry - oil marketing, refining, heating equipment suppliers, fuel additive companies, and trade organizations, to name a few. This diversity of backgrounds underscores the interest in and the importance of the role of fuel quality not only in heating oil production, but in its storage and end-use.

During the initial discussions the chairman raised current issues pertaining to fuel sulfur content, pour and cloud point concerns, and lubricity concerns. Feedback from the participants were sought on these topics in terms of comments or experience with the new low sulfur diesel fuels (0.05%) which had been mandated by the Federal Clean Air Act for use in vehicles since October 1993. Since then this low sulfur content No. 2 diesel has been available and marketed for use in vehicles and in some markets it has also been sold as No. 2 heating fuel as well. During the heating season of 1993/94, one of the coldest winters in recent history, oil distributors and other end-users (such as the truckers) voiced concerns over the difficulties with handling these fuels in terms of gelling and clouding. Significant kerosene blending was needed, as reported, in order for proper handling of the fuels. At that time it was presumed that the lower sulfur may have contributed to changes in fuel pour and cloud points.

To date, with the end of the 1994/95 heating season, it is still too early yet to have much information or experience with the use of low sulfur fuels in home heating systems. No additional concerns were brought up by workshop members regarding this issue. In general, most oil marketers have indicated that the trend towards using low sulfur fuels in heating systems is a positive one.

Two advantages for using the low sulfur fuels were pointed out, both practical and economical. BNL tests clearly show that the fouling rate of boiler surfaces can be reduced with lower sulfur fuels. This can improve on the long term stability of high efficiency levels and reduce the maintenance needs for the heating unit. Significantly, because of the wide availability of low sulfur fuels, its cost difference compared with the typical heating fuels has become quite small.

Interest remains on the topic of fuel additives. Specifically, oil companies want to know if additives will help to reduce the overall service needed for their customer's heating equipment or storage tanks. Other common questions include - Which ones work? How do you select an additive? How do you test whether an additive works before investing in a treatment program? Is there an additive that will prevent sludge? Testing of sludge, a major problem in some tanks, can become very expensive; and in some cases little information on the exact causes of sludge buildup can be obtained.

Representatives from service companies indicated that at some point they have used fuel additives (to prevent sludge accumulation, for example) and have had mixed results. One major oil distributor has been carefully conducting a field study for the past few years to evaluate different types of additives and their overall effects on reducing customers' service needs. As reported, no dramatic changes have been observed thus far with a relatively large sample of homes.

One way of addressing some of these questions is to actively involve the industry members to participate in field studies and surveys. Results from laboratory and bench tests can be limited in some applications because the numerous differences in actual field conditions often cannot be duplicated. Clearly, the industry has the capability to effectively evaluate products, methods and new technologies by focusing and combining their efforts in terms of data gathering and reporting on large scale basis. It has been suggested that BNL can play a central role in providing the expertise needed to organize field tests, evaluating methods and procedures, assist with quantifying and analyzing information collected, and serve as liason among the participants.

WORKSHOP TOPICS
GROUP B:

New Oil Heat Equipment Developments

Chairman: **Thomas A. Butcher**
BNL

Rapporteur: **John W. Andrews**
BNL

1. Are current oil burners perfect? What areas need improvement?

2. In what market segments is it most difficult for oil heat to compete?

   a. What types of new products are needed to expand the oil heat market?

      - sidewall vented systems
      - low input
      - compact boilers
      - condensing systems
      - equipment with better maintenance access
      - better controls
      - other

3. What factors drive new and retrofit equipment purchase decisions?

   - cost
   - efficiency
   - cleanliness
   - reliability
   - safety
   - ease of service
   - appearance

4. What is the preferred way of producing domestic hot water - tankless coil, separate water heater or storage tank and heat exchanger? Consider efficiency, equipment costs, reliability.

5. Are current systems providing enough hot water? Can firing rates be reduced? By how much?

6. Is it really necessary to clean all boilers annually? Do any need cleaning twice each year? Do modern high static burners help?

   Does prevention of puffbacks need more attention? Have recent experiences shown this to be getting better? Would the BNL FQI be helpful?

7. Do we need better data on actual, in-field performance and energy savings with different types of equipment and adjustments?

8. Should we pay more attention to the development of low NOx burners?

9. Is the BNL Fan Atomized Burner of interest? At what firing rates?

10. What technical obstacles limit conversion from electric heat to oil?

    - low cost or more flexible baseboard radiation
    - fuel tank
    - venting

    What can BNL do to help in this area?

11. How can oil-fired water heaters be used to replace electric DHW? What obstacles prevent this from happening? How can these be overcome?

12. Do we need new boiler designs?

    - for low input, small space requirements
    - direct venting without inducer
    - sealed combustion

13. Is BNL effectively communicating its research results to industry? How might this be improved?

14. **With limited R&D funding is the BNL program addressing the most critical industry needs? What is missing? Are some areas receiving too much attention at BNL?**

DISCUSSIONS

During this workshop session, there was lively discussion on developing trends in oil heat technology with an emphasis on issues which may be appropriate for BNL to address. At many times, there was not uniform agreement among the workshop participants. The most significant points raised during the discussions are as follows:

The industry may realize great benefit from the development of variable firing rate/variable output boilers and furnaces. The gas industry is moving forward rapidly in this area. Potential advantages for oil include: higher efficiency, less maintenance, and reduced noise. There are, however, some issues which should be addressed in this area. What are the real efficiency gains associated with variable firing rates, including effects of system losses? With reset controls and integrated appliances, can the same efficiency levels be achieved with fixed-firing rates? The maintenance benefits with variable firing rate need to be quantified. With variable firing rate, there is always a concern about heat exchanger corrosion. If the heat exchanger is sized for good efficiency at high firing rates, low gas temperatures, condensation may occur at low rates. One participant suggested the use of direct contact economizers to provide good efficiency over the entire firing-rate range, while avoiding the corrosion concern.

The industry should continue to pay attention to oxides of nitrogen (NO_x) emissions. The NO_x emissions associated with any new technologies should certainly be considered. It was suggested that BNL do some work on achieving modest NO_x reductions with small changes in conventional burner designs.

Proposed changes in DOE efficiency regulations are expected to make burner electric power consumption more important in the future. As firing rates decrease, the need to reduce power draw increases. Currently, cost/market constraints really prevent the use of higher efficiency motors.

System noise remains a concern with oil-fired appliances and it was suggested that BNL include noise measurements in their work. Noise concerns can impede the use of some higher efficiency equipment. An example of this is the replacement of an electric hot water heater with an oil-fired unit.

Interest is increasing in side-wall venting. Important issues remain in this area including: post-purge requirements, standards, sealed combustion, and inducer electric power requirements.

There was a small debate during the workshop session about relative maintenance costs of oil- and gas-fired appliances. These costs are difficult to quantify accurately because of the different service plans and ways that service costs might be buried into fuel costs. As gas appliance efficiencies rise to the level of oil, it is expected that maintenance costs will also rise.

It was suggested during the discussions that the oil industry should look for opportunities to integrate with heat pump heating and cooling equipment.

WORKSHOP TOPICS
GROUP C:

Application of Oil Heat Venting Tables
NFPA 31 Standard

Chairman: **Richard F. Krajewski**
BNL

Rapporteur: **John Strasser,**
BNL

The March 23, 1995 workshop session opened with a review the questions that had apparently survived through at least 2 previous workshop sessions. These questions address issues related to the proposed venting tables for masonry chimneys.

1) Do the proposed venting tables present problems in interpretation or use?

2) What is the field experience regarding venting metal chimney corrosion in the field?

3) How well do masonry chimneys stand up in oil fired applications?

4) What are the physical and material selection constraints for insulating vent connectors in the field?

5) BNL will be completing a few remaining activities related to the oil heat appliance venting project during this fiscal year, which ends September 30, 1995. Are there any existing venting issues of concern to the oil heat industry that have not yet been covered in BNL's work?

DISCUSSIONS

There were approximately seventeen oil heat industry representatives in attendance at the workshop session. Included in the group were service technicians, marketers, and several equipment manufacturers. The workshop session was structured to allow for industry questions, comments, and follow up discussions regarding the technical presentation on **The Application of Masonry Chimney Venting Tables for Oil-Fired Appliances, Paper 95-4,** which had been presented by the session's chairman the day before. The level of interest was quite intense and many comments and concerns regarding the proposed appendix to the NFPA 31 Standard were discussed.

In summary, the venting tables reflect a judgement of the numerical solutions for available draft at the appliance and clay liner surface temperature at the chimney exit. This is based on a conforming masonry chimney (NFPA 211) located exterior to the building and exposed to an average ambient temperature of 42° F on all four sides. The minimum criteria selected for the judgement of successful operation were 0.03 inches of water and 120° F respectively. This is considered a conservative criterion since the diluted flue gas water dew point will lie between 95 and 105° F. Evaluation of the solutions on this basis showed many conventional masonry chimneys failed to satisfy the minimum temperature criterion and many operated below the diluted flue gas water dew point as well. The recommendations are valid for both boilers and furnaces. The venting table recommendations along with text material are to be incorporated in the Appendix of the 1996 NFPA Standard 31. Common venting has not as yet been considered but the prevailing guidance suggests that a chimney should have a flow area equal to the connector area of the largest appliance connected plus 50% of the area of the additional connectors.

Laboratory measurements have been used to validate the OHVAP model. Some temperature data from manufacturers, including observations regarding the lack of visible condensate deposition, are also being used to validate OHVAP predictions. The intention is to continue this form of validation. The model predictions for relining of the conforming chimney, which consisted of the addition of a smooth metal liner with an insulating mica back fill, were judged on the same criteria described above.

The first topic of discussion at the workshop centered around the use of a mica back fill insulation system in modeling relined chimneys using stainless steel liners. BNL initially included its use on the basis of early reports and installation recommendations by one of the major manufacturers of this product in Canada. Consideration was also given to the thought that the back fill would help support the liner in the chimney, keep it from shifting and maintain it in a straight and fully extended position. Comments from the workshop participants indicated that this was not the current practice in the field and that liners without insulation are the norm. Subsequent to the workshop the issue was brought to light by a manufacturer that stated Underwriters Laboratory will **not** list any liner product if back fill is used in its installation. The primary concern being migration of the insulation into adjacent flues in multi-flue chimneys or the into the relined flue itself, if in failure, holes developed. Also subsequent to the workshop, an installer discussed the crushing of the lower portions of the liner due to settling and compaction of mica dust developed during expansion and contraction of the liner. The cost factors associated with installing insulation was another concern voiced by the participants. BNL has modeled some chimney systems and preliminary results indicate that an air gap is sufficient and the insulation is not essential for thermal control of the flue gas temperatures in the chimney.

There are also questions regarding the use of a smooth straight liner in the model when the liner of choice in the field was a flexible (bellows) type with a convoluted wall. These convolutions are formed in the wall as part of the manufacturing process to produce a flexible circular duct. The ability to flex is often required due to the fact that many chimneys are off-set in their construction. The use of straight sectional liners is difficult in off-set chimneys, frequently requiring the installer to make openings in the chimney walls at the off-set locations. In practice, when a flexible product is available, it will be used instead. A slightly higher friction loss may occur when using the flexible liner material but this is not considered a major concern because the draft can be adjusted with the barometric draft control.

The issue of acid damage to masonry chimneys was discussed. The issue has been examined at length by the gas industry. It appears to be a real issue but the question remains as to how much is too much and how long does it take to severely damage a masonry chimney. Corroded, softened and cracked clay tiles, damaged mortar, and missing bricks are often cited as examples of masonry chimney damage. Some of this damage may be due to rain and water condensate saturation of the masonry components with subsequent freezing. Many chimneys are not constructed properly (in accordance with NFPA 211) and the improper application of materials are other factors in the study of chimney longevity.

In discussing the proposed venting tables, it was suggested that their use, in their current embodiment, may open opportunities for unnecessary litigation. The gas industry, it was suggested, has potential problems with carbon monoxide formation which, under most circumstances, the oil industry does not. In addition, the history of existing installations does not support the theory that there is a general failure of masonry chimneys serving mid- and high-efficiency oil-fired appliances. Current field information suggests that lined masonry chimneys are not a problem and that only a small percentage of the installations have problem chimneys.

In terms of relining, one workshop participant offered these comments. The potential customer is sometimes subjected to hard sell scare tactics regarding the need to reline. The material used in the installation is sometimes whatever is at hand on the truck. Little attention is given to diagnosing the system's real problem. There is a need for training and certification of people who service chimneys. Another comment suggested that there needs to be a protocol which provides for a diagnostic approach to identifying the specific problem before any solutions are attempted. However, it was pointed out, the proposed venting guidelines may get in the way if they provide a path for governmental regulation where none is needed.

The participants felt that, in general, the table format was easy to use but the recommendations for chimney relining went beyond what the industry views as a problem. It was suggested that there is some problem with the assignment of a minimum acceptable liner temperature in terms of the reality of masonry chimney operation and longevity.

The Canadian CSA B139 M91 Installation Code Chimney Sizing Charts indicate that for any new installation of an oil-fired appliance, the chimney must be relined. It was suggested that in theory relining must be done but in practice it was not. The proposed (OHVAP) venting tables generally agree with CSA B139. For example, for a 20 foot clay lined masonry chimney conforming to NFPA 211, the minimum permissible flue gas temperature at the chimney base is 300^{o} F at a firing rate of 1.0 gph, according to CSA B139. The OHVAP predictions for this case showed flue gas temperatures less than 300^{o} F entering the chimney base and liner temperatures less than 120^{o} F at the top of the chimney, leading to a proposed recommendation to reline. The tables in CSA B139 are recommendations but they have already been adopted into the building code for Ontario and into the Canadian National Code.

Similar analysis in Canada conducted on masonry chimneys by a major oil company in the early 1980's showed that condensation would occur in nearly every installation. Burner conversions were required to have chimney relining but installer resistance forced a pull back from that position. Despite this being mandated in the code for new construction, inspectors do not get involved in conversions and the installer is allowed to make the final judgement. After 20 years there is no evidence of general chimney failure. There are special cases and a 3-6 month inspection should be called for after relining with annual inspections thereafter. Furnaces in Canada were frequently reduced by one nozzle firing rate size to match heating capacity requirements and no major problems were uncovered with outside chimneys in vary cold ambient conditions.

The condition of the existing inventory of masonry chimneys was discussed. It was suggested that the field experience with masonry chimneys be explored utilizing the resources of the oil heat organizations such as PMAA and the National Association of Oil Heat Service Managers. The preparation of an appropriate questionnaire will be pursued to support a field survey.

The comments and concerns voiced at the workshop session will be addressed prior to the final submission of the text and venting tables for the proposed appendix. The tables are intended to provide guidance in making the proper choice when the service person is faced with a chimney that requires relining. They will also be useful in the correct design of venting systems to be installed in new home construction. They are not intended to be the sole criteria for relining an existing chimney that has been operating satisfactorily for many years. The tables will be reformatted to include the current relining information only. Under the existing NFPA 31 Standard, reference is made to NFPA 211 for further guidance on chimneys. This guidance includes a requirement for the annual inspection of chimneys. In the proposed appendix this requirement will be reinforced. In addition, a recommendation will be included to inspect the chimney 3 to 6 months immediately after any equipment modifications, retrofits, or replacements to, or of, the attached heating system.

A question was raised regarding a specific solution and recommendation in the table. This was regarding the successful application of an appliance with 86% efficiency, 1 gph firing rate, 10 foot connector into a 4 inch insulated liner in a 25 foot chimney. A discussion followed regarding draft and friction loss. The chimney will work because the heat loss is very low due to the effectiveness of the insulated liner system. This would promote high temperatures and high draft in the chimney which would offset frictional losses due to the small diameter of the liner. A further concern about the vent system going positive in pressure was addressed in terms of the ability of retention head burners to overcome the system flow resistance and the short duration of such pressures due to rapid filling of the system with hot flue gas. The issue of additional elbows, in addition to the one elbow and a tee used in the simulations, presents a problem which needs to be addressed in terms of adjustment to the table recommendations.

Regarding the sizing of connectors in the simulation, the chimney connector diameter was held consistent with that of the liner. Equipment flue gas outlets frequently exceed the size of the connector required for the vent system. In order to correct the application of the connector diameter, appliance manufacturers and installers need some flexibility to accommodate the installation of smaller connectors. This will be carefully worded in the text revisions to NFPA 31.

WORKSHOP TOPICS
GROUP D:

PMAA National Oil Heat Service Technician Certification Program - Silver and Gold - Industry Role & Future Support

Chairman: **Don Allen**
E. T. Lawson & Son, Inc.

Rapporteur: **Roger J. McDonald,**
BNL

Part I: PMAA National Oil Heat Service Technician Certification Program - Silver and Gold - Industry Role & Future Support

1. What, when, where, and why? The current status of the PMAA Oil Heat Service Technician Certification Program will be reviewed with workshop participants who will be able to ask questions and discuss answers concerning the details of the program and how it will be organized in different parts of the country.

2. What, if any, changes are recommended for future revisions of the two training manuals? What subject(s) should receive higher priority?

3. What opportunities exist to promote the industry based on the national certification program? What, if any, problems are anticipated and how can these be resolved?

4. What opportunities exist to gain widespread industry support and cooperation in this effort? Manufacturer support through OMA? Local, state, and regional marketer association support? Service managers? Others?

5. How can PMAA, NAOHSM, and NEFI help get people aware of the program? Trade press? Industry newsletters? Direct mail listing?

Part II: BNL Oil Heat Technology Transfer Topics

Discussion Topics

1. How can the oil heat industry help DOE in promoting the introduction of new high efficiency technologies under development at BNL? The Fan-Atomized Burner? FQI? Others?

2. How can the oil heat industry support, assist, and contribute to the commercialization of high efficiency technologies in the marketplace?

3. Other thoughts or ideas concerning Oil Heat Technology Transfer?

4. Industry suggestions for the 1996 Oil Heat Technology Conference and Workshop.

DISCUSSIONS:

PMAA National Oil Heat Service Technicians Certification Program
- Silver and Gold - Industry Role and Future Support

Twenty-six industry participants attended the workshop which began with an overview of the status of the certification program, how it is intended to work, the training and examination requirements for certification, and how it was being organized to serve the needs of the industry. The certification program was the subject of workshop chairman Donald Allen's technical presentation on **PMAA's National Certification Program for Oil Heat Technicians** given earlier in the day. There was a great deal of enthusiasm and interest in the program and several important issues were brought out regarding testing, record keeping, and continuing education.

The issue of grand-fathering technicians which have already attained state or regional certification equivalent to that of a PMAA silver level was one of the first concerns. The representatives from the Fuel Merchants Association of New Jersey (FMA-NJ), the New England Fuel Institute (NEFI), members from the Pennsylvania Petroleum Marketers (PPA) and vocational technical schools all pointed out that they have had training and certification programs in place of equal quality and felt it would be difficult to ask those already certified to have to sit and be retested. The members of the PMAA education committee that were present agreed to take this under advisement at the next meeting of the committee scheduled in May. The organizations interested in grand-fathering existing certifications at the silver level were asked to submit a comprehensive package to PMAA containing a detailed description of the training and examination process required in existing programs certifying technicians along with a register of currently listed certified technicians for PMAA's consideration. The PMAA committee members felt that any existing program that reasonably matches or exceeds PMAA's proposed requirements would be allowed to grandfather those currently listed and certified prior to the PMAA program's implementation if documentation could be provided.

The gold level certification being based on the new training manual developed by BNL and published by PMAA did not present the same issue concerning grand-fathering. There was a general accord that this was indeed new information requiring training, applied field experience, and testing prior to certification.

FMA-NJ representatives reviewed the development of the voluntary industry established New Jersey certification program and that it preempted a state mandated and regulated requirement. Part of what was required and included was a requirement for long term detailed record keeping and continuing education requirements to periodically renew certification otherwise if the certification lapsed retesting is required. A general consensus was voiced that this was an excellent idea and that it should become part of the PMAA program as well. This was discussed in some detail and again the PMAA committee representatives agreed to bring the point up at the next PMAA meeting on the program. FMA-NJ voiced its interest in joining the national program under PMAA. They did insist that they would require that FMA-NJ be issued copies of permanent certification records for their own files. This to satisfy FMA-NJ and the state of New Jersey regarding prior record keeping requirement agreements.

The workshop discussions provided important information and input for consideration by the PMAA Education Committee which is in the process of developing the protocol for implementing the national certification program for oil heat service technicians. It opened up dialogues with various state associations regarding existing certification and state licensing requirements which must be considered. It initiated a review of concerns regarding continuing education and how this might be implemented either nationally or at a state level. It also provided concerns that must be considered regarding local proctoring of exams in those states without strong oil heat association representation. These items will be addressed by the PMAA committee with the help of and other industry representatives involved in the evolution of the national program and will be resolved over the next few months with meetings at the NEFI exposition in June and at the PMAA National Oil Heat Conference in August.

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