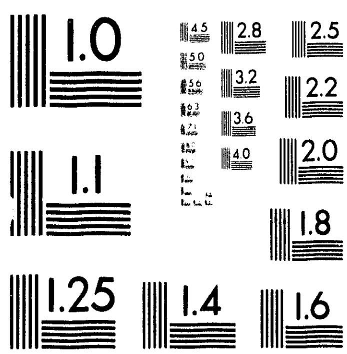
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PROCEEDINGS OF THE 1993 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP

Held at
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September 1993

Roger J. McDonald

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The 1993 Oil-Heat Technology Conference and Workshop was attended by 181 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 there 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), Gang Wei (associate staff engineer), and Jose Sanchez (senior mechanical technician). There would be no results to report on without their professional efforts and dedication to the research effort.

The high quality of the 1993 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, Francine Donnelly, and Bernadette Christian. 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 1993 Oil Heat Technology Conference and Workshop, held on March 25-26 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 seventh 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 to satisfy consumer needs cost-effectively, reliably, and safely;
- o Foster cooperation among federal and industrial representatives with the common goal of national security via energy conservation.

The 1993 Oil Technology Conference comprised: (a) four plenary sessions devoted to presentations and summations by public and private sector 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 12 formal presentations and one supplemental presentation made in addressing:

- o Integrated Oil-Fired Appliances;
- o Advanced Controls and Technology Transfer;
- o Oil-Heat Venting Technology;
- o Fuel-Quality and Combustion Technology.

2.1 Integrated Oil-Fired Appliances

Three presentations were scheduled in the first session, covering the results from ongoing research, product development and evaluation testing for integrated appliances.

The first paper, **Canadian R&D on Oil-Fired Combustion Systems**, describes research and development presently being conducted on oil-fired space and water heating systems at the Combustion & Carbonization Research Laboratory (CCRL) in Ottawa, Canada. (Due to budget constraints the CCRL representative was at the last minute unable to attend the conference and a statement was read on his behalf concerning the paper contents.) The paper concentrates on activities at CCRL to develop suitable oil-fired integrated systems and control strategies to satisfy the low energy demands of new homes in Eastern Canada, a region which does not have alternative energy options, and so offers a promising growth market for oil. Other topics discussed in the paper include the potential for second generation retrofit of electrically heated homes and burner performance problems due to variations in fuel quality.

The second presentation, **Residential Cogeneration - The Next Step for the Oil-Heat Industry**, presented a manufacturer's viewpoint on the subject of integrated oil-fired appliances. Cogeneration is the simultaneous production of heat and electricity. Thermodynamic considerations dictate economies of scale for electrical generation; large generators are inherently more efficient. However, in the 90's, the efficiencies of mass production are overcoming the efficiencies of scale. Multi-disciplinary system engineering and new patented technology have combined to make very small cogeneration systems, sized to fit most single family residences, not only technically feasible but capable of providing a three to five year payback for the typical household according to the authors of this paper. The author's system, manufactured by Intelligen Energy Systems, Westford, Mass., is designed to function as the sole central heating system. Rated at 85,000 BTU/hour (heating capacity), it operates whenever thermostats in the home call for heat, and generates 5 kW as long as it runs. If the household is using less than 5 kW at that moment, the excess power flows back into the electric grid.

The third paper in this session, presented by BNL, was an **Engineering Evaluation of an Oil-Fired Residential Cogeneration System**. This paper presents the results of an engineering test and analysis of the efficiency and energy-conservation potential associated with the above residential oil-fired cogeneration system. The system is designed to burn No. 2 heating oil as a fuel, which is consumed in an 11-horsepower, two-cylinder, 56.75-cubic-inch, 1850-RPM diesel engine. The cogenerator produced 4.8 kw of electric power under steady operating conditions. Its output is nominally 5 kw on a cold start, dropping somewhat over time as the generator unit comes up to constant operating conditions and temperatures. The cogenerator has a combined system efficiency of 92.8 ± 4.4 % including its electrical output, hydronic (hot water output), and warm-air output. This represents a new high-end reference mark for the efficiency range of oil-fired residential heating equipment performance. If the warm-air component is not used at all, the combined efficiency drops to 71.5 ± 1.2 %. The measured emissions are representative of those expected for a diesel engine of this size and type. The noise level was within measurement error of noise levels obtained at BNL for an oil-fired furnace and for an oil-fired boiler during comparison tests in the BNL Combustion Equipment Testing Laboratory (CETL).

2.2 Advanced Controls and Technology Transfer

The second session included three papers related to working experience in the field including tests of advanced oil-burner controls and technology transfer activities.

The first paper in this session was presented by BNL on the **Application of the Flame Quality Indicator (FQI)**. The FQI has been developed at BNL as part of a program to study, generally, advanced control and sensor options for residential oil burners. During this study optical approaches were found to be very interesting and the FQI is a simple, first application of the results of that work. Essentially, the FQI uses a standard CAD (cadmium sulfide sensor) cell and circuit to convert flame brightness to a voltage signal. The circuit provides a red "service required" light when the brightness (voltage signal), in steady state, changes beyond a limit range. The burner must still be adjusted, initially, by a qualified serviceman; the FQI simply indicates when something has changed and the burner should be examined. BNL is presently well along in a further set of field (and lab) tests in which the behavior of the FQI in a wide variety of system types is being studied. The primary subject of this paper is a comparison of the behavior of different system types and a discussion of further FQI improvements. The U.S. Department of Energy, which has sponsored the development of the FQI, currently holds a patent and is making licenses available on a non-exclusive basis.

The second paper is this session, **Integration of the Energy Kinetics System 2000 Controller and the BNL Flame Quality Indicator**, was presented by the first manufacturer to apply for a non-exclusive license of the DOE patented FQI technology. The author states that "the concepts of a Flame Quality Indicator (FQI) for monitoring oil fired residential heating systems offers the oil industry an opportunity to further promote the advantages of its equipment and services to the consumer. In the future, if for efficiency or low emissions reasons, units operate at low excess air levels, the window of clean operation may get even tighter and the FQI monitor may be the only way we can insure reliable operation." The author believes there are real advantages to the FQI and that it is close to commercialization. As with any development, the author prefers to continue field testing on a controlled basis before the product is released for general application.

The last of the papers in this session, **How to Increase Public /Industry Awareness of Oil-Heat Energy Conservation Opportunities**, was presented by the Nova Scotia Department of Natural Resources which has developed a number of approaches to increase awareness on the part of the public and industry groups of the opportunities for increased energy efficiency and conservation in housing. Several of these activities are directed specifically at the residential heating industry. The presentation described efforts to increase the use of efficiency testing through industry training, public information and a shared purchase of efficiency test equipment. The effect of recent code developments pertaining to combustion efficiency testing and the revisions to the venting codes was also discussed.

2.3 Oil-Heat Venting Technology

The first session on the second day included two presentations based on the BNL Oil-Heat Venting Technology Project.

Recent issues in the industry with respect to the growing popularity of side wall venting, the provision of combustion air in today's tighter energy efficient homes, and the retrofit of new high efficiency heating equipment into existing venting systems were outlined in the first paper, **Oil-Heat Venting Guidelines - Vent Materials and Corrosion**. This paper presented a brief overview of research work conducted in the application of metallic materials in oil-fired heating systems. The mechanism of sulfuric acid formation and the issue of surface corrosion of oil-fired heat exchangers were both discussed in terms of the implications of acid carried over into the vent system. The results of experiments studying vent wall temperature profiles were presented and discussed addressing the implications of water and acid dew point. A brief review of related research in metal corrosion rates in heat exchangers was presented and extended to the development of a proposed method of analyzing vent material loss through corrosion as a function of exposure time and temperature. The method was applied to actual laboratory time/temperature history test data for a vent system and the results were presented and discussed. A brief summary of the findings to date resulting from BNL research to be included in the Guideline document are:

1) Acid and water dew points are a source of concern for vent materials (and heat exchangers) in the operational environments presented by oil-fired equipment. The Sulfuric acid dew point for No.2 fuel oil lies between 225 and 240 F. Surfaces below these temperatures will permit acid condensation and possible corrosion. Flue gas-side surface temperatures below the acid dew point are prevalent in most modern oil-fired appliances and vent systems.

2) Vent wall temperatures are substantially less than centerline flue-gas temperatures. As shown, in the laboratory and extended to field use, a crude approximation of the vent wall temperature may be calculated as the average of the centerline flue-gas temperature and the local ambient temperature.

3) Downsizing of short vent connectors by reducing diameter, within the limits set by the appliance input rate, has marginal benefit in terms of increasing vent wall temperature and reducing the quantity of acid condensation. Reducing heat flow through the vent wall is more effective.

4) For each element in a given vent system there is a fixed period of time where that element is below the water and/or acid dew point during the burner "on" time. The amount of acid condensed and the amount of corrosion within each element is a direct function of the number of cycles the equipment experiences during its lifetime of operation. A reduction of the total number of lifetime cycles, through the use of low output appliances, variable firing rate, or thermal storage will extend the life of appliances and reduce maintenance needs.

5) In all cases, after any draft control device, reduction of heat flow through the vent wall is essential to maintain the vent wall above the acid dew point.

The second paper in this session provided **An Overview of the BNL Oil Heat Vent Analysis Program (OHVAP)**. OHVAP is being developed in response to oil heat industry needs in vent system analysis and is designed for desk-top PC (DOS) computers. The rationale for the development of a vent system analysis tool for the oil heat industry was discussed in terms of the need for properly sizing both chimney and advanced venting systems for mid- and high-efficiency oil-fired appliances. There are unique requirements for the venting of oil-fired appliances and the features that OHVAP will contain to meet these requirements were described. The Input Menu and Engineering program operation were described in some detail. The Input Menu was described in terms of the input sequence and flexibility of system representation for the analysis. The Engineering program description contains the basic theory behind the computational approach and a detailed step-by-step description of the program operation as it is carried out to obtain a solution. The current configuration of the OHVAP output is a data file format and a description of the data arrangement was presented. The program is being validated and the current status at this stage of development was discussed. As a result of the validation process some changes have already been implemented and some features remain under development. These were discussed along with future plans for OHVAP and its application.

2.4 Fuel Quality and Combustion Technology

The last technical session on fuel quality and combustion technology included three presentations and one supplemental presentation.

The first paper presented by BNL presented research results related to **Fuel Quality Effects on Home Heating Systems**. Good fuel quality directly relates to better performance and more efficient operation of residential heating equipment. Brookhaven National Laboratory (BNL) has investigated the effects of fuel quality parameters on heating equipment and has developed countermeasures to ensure that quality is maintained. In order to disseminate this information and promote the concept of fuel quality on a practical level, a set of guidelines has been developed specifically for service managers to use. The highlights of the research work and the ideas developed in the set of guidelines are presented in this paper. Two major factors influence the overall level of distillate fuel quality, the nature of the fuel itself and the conditions in which the fuel is stored. The characteristics of the fuel are generally defined in terms of standards (such as ASTM or state and local fuel quality requirements). As part of the current BNL studies, experiments were conducted to evaluate the adequacy of these standards in terms of heating equipment performance and emissions, and to determine the limits of acceptable fuel properties. The potential benefits that can be gained with the use of low-sulfur fuel in heating equipment has also been evaluated. The storage condition is perhaps the most important of the factors that ultimately affects fuel quality. Much of the perceived fuel related problems such as clogged filters and nozzles are caused by contamination. Minimizing and preventing reoccurring problems require an understanding of what to look for, how to evaluate it, and what to do next. The guidelines developed by BNL, "Maintenance and Storage of Fuel Oil for Residential Heating Systems" (BNL Report No. 48406), provides a reference to resources available and serves as a start to understanding and attacking this issue.

Residential Fuel Quality Study, a supplemental paper on this topic was presented by a fuel-oil marketer who has started to apply the information in the BNL guidelines as mentioned above. The presentation indicated that much study had been done on fuel degradation, biological growth and other mechanisms for bottom sediment formation, and that Brookhaven had developed a very good guide on the storage of fuel oil. Future work should apply the findings of this research to the particular conditions found in customers' fuel systems and should identify practical cost-effective solutions. Solving problems like this suggests some exciting possibilities for cooperation between fuel dealers and Brookhaven National Laboratory. This type of study can serve as a model. Dealers have the resources to try new products and techniques and the computer systems to collect data and track results. As an active arm of the laboratory R&D effort, they would be able to produce real results in a cost-effective manner. Some might say that the oil-heat industry is too busy, overworked, and too competitive to afford the time for such research. The fact is that the industry finds the time to change thousands of sediment-clogged filters and nozzles every year. "The alligators are living in the bottom of our customers' tanks. We need to stop embarrassing ourselves by wrestling the alligators in front of our customers and start draining the swamp."

The next paper on **Fouling of Oil-Fired Boilers and Furnaces**, which leads to reduced efficiency and increased service requirements, presented BNL's findings on how to eliminate or limit "soot" formation in heat exchangers. The average level of annual efficiency reduction due to fouling is generally taken as 2% per year. BNL is currently studying causes of soot fouling for the purpose of identifying practical methods of minimizing these deposits. Factors which control the fouling rate include the fuel sulfur level, the burner excess air (controls the SO_2/SO_3 ratio), and the surface temperature which affects the acid condensation rate. If the surface is above the acid dew-point (about 220 F) corrosion occurs only by attack from the gas phase. If the surface is below the acid dew-point but above the water dew-point (about 120 F) corrosion occurs by the direct condensation of sulfuric acid on the surface. This is the normal situation in heating boilers. If the surface is cooled below the water dew-point corrosion rates are greatly increased. This paper reports on studies of fouling rates with cast-iron boiler surfaces, steel boiler surfaces, and furnace surfaces. Effects of the sulfur level in #2 oil, excess air, and temperature trends during the burner-on period are discussed.

An Assessment of Fuel Oil Heaters and how they affect oil-burner performance in both steady and cyclic operation was the topic of the next to last paper. The viscosity of No. 2 fuel oil affects heating equipment performance and varies as a function of fuel temperature. The nominal viscosity of No. 2 heating oil can range between 1.9 and 3.4 cSt (at 104 F) as specified by the ASTM. When fuel temperature decreases, such as during the winter season, the viscosity can increase substantially and poor atomization can occur. Methods to heat the fuel are sometimes used to maintain the viscosity to within the acceptable operating range. Nozzle line heaters are available commercially and can be used for preheating the fuel before it is atomized. These are designed as retrofit devices and, in some cases, as original equipment in a new burner. This paper described work done at BNL to assess the benefits of such devices and other heating methods. Experiments were conducted using fuels with temperatures ranging from 40 to 120 F. A home heating system or fuel supply which is stored in an unheated basement or outdoors can become as cold as 40 F and lower. In such cases, improved burner operation can be achieved if the oil is preheated. The maximum temperature may be practically set to the level when nozzle afterdrip starts to occur. If the temperature is too high fuel oil can drip out of the nozzle assembly when the burner is off during cyclic operation. This is caused by the expansion and vaporization of hot oil at the nozzle tip.

Conclusions:

- Nozzle and fuel line heating devices used to preheat "cold" oil can maintain consistent viscosity of the fuel to within an acceptable range, improve atomization and reduce nozzle fuel flow rate.

- These heaters are most effective during the first two minutes of burner operation. The combined effects of improved atomization and reduced fuel flow rate (with relative increase in excess air) during this period leads to reduced transient smoke.

- The benefits from the use of the nozzle heaters are evident when the burners are set for very low excess air levels. Under these conditions fouling rates are reduced over long term use.

- In a one pipe system, the recirculation of oil within the pump housing is fairly effective in warming "cold" fuel oil. However, the rate and extent of heating is inadequate during the start-up period when it is most needed. Adding an external de-aerator does not provide more heat.

- The **potential** efficiency gain with the use of nozzle heaters is estimated to be 2.5%. Achieving this gain requires that service personnel set excess air to lower levels with the addition of a nozzle heater.

The last technical paper presented at the 1993 conference was a BNL presentation on **Advanced Air-Atomized Burners**. Domestic oil burner designs in the U.S.A. have long been limited by the relatively low cost of oil so that the high initial cost of advanced technology to provide efficiency gains was hard to justify. Another limitation has been caused by the lack of reliability of the conventional pressure-atomized nozzles used at rates below 0.60 gph oil input. Although the typical heating load of many homes today ranges from 0.25 to 0.60 gph, these homes are usually fired at inputs of 0.75 to 1.00 gph or higher. Work at BNL during 1990 and 1991 identified and demonstrated the possible feasibility of an air-atomizing nozzle that uses relatively higher air volume but at much lower pressure than other air atomizers. This allows the use of a blower to provide both atomizing and combustion air, eliminating the need for an air compressor. The paper's co-author was Mr. Leonard Fisher, a BNL consultant and an expert in oil burners. He advised BNL of the strong potential of this new concept, not because the burner would cost less, but becuase it could be justified when all its assets are considered:

- o Low input range with reliability
- o Low excess air (High CO_2)
- o Low NOx
- o Low CO
- o Low SO_3, hence low H_2SO_4 effluent
- o Small, intense flame
- o Insensitivity to draft
- o Less sensitive to fuel properties

More recent studies at BNL have shown that both corrosion of and soot deposition on the heat exchanger are reduced by low excess air (high CO_2) operation. So the ability to operate reliably at low excess air allows both higher initial and longer sustained efficiency as well as fewer cleanup servicings. During its fiscal year of 1992 (Oct-Sep) the BNL staff with some guidance from Mr. Fisher as a consultant undertook this project of demonstrating the feasibility of such a burner through iterative ("cut and try") design, test, data analysis and redesign, using a high pressure blower and the special air atomizer with No.2 fuel oil. Overall, the performance met the proposed objectives as follows:

- Firing Rate Range 0.30 gph to 0.60 gph
- Zero smoke at 5% excess air (1% O_2)
- Below 50 ppm NOx
- Below 30 ppm CO
- Burning intensity over $5x10^6$ Btu/ft^3 hr
- Insensitive to large draft variations

3.0 Workshop Sessions

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

A. New Oil-Burner Developments and Related Industry Issues on the Horizon
B. Guidelines for Oil-Appliance Venting - Industry Review and Consensus Actions
C. Fuels, Fuel Quality, and Storage - Part Three - Industry Actions
D. Oil-Heat Technology Transfer

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

GROUP A. New Oil-Burner Developments and Related Industry Issues on the Horizon

The workshop was attended by about 35 people, representing marketers, manufacturers as well as some people involved with technology development. Discussions were focused on problems with existing equipment and activities BNL might undertake to serve current and future needs of the industry.

The major concern raised with current equipment was the service and reliability issues related to fuel quality. In considering advanced burners BNL should put an emphasis on ability to handle poor quality fuel without the need for excessive filtration. One of the participants stated that this was one of the reasons he was so enthusiastic about the Babington burner which had been demonstrated at an earlier conference at BNL.

Another area of concern raised was an apparent decline in the reliability of both ignition transformers and controls. Newer components are much less reliable than older designs.

The group had considerable discussions about advanced control options. The BNL Flame Quality Indicator was seen as a very positive first step. In addition, however, the group would like to see sensors which will shut down the burner or provide a warning when a severe sooting situation has occurred. The FQI should call for service when a burner is starting to produce an excessive amount of soot but future controls should also look for a fouled heat exchanger problem. Sooting of homes is unacceptable and the industry must totally eliminate the possibility of this occurrence.

In deciding upon the output options for the FQI some concerns were raised about alarming the homeowners unnecessarily. An audible alarm might lead to a call to the local fire department.

In advanced burners a wide "window" of excess air levels for acceptable operation is seen as very desirable. It seems likely that in the future this window will generally be moving toward higher CO_2 levels (reduced excess air).

Generally BNL should pay more attention to NO_x in the future. Some of the participants said that we should start by knowing more about NO_x with existing equipment - what affects it and how might it be reduced. For example, the effects of the combustion chamber environment should be studied.

One participant raised the suggestion that the U.S. industry should pay more attention to the European ISO standards. These standards must be met for U.S. products (such as the FQI) to be marketed in Europe and elsewhere. BNL or some other group might aid exports by assisting U.S. oil heat companies in understanding these requirements.

GROUP B. Guidelines for Oil-Appliance Venting - Industry Review and Consensus Action

The first topic of discussion was the Venting Guidelines. The participants were quickly brought up to date on the current status of this work. The group then started going down the list of suggested questions from the conference program.

The first question: Are vent/chimney inspections commonly performed during equipment service calls? Was answered with: Is there a protocol for inspecting vent systems or should there be one? There is a code already in place in Canada. The Installation Code for Oil Burning Equipment (CSA B139 M91) requires chimney inspections, and regulates such variables as sizing, entrance and exit temperatures, clearances, appliance types, etc. Another question was then asked. Whose responsibility is the inspection? The county building inspector, or the service company? And how do you rate the inspector? There was no agreement or consensus on the answer.

The tools that are needed to inspect a chimney/vent system were also talked about. Miniature video cameras were a common though expensive option. Others said that they had a chimney sweep company come in and perform the inspection. A problem with both of these techniques was that they are only visual inspections. There was no way to properly evaluate the structural strength of the system, short of seeing obvious holes in the chimney.

Discussion then turned to the next question. What is the field experience regarding corrosion in the field? The L-vent installed in the field was mostly "rotten" through and through. PLEXVENT, the plastic vent pipe used in gas applications was failing with longitudinal cracks forming in straight sections and was in the process of being re-evaluated by Underwriters Laboratories. The temperatures provided by mid-efficiency equipment were apparently too high for the plastic. Soot and acid carryover were also talked about. Even in condensing systems soot and acid will pass through the heat exchanger. Along the same lines the question of flue fires was brought up. It seems that in older equipment there was a tendency to carry combustibles (soot and/or unburned fuel) out of the appliance and into the vent. If a restart was initiated with liquid fuel in the system or if the flue-gas exit temperature within the system then became too high, it was possible for vent system deposits to start burning.

The third topic was how well masonry chimneys performed for oil appliances. The general consensus was that too much heat was lost in the vent connector, either to the surroundings or through dilution, for older chimneys to work well. Most chimneys, it was felt, should be relined for the newer equipment. Next to inadequate draft, acid condensation was the biggest problem reported. The statement was made that chimney tile liners are supposed to be assembled using an acid resistant mortar. It was generally believed that this was not actually done. Instead, the acid would condense out of the flue gas within the liner and find its way out to the brick work and eventually destroy the chimney. According to the experience of one of the participants, chimneys located on the north side of the house were the worst, while those located on the south side were "generally OK".

The fourth question regarding what materials should be used to insulate the vent connector was never addressed. Instead this discussion centered on the contradictions between the manufacturer's instructions and the many regulating codes. This was an area where it was felt that BNL would probably do the most good; developing a document that would summarize and organize the various codes that apply.

The last question about the Guidelines involved what additional avenues should be used to perform an adequate review. There was general agreement that the equipment manufacturers should definitely review the document. IBR and ASHRAE (TC 3.7) were also mentioned as good forums for review.

The meeting then talked about the Oil Heat Vent Analysis Program (OHVAP). Before the questions from the agenda were even read, someone asked if OHVAP would handle house and outdoor pressure fluctuations. It doesn't, in its present form but further enhancement of the program should be considered. OHVAP, in its present form, is a program that is designed to model the independent behavior of the venting system under temperature and flow from an oil-fired appliance. Other effects due to appliance design characteristics or building de-pressurization are, at present, not included. One feature that people did want to see was the ability to have multiple appliances exhausting into one flue. While not currently implemented, if time constraints allow, this feature should be added.

When the question came up about how the program would be used by the industry, the answer was rather surprising; it wouldn't. It was believed that the venting tables produced from the program's output would be widely used instead. In keeping with this position, everyone was in agreement in stating that the program didn't need graphical output, tabular results would be sufficient. When asked for the types of tables that should be given priority, masonry chimneys topped the list. Relined chimneys came in second, with power vent systems being a distant third.

The workshop was brought to a close. A summary was prepared and presented to the attendees at the closing of the general session.

GROUP C. Fuels, Fuel Quality, and Storage - Part Three - Industry Actions

A total of 26 members attended this workshop session; they consisted of fuel oil distributors, additive marketers, refinery R&D researchers, heating equipment manufacturers, members of associations for petroleum marketers, tank cleaning/ fuel quality service representative, and a trade journal reporter.

The chairman began the session by asking whether anyone has experienced fuel quality related problems, and if so, whether they have determined the extent of these problems. There is a general awareness and concern that poor quality oil affects their business, i.e. the number of service calls, and customer perception of oil heat. However, little has been done to maintain records of the occurrence of fuel quality problems (i.e. filter changes) with respect to delivery of oil to their customers. The biggest problem affecting efficient operation of heating equipment is related to sludge and water buildup. Many servicemen acknowledge that poor handling of fuel could lead to contaminated fuel, but some were concerned that the fuel received from various suppliers is not of "good" quality. The participants discussed ways of how they dealt with sludge, i.e. tank cleaning, use of chemical additives, change in oil delivery practices so that tank bottom residue would not be stirred up during delivery, but all had varied success. In many situations, what worked for one company may not have worked for another.

Clearly, all the members agreed that the mechanisms of fuel degradation and sludge buildup must be better understood. A treatment (or a series of treatments) could then be applied to prevent or slow fuel breakdown processes.

The key to success of any treatment program is to isolate possible sources to the sludge problem.

The chairman initiated a discussion on stability of fuel. One of his concerns was the possibility that copper in the fuel delivery lines could be acting as a catalyst to accelerate the fuel oxidation process. Copper in solution has been known to function in this matter, although it is unclear in this case whether it is the leading factor causing fuel breakdown. The chairman brought in two oil samples showing the results of a small test he had previously conducted at his company. One sample contained fuel oil only, the other contained a piece of copper tubing immersed in the oil. The point of the discussion was that after several days the oil with the copper tubing turned a deep amber color while the control sample remained light in color. Could this be an indication of fuel breakdown after such a short time? and if this is the case, what are the consequences since all piping in a heating system is made of copper? Further research needs to be done to understand the catalytic effects of copper and other oxidation mechanisms.

The industry has expressed a great deal of interest in further research related to fuel degradation. Several members have agreed to participate in any field studies which may develop in order to provide a statistical basis for the data.

Representatives from refinery research divisions participated in this workshop and were able to provide a different perspective. Their comments indicated that at the refinery level they were unaware of the extent of fuel quality related problems confronted by the oil heat industry. They were interested in keeping abreast of any further developments in this field of study.

GROUP D. Oil-Heat Technology Transfer - Industry Role and Future Support Actions

1. How can the industry support, assist, and contribute to the commercialization of new high efficiency concepts (such as the FQI or the new BNL Fan-Atomized Oil-Burner) as products available in the marketplace?

   a) The oil-heat industry can best support, assess and contribute to the commercialization of new ideas and products by encouraging Brookhaven to participate in trade shows, industry meetings and industry related programs. Brookhaven must take the show on the road to provide the necessary credibility to new products.

   b) Equipment development is driven by market demand. Oil dealers must sell the flame quality indicator and similar developments to the consumer.

   c) More knowledge and background information is needed on new products from Brookhaven and other research groups. Many products never reach the market place because the dealer has little knowledge on a new product and is often not sold on its capabilities.

2. How can the marketing industry help DOE in promoting the introduction of new high-efficiency technologies currently under development?

   a) Tax rebates are good incentives to promote new technologies.

   b) Oil dealer education programs for their customers are important.

   c) In many cases, two-step programs are necessary:

      i) General information to overcome misconceptions about oil heat; and
      ii) Information on new oil heat advances.

3. BNL is about to complete the Oil-Heat Efficiency training manual. Which industry organizations should be considered to support continuation of the manual once BNL and DOE have completed the initial version? How should the manual be promoted and by who?

   The National Oil Heat Service Managers Association is one logical industry organization to support the manual and sponsor the combination of training seminars. Whoever obtains the rights to the Petroleum Marketers Education Foundation (PMEF) Oil-Heat Technician's Manual and other PMEF assets would be another logical choice.

4. How should the seminars be organized and supported?

   The seminars should be structured in modules and delivered in one day seminars. These should be arranged in a scheduled manner to ensure their success.

5. How frequently should the information be reviewed and who should be responsible to update it?

   The training material should be reviewed on an annual basis and appropriate addenda included as required. This procedure could be administered by the Service Managers Association.

6. Will the manual need to be supported with other materials other than workbooks and slides?

   In addition to the planned workbooks and slides presently being prepared, the program should be also supported by videos which can quite easily be developed from slide presentations.

4.0 DOE/BNL Perspective

The 1993 Oil Technology Conference brought into focus the realities of the marketplace and the role that federal sponsors and researchers can fill in promoting energy conservation consistent with the public benefit while recognizing the competitive nature of a free enterprise.

From a technical perspective, BNL has taken fundamental approaches to identifying and characterizing combustion phenomena which influence 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 which may transcend technical considerations.

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 facilities resources while serving as an objective evaluator of private industrial accomplishments. This support is critical to the enhancement of technology development and transfer, to the mutual benefit of the industry and the oil consumer.

I. INTRODUCTION

The 1993 Oil Heat Technology Conference and Workshop was held on March 25-26 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 fifty people were registered and participated at the conference.

The 1993 Oil Heat Technology Conference, which has been the seventh 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 satisfying consumer needs cost-effectively, reliably, and safely;
- Foster cooperative interactions among federal and industrial representatives in accordance with the common goal of national security via energy conservation.

<u>Special Addresses</u>

Introductory remarks were provided by Leon Petrakis, Chairman of the Department of applied Science, who welcomed the assembly on behalf of Brookhaven National Laboratory. Dr. Petrakis emphasized BNL's commitment of advancing oil heat technology and to effect technology transfer to the private sector. Dr. Petrakis concluded his address with the introduction of the Conference Keynote Speaker, John P. Millhone, Deputy Assistant Secretary of Energy for the Office of Building Technologies. John Huber, Heating Fuels Counsel for the Petroleum Marketers Association of America (PMAA), then welcomed the participants on behalf of PMAA. The Master of Ceremonies for the 1993 Oil-Heat Technology Conference, the current PMAA Heating Fuels Committee Chairman, Douglas Woosnam was then introduced. Prior to starting the technical presentations, Mr. Woosnam presented his thoughts on "Oil-Heat Technology - Marketer Perspective." The text all of these special addresses follows.

OPENING REMARKS - WELCOME AND INTRODUCTION

TO THE 1993 OIL HEAT TECHNOLOGY CONFERENCE & WORKSHOP

Dr. Leon Petrakis, Chairman
Department of Applied Science

It is a great pleasure to welcome you again to Brookhaven National Laboratory. BNL is a multi-program, multi-purpose national laboratory. It has activities both in basic sciences and, also, in applied programs and the Department of Applied Science is playing a key role, we like to think, in these kind of joint activities. During the last few years we heard a great deal about cooperation between government and industry in trying to take advantage of the science and technology that is being developed at the national laboratories so that the competitive advantage can be given to American industry.

I would like to share with you the mission of the Department of Applied Science that was written four years ago when I first came to BNL and I especially want to draw your attention to the second part of that mission statement. "We are committed to excellent science and technology, but also we want to transfer the useful results and the knowledge gained from our studies to the scientific community and to the commercial and industrial sectors." I wrote that statement for the department when I first came here long before it became fashionable to speak about such issues. So our commitment is true and in the Oil-Heat Technology area, I think there is one of the prime examples, if not the prime example, that would be used as a paradigm as to what the partnership that we are talking about between government laboratories and industry, should be.

The flame retention head burner demonstrated at Brookhaven and distributed and utilized through private industry to some 6 million households to date is one terrific example that needs, I think, to be emulated much more broadly. To date, almsot half a quad of oil savings has been effected through the utilization of that single development.

As we are debating, the deficit and the means by which that can be addressed, energy again, has been put at the epicenter. Oil has been singled out as a possible additional resource of funding for meeting the deficit. But this morning I am sure that you are all aware an amendment was suggested by Senator Kennedy and the extra charge above the Btu tax that was geared specifically for oil has been sidetracked.

We are talking about a very important issue, oil-heat, throughout the nation but especially in the Northeast. Brookhaven is pleased and proud to contribute and we will hope to continue to contribute in this vital area. Hopefully Deputy Assistant Secretary - John Millhone, who will follow me very shortly here, will have I hope some good news about that.

The activities of the department in this area are quite broad - there are some extremely interesting developments - and you will hear about them in the next day and one-half, but an equally important activity of this workshop is the fact that you and we are getting together and we are very much interested in your inputs. Those of you who come from industry know much better than we do what are the real problems, what are the real needs, where can our resource be most useful. So, indeed, we want to continue this partnership. We solicit and we value your inputs and I hope in the years to come we will continue working in this area.

Last year there was a very interesting development that I would like to share with you. The very prestigious IR 100 Award was given to the Laboratory in recognition of a very interesting development. Namely, the Flame Quality Indicator (FQI) that was developed here at Brookhaven. The award consisted of a very nice national recognition that was made at Chicago and a plaque. None of these developments would have been possible without the wisdom and the foresight of the Office of Conservation and Renewables, specifically the Buildings Program at DOE. Personally, I want to take this opportunity and thank John Millhone and his staff - Esher Kweller who is here - and some of the other people, Ted Kapus, John Ryan, and others who are not here for staying with this program and expressing their belief that it is something very important. So, at this stage, I would like to ask John Millhone and Esher Kweller to come up to the stage. We have copies of the plaque that Brookhaven was given and we would like to have them take them back to Washington in recognition of their significant contributions.

Indeed, we are very pleased that the representatives from the Department of Energy are here to see the evidence of this very close interaction because, quite frankly, if we do an excellent experiment, scientific or technological experiment, and we publish it in a Journal, that is wonderful, but that is not good enough. We need to get the technology out where it can be used by private industry as they see best fit. So, at this stage, we would like to ask John Millhone to make some remarks to this gathering here.

John Millhone is the Deputy Assistant Secretary for the Office of Building Technologies, within the Office of Conservation and Renewables. He has a long experience in matters of energy efficiency and conservation, an area we think is becoming paramount because as the energy intensity of the economy is lowered, the productivity and the jobs creating ability of the economy are decreased. So, we would like to think that energy conservation is at the forefront of this effort to make things better. John has a very interesting and diverse background - federal, state, and private experiences. He has had trade experience in Journalism, which has been an added tool in his being a very articulate and passionate speaker on behalf of Conservation. John, we are very pleased that you are hear and we look forward to your remarks.

John Millhone
Deputy Assistant Secretary
Office of Building Technologies
Office of Conservation and Renewable Energy
U. S. Department of Energy

1993 OIL HEAT TECHNOLOGY CONFERENCE & WORKSHOP

It is good to be here with a number of people that I have not seen for some time. One thing that I am noticing is that there is sort of a different group within the oil marketing association. I was head of the Minnesota Energy Agency and the Iowa Energy Policy Group in the 1970's, and back at that time I was Chairman of a Fuel Oil Marketing Advisory Committee. This was before I came to the Department of Energy and we had a number of interactions then. This was when there had been price controls and the marketing advisory committee was named to try to figure out if there were any violations of the price controls, and if there were, where did they take place, where within the fuel oil industry. It was a fascinating job. I found out at that time, that when you talk about the oil industry that it is not the monolithic combination that those on the outside perceive and ever since then I have had a special interest in the Brookhaven program and have had, I think, a lot of recognition of the significant advances that have been made in the oil-heat technology through Brookhaven and, also, a good recognition of the very significant contribution that oil-heat marketers have made over the years in terms of improved efficiency. Every time when we have had an issue at the Department of Energy where I have come to your industry and asked for some support we have had very good support. I remember when there were anticipated oil shortages and we talked about what might be done in that situation a few years back (the Gulf War crisis). So it is good to be back with you again.

We are now going through a very challenging period at the DOE with transitions. Transitions are always challenging. There is a story about the transition team walking through the DOE that you may find insightful. This was a transition team within the DOE, fortunately they were not in my part of the department, but they asked someone, "Tell me what is it that you do around here?" And the person said, "Well, I used to....well really I am not doing anything right now." The transition team did not say anything, walked around the corner and talked to someone else and said, "Tell me, what do you do at the DOE?" And it was sort of the same answer, "Well I have been...but that program was cancelled and I expect to be...but right now I am not doing anything." And the transition team said, "Ah, ah, duplication!"

What I am going to do is say a little bit about some of the changes that are taking part at the DOE right now and some of the national policy approaches. I want to say something about how I see these things affecting the oil-heat industry and then I am going to make some suggestions about how I think we might work together more effectively in the future. Some of the suggestions for how we might deal with this mix. You might say that this is sort of the good, the bad, and the beautiful.

The good thing at the DOE, and nationally, I think is, that at least from our perspective, from the perspective of the energy efficiency side of things, energy efficiency is going to be getting more attention, more priority than it has in the past. This, I think, is apparent from the statements that have been made by President Clinton, Vice President Gore, and Secretary O'Leary. Also, I think it is significant in terms of the Energy Policy Act of 1992 that was passed in the closing days of the Congress which has major additional responsibilities, not only in the regulatory area, in the outreach area and in the research area, as far as energy efficient technologies are concerned. Some 50 different sections of that legislation that just affect my part of energy efficiency in buildings and federal energy use itself. So, we are struggling to put together the plans for the implementation of that. Very much more aggressive national effort in the area of energy efficiency. I think that is a key theme that will be played throughout the department. The reason that I am mentioning some of these themes is that I think that there are some challenges that will be facing the oil-heat industry and what I will be getting at is how can the oil-heat industry recognize these themes, respond to them in a way that is beneficial, not only to the oil-heat industry, but also to the nation as a whole. So, the higher priority that is going to energy efficiency in general is important and that is driven significantly by environmental considerations associated with the use of energy. That is why looking at the (BNL Oil-Heat Research) lab I was impressed by how much of the work there is looking at some of the efforts to reduce the emissions and seeing that theme being repeated because I think that is critical.

There is also significant dollar benefits here. The Energy Policy Act says the goal ought to be to reduce the energy use 30% by the year 2010, compared to what it otherwise would be. If we are looking at the Building Sector, for example, that would mean a saving in 2010, if we meet that goal, of $75 billion and that is a lot of money and converts into a lot of freed spending that could go into other economic areas and create other jobs as well. So, there is a major thrust in this area.

A second theme, I think, comes out of the legislative and the environment and that is a mix of strategies that will be used to accomplish this objective. Now, one strategy will be to increased attention to regulations, more attention is being given to regulations and energy efficiency and in equipment and in buildings than had been true before. One of the key provisions of the legislation directs all states to certify that they have standards for the construction of new residential and commercial buildings that are equal to or exceed the CABO standard for residences and the ASHRAE standard for commercial buildings. So, there is a greater emphasis on standards. DOE will be supporting some of the state activities. One of the provisions deals with home energy heating rating systems, setting up a national program for rating the efficiency of homes. One provision deals with energy efficient mortgages so that you can get a higher debt income ratio for an energy efficient home on the basis of being able to spend more for the home if your energy costs are less. There is more emphasis on research in certain areas. I think that what we are seeing out of this is a mix of a little bit more aggressive regulation, trying to embody some incentive-type programs and, also, research. I think this mix of strategy is good for accomplishing these energy efficiency goals and seeing how you might identify what those changes are and how you can fit into them is a key item.

A third component, I think, is the strong emphasis on state programs and regional programs which had not been as significant as in the past. In part, I think this is because you have in President Clinton not only a former Governor but a former Chairman of the National Governor's Association. You also, I think, in area after area where the statements are being made about how to implement programs, references are made to the key role of the states. The first group that the President met with were the former governors. The governors clearly will have a big role with the new administration and, I think, as part of that additional attention to the role that regions might have. One of the provisions in the new legislation that I think is particularly important in this area and in other areas is the provision that will create ten regional technology transfers in lighting and building technologies. One of the things that we will be doing in my office is figuring how this can be done to make those regional centers as effective as possible in transmitting energy research results into people who can use them. In a sense I think that what is happening here is a good prototype of how this can work. I want to mention this a little bit later on.

Another theme that is very important, is increased emphasis on making the national laboratories the mechanisms for job creation and economic infrastructure advances. One way of describing this is that because we don't have the same defense needs and military obligation concerns that we have had, now we are able to downsize some of the defense activities and use some of that expertise in other areas where they can make a contribution. Clearly the need to deal with the modernization of the infrastructure and more aggressive and effective economic development is a good potential use for that talent. So, that is the theme that is taking place at the present time as well.

I think that these are the principal themes that I am seeing that affect us. Increase the attention to energy efficiency, this mix of strategies to get the job done, more emphasis on the part of state and regional activities and the use of the enormous technology and scientific expertise that we have in the federal system, to advance the economic activities to affect the domestic economy. That I would say is sort of a good mix.

The second is not so good, because what I am going to do next is discuss what are some of the implications of some of these as far as the oil-heat industry is concerned. This is not good news because there are some problems here and I would not be very honest with you if I did not candidly describe what I see taking place here. Now there are two issues that I want to mention. One is, obviously, the energy tax and the manner in which the energy tax has been proposed as requiring a heavier burden on oil-heat than on other energy sources. I am told that this morning there was a vote in the Senate that would make this a Btu tax rather than making a distinction between different energy sources. If that holds up, then I think that would make a significant contribution to the kinds of things that you are concerned about. But, that is something that, at least let's tell it like it is, and is something that, as an organization I would be concerned about. A second area is, the funding for the research in the oil-heat technology area that is done here at Brookhaven. Now, this has been something that sometimes has been in the budget and sometimes has not been in the budget. The latest information is that it is not in the proposed FY 1994 Budget. This is an area where you, and through the PMAA, have been very effective in getting the funding restored when it has not been there and some of us within the Department have tried to make the best argument we could that this is something that should be in the budget but we have not won those arguments and currently it is not in the FY 1994 Budget and the budget is frozen. So the budget will be going to The Hill from the Administration and won't include a request for this work. When I lost that battle I had some second thoughts, do you really want to go up and talk to the people at Brookhaven, but I thought that it would be best to let you know what the situation is. I think that there are some things that have been done about this in the past, and some things that have to be done about it now, but I wanted you to know what the situation is.

So that is the good, the bad and now the beautiful. But, I think that there are some positive things that can be said about the current situation. One is the work at Brookhaven and the work that you have supported and the work that you saw this morning. I was enormously impressed as I looked at the research being done and the display showing the research this morning; not only because of the accomplishments that were being shown there, because I have seen the reports and have known that this kind of work was being done, but the interaction between people in the industry and the researchers about this work. As Dr. Leon Petrakis said earlier, about the importance of the Laboratory serving this function of providing technical information to industry in a way tnat it is interested in using. I would say that was a living example of how this can best be done. I think you know, from those of you who were there, of the work that is being done at Brookhaven is at the cutting edge in terms of increased efficiency, in terms of reducing environmental emissions, and in producing technologies, interacting with you, that make your industry a leader not only in terms of efficiency but also in environmental areas as well, and leadership in those areas will be critical in the future. So, I think a very good story can be made. A good story can be made to people within the Administration when there are some Appointees at the Assistant Secretary level. At the present time I am sort of at the top non-political level with the Department and between me and the Secretary there is no one in those positions at the present time. So, when those people are named, the kind of story that can be made to them is a very persuasive story. What one can say is that this is an area that is critical to a region of the country and important in other areas as well. It is an area where major research accomplishments have taken place in terms of the award that was announced today. Before that, there was the National Energy Research Organization, NERO Award, which was a single award given to a major research accomplishment nationally. I don't think there is an area of the DOE Budget that has accomplished as much in terms of research advances for the dollars that have been spent as the oil-heat research program, so that there is something there to be told. I think that the interest the organization has shown in taking these results and using them are significant as well. So, I think there is a need and John Huber I know you will pursue it well and taking the message of what can be done here to the right people in Washington, both within the Administration and Congress, and doing that effectively is going to be important.

A second suggestion is that I think there is a way to use some of the things that are taking place positively. I suggested within the Department that we ought to provide some kind of a brochure of something on how to avoid the energy tax that would show how energy efficiency that is cost-effective can be used to reduce the energy cost more than what would be required by the energy tax. And, so you could say with these kinds of technologies you are familiar with, the technologies that are coming out of this research an individual can adopt these technologies, save more than they would be paying the energy tax and have a higher valued home and more comfort as well. So, using that in some kind of positive way, I think, would show not only that you are concerned about your customers in terms of their comfort and their cost, but you are also interpreting positively something that is being done in order to meet a clear national problem as far as the national deficit goes. So, I think that turning some of these positively is another thing that can be done.

A third thing I would suggest is that the oil-heat industry become actively involved in some of the State and Regional Programs that have started to develop. I mentioned, for example, the Regional Centers. Now these will probably be set up by Regions. New England is one Region. New York and New Jersey is another Region. Certainly the electric utilities will have a major goal in these activities but what we will be trying to do is set up centers that provide technologies for across the board for all fuel sources so that people can get information regardless of their fuel source in terms of improved energy efficiency and other factors in those areas. So, playing an active role in some of these regional activities, I think, is also a critical role in which you can play. Being part of the group that is providing information on how to accomplish improved comfort, energy efficiency at the state and regional level. I would certainly be happy to work with you in any of these activities in the future. It is a pleasure to be here. I salute Brookhaven for this effective organizational presentation meeting and the oil-heat industry for the fine job they have done over the years. Thank you very much.

PMAA OPENING REMARKS/CHALLENGE TO PARTICIPANTS

John Huber - Heating Fuels Counsel
Petroleum Marketers Association of America

1993 OIL HEAT TECHNOLOGY CONFERENCE & WORKSHOP

Thank you for having me here. As a Co-Sponsor of the Conference, PMAA would like to thank each of you for attending and welcome you to the Conference. This Conference is vitally important to PMAA and our members, as our members market up to 75% of the home heating oil sold in America. We at PMAA believe that heating fuel oil will continue to play a vital part in this country's energy future. Unlike other competing sources of energy, every aspect of production, wholesale distribution and transportation, as well as retail sales is competitive. As a result, we believe that the retail delivery of heating oil is the most price competitive fuel available. While the heating oil industry is extremely competitive and, thus, serves the consumer well, its competitive aspects and the fact that we are not a unified industry make it impossible for us to fund long-term research and development. That is why Brookhaven plays such a vital role through the industry. This Conference and the research projects discussed, as well as the research plans for the future, are extremely positive. They provide the long-term basic research and development that is so vital to maintaining this industry as a competitive force. Improvement in efficiency, reduction in emissions and improving fuel quality are all subjects which have been discussed at Brookhaven and which will continue to be explored in future years. This year marks a serious challenge for the oil-heat industry. President Clinton has proposed a tax that will be burdensome for our customers and we believe that the tax is unjustified. We will be fighting this tax increase during this year's Congress. Fortunately, the research at Brookhaven has helped us move farther and faster than any of the other fuels we compete with. Our efficiency is much greater than the competing fuels and in the free marketplace, our customers are clearly well-served by oil heat. We believe the case we will be presenting to Congress is strong and we are hopeful for an ultimate victory on this issue. However, we must all realize that this will not be the last significant challenge to our industry and as a result we must take steps to ensure that we meet that challenge.

The first step in meeting that challenge is to ensure that Brookhaven receives the necessary funding from the DOE and the Congress. Doug Woosnam, who will be your Moderator, will be testifying before Congress next week and will be making a strong pitch for increased funding for Brookhaven.

I would like to note that the tax proposed by President Clinton would result in additional taxes of over $600 million per year for our customers. We will be looking at funding in the $1.2 to $1.7 million range, which is a very small fraction of the taxes that President Clinton will be imposing. We believe that slight increase in energy efficiency, as Mr. Millhone noted, could make that tax invisible to our customers. So, continuing to get our efficiencies higher will make us able to bear those taxes and make us better than gas or any of the other competing fuels. So each of you I hope will be able to write your Congressman and encourage funding for this. We really do think this is the long-term future for the industry. I have fact sheets as well as sample letters that I brought with me that I will put out at the Registration Desk and I will try to distribute these to each of you during the breaks also.

The second challenge is to make sure the equipment and technology that is developed at Brookhaven makes it into the field. All the research that is done is meaningless to our industry if we can't translate that into real savings for our customers. That is why one of the more promising innovations is the Flame Quality Indicator (FQI), which I think Dr. Butcher will be discussing at length today. It promises to have a very long-term future for us. The FQI will allow us to keep the efficiency of the equipment at its highest level, prevent sooting, and will really be a big advance for the industry and I understand it can be done at very small cost. The problem is we have to get the manufacturers to put it out into the field. If we can keep jumping our efficiency, we can really prove to Congress, as well as to our customers, that this fuel has a long-term future.

Another area of interest to PMAA and its members is the work that is going on here regarding fuel quality. Like every retail business, we want to ensure that the product we sell is of top quality. We need to have satisfied customers. Therefore, the efforts of Brookhaven, to investigate fuel quality parameters and to develop countermeasures to ensure that quality is maintained, are vitally important. Because, as you know, we will be hitting a two-fuel system later this Fall where diesel and home heating oil are likely to be segregated. We hear increasing rumors that the diesel will be a very improved fuel where heating oil suffers as a result. In 1998, there is even talk that the diesel fuel market will get even tighter thus leading, perhaps, to additional degradation in home heating oil. It is really critical that we get a handle on fuel quality in the future and either maintain what we have or develop countermeasures that ensure that fuel quality does not hamper or interfere with our customers.

I want to thank Brookhaven National Laboratory and the staff of the Combustion Equipment Technology Laboratory for presenting this Annual Conference and I look forward to the presentations over the next two days.

OIL-HEAT TECHNOLOGY ADVANCEMENT - MARKETER PERSPECTIVE

Doug Woosnam, Heating Fuels Committee Chairman
Petroleum Marketers Association of America

1993 OIL-HEAT TECHNOLOGY CONFERENCE & WORKSHOP

On behalf of the Petroleum Marketers Association of America, a co-sponsor of the 1993 Oil-Heat Technology Conference and Workshop here at Brookhaven National Laboratory, I would like to welcome everyone to Day Two of the Proceedings.

This Conference is vitally important to the members of PMAA as we deliver about 75% of the total heating oil that is consumed in this country annually. We are also vitally confident of the role that heating oil is going to play in this nation's energy future. I think that, although we may have a preference, we believe that a balanced energy market for the consumers is something that we all must have as we go forward into the next century. The very competitive nature of our industry, the fact that the majority of us are small family-owned businesses provides a number of things. First off, it provides, I think, the best service available to our customers, the consumer. It provides competitive pricing for our customers but this is also one of the problems, that is, individually and even collectively, we can't raise the kind of dollars necessary to run an R&D program such as we have here at Brookhaven National Laboratory. This research provides a means, as we saw yesterday and as we will see today, to continually improve the product that our customer is using and without these improvements we cannot compete on a marketing standpoint with our utility counterparts. They have millions and millions more dollars to try to convince the consumer that they have the best product. The one thing that we continually have been able to do is outservice them. The other thing that we have continued to be able to do thanks to the efforts here at Brookhaven and other efforts is to provide a better product. A product that is safer, more efficient, burns as clean as, and provides better comfort than generally what our competitors can do.

Some of the studies currently going on here, especially the FQI and the Fuel Quality studies, especially when we go into next October when we go to a two-fuel system, I think arguably, may be another turning point in our industry. But studies like that are absolutely critically for those of us who are independent businessmen. However, this year as in past years, getting the funding to keep these programs going at Brookhaven continues to be a struggle. Historically, we have been able to succeed and get the funding. However, in the FY 1994 Budget, Oil-Heat R&D has been completely removed so we are starting at ground zero again. Next week on Tuesday, John Huber and I will be meeting with the DOE and later that day I will be testifying before the House Appropriations Subcommittee on the Interior to try and get the funding back for the program for FY 1994. I don't know how I can say it strongly enough, if you have never taken the time or have not been able to take the time to contact your Congressman and your Senator, I implore you to do that. The first thing you do when you go home, either tomorrow or when you get to work on Monday (John Huber has provided material, basic material in the back of the room, for that purpose), sit down, either use what is there, or customize what is there, and send a note or a letter to your Congressman and your Senator. Get their phone numbers, pick up the phone and say, "Listen, there are 13 million homes in America that are heated with oil-heat. The return on investment that the government has had in the programs at BNL is over 1000%, and if every program had a return on investment like this, then this country would not have the deficit it has today." There is nothing that they can appropriate funds for that comes back in the payoff that the programs here (at BNL) have proven to come back with.

Green Peace, Consumer Energy Council of America, have supported what our message has been, that is we need a balanced energy environment, that what we should be looking at is conservation and not conversion. That is the message that we want to take forward. I think that what I would like to do is go ahead and open today's program but just remember what we do here at Brookhaven or what they do here at Brookhaven does not just benefit the consumer through better efficiency and lower cost, it benefits the environment, benefits us the small business people and it benefits the country through a balanced energy program, so please write, call, do the things that it takes to support our effort on your behalf to get the funding to keep these programs going. So, with that I would like to open this morning's program.

Technical Presentations

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

- Canadian R&D on Oil-Fired Combustion Systems
- Residential Cogeneration - The Next Step for the Oil-Heat Industry
- Engineering Evaluation of an Oil-Fired Residential Cogeneration System
- Application of the Flame quality Indicator
- Integration of the Energy Kinetics System 2000 Controller and the BNL Flame Quality Indicator
- How to Increase Public/Industry Awareness of Oil-Heat Energy Conservation
- Oil-Heat Venting Guidelines - Vent Materials and Corrosion
- An Overview of the BNL Oil-Heat Vent Analysis Program (OHVAP)
- Fuel Quality Effects on Home Heating Systems
  - Residential Fuel Quality Study (Supplement)
- Fouling of Oil-Fired Boilers and Furnaces
- An Assessment of Fuel Oil Heaters
- Advanced Air-Atomized Burners

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. New Oil-Burner Developments and Related Industry Issues On the Horizon
B. Guidelines for Oil-Appliance Venting - Industry Review and Consensus Actions
C. Fuels, Fuel Quality, and Storage - Part Three - Industry Actions
D. Oil-Heat Technology Transfer - Industry Role and Future Support

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

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.

II. TECHNICAL PRESENTATIONS

Paper No. 93-1

CANADIAN R&D ON OIL-FIRED COMBUSTION SYSTEMS

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CANADIAN R&D ON OIL-FIRED COMBUSTION SYSTEMS

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.

The presentation concentrates on activities at CCRL to develop suitable oil-fired integrated systems and control strategies to satisfy the low energy demands of new homes in Eastern Canada, a region which does not have alternative energy options, and so offers a promising growth market for oil.

Other topics to be discussed include the potential for second generation retrofit of electrically heated homes and burner performance problems due to variations in fuel quality.

OVERVIEW

The residential and commercial sectors account for 20% of Canada's fossil fuel energy consumption and CO2 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 dwellings/buildings. Some 25% of the home heating in Canada is from oil-fired systems, with the potential for this figure to grow significantly if it can displace electricity in many presently electrically heated homes.

As electricity has suddenly become a less desirable heating source, both from the consumer's view due to rapidly increasing 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, at least in those areas of Canada where natural gas is not available. One problem, however, is that the minimum firing rate for oil (56-70 kBtu/h) is well above the design requirements for most new housing in Canada, resulting in very oversized equipment, with their attendant inefficiencies and comfort problems. CCRL is working on alternative solutions to this problem, usually through the application of advanced integrated systems. This is the prime focus of CCRL activity in oil heating at this time.

INTEGRATED SPACE AND WATER HEATING FOR IMPROVED EFFICIENCY, COMFORT AND DEMAND SIDE MANAGEMENT

The integrated space and water heating systems being developed by CCRL will couple mathematical modelling with laboratory and field results to develop an intelligent expert system-based control strategy to improve and optimize fuel usage and operational conditions of combined space and service water heating systems in the residential and commercial sectors for a range of load factors and customer requirements. Results from the work will be utilized to develop more cost-effective appliances that maintain high levels of efficiency under a wide range of varying load applications, diurnally and seasonally, as well as under source demands, such as family growth, house sale, apartment conversion to hotel, or change in commercial tenant applications.

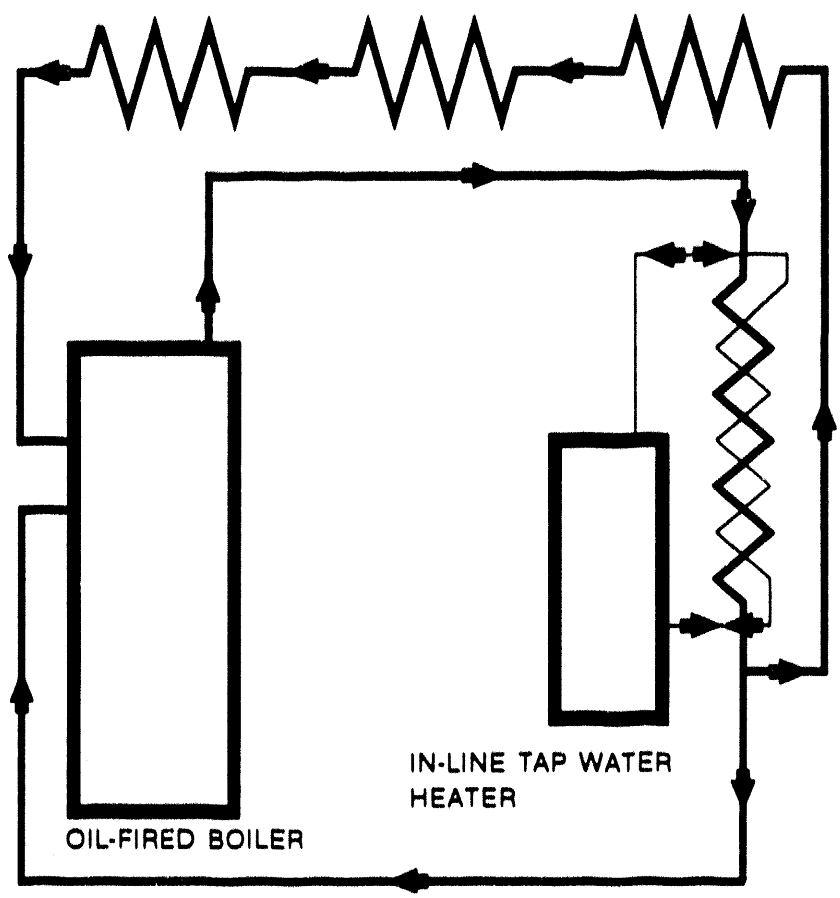
A dynamic modelling program will be developed for the design and operation of distribution systems supplied by high efficiency generators for high rise buildings, increasing the ability to supply heat and service water, while improving the hydraulic stability of the systems.

As mentioned in the Overview, a significant problem exists with oil heating systems in new housing. Because of the limitations in burner technology, firing rates cannot be reduced much below 0.5 US gph (70 kBtu/hr); well-insulated new homes can have a design heat load of one-third to one-half this level. Combining the space and water heating in an integrated system may allow efficient operation of the furnace/boiler without short cycling and the attendant losses in efficiency and comfort, in a similar manner to that discussed in the preceding section. In such a fashion, oil can indeed be an ideal energy source for new housing.

The basic system could be as shown in Figure 1, with the energy generator (boiler) coupled to a well-insulated storage tank by an efficient water-to-water heat exchanger, along with intelligent microprocessor controls and a reversible pumping system. When the thermostat calls for heat, the boiler would run normally. 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 actually operating. If hot tap water is required, it is taken directly out of the storage tank.

Both the overall operational time and the number of cycles of the boiler would be much less than a conventional system, the boiler operates more efficiently in its heating mode, and the tap water heating efficiency is improved dramatically.

A similar system is also being considered based on a warm air furnace as the energy generator. A fan coil is mounted in the furnace warm air plenum, but designed to operate in a non-conventional fashion. In this case the house thermostat causes the burner to run. Two alternatives to the system are as follows: (1) the fan coil operates continuously at this point, taking out a portion of the furnace heat and dumping it to the storage tank, while the other reduced portion goes to satisfy the house heat demand, causing the furnace to run much longer to actually satisfy the thermostat, as shown in Figure 2; (2) the fan coil is set in a bypass system to the main warm air plenum. When the thermostat is satisfied, the bypass is opened and the fan coil operating in reverse is activated in the warm air plenum and heat is dumped into the fan coil and then into the well-insulated water storage tank. In either case the next time heat is required, the process is reversed, and the heat is taken from the tank, through the fan coil where it is extracted and circulated around the house as heated air. As before, tap water can be taken directly from the storage tank whenever it is required.



INTEGRATING TAP WATER WITH OIL-FIRED BOILER

FIGURE 1

Control strategies are also being developed to optimize the synergistic efficiencies for these space and water heating combinations for a variety of loads and draws for both energy demands.

At this time, CCRL is concentrating its research on system optimization and load/storage/sizing and control optimization with an efficient tap hot water heat source base at this time, which "starts off life" as a hot water heater. A number of system configurations are being run to develop performance and control strategies which will be later utilized in the intelligent expert system.

The base configuration is quite simple, merely coupling the water heater to a fan coil to supply the space heating requirements, as shown in Figure 2.

The first modification to this system is the addition of a well-insulated water storage tank with indirect heat exchanger. The complete integrated system is shown in Figure 3.

The next stage utilizes two water-to-water heat exchangers, one on the supply line, and the other on the return line, to preheat water mains, along with the fan coil, as shown in Figure 4.

A further modification is similar, but uses two heat exchangers in parallel on the heat supply line, and one on the return line, as shown in Figure 5.

Data analyses of these experiments are presently underway and preliminary results will be presented at the conference.

Further system combinations will be assembled so as to develop the optimal system configuration for a generalized application.

Analysis of the performance of each system under a variety of space and water heating load combinations is presently being carried out. In the residential application, the dependent and independent component systems of the fossil fuel-fired energy generator will be developed for regional applications with different thermal requirements, using water with different chemical characteristics, and inlet temperature variations.

The premise of the final system(s) to be developed is that it will have the capability of learning what is required of it in terms of supply, and will be able to adjust its integrated operation in such a way as to maintain high levels of efficiency, usually in the condensing regime in spite of dramatic changes in operational requirements. By using sophisticated methods of expert system learning-based control, the next generation of these integrated systems may be designed to achieve their full potential, under a wide range of operational conditions and changing situations. The goal of this expert system concept is to be able to utilize what is effectively the same integrated system in a variety of applications, yet maintaining high efficiency in each. It would be capable of recognizing changes in load demand patterns and in heating load requirements (based on climatic, internal and human factors), and to adjust overall system operation to suit. The expert system itself would be based on internal CCRL expertise in this area, and applications being developed in the industrial area for other clients.

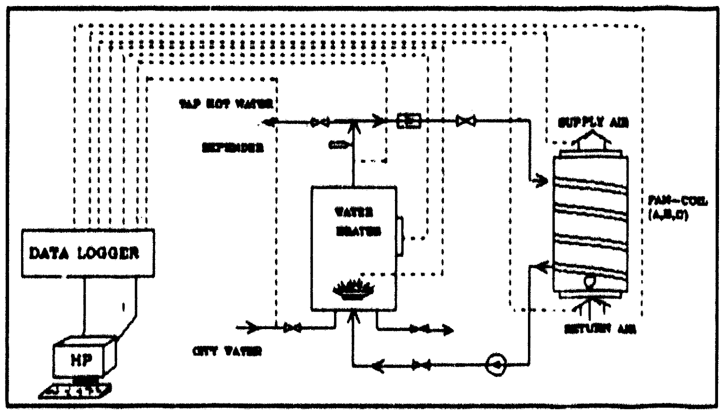


Figure 2.

Standard type integrated system

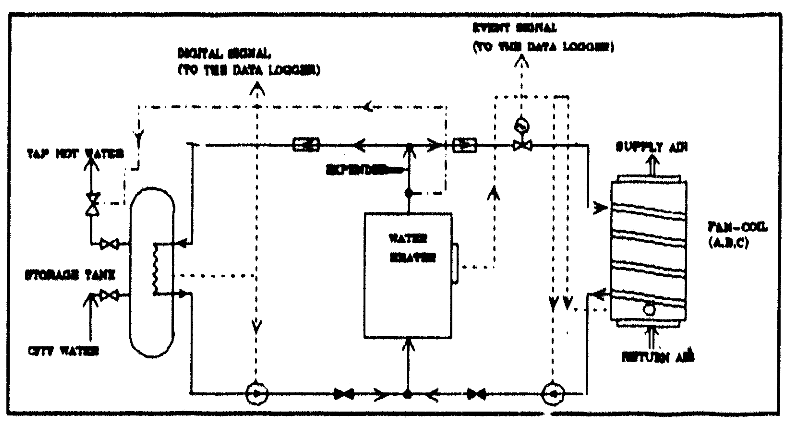


Figure 3.

Modified type integrated system
(including heat storage tank)

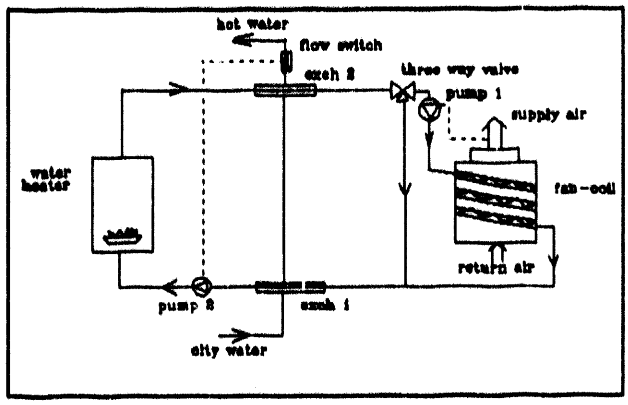


Figure 4.

Modified type integrated system
(including two heat exchangers)

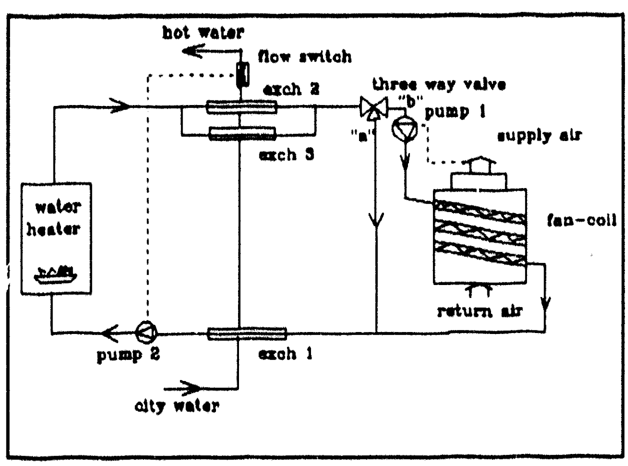


Figure 5.

Modified type integrated system
(including three heat exchangers)

By developing the new technological design control options of central systems for multi-family residential buildings, potential market gains for larger oil-fired boilers may also be realized, and may allow future integration of cogeneration applications.

<u>Improving Tap Water Heating in Existing Oil-Heated Homes</u>

In Eastern Canada, tap water heating is often done either by electricity, or by a tankless coil in an oil-fired hot water boiler. The tankless coil system is very inefficient, requiring the boiler to be hot at all times, even during the summer. Inefficient short-cycling is common, as is the potential for casing losses and high off-cycle stack losses. In other installations, hot water is often supplied by an electric water heater, and replacement of all or part of this electricity demand, especially during the peak winter season would be a Demand Side Management (DSM) technique attractive to electric utilities.

The tankless coil or electric water heater can be replaced by an efficient water-to-water heat exchanger, coupling the boiler to a well-insulated storage tank, along with intelligent microprocessor controls and a reversible pumping system. When the thermostat calls for heat, the boiler would run normally. 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 actually operating. If hot tap water is required, it is taken directly out of the storage tank.

Both the overall operational time and the number of cycles of the boiler are reduced, the boiler operates more efficiently in its heating mode, and the tap water heating efficiency is improved dramatically. These retrofit systems can give fuel savings and CO2 reductions of up to 43% for water heating. If the water was previously heated electrically, CO2 reductions for the latter of as much as 73% (35% to 85%, plus the difference between oil and coal CO2 of 24%) can be achieved. Even greater reductions in conventional emissions of particulates, carbon monoxide and hydrocarbons would result, due to fewer startups and shutdowns.

FUEL QUALITY AND ITS EFFECT ON PERFORMANCE

A continuing concern at CCRL is that heating oil quality is changing in the marketplace. The product yield from a crude barrel is being maximized by incorporating heavier distillate cuts, while synthetic distillates are being produced from unconventional sources such as oil sands and heavy crudes. Operational requirements of in-use equipment may not be compatible with these new fuels, which are generally of lower quality than current specifications. For example, synthetic distillates contain higher proportions of aromatics than olefins, compared to conventional distillates. These aromatics tend to generate higher particulate emissions.

The introduction of these fuels has created a need for suppliers and users to reexamine the design methodologies and expected performance characteristics of lower grade products in existing appliances. CCRL is conducting performance evaluation of a variety of lower grade fuels in residential combustion appliances. Such practical information will be beneficial to the oil industry, allowing greater blending flexibility and product control for cost saving. The standard writing bodies and regulatory agencies require this information to update their existing fuel specifications, relating to changes in product quality and equipment requirements. As well, fuel oil dealers and servicemen will know better how to set their clients' equipment to effectively burn these fuels. On the other hand, reducing sulphur levels in No. 2 fuel oil, in company with the proposed sulphur reduction for diesel, might mean the potential for higher efficiency appliances, and the potential for this should be clearly recognized and advantage taken of it.

Combustion Test Cell

In carrying out fuel quality, burner and venting experiments for specific clients, CCRL has a controlled environment test cell with provision for two furnaces. Ambient fuel and return air/water temperatures can be controlled independently to any level, as can the pressure (positive or negative) in the chamber. Transient performance of CO_2, CO, NO_x, hydrocarbons and particulates are measured continuously as are any applicable temperatures. Continuous recording of the flame character in each unit is also possible with special-lensed video cameras. Conventional and side-wall venting performance can be determined as can the effect of room depressurization.

VENTING

In order for the advanced oil systems to be taken up by the marketplace to their potential, venting system costs and problems must be resolved. Increased operational time per cycle may make well-sized lined chimneys a sure bet. Retrofitting electrically heated houses and minimizing the uncontrolled ventilation of advanced housing make sidewall venting continue to be an attractive option, if the air supply, blowback, spillage and terminal problems can be resolved. CCRL will be working with industry to resolve these and related issues in the Canadian context.

SUMMARY

1. Integrated systems offer the potential for oil to return to new housing as a preferred energy source, in many areas of Eastern Canada.

2. CCRL is developing the potential to design integrated systems which can maintain high efficiencies over a wide range of load requirements for both space and water heating, using learning-based expert system control strategies.

2. Retrofitting a water-to-water heat exchanger and storage tank to an oil-fired hydronic system have the potential to improve efficiency if the original water heating was by tankless coil, and to act as an effective Demand Side Management (DSM) tool for utilities if the water heating was originally by electricity. For the latter, there is the potential to produce significant immediate reductions in emissions of greenhouse gases, particularly carbon dioxide.

4. CCRL has a temperature controlled test cell with complete performance measuring equipment to determine the positive and negative effects of fuel quality and ambient effects including house depressurization, on equipment performance, emissions and longevity.

Paper No. 93-2

RESIDENTIAL COGENERATION - THE NEXT STEP FOR THE OIL HEAT INDUSTRY

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RESIDENTIAL COGENERATION - THE NEXT STEP FOR THE OIL HEAT INDUSTRY

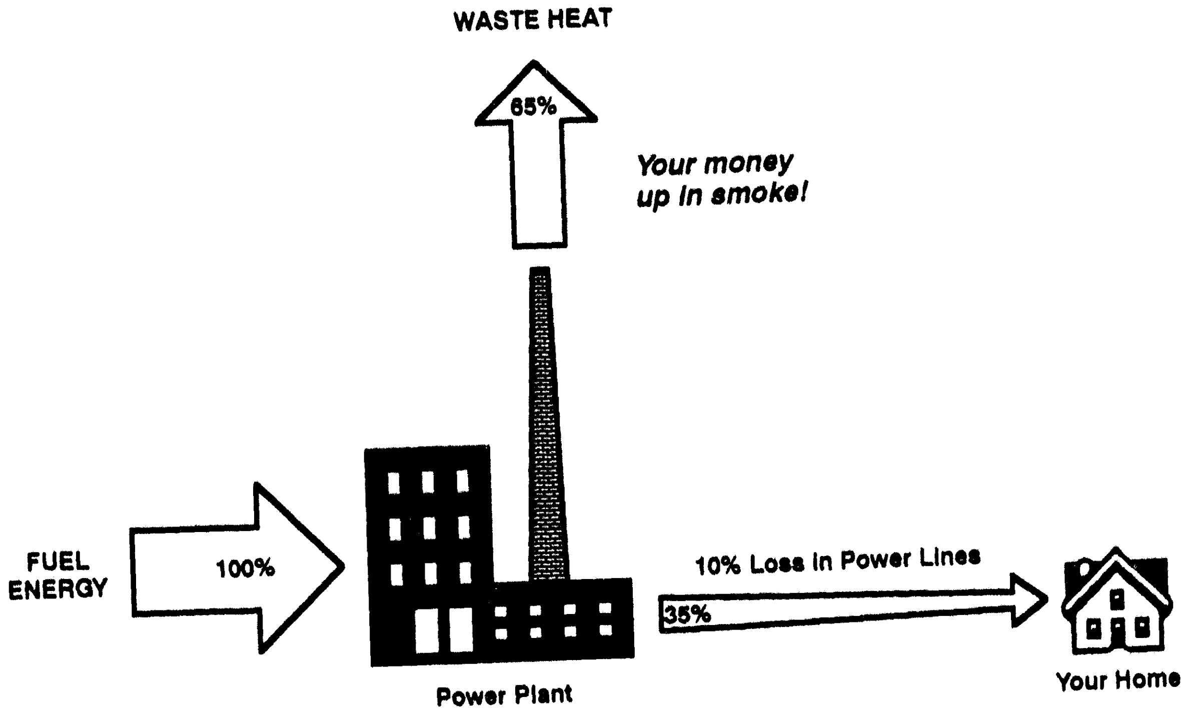
Residential energy usage falls into two general categories: space and water heating, and electrical. Historically, heating consumed much more energy than electrical appliances. In recent years, however, insulation, weather stripping, and improved building practices have drastically reduced average heat loads, while fossil fuel prices have remained stable in real terms. Simultaneously, electrical consumption in the average home has risen, and the average real price of electrical energy has also risen. In the northeastern and midwestern United States the typical residence now spends an approximately equal number of dollars in each area.

Technology to reduce heating expenses is readily available, and heat conserving strategies can also improve occupant comfort levels. In contrast, products that reduce electrical usage usually do so only marginally and often with some lifestyle adjustment by the occupants. A new technology is available, however, that completely eliminates household electric bills and can, in fact, improve lifestyles by allowing electricity to be used more freely: residential cogeneration.

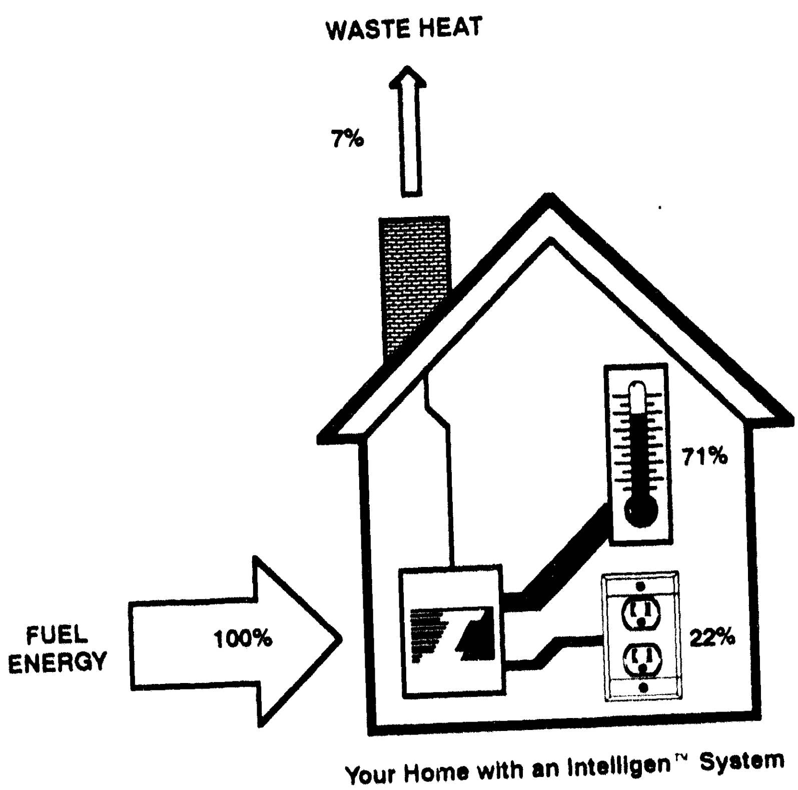
Cogeneration is the simultaneous production of heat and electricity. Electrical generation is inherently inefficient; on average only about one-third of the heat value of the fuel burned by a power plant is converted to electricity (see Figure 1). Thomas Edison recognized the importance of making use of the waste heat by locating his first generators in large cities and using the leftover steam to heat nearby buildings. As economies of scale became more significant power plants grew larger and were increasingly sequestered away from urban areas and vented waste heat to the environment. After the oil shock of the seventies and the passage of the Public Utilities Regulatory Policies Act (PURPA) in 1978, however, cogeneration came back into favor for large industrial and commercial installations. More than half of all new generating capacity is now provided by industrial cogeneration.

Thermodynamic considerations dictate economies of scale for electrical generation; large generators are inherently more efficient. However, in the 90's, the efficiencies of mass production are overcoming the efficiencies of scale. Multi-disciplinary system engineering and new patented technology have combined to make very small cogeneration systems, sized to fit most single family residences, not only technically feasible but capable of providing a three to five year payback for the typical household.

One such system, manufactured by Intelligen Energy Systems of Westford, Mass., is designed to function as the sole central heating system. Rated at 85,000 BTU/hour, it operates whenever thermostats in the home call for heat, and generates 5KW as long as it runs. If the household is using less than 5KW at that moment, the excess power flows back into the electric grid. Under the regulations of many states this power flows back through the standard meter, spinning it backwards. At the end of the billing cycle the homeowner pays only for his net usage, or is paid by the utility for his net generation. In midwinter the average household will generate three times its usage, while in spring and fall usage and generation will be approximately equal. Domestic water heating in the summer will offset about one third of the average electric bill.



WASTE HEAT
65%
Your money
up in smoke!
FUEL
ENERGY
100%
10% Loss in Power Lines
35%
Power Plant
Your Home



WASTE HEAT
7%
71%
FUEL
ENERGY
100%
22%
Your Home with an Intelligen™ System

Figure 1

Because of its very high overall efficiency the system only uses about 10% more fuel than a modern oil-fired boiler. The average homeowner would therefore pay less than one tenth as much for this extra oil as he formerly paid for electricity. Looked at another way, the value of the electricity produced is typically higher than the cost of ALL the oil burned by the system, so the heat is free!

Cost of the system to the dealer is $6400, and installation is similar to a conventional oil boiler. Use of the system to convert electrically heated houses will be more expensive but can be quite cost effective, as some electric radiation can be retained and no flue is required. Payback depends on current electrical usage and rates, but can be as little as two years.

The Intelligen system has been under development and testing for two and a half years, and will soon be in full production. It consists of a small diesel engine, generator, exhaust heat exchanger, micro-computer based control system, power switching system, and sound isolation cabinet (see Figure 2).

The Intelligen system is not the first residential cogeneration system ever designed. It was determined early on, however, that the product had to meet several crucial goals never before achieved:

1. It had to be oil-fired and had to be sold and serviced by existing full-service oil dealers. All previous attempts had been gas fired, and sold through generator dealers or other non-heating industry channels.

2. It had to be designed to operate as the sole household heating system. Previous attempts were sold as adjuncts to a primary system, making total costs considerably higher and paybacks much longer.

3. The product had to have the characteristics of an ordinary heating system, so homeowners would be faced with no tradeoffs other than price in considering the system. These characteristics include longevity, maintenance intervals, fully automatic operation, approximate size, sound levels, and safety.

4. The system must be installed much like a conventional heating system, and most especially with no complex and expensive electrical interfaces. The interaction with the utility must be as simple as possible.

5. The price had to be low enough so the average customer would see a payback of under five years.

Initially, all options were considered for prime movers. It was realized that heating systems can operate for several thousand hours per year, and the power source had to be capable of lasting at least ten to twenty years. Gas turbines and steam turbines were investigated and discarded as being too expensive in this size range. Diesel engines were determined to be the only technology mature and reliable enough to dependably operate over the required time span. Even then, most diesel engines were only built to last a few thousand hours. A global search ensued to find an adequately reliable engine, resulting

Intelligen System Block Diagram

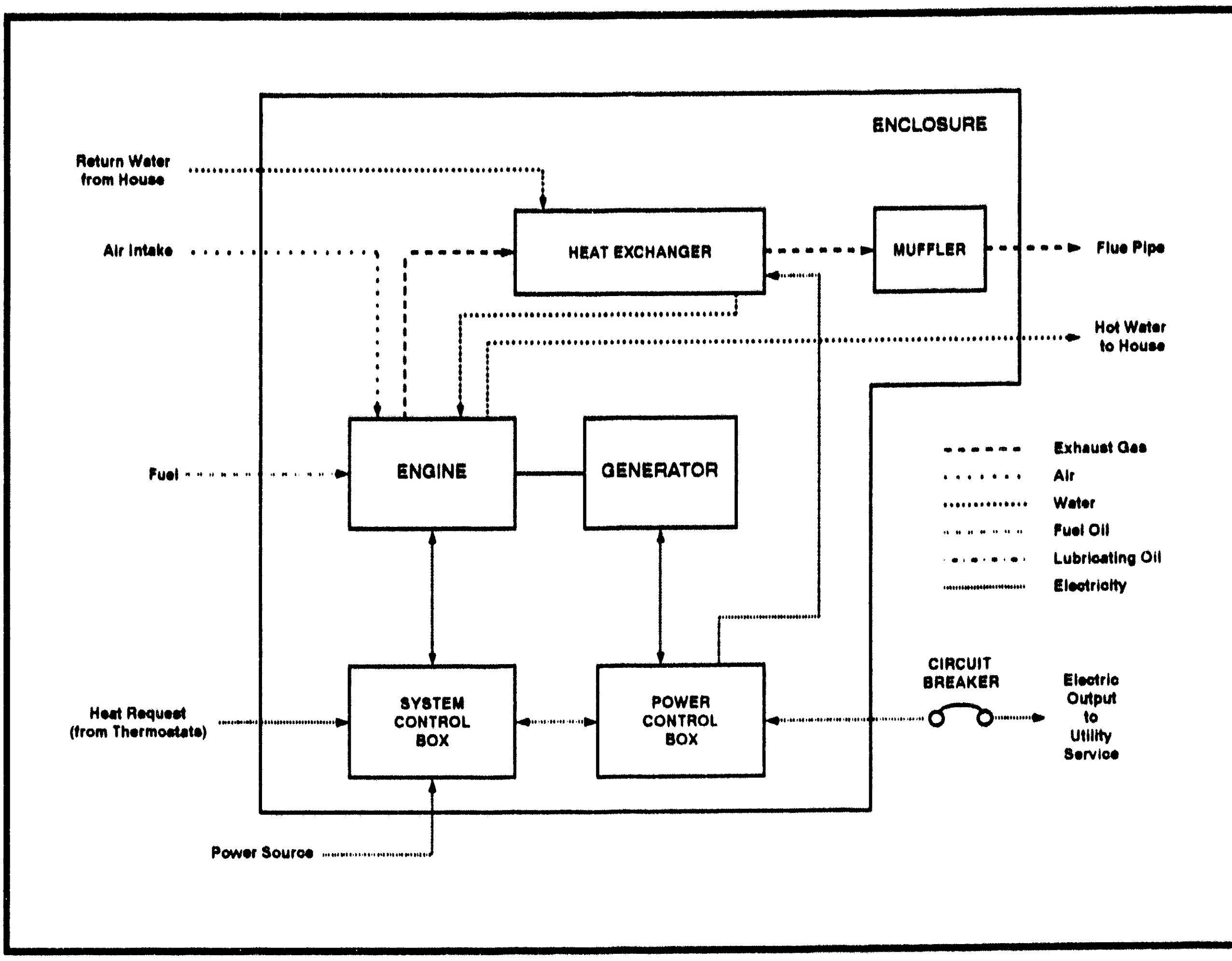


Figure 2

in the choice of Lister-Petter as the engine supplier. Lister engines, made in England, are currently used only in high-end military and industrial applications, such as unattended microwave relay links in the Arctic. In our opinion, these are the world's best small diesel engines, and nothing less is adequate for this application.

Considering the need to produce a cost effective consumer product, it was necessary to value-engineer every aspect of the system. For example, the smallest possible engine model was chosen, and a proprietary (patent pending) technique developed to boost the thermal output rating to the 85,000 BTU/hr deemed necessary to meet the needs of the majority of homes. The generator chosen was an induction model for simplicity and low cost, and the electric utility interface equipment, which normally would cost approximately $3000, was built into the microcomputer control system. The generator is used to start the engine with another patent pending technique, eliminating the cost (and reliability problems!) of a starter motor, battery, and charging system.

Unfortunately, an unmodified diesel engine does not meet one crucial constraint, the need for annual maintenance. All engines require oil changes, and in the middle of winter an oil change would ordinarily be required approximately every six weeks. To circumvent this requirement, a long-run oil system was developed consisting of a large external oil reservoir and a circulating pump to constantly circulate fresh oil to the engine. The twelve gallon reservoir is sufficient for both engine oil usage and contaminant dilution.

Another area in which any unmodified diesel engine falls short is quietness. Unenclosed, the noise level has been measured at 94 dba (at two meters), which is far more appropriate to a construction site than a residential basement! A heavy steel cabinet (approximately 4' x 2' x 3'high) with extensive sound insulation and numerous sound isolation techniques (patent pending) was designed. In actual home environments the resulting sound level has been measured as low as 58 dba, as compared to the 64 dba of a conventional modern system with a flame-retention burner.

A final crucial requirement is fully automatic operation. A homeowner cannot be expected to operate complex controls, and the system must start, operate, and shut down in response to thermostat closures just like a conventional system. A very sophisticated internal computer hides all the complexity, although total flexibility is still available to the service-person or technologically oriented homeowner through an optional service terminal. The computer also ensures that the electric utility requirements for frequency and voltage stability are met, and that the utility nightmare of energizing a dead line and electrocuting a lineman is rendered impossible. As a result, although the first installation in any utility area still requires extensive time and effort, every electric utility that we have approached has ultimately accepted the system as safe and approved the interconnection.

Eight field test units were installed, beginning in January of 1992. A ninth pilot unit was sent to Brookhaven National Laboratory and installed in the Combustion Equipment Technology Laboratory so that its efficiency performance could be assessed during a series of engineering evaluation tests. This unit was returned to Intelligen after the tests and subsequently installed in the field. A tenth unit was sent to Brookhaven National Laboratory for efficiency testing and engineering evaluation in the BNL Combustion Equipment Technology Laboratory. Although a number of problems have been found, none are fundamental and all have been eliminated with simple engineering design changes. One example: it was found that random engine oil pressure failures resulted from the fact that ordinary oil pressure senders, while perfectly adequate for use with an idiot light whose occasional flickering would not be noticed, cannot stand up to the ten thousand times per second scrutiny of a computer! Fortunately, a few cars now also use computers to monitor oil pressure, so appropriate senders do exist. Another example: lack of a key in a bushing allowed enough slippage to hit and grind the face of the external oil circulation pump (mentioned above) to nothingness. Unfortunately, this happened to the Brookhaven unit just as they were starting their evaluation.

By the time production begins most of the pilot units will have had a full season of operation, and the details will have been ironed out.

The bottom line is that a system now exists which can cut the total household energy usage in half!

Paper No. 93-3

ENGINEERING EVALUATION OF AN OIL-FIRED RESIDENTIAL COGENERATION SYSTEM

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Upton, NY 11973

ENGINEERING EVALUATION OF AN OIL-FIRED RESIDENTIAL COGENERATION SYSTEM

EXECUTIVE SUMMARY

The definition of cogeneration, within the context of this paper, is the simultaneous production of electricity and heat energy from a single machine. This paper will present the results of an engineering analysis of the efficiency and energy- conservation potential associated with a unique residential oil-fired cogeneration system that provides both heat and electric power. The system operates whenever a thermostat signals a call for heat in the home, just as with a conventional heating system. It has the added benefit of cogenerating electricity whenever it is running to provide space heating comfort. The system is designed to burn No. 2 heating oil as a fuel, which is consumed in an 11-horsepower, two cylinder, 56.75-cubic-inch, 1850-RPM diesel engine. This unit is the only pre-production prototype residential oil-fired cogeneration system known to exist in the world. As such it is considered a landmark development in the field of oil-heat technology.

The study used a direct thermal efficiency measurement technique developed by Brookhaven National Laboratory (BNL) for precise determination of heating system efficiency based on enthalpy (heat) flow measurements into and out of the cogeneration unit. Electrical power output was measured concurrently. Stack (exhaust) emissions were also characterized and measured. Comparative noise level measurements were also obtained during the evaluation tests.

The cogenerator produced 4.8 kw of electric power under steady operating conditions. Its output is nominally 5 kw on a cold start, dropping somewhat over time as the generator unit comes up to constant operating conditions and temperatures. The cogenerator has a combined system efficiency of 92.8 ± 4.4 % including its electrical output, hydronic (hot water output), and warm-air output. This represents a new high-end reference mark for the efficiency range of oil-fired residential heating equipment performance. If the warm-air component is not used at all, the combined efficiency drops to 71.5 ± 1.2 %. The measured emissions are representative of those expected for a diesel engine of this size and type. The noise level was within measurement error of noise levels obtained at BNL during operation of both an oil-fired furnace and boiler.

BACKGROUND

Oil Fired Cogeneration Systems

Residential energy loads fall into one of two general categories: 1) space and water heating loads, and 2) electrical loads including lighting, appliances, cooling, and many other devices powered by electricity. Historically, heating was a significantly larger energy load than that represented by electrical appliances, but in many cases, this is no longer true. Energy conservation technology has come of age in the residential buildings area. The use of high-efficiency appliances, windows, doors, insulation systems, shower heads, and other energy conservation and weatherization techniques have been widely adopted into existing and new housing stocks. Many homes have dramatically smaller space and water heating requirements. Electrical consumption has either remained constant or increased as new types of electrical devices are brought into the residential environment. The result is that the ratio of electric to heat energy requirements has been brought closer into balance and has made cogeneration of electricity and heat a more viable option.

Until recent changes in certain state utility regulations and the Federal Government's Public Utility Regulatory Policy Act, (PURPA) it was not considered economically viable to market cogeneration systems on the smallest scale, residential-sized systems sometimes called micro-cogenerators. Even now it is a matter questioned by some "experts." However, Intelligen Energy Systems Inc., believes it is a viable option and has already designed an oil-fired residential cogenerator system for the residential market.

The cogenerator basically consists of an engine, a generator, a heat exchanger, and controls. Figure 1 is a schematic of the system with its major components and illustrates the various energy flows which occur during operation. Heat given off by the engine (both jacket and exhaust) is transferred to the hydronic distribution system, while heat from the generator is transferred to the warm-air stream.

The efficient use of primary energy sources, including fossil fuels (oil, gas, and coal), is one of the important goals of the United States and a mission objective of the U.S. Department of Energy (DOE) as described in the National Energy Strategy (First Edition 1991/92). The technical assessment of this cogenerator was conducted for the DOE in response to technical inquiries and interests of the U.S. oil-heat industry and the energy conservation community at large.

The Brookhaven National Laboratory (BNL) evaluation of the Intelligen Alpha-550 was limited to laboratory tests only, and only the technical evaluation of efficiency, emissions, power output, and noise. This study did not evaluate: long-term durability, use under field conditions, maintenance requirements, code acceptance, and utility acceptance. These issues will be (appropriately) evaluated by the manufacturer in its own field trials of ten pre-production prototype units currently underway.

Intelligen Energy Systems - Model Alpha-550

The Model: Alpha-550 (Figure 2) a pre-production prototype 5-kilowatt, residential cogeneration system was loaned by the manufacturer, Intelligen Energy Systems Inc. (Intelligen) to BNL for evaluation and testing. The system is designed to supply: hot water for hydronic baseboard heating systems, 5 kilowatts of electricity during operation, and in addition a significant amount of warm air which is used to heat the space where the unit is installed or which can be ducted to other parts of the living space, if the unit is located in an unheated area in the house.

The system is designed to burn No. 2 heating oil, which is consumed in an 11-horsepower, two-cylinder, 56.75-cubic-inch, 1850-RPM diesel engine manufactured by Lister-Petter, Inc., custom configured for Intelligen. The engine powers a single-phase induction generator which is also custom configured for Intelligen. The heat from the water-cooled engine is combined with the heat recovered from a tube-in-shell exhaust heat exchanger and is circulated to the hydronic baseboard zones located throughout the house, exactly as in a conventional hydronic boiler system.

The unit is controlled by a proprietary system designed by Intelligen, based on a Motorola MC68HC705B5 microprocessor chip with input from standard heating-system controls. The control system has an input/output port for connecting a service terminal for diagnostic checks.

The Intelligen unit is specifically designed as a cogenerator, not as an emergency generator. If the local utility power grid, which normally provides electricity to the house, is down, for reasons such as downed power lines, the Intelligen Alpha-550 will not operate. This situation is exactly the same as the case when the power is off in a home equipped with a normal heating system. A boiler or furnace will not provide heat, because it needs electricity to power the electrical components.

The Intelligen unit is designed to take advantage of the efficiencies and economics of cogeneration, which is defined here as the simultaneous generation of electricity and useful heat energy. The major advantage is that the "overall system efficiency" can be much higher than the typical 33% obtained with a fossil-fueled electric utility power plant (including transmission line losses). The residential cogeneration system has the potential for 90% efficiency or better.

TEST RESULTS

The electrical output of the pre-production Intelligen Model Alpha-550 cogenerator unit was found to be 4.80 ± 0.04 kW under steady operating conditions (one hour average, fully warmed up). It produced a nominal 5.0 kW of electric power on a cold start, dropping slightly as the generator heated up to constant operating conditions. Consumption of fuel was measured and found to range from 0.54 to 0.57 gallons per hour (Btu/hr input range: 75,000 to 79,000). The results of the thermodynamic efficiency tests for the unit are plotted in Figure 3, which indicates overall efficiency as a function of load, expressed in terms of the fraction of the time that the system was operating. The combined steady-state value is 92.8 ± 4.4 %, including the electric output component (21.3 ± 0.2 %), the hydronic output component (50.2 ± 1.0 %), and the warm-air output component (21.3 ± 3.2 %). If the warm-air component is not used, the combined efficiency could drop to 71.5 ± 1.2 %. If the warm-air component is used, but not fully, such as heating a basement without proper insulation or heating controls, the efficiency may fall anywhere in the range from 71.5% to 92.8%. The range will depend on the design of the basement (or any other uncontrolled space where the cogenerator might be installed) and the degree of communication (in terms of heating and ventilation) between the uncontrolled and controlled living spaces in the home. If a well designed ducting system, properly sealed and insulated, is used the efficiency will reflect the high end of the efficiency range, near 92.8%. The error in the electric output component is very small ± 0.8% of the measurement, the error in the hydronic output component is approximately ± 2% of the measurement, and the error in the warm air output component is much greater at ± 15% of the measurement. The degree of difficulty and the error and uncertainty in measuring the warm air thermal output precluded performing detailed cyclic efficiency tests of the system.

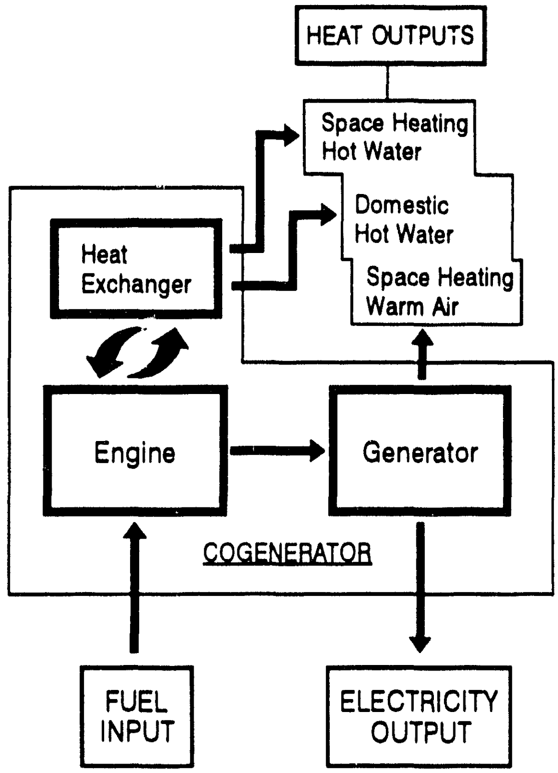

Figure 1: Cogenerator System Schematic Showing Energy Flows

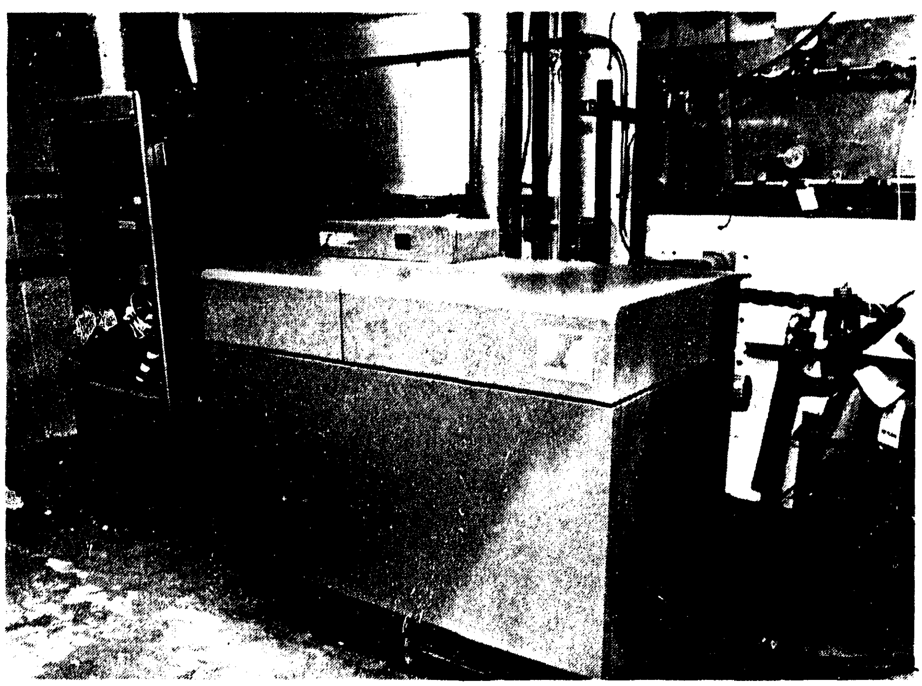

Figure 2: Alpha-550 Cogenerator - Intelligen Energy Systems Inc.

Figures 4 and 5 show the results of the emission tests. Figure 4 indicates the levels of nitrous oxides, carbon monoxide, and hydrocarbons (all in ppm) during steady-state operation for two different fuels (standard No. 2 oil with a 0.13% sulfur content and No. 2 fuel with a low 0.05% sulfur content). Figure 5 indicates the rates of particulate emission (pounds of particulate per 1000 gallons cf fuel) associated with the cogenerator during steady running conditions for the two fuel types mentioned above, and also the rate measured under cyclic conditions (5 minutes on, 15 minutes off) with the standard No. 2 fuel (0.13% sulfur).

The results of the noise measurements are given in Figure 6 and indicate levels measured in ten frequency bands at a distance of 5 ft from the front of the unit being tested and at a level 5 ft up from the floor, approximating the height of a human ear. Test data were recorded with the cogenerator operating by itself, and measurements were also recorded for a typical oil-fired, warm-air furnace and a typical oil-fired, cast-iron hydronic boiler. Standard "A" weighted measurements of noise level performance are also shown in Figure 6. This "A" weighting is typical of the human perception of noise levels when all frequencies are heard in unison. All sound levels were measured on the same day within a one-hour period with a calibrated sound meter. Test conditions were made as equal as the laboratory environment would allow, although the BNL CETL facility was not designed as a sound testing laboratory. The results are included to give some general indication of the sound levels that would be expected when operating the cogenerator. This question has been a subject of interest voiced by many representatives of the oil-heat industry involved in this technology.

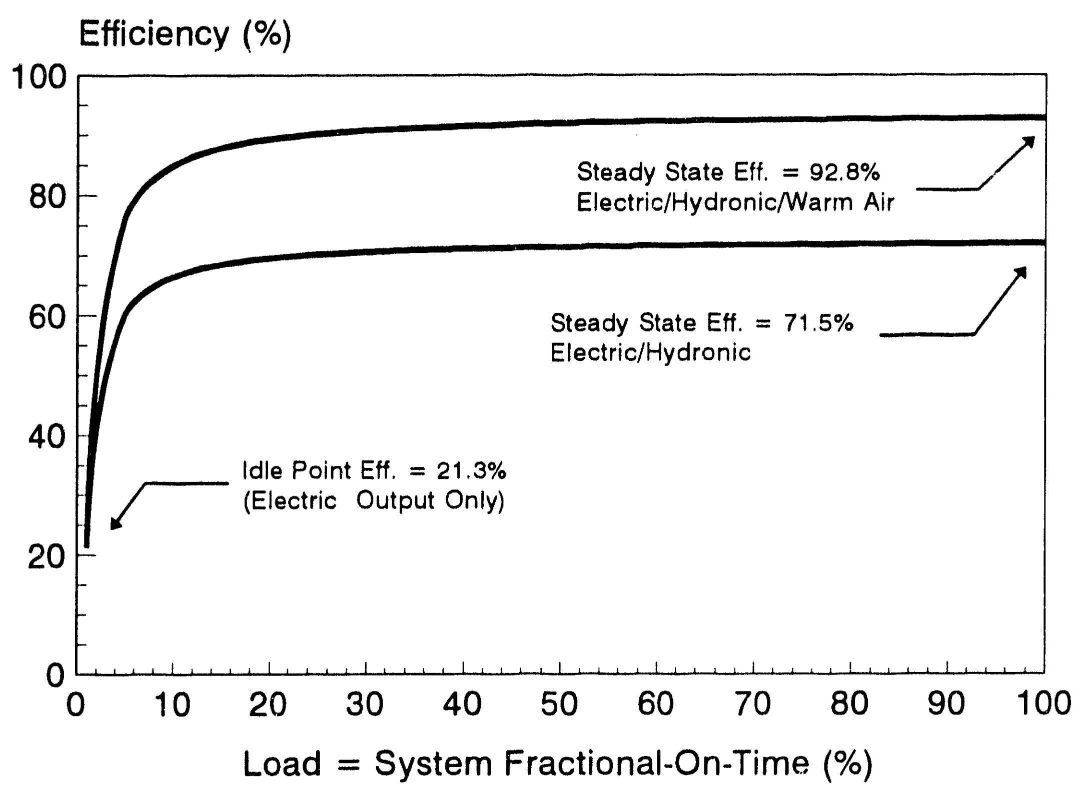

Figure 3: Efficiency Test Results

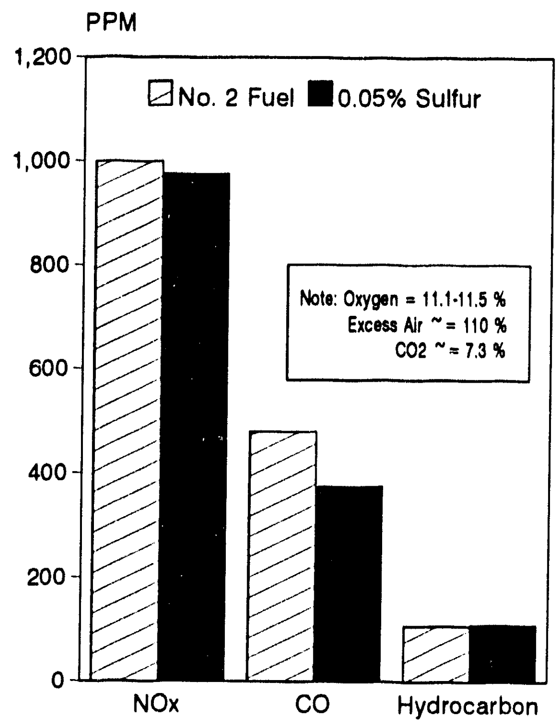

Figure 4: Emissions Test Results - NO_x / CO / Hydrocarbons

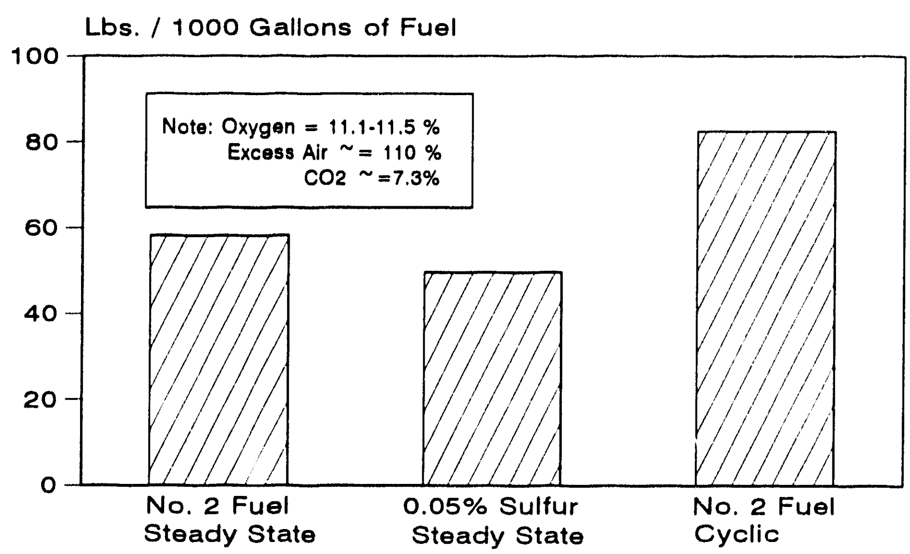

Figure 5: Emission Test Results - Particulates

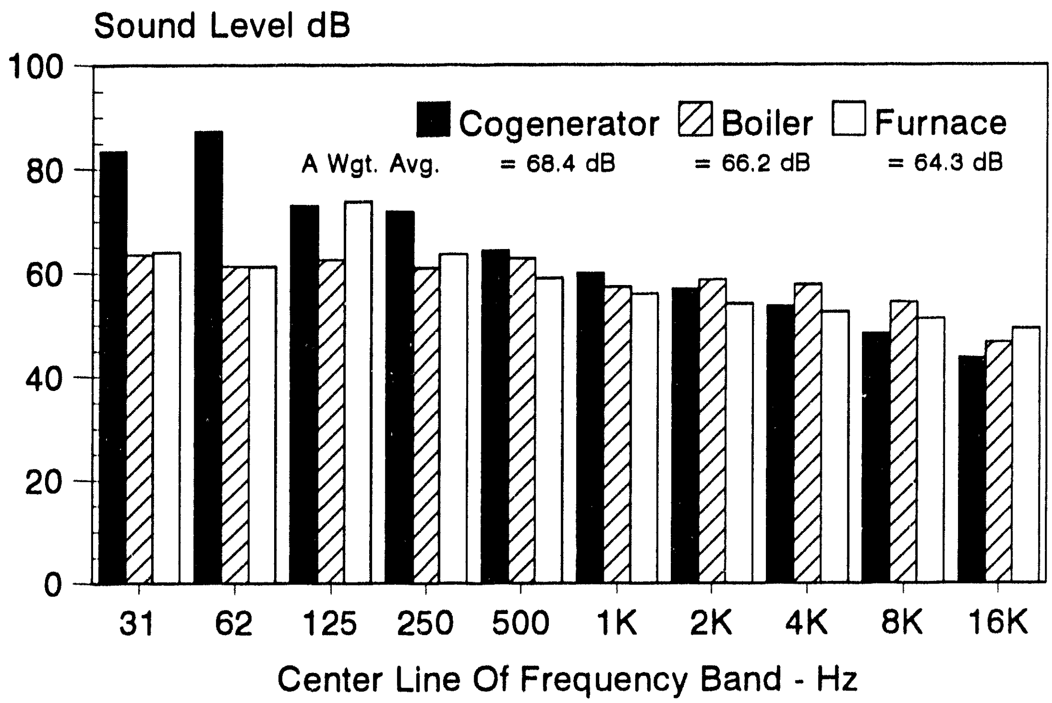

Figure 6: Noise Level Measurement Results

CONCLUSIONS

System Efficiency

The efficiency of the cogenerator system, at 92.8%, represents a new high-end reference mark for the efficiency range of oil-fired residential heating equipment. Its efficiency can only be compared to "condensing" oil-fired residential furnaces which have AFUE ratings in the 90-91% efficiency range. These condensing furnaces have the highest AFUE efficiency ratings of all the oil-fired heating systems in production.

The truly unique feature of the cogenerator is that approximately one quarter of the output (4.8 kw) is in the form of high quality electrical power. In a residential installation in the market areas targeted by the manufacturer, this will displace expensive electricity generated by utilities.

It can be argued that the electricity should be given a value approximately three times that of the heat, per unit of energy, because it displaces utility power that would have resulted in two units of waste heat for each unit of electricity produced. If this is done, then the unit has an effective efficiency of 135%.

The unit outputs ~39,000 Btu/hr for hydronic circulation during normal heating conditions. When needed, this output is boosted up to 69,000 Btu/hr by electric water heating elements (which are directly powered by the cogenerator). These elements are located inside the circulating water system of the unit. When the system starts to heat a cold house, for example, after a power outage, or when outdoor temperatures are very low, these electric elements will be turned on by the microprocessor control unit to augment the hydronic heating output. As stated a significant portion of the thermal energy is also output in the form of warm air, and to achieve the maximum efficiency of 92.8%, this energy must be used effectively and not wasted. The location of the cogenerator inside a house and the design of the house will be important factors. The amount of warm air produced (~16,000 btu/hr) represents 21.3% of the chemical energy in the No.2 fuel oil consumed by the engine during steady operation. If this energy is wasted, the overall efficiency is only 71.5%.

Environmental Emissions

A comprehensive analysis of cogenerator emissions should include factors for the emissions reductions associated with the electricity generated at the utility power plant that this technology is intended to displace. This analysis is beyond the scope of the current engineering assessment. The emissions data contained in Figures 4 and 5 are representative of what is expected for a diesel engine of this size and type. This information has been included so that others who wish to analyze regional emissions will have the necessary input data. All of the emission levels measured (see Figures 4 and 5) are significantly higher than those measured for modern oil-fired heating systems equipped with flame retention head oil burners [NO_x:~100-150 ppm; CO: ~30 ppm or less; hydrocarbons: ~5 ppm or less; and particulates: ~0.4 lb per 1000 gallons of fuel or less (cyclic), and ~0.1 lb./1000 gal or less (steady state)].

At this time, with the sole exception of limited areas in southern California (Los Angeles Basin), there are no federal, state, or local environmental emission performance requirements imposed on small residential heating systems manufactured for use in the United States. In addition, there are no published, pending, or announced plans by the U.S. Environmental Protection Agency to impose any federal regulations in the future. Emissions are not currently an issue that would impede the manufacture or marketing of diesel-engine-driven cogenerators, nor does it seem likely that it will be a problem any time in the near future. Currently manufacturers of diesel engine are conducting a great deal of research and development to reduce engine emissions for diesel applications in the transportation sector. When successful, these innovations will be available and will very likely mitigate any air quality concerns associated with residential diesel-engine-driven cogenerators, such as the technology discussed in this report.

Noise Levels

The Intelligen unit was designed to operate quietly at noise levels comparable to those associated with more traditional oil-fired appliances. The Model Alpha-550 tested at BNL exhibited very acceptable performance in this regard as shown in Figure 6. All measurements, which were recorded only five feet from the unit, are well within OHSA standards for constant noise exposure. The "A" weighted average approximating the perception of the average human ear was well within measurement accuracy of the levels recorded for a boiler and a furnace tested on the same day at BNL (68.4 dB, 66.2 dB, and 64.3 dB respectively, all $\pm$ 10% of reading) . Taking into account that the BNL CETL is not a sound-measuring facility and that no special effort was made to attenuate or decouple the engine exhaust noise of the cogenerator, it is quite possible that the actual noise levels in the field may be slightly lower. The manufacturer has stated that the unit sent to BNL was not equipped with all of the sound reducing components currently included in the cogenerator package.

The only other conclusion that can be drawn from the data is that the noise levels in the lower frequency bands are higher than those recorded for the furnace and the boiler. Low- frequency sounds are more difficult to attenuate than those at higher frequencies. The unit does have lower sound levels in the higher frequency ranges when compared to the furnace and the boiler. This is the reason that the overall weighted levels are approximately equal. Humans do not hear sounds in separate frequency bands, rather they hear sounds in unison. The "A" weighted procedure is a standard technique for predicting how humans will perceive the sound and is a good comparative representation of how things sound.

Reference

Technical Assessment of An Oil-Fired Residential Cogeneration System - Project Report, BNL, R. J. McDonald, January 1993.

Paper No. 93-4

Applications of the Flame Quality Indicator

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APPLICATIONS OF THE FLAME QUALITY INDICATOR

INTRODUCTION

The Flame Quality Indicator (FQI) has been developed at Brookhaven National Laboratory (BNL) as part of a program to study, generally, advanced control and sensor options for residential oil burners [1]. During this study optical approaches were found to be very interesting and the FQI is a simple, first application of the results of that work. Details of the FQI concept and initial work with it have been discussed at earlier Oil Heat Conferences [2,3,4]. Essentially, the FQI uses a standard cad cell sensor and circuit to convert flame brightness to a voltage signal. The circuit provides a red "service required" light when the brightness (voltage signal), in steady state, changes beyond a limit range. The burner must still be adjusted, initially, by a qualified serviceman; the FQI simply indicates when something has changed and the burner should be examined.

Early in the development of the FQI, field tests were done in Ottawa, Canada (in cooperation with Canada Mortgage and Housing Corporation) as well as in homes near BNL. These tests indicated several areas where improvements were needed including response to short cycles and long term drift. Most of the signal drift in the early field tests was caused by overheating of the sensor, which was located just behind the retention head. The sensor has since been moved back, eliminating the problem. A secondary factor leading to longer term drift is sooting and oxidizing of the internal surfaces of the air tube during use. This has been eliminated with new burners simply by pre-coating the inside of the air tube with flat black paint. The response to short cycles is discussed later in this paper.

We are presently well along in a further set of field (and lab) tests in which the behavior of the FQI in a wide variety of system types is being studied. The primary subject of this paper is a comparison of the behavior of different system types and a discussion of further FQI improvements. The U.S. Department of Energy, which has sponsored the development of the FQI, currently holds a patent and is making licenses available on a non-exclusive basis.

The types of equipment which are currently included in our testing program are listed in Table 1 along with a code used in this paper. In selecting these units we have attempted to cover most of the types of systems which would be encountered in the field. All of the units which are listed have been carefully monitored for basic behavior as well as FQI trends. For some of these sites we have installed remote data acquisition/monitoring systems. In other cases we have simply put data acquisition equipment at the site on a periodic basis. In addition to these sites other tests are in progress which do not have detailed monitoring in place.

EQUIPMENT CYCLING PATTERNS

For any system, like the FQI, to be practical it must be able to respond to a very wide variety of systems. Three of the boilers tested (DB, WBS1, and WBC) are in homes and have tankless coils for domestic hot water. These each have 3 distinct types of burner firing cycles: 1)"standby cycles" where there is no heat call and the burner simply makes up for off cycle heat loss, 2)"heating calls" where the burner fires several times to satisfy a thermostat call and 3)"hot water"cycles where there is a hot water load only.

Table 1. Units included in FQI test program

CODE	UNIT DESCRIPTION
WF	A conventional, high-boy warm air furnace at BNL.
DB	A dry base, steel boiler in a home; 14 years old.
WBS1	A new, wet base, steel boiler in a home. This unit has a refractory wall where the burner enters but otherwise the flame is exposed directly to the boiler steel wall.
WBS2	A wet base, steel boiler with a thick refractory liner in the combustion chamber. Several identical models in test program. Includes lab tests, tests in homes and tests of a unit which heats a small factory area.
WBC	A wet base, cast iron boiler in a home. This unit has a "bucket" type refractory chamber liner.
MB	A wet base, steel boiler used as part of a multiple boiler system in a Nursing Home near BNL; 2 identical boilers tested.

Figure 1 shows a typical FQI flame intensity signal response over a time period where each of these types of cycles have occurred (unit DB shown, WBS1 is similar). During standby cycles, the burner on-time is about 2 minutes. With hot water cycles the burner on-time varies from about 3 to 10 minutes. Heating call cycles are very repetitive. For the first firing the burner on-time is long, 10-20 minutes. The next firings are considerably shorter, 3-5 minutes. From site-to-site the duration of the burner on-time depends upon the size of the distribution system and the nozzle size. With a high firing rate the burner on-time will, of course, be shorter.

During this program we have field tested three boilers of the type WBS2 (same model). Two of these are in homes and one provides heat in a factory area. In one of the homes the boiler is slightly undersized and, as a result, the burner runs very often with long burner on-times (to 2 hours). In the other home, burner on-times of 5 minutes are more typical. The factory where the third unit is located has night setback. When the system "picks-up" in the morning the burner has extremely long on-times (to 2 1/2 hours). A part of the cyclic pattern at this site is shown in Figure 2.

The typical cycling pattern for unit MB is shown in Figure 3. This unit has a high firing rate (2.5 gph) and cycles very frequently. The burner on-time never exceeds 2 1/2 minutes.

All of the boilers that we have tested during this project have operating characteristics similar to some part, at least, of Figures 1-3. While a pattern like that of Figure 3 may indicate a serious case of nozzle oversizing, the site shown is not the only one where this has been observed. The warm air furnace (WF) currently included in our test program is installed in our lab and operates

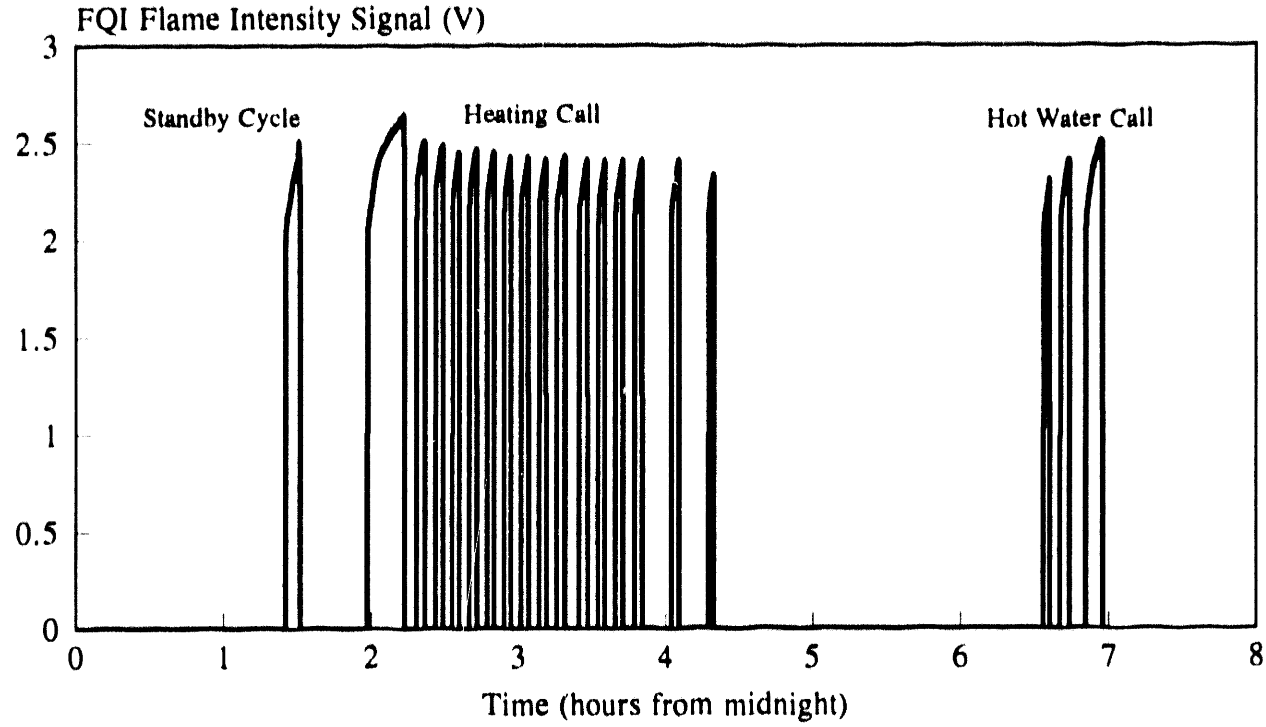

Figure 1. Illustration of the FQI signal trend in three different types of firing cycles. Unit DB in a home- dry base steel boiler. (signal filtered)

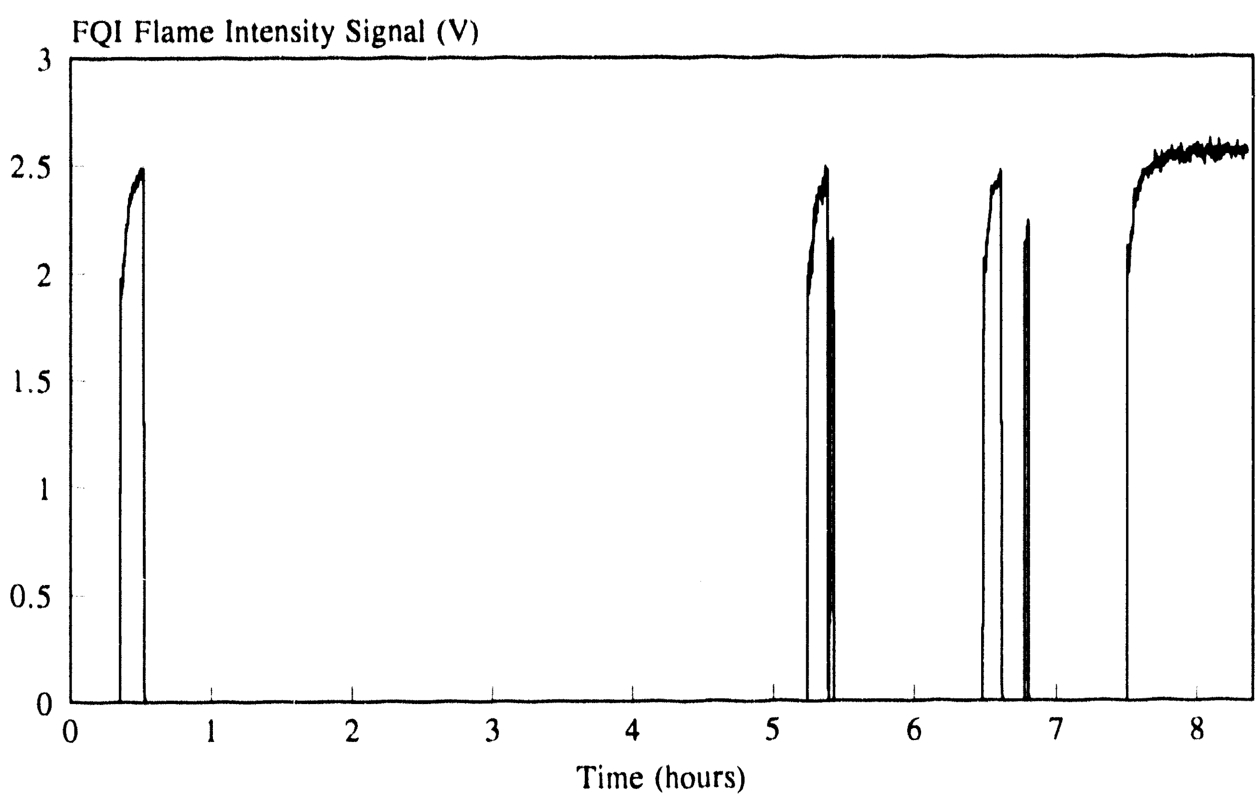

Figure 2. Illustration of the FQI signal trend through the night and early morning in Unit WBS2 in a factory - wet base steel boiler with a heavy combustion chamber refractory liner. (signal unfiltered).

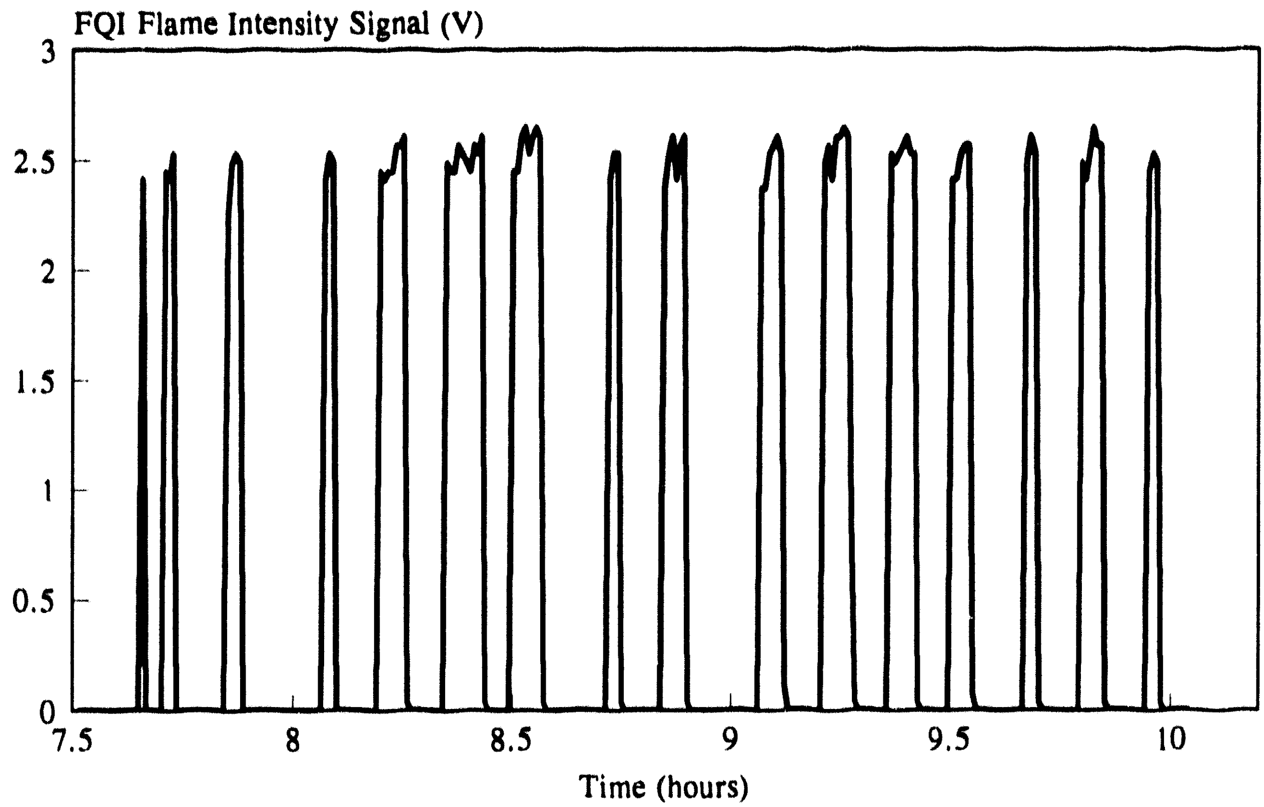

Figure 3. Illustration of the FQI signal trend in boiler installed as part of a modular system in a Nursing Home. Unit MB - wet base steel. (signal unfiltered).

with an imposed firing cycle. From our earlier test program we have considerable data on the cycling patterns of different furnaces. Firing times vary considerably and range from 2 to 40 minutes.

RESPONSE OF THE FQI TO CYCLING PATTERNS IN DIFFERENT EQUIPMENT

In this section, observed transients in the FQI flame intensities are discussed for different equipment and cycle types. The first FQI system developed at BNL used the signal intensity at the end of each burner-on period to gauge flame quality. This can lead to an occasional false "red light" condition if the "on" period is very short. An improvement under development would examine the signal only after the burner has been firing for some fixed period (e.g. 5 minutes). These two approaches are discussed along with the transient signal intensities in this section.

Throughout this paper some of the data is presented as "filtered" signals and some as "unfiltered". The purpose of the filter in the circuit is to eliminate effects of normal flame flicker and the BNL FQI has always used a filter in the part of our circuit which controls the flame quality lights. Only recently, however, has the design been modified to make the filtered signal available for input to our data logger as well as for initial FQI setup. A comparison of both the filtered and unfiltered signals during a startup transien' period is provided in Figure 4.

Generally, the initial transient period is dependent upon the amount of refractory around the combustion chamber. A heavy refractory liner leads to long warm-up time for flame brightness. Figure 5 shows the details of the transients for the dry base boiler, Unit DB, during the seven burner "on" periods which occurred in response to one typical heat call. The FQI flame intensity signals for each of the seven cycles have been superimposed for comparison. The first time the burner fires, it runs for 15 minutes. After 6 minutes, the signal is nearly at its final value although it never really reaches a steady value even after 15 minutes. In the burner "on" periods, which follow the first long one, the initial transients are much faster. When the burner fires the second time, the refractory is already somewhat hot and this effect makes a difference for flame brightness and the FQI.

Figure 6 shows the transient response during one firing cycle at Unit WBS1, which has very little combustion chamber refractory. In this case, the FQI signal shows very little warm up time. The signal maximum at this site generally occurs early in the firing cycle, as shown in the figure. This may be resulting from warming of the nozzle, which leads to reduced fuel flow, during the "on" period. For this site, with little refractory, this effect is apparently the most important. It may also be occurring at other sites with heavier refractories but at these other sites the refractory effects dominate. At one test site, FQI signals were monitored during a fuel line blockage incident. In this case, the FQI signal and, apparently, fuel flow decreased sharply during the burner "on" period.

The transient response for Unit WBS2 in a home is shown in Figure 7. This unit has a heavy refractory liner and so a long warm up time. After about 8 minutes, the signal reaches a steady value which changes little with firing times as long as 2 hours.

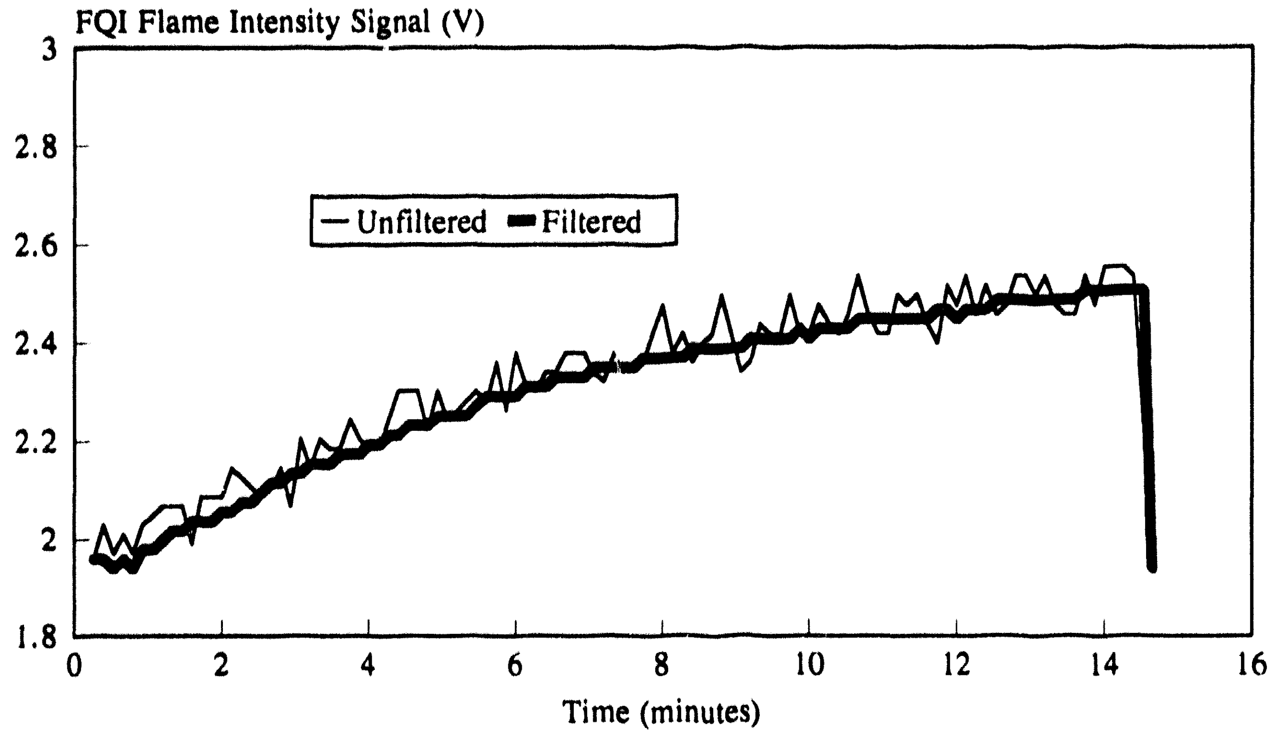

Figure 4. Comparison of filtered and unfiltered FQI flame intensity signals. Unit DB.

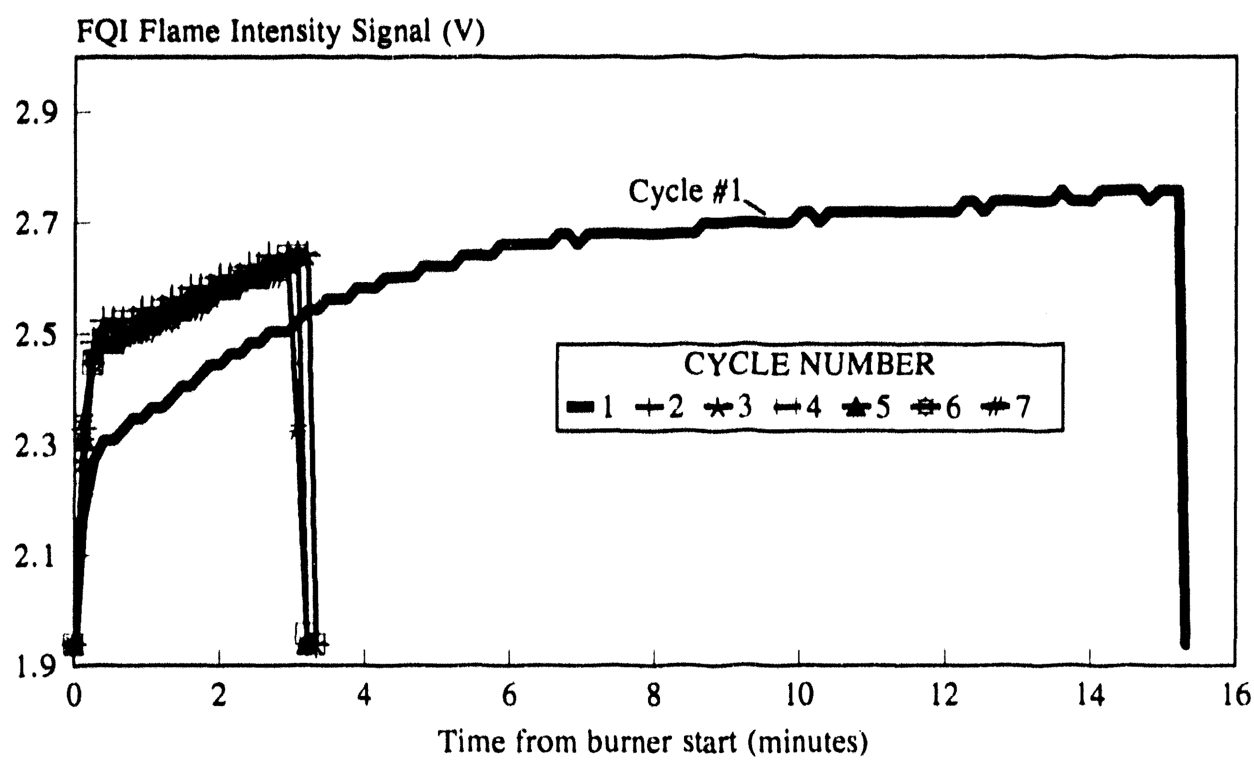

Figure 5. FQI response during a heating call, Unit DB dry base steel boiler in a home. First (long) burner on-period superimposed on following (short) burner on-periods. (signal filtered)

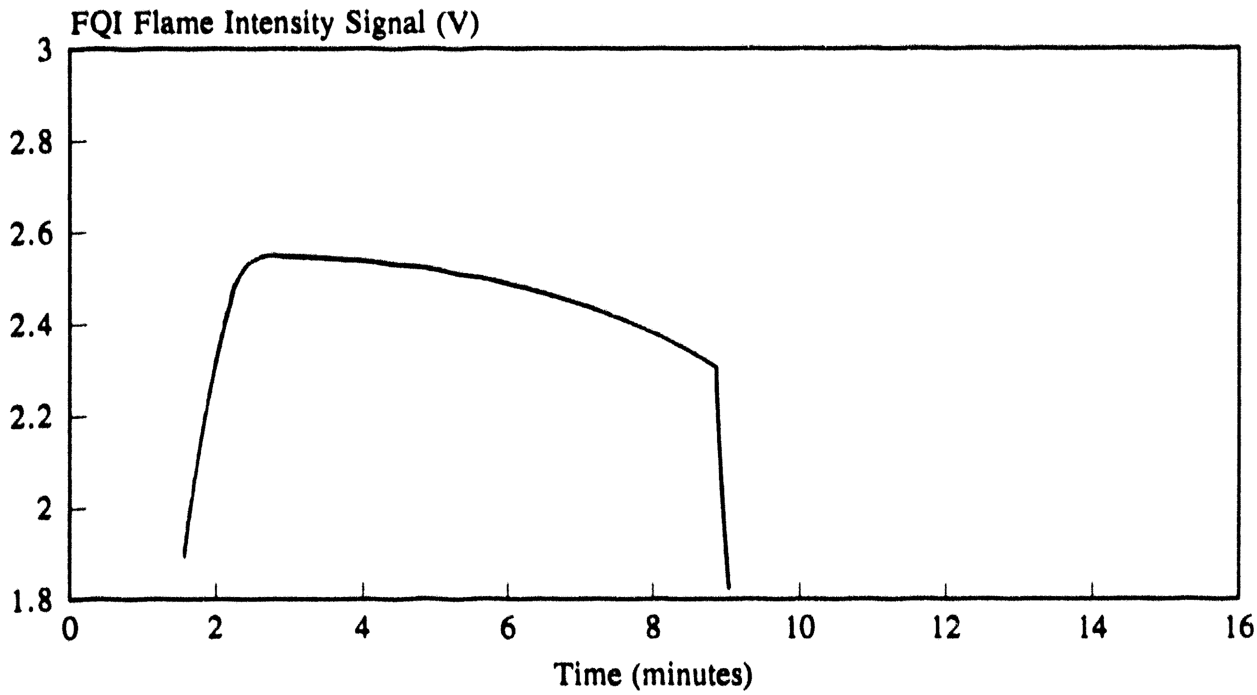

Figure 6. FQI Signal Transient. Unit WBS1 - wet base, steel boiler with only a target wall in the combustion chamber. (signal filtered).

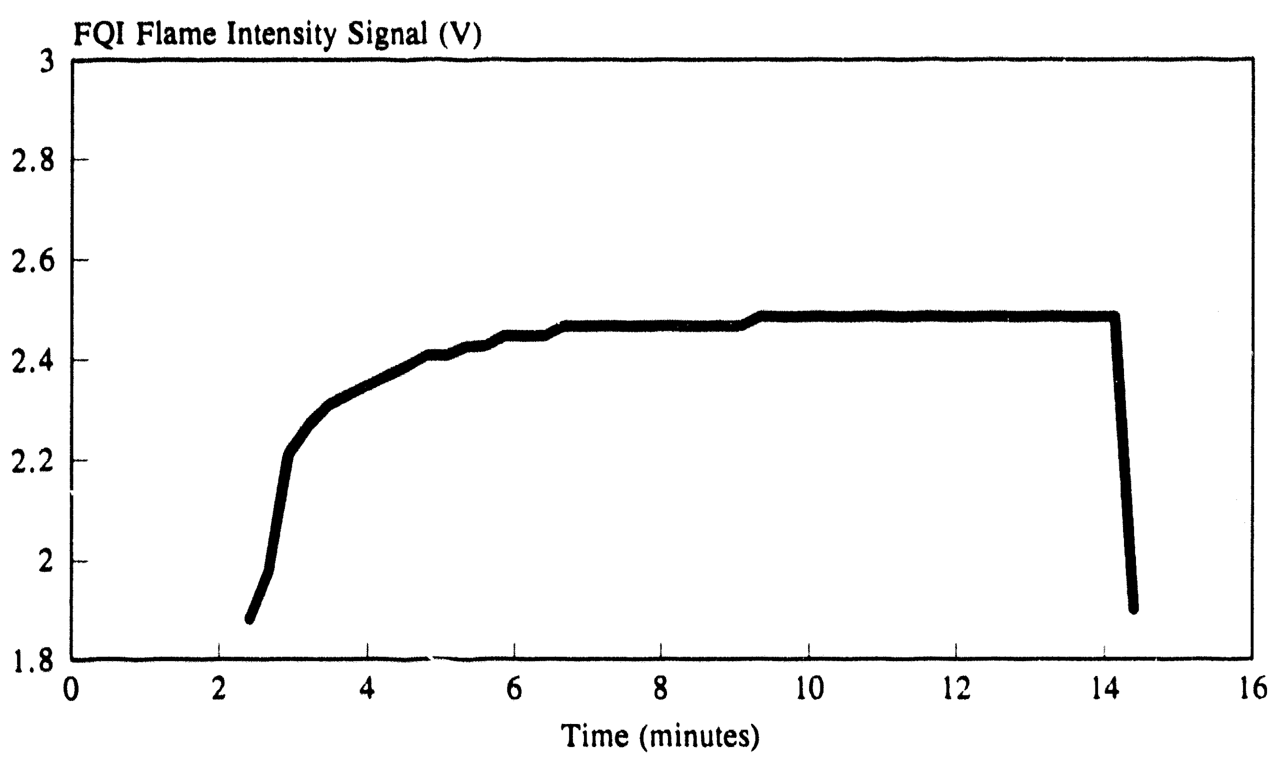

Figure 7. FQI Transient Signal. Unit WBS2 in a home - wet base steel boiler with a heavy refractory liner in the combustion chamber. (signal filtered).

The transient response at Unit WBC is shown in Figure 8. This wet-base boiler has a fairly light refractory liner and a short warm up period. Burner "on" times at this site rarely exceed 4 minutes.

Currently two approaches for the FQI are being considered. The first method, which has been used almost exclusively to date, uses the flame quality signal at the end of each firing cycle to control the indicator lights. The second approach would examine the FQI signal only at a fixed time after the burner starts. Figure 5 can be used to illustrate the difference. For the 7 cycles shown in response to a heat call the FQI signal at the end of the burner on-period is about 2.72 volts after the first cycle and about 2.65 after all of the other cycles - a difference of 0.07 volts. Considering that the acceptable voltage range is 0.50 volts this level of difference seems to be acceptable. This may not be true, however, in the case of a very short isolated cycle where the burner fires only to make-up for off cycle heat loss (no heat call or hot water load). In this case the FQI signal follows the curve for cycle #1 in Figure 5 but the burner would go off at about 3 minutes. The FQI signal at this point would be 2.5 volts or 0.22 volts less than the end-of-cycle voltage after cycle #1. A false red light may occur. With the second approach under consideration the FQI would only consider the signal at one fixed time- 5 minutes after burner startup, for example. In this case the flame quality would only be evaluated for the first burner- on period of a heat call or a long domestic hot water draw. All short cycles would be eliminated. A disadvantage of this approach is that the flame quality is not evaluated every cycle. During the heating season a 5 minute cycle might occur only a few times a day. During the summer a long cycle might occur only every few days. While the burner might operate for a few days with a non-critical burner problem this is still a considerable improvement over the current situation in which the burner might run for months with poor combustion, leading to a fouling problem.

For those cases where the firing rate is relatively high and burner on-times are short the choices are to downfire where possible, set the time for examining the flame quality shorter (e.g. 3 minutes) or use the first approach of monitoring the signal only at the end of the cycles. If all of the cycles are short (e.g. Figure 3) and the refractory mass is relatively small the end of the cycle approach is acceptable. If the refractory mass is great or a dry base boiler is used the FQI signal changes significantly with time during the first three minutes of burner on-time. The FQI signal at the end of three minutes may be considerably different from the signal at the end of two minutes.

For most of the boilers and furnaces tested in this program the use of the second approach, fixed time, would result in much less variation in the signal used by the FQI from cycle to cycle. By reducing this variation it may be possible to reduce the voltage range for the "green light" condition in the future and improve the effectiveness of the FQI.

FACTORS THAT CAN CAUSE A "RED LIGHT" CONDITION

In the current FQI system, the normal setpoint is 2.5 volts and the upper and lower limits are 2.15 and 2.65 volts, respectively. These field tests, as well as tests at the BNL laboratory, have identified many factors that can lead to a change in the FQI flame intensity signal and a "service required" alarm. These are summarized in Table 2. One of these has occurred several times in our

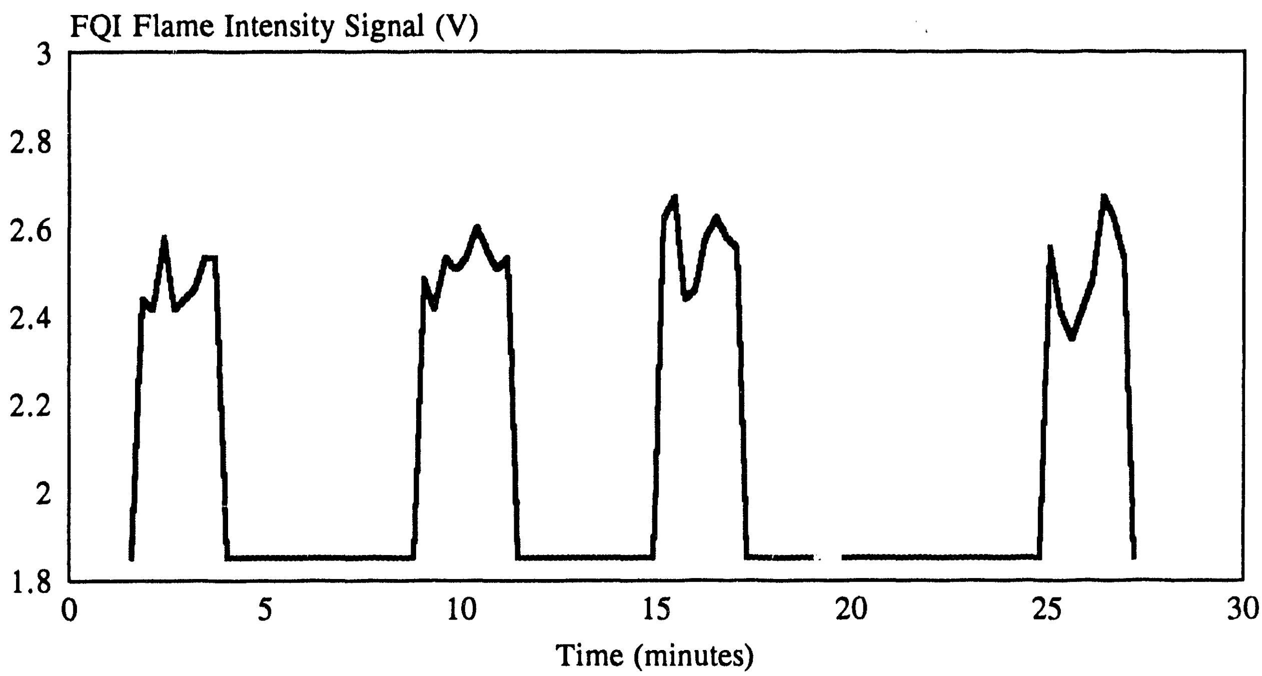

Figure 8. FQI transient signals. Unit WBC in a home - wet base cast iron boiler. (signal unfiltered).

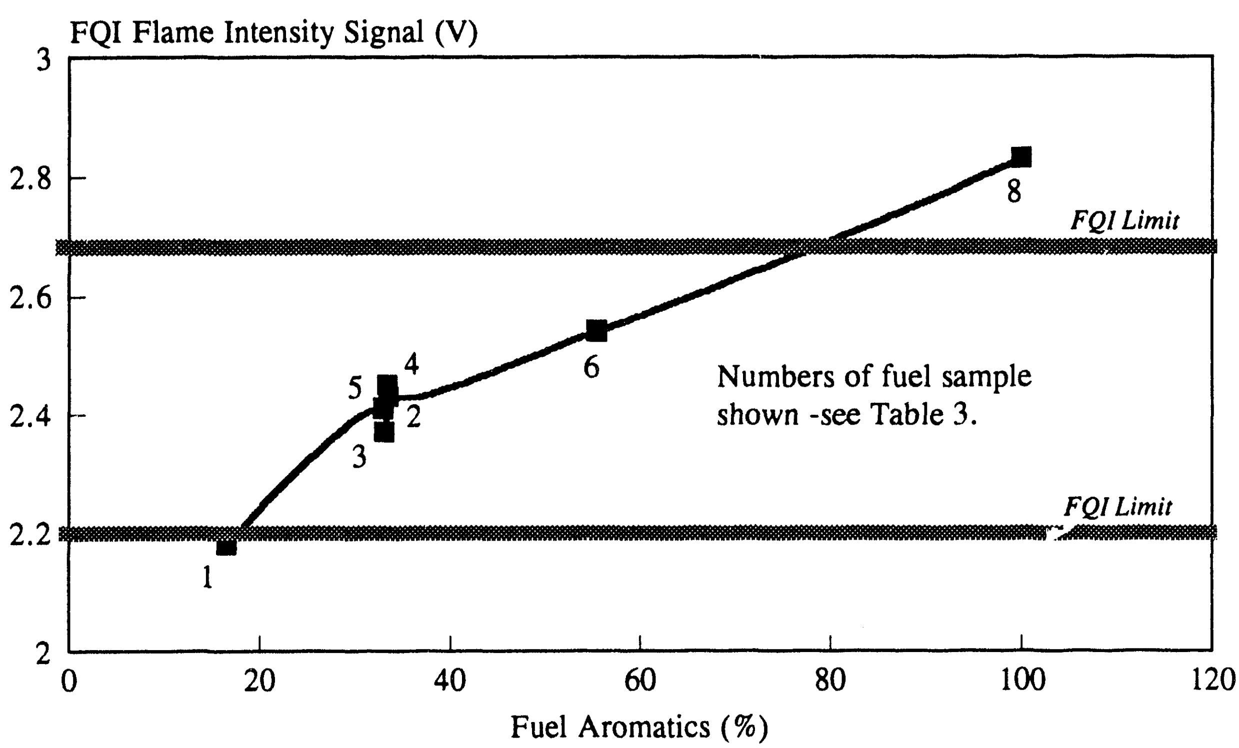

Figure 9. Response of the FQI to changes in fuel quality - Warm air furnace in the BNL lab

recent field studies - oil in the burner air tube. At one field test site, after installation, a steady climb in the FQI signal was observed. After one month, the system was at the trip point. An inspection showed that the burner tilt was incorrect and a pool of oil had collected on the inside of the air tube. The air tube was carefully cleaned and the tilt corrected. The FQI signal returned to normal and has remained there to date (3 months). The oil coating on the air tube surfaces increased both reflectivity and the amount of light hitting the sensor. At another site, we observed a severe case of oil back inside of the burner housing, probably due to a combination of poor ignition and weak draft. At this site, we observed a steady decrease in FQI signal. During inspection, the sensor cell was found to be dripping with oil. It was cleaned and the signal returned to near normal but the decreasing trend in the FQI signal started again. This unit is scheduled for service.

Table 2. Factors which can cause a "red light" condition.

•	An increase or decrease in excess air due to changes in the air shutter position, fouling of the air inlet, or blockage of the heat exchanger due to soot.
•	Nozzle fouling.
•	A partial blockage of the fuel line.
•	Sooting of the sensor cad cell - this is a particular concern in cases which have massive combustion chamber refractory liners and/or low off cycle draft.
•	The buildup of soot on the burner air tube or the nozzle assembly. This can reduce the amount of light which reflects back to the sensor cell.
•	Accumulation of oil on the air tube or nozzle assembly. This glossy film can increase the amount of light which reflects back to the sensor cell.
•	A very short firing cycle. In such a case the chamber may not get fully warmed up. The flame at the end of the cycle is relatively cool and emits less light than in a longer cycle. Future FQI designs will eliminate this effect.
•	Damage to the sensor. If overheated the sensor cells will lose sensitivity. Current placement of the sensor cell far back in the air tube has eliminated this in all cases tested to date.
•	Use of an off-spec fuel which has either very high or very low aromatics content. This includes lube oil.

In long-term use, some questions have been raised about changes in the FQI signal following fuel deliveries. One situation which could occur is plugging at the filter or fuel line after a delivery if sludge on the tank bottom is stirred up. This has not been observed in field tests to date. Another possible effect, mentioned in Table 2, would be due to a change in the viscosity and aromatics content of the fuel, which would lead to a change in flame brightness. This has also not been found to be important in field tests. To evaluate possible effects, however, a series of tests were done in the BNL laboratory with a variety of fuels firing in our warm air furnace. Throughout these tests, the furnace continued to operate with an imposed cycling pattern and the fuel supply changes were made without any changes to the burner. Table 3 identifies the test fuels and also shows the flue gas oxygen level, the smoke number and the FQI voltage observed when each fuel was fired. The test fuels in Table 3 are listed in order of increasing fuels aromatics content. Of the eight test fuels three do not meet ASTM specifications for No. 2 oil. Fuel No. 2 is off-specification due to high viscosity. Fuel No. 8 has too low a value for the API gravity. Fuel No. 7 is out on both API gravity and viscosity.

Table 3. Properties of Test Fuels

Number	Viscosity (cs@100 F)	Aromatics (%)	API Gravity	FQI Signal (Volts)	Flue Gas O2 (%)	Smoke Number in Steady State	Fuel Meets ASTM Specs
1	2.6	16.6	42.7	2.18	7.0	0	Y
2	5.5	33	-	2.41	6.5	0	N
3	1.6	33.2	38.4	2.37	8	trace	Y
4	2.8	33.5	36	2.45	6.8	trace	Y
5	2.3	33.6	35.6	2.43	7.3	trace	Y
6	2.3	55.5	30.9	2.46	7.4	trace	Y
7	8.0	76.7	27.6	2.23	5.2	trace	N
8	2.4	100	14	2.83	7.1	trace	N
ASTM Limits	1.9 to 3.4	-	30 min				

Fuel Nos. 1, 7 and 8 produced a change in the FQI signal which gave a red light or near-red light condition. In the case of Fuel No. 7, the very high viscosity caused the flame to stand far off from the retention head, leading to a low apparent flame intensity (low FQI voltage). This fuel is very difficult to burn at all in a conventional retention head burner. A red light indication is considered to be a correct response for this fuel. In the case of Fuel No. 8, the high aromatics content produced a high flame intensity signal. Table 3 lists a trace smoke for this fuel but examination of transient smoke numbers indicated very high startup smoke production with this fuel. In an off-spec fuel like this were used in a home, a red light condition would occur on the FQI. Fuel No. 2 is off-spec due to viscosity but in combustion tests no adverse effects on performance were noted. The FQI gives a green light condition and this is a correct response. Fuel No. 1 has a low FQI signal due to the low aromatics content. If this fuel were used in a home, a red light condition could occur and this is not a correct response. The aromatics content of this fuel, however, is extremely low and based on discussions with refiners it is extremely unlikely that a fuel with these properties could be found in the market. The aromatics content of nearly all #2 fuel oils is within a narrow range around 35%. Results of all tests with the exception of the ultra high viscosity test (Fuel No. 7) are illustrated in Figure 9 where the FQI flame intensity signal is plotted against the fuel aromatics content. This serves to illustrate the importance of this parameter.

In the absence of one of the factors listed in Table 2 the FQI signal will remain steady over time. The test furnace in the BNL lab, for example, has had a steady FQI signal for nearly one year of continuous duty.

CONCLUSIONS

Recent efforts at BNL have been in improving the performance and reliability of the Flame Quality Indicator. Since it's initial development numerous improvements have been made. Further improvements can come from more experience with field applications. The results of these improvements will be a smaller operating range for the FQI and less possibility of false "service required" calls. One improvement which might be implemented is the evaluation of the FQI signal only at a very specific time after the burner fires. This would eliminate transient and short cycle effects in most systems.

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ACKNOWLEDGMENT

The author would like to recognize the assistance, advice and initiative of Mr. George Wei and Mr. Yusuf Celebi in the completion of this work.

Paper No. 93-5

INTEGRATION OF THE ENERGY KINETICS SYSTEM 2000 CONTROLLER AND THE BNL FLAME QUALITY INDICATOR

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INTEGRATION OF THE ENERGY KINETICS SYSTEM 2000 CONTROLLER
AND THE BNL FLAME QUALITY INDICATOR

INTRODUCTION:

The concepts of a "Flame Quality Indicator" (FQI) for monitoring oil fired residential heating systems offers the oil industry an opportunity to further promote the advantages of its equipment and services to the consumer.

It could put the oil industry in a position to offer the ultimate in a preventative maintenance program which features the principle advantages of oil heat over competing energy sources.

A) **Clean:** Proper monitoring of flame conditions insures clean burning.

B) **High Efficiency:** Maintenance of a clean flame minimizes performance degradation and loss of appliance efficiency; the efficiency stays as high as when first set up.

C) **Safe:** Continuous monitoring of flame condition assures that the air-fuel mix remains in an acceptable range. Potential for carbon monoxide, already low with oil fired equipment, is virtually eliminated.

D) **Reliable:** The advance warning of service requirements to adjust the burner allows for more convenient scheduling of service calls.

E) **Economic:** Maintenance of high efficiency and reliable operation reduces the overall cost of operation of the equipment.

Preventative maintenance service schedules can possibly be extended with assurance that the combustion process is properly controlled, thus significantly reducing unnecessary annual tune-ups. (If it isn't broken, why take it apart, readjust it and/or possibly create a problem.)

Concepts:

Originally introduced at the 1990 Oil Heat Technology Conference, the FQI offered a relatively simple and cost effective oil burner flame monitor.

The concept and performance characteristics have been well described in prior papers presented in the 1990 and 1991 conference proceedings, U.S. Patent No. 5126721, issued in June, 1992 and in the 1993 conference presentation by Thomas A. Butcher, George Wei and Yusuf Celebi (see Paper No. 93-4).

Basically, a standard cad cell sensor and monitoring circuit converts flame brightness to a voltage signal. The voltage signal will vary with start-up transients, fuel and combustion air flow rates (excess air quantity) within a fairly narrow range in a given appliance.

The ability to monitor this signal level continuously over very many firing cycles permits an analysis of the quality of combustion. Changes in this output signal are an indication of changes in flame quality and cleanliness of the burning process and a resultant potential for a change in the appliance efficiency.

DEVELOPMENT PROGRAM

Step 1:

Energy Kinetics initially worked with Brookhaven Engineers in the Fall of 1990, using a boiler providing heat for its plant offices as a test site for one of the prototype FQI controllers developed by BNL.

Recorders continuously monitored the FQI, flue gas oxygen level and unit performance for a week at a time. The program indicated the FQI was fully capable of detecting variations in air/fuel ratio and irregularities in burner performance.

At the time, we were experimenting with the use of outside combustion air and the recorders were able to monitor combustion air temperature at the burner inlet and the FQI signal. Performance was satisfactory with combustion air temperatures as low as 36°F.

It is interesting to note that on lightoff, the combustion air temperature was close to the ambient room temperature. It would cool only slowly over a long period of time with near continuous burner operation on the coldest days. Thus initial lightoff would occur with, relatively warm air, and the air/fuel mix of a normal set-up. This removed our concerns of cold outside air affecting lightoff.

The test program indicated that some modification of the FQI monitor should be incorporated to improve reliability of its signal output.

a) The CAD cell can be subject to heat and should be located as far back as possible in the burner air tube.

b) Oil after drip, if and when it occurs can cause an oil film to build on the eye (CAD cell), reducing its response signal.

The concept of the FQI and its ability to detect variance in flame quality was felt to be very desirable and we continued to work with BNL in evaluating units.

Step 2:

The Energy Kinetics System 2000 utilizes a sophisticated electronic control (System Manager) to provide for energy management, zone control and domestic hot water production which significantly reduces off-cycle losses associated with most hydronic systems.

Quite simply, it provides for cold start operation. Through use of a timed cycle it preheats its low mass and water content boiler to a temperature greater than flue condensing level in approximately 1-2 minutes.

The control makes the System 2000 operate much like a warm air furnace.

Control sequence:

1. Preheat to approx. 140° F.

2. Distribute heat to zone or hot water tank until demand is satisfied.

3. Turns the burner off.

4. Continues distribution to last zone or hot water tank based on a timed cycle until boiler temperature is approx. 105° F. (much as a warm air furnace fan operates until the bonnet is cool).

The System 2000 contains LED lights which signal each of these functions and these lights have made it a valuable tool for assisting service personnel to diagnose any system malfunction.

For several years now, we have been developing an advanced version of the System Manager which uses advanced logic controls. It was obvious that we should incorporate into its functions advanced concepts to further assist in service, diagnostics and maintenance.

Addition of the FQI concepts as an additional optional input to the control was included early in the design (see Figure 1). Several advantages could be included:

A) The System Manager controls the burner on/off function, so its program could also be used with the FQI to eliminate starting transients and monitor the flame intensity at a set time in the burner on cycle.

Thus a principle variant in the level of flame intensity could be made more consistent. The FQI was monitored only after five minutes of operation. The characteristics of short cycles or very long cycles could be eliminated.

B) The System Manager could provide electric power at a fixed voltage to the FQI eliminating the need for a separate controlled power circuit in the FQI device.

C) The System Manager could interpret the signal level and determine if it was consistent with the original signal (satisfactory operation) or if there had been a change and that service/maintenance was required.

D) The System Manager would then trip the service light on the FQI as well as close contacts which could transmit the service requirement to:

1. A local or remote alarm/bell or light to indicate heating service requirement.

2. A house central alarm system or direct dial system to indicate a heating system problem to the alarm monitoring service or dealer servicing the equipment.

Two signals are possible:

1. FQI indicating tune-up is required. Not an emergency.

2. Heating system/burner failure resulting in a no-heat indication which, depending on time of year, might require immediate service.

   This has an advantage in that the failure is reported immediately rather than after the fact when it is realized the home is getting cold or the home owner is out of hot water.

The new System Manager control recently developed is now undergoing prototype field tests in 20 locations.

Six of these units are equipped with FQI units from Brookhaven which have been modified to adapt to our System Controller. A typical installation is shown in Figure 4. The FQI with Manager and recorder is shown in Figure 5.

The signal level vs. excess air and smoke number for a System 2000 Model EK-1 is shown in Figure 2.

Periodically, we are attaching recording equipment to several of the locations to record operating characteristics of the system for five day periods with data transmitted to BNL via modem for analysis.

The FQI signal is quite constant over a period of time. Data from one site is shown in Figure 3.

The performance of the FQI has been excellent. In several instances, it has indicated performance deterioration, well in advance of a significant problem.

CONCLUSION

The FQI is not the end all solution to insuring long term, low service, reliable, clean burning oil-heating system operation. It can only monitor that which is occurring and can extend service intervals on appliances which:

1. Have a wide window of reliable clean burning characteristics, i.e., able to burn clean and stable within a range of CO_2 from say, 10 1/2 to 13 1/2% CO_2.

2. Are supplied clean, well filtered fuel without contaminants and preferably low sulfur levels.

3. Interrupted ignition systems which allow electrodes to maintain excellent spark conditions for 3 to 5 years without resetting of the gap and position.

4. Rugged and reliable components, such as pumps, motors and controls.

In the future, if for efficiency or low emissions reasons, units operate at low excess air levels, the window of clean operation may get even tighter and the FQI monitor may be the only way we can insure reliable operation.

We believe there are real advantages to the FQI and it is close to commercialization. As with any development, we prefer to continue field testing on a controlled basis before the product is released for general application.

In this regard, we look forward to working with interested dealers to expand our test program and get feedback which will result in user friendly, reliable operation.

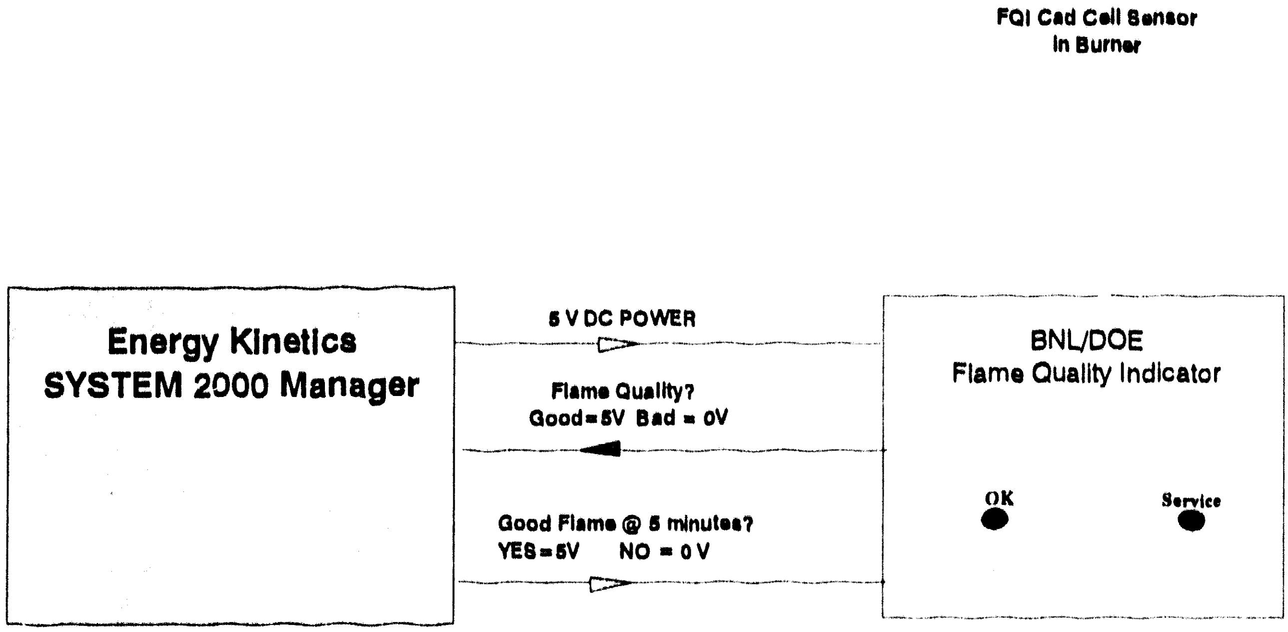

Figure 1. Interaction of the Flame Quality Indicator with the Energy Kinetics System 2000 Manager

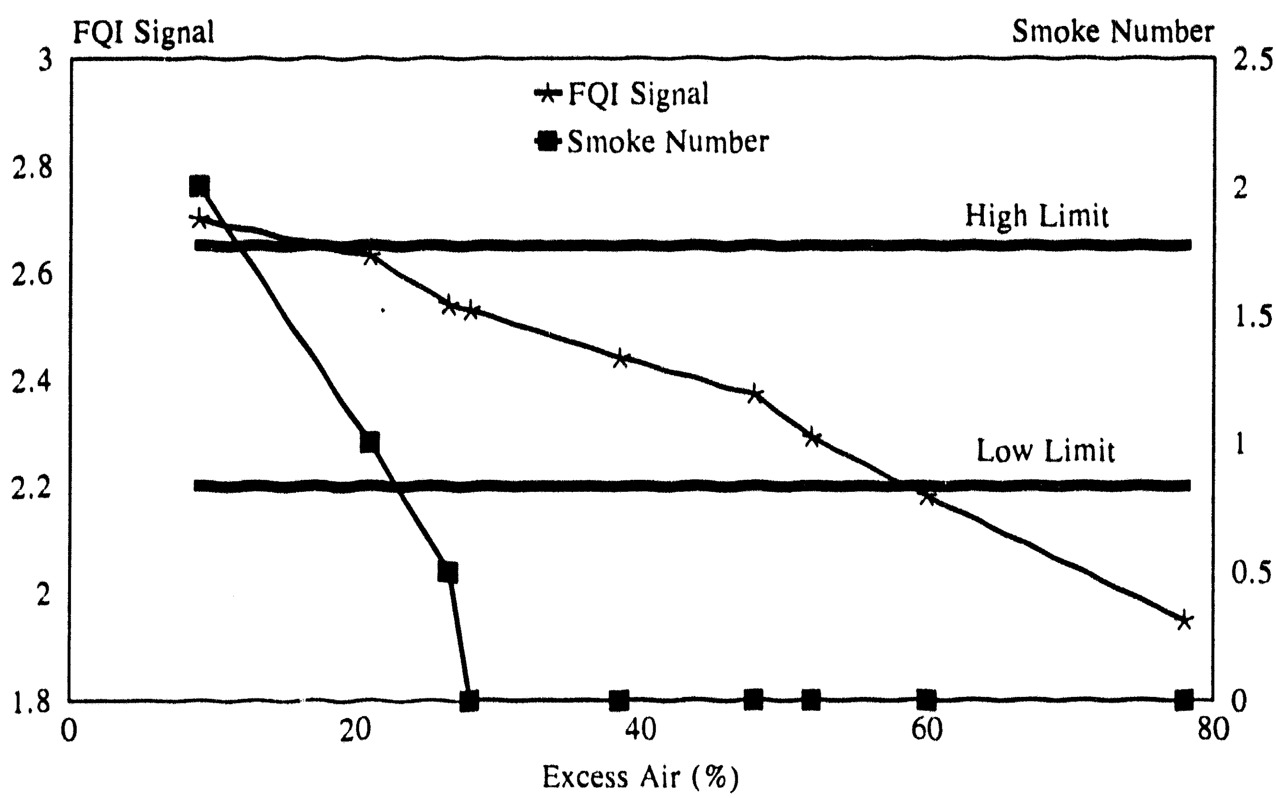

Figure 2. Effect of excess air on smoke number and FQI signal.

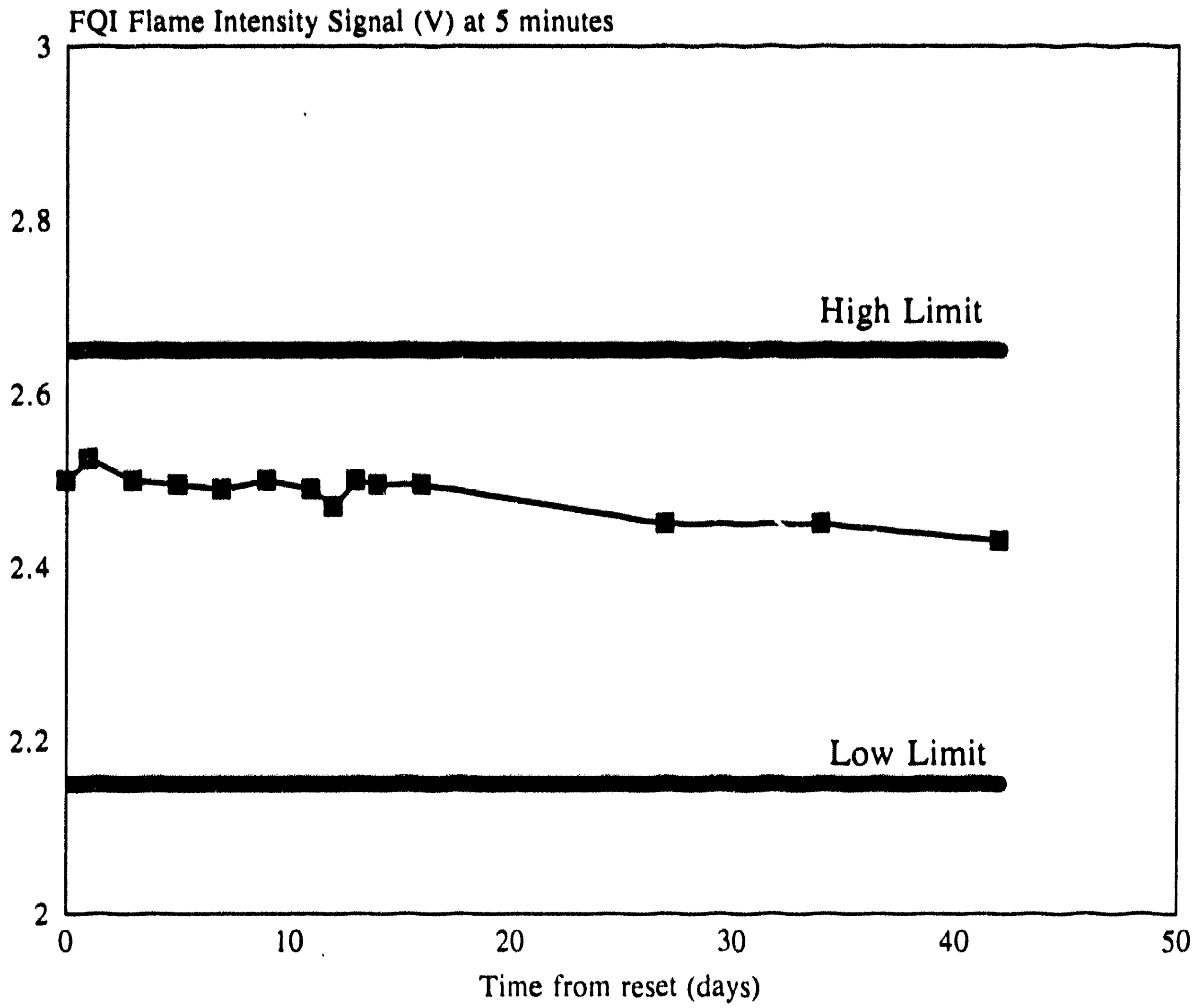

Figure 3. Trend in FQI signal over time at one home site.

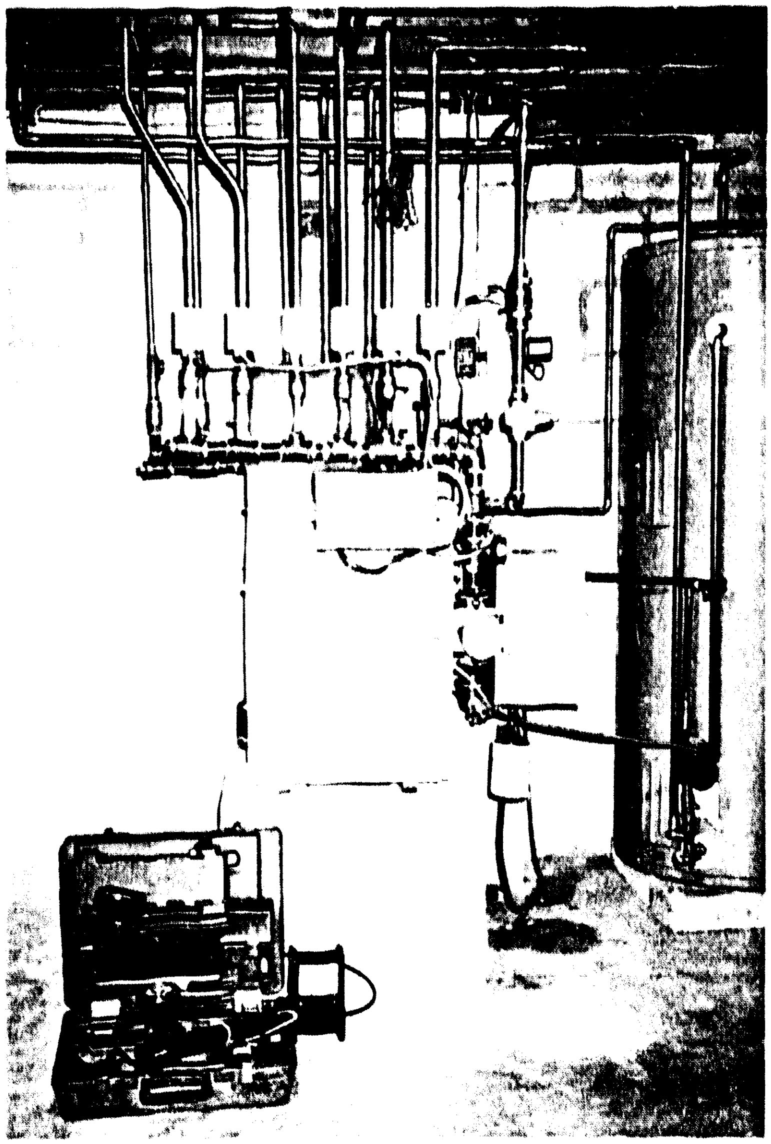

Figure 4. System 2000 Manager with FQI
and Data Recorder.

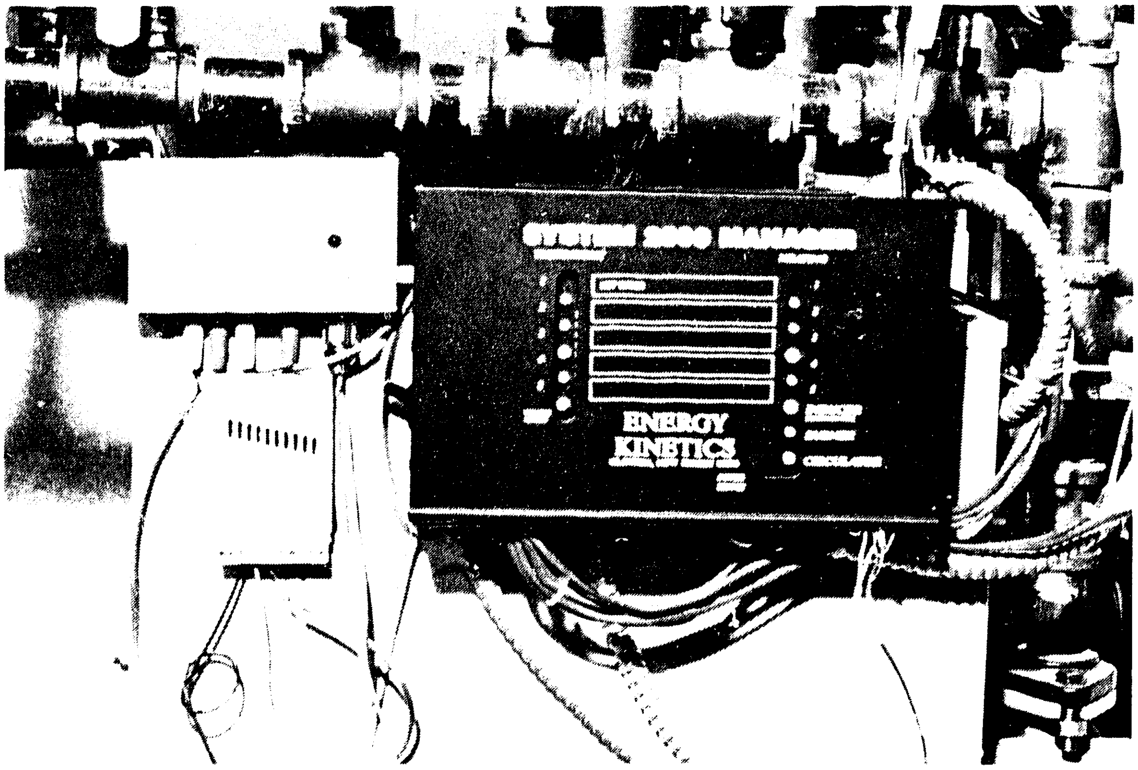

Figure 5. System 2000 Installation with FQI.

Paper No. 93-6

HOW TO INCREASE PUBLIC/INDUSTRY AWARENESS OF OIL-HEAT ENERGY CONSERVATION OPPORTUNITIES

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HOW TO INCREASE PUBLIC/INDUSTRY AWARENESS OF OIL-HEAT ENERGY CONSERVATION OPPORTUNITIES

ABSTRACT

The Nova Scotia Department of Natural Resources has developed a number of approaches to increase awareness on the part of the public and industry groups of the opportunities for increased energy efficiency and conservation in housing. Several of these activities were directed specifically at the residential heating industry.

The presentation will describe efforts to increase the use of efficiency testing through industry training, public information and a shared purchase of efficiency test equipment.

The effect of recent code developments pertaining to combustion efficiency testing and the revisions to the venting codes will be discussed.

Recent issues in the industry with respect to the growing popularity of side wall venting, the provision of combustion air in today's tighter energy efficient homes and the retrofit of new high efficiency heating equipment into existing venting systems will be outlined.

INTRODUCTION

The Nova Scotia Department of Natural Resources (NSDNR) Energy Branch administers provincial government energy policy within the province. Within the Energy Management Division, Public Energy Programs provides a range of programs to increase energy efficiency in housing.

Energy related information is provided to the industry through workshops, conferences and on-site visits. Similar services are provided to the homeowner through a toll free telephone service, a broad selection of print material, home energy workshops offered through the Community Schools Program, home shows, on site energy audits and through other information activities.

PUBLICATIONS

Publications dealing with residential energy issues have been developed to better inform the public of any new products or technologies. For example; a brochure on windows provides detailed information on Low E glass and gas filled windows. Comparisons in "R" values are given. We have produced a variety of publications on residential ventilation and corrective measures dealing with mould, mildew and moisture problems. Our "Home Heating Workbook" provides an overview of basic residential heating systems and fuels. The advantages and disadvantages of each are given, with a comparison of operating costs for fuel options. Our most recent publication also deals with domestic water heating options.

<u>ENERINFO</u>: One of our popular efforts is the ENERINFO province-wide toll-free telephone line. The service is available from 8:30 a.m. to 5:00 p.m. weekdays. Calls are tallied up in several categories, new or existing housing, insulation,

moisture, heating, ventilation, domestic water and solar. We receive 2000-2500 calls annually.

SITE VISITS

For those homeowners with extensive energy related problems, we carry out on site assessments on the building envelope, the heating system and ventilation equipment. A detailed report which specifies corrective measures is prepared for the homeowner. These site visits also reveal many field problems. Information gained on site visits is used in the development of new printed materials and to more readily determine the needs of the industry.

HEATING SEMINARS

In the past five years, we have held three very successful, residential heating conferences. A steering committee was set up with representation from a cross section of the heating industry to establish a programme that was most beneficial to all. The Residential Heating Conference, held every two years, provides a forum for the industry to come together, not only to participate in presentations of interest to members, but to share common problems and solutions about work in the field. Speakers included researchers, manufacturers and suppliers, the service industry and marketing. Seminars such as ours and this one enable the industry to see what is being developed and also allows for a better dialogue between the many branches of the industry.

PHONE IN RADIO SHOW

For several years, I have been the monthly guest on the hour long "Maritime Noon" Radio Show. The show is carried throughout three Maritime provinces by the Canadian Broadcasting Corporation (CBC). People call toll-free with a very broad range of questions dealing with energy related issues.

COMBUSTION ANALYSIS TEST KIT ASSISTANCE PROGRAM

For many years, we stressed the importance of efficiency testing to the consumer, advising that this is the only accurate way to check the oil burner's performance. Many burner technicians were not suggesting efficiency testing to the consumer. We carried out considerable promotion on this subject including a print advertising campaign to create consumer awareness of the importance of efficiency testing. The consumer began requesting the tests. In many cases, especially in rural areas, small independent operators did not have the equipment. If enough consumers created the need, something had to happen! At this point, we sent letters to certified burner technicians inviting them to participate in our cost shared program and we received responses from over sixty companies.

Our department agreed to pay 50% of the cost of efficiency test kits up to a maximum of $350.00 per kit. In several cases, we provided funding for more than one kit per company, based on the number of customers.

In Canada, we have had a number of code changes and the most recent B139-M91 CSA code specifies that an efficiency test must be carried out on combustion equipment at the time of installation or at any time service is performed on a burner. This is a common sense procedure but, as in many cases, it often takes government legislation to make it happen. While the use of efficiency tests is increasing, there is still a long way to go before testing becomes an accepted practice for all residential heating service.

CONSUMER, HEATING CONTRACTOR RELATIONSHIP

The method of doing business varies to a great extent in various parts of the country. We see strong pockets of hydronic heating in specific areas, large pockets of warm air heating in other regions. On Canada's east coast, the majority of oil suppliers lease heating equipment to the consumer.

There are a number of areas in the heating field where improved communications between the customer and the heating contractor would result in more and better installations. More time must be spent briefing the customer about the proposed system. I receive calls from homeowners who have been quoted a price on a new system. I ask "How many zones?; What areas does each zone include?" and "How many lineal feet of radiation will be installed in each room?" These points are not always addressed. In most cases, the homeowner have been sold on efficiency and reduced fuel costs but they visualize pipes running in all directions and large gaping holes throughout the building.

It is time that "simplicity" has been emphasized. In the average two story home, a one inch supply and return to the second floor is often all that is necessary. The supply pipe runs to the second floor, splits, and each loop runs around the perimeter of the building. A zone valve is installed in each loop and we have a four zone, well controlled system (see Figure 1). I have explained this simple approach to many people and they immediately decide to install the new system.

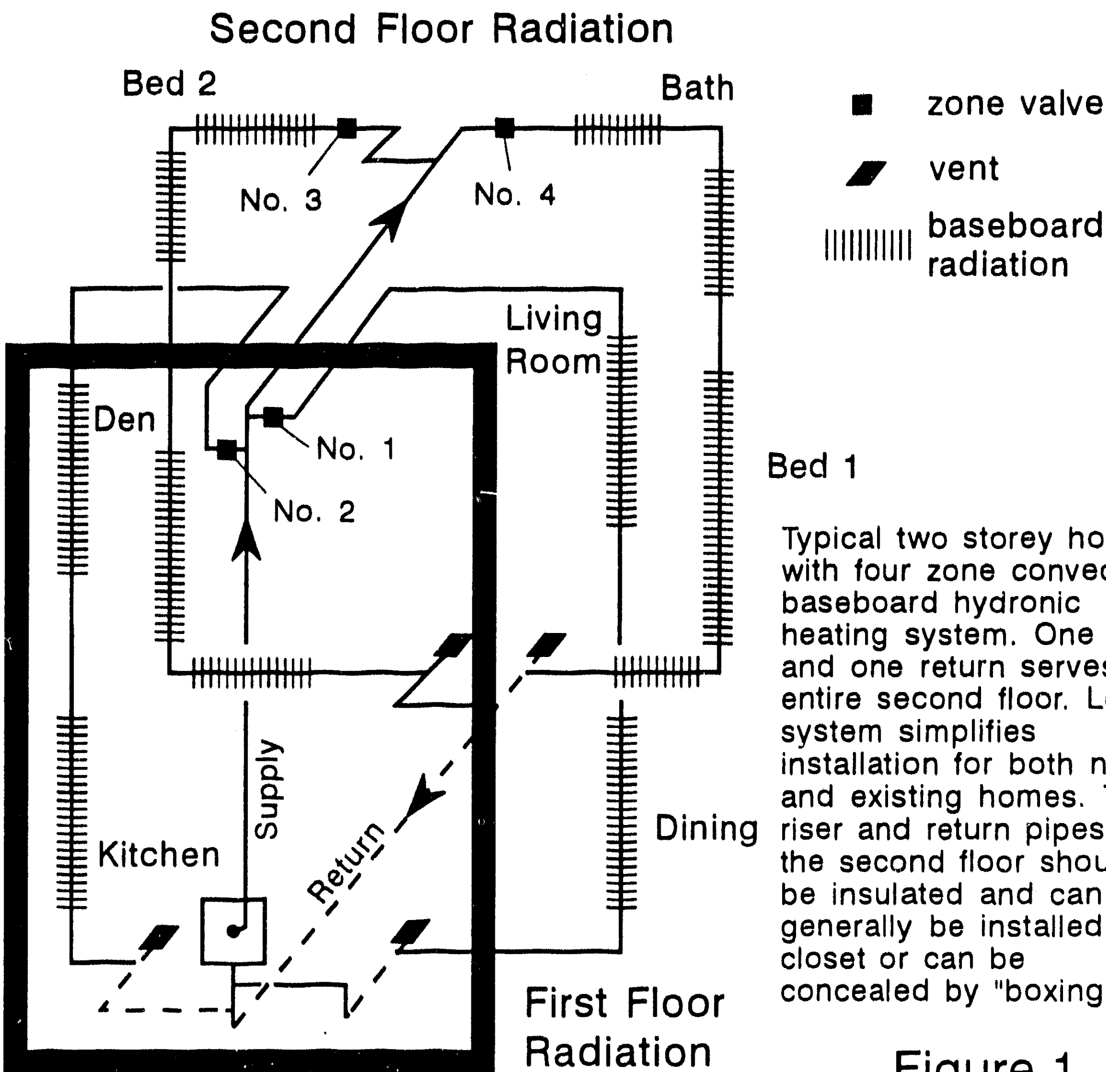
ARE YOU USING THE MOST COST EFFECTIVE FUEL?

Information in our Home Heating Workbook on fuel costs surprises many people. Recently in Nova Scotia, many homeowners have installed electric heat and used wood as a back up. Generally, they found heating electrically to be very expensive. They wind up using wood as the prime heat source and electric as the back up. Most homeowners state; "Wood is cheap". They actually know the cost of heating electrically but are vague about the cost of wood. Our sample chart (Figure 2) compares the cost of producing one million BTUs of heat energy using various fuels.

At $120.00 for a cord, wood heating costs about the same as heating with oil but without the work of the cutting, splitting, etc.. Taking electric heat at 8¢ per kilowatt hour, the cost is $24.17 per million BTU, while oil costs $11.22 at 34¢ per litre at an efficiency level of 83%.

THE HIGH COST OF EFFICIENCY!!

In today's society, we want the best ski boots, the best video camera, and the most efficient furnace. Too many times, the salesperson tells the homeowner the remarkable fuel savings achievable with 88% efficiency furnaces. The homeowner is not told about the disastrous problem that will occur when installed in the oversized outside brick chimney. If the boiler/furnace has been approved for side venting, this is the ideal solution. If the vent is on the driveway



Typical two storey home with four zone convector baseboard hydronic heating system. One riser and one return serves entire second floor. Loop system simplifies installation for both new and existing homes. The riser and return pipes for the second floor should be insulated and can generally be installed in a closet or can be concealed by "boxing in".

Figure 1

side of the building or too close to other intakes, side venting may be impossible. The frustrated, irate homeowner is now advised that the stainless steel chimney liner is the only solution at an extra $1100. Here again, we need better communications and should advise the homeowner of the potential problems in advance.

Low stack temperatures will result in chimney condensation and, in severe cases, can destroy the chimney.

I have seen installations where condensing occurred because of the low stack temperatures. The burner technician increased the temperature to reduce the severity of the problem. Of course this drops the efficiency level which defeats the purpose of installing a high efficiency heating appliance. In general, for every 33°F temperature change, the efficiency will change 1 percent. A side wall vent system will permit the heating device to operate at maximum efficiency with low stack temperatures and no condensing problems.

In installations where side venting was not possible, and the flue gas temperature was marginal, insulating the breeching will help prevent the problems. In Figure 3, the illustration shows how an average temperature increase of 62°F was realized by insulating a 53 inch long section of breeching. The barometric damper does add diluted air and this was included in the temperature readings. The breeching was wrapped with 1½" of high temperature insulation.

Insulating the breeching is not meant as a cure-all but many times will correct a minor problem and satisfy the customer.

ISSUES FOR THE FUTURE

The NSDNR intends to continue on with our very successful programs and information activities as in the past.

Our residential heating conferences will be held every two years. These conferences are tailored to the needs of the installation and service industry.

Areas that require further development are as follows:

1 More emphasis on the importance of efficiency testing and to assist in the enforcement of the new code.

2. Widen the field and produce more information on heating system retrofits.

3. Further development and simplification of the provision of combustion air and backdrafting in airtight housing.

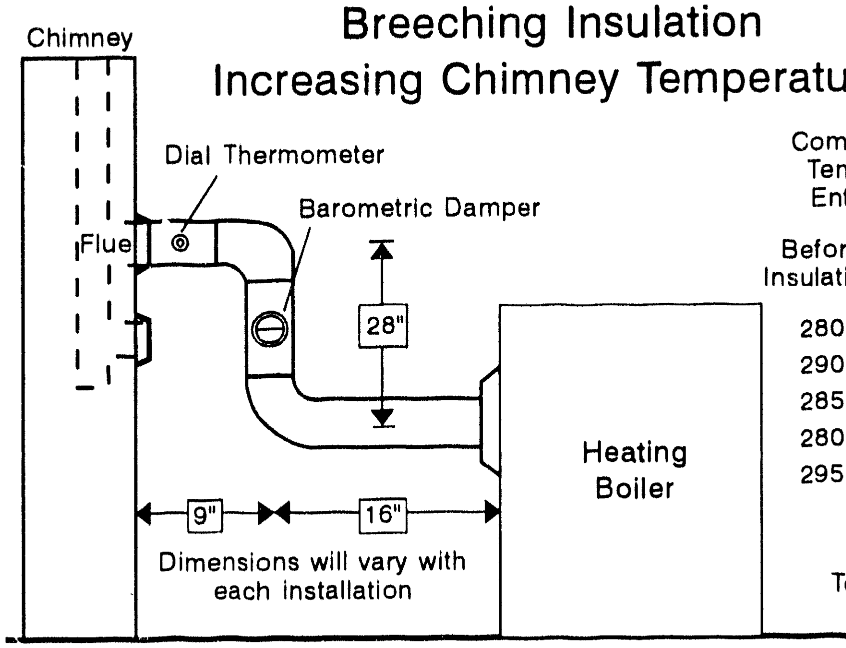
4. Ongoing education programs for the industry to keep pace with new technologies.

Nova Scotia
Current Fuel Cost Comparsion - Feb/93

Fuel	Unit	Effic.	Btu/ unit	Cost/ unit, no GST	Cost/ mil. Btu	Heating Cost for 75 Mbtu	% Diff.
Electric	Kwh	100%	3413	$.0825	$24.17	$1812.92	Base
Oil	litre	83%	36500	0.34	11.22	841.50	-54
Propane	litre	75%	24200	0.389	21.46	1609.50	-11
Wood	cord	55%	18.4M	120	11.86	889.50	-51
Wood	cord	55%	18.4M	160	15.81	1185.77	-35
Wood	cord	55%	18.4M	200	19.76	1482.00	-18
Pellet	ton	75%	16.4M	225	18.29	1371.95	-24

Figure 2

Breeching Insulation
Increasing Chimney Temperature



Combustion Gas Temperatures Entering Flue

Before Insulation	After being Insulated
280	340
290	345
285	350
280	355
295	350

Test results by A. Irwin

No Scale Implied

Figure 3

APPENDIX

FLAME QUALITY INDICATOR (FQI)
THE NOVA SCOTIA EXPERIENCE
FIELD TEST RESULTS

Arthur A. Irwin
Nova Scotia Department of Natural Resources

INTRODUCTION

In January 1992, an optical flame quality indicator (FQI) was provided by Brookhaven and installed in a hot water heating boiler in Halifax, Nova Scotia. The boiler is also used to heat the domestic water which meant the device has now had a twelve month field test.

THE INSTALLATION

The FQI was installed in a Circle cast iron boiler; boiler model CB2A6 with a net heat output of 123,000 BTU/HR. The boiler is fired with a Riello, series 40 model F5 burner, nozzle - .85 with a firing rate of 1.00 gph at 150 PSI. The boiler is used to heat an Aerotherm A-50 storage tank and domestic water heat exchanger. The heat distribution system consists of a seven-zone hydronic convector baseboard system in a seventy-five year old home.

FIELD TESTING

In addition to the field testing of the FQI, oil consumption is being monitored with an oil flow meter and the domestic hot water is being monitored with a water flow meter. The burner cycles and operating time is being metered and thermometers are used to monitor the tank in and tank out water temperatures. The data has been recorded weekly for the past 16 months.

FQI INSTALLATION

The FQI is supplied with a cast aluminum clamping device which simplifies installations of the sensor on the drawer assembly. This cannot be used on the Riello burner because of the design. The sensor must be easy to remove and not hinder servicing of the burner. Following a bit of experimenting, the sensor was fastened to the inside of the air tube cover by drilling and securing the bracket with sheet metal screws. When the cover comes off for servicing, the sensor is attached which simplifies the procedure.

FQI PERFORMANCE

The FQI performed very well over the twelve month period with the digital lights indicating each mode of operation. On burner start up, the red light comes on, following the burner pre-purge and ignition and flame stabilizing period, the green light comes on. At burner shut down, the green light stays on and the amber light also comes on indicating a "hold" mode.

On January 12, 1993, one year following installation, the red light came on during the run cycle. At this point, a buzzing in the fuel pump sounded like pump cavitation. When the noise occurred, the pump pressure dropped approximately 10 PSI which indicated a restriction in fuel delivery. The filter on the fuel tank was inspected and there was a heavy accumulation of sludge around the filter cartridge. This restricted the flow of oil and in turn, the fire became unstable and the FQI indicated there was a problem. Without the FQI, the burner would no doubt perform for days or weeks in a very inefficient manner, sooting the heat exchanger and eventually shutting down. The FQI was responsible for diagnosing irregular performance at an early stage and one would assume it prevented a burner outage and much discomfort.

Paper No. 93-7

OIL HEAT VENTING GUIDELINES - VENT MATERIALS AND CORROSION

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Upton, NY 11973

OIL HEAT VENTING GUIDELINES - VENT MATERIALS AND CORROSION

ABSTRACT

This paper presents a brief overview of work conducted in the application of metallic materials in oil-fired heating systems. The mechanism of sulfuric acid formation and the issue of surface corrosion of oil-fired heat exchangers are both discussed in terms of the implications of acid carried over into the vent system. The results of experiments studying vent wall temperature profiles are presented and discussed addressing the implications of water and acid dew point. A brief review of related research in metal corrosion rates in heat exchangers is presented and extended to the development of a proposed method of analyzing vent material loss through corrosion as a function of exposure time and temperature. The method is applied to actual laboratory time/temperature history test data for a vent system and the results are presented and discussed.

INTRODUCTION

An important issue related to vent surface temperatures is the formation and condensation of sulfuric acid in both chimney and power vented oil-fired systems. Sulfuric acid formation and corrosion in oil-fired heat exchangers has been investigated in BNL laboratory experiments. The results of these experiments have confirmed that because of the presence of excess available oxygen (excess air) in the combustion process, about 1 percent of the fuel sulfur results in SO_3 formation. This SO_3 combines with moisture from the combustion process to form H_2SO_4 (sulfuric acid) in the flue gas.

$$SO_3 + H_2O \Longrightarrow H_2SO_4 \quad (1)$$

Hot-water boilers are usually maintained at temperatures at or below 200 F. The wall temperatures of the flue-gas-side of these boilers are only a few degrees warmer than the water-side temperature. One evaluation of the sulfuric acid dew point as a function of SO_3 concentration in the flue-gas shows a typical acid dew point range of 230 F to 266 F for fuel-oil containing between 0.2 and 0.3% sulfur.[1]

An evaluation has been conducted in the BNL laboratory of the acid dew point of the flue gas generated from the combustion of No.2 Fuel Oil containing 0.25% sulfur. Although the maximum limit for No.2 Fuel Oil is 0.5% sulfur [2], the 0.25% level is typical for the Long Island, N.Y. area. As a result of the laboratory experiments, it has been observed that at 0.25 percent sulfur, the acid dew point ranges from about 225 F to 240 F. The experiments also indicated that about 50% of the acid formed condenses out on the flue-gas side of heat exchanger surfaces within oil-fired heating equipment. This suggests that the balance of the acid leaves the appliance and enters the vent system. Unfortunately, the temperatures of the metal surfaces exposed to the flue gases in vent pipes and vent-system components of oil-fired appliances are at or below the acid dew point for substantial portions of the burner "on" period. This means that acid condensation will occur, and the resulting corrosion will damage these surfaces. Metal vent systems are frequently constructed of galvanized (zinc dip coated) steel. The corrosion of the vent material will generally proceed with the corrosion of the zinc coating in accordance with the following equation:

$$Zn + H_2SO_4 \text{ (aqueous)} \Longrightarrow ZnSO_4(xH_2O) + H_2 \qquad (2)$$

Once the zinc coating is penetrated the steel will be exposed and the corrosion process will follow the following equation:

$$Fe + H_2SO_4 \text{ (aqueous)} \Longrightarrow FeSO_4(Xh_2O) + H_2 \qquad (3)$$

The primary products of these two reactions are hydrated sulfates of the metals involved and hydrogen which is typical of acid corrosion.[1] Corrosion rates, degree of damage and the effects on system performance and safety remain open questions and require further evaluation.

In addition to work being conducted in vent loss for power-vent oil-fired appliances, some investigations were conducted regarding vent temperatures. These investigations have led to some tentative conclusions regarding system operation, acid condensation, and the potential for corrosion.

An experiment was conducted using a vent connector of exaggerated length consisting of a horizontal, 24 ft length of single-wall galvanized vent pipe. This extreme length was used specifically for the purpose of measuring the effects of extreme ambient cooling in the laboratory environment and would be prohibitive for general field installations. The system was connected to an oil-fired boiler which served as a flue gas generator. Flue-gas exhaust from the vent system was augmented using a side-wall mounted inducer. Instrumentation was installed to permit measurements of flue-gas temperatures and wall surface temperatures at various positions along the vent were recorded.

VENT WALL TEMPERATURES
BOILER OPERATION INTO A LONG VENT CONNECTOR

The ASHRAE 103 Standard [3][4] assumes an "average burner on" time of about 9.7 minutes and a burner "off" period of 33.3 minutes. For purposes of reducing test time and simplifying timing in recording test data, a burner "on" period of 10 minutes and a burner "off" period of 20 minutes was selected for these tests. Using this cycling scheme, repetitive tests were conducted to examine centerline flue-gas and vent wall temperatures in a long horizontal vent system. While the experiment was originally designed around the examination of the vent during the burner "on" period, the effects of burner "off" period cooling were also measured. The vent connector was cooled by natural convection with laboratory room air at 70 to 85 F.

Figures 1 and 2 show the results of a series of tests using a 24 foot long 6 inch diameter un-insulated galvanized vent connected to an oil-fired boiler and operated under cyclic control as described above. The centerline flue-gas

FIGURE 1 - FLUE-GAS/VENT WALL TEMPERATURE
6 INCH UNINSULATED GALV. VENT PIPE

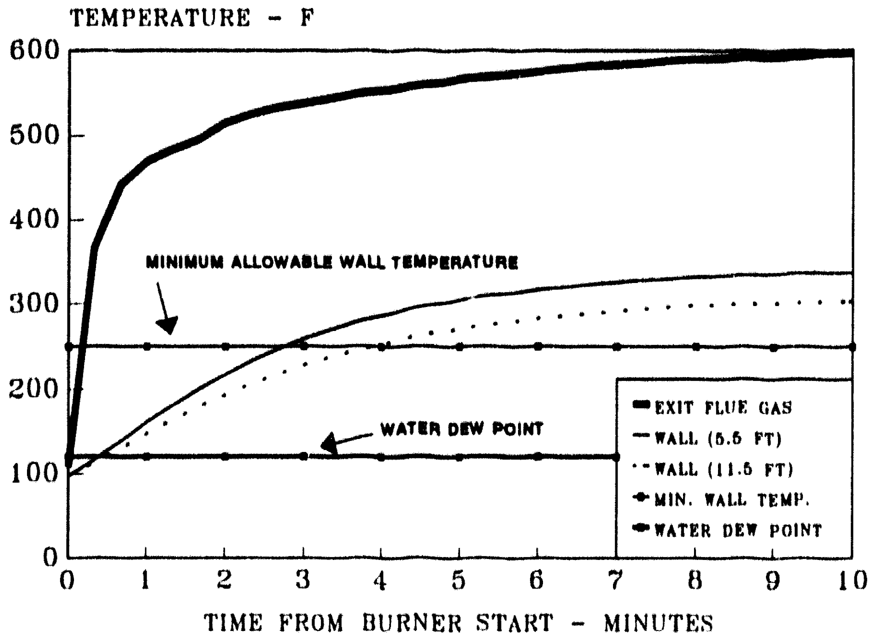
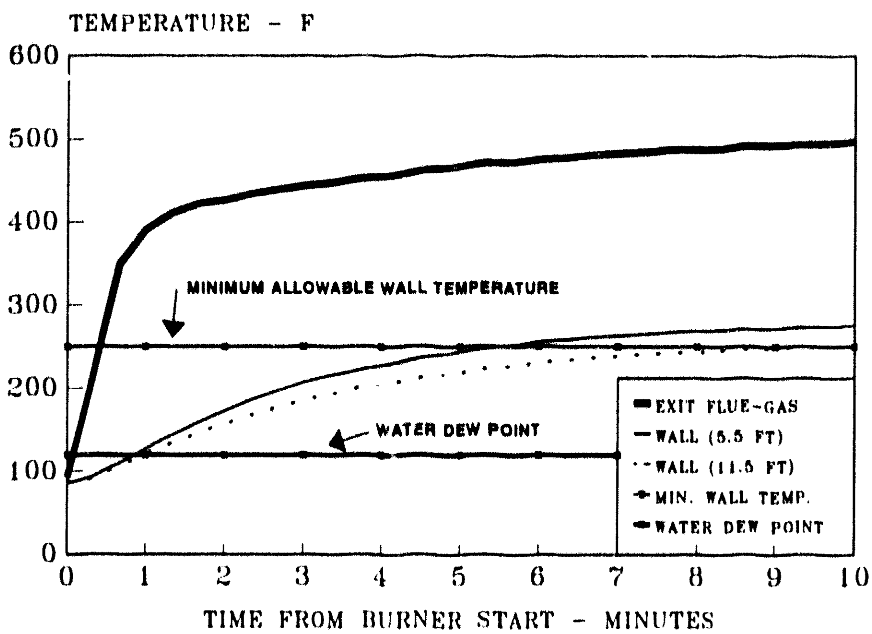
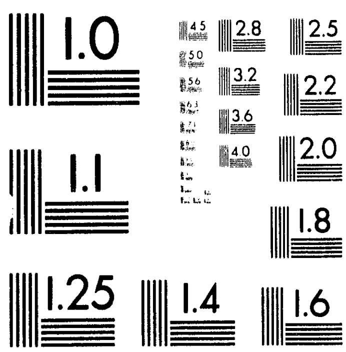


FIGURE 2 - FLUE-GAS/VENT WALL TEMPERATURE
6 INCH UNINSULATED GALV. VENT PIPE




1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

2 of 3

temperature as well as metal wall temperature were measured at uniformly spaced locations along the length of the vent system. For purposes of discussion within this paper, a temperature of 250 F was selected as a minimum allowable surface temperature for vent surfaces exposed to flue gas resulting from the operation of oil-fired appliances. Based on the sulfuric acid dew point measurements discussed earlier, it was assumed that at vent surfaces at or above 250 F, acid condensation would not occur. Conversely, with vent surfaces below 250 F, acid condensation could occur. In a similar vain, the water dew point for oil-fired flue gases was estimated to be about 120 F. The significance of the water dew point in this discussion will be presented later.

For the tests depicted in Figure 1, the end of the burner "on" period centerline flue-gas temperature at the boiler exit was about 600 F. This temperature probably typifies existing older but well maintained oil-fired appliances in the field. From Figure 1, therefore, it is apparent that for 6 inch connectors up to 11.5 feet long operating under "average" cycling conditions, the vent wall is above the 250 F in under 4 minutes of burner operation. For high heat loads (long burner "on" periods and short "off" periods) the vent system will likely be warmer prior to the next burner start. Thus, for high heat load periods, the exposure to acid condensation may be relatively short per unit of fuel used. More importantly, as will be discussed later, the period of time that the vent is below the water dew point will be greatly diminished if not eliminated during high heating loads. It should be noted that at both positions along the vent shown in Figure 1, the vent wall temperature started at about 100 F and remained below the water dew point for about 30 seconds.

Many boilers must maintain water temperature under "standby" operation for domestic water demands. Much of the heating season (fall and spring) will exert low loading demands (short burner "on" periods below the "average"). Under these standby conditions and/or in cases of heating equipment over-sizing, there is the potential for short cycling, probably close to the 2- to 3-minute range for the burner "on" period. This is inevitably coupled with long "off" periods which allow the vent to cool nearly to ambient conditions. Even with an "older" system, which typically have higher flue-gas exit temperatures, represented in Figure 1, there is a greater risk of exposure to water and acid condensation for the entire vent system for cycling periods less than 3 minutes.

In Figure 2 we can see a temperature profile which probably is typical for a major fraction of modern oil-fired boilers in the field. Even though the centerline temperature has risen to 500 F at the end of burner "on" period, the vent-wall temperature at a point 5.5 ft from the appliance is at the acid dew point in under 6 minutes but only rises marginally above that point as the burner shuts down. The implication here is that for this type of equipment un-insulated vent connectors should not exceed a length of about 5 to 6 ft. In addition, burner "on" periods of less than 6 minutes will place the entire vent connector wall below the acid dew point for most of that period. This may be a particularly difficult situation for oil-fired furnaces which exhibit an average burner "on" period of 3.9 minutes according to the ASHRAE Standard 103.[3][4] Again, it is significant to note that the vent wall temperatures start at about 85 F and remain below the water dew point for almost 1 minute.

In order to determine the wall temperature effects of a smaller vent diameter, studies were performed using a long (24 foot) 4 inch vent connector.

The recommended minimum vent size for mechanical draft oil-fired boilers is 4 inches in diameter for a gross boiler output of up to 132,000 Btu/hr..[5] Tests were performed using the bare (un-insulated) vent with a peak (end of burner "on" period) boiler flue-gas outlet temperature of 500 F. The results of these tests are shown in Figure 3 and revealed no dramatic improvement over the un-insulated 6 inch diameter vent shown in Figure 2. There was a small reduction (-1.5 min.) in exposure below 250 F at the 5.5 foot location and a small reduction in the exposure below 120 F.

The 4 inch vent was then insulated with 1.5 inch fiberglass which had an aluminized face and an R-value of about 4.2. The tests were repeated as before and revealed significant improvements. As shown in Figure 4, at 5.5 feet from the boiler outlet, the insulated 4 inch vent wall reached 250 F in under 3 minutes. The un-insulated 6 inch vent took more than 5 minutes to reach the same temperature. At 11.5 feet from the boiler the insulated 4 inch vent wall was at 250 F in less than 4 minutes whereas the un-insulated 6 inch vent wall required the entire 10 minute burner "on" period to reach 250 F. In terms of the water dew point exposure, the vent wall temperatures started at 150 F, well above the water dew point.

OTHER RESEARCH IN CORROSION FOR OIL-FIRED SYSTEMS

Studies conducted at Battelle Columbus Laboratories offer some insight in terms of appropriate material selection for use in oil-fired venting systems.[6] It should be noted that the studies were conducted for condensing heat exchanger materials at <u>surface condensing conditions near the water dew point</u> in oil-fired flue gas. These conditions represent the most severe in terms of metal corrosion attack and are generally considered to be <u>7 - 10 times</u> worse than the general sulfuric acid corrosion occurring at metal surface temperatures between the water dew point (120 F) the acid dew point (225 to 240 F)[7][8]. The corrosion rates shown in mils per year (mpy) must therefor be judged in terms of the actual vent design imposed and the inner wall material exposure to water dew point conditions in the field.

Most of the commonly used conventional heat-exchanger materials were shown to be unsatisfactory for use in the oil-fired flue gas environment.[6] These materials include:

1) Carbon, low-alloy steels and cast irons (44-67 mpy)
2) Nickel alloys containing no chromium (9-45 mpy)
3) Some nickel-chromium-iron alloys containing no molybdenum (4-20 mpy)
4) All copper alloys tested (5-33 mpy)
5) All aluminum alloys tested (20-71 mpy)
6) All brazing alloys tested (6-31 mpy)
7) Tin, zinc, and cadmium. (14-36 mpy)

From the standpoint of corrosion the most favorable alloys which would probably give satisfactory service in the oil-fired flue gas environment would be the following:

1) Iron alloys: Silicon iron (0.4 mpy)
2) Iron-chromium-molybdenum alloys: 26-1, 29-4, MYBY MoT (<0.2 mpy)

FIGURE 3 - FLUE-GAS AND VENT WALL TEMPERATURE
4 IN"'I UNINSULATED GALV. VENT PIPE

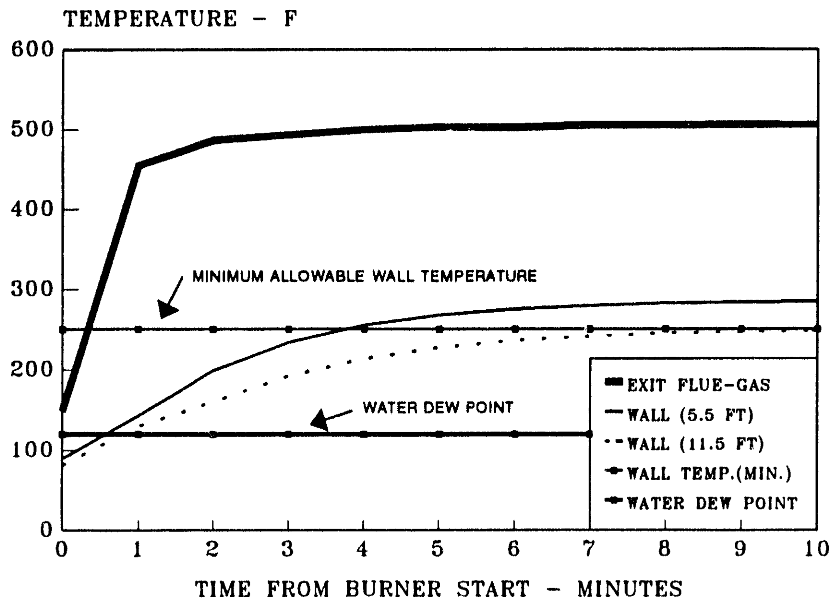
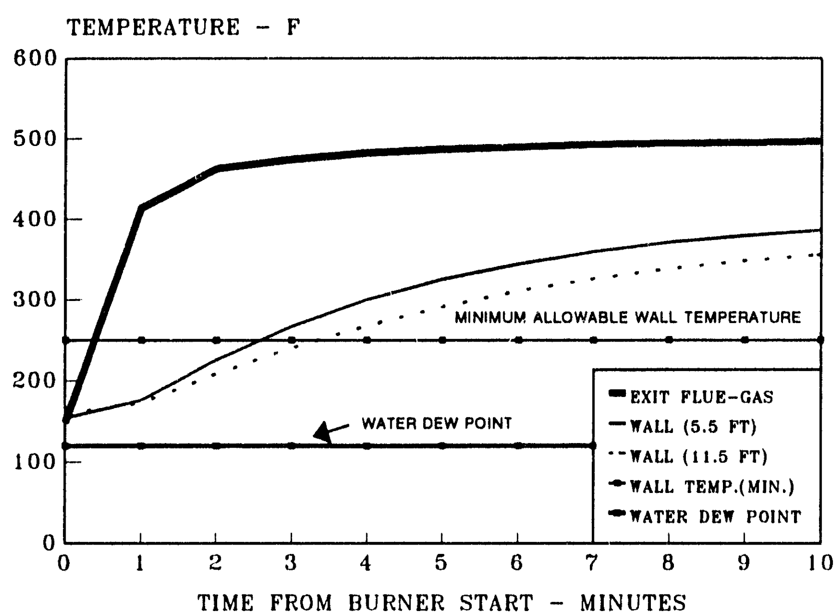


FIGURE 4 - FLUE GAS AND VENT WALL TEMPERATURE
INSULATED (R4.2) 4 INCH GAL. VENT



3) Iron-chromium-low nickel-molybdenum alloys: Ferralium (R), Monit (R) 10 (<0.2 mpy)
4) Nickel alloys: Hastelloy (R) C-276, Hastelloy (R) F, Hastelloy (R) G, Inconel (R) 690, and Inconel (R) 671 (<1 mpy)

The following alloys were judged to have acceptable general corrosion rates, but were considered unsatisfactory for use in the oil-fired flue gas environment (for heat exchangers) because of the susceptibility to local corrosion attack as shown by the "X" below:

Table 1
Corrosion Resistant Steel Alloys [6]

Material	General	Crevice	Weld	* SCC MA	**SCC S
304 SS	0.6 mpy	X	-	-	X
304L SS	0.2 mpy	X	-	-	X
309 SS	0.1 mpy	_	_	X	X
310 SS	0.5 mpy	X	X	_	_
347 SS	0.3 mpy	X	-	-	-
348 SS	0.5 mpy	X	-	-	-
17-4 Ph	0.3 mpy	-	X	-	-
316 SS	0.1 mpy	_	_	_	X
316L SS	0.2 mpy	-	-	-	X
PH15-7Mo	0.4 mpy	-	X	-	-
409 SS	0.8 mpy	-	-	-	-
418 SS	1.6 mpy	-	-	X	-

<u>* SCC MA</u> - Stress corrosion cracking in the mill annealed condition.
<u>**SCC S</u> - Stress corrosion cracking in the sensitized condition. The sensitized condition was induced by heat treatment of 4 hours at 1200 F to simulate the effects of welding on the parent metal.

Pitting and crevice corrosion can develop in stainless steels where the materials passivity has been destroyed by exposure to strong acids, such as sulfuric acid or by means that reduce the oxygen concentration on the metal surfaces. If debris is allowed to accumulate oxygen accessibility is reduced to the covered area and pits may develop. Once pitting begins, conditions within the pit become more aggressive and the rate of penetration can increase with time.[9] For thin section un-insulated vent pipe applications, periodic inspections for pitting penetration should be required.

Fabrication techniques, for vent system components, should be chosen to avoid welding (with the possible exception of electron beam welding). In forming operations, the use of sharp (small radius) bends should be avoided. The careful choice of fabrication operations can reduce the potential for crevice and stress corrosion.

All of the stainless steels shown in Table 1 above appear to have potential application in the corrosive environments of oil-fired venting systems. Although there are some concerns for their application in condensing heat exchangers [6], with the appropriate fabrication techniques, their application in venting systems may be feasible. In addition, in the vent system environment these materials would be subject to low structural loads and thermal stresses and should give longer service than plain carbon steel.

MATERIAL LOSS IN SINGLE WALL GALVANIZED VENTS

From the work conducted at Battelle, it could be concluded that galvanized steel vent pipe is a totally unsatisfactory material for the venting of mid- and high-efficiency oil-fired equipment. Corrosion at the water dew point will occur to some extent for un-insulated vent pipe exposed to indoor ambient air temperatures (60-70 F). From BNL tests it was found that the galvanized layer (about 2 mils thick) was severely corroded after a single heating season and would probably be entirely removed after the second heating season. The extent of further corrosion will likely be some fraction of the "whole year" 44-67 mpy (56 mpy average) found by Battelle using a 4.0 minute burner "on" period. Battelle assumed corrosion over the entire year (8760 hours). The fraction applied to the 56 mpy figure will depend on length of the heating season (to be precise, the total number of operational cycles of the burner) and the time history of the actual vent wall temperature, above and below the water dew point, during the burner "on" period.

From tests conducted at BNL, the vent wall exposure periods from near ambient to 120 F ranged from about 0.3 minute to 1.5 minutes per burner "on" cycle for un-insulated vent walls. For a 6 month heating season and the above BNL exposure periods the 56 mpy corrosion loss may be adjusted to 2.1 - 10.5 mpy. In the case of an insulated (R4.2) vent pipe, BNL tests showed vent wall temperatures to be always above the water dew point. In this latter case, these figures may be reduced by a factor of 10 to a range of about 0.2 - 1 mpy.

Much of the above discussion of galvanized steel also applies to the use of aluminized steel.

ESTIMATING VENT MATERIAL LOSS

In an attempt to establish a rational procedure for estimating vent wall penetration due to sulfuric acid corrosion, a review of research pertaining to the subject of sulfuric acid corrosion of steel in oil-fired boilers yielded the following results. From one source, measurements of corrosion for temperature controlled steel test samples is given in terms of operating temperatures of the sample.[7] Steady, continuous operation above 140 F (60 C) resulted in a material removal as high as .3 mm/year. For intermittent burner operation the material loss rates were found to be directly proportional to percent of burner "on" time. Operation at temperatures approaching 104 F (40 C) resulted in a dramatic increase in material loss to as much as 5 mm/year. The findings are supported by work conducted at Battelle [8] where sharp increases (by a factor of 7) in the pitting corrosion of carbon steel were found to occur when the metal was cycled repetitively across the water dew point.

This data was used to develop an equation to estimate the penetration rate of steel vent pipe material as a function of vent wall temperature and time. The following assumptions were made for flue gas from oil-fired systems:

(1) The sulfuric acid dew point is < 250 F

(2) The water dew point is approximately 120 F

(3) For vent wall temperatures <= 120 F the vent wall material loss rate can be taken as 5 mm/yr for continuous operation.

(4) For vent wall temperatures >= 120 F and < 250 F the vent wall material loss rate can be taken as .3 mm/yr for continuous operation.

Applying the above assumptions the estimated vent material loss in mm per year for a boiler application may be expressed as:

$$VML = HF/CY*(CR1*(t_{120}) + CR2*(t_{250} - t_{120}))$$

Where:

HF = Heating Fraction, the ratio of the total burner "on" time to the total time in the heating year
CY = Cycle duration in minutes (boiler = 43, furnace = 17.2)
CR1 = General corrosion below water dew point = 5 mm/yr
CR2 = General corrosion above water dew point = .3 mm/yr
t_{120} = Time from a start to a wall temperature of 120 F.(min.)
t_{250} = Time from a start to a wall temperature of 250 F.(min.)

Conversion of the resulting material loss rates in mm/yr to mils per heating season is achieved by dividing by 0.0254. An estimated value for HF may be derived for a given building and region using the approach outlined in the Appendix under Building Heat Load and Equipment Effects.

The above formula may be simplified by making a very conservative assumption that HS = 0.5. Making the appropriate substitutions for the values defined above, the formula for Vent Material Loss (VML) in mils (thousandths of an inch) per heating season becomes:

For boiler applications:

$$VML = 2.15*(t_{120}) + 0.14*(t_{250})$$

For furnace applications:

$$VML = 5.38*(t_{120}) + 0.34*(t_{250})$$

Using the above formula, vent wall temperature/time history data taken in the laboratory has been converted to reflect an estimate of seasonal material loss for single wall galvanized vent pipe. The corrosion of the galvanized coating was assumed to occur at the same rate as the steel. The material thickness of the vent wall is initially 0.019 inches or 19 mils. Figures 5,6 and 7 show the result of these calculations for a boiler using the following vent sizes and test configurations:

(1) 6 inch diameter vent, un-insulated, peak end of burn (EOB) temperature = 600 F.

(2) 6 inch diameter vent, un-insulated, peak end of burn temperature = 500 F.

(3) 4 inch diameter vent, un-insulated, peak end of burn temperature = 500 F.

(4) 4 inch diameter vent, insulated R4.2 high temp. fiberglass with aluminum foil facing, peak end of burn temperature = 500 F.

(5) 4 inch diameter vent, un-insulated, peak end of burn temperature = 400 F.

(6) 4 inch diameter vent, insulated R4.2 high temp. fiberglass with aluminum foil facing, peak end of burn temperature = 400 F. with both hot and cold starts

Examining Figure 5, the estimated vent wall penetration for the un-insulated 6 inch vent with an EOB temperature of 600 F is significantly less than the same vent with an EOB of 500 F. Comparing Figures 5 and 6, the estimated penetration for both 6 inch and 4 inch single wall vent pipe (EOB = 500 F) appear to be essentially the same. In each case the estimated penetration by corrosion would occur in about 6 heating seasons at 10 feet. With insulation added, the 4 inch vent wall never fell below the water dew point. The total corrosion effect was therefor estimated at conditions above the water dew point for which a much reduced general corrosion rate applies. This resulted in a projected life of about 40 heating seasons. In Figure 7, the operating conditions for an EOB = 400 F are shown. For the insulated and un-insulated cases, the corrosion rate are only slightly higher than that shown in Figure 6 (EOB = 500). However, when the insulated system was subjected to a cold start (C), after a long "off" period, the first cycle exhibited corrosion effects very similar to the un-insulated case. The following cycles exhibited subsequent hot start (H) characteristics.

There appears to be good general agreement in the applied analysis of Battelle's results [6][8] and those of Koebel/Elsner [7]. In addition, the predicted material loss due to corrosion for single wall galvanized vent pipe does not seem unreasonable based on experience and offers a conservative guide for periodic inspections. Periodic examination and replacement of the vent connector, as required, remains as the current least cost option. The

FIGURE 5 – ESTIMATED VENT WALL PENETRATION
6 INCH, GALVANIZED, SINGLE WALL

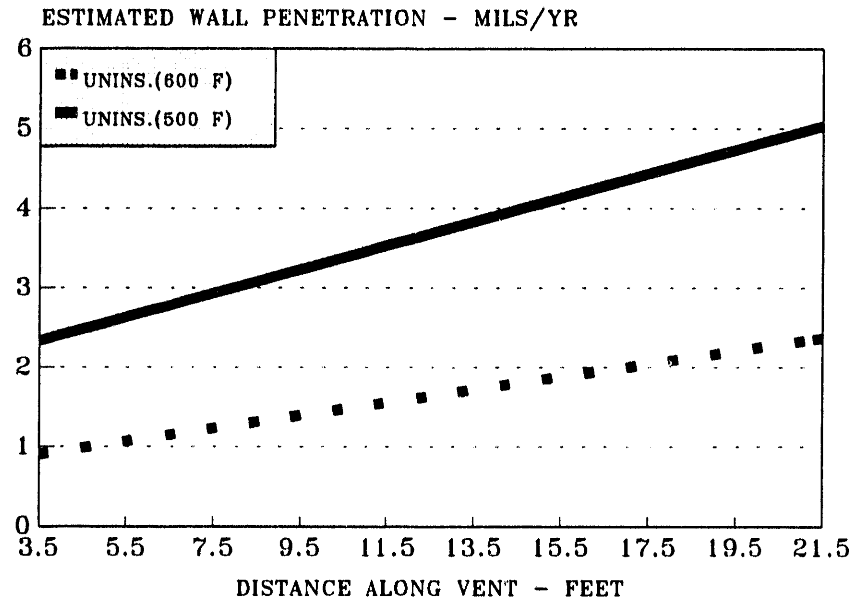


FIGURE 6 – ESTIMATED VENT WALL PENETRATION
4 INCH, GALVANIZED, SINGLE WALL

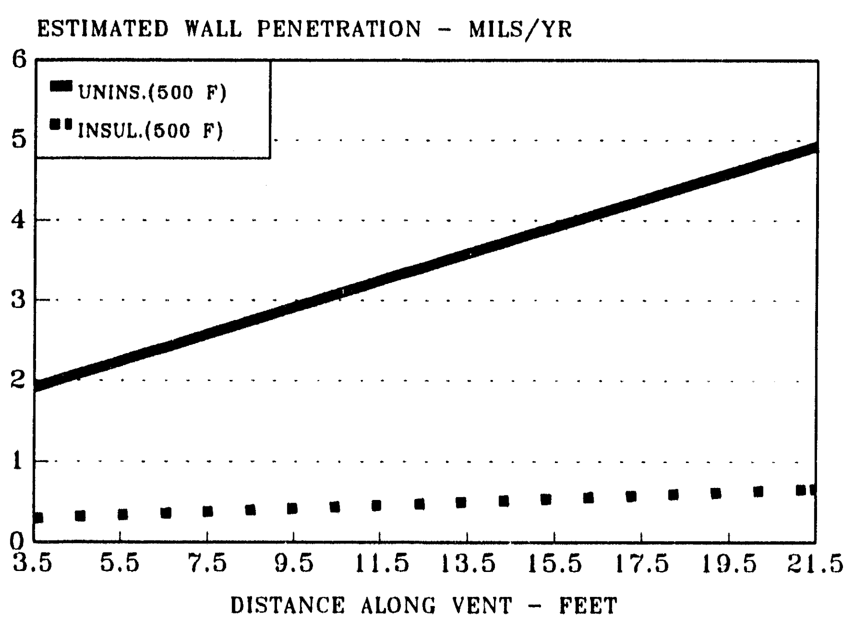
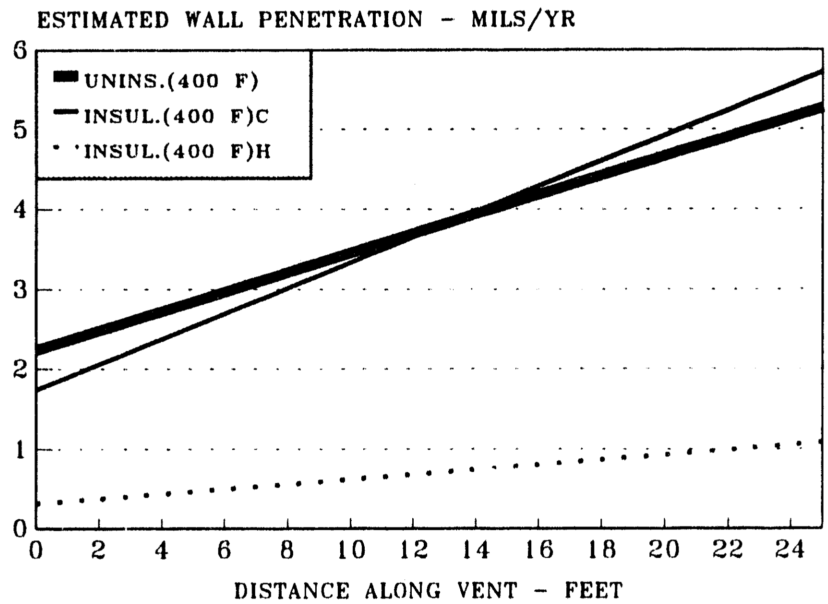


FIGURE 7 - ESTIMATED VENT WALL PENETRATION
4 INCH, GALVANIZED, SINGLE WALL



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application of existing vent connector systems, such as "L" Vent may also offer a satisfactory solution (see Appendix - Vent Pipe and Chimney Materials).

It is interesting that while "B" vent systems are not listed for oil-fired applications, the identical configuration using a stainless steel liner apparently qualifies as "L" vent. At least one version of this system uses a high-temperature insulation in lieu of a simple air gap for further heat loss reduction. Until a low cost/low loss/corrosion resistant connector system emerges for oil-fired applications, this may be another acceptable alternative.

In terms of long term potential, the application of high-temperature plastics remains a wide open area. The reader should refer to Plastics, Table A-4 in the Appendix for further information in this regard.

One real concern remains in the use of galvanized material in multi-wall (but un-insulated) chimney systems. In these systems, even though the vent inner wall is not directly exposed to outside ambient conditions, it is likely that the chimney will be located outside the insulated building envelope. Under these conditions, cooling of the inner wall may be more pronounced than in interior vent connector. Periodic inspection may not be practical if the chimney is structurally enclosed within a vertical chase. Structural and/or gas integrity of the inner liner and secondary steel wall may be compromised long before the outer shell is penetrated. Since these metal chimneys are frequently installed in inaccessible locations within residential buildings, it would seem reasonable to expect a 30 - 50 year life for such an installation.

SUMMARY AND CONCLUSIONS

A brief summary of the findings to date resulting from BNL research to be included in the Guideline document are:

1) Acid and water dew points are a source of concern for vent materials (and heat exchangers) in the operational environments presented by oil-fired equipment. The Sulfuric acid dew point for No.2 fuel oil lies between 225 and 240 F. Surfaces below these temperatures will permit acid condensation and possible corrosion. Flue gas-side surface temperatures below the acid dew point are prevalent in most modern oil-fired appliances and vent systems.

2) Vent wall temperatures are substantially less than centerline flue-gas temperatures. As shown, in the laboratory and extended to field use, a crude approximation of the vent wall temperature may be calculated as the average of the centerline flue-gas temperature and the local ambient temperature.

3) Downsizing of short vent connectors by reducing diameter, within the limits set by the appliance input rate, has marginal benefit in terms of increasing vent wall temperature and reducing the quantity of acid condensation. Reducing heat flow through the vent wall is more effective.

4) For each element in a given vent system there is a fixed period of time where that element is below the water and/or acid dew point

during the burner "on" time. The amount of acid condensed and the amount of corrosion within each element is a direct function of the number of cycles the equipment experiences during its lifetime of operation. A reduction of the total number of lifetime cycles, through the use of low output appliances, variable firing rate, or thermal storage will extend the life of appliances and reduce maintenance needs.

5) In all cases, after any draft control device, reduction of heat flow through the vent wall is essential to maintain the vent wall above the acid dew point.

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APPENDIX

Building Heat Load and Equipment Effects

It is frequently convenient to refer to the heating load required for a typical house. For example, in the Northeast, BNL has used the configuration of a house of about 1500 sq.ft. area and a steady state heat loss of 50000 Btu/hr. with 70 F. inside temperature and 0 F. outside temperature. A convenient term to represent this house is the term "UA value" which simply put, expresses the heat loss of the house in terms of Btu per degree-hour or Btu/F.hr. This is derived as the steady state heat loss divided by the indoor-to-outdoor temperature difference (50000/70) and for the house described above results in a UA value of 714 Btu/F.hr. Thus, in order to determine the annual space heating requirement for this house in a specific region, one simply needs to know the annual heating degree-hours for that region. The product of the UA value and the local heating season degree-hours is equal to the annual space heating requirement in Btu units. For the New York metropolitan area as an example, the average number of heating degree-hours is about 125,000 accumulated over about 7 months of the year. Therefore the annual space heating requirement is equal to (714)x(125000) or 89,250,000 Btu. Once this figure is derived it can be used to estimate some useful things about the operation of the space heating appliance in the house.

For instance, the annual fuel input required for space heating can be estimated. Assuming an appliance AFUE of 80%, the annual fuel input is equal to (89,250,000)/(0.8) or about 111,600,000 Btu. Assuming the heating value of a gallon of fuel oil is 140,000 Btu, the number of gallons of fuel used for heating would be (111,600,000)/(140,000) or 797 gallons.

Assuming that the heating appliance is a boiler, the number of operational cycles per heating season can be estimated. From the AFUE procedure we may assume an average burner "on" time of about 9.7 minutes.[3][4] The heat input using a 1 gph nozzle is (1)x(140,000)x(9.7)/(60) or 22,633 Btu. The number of burner operations required for space heating per year would be (111,600,000)/(22,633) or 4931. A similar calculation for a furnace with an average burner "on" time of about 3.9 minutes results in an input of 9,100 Btu and 12,264 burner operations.

To determine the Heating Fraction (HF), as a fraction of the entire year (12 months or 525,600 minutes), additional terms, such as water heating and idle loss must be accounted for as well as space heating. In order to do this, an apportionment of the various heating loads must be made between the Heating Season (HS)(7 months or 306,600 minutes) and Non-Heating Season (NHS)(5 months or 219,000 minutes).

Idle loss is the heating required for a boiler to maintain temperature for hot water production. The cumulative burner operation time for idle loss can be conservatively estimated as 3% of the total time, accountable largely during the Non-Heating Season. The total burner "on" time would be (.03)(219,000)/60 or 109.5 hours. A calculation of the heat input for idle loss would therefor be (109.5)(1)(140,000) or 15,300,000 Btu.

In addition, the boiler will be called upon to produce about 65 gallons of hot water per day. Assuming a temperature rise of 100 F in the water, this heat amounts to (65)(8.35)(1)(100)/.8 or 67844 Btu per day or about 25,000,000 Btu per year.

An accounting of these heat loads is presented in the table below:

	Heating Season	Non-Heating Season
	(7 months)	(5 months)
Space Heating	111,600,000 Btu	-----------------
Water Heating	14,600,000 Btu	10,400,000 Btu
Idle Loss	---------------	15,300,000 Btu
TOTALS	126,200,000 Btu	25,700,000 Btu

For the Heating Season, the calculation of the number of burner operations for the combination of space heating and water heating may be estimated as (126,200,000)/(22,633) or 5576 operations. In this calculation it is assumed that the effects of short burner "on" periods for idle loss and water heating are overwhelmed by the longer burner "on" periods space heating. For the Non-Heating Season, however, it is assumed that short burner "on" periods are experienced, reducing the average burner "on" period to about 4.9 minutes or half that of the average Heating Season period. The calculation for the number of burner operations for the combination of water heating and idle loss may therefor be estimated as (25,700,000)/(11,316) or 2271 operations.

Using the above calculated values, an annual Heating Fraction can be obtained using the following equation:

$$HF_{ANNUAL} = [(NBO_{HS})(BOP_{HS}) + (NBO_{NHS})(BOP_{NHS})]/(525,600)$$

where:

NBO = number of burner operations per season

BOP = burner "on" period (minutes) per season

and: the number of minutes in a 12 month period = 525,600

Making the appropriate substitutions in the above equations:

$$HF_{ANNUAL} = [(5576)(9.7) + (2271)(4.9)]/525,600 = 0.124$$

Flue and Stack Connector

The flue connector refers to a length of smoke pipe connecting the flue collar (appliance combustion gas exit) to the draft regulator, if one is used in the system. This smoke pipe which is relatively light weight is generally made of galvanized steel. The wall thickness of this pipe is usually about .019 inches (26 Ga. material). The smoke pipe is supplied in 2 foot lengths with opposing ends designed to engage. The resulting joints are not gas tight and require sheet metal screws to maintain joint integrity. The pipe is generally un-insulated resulting in substantial cooling of the flue-gas in transit. Because of the relatively cool operating environment for most oil-fired appliances the walls of the flue connector are likely to be at or below the acid dew point of the flue-gas. Because of this condition, a solution of sulfuric acid and water may condense on the flue connector surfaces resulting in corrosion of the metal. Close examination of the flue connector joints, seams and surface for signs of corrosion is required whenever servicing is performed (at least on an annual basis). Corrosion damage left un-repaired could result in failure of the flue connector and the leakage of flue gases into the building space.

The stack connector consists of the same sort of smoke pipe assembly as is used for the flue connector. It provides the connection from the draft regulator to the inlet of the draft inducer. This connector is also generally un-insulated thus permitting further cooling of the flue-gas. The flue-gas, already cool from dilution with room air entering the barometric damper will likely be below the acid dew point along the length of the stack connector. The cautions for periodic inspection and replacement apply here as with the flue connector discussed above.

Table A-1
Vent Connector Material Thickness

Diameter of Connector (inches)	Minimum Thickness (inches)	Galvanized Sheet Gage No.
5 or less	0.013	(23)
5 to 9	0.019	(26)
9 to 12	0.030	(22)
12 to 16	0.036	(20)
over 16	0.058	(16)

Vent Pipe and Chimney Materials

Type L Venting System [10] is defined as a passageway, vertical or nearly so, used for conveying flue gases from oil or gas appliances or their vent connectors to the outside atmosphere.

A listing, in conformance to UL 641, Low-Temperature Venting Systems, Type L, entails meeting substantial construction and performance requirements which are set forth in the Test Standard.

In terms of vent pipe construction, minimum material thicknesses are stipulated for several metals:

Table A-2
Structural Materials for Type L Vent

Material	Thickness - inches
Aluminum alloys (1100, 3003)	0.016
Steel (un-coated or painted)	0.042
Galvanized steel (G90 coating class)	0.018
Aluminum-coated steel Type T1-40	0.018
Stainless Steel	0.012

For flue-gas conveying conduit the materials shall be:

Table A-3
Liner Materials for Type L Vent

Material	Thickness - inches
Cast refractory or clay tile	0.4
Porcelain coated steel-base metal	0.026
Series 300 or Types 400 and 446 SS	0.012

Other parts in contact with flue-gas or flue-gas air mixtures at locations beyond the terminus of the flue-gas-conveying conduit are to be made of Series 300 or Types 430 and 446 or the equivalent. The outer casing of the vent shall be made of stainless steel, galvanized steel, or aluminum coated steel Thermal insulation, as employed, under test shall, be noncombustible, have products of binder combustion or volatilization discharged to vent terminus, remain in intended position, not increase in thermal conductivity, and not show evidence of deterioration.

In general, tests of the vent system in a test structure at flue-gas temperatures of 500 F (to equilibrium) and 1630 F (10 minutes exposure) above ambient are performed. Determination of the surface temperatures of the test structure to meet 90 F and 175 F above ambient respectively will qualify the system. Other specific material and structural tests also apply; see UL 641.

Masonry Chimney [11]

Masonry chimneys are well described in the code in terms of minimum construction and material requirements. The level of detail is such that direct reference to the code is necessary.

Some of the general descriptions include foundations, corbeling (structural offsets), cleanouts, firestops, field testing, structural design, inspection and maintenance, thimbles (connector penetrations), relining, construction procedures, termination, and clearances.

Plastics [6]

There are a large number of plastic materials which are potential candidates for application in oil-fired venting systems and associated components. The following list summarizes some of those materials:

Table A-4
High Temperature Plastics

Generic Name	H.D. Temp.(F)*	Continuous (F)	Acid Res.
Polyethersulfone	410	347	E
Polyarylsulfone	400	365	E
Polyphenylenesulfide	>500	>400	E
Polymide	300 - 680	340 - 600	F-VG
Polymide-imide	535	410	G
Poly-p-oxybenzoate	570	392	F
Epoxy-Imide	575	400	G
Epoxy Novalac	---	400	VG
Polyphenylquinoxaline	---	600	E
Polyparabanic Acid	---	500	E

* Heat Deflection Temperature @ 264 psi, ASTM D648

One specific plastic material, not included in the above list, has been used in the manufacture of PLEXVET, a system of plastic pipe and fittings, which can be used with mid- and high-efficiency gas-fired heating equipment. The system of pipe and fittings has been assigned a 480 F rating by UL. The material used is a Polyetherimide with a Heat Deflection Temperature of 392 F, a continuous use temperature of 338 F, and good acid resistance (ph < 9). This material and venting system is very interesting as a candidate for oil-fired applications but as yet, it is not UL listed for oil and should not be used for oil-fired venting systems.

Paper No. 93-8

AN OVERVIEW OF THE BNL OIL HEAT VENT ANALYSIS PROGRAM (OHVAP)

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AN OVERVIEW OF THE BNL OIL HEAT VENT ANALYSIS PROGRAM (OHVAP)

ABSTRACT

This paper provides an overview of the Oil Heat Vent Analysis Program (OHVAP). OHVAP is being developed in response to oil heat industry needs in vent system analysis and is designed for desk-top PC (DOS) computers. The rational for the development of a vent system analysis tool for the oil heat industry is discussed in terms of the need for properly sizing both chimney and advanced venting systems for mid- and high-efficiency oil-fired appliances. There are unique requirements for the venting of oil-fired appliances and the features that OHVAP will contain to meet these requirements are described. The Input Menu and Engineering program operation are described in some detail. The Input Menu is described in terms of the input sequence and flexibility of system representation for the analysis. The Engineering program description contains the basic theory behind the computational approach and a detailed step-by-step description of the program operation as it is carried out to obtain a solution. The current configuration of the OHVAP output is a data file format and a description of the data arrangement is presented. The program is being validated and the current status at this stage of development is discussed. As a result of the validation process some changes have already been implemented and some features remain under development. These are discussed along with future plans for OHVAP and it's application.

INTRODUCTION

The evolution of the Flame Retention Head Burner designs from 1960 to the present and the evolution of modern heat exchanger designs have spurred a continued growth in the number of oil-fired mid- to high-efficiency residential furnaces and boilers entering the market place.

In 1987, the National Appliance Energy Conservation Act (NAECA) was passed into Federal Law by Congress. This Law required that, starting January 1, 1992, for firing rates less than 300,000 Btu per hour, all boilers and furnaces must have an Annual Fuel Utilization Efficiency (AFUE) rating of at least 80% and 78% respectively. Many available oil-fired boilers and furnaces already exceed these minimum requirements with AFUE ratings between 82 and 88%.

These modern heating systems are being installed as replacements for older systems and in new construction. In the replacement of existing older systems, the venting system, largely masonry chimneys, are often found to be oversized and in poor repair. These masonry chimneys were originally designed for higher firing rates and flue-gas temperatures of 600 F or more. The operational flue gas temperatures for modern mid- and high-efficiency oil-fired systems ranges from about 250 F up to about 450 F at the outlet of the unit. These low flue gas temperatures will be further reduced before reaching the chimney because of heat loss from the flue connector and through dilution when a draft control is used (a barometric damper is usually installed). In either case, the resulting available flue gas temperatures are frequently insufficient to sustain adequate draft in an older, oversized masonry chimney.

At the present time the only specific recommendations for oil-fired vent sizing reside either in oil-fired appliance manufacturers literature or in the Testing and Rating Standard for Heating Boilers (IBR), Sixth Edition, June 1989, published by the Hydronics Institute (HI). The information published by (HI) is presented in terms of minimum vent areas required for a range of burner capacities for both natural draft boilers and mechanical draft boiler-burner units.

To provide a satisfactory evaluation of the flow and heat-transfer dynamics of chimney and power-vent systems a transient analysis is required. This is essential to the development of guidance for the efficient and safe installation of new systems, and refit or replacement of existing vent systems. In addition, there are opportunities to improve building energy utilization and increase the base of application for oil-fired equipment through the effective design and safe installation of power vented systems.

BACKGROUND

An examination of two existing vent analysis programs was undertaken to establish an appropriate approach for the Oil Heat Vent Analysis Program (OHVAP). The first program evaluated was the GRI VENT II program, which is well structured from the users perspective in terms of inputs for vent geometry, vent operation and output format presentation. In addition, a Canadian whole house model (FLUESIM) was also examined. This program provided analysis functions that reached well beyond the goals set for OHVAP and included intensive analysis of whole building ventilation effects on the venting system.

The OHVAP development activity was initiated using the venting system portions of FLUESIM as a framework. The vent system analysis sub-routines were rewritten to reflect the specific needs for flue-gas products from the combustion of fuel oil. During 1991-1992 much of this rewrite was completed along with supporting routines for data input and output. The program was essentially completed in late 1992 with the first runs being conducted at that time. A Users Manual for OHVAP has been completed and validation of OHVAP is currently underway.

SPECIAL FEATURES

OHVAP is intended to serve as a design and analysis tool for chimney and mechanically augmented oil-fired venting systems applied to residential and small commercial space and water heating appliances.

The parameters that OHVAP will evaluate, in a dynamic manner, for oil-fired venting systems include:

a) Vent flue-gas total and constituent mass flows as a function of fuel-oil chemistry, firing rate, and excess air.

b) Vent system flue-gas volumetric flows as a function of firing rate, excess air, and flue-gas temperature along the vent system.

c) Vent system pressures as a function of flue-gas flow rate, system geometry, natural draft, and available fan pressure along the vent system.

d) Vent system heat loss as a function of flue-gas flow rate, system geometry, flue-gas temperature, vent wall material properties, and ambient conditions along the vent system.

e) Vent system surface condensation rates of water and/or sulfuric acid as a function of fuel sulfur content, excess air, ambient humidity, fuel water content, and vent surface temperatures along the vent system.

The intended users for the software package includes equipment designers, field service engineers, and researchers. The expected output from the program, which will include equipment categorization definitions and vent sizing tables, will be most useful for installers and service personnel.

GENERAL PROGRAM STRUCTURE

Input Menu

The input to the program is a menu based system which permits the user to: design the vent system to be analyzed, specify it's operating conditions, control the duration of the program analysis, and specify the format of the program output. The following is a brief overview of the menu system and its major features:

The first menu the user will see after starting OHVAP will contain four major headings - FILE, EDIT, SETUP, and RUN.

Under the "FILE" menu, the user can perform a number of routine functional operations such as loading a "test case" for analysis, saving a "test case" which the user has prepared, clearing "test case" values, displaying or changing the directory, and exiting OHVAP.

The "EDIT" and "SETUP" menu's contain the core instructions to the user for the "test case" preparation procedure.

Under The "EDIT" menu the user can specify the following input information:

1) Geometry of System - Vent system geometry, vent system variability and materials of construction.

2) Temperatures - Vent system operating temperatures in terms of ambient conditions and flue-gas time/temperature profiles.

3) Equipment Timing - Operational timing for the vent system in terms of burner "on" period, pre- and post-purge, and cycle duration.

4) Combustion Parameters - Combustion conditions in terms of firing rate, excess combustion air, and combustion air source.

5) Flow Control - Vent system flow control in terms of draft control settings. The draft control is a special segment wherein dilution air flow is a function of draft within the segment. Three parametric functions of dilution flow versus draft for the draft control are available for user selection.

Under the "SETUP" menu the user can set the controlling parameters for OHVAP operation as follows:

1) Time Settings - Sets up the number of cycles to be analyzed, and frequency of output printing.

2) Fuel Composition - Specification of fuel constituents as percent by weight.

3) Relative Humidity - Indoor and outdoor relative humidity.

4) Output Settings - Output format selection as ASCII or spreadsheet.

Having completed the definition of the "test case" the user can return to the "FILE" menu and save the "test case" for future reference. The next step would be to enter the "RUN" menu to activate OHVAP and start the vent system analysis.

Program Operation

The input menu, reviewed in the previous section, permits set-up of the parameters that OHVAP needs to commence it's calculations. One of the major parts of this input is the vent system geometry which usually requires the users specification of one or more "segments" of vent system conduit. A segment is defined as any section of vent system conduit which has unique geometric, material, thermal properties or operating conditions. Thus, any change to these properties or operating conditions along the overall vent system conduit will require the user to define a segment for that change. Any segment, in turn, may be subdivided into elements which will permit more detailed OHVAP calculations to be performed within that segment.

The user specified vent geometry, in it's most simplified form, will most likely consist of four basic segments with one element each for a basic chimney vented system. These four segments would consist of 1) a flue connector, 2) a draft control (Barometric), 3) a stack connector, and 4) a vertical chimney. It is this simple system which will be used to describe the OHVAP operation. This type of simple chimney configuration is illustrated in Figure 1.

The OHVAP Engineering program, although accessed from the Input Menu program is, in fact, a separate entity. When the program is directed to "RUN", information supplied by the user in the Input Menu program is passed as an array of variables for processing in the Engineering program.

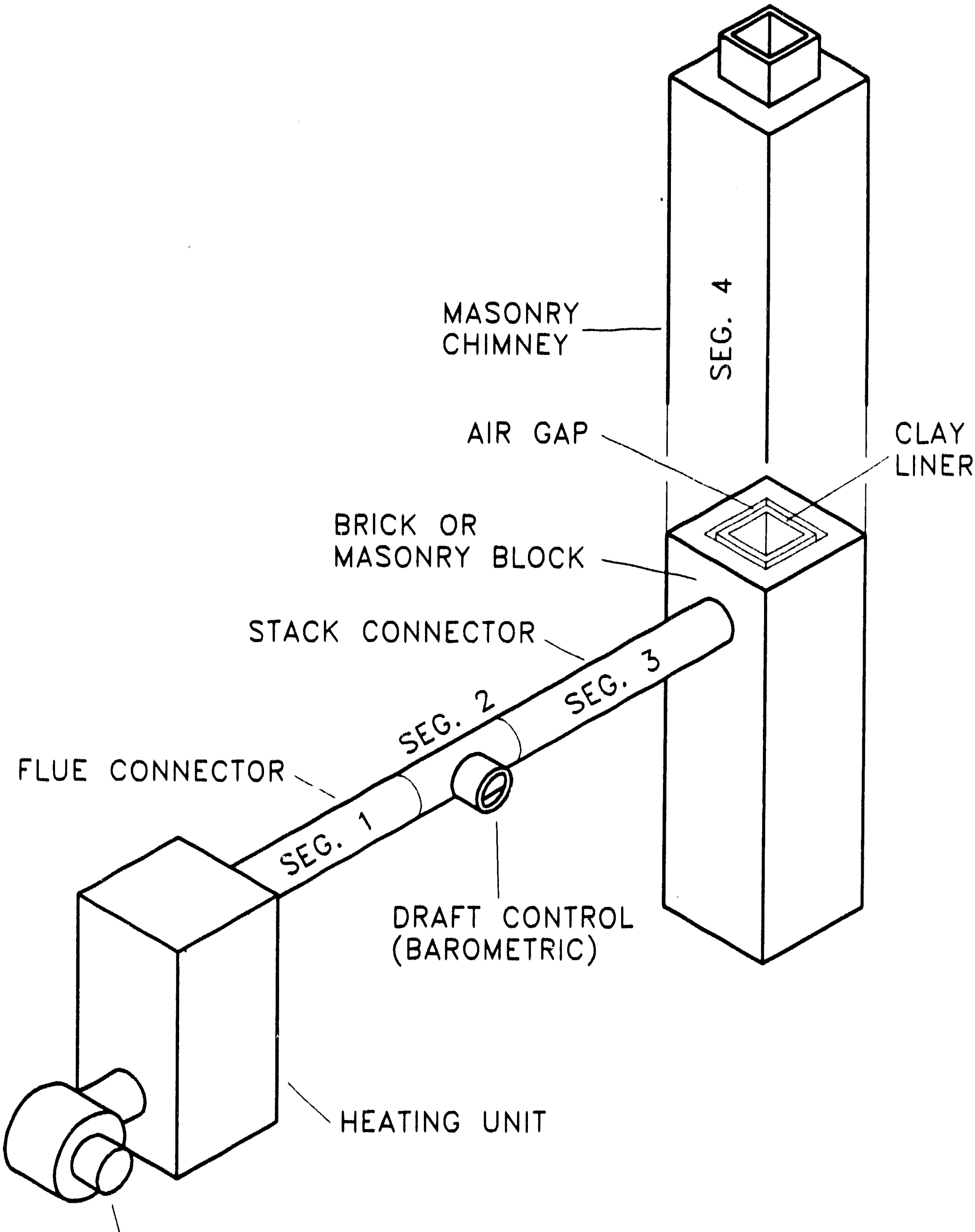


FIGURE 1 – SIMPLE EXAMPLE OF OIL-FIRED CHIMNEY VENTED SYSTEM

It should be noted that as defined above, the first, third, and fourth elements, form the entire flue connector segment, stack connector segment, and chimney segment respectively, and are very "large" elements. Because of this, the values calculated within OHVAP would normally be considered crude estimates of the actual segment operating conditions. They are only used in this context as an illustration of the program operation. In actual user operation of OHVAP, there are available a maximum of 25 elements which can distributed among the user defined segments. It should be noted that the draft control (segment 2) shown in Figure 1 is considered a special segment and is not devisable into elements. Although it is shown in Figure 1 for illustrative purposes, it actually represents a point of entry for dilution flow between segments 1 an 3 without any significant size associated with it. This being the case, the flue connector (segment 1) and stack connector (segment 3) can each have 5 elements with the remaining 15 assigned to the chimney (segment 4).

Referring to Figure 2, the initial activity performed by the Engineering program is the calculation of initial system and program operating conditions from information supplied by the Input program. These conditions would include such things as initial vent flows based on combustion conditions, and combustion air moisture based on relative humidity conditions.

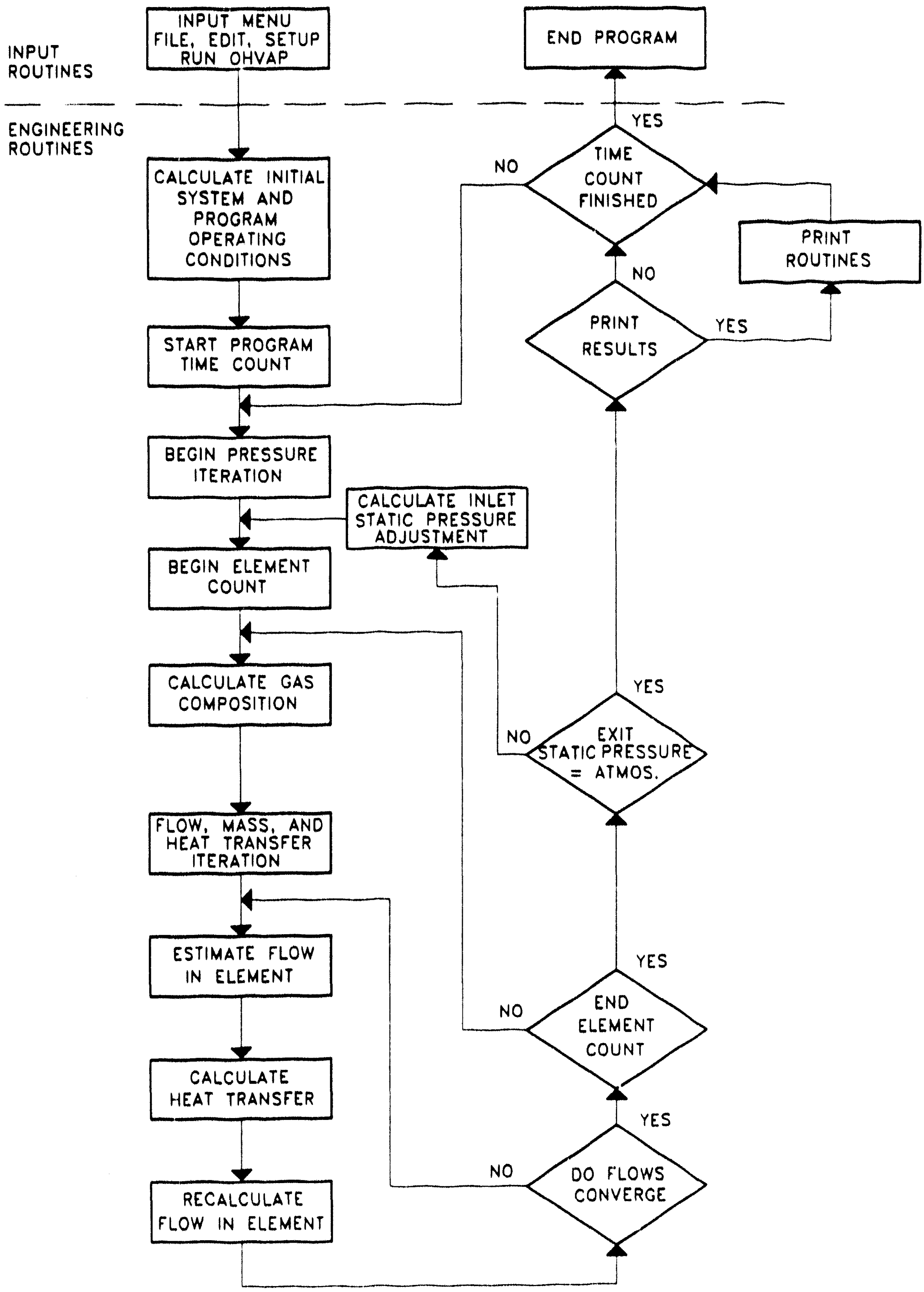
Three things occur simultaneously at this point. The program "time" count is started at the first time-step and serves to track where the program is working within the user defined vent system operational cycle. The program also enters the routine which starts the iterative vent pressure calculations with the fixed flue-gas flow calculated earlier. The "element" count is started at the first element and serves to track where the program is within the physical geometry of the user defined vent system.

An initial calculation of entering flue-gas composition, based on input combustion conditions, is made. This is followed by an evaluation of total mass, volumetric flow (based on temperature) and other properties (such as specific heat, viscosity, thermal conductivity, and coefficient of volumetric expansion) for the flue-gas entering the vent system during the first time step.

The program then enters the routine which starts the iterative calculations for the flue-gas flow and heat/mass transfer for the first time step based on individual elemental characteristics. These calculations form a transient analysis based on the assumption of quasi-static incompressible flow on an element-by-element basis for the vent system. This means that for the first and all succeeding time steps, the pressure-volume-temperature conditions for the initial flow entering each element is held constant for that specific time step. This is a reasonable engineering assumption for the pressures and temperatures occurring in the vent system. Within each element, an iterative calculation of flow and heat/mass transfer is performed, the pressure-volume-temperature conditions of the flue-gas are corrected to satisfy conservation of energy requirements, and a solution is achieved. A more detailed description of the implementation of this approach is offered below.

During the each time step, complete displacement of the existing elemental gas volume is assumed to occur with the displaced gas moving ahead to each succeeding element until the inlet gas volume for the time step is satisfied. Mixing at the interface of inlet gas and displaced gas is assumed to be negligible. In the event of partial filling of an element, the element will be

FIGURE 2 – OHVAP FLOW CHART



considered filled with gas at mixed conditions defined by the fractions of new and expelled gas.

Starting with the first element during the first time step, an estimate of the average flow velocity for the first element is known from flue-gas flow conditions entering the system (the elemental entrance and exit flows are initially assumed equal). For the inlet and exit of the first element, a solution of the equation of state for a mixture of ideal gases (flue-gas) will yield the local total pressure. Estimates of friction loss and static pressure are made (based on flow velocity) and flue-gas elevation effects are accounted for. The flue-gas velocity together with estimates of average flue-gas density, and other flue-gas properties, described above, permits a first estimate of the flue-gas film coefficient for the flue-gas within the first element. An estimate of the exterior vent wall film coefficient is made. The physical characteristics of the vent wall, having been defined, permits a calculation of the overall conductance for the wall (including inner and outer gas films). The elemental heat loss from the flue-gas, through the element wall to the ambient surroundings is then calculated.

In conjunction with evaluation of the elemental heat transfer, calculations are made of rate of the water vapor and sulfuric acid condensation. For the water vapor, an evaluation is made of the gas diffusivity and the mass diffusion coefficient based on the local flue-gas properties, vent wall temperature and film coefficient, and the estimated liquid condensate film temperature. A calculation follows which results in a value for the condensate mass rate transferred per unit area to the condensate film on the vent wall. For the sulfuric acid condensation, a similar approach is used in the form of empirical relationships presented by Lamb [1]. These calculations yield the mass flow per unit time per unit area of sulfuric acid to the vent surface.

The elemental change in flue-gas temperature is calculated by applying conservation of energy requirements. By solving the fluid energy equation for the elemental temperature change, the solution takes into account the elemental heat loss (sensible and latent for condensate), fan work input(if any), kinetic energy (flow velocity) change, elevation effects, and the flue-gas specific heat. With this adjustment of the elemental flue-gas temperature, a recalculation of the flue-gas specific volume and elemental exit flow is made. The new exit flow rate for the flue-gas in the first element is compared with the initial estimate of the exit flow. If this comparison fails (within certain bounds set in the program) the iterative calculation for flow and heat transfer in the first element is re-entered, this time with the last calculated flow as a starting point. The iteration will continue until there is agreement between an initiating exit flow and the calculated exit flow for the first element.

When there is agreement between the initiating and calculated exit flows for first element, the friction loss and flue-gas elevation effects will also have been resolved. For the inlet and exit of the first element, a solution of the equation of state for a mixture of ideal gases (flue-gas) will yield the local total pressure. At this point, the program re-enters the iterative pressure loop and proceeds to the next element. Each element, in turn, has as it's entering flow, the flow exiting the previous element and undergoes an iterative calculation of flow and heat transfer which culminates in friction loss, total pressure, and static pressure calculations. This continues element-by-element until the element count is satisfied or a draft control device segment is reached.

For the special segment defined as the draft control device, a user selected dilution flow versus static pressure characterization is applied. The characterization is an experimentally derived empirical formula which will calculate the ambient air dilution flow into the flue-gas as a function of the local static pressure. The dilution flow is mixed with the flue-gas flow and the resulting mixture conditions are calculated. The mixture enters the next element at the calculated conditions and the element-by-element flow and heat transfer iteration continues until the element count is satisfied.

The next major programmatic operation is to calculate and balance the system total pressure conditions. By definition, the total vent system pressure at the exit of the vent system must be equal to the local atmospheric pressure plus the velocity pressure of the exiting gases. It is possible that the calculated total pressure at the exit of the last element will not equal the actual local conditions at the exit. An appropriate adjustment, upward or downward, to the exit static pressure term of the last element is made to conform to local atmospheric pressure. This adjustment is applied to the entrance to the first element and the flow temperature iteration is reentered for the first time step. The iteration continues in this manner until the static pressure adjustment falls between prescribed bounds. This formulation of the system pressure balance permits a solution for the total pressure (as well as the static pressure) at not only the inlet but at any other point in the vent system.

An agreement within the above comparison of flow conditions and/or completion of the system pressure iteration will cause OHVAP to record to a permanent user defined file on the computer hard-drive. This file will contain the calculated results for each vent system element for the first time-step. The format of this file is pre-defined by the user in the Input discussed above. A hard-copy printout of results for all the time-steps can also be made if so defined by the user in the Input.

If the time-count is not satisfied, OHVAP will re-enter the calculation at the next time-step and, in turn, start a new iterative pressure calculation. Results from completed iterative calculations for each element and time-step will be added to the permanent file. When the time-count for vent system operation and analysis is satisfied, the OHVAP program will end.

It should be noted that the element-by-element "filling" approach used in OHVAP may permit analysis of certain unfavorable flow conditions of cold-start vent systems to be identified, particularly in the uppermost portions of a chimney-vent system. These conditions have been tentatively identified by some researchers as a localized back-flow in oversized natural draft chimney systems. Under these conditions it is suggested that the exiting warm flow may not actually "fill" the available vent. Rather, the warm gases form an upward rising core surrounded by a downward flowing annulus of cool gas. This annulus may be formed in part from heat loss to the vent wall and in part from downward ambient air intrusion into the chimney from above. It is thought that this flow pattern is unstable and mixing quickly occurs.

In the transient analysis, it is expected that start-up as well as continuous operating conditions will be identified which predict less than satisfactory vent system operation where gains (elevation effects and/or fan work) are less than required to overcome friction losses. These operating conditions are expected to reveal relatively high (above atmospheric) vent system inlet pressures in both cold-start and undersized chimney-vent operation. For a properly operating natural-draft vent system, these calculations should result in a solution that shows the summation of available fan pressure and/or elevation effects in the vent system is greater than the friction loss of the vent system.

Program Output

Presently, all OHVAP output will be displayed in tabular format in the style chosen by the user in the output menu. The user can choose output in ASCII format for tabular display or in Spreadsheet format for graphical processing by another Spreadsheet program. The Spreadsheet format used is found in most common and popular Spreadsheets (e.g., LOTUS, QUATTRO) allowing for easy importing into other programs. In either case, data headings and their meanings are clearly defined in the data key which is included in every OHVAP output. The default output is the ASCII output which consists of eleven (11) data files and one (1) header file, all generated by OHVAP at the completion of the program.
Each data file contains one specific vent parameter as a function of **time** and as a function of each **sequential element**. Those vent parameters are listed as follows :

Vent Parameters:

- Time/Temperature Profile
- Acid Condensation
- Water Condensation
- Draft
- Mass Composition of Flue Gas
- Flow Rate
- Density
- Static Pressure
- Gas Temperature
- Liner Temperature
- Wall temperature

Other output parameters may be computed as required for the validation process.

Currently, the OHVAP code is undergoing a series of validation procedures which will compare OHVAP predictions with the results of experimental tests. As required, additional tests of various vent types and configurations will be conducted in the BNL research lab. Initially, these tests will be designed so that their geometry and conditions can be easily modelled by the OHVAP system. As the validation continues, more complicated and sophisticated vent system configurations will be introduced in order to establish the broadest and most general comparisons for the OHVAP predictions.

The data collected, will attempt to explore local flow conditions that might be present in an actual vent system but not accounted for in the OHVAP code. then the empirical relations generated from the data will be formulated numerically and then will be imbedded in the OHVAP code as required.

Current OHVAP code validation is using data generated from earlier tests as a preliminary comparison against vent conditions predicted by the OHVAP code. The OHVAP code qualitatively predicts the experimental data to a high degree. The code at present is largely based on theoretical and analytical relations as well as a complete data base of material and gaseous properties encountered in vent systems. It is expected that the validation procedures will provide the basis for empirical refinements to the existing numerical algorithms.

Planned Activities:

The following is a list of the **Basic Test Series** planned for the OHVAP Validation experiments. Some of the systems described are already in place but may be re-instrumented to facilitate the validation procedure. Other systems will be assembled as needed.

Basic Test Series:

1) **Conventional Chimney** (masonry) with draft control. Appliances to be tested will include units with 82% and 87% AFUE.

2) **Relined Masonry Chimney** with draft control. Appliances to be tested will include units with 82% and 87% AFUE.

3) **Direct-Exhaust/Direct-Vent** system. Appliances to be tested will include units with 82% and 87% AFUE.

4) **Vertical Vent Flow Simulator** - To be developed in conjunction with the analysis of OHVAP during the validation described in (1) above. Possibilities include flow visualization and/or flow tracing inside a special vertical vent section to be built with transparent opposing sides. The possible methods of flow tracing include smoke injection, illuminated soap bubbles, shadowgraph or schlieren methods and Laser Interferometry to image the density field through the transparent vent.

SUMMARY AND CONCLUSION

The Oil Heat Vent Analysis Program (OHVAP) continues to be under development at BNL. It will be capable of transient analysis and is intended as a design and diagnostics tool for vent systems and chimneys used with oil-fired appliances. This activity was undertaken because manual vent calculation procedures were difficult to use, time consuming and did not yield an understanding of the transient operation of vent and chimney systems. In addition, other existing transient analysis programs did not fulfill the specific needs of oil-fired appliances. The detailed analysis of these systems has become an issue of increasing importance as modern high-efficiency oil-fired appliances replace less efficient units and many of the existing vent systems are found to be unsuitable for the application.

VAP will evaluate the following:

(1) Flue gas temperature, flow, and draft

(2) Condensation of sulfuric acid and water

(3) Vent spillage during starting and operation

(4) Dilution control performance as a function of draft

(5) Performance of chimney and power-vent systems

(6) The effect vent geometry, material and configuration

Current plans for the validation of OHVAP include the use of laboratory and field data for comparative testing of the program. VAP is soon to be available for use by interested parties wishing to contribute to the programs validation. A users manual has been prepared. The expectation is that finalization of the program and supporting documentation will take some time. During 1993, however, VAP will be used to initiate the development of venting tables in the form of installation guidelines for oil-fired appliances.

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Paper No. 93-9

FUEL QUALITY EFFECTS ON HOME HEATING SYSTEMS

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FUEL QUALITY EFFECTS ON HOME HEATING SYSTEMS

ABSTRACT

Good fuel quality directly relates to better performance and more efficient operation of residential heating equipment. With current challenges that the oil heat industry has to face in the retail business, maintaining a competitive market requires quality and service for the homeowners. Brookhaven National Laboratory (BNL) has investigated the effects of fuel quality parameters on heating equipment and has developed countermeasures to ensure that quality is maintained. In order to disseminate this information and promote the concept of fuel quality on a practical level, a set of guidelines has also been developed specifically for service managers to use, either as reference material or training material for the service technicians. The highlights of the research work and the ideas developed in the set of guidelines will be presented in this paper.

Two major factors influence the overall level of distillate fuel quality, the nature of the fuel itself and the conditions in which the fuel is stored. The characteristics of the fuel are generally defined in terms of standards (such as ASTM or state and local fuel quality requirements). As part of the current BNL studies, experiments were conducted to evaluate the adequacy of these standards in terms of heating equipment performance and emissions, and also to determine the limits of fuel properties within which acceptable performance is attained. A primary focus will be to evaluate the effects of fuel sulfur and aromatics on equipment operation. In light of the changes to refinery operations to meet the requirements of low-sulfur diesel for on-highway use in 1993, the potential benefits that can be gained with the use of low-sulfur fuel in heating equipment has also been evaluated.

The storage condition is perhaps the most important of the factors that ultimately affects fuel quality. Much of the perceived fuel related problems such as clogged filters and nozzles are caused by contamination. Minimizing and preventing reoccurring problems require an understanding of what to look for, how to evaluate it, and what to do next. A great deal of literature is available to accomplish this task. A set of guidelines developed in a separate booklet entitled, "Maintenance and Storage of Fuel Oil for Residential Heating Systems," provides a reference to resources available and serves as a start to understanding and attacking this issue.

INTRODUCTION

Two main factors influence the overall quality of distillate fuel - the properties of the fuel, and the conditions associated with its storage. The specific properties of the fuel can affect combustion performance and flue gas emissions. Combustion performance can be defined by the excess air requirement for clean burning, ignition quality, and emissions characteristics (carbon monoxide, oxides of nitrogen, and smoke). In these studies, the effects of fuel viscosity, aromatic content and sulfur content have been evaluated. These fuel properties are generally defined in terms of ASTM standards. For No. 2 oil the ranges of typical or acceptable values are, 1.9-3.4 cSt (at 40 C) for viscosity, 30-35% for aromatic content, and a maximum of 0.5% sulfur . The requirement for aromatic content is not explicitly defined in the ASTM, however, its content is limited indirectly by other requirements such as specific gravity. Aromatic components in the fuel are more dense and tend to increase the specific gravity. Also as part of this work, specifically blended fuels were used with properties extending beyond the ASTM limits to determine the range within which acceptable performance is possible.

BACKGROUND

The amount of sulfur in the fuel directly affects the amount of sulfur oxides emitted from combustion sources. For oil-burning, residential heating systems these emissions are typically very small compared to other sources and are on the order of 36 lb/1000 gal (roughly 1% is in the form of sulfur trioxide and the remaining as sulfur dioxide), assuming a typical sulfur content of 0.25% [1,2]. Sulfur trioxide can further convert to sulfuric acid which contributes to the corrosion and fouling of heat exchangers in the boiler and furnaces.

In diesel engines, the fuel sulfur and aromatic content has been found to be the most important factors contributing to emissions of particulate and sulfur dioxide [3]. In an effort to improve ambient air quality one of the new regulations under the Clean Air Act Amendments have placed new restrictions on the limits for sulfur and aromatics content to reduce particulate and sulfur dioxide emissions from engine exhausts. By October 1993, diesel fuel used for transportation will contain reduced sulfur, at 0.05% wt maximum (as compared to the typical value of 0.25%), and aromatic levels will be held at or below current average levels (approximately 34%). Since both diesel and No. 2 heating oil are currently derived from the same pool and can be used interchangeably, studies were conducted at BNL to quantify the effects of sulfur and aromatics on emissions from residential heating equipment.

The viscosity of the fuel is another property which can significantly affect oil burner operation. Although other fuel characteristics remain constant and are determined by the refining and blending practices, the viscosity can fluctuate markedly with variations in fuel temperature. The effects are most prominent during winter operation when fuel oil is subjected to outdoor ambient conditions. A decrease in temperature causes a rise in viscosity; associated operational problems which can occur include loss in fluidity of the fuel, poor atomization, and inefficient burning requiring additional excess air.

EXPERIMENTAL

Studies of the effects of changes in fuel properties on burner performance and emissions are complicated by the fact that few changes in fuel properties can be carried out independently. For example, varying the aromatic content will undoubtedly change other properties such as the density and the distillation end points. For this study, BNL worked with a petroleum refinery to obtain the fuel samples which were specifically blended to provide the properties of interest. In order to investigate the effects of a specific property, the others were held constant to within an acceptable range, as dictated by the ASTM.

Emissions Testing

A series of combustion tests using several different burners were performed to look at the effects of fuel sulfur content, aromatic content, and viscosity. By custom blending the fuel and analyzing its components, each of the fuel properties were examined individually while keeping the other properties within a constant range. Refer to Table 1 for some of the characteristics of the test fuels. Three burners were used to conduct these tests, a flame retention head burner, a high static pressure retention head burner, and an air atomizing burner. The nominal firing rate for each test is 0.5 gal/hr.

All operating conditions were initially set for each burner and test fuel to achieve the same Bacharach (ASTM D2156) Smoke Number (No. 1) at steady state. The draft was adjusted to a low level (less than 0.005 in. wc) to minimize air leakage around the seals of the boiler. The excess air level for each test was set at 10% higher than that required to obtain a Smoke No. 1 on the Bacharach scale. This was adjusted by monitoring the oxygen level of the flue gas. Under cyclic operations the burner was set to turn on for 5 minutes and shut off for 15 minutes.

During steady state operation when the oil burner stays on continuously, flue gas emissions, such as carbon monoxide (CO) and particulates, are negligible. Elevated concentrations of these flue gas components are observed only during the startup and shutdown periods in cyclic operation. During these transient periods, emissions of nitrogen oxides (NOx), CO, and smoke number are recorded over several cycles. The peak values or concentrations are averaged and reported in the next section.

For some of the tests, the total particulate matter emitted as soot was determined by gravimetric analysis. Using a modified EPA Method 5 collection train, filterable particulates emitted over many cycles were collected and weighed. In order to collect enough samples for weighing, each test required approximately a minimum of 24 hours of burner operation. These studies were conducted to determine the benefits, if any, which can be realized by using fuel with reduced sulfur (0.05% wt.), and low aromatic content (17% vol). The aromatic content selected is roughly half of the amount contained in typical distillate oil. All emissions data are compared with the baseline fuel which has characteristics resembling the typical No. 2 oil.

RESULTS

Some of the results from the data collected with a flame retention head burner are shown in this section. The simplest measurement that can be made is the smoke number which is measured with the Bacharach spot test (ASTM D2156). This is a method to evaluate the smoke density of the flue gas. A curve showing the smoke number varying as a function of excess air level provides a measure of burner performance with the test fuel. Figures 1 and 2 illustrate the effects of sulfur and aromatics under steady state operating conditions. These results show that under steady state conditions, burner performance does not vary with sulfur content (up to .70% S) or aromatics (up to 55.5% - High Arom). Slight degradation occurs only at the aromatic concentration of 100%, which is at a level that would not be found with typical No. 2 oil. It is likely that a burner which is out of tune, or unfavorable changes to operating conditions, can cause

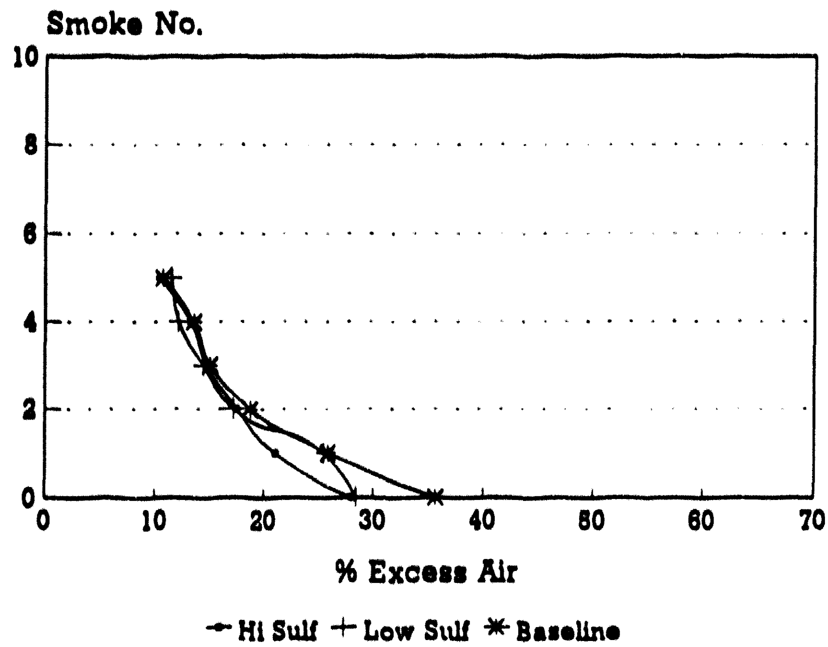

Figure 1. Smoke number vs. excess air with varying fuel sulfur content Steady state operation

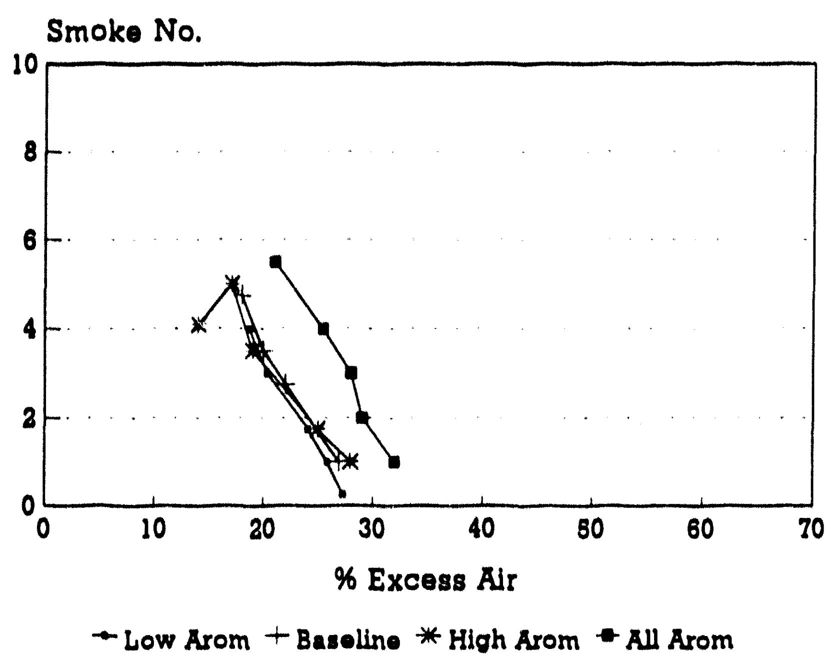

Figure 2. Smoke number vs. excess air with varying aromatic content Steady state operation

ASTM Limits

Fuel Type	Sulfur, wt% 0.5% max.	Viscosity, cSt (at 40C) 1.9 - 3.4	Aromatics, vol% no limit	API grav 30 min
Baseline	0.26	2.3	33.6	35.6
High Sulfur	0.7	2.1	ND	34.8
Low Sulfur	0.037	2.8	33.5	36
Low Aromatic	0.271	2.6	16.6	42.7
High Aromatic	0.25	2.3	55.5	30.9
All Aromatic	0.0035	2.36	100	14
Low Viscosity	0.25	1.6	33.2	38.4
High Viscosity	0.31	5.0	38	35.2
Hi Arom/Visc	0.12	8.0	76.7	27.6

ND - No Data

Table 1. Test Fuels

this same degree of degradation or even higher. In other words, changes to equipment and operating conditions have a bigger effect on burner performance than the effect of fuel type - with varying sulfur or aromatic content. Sulfur content does correlate with heat exchanger fouling rates; the lower the sulfur the lower the deposition rates. This result is part of the ongoing BNL program to minimize soot formation in oil-fired heating systems.

Much larger effects are found with fuels with varying viscosities. Viscosity can fluctuate slightly from one batch of fuel to the next, but overall changes are dominated by the effects of fuel temperature. For these tests, fuels were specifically blended to obtain a broad range of viscosities. During steady state operation, burner performance varies slightly with viscosity (up to 5 cSt). However, more dramatic changes are observed during cyclic operation. Figure 3 shows peak smoke values for the startup transient period. For comparison, the values for fuels with different aromatic content were included. As fuel viscosity increases substantially poor atomization can occur. Figure 3 shows that at high viscosities (at approximately 5 cSt) smoky conditions will occur during cyclic operation. When the boiler unit is running during steady state, the combustion chamber and the oil recirculating within the burner does not cool, the oil flows continuously at a constant rate and the transient effects during startup (or shutdown) is minimized.

Carbon monoxide exhausted with the flue gas results from incomplete combustion. This can be caused by insufficient fuel-air mixing or insufficiently high temperatures within the combustion zone. These conditions generally occur for a very short time (about 30 seconds or less) during startup periods and will result in higher CO emissions when compared to the steady periods during the on-

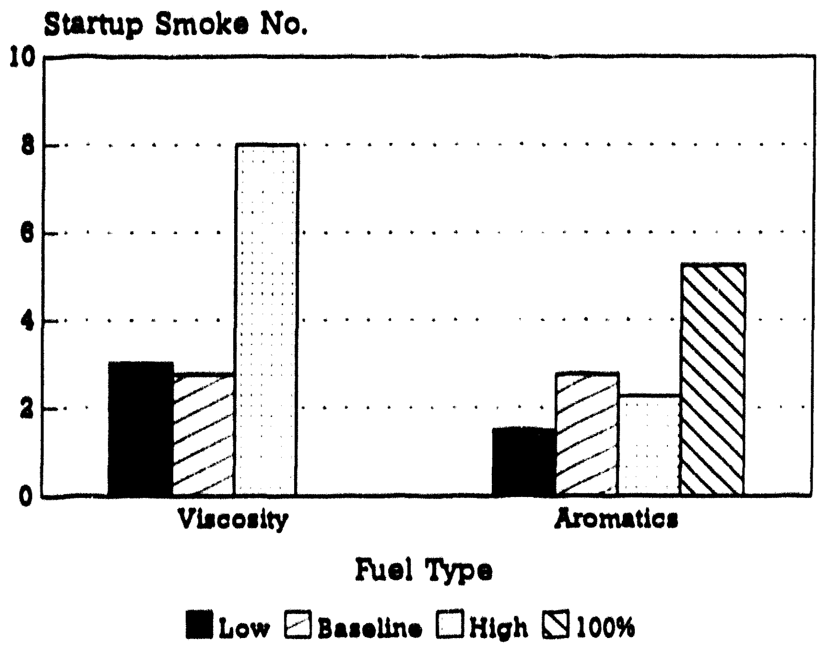

Figure 3. Startup smoke number vs. fuel type

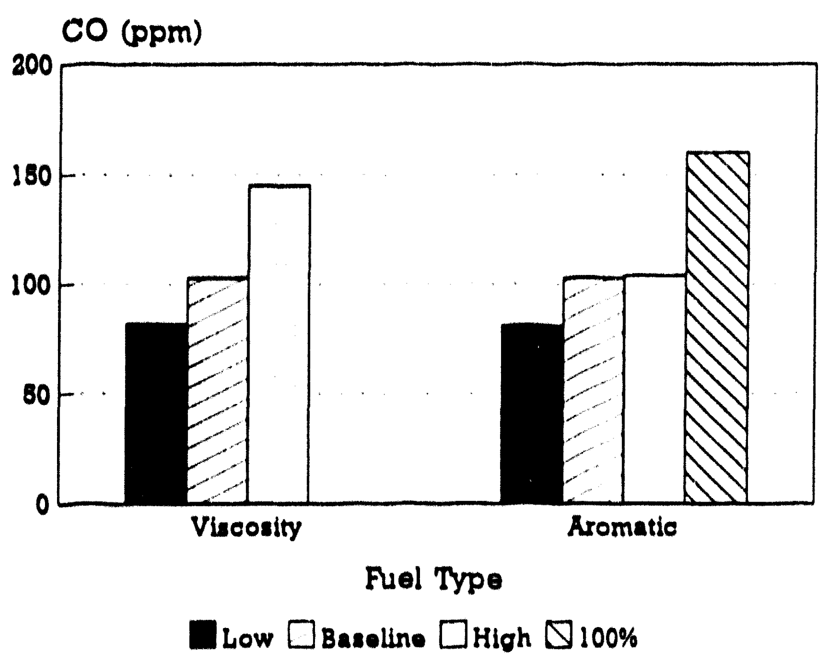

Figure 4. Carbon monoxide concentration during startup

cycle. The peak values are averaged over several cycles to provide a comparison of maximum concentrations during these transient periods for each fuel type, refer to Figure 4. These results follow the same trend as the smoke number measurements taken during startup.

The major source (80%) of nitrogen oxides in the flue gas when No. 2 oil is burned in air is formed from the atmospheric nitrogen. Nitrogen oxides (NOx) concentrations increase after the start of the on-cycle and will reach a steady level; when the burner is shutoff levels will drop. Average NOx concentrations measured during the on-cycle for a particular burner does not vary much with fuel type under the same operating conditions. The amount of nitrogen in the fuel is usually small. Different burner types can exhibit different NOx levels.

Filterable particulate matter in the flue gas were collected and analyzed. These tests were conducted with low sulfur and low aromatic fuels. Two measurements were made with each fuel type. The results are shown in Table 2. By comparison, there are negligible differences in particle concentration among the test fuels.

Fuel Type	Particulate Emissions	(lb/million Btu)
Baseline	Min.	0.0014
	Max.	0.0018
	Avg.	0.0016
Low Sulfur	Min.	0.0020
	Max.	0.0024
	Avg.	0.0022
Low Aromatic	Min.	0.0016
	Max.	0.0016
	Avg.	0.0016

Table 2. Particulate Emissions with low sulfur and low aromatic fuels

CONCLUSIONS

The type of burner, how it is setup and the operating conditions of the system are important factors to consider when evaluating combustion performance. Based on this study, these factors outweigh the effects of variations in fuel property, especially if the properties do not exceed such ranges as those established in the ASTM limits. The fuel viscosity is one of the most important properties affecting performance because it varies to a great extent with fuel temperature, and affects the atomization of the oil.

DISCUSSION

At the end of 1993, low sulfur distillate fuel will become available for transportation use. Although this study shows very small differences in heating system performance with fuel of varying sulfur content, in terms of particulate, CO, and NOx emissions, other benefits can be realized with using low sulfur fuel. Sulfur oxides (SOx) emitted to the atmosphere will be reduced because the amount of SOx in the flue gas is a direct function of the amount of sulfur in the oil. A small portion of the sulfur oxides (less than 5%) converts to sulfuric acid in ambient conditions. BNL currently has an on-going study to evaluate the effects of acid deposition on corrosion and fouling of heat exchanger surfaces in residential heating systems. Preliminary results indicate a correlation between low sulfur fuel and reduced fouling rate.

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Paper No. 93-9
Supplement

RESIDENTIAL FUEL QUALITY STUDY

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RESIDENTIAL FUEL QUALITY STUDY

INTRODUCTION:

How many times can we fix the same problem? Answer: As many times as we want.

I suspect others of you have had an experience similar to the following. My company has spent tens of thousands of dollars on reducing customer fuel system failures. We have bought only low sulphur Colonial 76 grade heating oil, we clean our bulk storage tanks annually, we have installed large capacity filters on all our customer's fuel lines, we have treated our fuel with various chemicals for the better part of ten years. After all this, fuel system failures continue to be the number one cause of in season heating system failures among our customer base. Why is this?

We don't fully understand the mechanisms causing the tank contamination in the typical residential condition.

We have not cultivated a working relationship with the refiners who might have the answers.

Based on incomplete knowledge we select solutions based on hunches.

Most importantly once we have implemented a corrective action we fail to carefully measure the results and therefore never accurately know what solutions work.

With this in mind our company launched a campaign to solve this problem, ONCE AND FOR ALL (we hope).

Purpose of study:

To determine the cause of in season fuel system failures and to develop a strategy to greatly reduce such failures.

Step #1:

Develop a method for identifying and quantifying the fuel system failures.

a) Generate a monthly report of the number of filter changes excluding annual maintenance and new installations (this is a valid measure at our company because 99% of customers have a filter).

b) Download statistics to spreadsheet program and analyze results.

Step #2:

Sort filter changes by:

Change date
Change date compared to delivery date

Town
Service technician
Tank Size
Annual consumption
Account #
Service plan
Service call type
Delivery size vs. tank size

Tank age statistics are unavailable but enough anecdotal evidence exists of problems in young tanks to conclude that the failure mechanism is not necessarily due to tank age.

Observations to date:

- Change rate for u/g 550 tank was double that of inside 275's.
- Over 30% of failures occurred within one day of a delivery.
- In a six month period one third of filter changes were made on 1% of the accounts.
- Filter change rate varies with total deliveries very precisely. Between October and February the rate per 100,000 gallons delivered varied from the highest month to the lowest by only 15%.
- Perhaps the most important result of this study is the establishment of accurate baseline statistics for the customer population. We can now examine the problem and try different solutions on discrete segments of our customer base and precisely monitor the results.

So now what do we do?

Suspected Cause: Delivery practices resulting in excessive agitation of tank bottoms.

Proposed Action: Replace "whistle pipes" with one that will break the flow of oil into tanks (see Figure 1).

Result: Failure on 550's dropped 30% (see Figure 2).

Suspected Cause: Biological contamination of tank bottoms.

Proposed Action: Sample a group of tanks for biological and begin treating customer tanks in one town with a proven EPA registered biocide.

Result: 10 random tanks and 10 problem tanks were sampled. All showed some degree of biologicals with the problem tanks being more heavily contaminated. Treatment was begun on February 1, 1993. The percentage of failures in the test town had been running between 7.8 and 11.6%, average 9.3% of filter changes for the 5 months prior to treatment.

Failures in February were 8.2% of customer base which is at the low end of the scale but the test town has a high % of 550 tanks so the decrease can be attributed to the new fill procedure.

One concern was that killing biological would lead to a short term increase in failures--this does not seem to be the case.

Biocide treatment is not expected to be a short term fix and we intend to closely monitor results in the test area on a long term basis (see Figure 3).

Suspected Cause: Filters could actually be causing the problem. Either by providing a site for biological growth, breakup of the filter itself, rapid filtration efficiency increase due to removal of particles that would otherwise pass the nozzle or some other mechanism.

Proposed Action: Replace felt media filters in one town with continuous filament (white) filters. Begun 3/8/93, no results to date.

Suspected Cause: Fuel degradation due to unstable fuel or some catalytic acceleration of the fuel degradation. There is much evidence that the presence of copper in the fuel system acts as a catalyst to break down fuel into insoluble particulate (alias sludge). In a two-pipe system with copper lines fuel is being continuously exposed to copper.

Another factor contributing to the rapid degradation of the fuel in a two-line system is the constant aeration of the fuel. In a typical residential system with a single stage fuel pump the oil is being recirculated at a rate of 24 gallons per hour. If the unit is consuming 10 gallons per day at 1 gallon per hour then 230 gallons per day are being returned to the tank. This means a 550 gallon tank is being turned over once every 2 days, introducing plenty of air into the fuel to facilitate oxidation.

Proposed Action: Treat fuel with a stabilizer and metal deactivator to stop the catalytic reaction. Scheduled for distribution to entire system in the spring of 1993. Results possible by next winter.

Suspected Cause: Tanks with severe long term accumulations of sludge.

Proposed Action: A) Promote tank replacement, and B) Investigate in place filtration systems to agitate and suspend sludge, filter and treat with biocide, stabilizer and metal deactivator and replace.

<u>Conclusion:</u>

Much study has been done on fuel degradation, biological growth and other mechanisms for bottom sediment formation. Brookhaven has developed a very good guide on the storage of fuel oil. The work that lies ahead is applying the finding of this research to the particular conditions found in our customers' fuel systems and identifying practical cost effective solutions.

Solving problems like this suggest some exciting possibilities for cooperation between fuel dealers and Brookhaven National Laboratory. This type of study can serve as a model. As dealers we have the resources to try new products and techniques and the computer systems to collect data and track results. As an active arm of the Laboratory we can produce real results in a cost effective manner.

Some might say that we are too busy and overworked and our industry is too competitive for us to afford the time for such research. The fact is that as an industry we find the time to change thousands of sediment clogged filters and nozzles every year. The alligators are living in the bottom of our customers tanks, we need to stop embarrassing ourselves by wrestling the alligators in front of our customers and start draining the swamp.

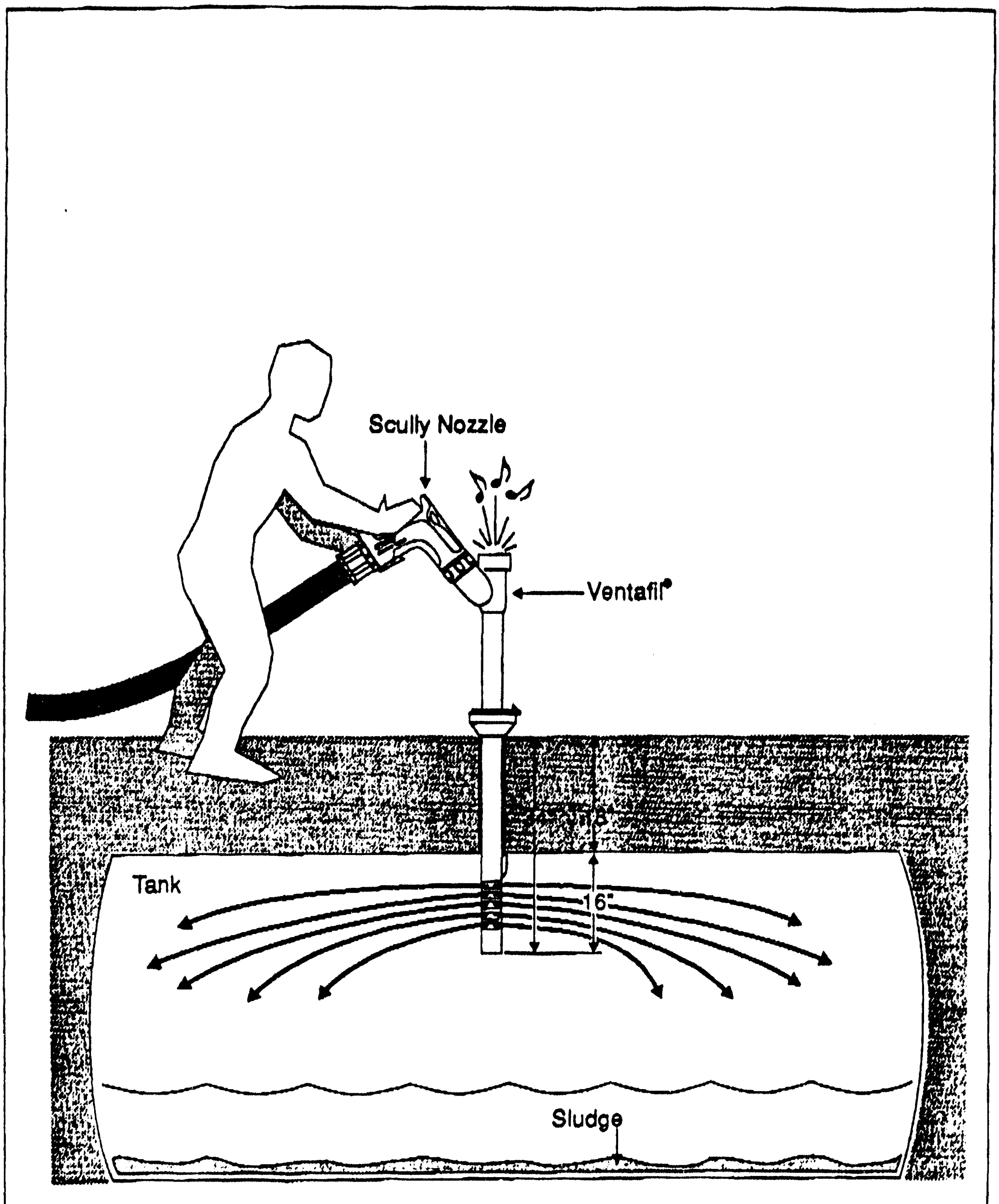

FIGURE 1

UNDER GROUND TANKS AS A PERCENT (%) OF ALL FILTER CHANGES USING NEW FLOW BREAKING "WHISTLE PIPES"

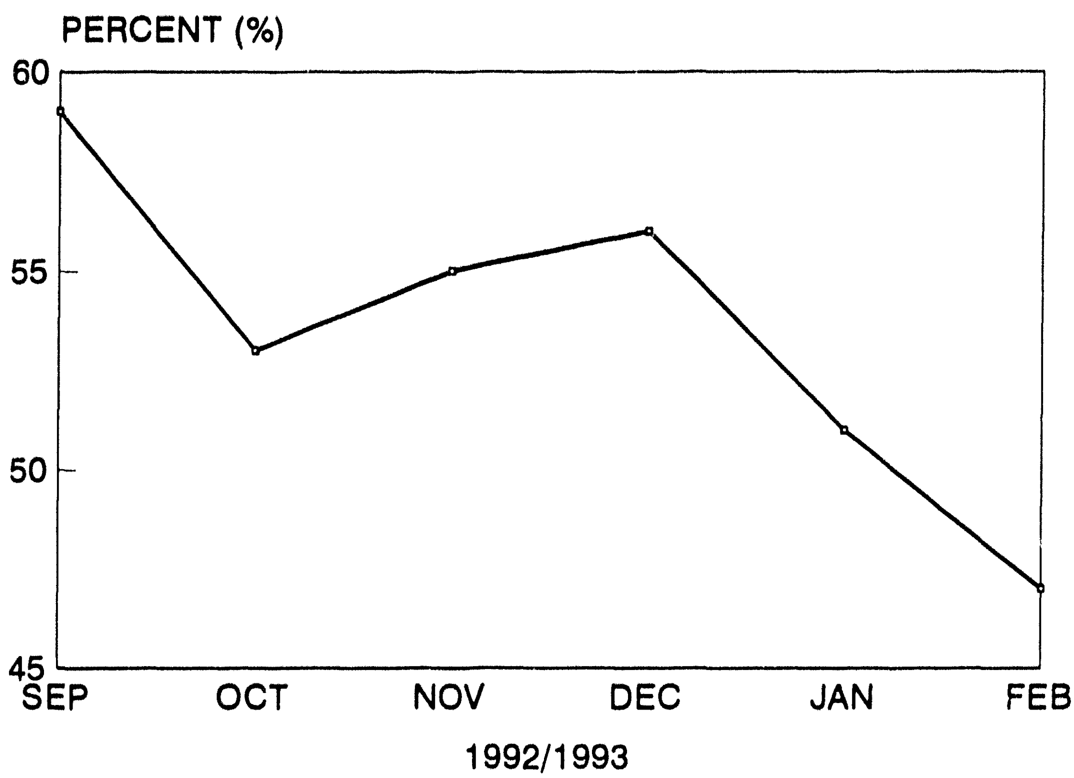

Figure 2

WESPORT PERCENT (%) OF TOTAL FILTER CHANGES USING EPA REGISTERED BIOCIDE TREATMENT

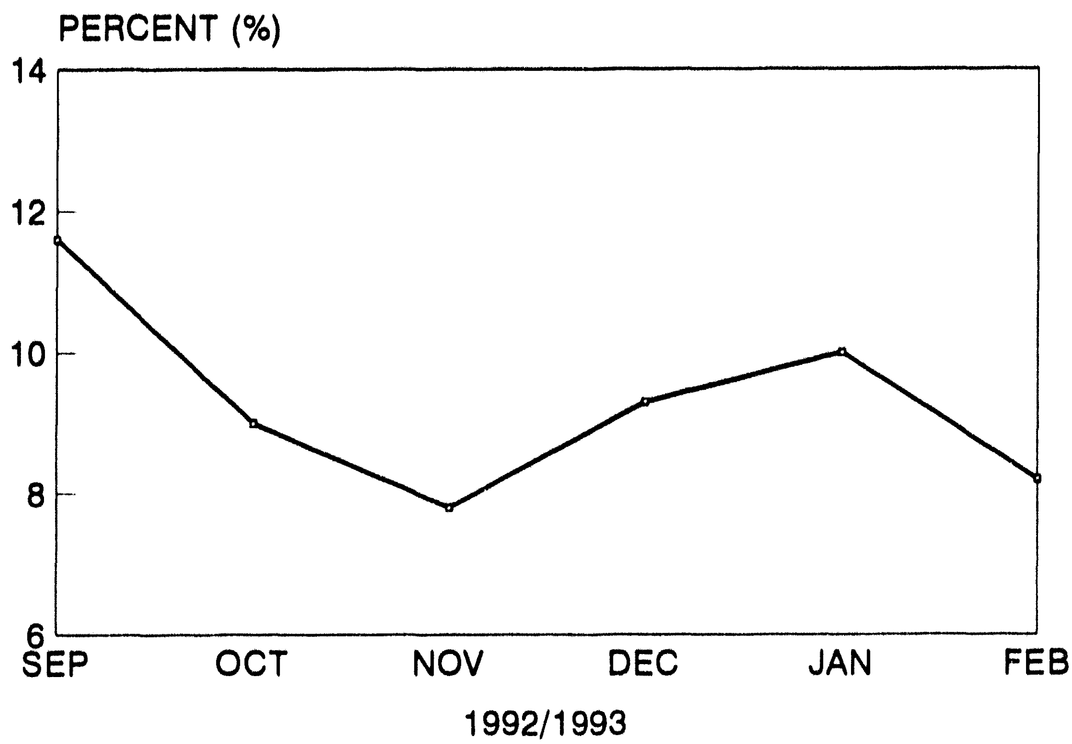

Figure 3

Paper No. 93-10

Fouling of Oil-Fired Boilers and Furnaces

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FOULING OF OIL-FIRED BOILERS AND FURNACES

INTRODUCTION

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 due to fouling is generally taken as 2% per year. Brookhaven National Laboratory (BNL) is currently studying causes of soot fouling for the purpose of identifying practical methods of minimizing these deposits.

Studies of the fouling process in full sized boilers is difficult because of generally poor access to the heat transfer surfaces. Studies which include efficiency degradation as a measured parameter must be done over long time periods (months) to obtain efficiency changes large enough for measurable and repeatable results. Work at BNL has focused on the development of more rapid fouling tests which permit fouling deposits to be repeatably weighed and analyzed. Preliminary studies were done using water-cooled stainless steel fouling probes [1]. This was followed by the development of a test which uses controlled temperature test sections where fouling deposits are formed on materials actually used in boilers and furnaces. This system, which has been used for essentially all of the results included in this paper, was introduced during the 1991 Oil Heat Technology Conference [1]. It is described as well in the next section.

Earlier studies at BNL as well as analyses made of deposits removed from boilers in the field, have shown that the fouling deposits are primarily composed of two parts- carbon derived from the fuel oil and iron sulfate scale. During combustion 99% of the sulfur in the fuel is emitted from the stack as SO_2. The remaining 1% of the sulfur is converted first to SO_3 and then to sulfuric acid (H_2SO_4) in the flame zone. The sulfuric acid condenses on the relatively cool heat exchanger surfaces and quickly corrodes the iron to form iron sulfate scale [2].

Factors which control the fouling rate include the fuel sulfur level, the burner excess air (controls the SO_2/SO_3 ratio), and the surface temperature which affects the acid condensation rate. If the surface is above the acid dewpoint (about 220 F) corrosion occurs only by attack from the gas phase. If the surface is below the acid dewpoint but above the water dewpoint (about 120 F) corrosion occurs by the direct condensation of sulfuric acid on the surface. This is the normal situation in heating boilers. If the surface is cooled below the water dewpoint corrosion rates are greatly increased. This paper reports on studies of fouling rates with cast iron boiler surfaces, steel boiler surfaces, and furnace surfaces. Effects of the sulfur level in #2 oil, excess air, and temperature trends during the burner-on period are discussed.

EXPERIMENTAL

Figure 1 illustrates the arrangement developed during this work for rapid studies of fouling. A conventional steel boiler has been modified to allow extraction of a part of the combustion products from the back end of the combustion chamber. About 10% of the total boiler gas flow is drawn through the fouling test section. Here the gas passes through four test sections which are either water or air cooled. In the water cooled system the test sections can be maintained at constant temperature by circulating water from an external water bath. Alternatively, the test sections can be cooled with water circulating from the boiler and, in this case, the surface temperature cycles along with the boiler water temperature. This second approach was used in all tests included in this paper. Each of the four test boxes has a face (4" x 4") which is exposed to the hot gas. After each specific fouling test these can be easily removed and the surface deposit recovered for accurate weighing and analysis. Typically, 24 hours of cyclic operation was found to be a sufficient time period to recover enough deposits. Tests with longer time periods (to 3 days) indicated essentially a linear fouling rate.

To simulate furnace conditions the fouling section surfaces were cooled with air flowing across the back face as shown in Figure 2. Thin foil thermocouples were mounted on the back (cool) face of the fouling surface to monitor temperature trends during the firing cycle. On one of the air cooled furnace surfaces four foil thermocouples were mounted to evaluate surface temperature uniformity. Figure 3 shows the trend in each of these four temperatures measured on one plate during a typical test. The uniformity indicated by this data was seen as adequate for the purposes of this project.

After each fouling test the surface deposits were carefully removed by brushing and water rinse. In addition to measuring the mass of the removed deposits, analysis was also done to determine the soluble iron and sulfate ("wet" analysis). The balance of the deposit was assumed to be carbon and for selected test conditions this was confirmed by more detailed analyses using Electron Specroscopy for Chemical Analysis (ESCA) and Infrared Spectroscopy (IR).

In tests intended to simulate fouling of cast iron boiler surfaces the fouling test sections were cut from a pin-fin section of a new cast iron boiler. Similarly test sections for steel boilers and steel furnaces were donated by manufacturers.

During this program the effects of fuel sulfur content on fouling rate were evaluated. To accomplish this a set of test fuels was obtained, with cooperation from a refiner- Philips Petroleum Co. of Bartelsville, OK., which had varied sulfur content but all other properties constant. This provided a good evaluation of the effects of sulfur content alone.

RESULTS

SURFACE TEMPERATURE

In prior studies at BNL, with water cooled surfaces, it was shown that fouling rates increase dramatically when the surface temperature decreases below the dewpoint of water vapor [1]. This might occur in the case of a purge type boiler for at least the beginning of the firing cycle. In the case of a furnace, Figure 4 shows the effect of the surface temperature at the end of the firing cycle on the total fouling rate. This data was obtained during sustained cyclic operation with a burner on-time of 5 minutes and off-time of 15 minutes. In this case a higher temperature at the end of the firing cycle is achieved by reducing the cooling air flow. As the air flow is reduced and the surface temperature at the end of the firing cycle is increased the fraction of the total burner on-time for which the surface is below the dewpoint of water vapor is reduced.

FUEL SULFUR CONTENT
Increasing the fuel sulfur content generally increases the concentration of sulfuric acid in the combustion products and the rate of deposition of sulfuric acid on the heat exchanger surfaces. Figure 5 shows the resulting effects on fouling rate with the cast iron boiler surfaces. The top line in this figure is the total rate of accumulation of deposits on all four surfaces. The line just below this is the sum of the measured soluble iron and sulfate removed from the deposit. The difference between these two lines is the carbon in the deposit as discussed above. These results clearly show the strong effect of fuel sulfur level. Typically heating oil contains 0.25% sulfur and at this level the iron sulfate is roughly 70% of the total deposit mass. As the fuel sulfur level is reduced toward zero the relative contribution of the carbon part to the total deposit becomes increasingly important.

Figure 6 shows the results of a similar set of tests with steel boiler sections. Results are generally similar both with regard to the magnitude of the fouling rates and the effects of sulfur content. Figure 7 shows the effects of fuel sulfur content on total fouling rate for the air cooled "furnace" sections. In this case only the total deposition rate was measured for all of the four test surfaces combined. A detailed iron and sulfate analysis was done only for one of the four surfaces and this is shown in Figure 8. Results are similar although in this case the carbon deposit is more significant than the iron sulfate deposit.

EXCESS AIR
Reducing burner excess air level reduces the fraction of fuel sulfur which is converted to sulfuric acid in the flame. This in turn reduces the rates of acid condensation and formation of iron sulfate scale. Operation with very low excess air levels is common practice in very large boilers, in part to minimize acid corrosion of heat exchanger surfaces at the back end of the boiler. In tests done on cast iron and steel boiler surfaces as well as furnace surface operation with very low excess air was found to reduce the total fouling rate if the burner operated without soot. This is demonstrated in the case of cast iron surfaces in Figures 9 and 10. To achieve very low excess air levels an air atomized burner (Airtronic) was used. This feature of very low excess air operation is expected to be an attractive feature of advanced burners. If a conventional burner is operated at very low excess air smoke number is high (over 2). In this case the rate of formation of iron sulfate scale is reduced (relative to the same burner at high excess air), but the rate of collection of soot on the surface increases. The result is a great increase in both the total fouling rate and the fraction of carbon in the collected deposit.

CONCLUSIONS AND FUTURE PLANS

The rapid fouling test developed at BNL has been found to be a very useful tool in studying the effects of burner and heat exchanger parameters on fouling rate. Generally iron sulfate scale formation was found to be a very important parameter and anything which reduces this formation rate will reduce fouling. This includes avoiding the water dewpoint temperature on the surface, reducing fuel sulfur content and operating without soot at very low excess air levels.

To demonstrate the primary conclusions of this work on a practical level two identical boilers have been installed in the BNL lab. These will be operated with identical cycling conditions to demonstrate the effects of low boiler water temperature, low fuel sulfur content and ultra low excess air operation on fouling over extended time periods. Unlike the rapid test method developed at BNL these tests will each be conducted over 4 months of cyclic operation. These boilers will be both controlled and carefully monitored by the BNL lab computer system.

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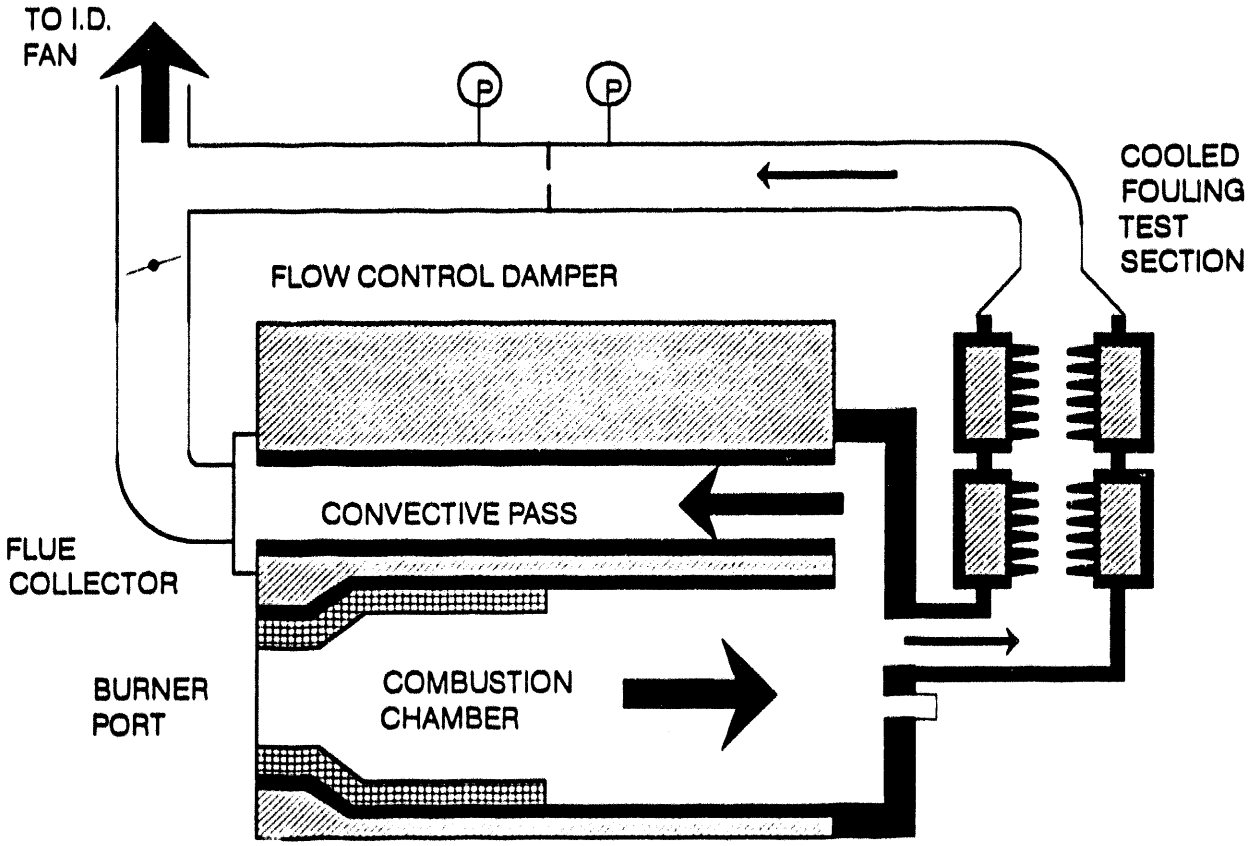

Figure 1. Illustration of BNL rapid test for heat exchanger fouling. Fouling test sections are shown as a modification to a conventional steel boiler.

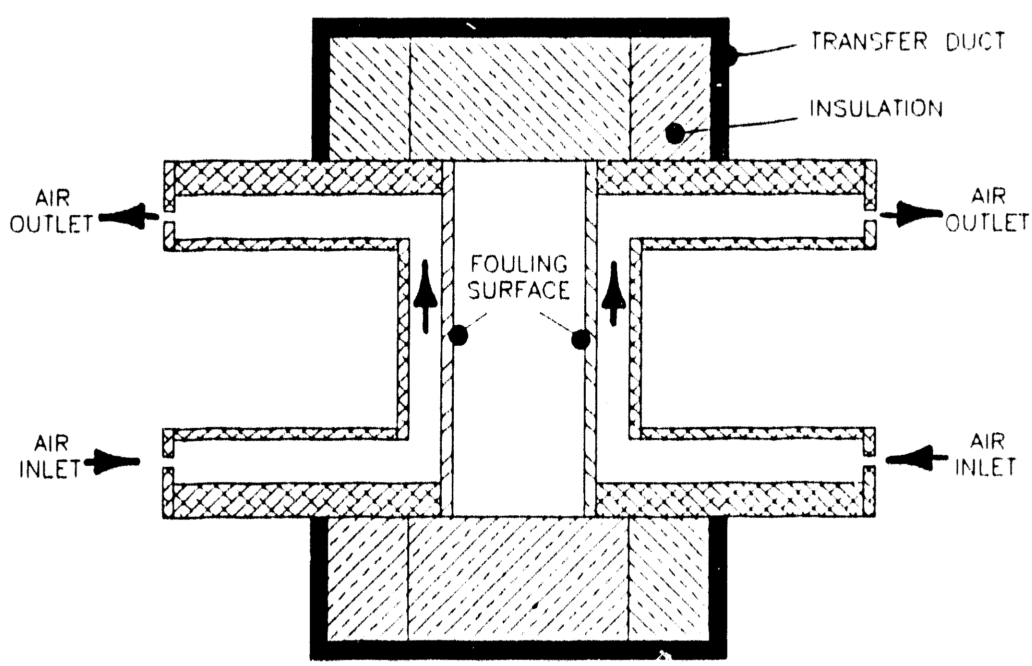

Figure 2. Top cross-section of air-cooled fouling test section.

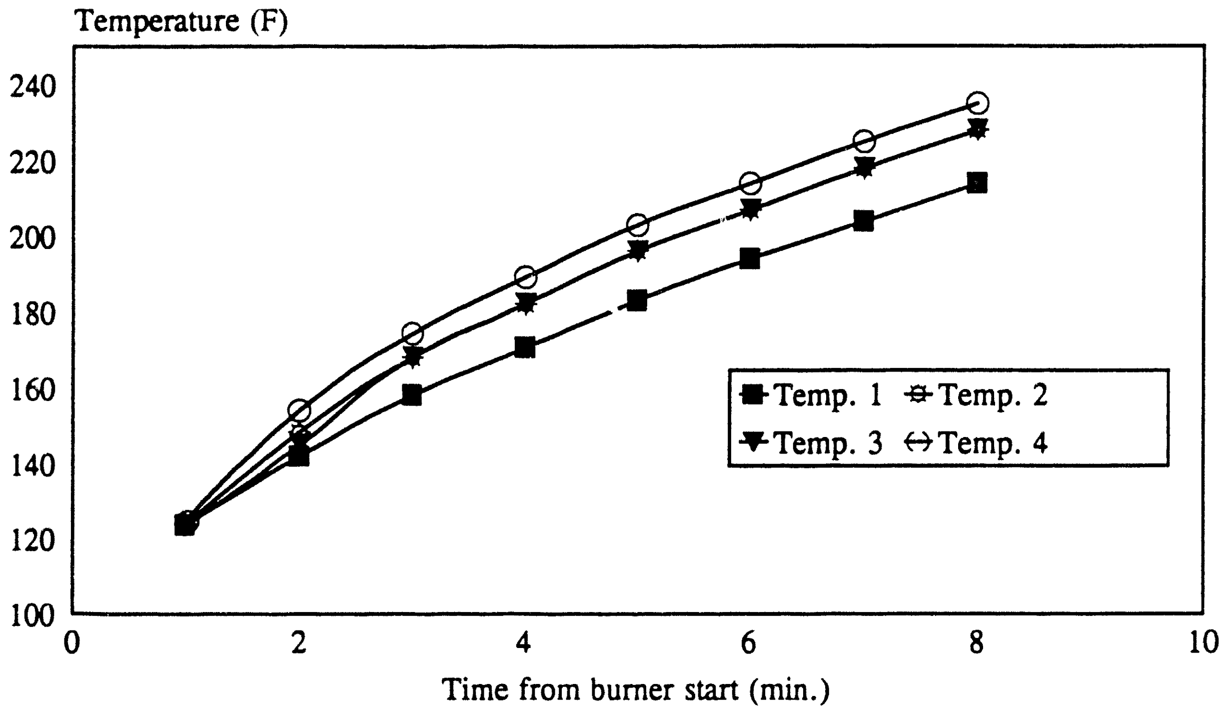

Figure 3. Fouling tests with air-cooled (furnace) sections. Temperature trends during tyoical firing cycle. Four surface-mount thermocouples on one section.

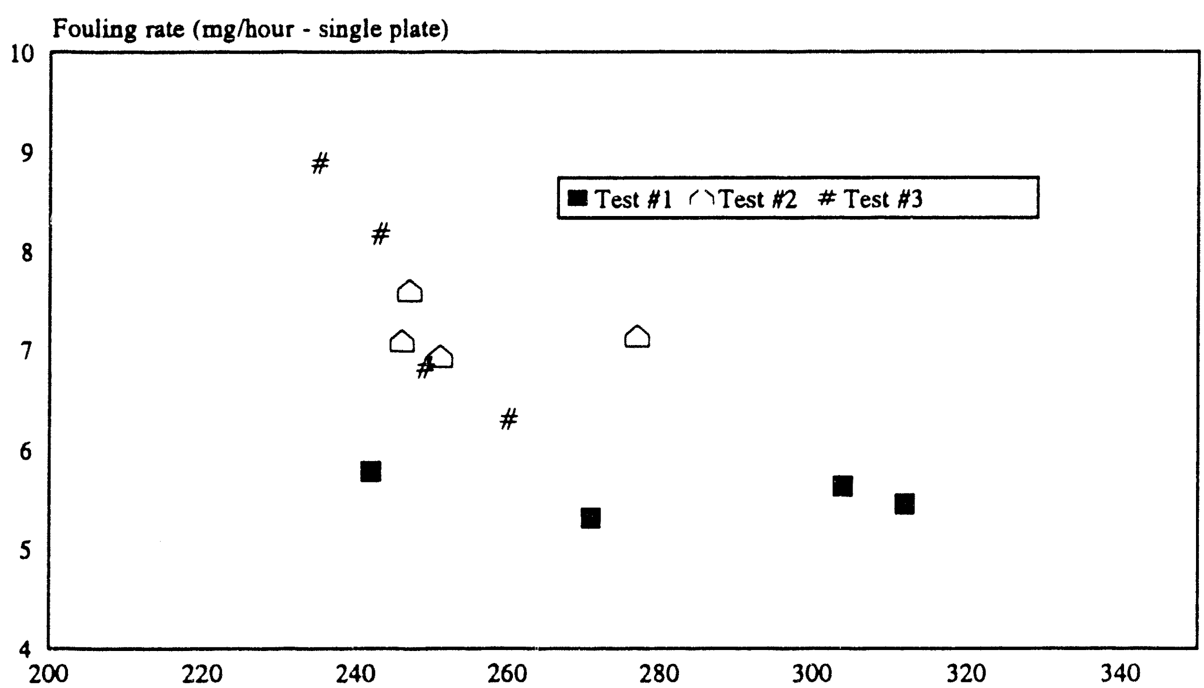

Figure 4. Fouling tests with air-cooled (furnace) sections. Fouling rates vs. plate temperature at the end of the firing cycle.

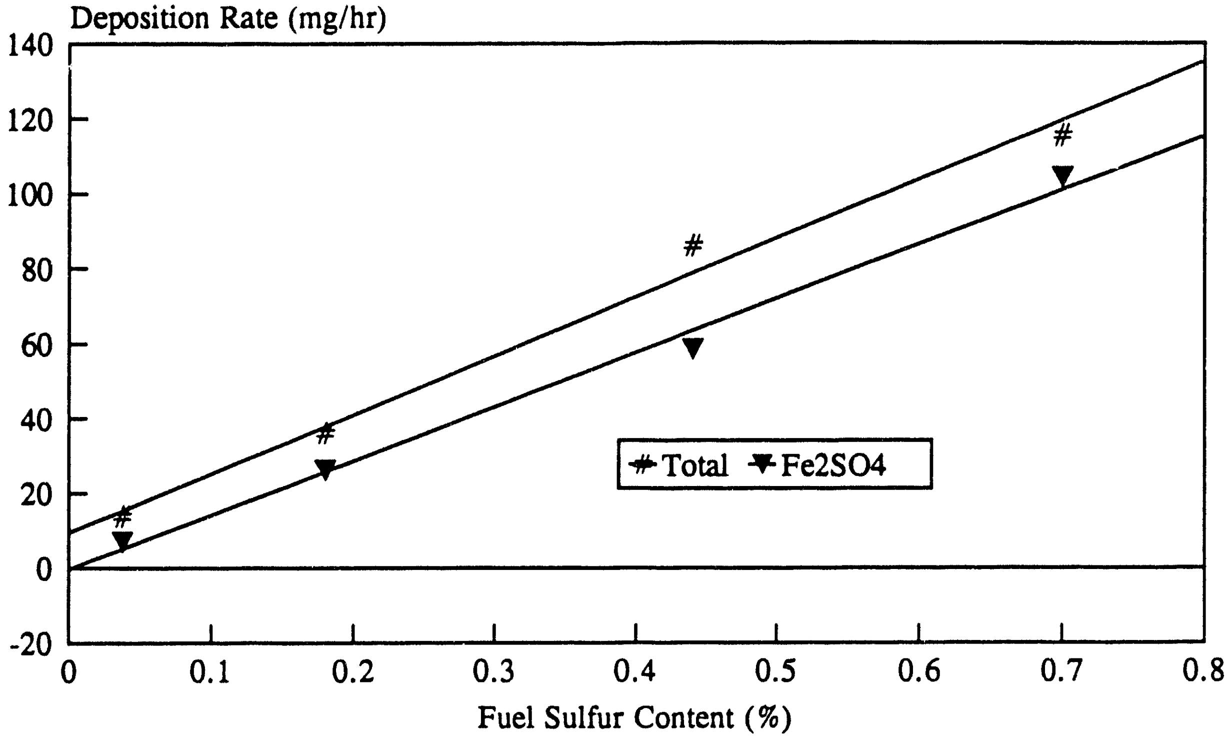

Figure 5. Effect of fuel sulfur content on total fouling rate and rate of accumulation of iron sulfate scale. Cast iron sections. (Note: difference between top and lower line is primarily carbon deposits).

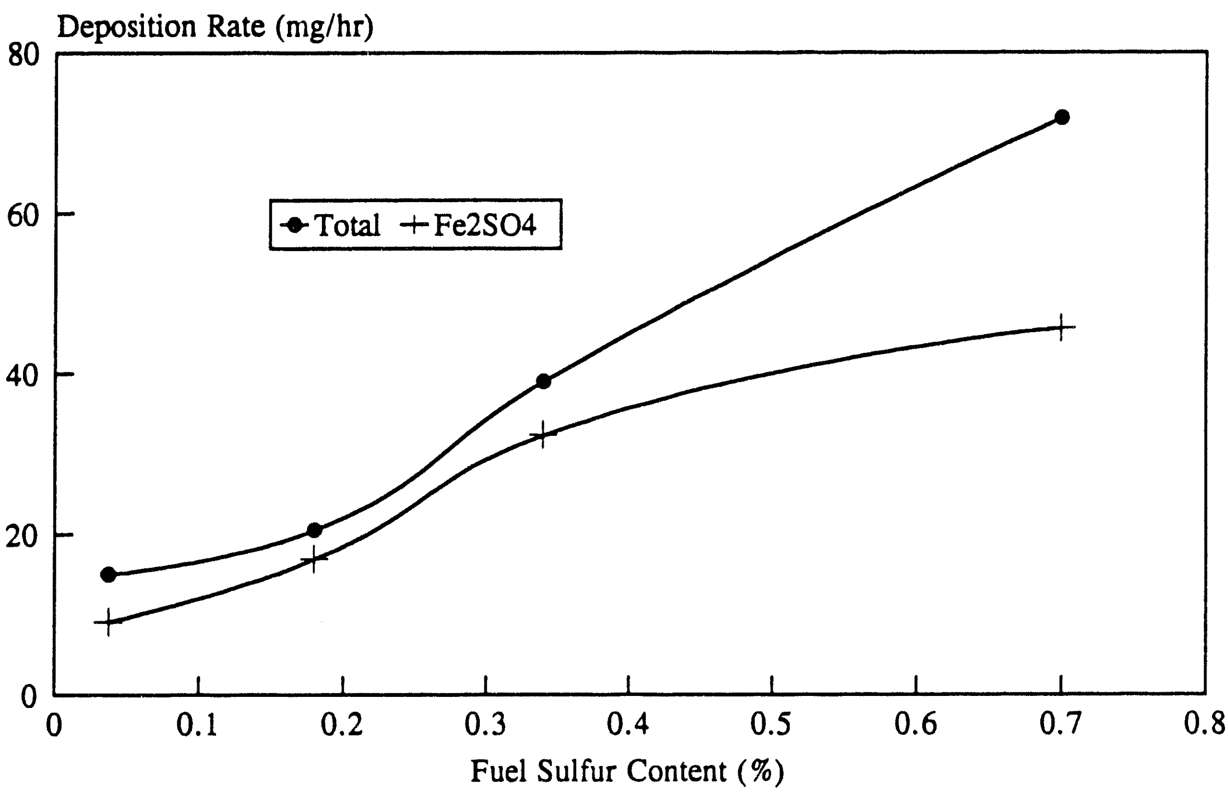

Figure 6. Effect of fuel sulfur content on total fouling rate and rate of accumulation of iron sulfate scale. Steel sections. (Note: difference between top and lower line is primarily carbon deposits).

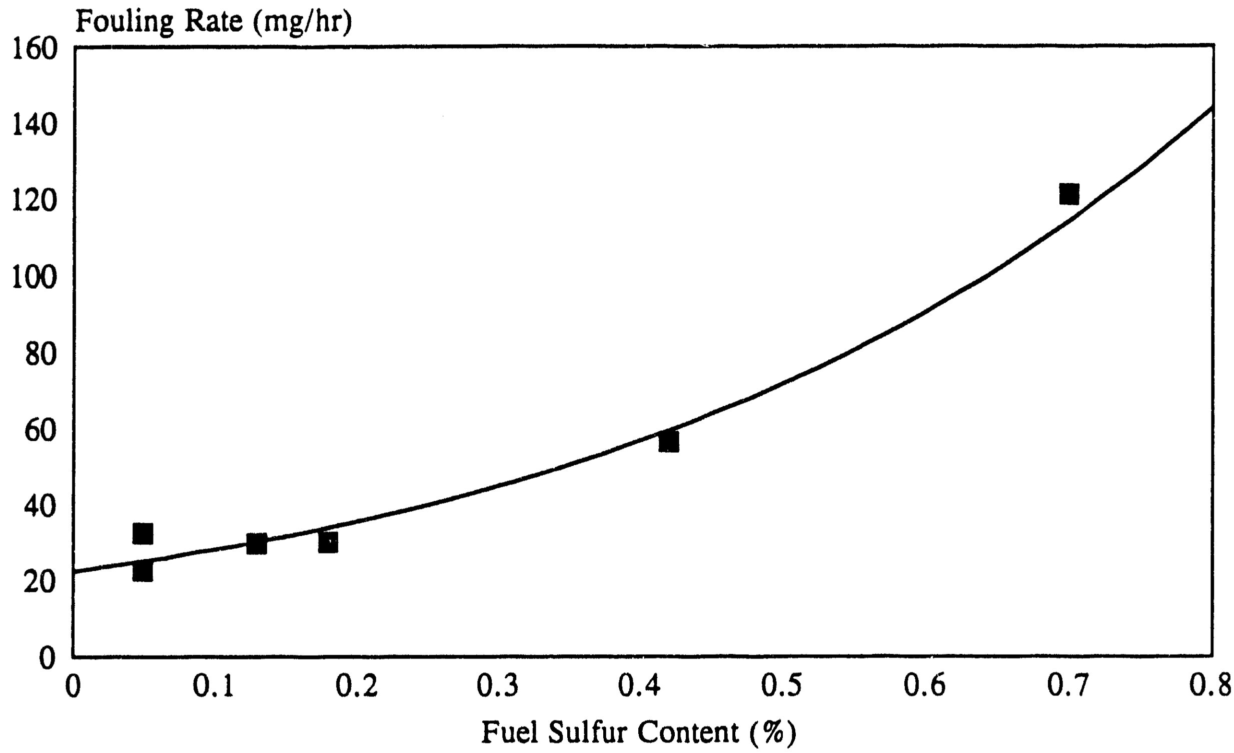

Figure 7. Effect of fuel sulfur content on total fouling rate. Air-cooled furnace sections.

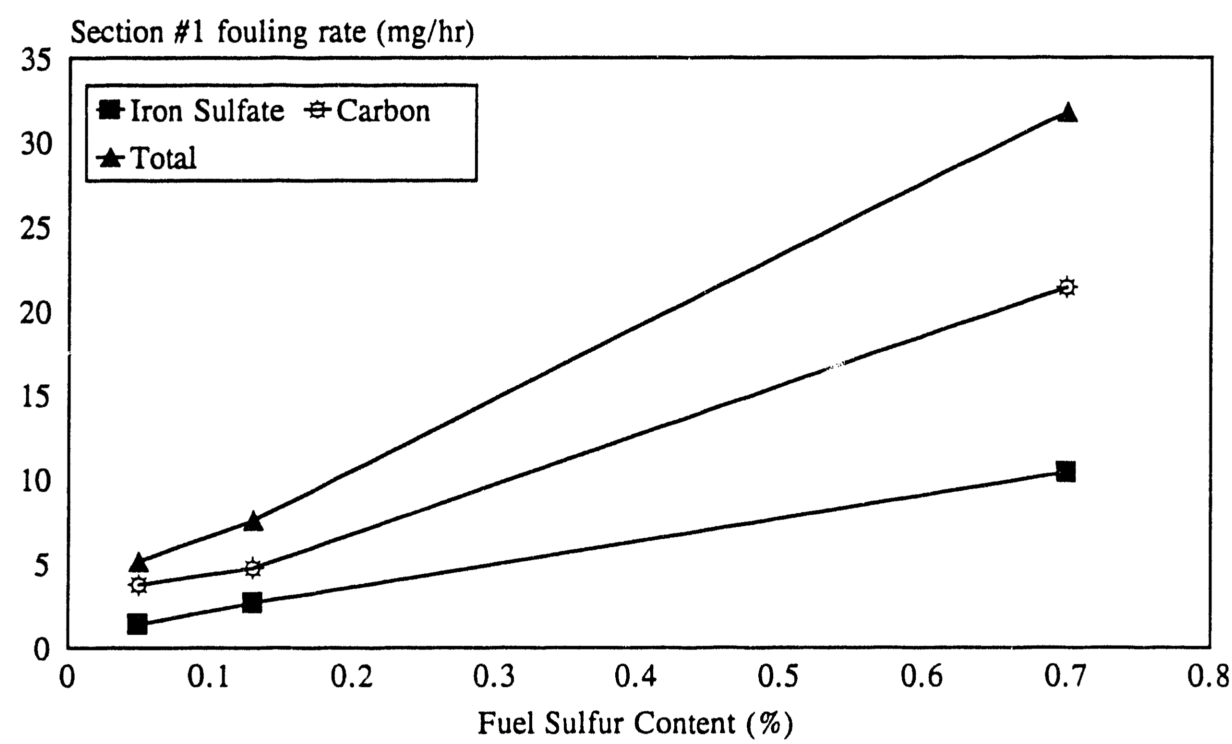

Figure 8. Effect of fuel sulfur on fouling - air cooled furnace sections. One of the four sections only. Showing carbon, iron sulfate and total deposit.

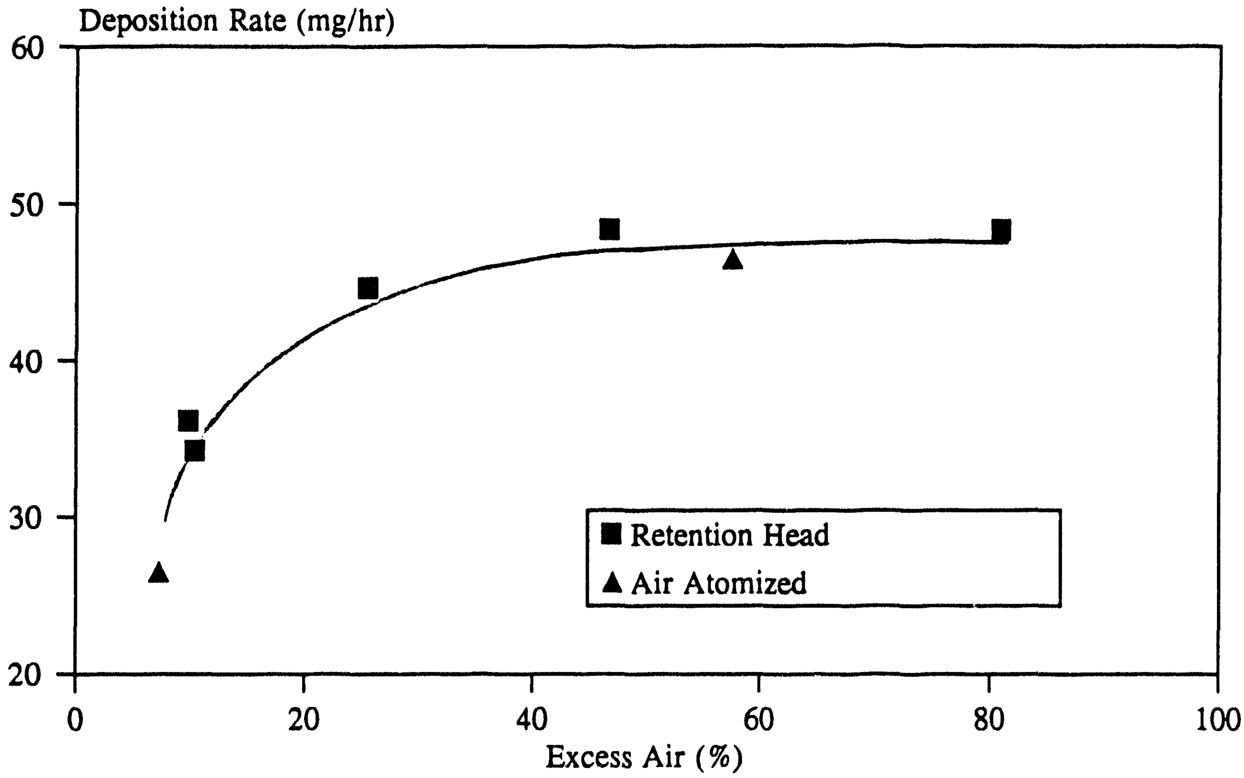

Figure 9. Effect of excess air on the total deposition rate. Cast iron test sections both a pressure atomized and an air atomized burner are shown.

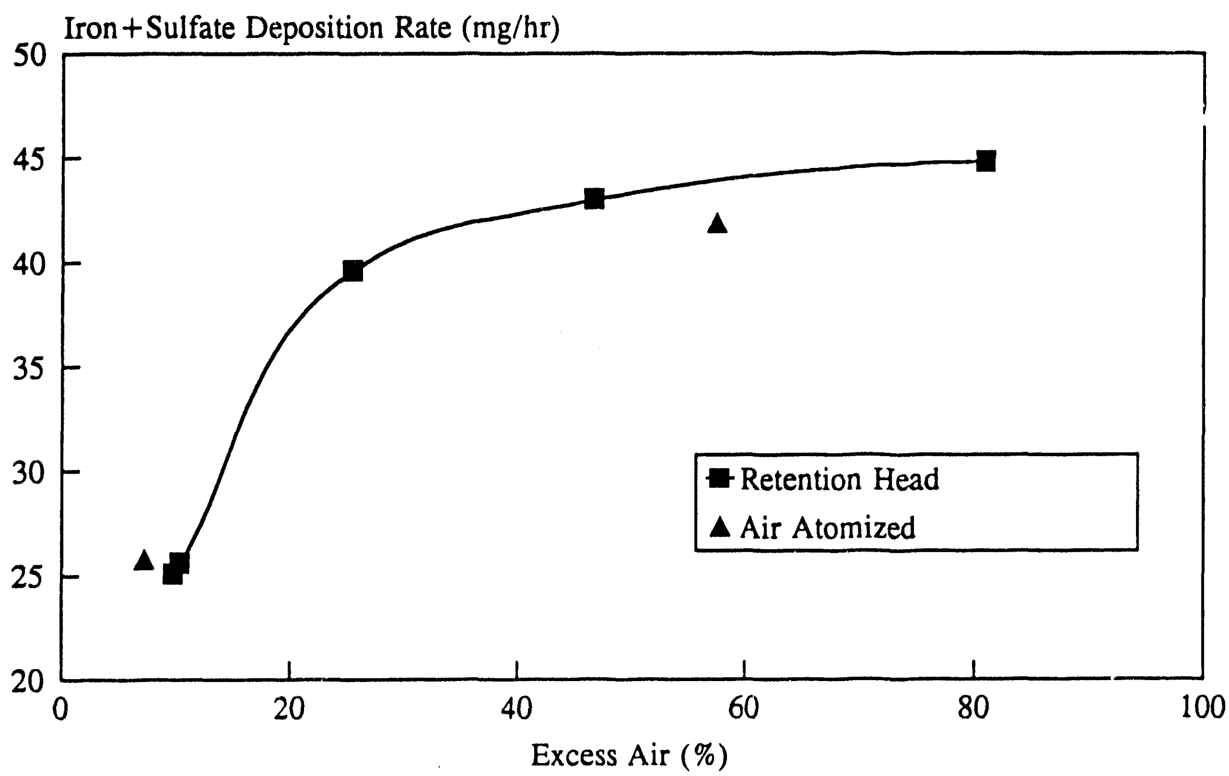

Figure 10. Effect of excess air on the rate of accumulation of iron sulfate deposit. Cast iron sections. Both pressure atomized retention head burner and an air atomized burner are shown.

Paper No. 93-11

AN ASSESSMENT OF FUEL OIL HEATERS

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AN ASSESSMENT OF FUEL OIL HEATERS

INTRODUCTION

The viscosity of No. 2 fuel oil affects heating equipment performance and varies as a function of fuel temperature. The nominal viscosity of No. 2 heating oil can range between 1.9 and 3.4 cSt (at 104 F) as specified by the ASTM. When fuel temperature decreases, such as during the winter season, the viscosity can increase substantially and poor atomization can occur. Methods to heat the fuel are sometimes used to maintain the viscosity to within the acceptable operating range. Nozzle line heaters are available commercially and can be used for preheating the fuel before it is atomized. These are designed as retrofit devices and, in some cases, as original equipment in a new burner. This paper describes work done at BNL to assess the benefits of such devices and other heating methods.

Experiments were conducted using fuels with temperatures ranging from 40 to 120 F. A home heating system or fuel supply which is stored in an unheated basement or outdoors can become as cold as 40 F and lower. In such cases, improved burner operation can be achieved if the oil is preheated. The maximum temperature may be practically set to the level when nozzle after-drip starts to occur. If the temperature is too high fuel oil can drip out of the nozzle assembly when the burner is off during cyclic operation. This is caused by the expansion and vaporization of hot oil at the nozzle tip.

EXPERIMENTAL

Several methods of preheating the fuel were evaluated. One unit available for retrofit consists of a small cartridge heater which clamps onto the fuel line just behind the nozzle. In a single stage unit, the electrical heating element is self-regulating. It is powered continuously and maintains a fuel line temperature of about 120 F. Another similar type of heater was also tested which is actually an integral part of the fuel line. Installation requires replacement of the nozzle assembly. This second unit has a two stage heater, one which is powered during the off cycle and a second, more powerful heater, which is powered only when the burner is on.

A modified version of the commercial heaters was made in the laboratory to provide flexibility for additional tests. The nozzle assembly and fuel line inside of the burner housing were wrapped with electrical heating tape and insulated. The electric power to the heater was controlled to achieve a range of temperatures. Thermocouples were installed to monitor the nozzle assembly and fuel line temperatures.

To quantify the effects on atomization from nozzle heating, measurements were made of the spray drop size distribution over a range of fuel line and nozzle temperatures. The drop size measurements were made using a commercial particle sizer based on Fraunhofer diffraction. Oil pumped from a conventional burner was either heated or cooled in a 4-foot long double pipe heat exchanger before being atomized. Circulating water from a controlled temperature bath was used to maintain the desired fuel temperature. The system was arranged to provide uniform temperature of the fuel line and nozzle assembly. Atomized fuel passing a laser measurement beam was collected in a vented chamber, which prevented drifting of the smallest drops back into the measurement beam and skewing the measured size distribution.

Another device which has been of considerable interest to the industry is described as an oil deaerator. This device is installed in a one pipe system and its primary function is to deaerate the oil before reaching the burner. It is basically a reservoir that is connected to the pump and to the tank by means of one suction line. Bypass oil is returned to the device where any air in the system is vented and returned to the pump along with fresh oil. The benefit of the design, as suggested by the manufacturer, is that nozzle afterdrip is reduced and combustion is improved. It was suggested that there are other added benefits because the device also preheats the oil by utilizing the gear friction of the pump. The effectiveness of this device for removing air was not tested, but only its effectiveness as an oil heater.

The standard ASTM smoke spot test was used to compare burner operation with fuel at varying temperatures. The smoke density was measured during the transient startup period when the burner turns on in a cyclic mode. The ASTM method was modified so that a continuous sample could be collected during the entire startup period. The total sampled flow volume was set to match the ASTM standard.

The effect of nozzle line heating on the rate of fouling of boiler heat exchanger surfaces was measured in some of the experiments. This was done using the Fouling Test Facility developed at BNL [1]. In this test combustion products were passed over special boiler heat exchanger sections which were maintained at carefully controlled temperatures. These small sections were easily removed after a test period and the mass of soot collected was accurately measured. The deposit was also analyzed for chemical constituents. The deposits from cast iron and steel boiler surfaces contain two primary components, iron sulfate scale and carbon.

RESULTS

Atomization Tests

The effect of variation in fuel line and nozzle temperatures on the mean drop size of a fuel spray is shown in Figure 1. Very large drops of oil are difficult to burn and contribute to most of the soot emitted in the flue gas. The percentage of large drops in a spray pattern determines the effectiveness of the atomization. Using a value of 84 microns to represent the cutoff for "very large" drops, Figure 2 shows the effect of fuel line temperature on this cutoff point. As the temperature increases with nozzle heating, the drop sizes become smaller and atomization improves.

Combustion Tests

The fuel flow rate is also affected by the fuel temperature. Tests were conducted in steady state operation to evaluate the effect of fuel line heating on flow rate. Figure 3 shows that fuel flow rate decreases significantly with higher nozzle temperatures.

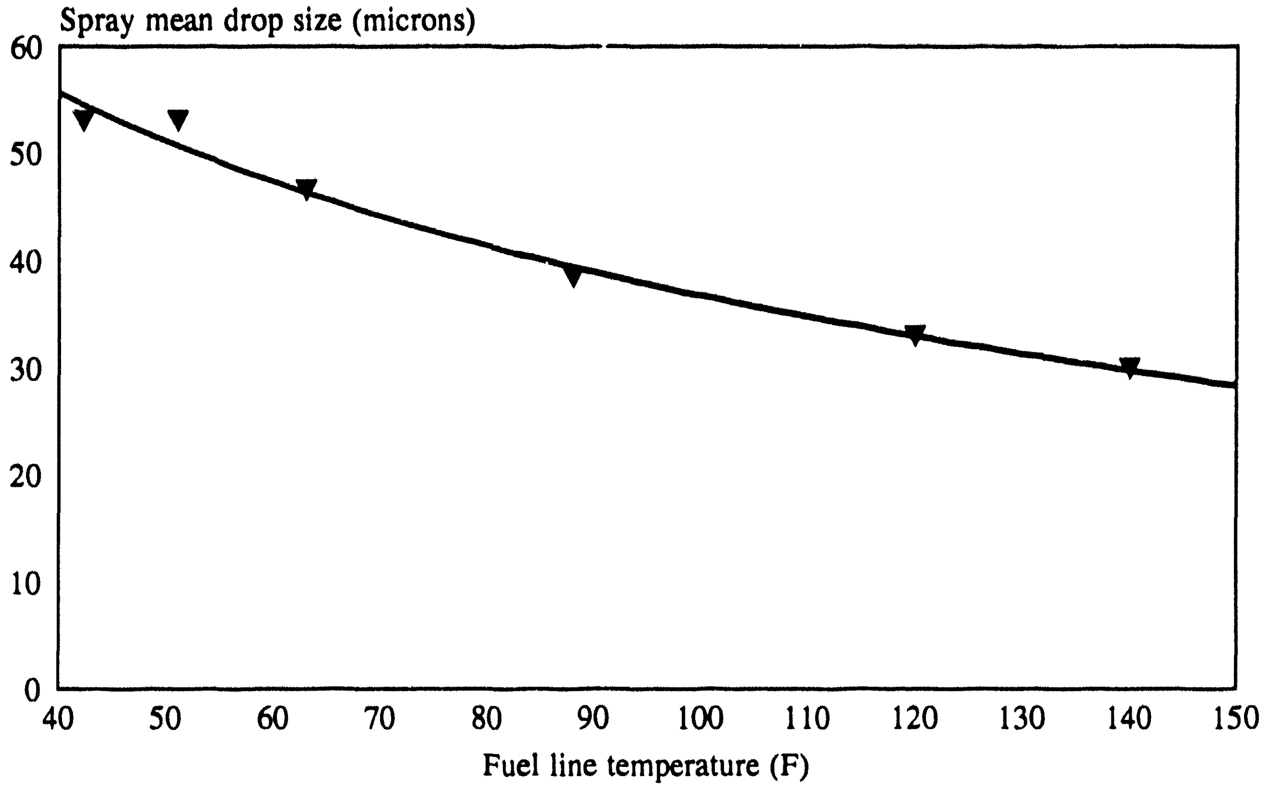

Figure 1. Effect of fuel temperature on spray mean drop size.

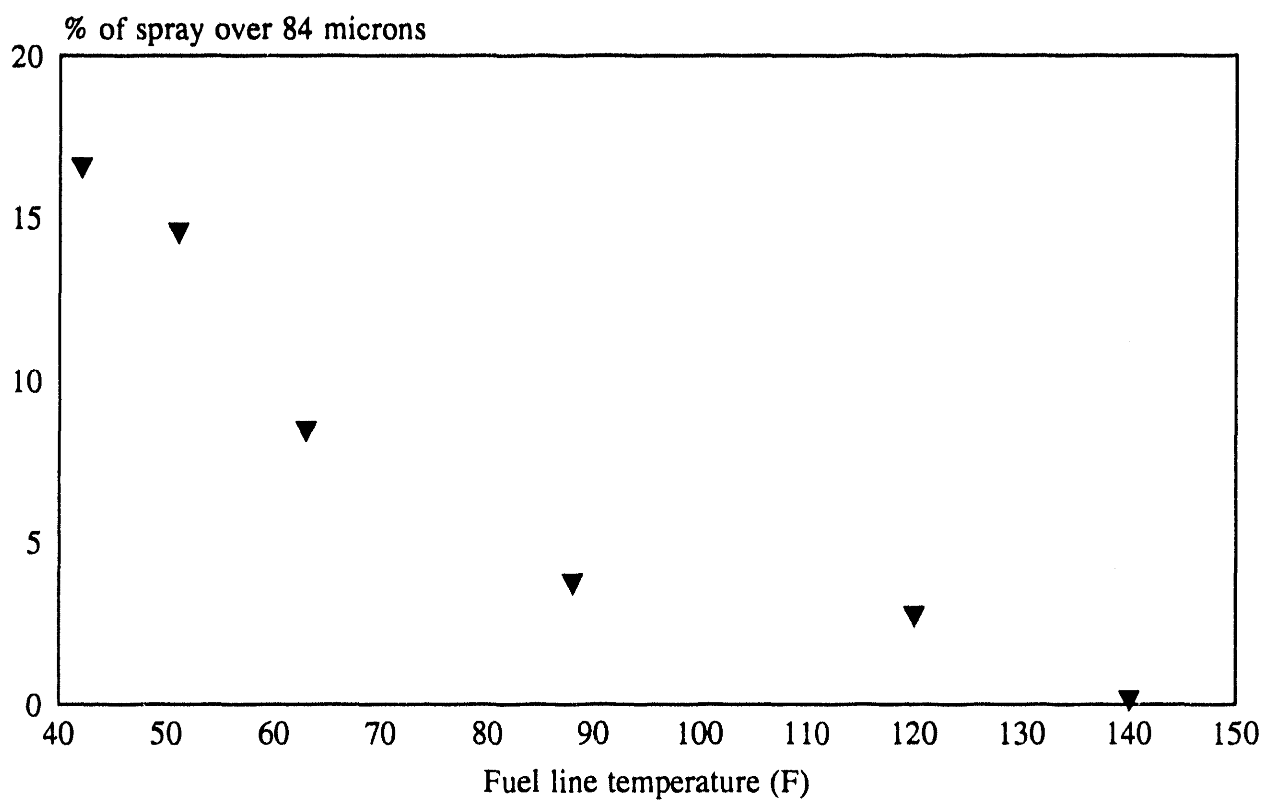

Figure 2. Effect of fuel temperature on fraction of large drops.

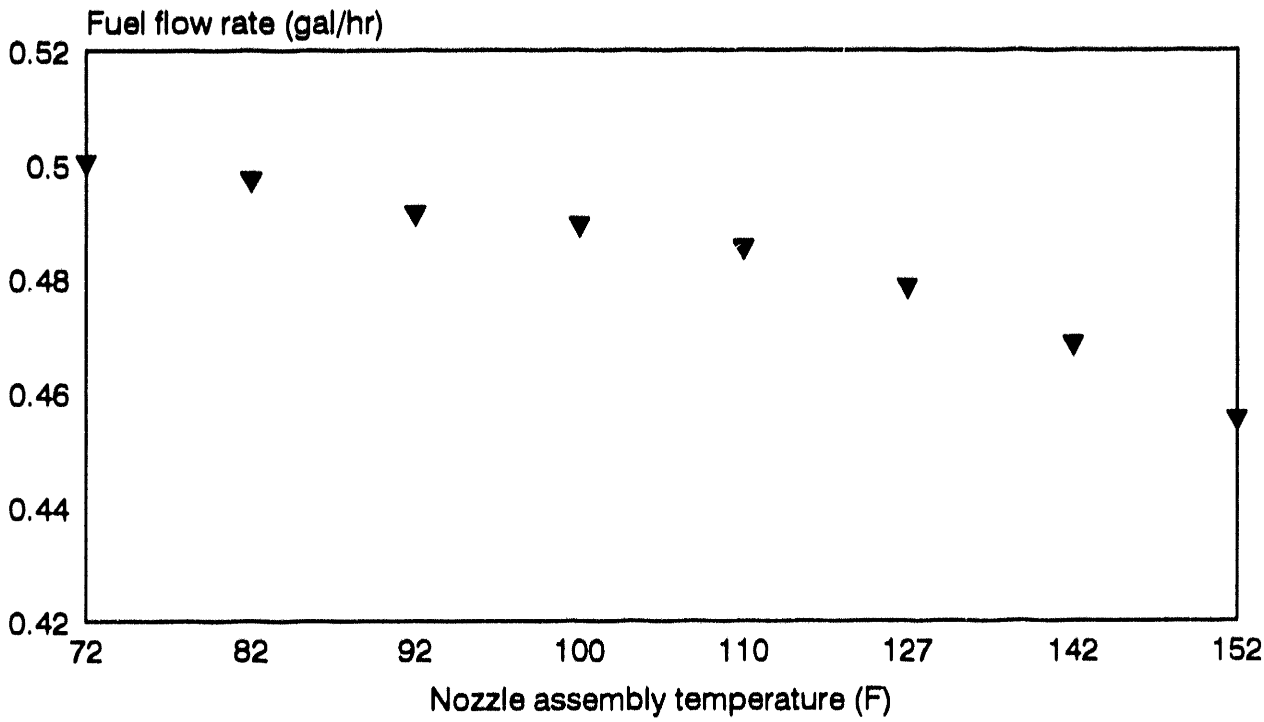

Figure 3. Effect of nozzle temperature on fuel flow rate. Steady state tests.

A series of tests were conducted with commercial nozzle heaters to measure the fuel line temperature, nozzle body temperature, fuel flow rate, and smoke numbers. Using the single stage heater, these measurements were made during cyclic operation with a conventional flame retention head burner. The tests were done in a cast iron boiler and at a firing rate of 1.0 gallon/hour. The laboratory was maintained at 60 F for these tests. A one hour cool down ("off") period between each "on" cycle was used to ensure consistent cold starts.

Figures 4 and 5 show fuel line and nozzle assembly temperatures during startup with and without the heater at a fixed steady state excess air level. This data shows that the heater "on" and heater "off" cases tend to converge in steady state. After 2 minutes of burner "on" time the difference between heater "on" and "off" temperatures was less than 20 F. Figure 6 shows the fuel flow rate versus time relationship with and without the heater. With the heater on there is roughly a 15% reduction in fuel flow at startup. The corresponding relative increase in excess air would certainly be expected to contribute to reduced smoke during startup.

Figures 7 and 8 show measured smoke numbers during the startup period with and without the heater at two different steady state excess air settings. These figures show a significant reduction in smoke numbers during the startup period, particularly in the higher CO_2 case.

The tests above were all conducted with an ambient temperature of 60 F in the laboratory. To evaluate performance at a lower ambient temperature, the burner area was enclosed in a box which was cooled with a chiller to 34 F.

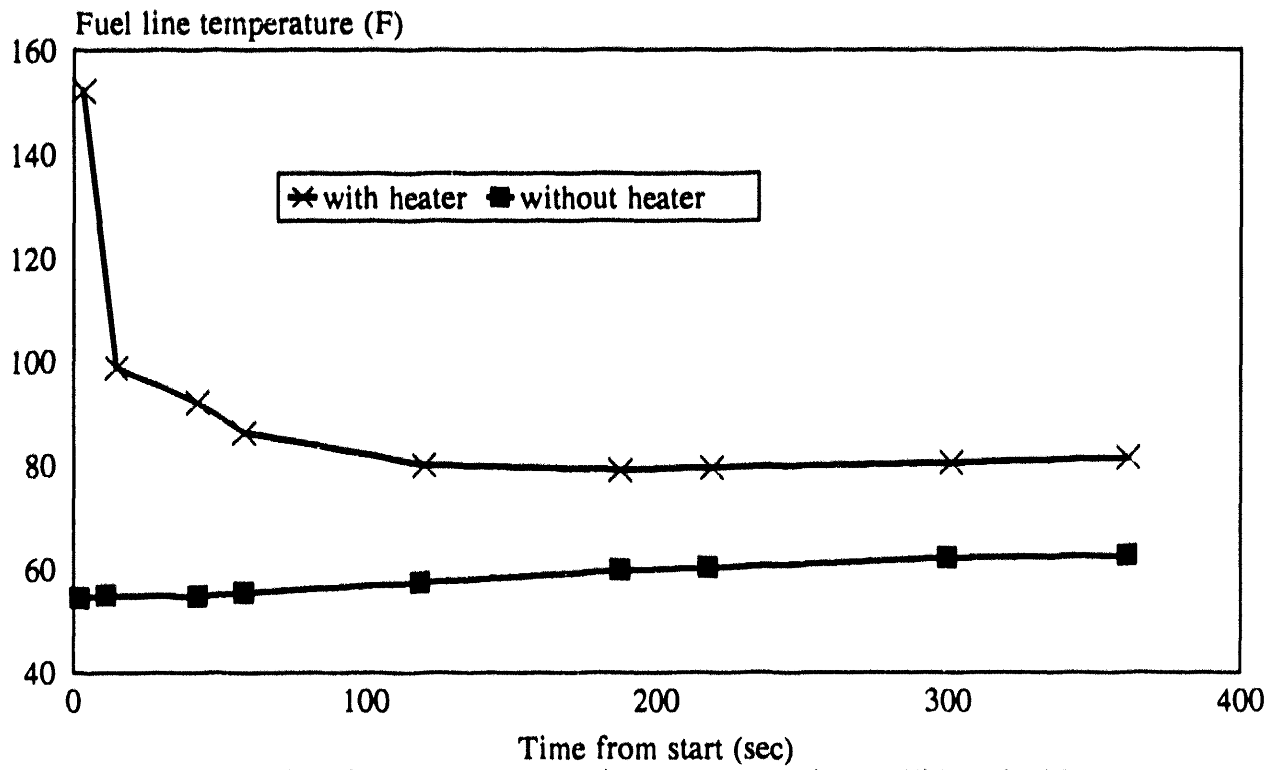

Figure 4. Trend in fuel line temperature during startup transient. With and without a commercial nozzle line heater.

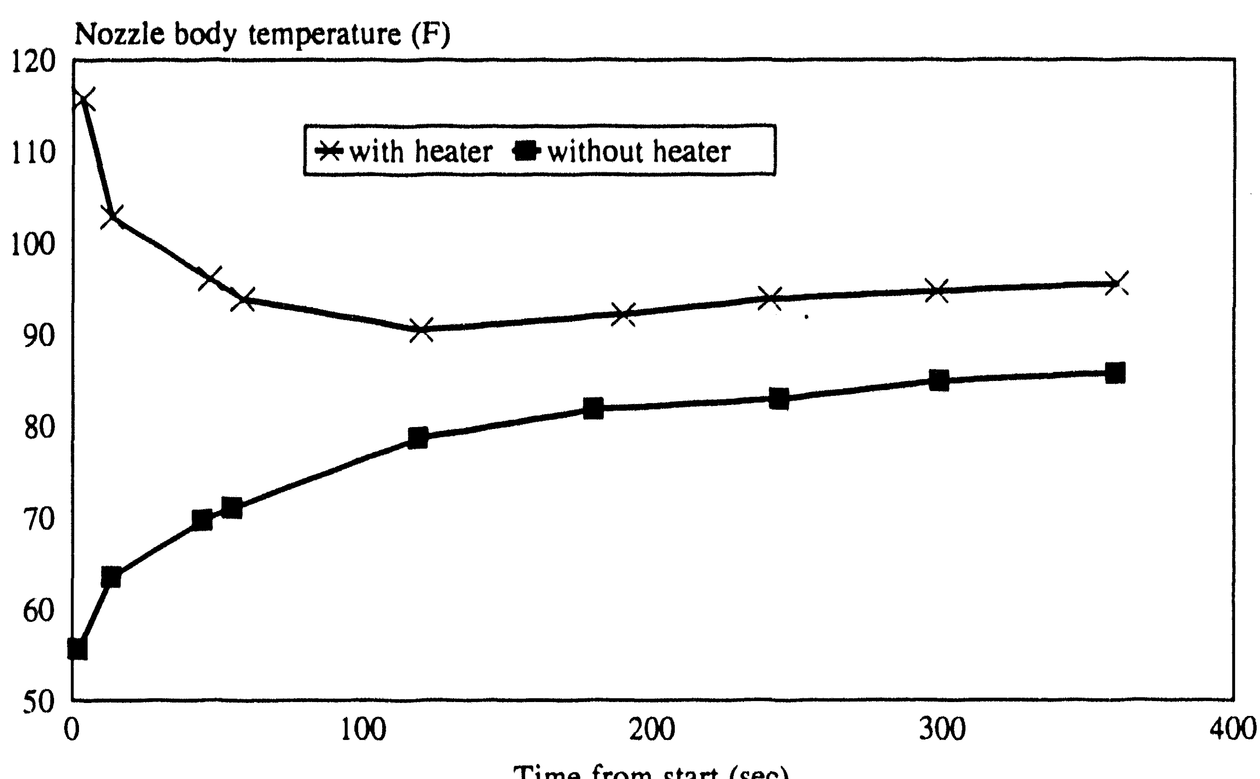

Figure 5. Trend in nozzle body temperature during startup transient. With and without a commercial nozzle line heate:.

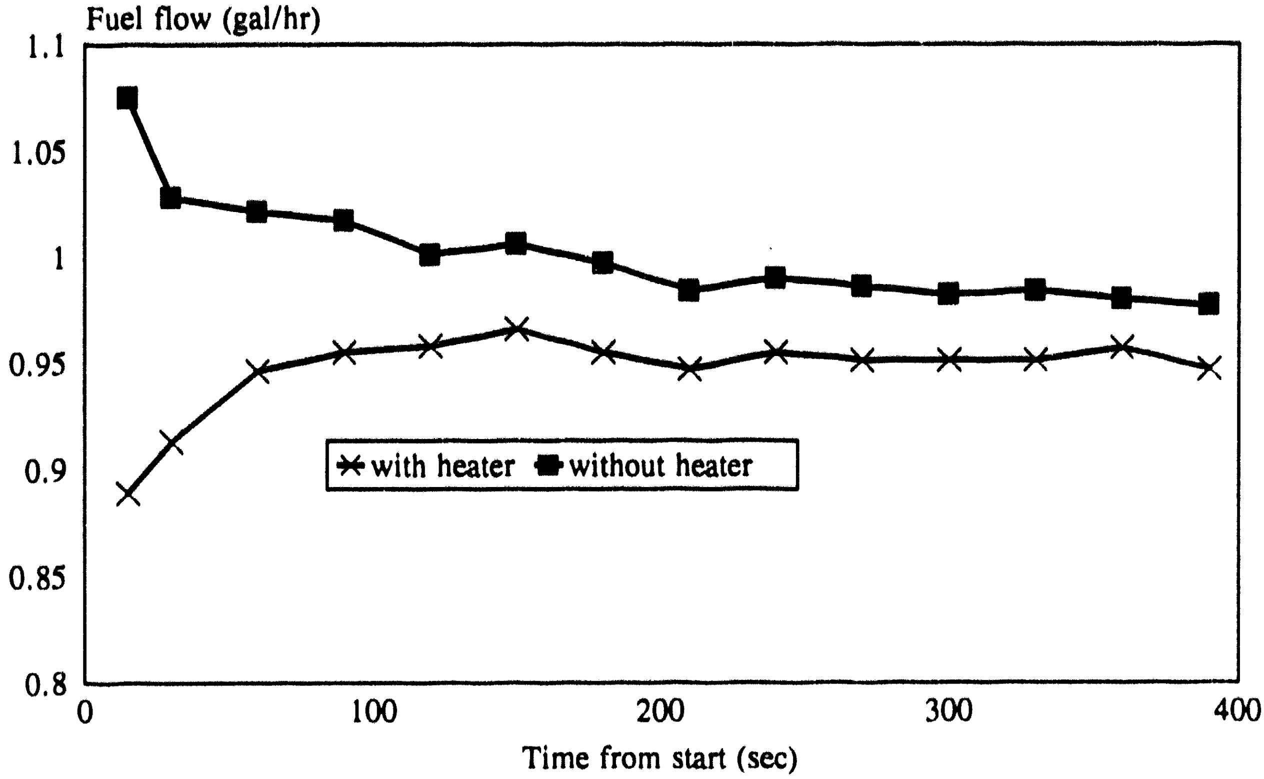

Figure 6. Trend in burner fuel flow during startup transient. With and without a commercial nozzle line heater.

Figure 9 shows the effects of the single stage nozzle heater on transient smoke numbers at this condition. This illustrates that at low temperatures the effects on transient smoke numbers generally become more important. The nozzle heater effectively reduced the smoke number.

While cold ambient air can clearly affect burner performance it is not clear that cold oil can. Assuming the oil can flow to the pump it will be heated at least partially in the pump. This heating would be expected to be greater in a one pipe system. A two pipe system would continue to pull cold fuel through the pump mechanism retarding any heating effects. Some tests were done to evaluate this case; the ambient temperature at the burner was cooled to 50 F and the oil supply was maintained at 32 F with an ice bath. Figure 10 shows the temperature of the oil measured at the pump discharge as a function of time during a typical firing cycle. Although the oil supply was initially cold the pump was capable of heating the oil and maintain it at a relatively constant temperature.

Fouling Tests

The fouling tests were done with an ambient temperature at the burner of 40 F. Two tests with a nozzle line heater at a high and at a low excess air level, and also two tests without the nozzle line heater at the same excess air levels were conducted. Figure 11 shows the results for the total fouling rate.

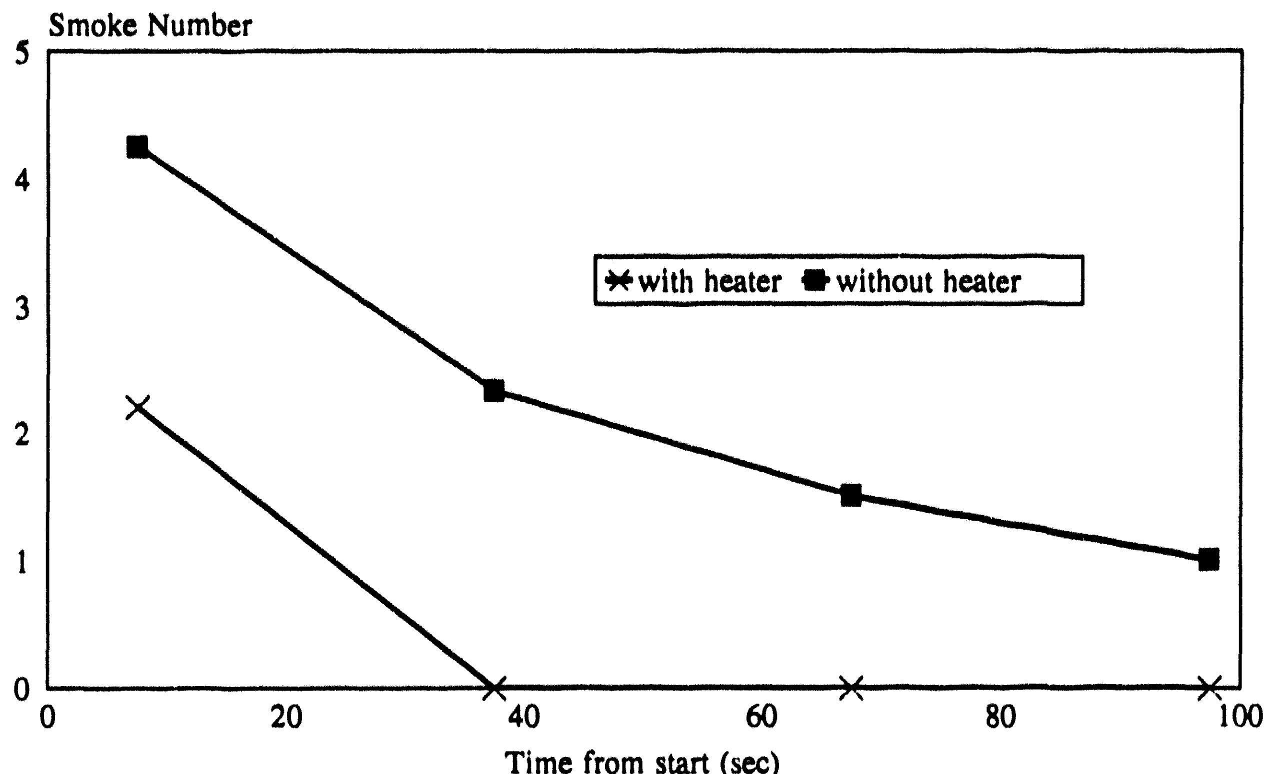

Figure 7. Smoke number during startup with and without nozzle line heater. Retention head burner -set with 12% CO_2, smoke number 0 in steady state

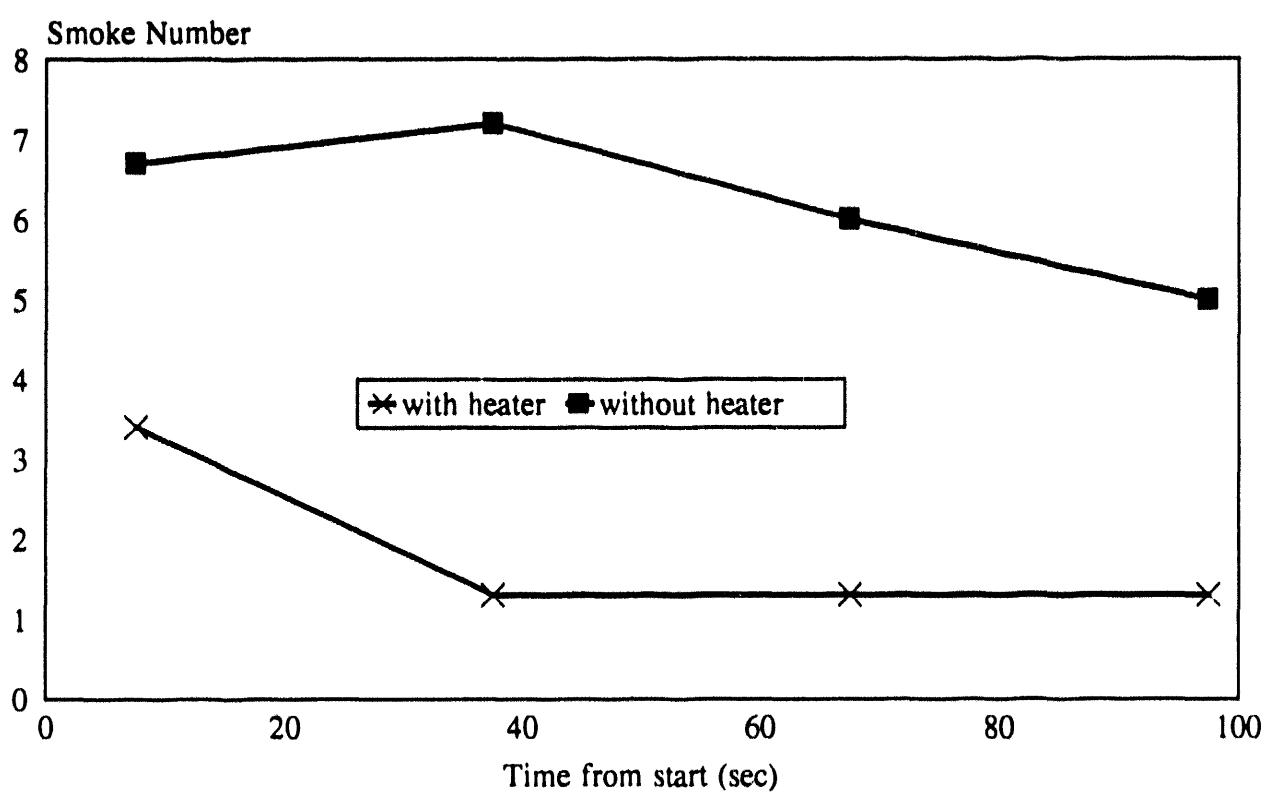

Figure 8. Smoke number during startup with and without nozzle line heater. Retention head burner - set with 13.4% CO_2, smoke number 2 in steady state.

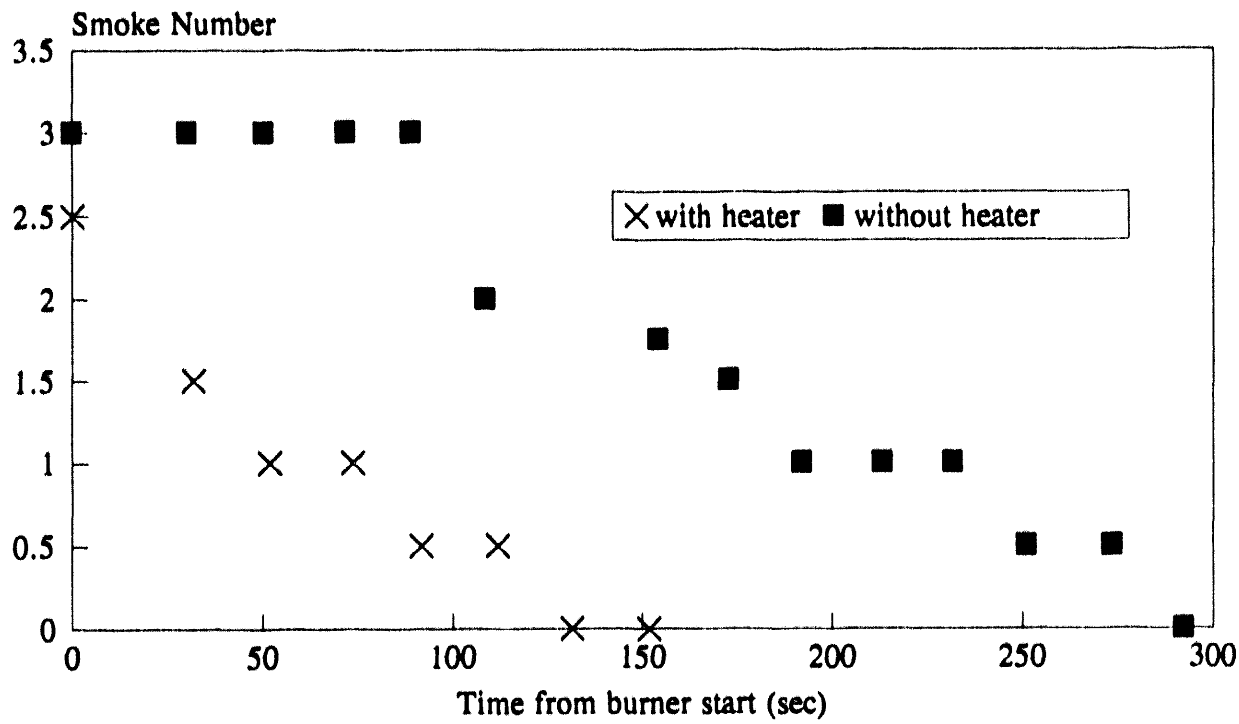

Figure 9. Effects of a nozzle heater on transient smoke. Burner ambient at 34 F. Retention head burner

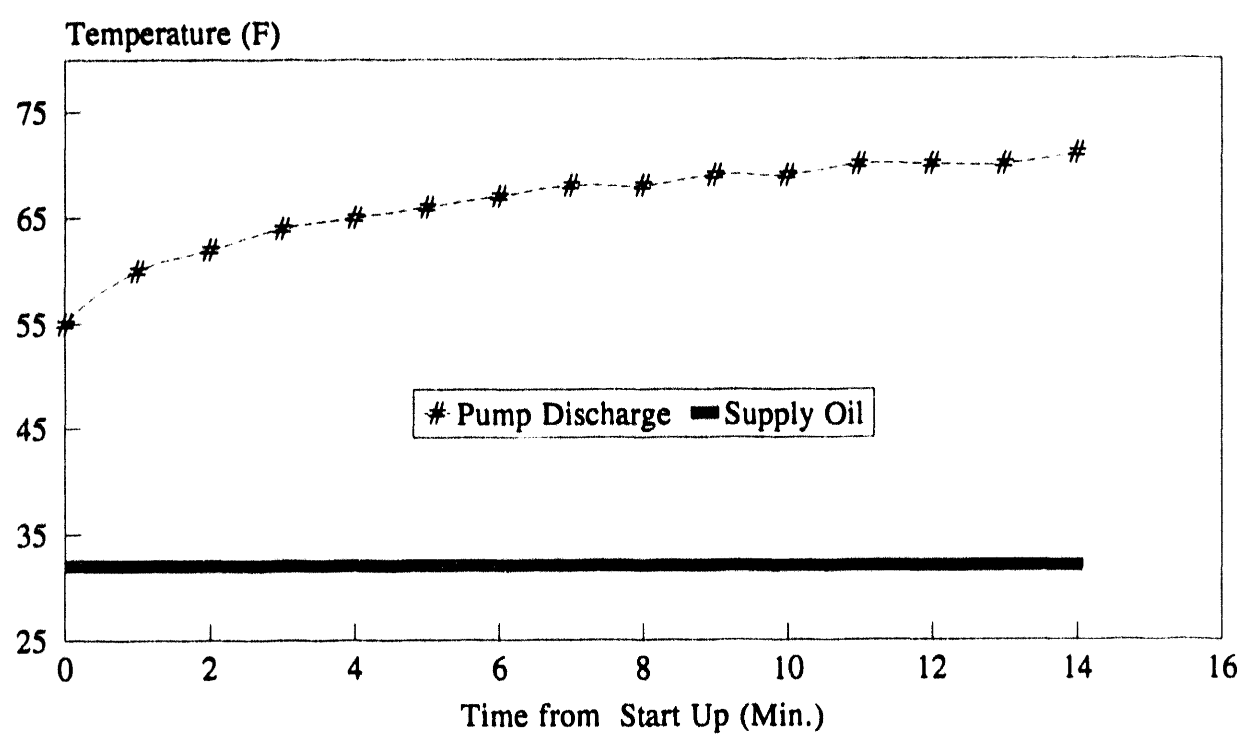

Figure 10. Illustration of oil heating in the fuel pump during transient operation. One pipe system.

At the high excess air level (25%) the nozzle heater does not affect the total deposition rate. At the low excess air level (6%), however, there was a significant reduction in fouling with the addition of the heater. The smoke number at the low excess air level was #1 and at the high excess air level it was #0. Figure 12 shows the deposition rate for the iron sulfate (scale) part of the total deposit. Using the heater did not significantly affect the scale deposits. Clearly the heater was effective in reducing only the carbon part of the deposits when the burner is set to very low excess air levels. The benefit of using a nozzle heater would be to allow burner operation at lower excess air levels with less fouling due to soot produced during transient operation.

The two stage nozzle heater tested maintains the fuel temperature at about 120 F during the off cycle, which is about the same as the single stage unit. When the burner is firing the electrical power input increases significantly, and the oil temperature is raised even higher. In tests with a conventional flame retention head burner at an ambient temperature of 40 F no improvement in steady state performance was observed. The benefits of the two stage unit can be realized with just the single stage heater.

Tests of the deaerator, described earlier, were done with a one pipe arrangement. The purpose of these tests was to determine the extent of preheating, the time required to reach steady state, and the overall effectiveness of preheating. Temperatures were monitored of the oil supply, the oil from the deaerator to the burner, the oil returning from the pump to the deaerator, and the nozzle tip. Measurements were made for three different operating conditions: cold start, cyclic 5 min on/30 min off, and cyclic 5 min on/10 min off. Results of the measurements made during just one of these tests, the cold start test, are shown in Figure 13. The results of all of the tests basically show that the deaerator is not very effective in heating the oil during the most critical period which is roughly the first two minutes of burner operation. As was shown earlier, the pump alone in a one pipe system is fairly effective in providing about the same level of heating as the deaerator. The primary advantage of this device remains air removal.

DISCUSSION

During the first two minutes of burner operation in cyclic mode, performance is improved with the use of nozzle line heaters. This results from both improved atomization and reduced fuel flow. The reduced fuel flow provides a relative increase in excess air at a time when it is needed during the startup transient. In earlier studies at BNL the use of increased excess air during startup was tested and demonstrated as a soot reduction method. Those tests were done using a simple burner modification [2].

For a typical system in the field where the heating unit is located in a space which does not experience very cold temperatures and the excess air is set far above the steady state smoke level, the benefits of the nozzle heater are small. However, in cases where the excess air is set very low during steady state the nozzle heater is quite effective in reducing transient smoke emissions. This is an important point. In any strategy to improve heating system efficiency through excess air reduction, the use of nozzle heaters to improve long term reliability could be significant. The results from prior BNL fouling studies show that a major cause of degradation of boiler efficiencies over time results

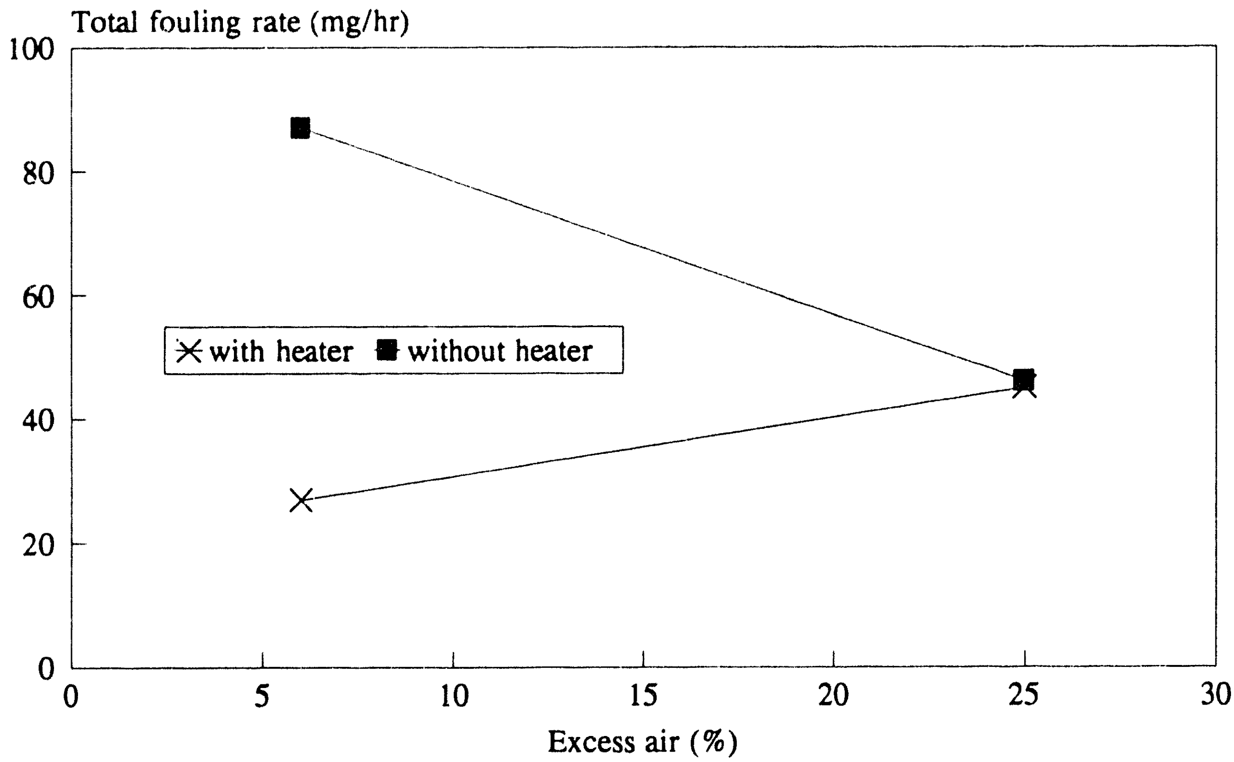

Figure 11. Effect of a nozzle line heater on heat exchanger fouling rate. BNL Fouling Test Facility. Burner ambient at 40 F.

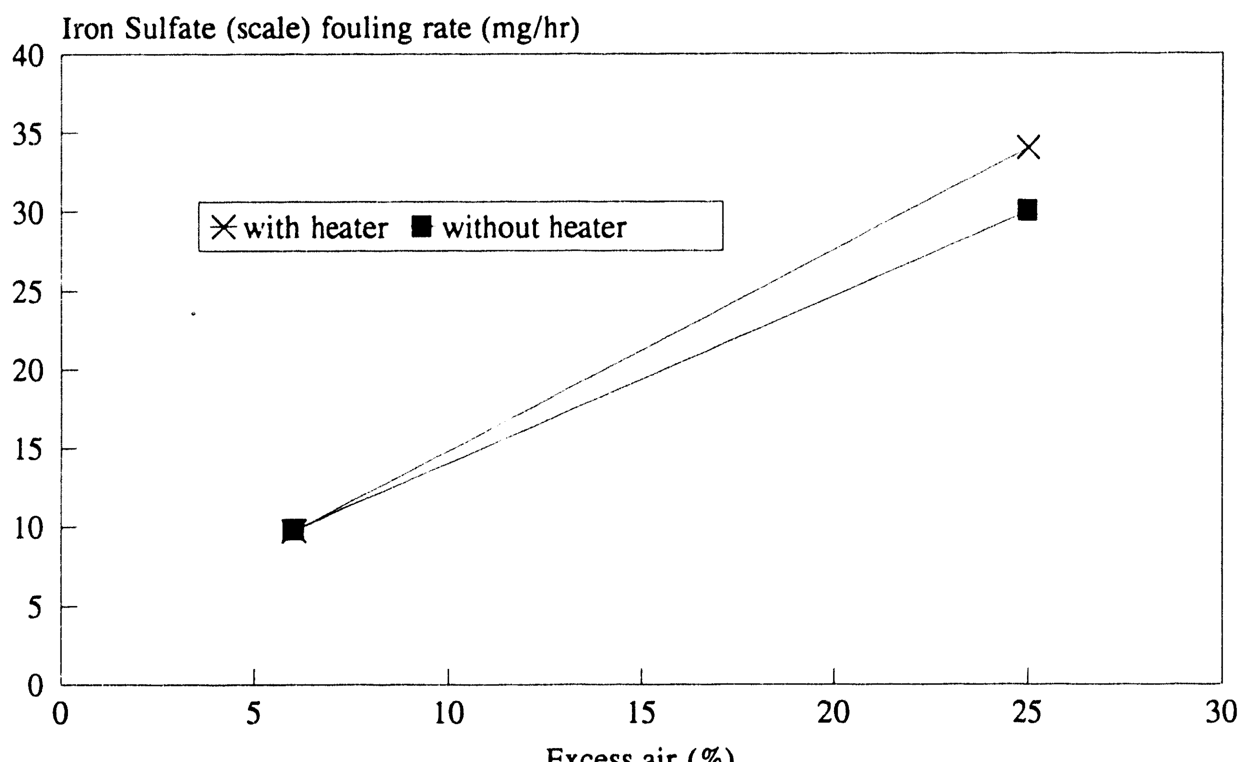

Figure 12. Effect of nozzle line heater on rate of formation of iron sulfate scale on heat exchanger surfaces. Burner ambient at 40 F.

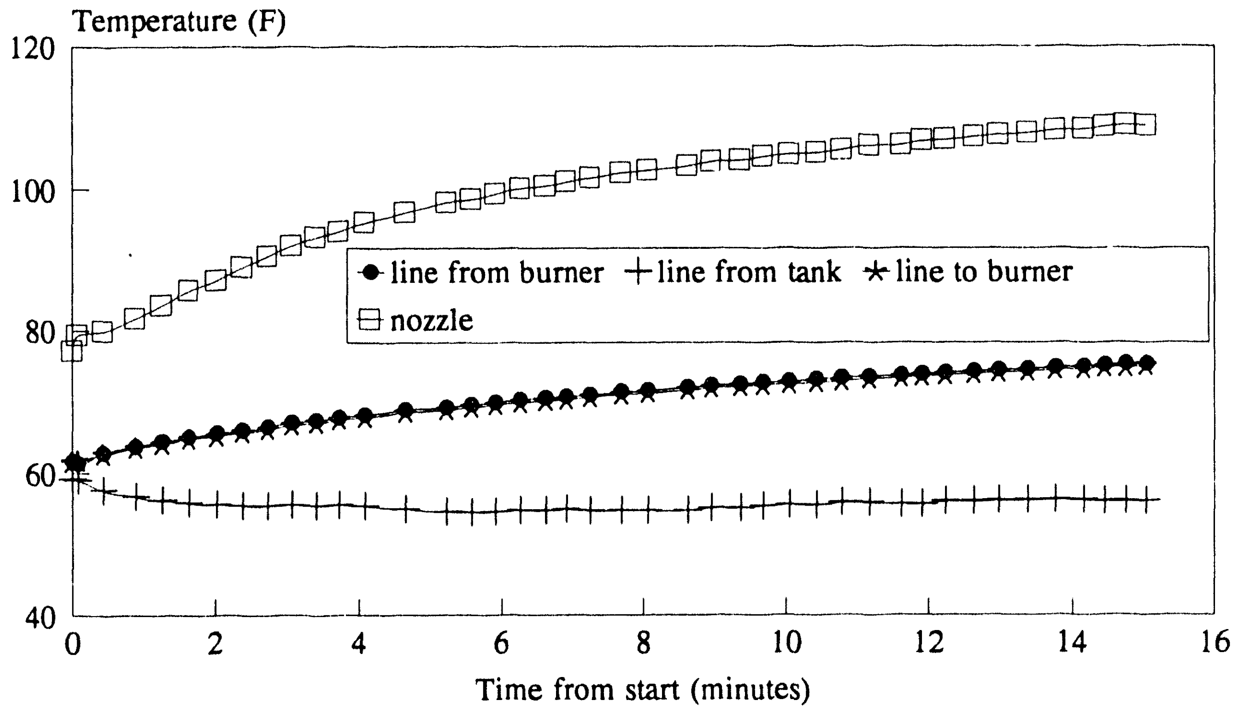

Figure 13. Illustration of some startup temperature trends with an oil deaerator.

from iron sulfate scale deposition which is a function of the excess air levels. Operating at very low excess air levels can reduce the rate of production of this scale. The nozzle line heater allows the burner to be operated with less excess air.

Assessing the maximum efficiency gains which might be realized when nozzle heaters are used in the field is difficult. Operating a burner at reduced excess air levels with the use of a nozzle heater would improve the efficiency under steady state conditions. For example, if an excess air level is set at 45% (10.5% CO_2) without the nozzle heater, the excess air level may be adjusted to 25% (12.3% CO_2) with the heater. Depending upon stack temperature at both excess air levels, the efficiency would improve by about 1.5% during steady state. In the field, this efficiency gain can be realized only if the burner is serviced and adjusted in the correct and consistent manner. That is, the burner must be adjusted to the lower excess air level when a nozzle heater is used, and not adjusted if there is no heater.

A second possible source of efficiency improvement with the nozzle heater is reduced degradation of efficiency during the heating season. This is usually considered to be about 2% per year and this puts an upper bound on the maximum efficiency improvement which might be realized by the end of the season. Assuming annual cleanings and considering that the efficiency degradation is not present for all of the season, an approximate efficiency improvement potential is 1%. The combined efficiency improvement potential with both reduced excess air and reduced fouling is about 2.5%.

CONCLUSIONS

- Nozzle and fuel line heating devices used to preheat "cold" oil can maintain consistent viscosity of the fuel to within an acceptable range, improve atomization and reduce nozzle fuel flow rate.

- These heaters are most effective during the first two minutes of burner operation. The combined effects of improved atomization and reduced fuel flow rate (with relative increase in excess air) during this period leads to reduced transient smoke.

- The benefits from the use of the nozzle heaters are evident when the burners are set for very low excess air levels. Under these conditions fouling rates are reduced over long term use.

- In a one pipe system, the recirculation of oil within the pump housing is fairly effective in warming "cold" fuel oil. However, the rate and extent of heating is inadequate during the startup period when it is most needed. Adding an external deaerator does not provide more heat.

- The potential efficiency gain with the use of nozzle heaters is estimated to be 2.5%. Achieving this gain requires that service personnel set excess air to lower levels with the addition of a nozzle heater.

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2. Butcher, T., McNeill, F., Celebi, Y., and Wegrzyn, J., Impact of Burner Design Features on Sooting in Residential Oil Fired Systems, BNL Report 52102, November, 1986.

Paper No. 93-12

Advanced Air-Atomized Burners

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ADVANCED AIR-ATOMIZED BURNERS

INTRODUCTION

Domestic oil burner designs in the U.S.A. have long been limited by the relatively low cost of oil so that the high initial cost of advanced technology to provide the efficiency gains was hard to justify. Another limitation has been caused by the lack of reliability of the conventional pressure-atomized nozzles used at rates below 0.60 gph oil input. Although the typical heating load of many homes today ranges from 0.25 to 0.60 gph, these homes are usually fired at inputs of 0.75 to 1.00 gph or higher.

Work at BNL during 1990 and 1991 has identified and demonstrated the possible feasibility of an air-atomizing nozzle that uses relatively higher air volume but at much lower pressure than other air atomizers. This allows the use of a blower to provide both atomizing and combustion air, eliminating the need for an air compressor. Mr. Fisher, a BNL consultant and an expert in oil burners, advised BNL of the strong potential of this new concept, not because the burner would cost less, but that it could be justified when all its assets are considered:

- Low input range with reliability
- Low excess air (High CO_2)
- Low NOx
- Low CO
- Low SO_3, hence low H_2SO_4 effluent
- Small, intense flame
- Insensitivity to draft
- Less sensitive to fuel properties

More recent studies at BNL have shown that both corrosion of and soot deposition on the heat exchanger are reduced by low excess air (high CO_2) operation. So the ability to operate reliably at low excess air allows both higher initial and longer sustained efficiency as well as fewer cleanup servicings.

During its fiscal year of 1992 (Oct-Sep) the BNL staff with some guidance from Mr. Fisher as a consultant undertook this project of demonstrating the feasibility of such a burner through iterative ("cut and try") design, test, data analysis and redesign, using a high pressure blower and the special air atomizer with No.2 fuel oil.

OBJECTIVE

The objective was to develop and demonstrate the feasibility of a new and superior low input burner prototype with the following performance characteristics:

- Firing rate range: 0.30 to 0.60 gph
- Zero smoke at less than 10% excess air
- Below 50 ppm NOx effluent
- Below 30 ppm CO effluent
- Below 0.2 ppm H_2SO_4 effluent
- Burning intensities of over 5×10^6 Btu/ft^3 hr

- Insensitivity to draft variations
- Reduced sensitivity to fuel properties

The nozzle used was provided by The Gas Turbine System Division of Parker Hannifin Corporation with some help and direction provided Mr. John Gaag, Manager of Advanced Technology in Cleveland, Ohio. It was developed by Parker Hannifin in a joint project with the General Motors Corporation to heat air and clean a catalytic filter used to reduce particulate concentration in diesel engine exhaust.

A schematic showing the principle of operation of the atomizer is shown in Figure 1. Air at a pressure of 10-20 inches of water enters the back. Most of the air passes through the outer swirler and spins out through the main exit orifice. A smaller amount passes through four small offset holes providing counter-swirling air. Fuel entering at the centerline flows out through three small holes near the tip where the swirling air distributes and swirls the oil, prefilming it as it leaves the inner orifice. The two counterswirling vortices shear the sheets and ligaments of fuel into a conical spray which is mixed with about 3-4 cfm atomizing air, depending on its initial pressure.

The blower used in this project at BNL was provided by the Lamb Electric Division of Ametek in Kent, Ohio. It is designated as a single stage, hi-flow (No. 116637-01 "Windjammer"). It utilizes a single backward curved wheel driven by a brushless DC motor with a DC power supply and controller. The blower speed can be controlled and the operating pressure set at from 1" to over 20" WC and at the flows required for both atomizing and combustion processes (5-20 scfm).

DESCRIPTION OF THE PROTOTYPE

The prototype configuration shown in Fig. 2 is the result of many iterations including changes in air pressure, flame holder design, secondary and tertiary air velocities, electrode design and spark location, burner diameter, and location of the retention ring behind the end cone.

Referring to Fig. 2, the mechanics of the burner operation are as follows:
From an elevated tank No. 2 fuel is metered through a calibrated rotameter into the fuel line 14 and into the nozzle 6 described above. Air from the blower is ducted through a hose to the top connector shown. Its pressure is regulated via blower rpm. The air distribution in the airtube is very uniform because of the high pressure drop across the burner head. This is an important factor in achieving good performance at very low excess air levels. At 15 inches of water the primary air through the nozzle swirlers and orifices flows at about 4 scfm and does an adequate job of atomizing the oil at rates of .25 to .60 gph. The spray angle is about 70 degrees. Complete combustion of oil requires about 24 scfm of combustion air at 1.00 gph. This means that at .25 gph the nozzle provides 4 of the 6 cfm needed for completion leaving 2 cfm as the secondary air requirement. The secondary air is metered through four orifices in the metering plate 7 and then through four louvers in the retention ring 5 which provides swirl in the same direction as the nozzle air swirl. The orifices were sized to provide under 2 cfm at 15 inches of water with some allowance for leakage air and little or no tertiary air when firing .25 to .30 gph. Tertiary air is controlled by adjusting the head positioner 19 on the back of the burner. This moves the entire internal assembly which varies the pressure drop in two places:

first around the orifice plate 7 and second at the exit between the tube 10 and the air cone 3. When set at the full forward position the head will allow no tertiary air flow barring leakage. So at .25 gph the primary air (4 cfm) plus the secondary air (2 cfm) provides only the theoretical air while the tertiary air can supply excess air by the thumb screw adjuster 19. At higher inputs the primary air (4 cfm) plus the secondary (2 cfm) remain essentially constant and the deficit is made up by the tertiary air. Firing at 0.60 gph requires 0.6 x 24 - 14.4 cfm or more total, or about 8.4 cfm or more tertiary added.

OPERATING PRINCIPLES AND CONCEPTS

The requirements for stable, intense, complete and clean combustion of oil includes the following:

- Adequate atomization of the fuel
- A hot spark located at the perimeter of the fine spray
- A stable initial vortex or bubble to provide a well stirred reaction zone and providing recirculation into the initial fuel spray cone to quickly evaporate the fuel
- Injection or induction of air into the vapor-rich zones as soon as they occur (not too soon where liquid drops need heat)
- An air and flame pattern that will foster plug flow
- An air-tight combustion chamber just large enough and long enough to avoid impingement
- For low NOx a high axial velocity air and flame jet pattern is also needed to induce cooler combustion gasses into the reaction zone so as to reduce the flame temperature even at near stoichiometric conditions.

Referring to Fig.3 the prototype burner is shown in a combustion chamber perceived to be about proper (6" diameter x 6" long) for this burner. The atomization is similar to that of a simplex pressure nozzle at 100 psi except that it is admixed with about 4 cfm of high velocity air in a conical vortex. The hot spark is located at the spray's outer envelope. Swirling secondary air increases the vorticity of the nozzle air to promote a torroidal vortex that recirculates hot combustion gasses (hot CGR) into the spray cone and accelerates the evaporation process while stabilizing the flame. Tertiary air is injected into the vapor-rich envelope and the flame and after-flame reactions go to completion in the microscopic eddy mixing area of the plug-flow zone. Besides shaping the flame into a short ball the tertiary air jet induces cool combustion gasses to recirculate (cool CGR) into the reaction zone and reduces the flame temperature. This would be especially true in a water cooled combustion chamber without any refractory liner. Here lower NOx emissions would be expected.

RESULTS OF PERFORMANCE TESTS

Most of the testing was done in a wet base steel boiler with a 10" diameter by 20" long water backed unlined combustion chamber that discharged into a square flue collector and up into the return tubes above, then out the front. The over fire and flue drafts were maintained at +.01 to +.02 inches of water to prevent any infiltration of air into the flue gas sampling probe. The boiler water exit temperature was kept at 140 to F.

Overall, the performance met the proposed objectives as follows:

- Firing Rate Range 0.30 gph to 0.60 gph
- Zero smoke at 5% excess air (1% O_2)
- Below 50 ppm NOx
- Below 30 ppm CO
- Burning intensity over $5x10^6$ Btu/ft^3 hr
- Insensitive to large draft variations

SO_3 and sulfuric acid effluent were not analyzed but typically it would be a function of excess oxygen in the flame which was very low. The sensitivity of the burner to fuel specifications was not measured in work to date but is planned.

RECOMMENDATIONS FOR THE NEXT PHASE OF THE PROJECT

There was one problem with the burner at the lower firing rates. Ignition and flame stability were weak at rates below 0.40 gph. It is believed that the strong aspirating effect of the atomizing air is inducing too much cool excess air from the combustion chamber into the already vapor-lean vortex in front of the nozzle. This problem should be addressed as follows:

- Modify the nozzle to produce good atomization with less air flow.
- Try lower air pressure for atomization.

Since this effort was basically a feasibility study, the next phase will need to bring the design to a point that would prove its ability to be commercially viable and attractive to a burner, furnace, or boiler manufacturer. It would include an integration phase as follows:

- Finalize the nozzle and burner head design. Consider using a two stage blower to provide 3 cfm at 10 to 20 inches of water and the remaining 14 cfm at 2 to 4 inches of water so as to reduce the electric power required.
- Enlist the help of a fuel unit company to provide a metering pump that will also provide lift. Also look at the potential of a solenoid pump.
- Evaluate the flame signal for use with a cad cell flame sensor. If the signal is not adequate, evaluate alternatives.
- Build and demonstrate an integrated burner that would be of interest and commercially attractive to a manufacturer.

ACKNOWLEDGMENT

The authors would like to acknowledge the assistance obtained from Yusuf Celebi who was responsible for all of the burner testing.

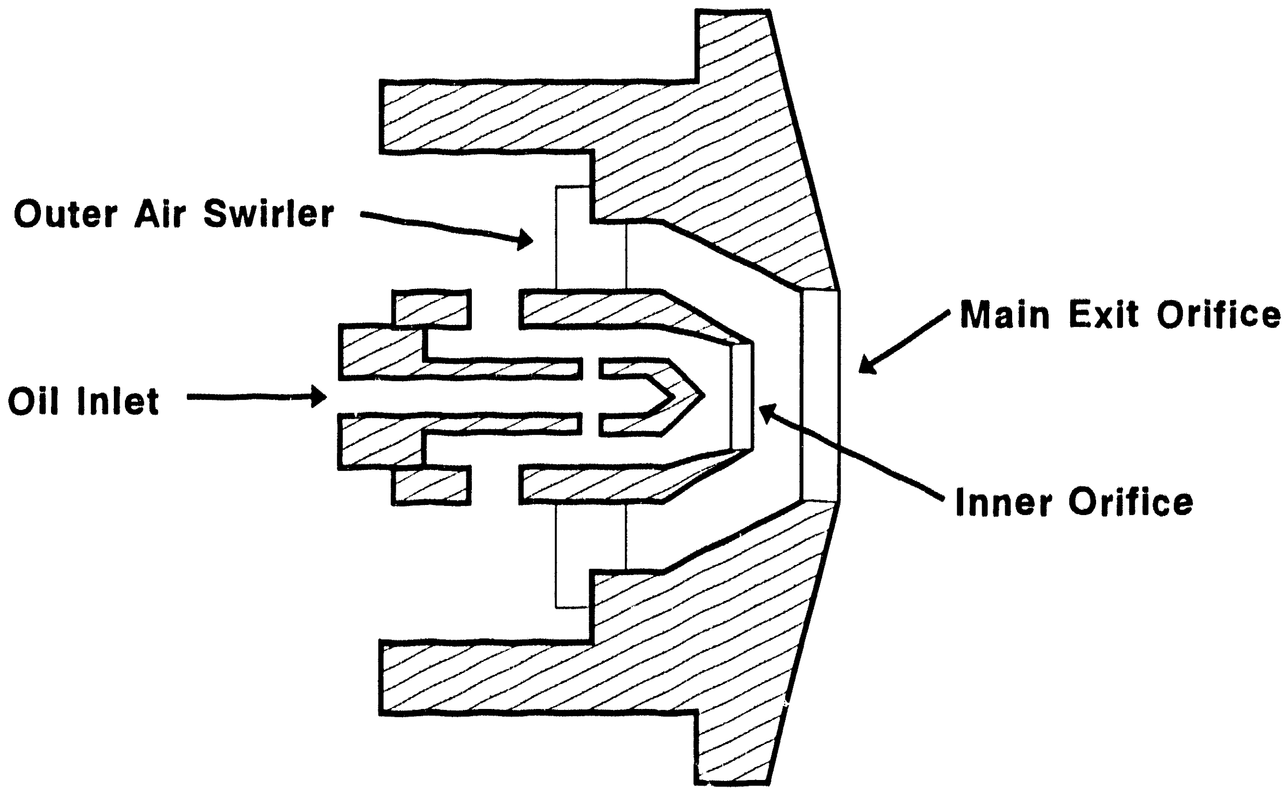

Figure 1

Schematic Drawing of Low Pressure, High Volume Air Atomizer

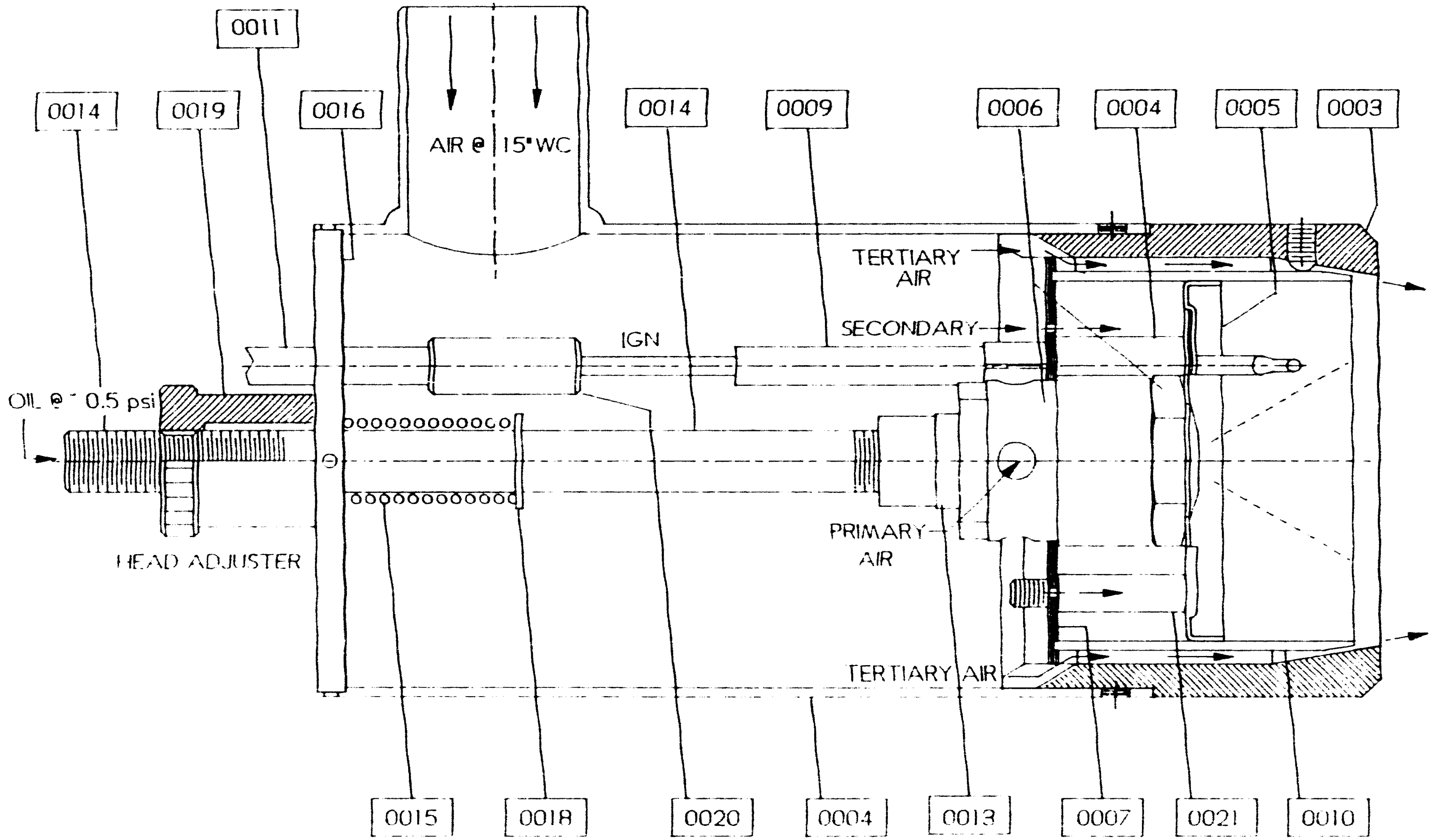

Figure 2. Illustration of Burner Internal Arrangement

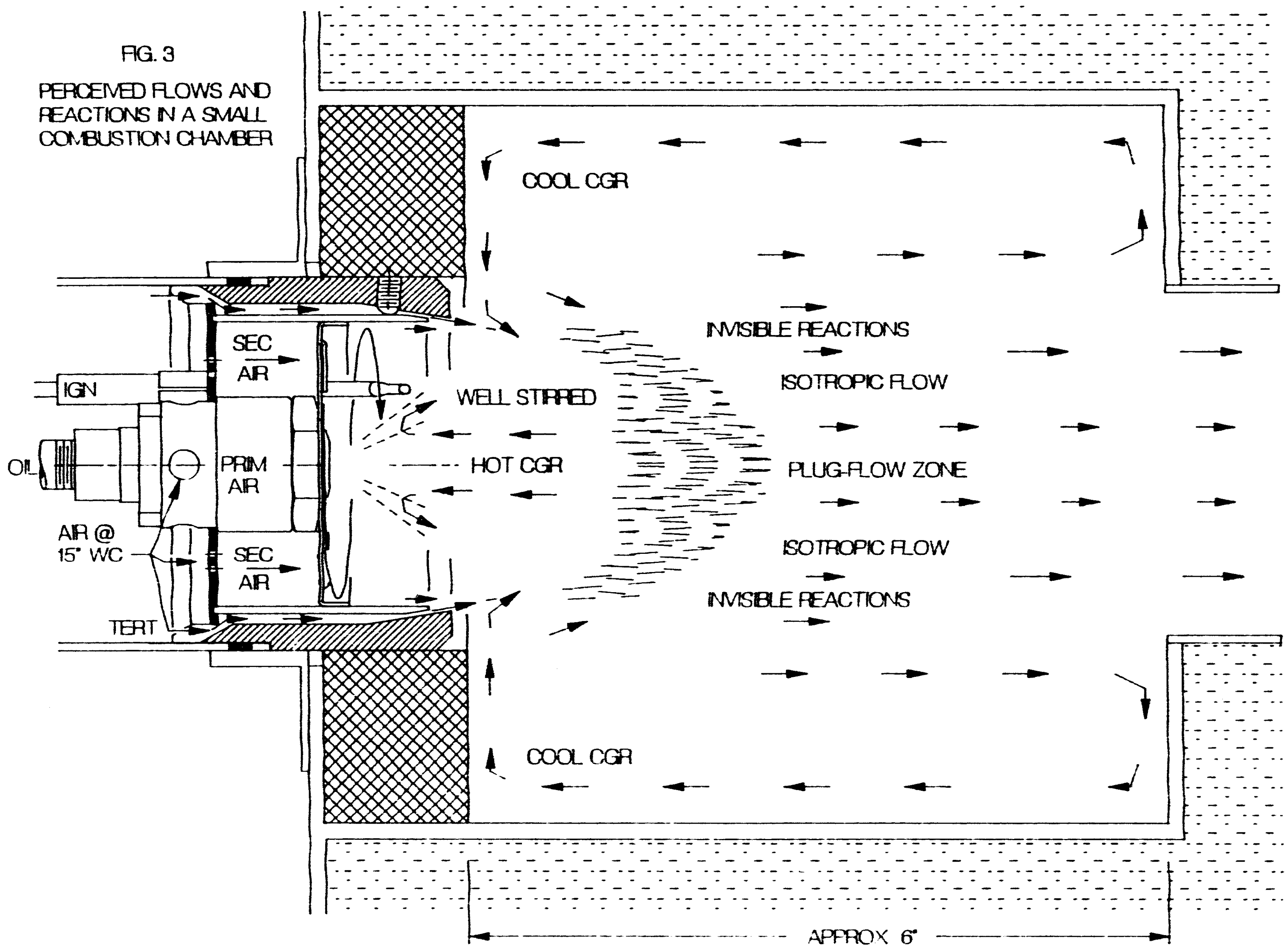

Figure 3. Perceived Flows and Reactions in a Small Combustion Chamber

III. WORKSHOP SESSIONS

GROUP A. NEW OIL BURNER DEVELOPMENTS
INDUSTRY ISSUES ON THE HORIZON

Chairman: Jim Connors, Mestek
Rapporteur: Dr. Thomas A. Butcher, Brookhaven National Laboratory

TOPICS:

1. With conventional burners, in what areas are improvements needed? [Reliability, Controls, Sooting, Excess Air, Service, Side-wall Venting, NO_X, Sensors, Fuel Flexibility, Cold Locations]

2. Does oil deserve a reputation for being a dirty fuel? What might be done to improve this image? Should this be done by BNL?

3. Has burner technology moved faster than the field? Should BNL put more effort on analysis of field problems with existing equipment? Would the service industry participate?

4. What are the needs in advanced burners? What features will the oil-heat industry want in burners/systems over the next twenty years?

5. What changes should BNL make in their R&D program?

DISCUSSIONS:

The workshop was attended by about 35 people, representing marketers, manufacturers as well as some people involved with technology development. Discussions were focused on problems with existing equipment and activities BNL might undertake to serve current and future needs of the industry.

The major concern raised with current equipment was the service and reliability issues related to fuel quality. In considering advanced burners BNL should put an emphasis on ability to handle poor quality fuel without the need for excessive filtration. One of the participants stated that this was one of the reasons he was so enthusiastic about the Babbington burner which had been demonstrated at an earlier conference at BNL.

Another area of concern raised was an apparent decline in the reliability of both ignition transformers and controls. Newer components are much less reliable than older designs.

The group had considerable discussions about advanced control options. The BNL Flame Quality Indicator was seen as a very positive first step. In addition, however, the group would like to see sensors which will shut down the burner or provide a warning when a severe sooting situation has occurred. The FQI should call for service when a burner is starting to produce an excessive amount of soot but future controls should also look for a fouled heat exchanger problem. Sooting of homes is unacceptable and the industry must totally eliminate the possibility of this occurrence.

In deciding upon the output options for the FQI some concerns were raised about alarming the homeowners unnecessarily. An audible alarm might lead to a call to the local fire department.

In advanced burners a wide "window" of excess air levels for acceptable operation is seen as very desirable. It seems likely that in the future this window will generally be moving toward higher CO_2 levels (reduced excess air).

Generally BNL should pay more attention to NO_x in the future. Some of the participants said that we should start by knowing more about NO_x with existing equipment -what effects it and how might it be reduced. For example, the effects of the combustion chamber environment should be studied.

One participant raised the suggestion that the U.S. industry should pay more attention to the European ISO standards. These standards must be met for U.S. products (such as the FQI) to be marketed in Europe and elsewhere. BNL or some other group might aid exports by assisting U.S. oil heat companies in understanding these requirements.

GROUP B. GUIDELINES FOR OIL-APPLIANCE VENTING INDUSTRY REVIEW AND CONSENSUS ACTIONS

Chairman: Richard Krajewski, Brookhaven National Laboratory
Rapporteur: John Strasser, Brookhaven National Laboratory

TOPICS:

Issues related to the Venting Guidelines presentation on Materials and Corrosion:

1. Are vent/chimney inspections commonly performed during equipment servicing calls?

2. What is the field experience regarding vent and 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?

Issues related to the Oil-Heat Vent Analysis Program (OHVAP) presentation:

5. From an industry perspective, how would OHVAP be used by Engineering Staff and/or Field Service personnel?

6. In order of priority, what types of venting tables should OHVAP be called upon to generate?

7. The output refinements anticipated for OHVAP should take what form?

A general discussion of the status of the BNL Oil-Appliance Venting Guidelines document is also planned:

8. What additional avenues should be taken in securing an adequate review of the document?

DISCUSSION:

The workshop on oil appliance venting followed the list of suggested topics fairly well. Discussion was lively and centered around two overall topics: The forthcoming Venting Guidelines and the Oil Heat Vent Analysis Program.

The first topic of discussion was the Venting Guidelines. The participants were quickly brought up to date on the current status of the Guidelines. The talk then started going down the list of suggested questions from the conference program.

The first question was: Are vent/chimney inspections commonly performed during equipment service calls? Which was answered with: Is there a protocol for inspecting vent systems or should there be one? Apparently there is a code already in place in Canada. The Installation Code for Oil Burning Equipment (CSA

B139 M91) requires chimney inspections, and regulates such variables as sizing, entrance and exit temperatures, clearances, appliance types, etc. Another question along the same vein was then asked. Whose responsibility is the inspection? The county building inspector, the service company? And how do you rate the inspector? There didn't seem to be any answer.

The tools that are needed to inspect a chimney/vent system were also talked about. Miniature video cameras were a common though expensive option. Others said that they had a chimney sweep company come in and perform the inspection. A glaring problem with both of these techniques was then immediately brought forth-all of the inspections performed were visual. There was no way to properly evaluate the structural strength of the system, short of seeing obvious holes in the chimney.

Discussion then turned to the second question on the agenda. What is the field experience regarding corrosion in the field? The discussion was short and quick. The L-vent installed in the field was mostly "rotten" through and through. PLEXVENT, the plastic vent pipe used in gas applications was failing with longitudinal cracks forming in straight sections and was in the process of being re-evaluated by Under Writers Laboratories. The temperatures provided by mid-efficiency equipment were may be too high for the plastic.

Soot and acid carryover were also talked about. Apparently, even in condensing systems soot and acid will pass through the heat exchanger. Along the same lines the question of flue fires was brought up. It seems that in older equipment there was a tendency to carry combustibles (soot and/or unburned fuel) out of the appliance and into the vent. If a restart was initiated with liquid fuel in the system or if the flue-gas exit temperature within the system then became too high, it was possible for vent system deposits to start burning.

The third topic was how well masonry chimneys performed for oil appliances. The general consensus was that too much heat was lost in the vent connector, either to the surroundings or through dilution, for older chimneys to work well. Most chimneys, it was felt, should be relined for the newer equipment. Next to inadequate draft, acid condensation was the biggest problem reported. The statement was made that chimney tile liners are supposed to be assembled using an acid resistant mortar. It was generally believed that this was not actually done. Instead, the acid would condense out of the flue gas within the liner and find its way out to the brick work and eventually destroy the chimney. According to the experience of one of the participants, chimneys located on the north side of the house were the worst, while those located on the south side were "generally OK".

The fourth question regarding what materials should be used to insulate the vent connector never got addressed. Instead this discussion centered on the contradictions between the manufacturer's instructions and the many regulating codes. This was an area where it was felt that BNL would probably do the most good; developing a document that would summarize and organize the various codes that apply.

The last question about the Guidelines involved what additional avenues should be used to perform an adequate review. There was general agreement that the equipment manufacturers should definitely review the document. IBR and ASHRAE (TC 3.7) were also mentioned as good forums for review.

The meeting then talked about the forthcoming Oil Heat Vent Analysis Program (OHVAP). Before the questions from the agenda were even read, someone asked if OHVAP would handle house and outdoor pressure fluctuations. It doesn't, in it's present form but further enhancement of the program should be considered. OHVAP, in it's present form, is a program that is designed to model the independent behavior of the venting system under temperature and flow from an oil-fired appliance. Other effects due to appliance design characteristics or building de-pressurization are, at present, neglected. One feature that people did want to see was the ability to have multiple appliances exhausting into one flue. While not currently implemented, if time constraints allow, this feature should be added.

When the question came up about how the program would be used by the industry, the answer was rather surprising; it wouldn't. It was believed that the venting tables produced from the program's output would be widely used instead. In keeping with this position, everyone was in agreement in stating that the program didn't need graphical output (except as a "neat toy"), tabular results would be just fine. When asked for the types of tables that should be given priority, masonry chimneys topped the list. Relined chimneys came in second, with power vent systems being a distant third.

The workshop was brought to a close at this point, since we were running late. A summary was prepared and presented to the attendees at the closing of the general session.

GROUP C. FUELS, FUEL QUALITY, AND STORAGE INDUSTRY PERSPECTIVE AND ACTIONS

Chairman: Thomas A. Santa, Santa Fuel Inc.
Rapporteur: Wai Lin Litzke, Brookhaven National Laboratory

TOPICS:

1. What actions are being taken by industry members to deal with fuel quality related problems? (Mr. Santa will review the range and extent of field problems, quality control, documentation, database system, studies with biocides, his data, and his results.)

2. Can a network or database system be established by industry members to refer to, for products evaluated out in the field and to share experiences and information? How much interest is there to participate in field studies?

3. BNL has put together a set of guidelines for maintaining fuel oil quality to be used as a reference and training material for servicemen and managers. How much interest is there to further develop, revise, and upgrade this booklet? (Discussions shall include industry support for funding for future publications, methods of distribution, and use.)

DISCUSSIONS:

A total of (26) members attended this workshop session; they consisted of fuel oil distributors, additive marketers, refinery R&D researchers, heating equipment manufacturers, members of associations for petroleum marketers, tank cleaning/ fuel quality service representative, and a trade journal reporter.

The chairman began the session by asking whether anyone has experienced fuel quality related problems, and if so, whether they have determined the extent of these problems. There is a general awareness and concern that poor quality oil affects their business, ie. the number of service calls, and customer perception of oil heat. However, little have been done to maintain records of the occurrence of fuel quality problems (ie. filter changes) with respect to delivery of oil to their customers. The biggest problem affecting efficient operation of heating equipment is related to sludge and water buildup. Many servicemen acknowledge that poor handling of fuel could lead to contaminated fuel, but some were concerned that the fuel received from various suppliers are not of "good" quality. The participants discussed ways of how they dealt with sludge, ie. tank cleaning, use of chemical additives, change in oil delivery practices so that tank bottom residue would not be stirred up during delivery, but all had varied success. In many situations, what worked for one company may not have worked for another.

Clearly, all the members agreed that the mechanisms of fuel degradation and sludge buildup must be better understood. A treatment (or a series of treatments) could then be applied to prevent or slow fuel breakdown processes.

The key to success of any treatment program is to isolate possible sources to the sludge problem.

The chairman initiated a discussion on stability of fuel. One of his concerns was the possibility that copper in the fuel delivery lines could be acting as a catalyst to accelerate the fuel oxidation process. Copper in solution has been known to function in this matter, although it is unclear in this case whether it is the leading factor causing fuel breakdown. The chairman brought in two oil samples showing the results of a small test he had previously conducted at his company. One sample contained fuel oil only, the other contained a piece of copper tubing immersed in the oil. Both samples came from the same source and were allowed to age for about two weeks. The point of the discussion was that after several days the oil with the copper tubing turned a deep amber color while the control sample remained light in color. Could this be an indication of fuel breakdown after such a short time? and if this is the case, what are the consequences since all piping in a heating system is made of copper? Further research needs to be done to understand the catalytic effects of copper and other oxidation mechanisms.

The industry has expressed a great deal of interest in further research related to fuel degradation. Several members have agreed to participate in any field studies which may develop in order to provide a statistical basis for the data.

It is interesting to note that representatives from refinery research divisions participated in this workshop and were able to provide a different perspective. Their comments indicated that at the refinery level they were unaware of the extent of fuel quality related problems confronted by the oil heat industry. They were interested in keeping abreast of any further developments in this field of study.

GROUP D. OIL-HEAT TECHNOLOGY TRANSFER INDUSTRY ROLE AND FUTURE SUPPORT

Chairman: Art Irwin, Department of Mines & Energy, Nova Scotia, Canada
Rapporteur: John Batey, Brookhaven National Laboratory Consultant

TOPICS:

Technology Transfer - Product Development

1. The oil-heat industry has indicated that it is very interested in several new concepts (FQI, advanced oil-burner designs, etc.) currently being developed by BNL. How can the industry support, assist, and contribute to the commercialization of these ideas as finished products available on the market?

2. How can the marketing industry help DOE in promoting the introduction of new high efficiency technologies currently under development?

Oil-Heat Efficiency Training Manual

3. Prior BNL/DOE/PMAA Oil-Heat Technology Conferences identified the need for an Oil-Heat Efficiency Training Manual for use by the industry in developing a firm understanding of the many options that exist to improve or upgrade the efficiency of oil-fired equipment or replace it with new modern high efficiency systems. BNL has been working on a manual of this type and will be releasing the first working drafts this summer in June. A limited series of training seminars are being planned to "train the trainers." The manual will be revised based on any suggestions that arise from the pilot seminar series. After the pilot program BNL(DOE) will be seeking an industry organization to support the manual and sponsor continuation of the training seminars. Which industry organizations should be considered? How should the manual be promoted and by who?

4. How should the seminars be organized and supported?

5. How frequently should the information be reviewed and who should be responsible to update it?

6. Will the manual need to be supported with other materials other than workbooks and slides?

DISCUSSIONS:

1. a) The oil-heat industry can best support, assess and contribute to the commercialization of new ideas and products by encouraging Brookhaven to participate in trade shows, industry meetings and industry related programs. Brookhaven must take the show on the road to provide the necessary credibility to new products.

b) Equipment development is driven by market demand. Oil dealers must sell the flame quality indicator and similar developments to the consumer.

c) More knowledge and background information is needed on new products from Brookhaven and other research groups. Many products never reach the market place because the dealer has little knowledge on a new product and is often not sold on its capabilities.

2. a) Tax rebates are good incentives to promote new technologies.

b) Oil dealer education programs for their customers are important.

c) In many cases, two-step programs are necessary:

i) General information to overcome misconceptions about oil heat; and

ii) Information on new oil heat advances.

3. Oil Heat Training Manual - The National Oil Heat Service Managers Association is a logical industry organization to support the manual and sponsor the combination of training seminars.

4. The seminars should be structured in modules and delivered in one day seminars. These should be arranged in a scheduled manner to ensure their success.

5. The training material should be reviewed on an annual basis and appropriate addendum included as required. This procedure could be administered by the Service Managers Association.

6. In addition to the planned workbooks and slides presently being prepared, the program should be also supported by videos which can quite easily be developed from slide presentations.

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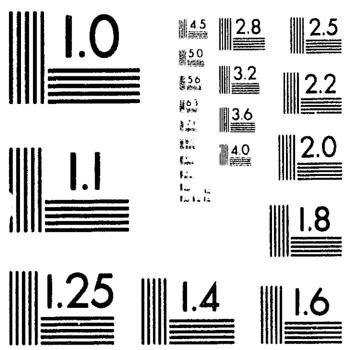

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1.1
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1.25
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