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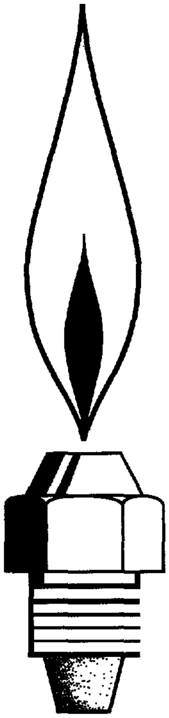
PROCEEDINGS OF THE 1997 OIL HEAT TECHNOLOGY CONFERENCE AND WORKSHOP



Held at
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973
April 3-4, 1997

September 1997

Roger J. McDonald

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

In cooperation with
PETROLEUM MARKETERS ASSOCIATION OF AMERICA

Under Contract No. DE-AC02-76CH00016 with the
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ENERGY EFFICIENCY AND CONSERVATION DIVISION
DEPARTMENT OF APPLIED SCIENCE
BROOKHAVEN NATIONAL LABORATORY
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ACKNOWLEDGMENTS

The 1997 Oil-Heat Technology Conference and Workshop was attended by 171 participants and was a large success thanks to the hard work of many people. The editor of this report would like to thank the authors for their efforts and splendid cooperation in submitting papers promptly and in the word processing format requested. This made the our conference report staff very happy.

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

The high quality of the 1997 Oil-Heat Conference and Workshop advanced preparations, the smooth operation during the meeting, and the efficient post meeting effort in assisting in preparing the proceedings for publication is all due to the professional efforts of the BNL Conference-Coordinator: Gail Brown. The Editor greatly acknowledges the hard work and effort required to make this conference a success.

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EXECUTIVE SUMMARY

1.0 Introduction

This report documents the Proceedings of the 1997 Oil Heat Technology Conference and Workshop, held on April 3-4 at Brookhaven National Laboratory (BNL), and sponsored by the U.S. Department of Energy - Office of Building Technologies, State and Community Programs (DOE-BTS), in cooperation with the Petroleum Marketers Association of America (PMAA).

This Conference, which was the eleventh 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:

- Identify and evaluate the state-of-the-art and recommend new initiatives for higher efficiency, a cleaner environment, and to satisfy consumer needs cost-effectively, reliably, and safely;

- Foster cooperation among federal and industrial representatives with the common goal of sustained national economic growth and energy security via energy conservation.

The 1997 Oil Technology Conference comprised: (a) five plenary sessions devoted to presentations and summations by public and private sector industry representatives from the United States, and Canada, and (b) four workshops which focused on mainstream issues in oil-heating technology.

2.0 Plenary Sessions

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

- Oil Burner Technology Development (Part I);
- Oil Burner Technology Development (Part II);
- Oil Heat Association Research Related Activities;
- Updates on Private Sector Fuel Quality Activities; and
- Private Sector R&D Project Activities

2.1 Oil Burner Technology Development (Part I)

Paper 97-1: Computational Fluid Dynamics in Oil Burner Design

The first paper presents an introduction to computational fluid dynamics and describes how it can be used to aid in the design of oil burners. The paper delineates how differential equations are used to describe flow, heat transfer, and mass transfer, etc. Then through the power of the computer, the laborious task of solving these equations using various numerical techniques results in useful information about the details of velocity, pressure, temperature and other data throughout the flow field. Details of how fuel spray characteristics including droplet trajectories and evaporation, the reaction of evaporated fuel with air, heat transfer away from the combustion zone by radiation, and pollutants can all be modeled. This leads to information on the location of combustion zones, realistic gas temperature fields, gas velocities and recirculation zones, burner component surface temperatures and can possibly provide realistic assessments of pollutant emissions. The paper presents information on BNL's on going work in CFD studies of the understanding of the basic pressure atomized flame retention head burner and validation of the CFD techniques. The end result of this effort will be the ability to help streamline the development process and provide better results in new oil burner design efforts. The use of CFD analysis is one tool to aid in the engineering design effort. It will not eliminate the need to build and test prototypes but the effort should be vastly more productive.

Paper 97-2: Oilheat Venting Technology and NFPA Standard 31 Revision Year 2000

The revision of National Fire Protection Association (NFPA) Standard 31 for the year 2000 offers an opportunity to update the Appendix which currently offers recommendations for basic metal relining of masonry chimneys up to and including 25 feet. The paper discusses the proposed update of the existing recommendations to include flexible (rough) metal liners. In addition, the discussion addresses the inclusion of additional information for unlined (non-conforming), lined (conforming to NFPA 211) masonry chimneys, insulated metal chimneys, chimney heights beyond what are now published, as well as power venting both forced and induced draft. Included in the paper is a discussion of the existing Oil Heat Vent Analysis Program (OHVAP) and issues that need resolution to make it a better vent system model.

Paper 97-3: Practical Approaches to Field Problems of Stationary Combustion Systems

This paper presents a few selected research projects conducted for industrial clients in north and central America. The combustion systems investigated are mostly liquid fuel fired, with the exception of a utility boiler which was coal-fired. The key areas involved include fuel quality, fuel storage/delivery system contamination, waste derived oils, crude oil combustion, unacceptable pollutant emissions, ambient soot deposition, slagging, fouling, boiler component degradation, and particulate characterization. Some of the practical approaches taken to remedy these field problems on several combustion systems including residential, commercial and industrial scale units are discussed.

2.2 Oil Burner Technology Development (Part II)

Paper 97-4: Research, Development, Testing of a Prototype Two-Stage Low-Input Rate Oil Burner for Variable Output Heating Systems Applications

The use of a Two-Stage Fan Atomized Oil Burner (TSFAB) in space and water heating applications will have dramatic advantages in terms of it's potential for a high Annual Fuel

Utilization Efficiency (AFUE) and/or Energy Factor (EF) rating for the equipment. While demonstrations of a single input rate burner in an actual application have already yielded sufficient confidence that space and domestic heating loads can be met at a single low firing rate, this represents only a narrow solution to the diverse nature of building space heating and domestic water loads that the industry must address. In this paper the mechanical development, proposed control, and testing of the two-stage burner are discussed with attention given to near term and long term project goals.

Paper 97-5: Low Excess Air Operation and the Effects on Heat Exchange Fouling

For high efficiency, oil fired heating appliances should be operated with the lowest excess air achievable without producing smoke. Excess air affects steady state efficiency in two ways. First excess air is unnecessary mass heated from room temperature to flue temperature and discarded. In addition, increasing excess air increases the flue gas temperature, also increasing the rate of energy loss out of the chimney. There is approximately a 1% decrease in steady state efficiency for each 33 degrees (°F) of increase of flue gas temperature. In addition to affecting steady state efficiency, excess air may also affect the rate of fouling of boiler heat exchangers. Prior studies at BNL have shown that a very important part of fouling is the condensation of sulfuric acid on the heat exchanger surfaces, and the reaction of that acid with the iron in the boiler wall to form an iron sulfate scale. Reduced fuel sulfur has been clearly shown to reduce the rate of fouling.

Beyond reducing fuel sulfur it may be possible to reduce sulfuric acid condensation and fouling rates by operating burners at very low excess air levels. In the flame most of the sulfur is converted to SO_2 and simply emitted from the chimney. A small fraction (1-4%) of the fuel sulfur is converted to SO_3 in the flame. This then converts to acid and is available to condense on the heat exchanger surfaces, leading to fouling scale. The fraction of the fuel sulfur which is converted to SO_3 depends in part, on the amount of free oxygen available or excess air. The operation of large electric utility boilers with minimum excess air is a common approach to reducing flue gas acid concentration and minimizing "cold end corrosion" which is very similar to the process of fouling of a residential boiler. This paper deals with the measurement of the effects of excess air on fouling rates in residential boilers and introduces the concept of a self tuning burner based on a zirconium oxide oxygen sensor to determine excess air levels and as an input to a trim control for burner operation at very low excess air.

Paper 97-6: Development and Certification of the Innovative Pioneer Oil Burner for Residential Heating Appliances

The Pioneer burner represents another important milestone for the oil heat industry. It is the first practical burner design that is designated for use in small capacity heating appliances matching the needs of modern energy efficient home designs. Firing in the range of 0.3 GPH to 0.65 GPH (40,000-90,000 Btu/hr) it allows for new oil heating appliance designs to compete with the other major fuel choices in the small design load residential market. This market includes energy efficient single family houses, town-houses, condominiums, modular units, and mobile homes. The firing range also is wide enough to cover a large percentage of more conventional heating equipment and home designs as well. Having recently passed Underwriters Laboratory certification tests the burner in now being field tested in several homes and samples are being made available to interested boiler and furnace manufacturers for product development and application testing.

Representing the best in true cooperation between government and industry it is the latest in a series of innovative concepts developed by Brookhaven National Laboratory (BNL) and selected for commercialization by the oilheat equipment manufacturing industry. The new burner was developed under a cost shared agreement between the New York State Energy Research and Development Authority (NYSERDA) and Heat Wise Inc. The BNL Oilheat research staff has assisted through technology transfer and engineering support to the project. The engineering support efforts of the BNL staff were provided under the terms of a separate Cooperative Research and Development Agreement (CRADA) between the United States Department of Energy, BNL, and NYSERDA.

The Pioneer burner incorporates the original BNL Fan Atomized Burner (FAB) concept in a product package designed by Heat-Wise Inc. incorporating the extensive use of conventional burner components. The sole exception is the unique nozzle assembly, the low pressure combustion air driven fuel atomizer, which has also been redesigned (Patent Pending) by Heat-Wise Inc. to incorporate features for enhanced reliability and service in the field.

2.3 Oil Heat Association Research Related Activities

Paper 97-7: Updates on Oilheat Manufacturers Association and the National Oilheat Research Alliance

A review of the Oilheat Manufacturers Association's (OMA) 1996 activities and projects was presented. These included a report on the Oilheat Advantages project status, the Build With Oil program, the PMAA Technician Certification Program where OMA is working with PMAA to revise and update the Oilheat Technician's Manual and establish a list of approved manufacturer seminars for Continuing Education Unit Credits, and possible PMAA/OMA Advantages Certification. In other areas of interest OMA was successful in getting EPA to recognize in its AP-42 document that modern oilheat equipment is truly clean burning, by revising the oilheat particulate emissions rate downward from 2.5 to 0.4 pounds per thousand gallons of fuel consumed. This level is comparable to that reported by AP-42 for gas heating equipment particulate emissions. OMA was also active in helping to get boilers over 85% AFUE included in the EPA Energy Star Program and is still working on furnace inclusion. On the future horizon OMA is looking into the impacts of EPA's proposed revisions to the ambient air quality standards for ozone and particulate on the oilheat industry.

The status of National Oilheat Research Alliance (NORA) was also included in the presentation including a review of the recent years events. A new NORA Legislative Action Committee was formed to take the proposed package for NORA and build a basis for Congressional support for its passage during the next eighteen months. The results of the NORA Executive Committee's industry survey of 500 oilheat dealers indicates over whelming support for NORA (96%). Issues of collection point, allocation of funding, assessment level and time line for NORA were also presented. If all goes as planned NORA would be started by 1999 and fully in place by the year 2000. It would be based initially on an assessment of 20 points, with the major allocation for consumer education (85%) and the remainder (15%) to provide for both NORA's management and research activities.

Paper 97-8: NAOHSM and the Oilheat Industry on the Internet

This presentation provides an informative introduction to the National Association of Oil Heat Service Managers' (NAOHSM) Internet Web site. NAOHSMs' mission has always been to educate both the service manager and his technicians. By providing video tapes, sponsoring training seminars and the yearly trade show NAOHSM has been the central information conduit between manufactures and the service trade. In addition local chapter meetings are a forum for exchanging ideas. With the addition of the world wide web site needed information will be available 24 hours a day seven days a week matching the working hours of most service departments.

The Web site is divided into two sections. Member and Non-member. The non-member side contains information related to the Association and also provides a help desk to respond to questions about the oil heat industry. The member area contains information useful to both the service trade and industry. The bulletin board provides members an open forum to exchange information and post questions. Ongoing discussions of industry trends and problems can take place year round instead of just at conventions and meetings. Manufactures can post updates on equipment or to solicit comments. The calendar is open to all to post up coming events such as meeting, training seminars, and schools. A large area to list contacts and phone numbers of an event can be viewed by clicking on the day of the month the event is listed.

Paper 97-9: NCPMA's Efforts to Establish New Outdoor *OILPAK* in the Southern United States

For the last twenty years fuel oil marketers in the North Carolina Petroleum Marketers Association (NCPMA) have tried to convince fuel oil equipment manufacturers to develop and market a packaged outdoor oil furnace with electric air conditioning for southern homes and businesses. In order to accomplish this, NCPMA had to identify, if indeed, that there was a market for this type of product, and if so, the size of the market. Market identification was a simple process after NCPMA staff received numerous inquiries each winter about the need for such equipment from fuel oil marketers and HVAC contractors and even homeowners. Marketers share for fuel oil heated homes began to suffer partly because new building codes prevented the replacement of existing oil furnaces without much difficulty and expense. Furthermore, the limited number of basements in the southern United States contributed to the problem of the replacement market. Market size was determined by a NCPMA survey to fuel oil marketers, HVAC contractors, other state petroleum associations and other forces in the industry.

After determining the market size and need for the outdoor Oilpak™, as the equipment was later to be called, NCPMA members had to negotiate and convince a fuel oil equipment manufacturer and/or distributor to actually build, test and manufacture one. This was not easy, as proven by the many years and extensive effort that went into this process. NCPMA contacted by phone or letter nearly every manufacturer of fuel oil equipment regarding the production of an outdoor oil furnace. Individual NCPMA members spoke to high ranking company officials about the Oilpak™. Some industry personnel and distributors conducted a meeting with NCPMA members at various locations on the subject. Finally, after getting R.E. Michel Company involved, the distributor for Armstrong Air Conditioning Inc., a breakthrough occurred. The manufacturer along with the distributor then flew NCPMA members and HVAC contractors, to the manufacturing facility in Ohio to meet with company engineers to help develop the proto-type Oilpak™. After successful field testing of ten proto-type units (four in North Carolina) in the extreme winter of 1995/1996, the Oilpak™ was launched to the public in the late summer of 1996. NCPMA has since then produced a Oilpak™ television commercial and several mailers that focuses on this new HVAC equipment.

2.4 Updates on Private Sector Fuel Quality Issues

Paper 97-10: Fuel Oil Quality Task Force

In April, 1996, the R. W. Beckett Corporation became aware of a series of apparently unrelated symptoms that made the leadership of the company concerned that there could be a fuel oil quality problem. A task force of company employees and industry consultants was convened to address the topic of current No. 2 heating oil quality and its effect on burner performance. The task force studied changes in fuel oil specifications and trends in properties that have occurred over the past few years. Experiments were performed at Beckett and Brookhaven National Laboratory to understand the effect of changes in some fuel oil properties. Studies by other groups were reviewed, and field installations were inspected to gain information about the performance of fuel oil that is currently being used in the U. S. and Canada. There was a special concern about the use of red dye in heating oils and the impact of sulfur levels due to the October, 1993 requirement of low sulfur (<0.05%) for on-highway diesel fuel. The primary conclusion of the task force was that there is not a crisis or widespread general problem with fuel oil quality. Localized problems that were seen may have been related to refinery practices and/or non-traditional fuel sources. System cleanliness is very important and the cause of many oil burner system problems. Finally, heating oil quality should get ongoing careful attention by Beckett engineering personnel and heating oil industry groups.

Paper 97-11: Residential Fuel Quality

This paper details progress made in improving and maintaining the quality of No. 2 heating oil in residential applications. Previous research in this area is documented in papers published in the Brookhaven Oil Heat Technology Conference and Workshop Proceedings in 1993, 1994 and 1996. Santa Fuels Inc. has in prior years investigated a number of variables in the search for improved fuel system performance. These include the effect of various additives designed to address stability, dispersion, biotics, corrosion and reaction with metals. They also investigated delivery methods, filtration, piping arrangements and the influence of storage tank size and location as reported in prior presentations. As a result of this work Santa Fuel Inc. in conjunction with Mobil Oil Corporation have identified an additive package which shows strong evidence of dramatically reducing the occurrence of fuel system failures in residential oil burners. In a broad market roll-out of the additized product they report that they have experienced a 29% reduction in fuel related service calls when comparing the 5 months ending January 1997 to the same period ending January 1996.

2.5 Private Sector R&D Project Activities

Paper 97-12: Development of a Practical Training Program Based on BNL's Input to New NFPA Lined Masonry Chimney Venting Tables

This paper describes how Agway Energy Products developed a practical training program for technicians and sales personnel based upon the BNL studies that evolved into "Appendix E., Relining Masonry Chimneys in NFPA 31 Standard for the Installation of Oil-Burning Equipment." One of the topics discussed is Agway's search for solutions to the reoccurring problems associated with flue gas condensation on newly installed oil fired appliances. The paper also discusses Agway's own experiences in applying the new venting tables and working through the questions that arise when Agway encountered installations beyond the scope of the present tables.

Paper 97-13: Overview of Carbon Monoxide Generation and Release by Home Appliances

Carbon monoxide (CO) is an odorless, colorless and tasteless gas which is ***highly toxic*** and can be produced by many combustion sources commonly found within homes. Potential sources include boilers and furnaces, water heaters, space heaters, stoves, ovens, clothes dryers, wood stoves, fireplaces, charcoal grilles, automobiles, cigarettes, oil lamps, and candles. Any fuel that contains carbon can form CO including, natural gas, propane, kerosene, fuel oil, wood, and coal. Exposure to elevated CO levels typically requires its production by a combustion source and its release into the home through a venting system malfunction.

The health effects of CO range from headaches and flu-like symptoms to loss of concentration, coma and death depending on the concentration of CO and the exposure time. At levels of only 1%, which is the order of magnitude produced by automobile exhaust, carbon monoxide can cause death in less than 3 minutes. While most combustion equipment operate with low CO levels, many operating factors can contribute to elevated CO levels in the home including: burner adjustment, combustion air supply, house air-tightness, exhaust fan operation, cracked heat exchangers, vent blockages, and flue pipe damage. Test data on CO emissions is presented from a wide range of sources including Brookhaven National Laboratory, Gas Research Institute, American Gas Association, the US Environmental Protection Agency, and the US Consumer Product Safety Commission for many potential CO sources in and near the home.

General information is presented concerning burner adjustment and some other conditions that may contribute to elevated CO release in homes. Also, several case studies of CO hazards are reviewed as well as some ways to reduce the risk of CO exposure in homes. Two common misconceptions about carbon monoxide include: oil burners cannot produce carbon monoxide, and oil burners automatically shut themselves down before high CO levels are produced. Both of these statements are **false**! However, oil burners usually produce elevated smoke levels **before** high carbon monoxide levels are reached which serves as a **warning signal** not available with most other energy sources. The good news is that the risk of exposure to high carbon monoxide levels by operating oil burners is lower than many other combustion sources commonly found in homes including gas appliances. This paper briefly introduces the subject of carbon monoxide exposure in homes and includes the following subjects: What is carbon monoxide and what are its health effects? Case studies of carbon monoxide exposure and injury in homes. How does CO build up in homes? What are typical carbon monoxide emissions from home appliances?

Paper 97-14: The Advanced Flame Quality Indicator System

By combining oil tank monitoring, systems diagnostics and flame quality monitoring in an affordable system that communicates directly with dealers by telephone modem, Insight Technologies offers new revenue opportunities and the capability for a new order of customer relations to oil dealers. With co-sponsorship from New York State Energy Research and Development Authority, they have incorporated several valuable functions to a new product based on the original Flame Quality Indicator concept licensed from the US DOE's Brookhaven National Laboratory. The new system is the Advanced Flame Quality Indicator, or AFQI. As before, the AFQI monitors and reports the intensity of the burner flame relative to a calibration established when the burner is set up at AFQI installation. Repairs or adjustments are summoned by late-night outgoing telephone calls when limits are exceeded in either direction, indicating an impending contamination or other malfunction. A microprocessor-based customer unit incorporates CAD cells for monitoring up to two oil flames independently, a pressure transducer for monitoring oil tank level and filter condition, safety lockout alarms and a temperature monitor; all reporting automatically at instructed intervals via an on-board modem to a central station PC computer (CSC). Firmware on each AFQI unit and Insight-supplied software on the CSC automatically interact to maintain a customer database for an oil dealer, an OEM, or a regional service contractor. In addition to ensuring continuously clean and efficient operation, the AFQI offers the oil industry a new set of immediate payoffs, among which are reduced outages and emergency service calls, shorter service calls from cleaner operation, larger oil delivery drops, the opportunity to stretch service intervals to as along as three years in some cases, new selling features to keep and attract customers, and greatly enhanced customer contact, quality and reliability. Prices for sale or lease are targeted for payback in less than two years, with payback in less than one season for the most troublesome customers in the franchise. Some of the more exciting possibilities for the near future are establishing insurance rebates (from reduced exposure to smoke and puffback damage), adaptation of AFQI's to commercial and industrial installations (including dual fuel) and adding the ability with infrared to tune the burner from AFQI measurements alone; a feature that is one of the objectives of a new NYSERDA contract that Insight Inc. is now just starting. The paper covers details of the operation of the hardware, outline the modes and magnitudes of payback for customers, dealers and OEM'S, and shows some sample installations and results.

3.0 Workshop Sessions

The conference attendees divided into four workshop groups addressing specific subjects. A brief summation of the conclusions and recommendations for each workshop group follows.

Workshop Group A
Panel Presentation: ISH Show Impressions and Opinions and Should Oilheat Standardize on 150 psi Pump Pressure ?

International Sanitation and Heating (ISH)

ISH is the largest international heating equipment show with over 2000 exhibitors and 250,000 visitors. Based on informal observations, about 80% of the exhibitors are German, another 10-15% are Italian and the remainder from other European countries. There were a few U.S. companies represented.

In the burner hall there are blue flame burners nearly everywhere. Europe has in place a set of both voluntary and mandatory standards for small oil burners which include NOx emission limits. To date the use of blue flame burners has been non-uniform. Some countries (e.g. Switzerland) have now NOx limits for new units equivalent to about 60 ppm (@ 3% O2). On Jan. 1, 1998 Germany will adopt a similar regulation. The effect of this is to force all new installations to use blue flame burners. Currently only about 40% of the new installations in Germany use blue flame. In other countries (France, Spain, Italy) a considerably lower fraction is blue flame.

In the European market, heating systems cost at least twice as much and in the U.S. They are obviously a lot nicer but questions were raised during the workshop about the actual value. How much of the extra cost really results in true functionality and benefits for the homeowner? From a design and aesthetics perspective the appliances, however, are very impressive. Relative to the U.S. market there is much greater effort put into noise control, with covers filled with foam insulation. Controls and boiler face panel displays are very big. Outdoor reset appears to be universal. Constant circulation is common. There is little or no use of tankless coils, with hot water being produced either in an indirect system or in a wall mounted, instantaneous water heater. There was some discussion about cultural differences. Europeans are prepared to spend considerably more for their systems. Part of this is due to the existing regulations on minimum efficiency and inspections. Part may also be related to home ownership patterns. European families keep homes longer, often passing them down through generations, making it easier to justify greater heating system investment.

Fuel Pump Pressure Standard 150 PSI ?

These second topic raised during the workshop was the concept of an industry standard, 150 psi pressure level for all fuel pumps. Such a standard would improve service quality and performance overall. After considerable lively discussion the consensus was that it is really not possible to regulate a base fuel pressure. The industry is now changing at such a rapid rate that the pressure is likely to remain a moving target for some time. In may be better to improve technician education. In addition, we need a better labeling system to make it clear what the pump pressure should be on each installation. Robert Hedden will raise this questions further with the Oil Heat Manufacturer's (OMA) association. The technician in the field should be able to know the pump pressure quickly and easily.

Workshop Group B
Carbon Monoxide Discussion Forum

Initial discussions focused on the question of what are acceptable CO levels in homes. Many different levels can be cited included US-EPA recommendations of 9 ppm for ambient levels and 35 ppm for 6-hour exposure; 40 ppm for flue concentration in gas-fired equipment; some fire department policies to evacuate houses when CO levels exceed 10 ppm. One example cited was a Pennsylvania Fire Department which evacuates buildings when CO levels are above 10 ppm. Some standard and accepted CO levels and action levels are needed, and do not now exist. Perhaps the US Consumer Product Safety Commission, BNL, and other groups can work together to formulate acceptable CO levels in homes Some information was presented by John Batey from one reference on estimates of CO blood levels versus common exposure conditions:

CO Blood Levels
(Estimates)

Less than 1%	People living in rural areas
3%	People living in cities
4% -6%	Cigarette smokers
6% -10%	Smokers who work in enclosed area with CO (e.g. parking garages)
10%	Firefighters after a fire(highest CO level considered safe)
up to 20%	Police officers in heavy traffic

CO Poisoning Levels

20% - 25%	Blurred vision, nausea and vomiting, severe headache
30% -35%	Unconsciousness
40% or higher	Death

NOTE: A person's size and general health both effect response to elevated carbon monoxide levels.

The precision and accuracy required for CO test equipment was discussed next. A highly accurate instrument capable of measuring down to as low as 1 ppm with an uncertainty of only several ppm may be needed for ambient air measurements in homes. Regular calibration is also needed to a assure continued measurement accuracy. Measurement accuracy and precision is an important topic to address after action levels are determined.

Some discussions then followed on the impact of positive pressure oil equipment that produces a gas pressure in the combustion chamber that is above atmospheric pressure. It is possible that some combustion gases could escape form the heating unit which could contribute to elevated CO levels if the burner was producing carbon monoxide. The need for standardized test procedures to evaluate this situation was briefly discussed.

The need for CO meters with advanced oil burners was presented by one workshop attendee and a discussion followed. Some newer oil burners can produce elevated CO levels at the same time or before flue gas **smoke** levels increase. Therefore, CO measurement may become an important part of burning servicing and tune-ups in the future. Two problems include equipment drift and house depressurization, which can contribute to increased CO levels in homes. Typically CO levels from oil burners are low when the burners are set up according to manufacturer recommendations which includes near-zero **smoke** levels. One attendee cited a case where a plugged nozzle resulted in CO levels of 3200 ppm due to flame impingement on cold surfaces. Also, interaction of the burner with the house and house depressurization are important factors that must be evaluated. Possible solutions include:

- Relief damper to admit outside air when depressurization occurs.
- Dedicated air supply to the burner
- Use of *smoke pencils* to identify back drafting
- Use of draft gauge to measure the indoor-to-outdoor pressure differential

Homeowner should be advised about the risks associated with operating many exhaust devises at the same time in a tight home. Also, service technicians need to be educated about the problem of house depressurization and burner/house interactions so that problems can be avoided. New training programs are recommended for both gas and oil service technicians.

The advantage offered by a *safety switch* to turn the burner off if a room becomes too negative was discussed. This can be particularly important for tight homes. Also, chimney construction and design was discussed, and it can have an important impact on house depressurization and CO formation. Installing chimneys indoors was discussed as one approach for reducing venting problems.

Specific action recommend by the workshop attendees include:

- Set acceptable ambient CO limits for homes
- Regularly service of oil burners and vent systems
- Educate oil heat service technicians and homeowners about potential risks form CO in homes and how to avoid unhealthy levels
- Use CO detectors in homes to protect occupants - the less sensitive models that alarm at ambient CO levels of 50 to 100 ppm are recommended to avoid false alarms.

Workshop Group C

Forum: NFPA Standard 31 Revision Year 2000 Actions ?

The discussion was animated and moved about among the several questions posed to the group. This discussion has been edited to address these questions as they were posed in written form.

1. From the Field - What problems have been uncovered using masonry chimney tables in the NFPA 31 Standard ?

In the report presented at the conference (Paper No. 97-12) the figure shown on page 9 is not correct. A correct version of this figure can be found in NFPA 31 1997 Edition. The tables for metal re-lined masonry chimneys are consistent with the latest edition of NFPA 31

In general, the metal re-lined masonry chimney tables in Appendix E of NFPA 31 (1997) offer good, easy to use information but are limited in their present form. The natural gas appliance tables in NFPA 54, generated by use of Vent II, have proven to be complicated and difficult to apply. In terms of interpolation, field applications of the existing NFPA 31 tables have revealed some success in going to higher chimney heights. In addition, the reported successful application of the NFPA 31 tables to size chimney liners for two furnaces into a single non-conforming brick chimney lends some confidence in their (the tables) flexibility.

The tables should be expanded to include 30 to 60 foot chimneys. The text of NFPA 31 needs to be reviewed regarding the permitted connector/liner sizing protocol currently offered to the installer. Common venting of multiple appliances can be pursued through the use of the existing tables but "rule-of-thumb" recommendations should be included for now. Ultimately, the model should be upgraded to handle multiple appliances.

2. The list of industry identified issues discussed earlier includes:
   - -Items that can be done using the existing OHVAP model
      - Flexible liners
      - Masonry chimneys with and without tiles
      - Chimney heights greater tan 25 feet
      - Larger flue sizes
   - -Items that would require significant model revisions
      - Ambient temperatures below 0 Deg.F
      - Multiple appliance operation

There remains a strong need for multiple appliance recommendations and lower ambient temperatures. Direct recommendations are needed for derating of the appliance when; flexible (rougher) liners are used, offsets are present in the chimney, multiple elbows are used. In addition to the low ambient temperature requirement, some consideration should be given to the issues of ambient pressure (high altitude) as well as whole house depressurization.

3. *Suggestion for diagnostic aid/tools for venting system inspection?*

Beyond a brief discussion of the newly presented slide-rule which interprets the current NFPA 31 tables, no additional offerings were made. New applications of existing field instrumentation should be written up and included in the text portion of the NFPA 31 tables. Labeling of appliances is an important concern and needs to be addressed. A permanent means of recording the entry of servicing information (especially vent sizing/firing rate) is important for subsequent service personnel to have at their finger tips.

In Summary:

Venting Research Activities for the Remainder of FY1997

1) Prepare revision outline of the OHVAP Final Report
2) Continue special case runs of OHVAP to expose possible limitations
3) Continue chimney survey effort
4) Comparison checks with the ASHRAE analysis for large chimneys; issue guidance

Venting Research Activities for FY1998 and Beyond (No Assigned Priority)

1) Expand the tables to include metal chimneys and power vents and develop new tables
2) Expansion of the tables to 30 to 60 foot chimneys and incorporate into tables
3) Examine the effects larger flue tile sizes and incorporate into tables
4) Examine the effects of additional connector elbows, chimney offsets, altitude and less than ideal chimneys and issue guidance
5) Examine the applicability of the existing tables to furnace operation and issue guidance
6) Examine the effects of proposed new integrated systems and issue guidance.
7) Examine the usefulness of the tables for common venting applications and issue guidance.
8) Examine the effects of dilution air on whole house energy conservation and chimney drying and issue guidance.
9) Examine the application of *weather proofing* existing masonry chimneys
10) Develop the characterization of clay liners and alternative liner materials.

Workshop Group D
Fuel Quality, Storage, & Maintenance - Industry Discussions

There is generally a strong interest in fuel quality issues both in the U.S. and Canada. Frequently encountered fuel quality related problems in the field include suspended water and high cloud point. ASTM standard D-396 does not specify cloud point; only the pour point is specified. In Canada the petroleum industry is working on developing a standard for evaluating cold flow properties of heating oil.

There is also considerable interest and concern on the effects of fuel sulfur and fuel stability on the performance of residential heating systems. ASTM specifications have broad ranges for the various fuel properties. Even though the national average for fuel sulfur in heating oil is 0.3% by weight or less there are regions where much higher levels are found. It was suggested that lowering the standard requirement from 0.5% to 0.3% would direct the trend to lower average sulfur. Consistency of product is a concern for many fuel marketers. Fuel stability is also not specified in D-396 but maybe it should be. A stability specification like D-2274 for diesel fuel may be desirable for fuel oil. Much research work is being conducted by the petroleum industry to look at methods of evaluating fuel stability with accelerated techniques and correlating it with long-term fuel degradation.

Clearly, the heating oil industry needs to be actively involved in standards generating organizations in order to voice their fuel quality concerns and effect changes to specifications. There may be a desire for a ***premium*** grade ASTM specification for heating fuel. Several participants of this workshop are members of the American Society for Testing and Materials (ASTM) and the International Association for Stability and Handling of Liquid Fuels (IASH). It was noted that ASTM needs data and test results to support recommendations for specification changes. It is suggested that BNL should expand its capabilities to test fuel quality parameters with heating systems and provide the necessary technical data to support measures in changing specifications.

BNL is currently revising a manual, **Maintenance and Storage of Fuel Oil for Residential Heating Systems**, which was first published in 1992. This revised manual will be published and distributed to the heating industry by Petroleum Marketers' Association of America (PMAA) during the summer of 1997. It was suggested that problem tanks be replaced, not just cleaned, like other major home replacements (ie. roofs, etc.). Also, tanks need to be accessible. There is general interest by the workshop participants to have included in this manual test methods for evaluating fuel additives. It appears, however, that because fuel properties vary extensively a specific method to determine acceptability of an additive with one fuel may not necessarily show the same results with another fuel.

A poll of the workshop participants, by show of hands, was done to determine the level of interest on the proposal for round-robin testing of fuel oil additives as proposed by Robert E.

Tatnall, P.E. This would require individual fuel marketers to participate in a relatively large-scale field testing program to evaluate the various after-market additives. BNL would have the role of coordinating this effort, collecting and analyzing the data. Almost half of the participants indicated interest.

4.0 DOE/BNL Perspective

The 1997 Oil Heat Technology Conference and Workshop brought into focus the realities of the marketplace and the role that federal sponsors and researchers can fill in promoting energy conservation consistent with the public benefit while recognizing the competitive nature of a free enterprise. In the future, NORA will provide an opportunity to greatly enhance and expand the scope of these activities for the mutual benefit of the oil-heat consumer and industry.

From a technical perspective, BNL has taken fundamental approaches to identifying and characterizing combustion phenomena that influence the performance efficiency of oil-fired space-conditioning equipment. The controlled interrelationships of fuel atomization, combustion, soot abatement, and venting are conveyed to designers and manufacturers with the mutual understanding that their adoption may be constrained by market acceptance factors that may transcend technical considerations. The Oil Heat Technology Conference and Workshop, along with the use of a technical advisory group comprised of representatives from various facets of the oil heat industry, helps provide targeted planning of the research and development effort to enhance market acceptance while satisfying energy conservation and environmental program objectives.

BNL announced the continuing availability of a unique, sophisticated facility to the industry. The facility provides a controlled laboratory environment, support instrumentation, and data acquisition/analysis for development, testing, and evaluation of novel components, subsystems, and systems. The arrangements for access encourage technical interaction with BNL scientists and engineers and recognize the user's proprietary constraints by providing access on a full cost-recovery basis.

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

I. INTRODUCTION

The 1997 Oil Heat Technology Conference and Workshop was held on April 3-4 at Brookhaven National Laboratory (BNL) under sponsorship by the U.S. Department of Energy - Office of Building Technologies (DOE-OBT). The meeting was held in cooperation with the Petroleum Marketers Association of America (PMAA). One hundred and eighty-five (185) people were registered and participated at the conference.

The 1997 Oil Heat Technology Conference, which has been the eleventh held since 1984, is a key technology transfer activity supported by the ongoing Combustion Equipment Technology program at BNL. The reason for the conference is to provide a forum for the exchange of information and perspectives among international researchers, engineers, manufacturers and marketers of oil-fired space-conditioning equipment. They have provided a channel by which information and ideas are exchanged to examine present technologies, as well as helping to develop the future course for oil heating advancement. They have also served as a stage for unifying government representatives, researchers, fuel oil marketers, and other members of the oil-heat industry in addressing technology advancements in this important energy use sector. The specific objectives of the Conference are to:

- Identify and evaluate the current state-of-the-art and recommend new initiatives for higher efficiency, a cleaner environment, and to satisfy consumer needs cost-effectively, reliably, and safely;

- Foster cooperative interactions among federal and industrial representatives for the common goal of sustained economic growth and energy security via energy conservation.

Special Addresses

Introductory remarks were provided by James Davenport, Chairman, Department of Applied Science, BNL, who welcomed the assembly on behalf of Brookhaven National Laboratory. Dr. Davenport emphasized BNL's commitment of advancing oil heat technology and to effect technology transfer to the private sector. Dr. Davenport concluded his address by congratulating the organizers and welcomed the participants of the Conference. Roger McDonald welcomed the participants on behalf of the BNL Oilheat Research Program and presented a brief overview of the conference agenda for the next two days. John Huber, Government Affairs Counsel, Petroleum Marketers Association of America (PMAA), followed by welcoming the participants on behalf of PMAA and then introduced the Master of Ceremonies, Don Allen, current Chairman of the PMAA Heating Fuels Committee. Mr. Allen introduced the Keynote Address by Mr. John Santa, NORA Steering Committee Chairman and President of Santa Fuels, Inc

Technical Presentations

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

- Computational Fluid Dynamic's (CFD) Role in Oil Burner Design
- Oil Venting Technology and Issues Regarding NFPA 31 Revision 2000
- Approaches to Stationary Combustion Problems in the Field
- Two Stage Low - Input Rate Prototype Oil Burner Development
- Low Excess Air Operation and the Effects on Heat Exchanger Fouling
- Development and Certification of the Innovative ***Pioneer*** Oil Burner
- Oilheat Manufacturers Association (OMA) - Review of Projects
  National Oilheat Research Alliance (NORA) - Review of Status
- Oilheat Industry and NAOHSM on the Internet
- NCPMA's Cultivation of the ***OILPAK*** for the Southern United States
- Fuel Oil Quality Task Force Report
- Residential Fuel Quality - Field Performance of a Premium Heating Oil
- Development of a Practical Training Program Based on BNL Venting Research
- Overview of Carbon Monoxide Generation and Release by Home Appliances
- Advanced Flame Quality Indicator System

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. Panel Discussion: ISH Show Impressions and Opinions and
   Should Oilheat Standardize on 150 psi Pump Pressure ???

B. Carbon Monoxide Discussion Forum

C. Forum: NFPA 31 Standard Revision Year 2000 Actions ???

D. Fuel Quality, Storage & Maintenance - Industry Discussions

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

Combustion Equipment Technology Laboratory

Conference participants were welcome to visit the BNL combustion research facilities and witness equipment demonstrations of some of the advanced oil-fired heating systems under development at BNL. The equipment demonstrated included the HeatWise Inc. ***Pioneer*** oil burner based on the BNL FAN-Atomized Low-Firing-Rate, Low-Emission Oil Burner (FAB). The ***Pioneer*** was shown in several applications and displayed in various stages of disassembly so that it could be examined by those attending. Insight Technologies displayed the Advanced Flame Quality Indicator (FQI) which is based on the FQI concept developed by BNL and licensed to Insight Technologies Inc. Side by side boilers installations as used for long term comparison tests of operation at reduced excess air levels to reduce fouling in heat exchangers were also on exhibit. BNL also provided numerous visual displays based on prior and ongoing research related to Oil Heat R&D.

Closing Session

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

II. TECHNICAL PRESENTATIONS

Paper No. 97-01

Computational Fluid Dynamics in Oil Burner Design

Dr. Thomas A. Butcher, Ph.D., BNL

CFD - A TOOL FOR ENGINEERING DESIGN

There are many cases where the Engineer would like to have information about the details of the velocity and pressure throughout a flow field. A relevant example may be the flow of cold air across the head of a retention head oil burner. Knowing the flow field details, even under non-combusting conditions, and the effects of head geometry changes, can help efficiently design new burner heads.

The flow of cold (constant property) air is fully described by a set of non-linear, differential equations which are generally not solvable. For many years the subject of Fluid Mechanics has been dedicated to applying simplifying assumptions to develop solutions to the equations of motion and/or solving these equations for specific simplified cases. For the case of oil burners, the designer would also like some idea of the expected behavior after the burner is lit. Here the temperature field is important in addition to the flow field. This adds complications such as density, viscosity, and thermal conductivity which vary as a function of temperature (often in a non-simple way) through the field. In this case it is not reasonable to consider solving the equations which describe flow and heat transfer directly.

In Computational Fluid Dynamics (CFD) the differential equations which describe flow, heat transfer, and mass transfer are approximately solved using a very laborious numerical procedure which can only be practically managed by computer. As a first step the flow field is divided into a grid. The number of "points" in the grid is chosen based on the complexity of the problem, the computer being used for the solution, and the time allowable for the solution. The terms of the relevant equations are then each replaced by local, linear approximations. This is illustrated in Figure 1 for one term in the equations of motion, the pressure gradient. This results in a set of linear simultaneous equations. One equation for each point in the grid for each differential equation being solved. The computer then executes an iterative procedure to develop a solution to all of the simultaneous linear equations. For an excellent basic description of the methodology see Reference 1. In CFD runs it is not uncommon for the number of equations to reach hundreds of thousands.

Flows of practical interest to burner designers are always turbulent, adding the complexity of requiring a turbulence model. While different models have been used to improve CFD simulation results, the two parameter, k-ϵ, model is very often used and has been used for all simulations presented in this paper. See Reference 2 for additional discussion on turbulence models.

COMBUSTION SIMULATIONS

A basic CFD analysis can predict basic flow patterns and convective heat transfer in flows fields of interest to burner designers. The next step up from this in complexity is modeling the combustion itself and this can lead to information on: location of the combustion zones, realistic gas temperature field, gas velocities and location of recirculation zones, burner component surface temperatures, and possibly even realistic assessments of pollutant emissions. To accomplish these objectives requires adding models for: fuel spray droplet trajectories and droplet evaporation, the rate of reaction of evaporated fuel with air, heat transfer away from the combustion zone by radiation, and formation of pollutants (NO).

At point "e" the pressure gradient, $\frac{\partial P}{\partial X}$, is approximated as:

$$\frac{P_E - P_P}{\Delta X_e}$$

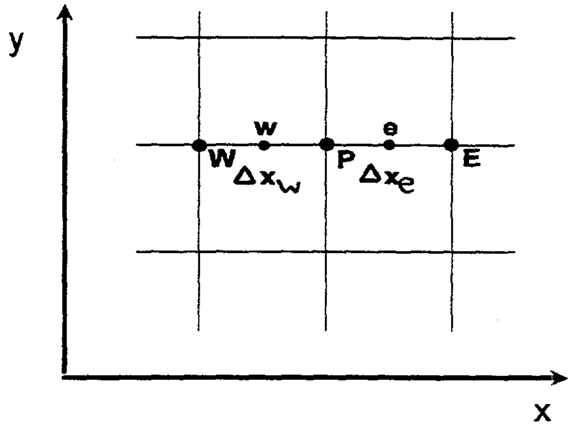

Figure 1. Illustration of the approximation of one term from the equations of motion of air flow in CFD.

For prediction of the droplet trajectories information is first needed about the fuel spray size distribution, spray angle, and spray velocity. The distribution of drops is divided into groups and each group assigned a mean diameter for analysis. The drop trajectories are then calculated for each group by analyzing the forces that the flow field imposes on the drops (e.g. drag forces). The evaporation rate for each droplet group is calculated depending upon local flow conditions and temperature [3]. The procedure here is obviously iterative. Given a gas velocity and temperature field the droplet trajectories and evaporation rates can be determined. However, the droplet evaporation provides a local source of fuel vapor which reacts and really defines the temperature field.

In many simulations the reaction of the evaporated fuel with oxygen to form combustion products is assumed to be a one-step process with the reaction rate dependent upon temperature or the local turbulent mixing rates [3,4]. Multiple reaction step models have also been used which provide greater detail on the combustion chemistry [5]. These may allow prediction, for example, of CO or soot.

There is great interest in the use of CFD combustion models to predict NOx emissions or (possibly more importantly and realistically) to predict the relative effects of burner head changes on NOx emissions. Three mechanisms contribute to oil burner NOx emissions: 1) conversion of fuel nitrogen to NOx, 2) thermal NOx, and 3) prompt NOx [6]. NOx from fuel nitrogen is dependent upon fuel nitrogen content and is a small percentage of the total NOx for most distillate oil burners. Often this is ignored or simply calculated assuming, for example, 80% conversion of fuel nitrogen to NOx. Thermal NOx is a very strong function of the flame temperature and depends also upon the local concentration of "O" atoms. Often the O atom concentration is calculated from equilibrium considerations, although in some cases this may greatly underestimate actual O concentration and NO production. In the turbulent flame temperature at any point fluctuates and the thermal NO production must be integrated over the assumed distribution curve, rather than calculated at the mean temperature. For prompt NOx production an empirical rate expression due to DeSoete has been used [7,8,9].

EXAMPLE - A RETENTION HEAD BURNER

To illustrate the use of CFD analysis BNL is currently studying the basic pressure atomized, retention head burner. Figure 2 shows a simple cross section of the head of the burner and the grid structure used in some of the cold air flow simulations. While one specific burner has been selected for this study general flow patterns are similar in other commercial burners. The study is being done at one firing rate - 0.75 gph with a fixed excess air level. The geometry and grid structure is based on actual dimensions at the design condition.

In the burner combustion air enters the flame zone in three parts. Most of the air at this firing rate enters through the center hole in the retention plate, around the nozzle. This is often termed "primary air". A small portion of the air ("secondary air") enters the flame zone through slots in the retention plate. The remainder of the air ("tertiary air") enters through an annular opening around the retention plate. In the first cold air flow simulation done all of the air was assumed to be entering the flame zone at a constant velocity of about 19 m/s in each of the three zones.

The basic cold air flow patterns in this burner are illustrate in Figure 3 which shows contours of constant axial velocity. Many other parameters resulting from the CFD analysis could also be shown including: pressure, swirl, turbulence intensity, streamlines, radial velocity. From Figure 3, however, the basic nature of the flow can be illustrated. There is a strong, central flow of primary air and a smaller region of high velocity from tertiary air. Between the two, in the wake of the retention plate there is a recirculation zone where the axial velocity becomes negative. It is in this recirculation zone where hot combustion products deliver heat back to the root of the flame providing stability. The overall impact of the secondary air on the general flow pattern is small.

Beyond cold air flow analysis, BNL has been cooperating with ASC Ltd. of Canada to complete at least some preliminary CFD simulations of the same burner head under combusting conditions. Simulations done to date show that the greatest combustion rates occur in an annular region between the air-rich central core and the envelope of the fuel spray. The air rich-core, from the primary air flow extends far into the flame zone.

CFD VALIDATION

In parallel with the CFD simulations, BNL is beginning a program of measurements to provide detailed flame field information which will help to verify the validity of the CFD simulations.

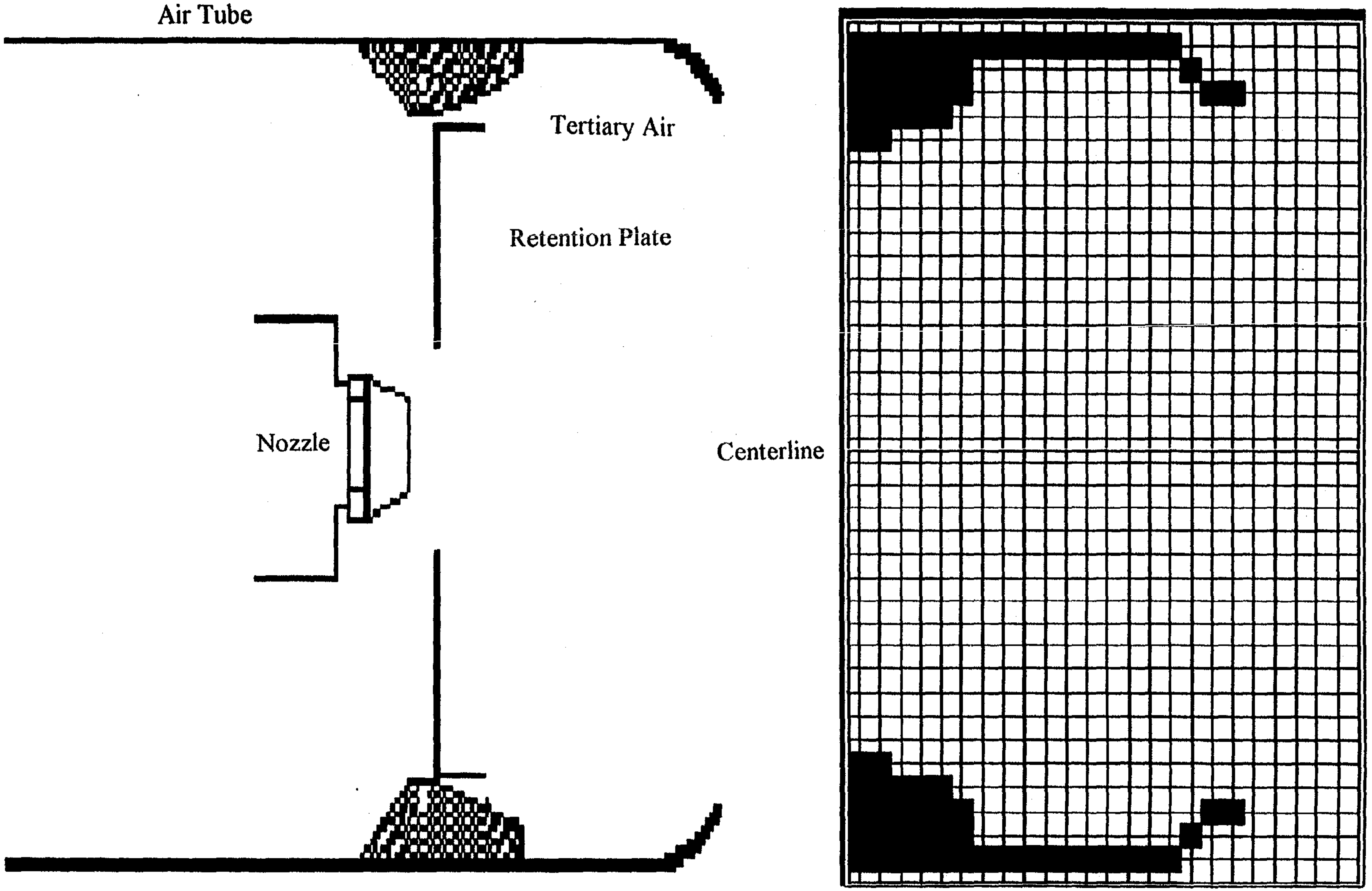

Figure 2. Illustration of head of retention head burner and grid structure close to head used in CFD simulation of cold airflow.

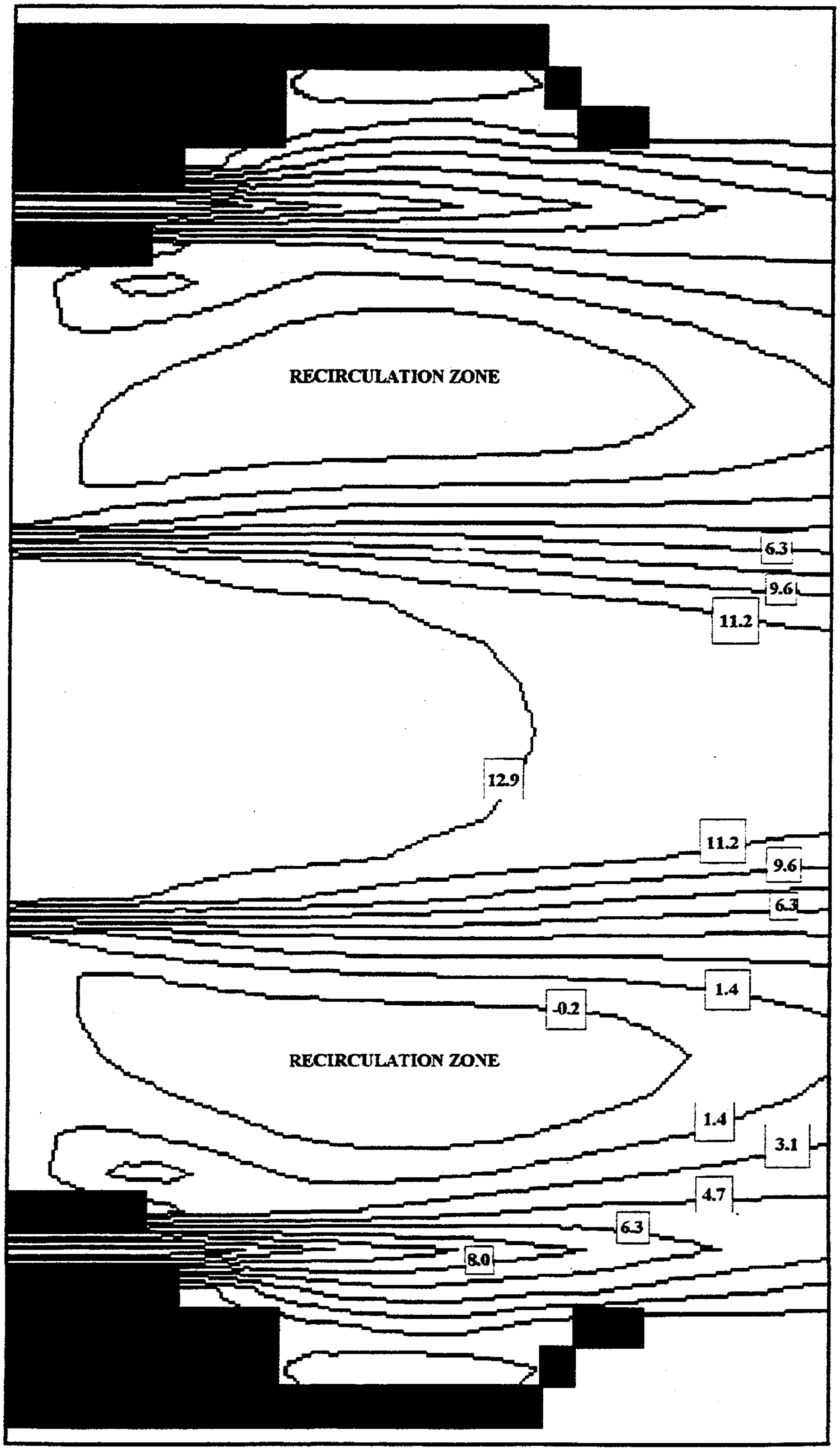

Figure 3. Results of CFD simulation of cold air flow across retention head burner. Velocity in axial direction only. Contours of constant velocity. Velocity values are in meters/sec.

Specifically, this includes the axial velocity field by pitot tube, oxygen and CO field using a water cooled quench type sampling probe, and a radiation shielded suction pyrometer for temperature field measurements. To date, comparison of CFD simulations with measurements have shown agreement in general trends although differences in detail. These show the need to input into the CFD more detailed information about the flow of air through and around the retention plate. The burner components upstream of the retention plate and the air velocity distribution have a considerable impact on the flow patterns in the flame.

FUTURE PLANS

BNL is currently involved with the verification measurements and will complete a series of these for comparison with CFD simulations completed to date. In the future BNL is planning to further develop capabilities in this area and apply CFD tools to advanced burner development for improved performance and reduced emissions.

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Paper No. 97-02

Oil Heat Venting Technology and NFPA Standard 31 Revision Year 2000

Richard F. Krajewski, P.E., BNL

Oil Heat Venting Technology and NFPA Standard 31 Revision Year 2000

Abstract

The revision of National Fire Protection Association (NFPA) Standard 31 for the year 2000 offers an opportunity to update the Appendix which currently offers recommendations for basic metal relining of masonry chimneys up to and including 25 feet. The paper discusses the proposed update of the existing recommendations to include flexible (rough) metal liners. In addition, the discussion addresses the inclusion of additional information for unlined (non-conforming), lined (conforming to NFPA 211 [1]) masonry chimneys, insulated metal chimneys, chimney heights beyond what are now published, as well as power venting both forced and induced draft. Included in the paper is a discussion of the existing Oil Heat Vent Analysis Program (OHVAP Version 3.0 [2]) and issues that need resolution to make it a better vent system model.

Introduction

Computer simulations run with OHVAP Version 1.0 resulted in a set of tables which were included in the 1997 revision of NFPA Standard 31 [3]. This set of tables provided recommendation for the addition of smooth metal linings to existing clay lined masonry chimneys. The tables offered the user recommendations for acceptable firing rates for differing applications of smooth wall metal liner sizes with connector length and chimney height as the other variables. Subsequent revisions of the model and addressing the needs of the industry require that additional information be included in the standard. This additional information is based on the input from the industry at Workshop D of the 1996 Oil Heat Technology Conference [4].

Conforming Masonry Chimneys

The current status of the recommendations contained in NFPA 31 is based on computer runs with a version of the model (OHVAP) which did not take into account the effects of radiant heat transfer and of flue gas water condensation. The addition of radiant heat transfer from surfaces and to the surroundings and across gaps would be eventfully be manifested as an additional loss from the flue gas. Water condensation from the flue gas and vaporization of water back into the flue gas further complicates the process and the net effect of cannot be generalized here for any specific case. A new set of runs using the latest version of OHVAP is required to reaffirm the existing recommendations contained in NFPA 31.

The current recommendations are based on smooth wall liners. Many liners used in practice are of the flexible type which have a highly convoluted wall. These liners have rougher surfaces and offer greater resistance to flow than the smooth wall type. There is enough information to "guess" at an absolute roughness for this material but other properties, such as, the effective density, specific heat, and thermal conductivity, which are affected by the convoluted wall geometry, need to be estimated. The application of the flexible liner will evaluated as an addition to the masonry chimney and recommendations will be incorporated in the standard.

The current recommendations are also based on conforming chimneys, constructed to meet the requirements of NFPA 211 and a nominal as-built configuration using an 8" by 8" clay tile flue liner. There is an expressed industry need for recommendations based on computer runs using other clay tile liners probably sized as 8" by 12" and 12' by 12'. In addition, the choice of chimney height has come into question and it appears that higher chimneys will have to be addressed.

In general, recommendations for conforming masonry chimneys which do contain a clay liner but no additional metal liner, have not been addressed in the standard. They should be included in the upcoming revision of the standard for completeness and comparative purposes.

Non-Conforming Masonry Chimneys (NC)

There is some evidence that a large number of existing masonry chimneys are not built to NFPA 211 standards and, as such, are considered non-conforming. The non-conformance of construction ranges from not having an effective air gap between the required clay tile liner and the outer masonry to not having any liner at all. The latter geometry, no clay liner, is a configuration which could yield considerable information in terms of comparison. The as-found condition assuming nominal masonry brick and metal relining recommendations should be incorporated in the standard.

Factory Built Chimneys

The current version of OHVAP will effectively model metal chimney systems with single or multiple air gap insulation systems which meet "L" vent requirements for listing. In addition, insulated metal chimney systems can be modeled using a selection of insulation materials identified in the material listing of OHVAP. The "L" Vent as well as the insulated metal chimney should be part of the recommendations contained in the standard.

Power Venting

The application of an induced draft fan and the necessary fan inlet control damper are part of the input by the user and are effectively modeled by OHVAP. In applications where the burner is used in a forced draft mode, the appropriate positive vent pressure is calculated and must be compared to the pressure capacity of the burner used. This would include induced and forced draft applications. The power vent in a side-wall application as well as in the chimney should be part of the recommendations contained in the standard.

Implications for NFPA 31 2000 Edition

The following Table 1 represents is a summary of the items to be evaluated and incorporated in the upcoming revision of NFPA 31. The task is ambitious but the allotted time to run the computer simulations and write the required text is within the window of opportunity which may be offered during FY 1998 to FY 1999.

Table 1 - Vent Configuration

Vent Type	Min. Hgt.	Max. Hgt. [2]	Min. Len.	Max. Len. [3] [4]	Min. Dia.	Max. Dia. [5]
Masonry Chimney (NC)	10 Ft.	100 Ft.	4 Ft.	10 Ft	4 in.	8 in.
Masonry Chimney © [1]	10 Ft.	100 Ft.	4 Ft.	10 Ft.	4 in.	8 in.
Masonry Chimney (NC) Relined [6]	10 Ft.	100 Ft.	4 Ft.	10 Ft.	4 in.	8 in.
Masonry Chimney © Relined [1][6]	10 Ft.	100 Ft.	4 Ft.	10 Ft.	4 in.	8 in.
Factory Built "L" Vent	10 Ft.	100 Ft.	4 Ft.	10 Ft.	4 in.	8 in.
Factory Built Insulated Metal	10 Ft.	100 Ft.	4 Ft.	10 Ft.	4 in.	8 in.
Power Vent Induced Draft			4 Ft.	20 Ft.	4 in.	8 in.
Power Vent Forced Draft			4 Ft.	20 Ft.	4 in.	8 in.
Power Vent Chim. Induced Draft	10 Ft.	100 Ft.	4 ft.	20 Ft.	4 in.	8 in.

Notes:

[1] Clay lined conforming © chimneys will be evaluated for nominal 8"x8", 8"x12", and 12"x12" liners. Non-conforming (NC) chimneys will be evaluated as constructed from nominal masonry brick.

[2] Chimney heights will be evaluated at 10, 20, 30, 40, 60, 80, and 100 feet.

[3] Connector horizontal lateral lengths will be evaluated at 4, 6, 8, and 10 feet. An additional vertical length of 2 feet plus a single elbow will be included in all cases.

[4] Power Vent horizontal lateral lengths will be evaluated at 4, 6, 8, 10, and 20 feet. An additional vertical length of 2 feet plus a single elbow will be included in all cases.

[5] Diameters of 4, 5, 6, 7, and 8 inches will be evaluated.

[6] Metal lining system of both the smooth wall and flexible (convoluted) wall will be evaluated.

Proposed Revisions for Venting Model (OHVAP Version 3.0)

OHVAP goes beyond the limitations that currently prevent the other transient vent analysis programs that are available from satisfying the needs of the oil heat industry. However there are other limitations within OHVAP. As a brief overview of the status of the current venting model, some of it's limitations should be presented here. It is hoped that at some point in the future these limitations will be addressed. The extent of the effects on predictive results by correcting these limitations and the cost of correction has not yet been evaluated. The priority of correction is an estimate based on ease of use of the model. They can be prioritized as follows:

1) Correction is required of the calculation to permit ambient temperatures below 0^{o}F and the accounting for the heat transfer effects of condensate freezing in the vent system. Currently OHVAP only calculates flue gas constituent properties down to 0^{o} F and locks up when lower temperatures are calculated for the flue gas during warm-up from below zero ambient conditions defined by the user.

2) An implementation of a second source of dilution air, located in the base of the masonry chimney is required. This can be a "simple" single point air leakage into the chimney flue gas based on ambient conditions surrounding the chimney. Currently OHVAP provides only for the inflow of dilution air at the location of the draft control device which is commonly located in the chimney connector. Leakage flow into the flue gas can be forced as additional terms to the dilution air flow equation for the draft control device. This can currently be defined in the input to OHVAP by the user, but then the draft control device itself must be positioned in the base of the chimney, an infrequently used location.

3) Correction is required of some of the elevation calculations to permit "hot" flue gas buoyancy effects for vertical elbows, tees, and special fittings. Currently OHVAP incorrectly assigns elevation effects and the model has been modified to ignore these calculations for the above fittings.

4) Enhancement the condensation model is required to provide a fully dynamic transient analysis of the water and sulfuric acid condensation within the vent system. Currently OHVAP uses a steady state condensation model that is attached to the transient heat transfer model.

5) Support multiple appliance systems (common venting) and a rigorous elemental leakage into the flue gas is required. The current version of OHVAP will currently handle a vent system that is designed for one appliance. While OHVAP was being developed, many questions arrived from the industry regarding multiple appliance systems. While this condition can be "forced" in the model by combining the appliances

into one larger appliance, this does not truly answer the need, especially for non-synchronized operation or appliances that may be located at different elevations.

6) Conversion of the heat transfer routines from a one dimensional to a two dimensional form is required. This will allow the program to more realistically account for the fact that many conventional chimney systems are sheltered along one wall from outside ambient conditions. It will also allow a lined chimney system to have the round liner within a rectangular chimney. Currently, the rectangular chimney is modified into a square to allow the nodes to fall into place. A two-dimensional heat transfer model would allow the walls to be modeled directly, without conversion.

7) Refinement is required of the flow model to allow finer divisions within the gas plugs. Currently gas plugs may occupy more than one element within the system. To achieve greater accuracy, a greater number of gas plugs would better simulate the continuum of flue-gas in the system.

8) An increase of the flexibility of the printing functions is required. OHVAP currently limits the user to reporting on six variables over a maximum of fifty elements. Furthermore, this output is limited to two files. These limitations were built into the model purposely to conform to the LOTUS™ version 1 spreadsheet format. By allowing other file formats, there is no reason to limit the output choices to six variables or even fifty elements. The newer WINDOWS™-based spreadsheets can handle much greater amounts of data than the older LOTUS standard.

9) Proper error checking built into the menu module is required. The program provides no error checking at all. If there is an error in the information fed into the program the only way that it will be revealed is by the program stopping its execution or a crash of the computer.

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Paper No. 97-03

Practical Approaches to Field Problems of Stationary Combustion Systems

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ABSTRACT

The CANMET Energy Technology Centre (CETC) business plan dictates collaboration with industrial clients and other government agencies to promote energy efficiency, health and safety, pollution reduction and productivity enhancement. The Advanced Combustion Technologies group of CETC provides consultation to numerous organizations in combustion related areas by conducting laboratory and field investigations of fossil fuel-fired combustion equipment. CETC, with its modern research facilities and technical expertise, has taken this practical approach since the seventies and has assisted many organizations in overcoming field problems and in providing cost saving measures and improved profit margins.

This paper presents a few selected research projects conducted for industrial clients in north and central America. The combustion systems investigated are mostly liquid fuel fired, with the exception of a utility boiler which was coal-fired. The key areas involved include fuel quality, fuel storage/delivery system contamination, waste derived oils, crude oil combustion, unacceptable pollutant emissions, ambient soot deposition, slagging, fouling, boiler component degradation, and particulate characterization. Some of the practical approaches taken to remedy these field problems on several combustion systems including residential, commercial and industrial scale units are discussed.

INTRODUCTION

The steady increase of world energy consumption, combined with the recent rapid rise of energy demand by the third world, indicate that the continued use of the primary fossil fuels will be with us for a number of years to come. In the meantime the environmental aspects of combustion of these fuels, oil, coal and natural gas, and the relationship between energy use and climate change have become major scientific and policy challenges globally. For the energy industry, the major focus has been the efficient use of these fuels while maintaining the goals to achieve sustainable development. At Natural Resources Canada, the federal department responsible for energy R&D, great opportunities exist to be involved in research programs to improve energy efficiency and reduce emissions from conventional fuels while encouraging the use of unconventional fuels and new technologies. CANMET (Canada Centre for Mineral and Energy Technology) focuses on several program areas of advanced combustion technologies, with the aims to develop practical, cost-effective, combustion driven strategies for reducing emissions and increasing overall system efficiency from fossil fuel-fired stationary combustion sources. The CETC business plan also includes collaboration with industrial clients and other government agencies to promote energy efficiency, health and safety, pollution reduction and productivity enhancement. The program objectives focus on a range of energy sectors: power generation, industrial combustion processes, residential and commercial space and water heating and fuel performance optimization. This paper summarizes a few selected projects conducted under the sub-programs of "Industrial Efficiency" and "Residential and Commercial Heating Systems". These tasks were restricted to field problem solution while most of the projects were carried out in support of the needs identified by industrial and public sector organizations.

OIL COMBUSTION RESEARCH FACILITIES AT CETC

CETC has bench and pilot scale combustion equipment and unique facilities to assess fuel quality, appliance performance and emissions as well as to develop new environmentally sound combustion technologies. About 30% of the projects performed under the above two programs required field operations at a client's plant site while about 45% involved laboratory experiments at CETC's facilities. The balance dealt with systematic investigations or assessments of the problems involved by providing scientific consultation to remedy adverse situations, based on in-house expertise, scientific data and literature reviews. Some of the field combustion problems were resolved by systematic investigations which included conducting experiments using field simulation test facilities. For experimental work, CETC's oil combustion research laboratory is equipped with a field-simulating, temperature controlled test room, advanced continuous emission analyzers, particulate sampling systems, video equipment for flame characteristics assessment and computer and electronic hardware for state-of-the-art, on-line data acquisition control and analysis systems. The laboratory facility allows combustion experiments to be carried out on different residential and commercial furnaces and boilers installed in-house or supplied by clients. Currently there are four boilers and a furnace in the laboratory, unit ratings: a 300,000 Btu/h hot water unit and a 400,000 Btu/h hot water/steam unit and a residential furnace with 120,000 Btu/h capacity. A typical laboratory test rig is designed using combustion unit(s), various analyzers and sampling systems as illustrated in Figure 1. A 0.7 MW (2.5 GJ/h) thermal input, flame tunnel furnace and a 0.8 MW thermal input, pilot scale research boiler are often used for combustion, heat transfer and emissions evaluation of industrial scale burners and commercial fuels such as coal and oil emulsions.

The scope of combustion research projects generally involve a thorough identification of the problems and project objectives, development of a project strategy based on its dynamics and the systematic execution of subsequent laboratory or field combustion tests. A typical combustion performance evaluation experiment includes examination of burner ignition behaviour, flame characteristics, gas phase emission concentrations of oxygen (O_2), carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), sulphur dioxide (SO_2), hydrocarbons (HC), and particulates in the flue gas and the measurement of temperatures at several critical appliance component locations. Particulate emissions are measured using a commercial smoke tester, a commercial in-line smoke opacity metre or a standard source particulate measurement system. Source characteristic profile of particulate emissions can also be determined using a source dilution sampling system. These facilities can be easily modified to meet individual project needs by clients. Recently one client required the burner to be tested under extreme temperatures and the combustion rig was cooled to provide test temperatures of -15°C and fuel temperature of -24°C.

CLIENTELE AND NATURE OF PARTNERSHIPS

The following organizations have established business associations with CETC in recent years in connection with the research programs performed under the two program areas discussed earlier. The research assignments are carried out for various clients and partners under full cost recovery, cost-shared or task shared arrangements. Ninety-five percent of the projects involved in these programs were full cost recovery while only about 5% represent joint-venture activities.

American Society of Heating, Refrigerating and Air-Conditioning
    Engineers Inc., USA
Canada Northwest Energy
Canadian Explosive Atmospheres Laboratory
Canadian General Standards Board
Canadian Petroleum Product Institute
Department of National Defence
DMO Industries
Ensyn Technologies Inc.
Environment Canada
Ethyl Corporation, USA
Government of Northwest Territories
Government of Ontario
Health Canada
Imperial Oil, Canada
Iron Ore Company of Canada
National Centre for Upgrading Technologies
Niagara Mohawk Power Corporation, USA
Petro-Canada Products
Provincial Hospitals in Eastern Canada
Shell Canada Limited
    Syncrude Canada Limited
Sunoco Inc., Canada
Suprex Corporation, USA
TransAlta Utilities Corporation, Canada
Ultramar Canada

STATIONARY COMBUSTION SYSTEMS OPERATIONAL DIFFICULTIES

This paper addresses some of practical approaches taken to remedy different field problems of a number of oil-fired combustion systems. To protect client identity and confidentiality of the projects, the location and nature of company business as well as scientific details involved in the investigations are discussed in general terms.

Residential Oil-Fired Heating Systems:

A majority of the operational problems associated with residential space and water heating equipment can be attributed to fuel oil quality. Fuel quality is a complex but critical issue since there are many aspects of fuel properties that can adversely affect engines and combustors to varying degrees. Based on CETC's experience, the most common field problems are associated with contamination that occurred after production. Fewer number of cases were noted where the poor quality is related to the original refinery blending. A fuel can be contaminated chemically, physically or microbiologically. Chemical contamination generally originates from the presence of various materials such as off-specification hydrocarbons, solvents and chemically altered byproducts by polymerization or decomposition, which are often accelerated by the presence of reactive compounds such as refinery catalysts. The mixing of heavier residual fuel components or water into light distillates are common chemical contamination routes. Significant changes in fuel hydrocarbon composition normally create deleterious combustion problems including fire and explosion hazards, appliance failure and excessive pollution. The presence of solid particles such as sand, dust, debris and metal corrosion products create physical contamination which could lead to appliance failure from plugging of critical fuel system components. Microbiological contamination is more common in transportation fuels. However, cross-contamination does occur occasionally and heating fuels have been known to have such problems in Canada. Untreated, the infestation could accelerate resulting in degradation of fuel quality with undesirable consequences. Potential problems include combustor failure due to filter plugging with accumulated debris from microbes, tank corrosion caused by increased acidity and ignition difficulties due to the loss of lighter hydrocarbons.

One particular case relating to fuel quality involved heating fuels which were re-processed from automobile garage waste oils. Due to the observed excessive environmental emissions and hazardous appliance operating problems from combustion of these fuels, the provincial environmental authorities charged the fuel producer and CETC was required to provide expert witness testimony in court. Several home owners experienced burner failure, appliance malfunction including front-end blow-out and minor illnesses due to indoor fumes and odour from combustion of these fuels. A thorough analysis of the fuels revealed the presence of very volatile as well as very heavy hydrocarbon components, which were blended with less than desirable amounts of medium hydrocarbon fractions. The results suggested a potential fire and explosion hazard related to very low flash points of these off-specification fuels. However, insufficient fuel samples did not allow for comprehensive combustion tests. Combustion performance evaluations were estimated using the CETC fuel quality/performance data base established from a comprehensive research program using 50 petroleum fuels. Operating problems related to premature ignition, flame instability and burner failure were predicted. Estimated pollutant emissions from combustion of these fuels were also high due to the increased heavy, aromatic hydrocarbon contents of the fuels. The authorities won the case and were able to terminate the production and sale of these fuels.

An emergency field appliance problem which affected several hundred households in a Canadian city occurred when an inadvertently contaminated fuel oil was delivered for home heating. The company received several no-heat calls requiring emergency services. The service personnel did not find any equipment problems and managed to restart the burners only after external cleaning of the oil nozzles. No visible coking nor blockage at nozzle tips were observed. However, the appliance failures recurred within a few days, requiring repetitive service calls to most of the homes. The chemical analysis results of the fuel samples taken at some affected homes and the receiving terminal as well as the producers' product quality data showed compliance with the standard heating fuel specifications. Due to the urgency of the problems taking place in a city with extreme cold temperatures in mid-winter and the mounting service costs, the distributor required immediate assistance. In addition the situation could have developed into a legal matter if the source of the problem were not accurately identified; whether the producer or the distributor was at fault. The key fuel property results suggested the physical nature of contamination. The client was instructed for immediate installation of fuel line filters with much finer screens than those being used, to prevent nozzle plugging. A series of filtration experiments were then conducted to determine the presence and size of suspended particles in several fuel samples taken from the storage tank. These results indicated the presence of very fine suspended rust particles, a finding confirmed by the client's discovery of the tank corrosion problems resulted from poor maintenance and previous storage of residual fuels in the tank. Due to the very fine nature of the particles, nozzle plugging problems were intermittent and difficult to detect. The subsequent, laboratory combustion evaluations revealed that the problems were intermittent and were directly related to the bulk location of the fuel inside the tank. Detailed hydrocarbon profile analysis showed only traces of residual fuels. In the field, the problems were compounded by the fact that the fuels were mechanically agitated through pumping during delivery and the tanks in some homes received more contaminated fuels than others. This investigation assisted the client in identification of the problem at an early stage and in saving thousands of dollars in service maintenance charges.

Another case, for example, originated abroad where a client purchased light distillate fuels for air craft, diesel engine and space heating applications. One of the fuels in client's bulk storage tanks showed minor microbiological contamination within a short period of time after delivery. The investigation on how the fuel became contaminated was difficult since neither the imported fuel nor the existing tank fuel were initially tested for microorganisms. However, an emergency situation arose from the fact that the provincial authorities were not sure of the nature and the extent of the problems that could arise from using these fuels and that the entire remote community where the problem occurred had to be evacuated in the middle of a very cold winter, should any of the fuels caused operating difficulties. This urgent situation was diffused when CETC confirmed the presence of only minor microbial contamination in the fuels and low levels of suspended particles were found in aviation fuels. The client was urged to install finer screens and filters on all combustion equipment immediately to prevent injector and nozzle plugging. It was necessary to brief the client on the nature of the problems associated with microbial contamination and to provide immediate assessment of the situation, based on the limited information made available to the project leader. The most common type of microbes, *Hormoconis resina* fungus, usually produce threadlike webs called mats (fungal mycelium). This process is known as biofouling and which could lead to plugging of the nozzles and injectors, resulting in system failures. Another type of microbe, "sulphate reducing bacteria" are known to produce H_2S through metabolizing the sulphur in fuel. This, being a well known corrosion enhancer, causes structural damage including pitting and corrosion of storage tanks and fuel lines.

The systematic investigation that followed involved examination of the contaminated fuels using several physical, chemical, microscopic and microbiological tests, short-term combustion evaluation tests and consultation with aviation fuel experts from the Canadian military. The results revealed that the fuel properties allowed for the short-term use of the fuel in aircraft, provided water contamination is routinely checked. The short-term combustion results also revealed normal fuel performance in high pressure burners. However, serious implications over long term use of the fuel exist if used without proper and timely chemical treatment. Recommendations on treatment with biocides, clean-up and maintenance procedures of the fuel tanks for safe handling and long-term storage were provided in the report.

In another case, consultation was needed to identify field problems associated with the company's oil-fired space heating units in Europe. A Canadian manufacturer received complaints on its appliance's malfunction but could not identify any specific mechanical problems. The difficulty arose due to an apparent incompatibility between the appliance and the fuel. Since the client could not provide adequate fuel for combustion evaluation in Canada, expected combustion characteristics were predicted using the existing data base at CANMET. Through an investigative characterization of the fuel in question and systematic analysis of the problems, it was possible to resolve this difficulty for the client.

Commercial and Industrial Scale Oil-Fired Combustion Systems:

In commercial and industrial sized boilers, operational problems related to mechanical equipment such as boiler components and control systems are prevalent, in addition to fuel quality effects. All of these, however, contribute to equipment malfunction and increased pollutant emissions. It has been well established that pollutant emissions from various combustion sources impact profoundly on the environment, human health and natural habitats, operation of combustion and abatement equipment and associated costs. Since emissions from larger combustion systems are more prominent than those used by the residential sector, they are subject to the local, state/provincial and federal regulatory emissions standards compliance. The energy industry also has to deal with the increasingly tighter specification standards for various petroleum products.

Recently CETC was involved in efficiency improvement and resolving the excessive particulate emission situation at the heating plants of two provincial hospitals in Canada. The residual oil-fired industrial scale boilers were emitting high particulates, with smoke opacities as high as 40% at peak load. Due to their critical locations, close to the highly populated areas of the cities, it was necessary to remedy the situation in a speedy manner. The plants also reported very high fuel costs and difficulty in controlling boiler operations. A thorough on-site equipment inspection and emission performance evaluation of the boilers provided identification of a number of areas that needed to be corrected in both sites. These included very high sulphur content of the No. 6 fuel; poor atomization of the fuel at the burner; flame impingement on the side walls, reducing the local temperature to below that necessary for complete combustion; the incorrect position of the flame sensors creating delays in startup of one of the burners; malfunction of the fuel control valve creating transient fuel-rich conditions at increasing load; lower than desired differential pressure between the atomizing steam and the oil pressures; poor response sensitivity of the automatic fuel/air supply control system; and too high air swirl created by the slightly-off position of the air veins on the diffusor. Necessary modifications to the equipment and correction of operational procedures were implemented on site until real improvement in both efficiency and emissions were realized.

One major production company in Canada contacted CANMET for scientific consultation when the furnace temperature variations were suspected to have caused product quality imperfections. The multiple burners inside the plant's large furnaces caused product drying temperature variations due to poor combustion conditions. The degradation of combustion process was linked to the bunker C fuel supply system which included primary and secondary pre-heaters. The specifications of the fuel as delivered showed no indication of fuel quality problem. CETC's investigation discovered that one of the reasons for the degradation of residual fuel, after delivery to the plant, was due to the malfunction of the heat exchangers installed on the pre-heaters. Inspection of filters on the pre-heaters also revealed excessive solid deposits which were highly undesirable. Subsequent investigations showed the presence of fuel degradation products in the supply system and the contamination of fuel with heavier hydrocarbon components from other petroleum products used in the plant. Other sources of fuel contamination in the delivery systems and potential problem areas in the fuel storage tanks were also identified. Burner combustion conditions improved with the corrective measures implemented on heat exchangers and with the use of cleaner fuels. Plant personnel managed to remedy these undesirable situations at the early stages and subsequently prevented significant losses on product sales, which otherwise would have continued.

Recently, the author completed a research project for the American Society of Heating, Refrigerating and Air-Conditioning Engineers Inc. (ASHRAE) to study the impact of fuel sulphur content on the energy and environmental performance of oil-fired boilers. The project, though not a problem solving matter, is relevant since the results provided the knowledge of how fuel sulfur can influence the boiler emissions and heat exchanger corrosion. This can then be applied to prevent fuel sulfur related field problems on boilers. Other issues related to this project were the introduction of new diesel fuel specifications with a reduced sulfur limit and to the recent findings of a possible association of fuel sulphur with fine particulate emissions. A 300,000 BTU hot water, reversed-flow boiler was modified to accommodate a special flue section for collection of sulphur-derived surface deposition products. Six test blocks were designed so that their steel surfaces closely simulated those of the main heat exchanger and were exposed to part of the flue gas stream. The specially formulated heating fuels used in the experiments contained sulfur in the range of 0.01 to 1.2%. In addition to gas phase emissions, including SO_2, the pH, SO_3, SO^{-2}_4 concentrations in flue gas condensate and soluble deposit portion were measured. The detailed analysis of Fe and SO^{-2}_4 in the insoluble deposit (solids) and soluble deposit allowed for the determination of the total deposition rate and the type of corrosion processes involved. The results showed that with the increase of fuel sulphur concentration: flue gas SO_2 increased linearly with a correlation coefficient (R^2) of 0.99; flue gas acidity and SO^{-2}_4 concentrations increased; acidity of soluble deposit increased due to free acid formation; Fe in the soluble deposit solution increased with a R^2 of 0.96; SO^{-2}_4 in soluble deposit solution increased with a R^2 of 0.96. In addition, the observations indicated that the insoluble portion of total deposit decreased, while Fe in the insoluble deposit also declined, as the deposits became more soluble with increasing fuel sulfur. Oxygen corrosion was dominant at sulfur concentrations below 2000 ppm while above that level, sulphuric acid corrosion appeared to be primary. In summary, the study indicated that appliance integrity will degrade over long term use of high sulfur fuels, as evidenced by the linear increase of deposition products with increasing fuel sulphur.

Utility Scale, Fossil Fuel Fired Combustion Systems:

The environmental emissions associated with these very large combustion systems are of major concern to organizations such as power utilities. The previously discussed emission standards are more stringent for these combustion systems and the emissions control measures are accordingly more costly to implement. These undesirable pollution emissions are usually associated with the equipment's abnormal performance, whether it is due to mechanical component problems, operating conditions, or the fuel quality effects. In cases where fuel quality has drastically affected the performance of a combustor over a long period, costs of pollution control and maintenance become excessive. One of the clients experienced serious operating difficulties requiring daily corrective procedures and high maintenance costs from the combustion of a local crude oil in its power generation plants in the Caribbean. Severe heat exchanger fouling and slagging, with excessive levels of pollutant emissions occurred in the utility boilers due to the high amounts of asphaltene, sulphur and chlorine present in the extra heavy crude being used. The problems were compounded by the fact that the boilers, which were originally designed for the much lighter petroleum residual fuels, were utilized without modifications and by the poor maintenance of the units over a number of years. Scientific consultation and recommendations were provided based on the nature of operational problems reported and the crude characterization results. The observations were interpreted in terms of specific fuel properties and suggestions were made on ways to improve the overall fuel quality. These include dilution of the crude with appropriate, light petroleum distillates; removal of water and salt from the crude; avoidance of conditions which would enhance precipitation of asphaltenes in fuel streams; and methodologies for selective fuel analysis and fuel delivery system maintenance. The client later reported improvement of plant operations after incorporating the suggested protocols.

Serious corrosion and fouling problems also occur in the coal and residual oil-fired combustion systems, due to the increased particulate and sulfur oxide emissions contributed by the fuels' high sulphur and aromatic contents. Recent Canadian and US studies have linked respiratory illnesses, lung cancer and increased mortality rates to ambient SO^{-2}_4 and particulate matter (PM) concentrations in heavily polluted cities [1-4]. These studies suggested that the fine PM (<2.5 μm) have a greater health impact than coarse particles. In November 1996, the USEPA proposed the revised National Ambient Air Quality Standard, which requires the reduction of current ozone limits and the introduction of the new PM limit of 2.5 μm. This has become the most controversial regulatory issue in North America since this will affect numerous industries which do not have sufficient data nor the accurate measurement technology for $PM_{2.5}$. In view of these developments, a major Canadian utility approached CANMET for consultation on the characterisation of PM emissions form its coal-fired power plants. While oil and coal-fired stationary combustion systems have been identified as fine particle emitters, their actual contribution to ambient concentrations is difficult to elucidate due to the complex transformation pathways involved and contributions from other nearby sources. The current ambient monitoring techniques provide total contributions from numerous sources at a specific receptor site and therefore cannot be used for identification of contributions from specific point sources. A new particulate characterization strategy using a source dilution sampling system and a detailed particle analysis scheme for size distribution and chemical composition was developed. Particulates are sampled at the source using a modified EPA 5 sampling train and under simulated ambient conditions by means of a new source dilution sampler. This equipment, in which a portion of boiler combustion gases are diluted with clean, dry air, allows simulation of atmospheric condensation and coagulation processes that would occur after exiting the stack. Particulate characterization include PM-2.5, PM-10, total PM, sulphate and nitrate concentrations, elemental and organic carbon. Gas phase emissions including SO_2 and NO_x are also examined. This novel, ambient-simulating, sampling approach will provide source characteristic profiles which are critically required for source apportionment modelling. Source apportionment is a atmospheric modelling process used to identify individual point sources which contribute specific pollutants to the ambient environment in a very complex way. It is expected that the project results will provide critical information for corporate strategy development to utilities and the scientific basis to regulators for policy formulations.

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To protect the confidentiality of the business associated with individual organizations, author's publications and confidential business reports are not cited in this paper.

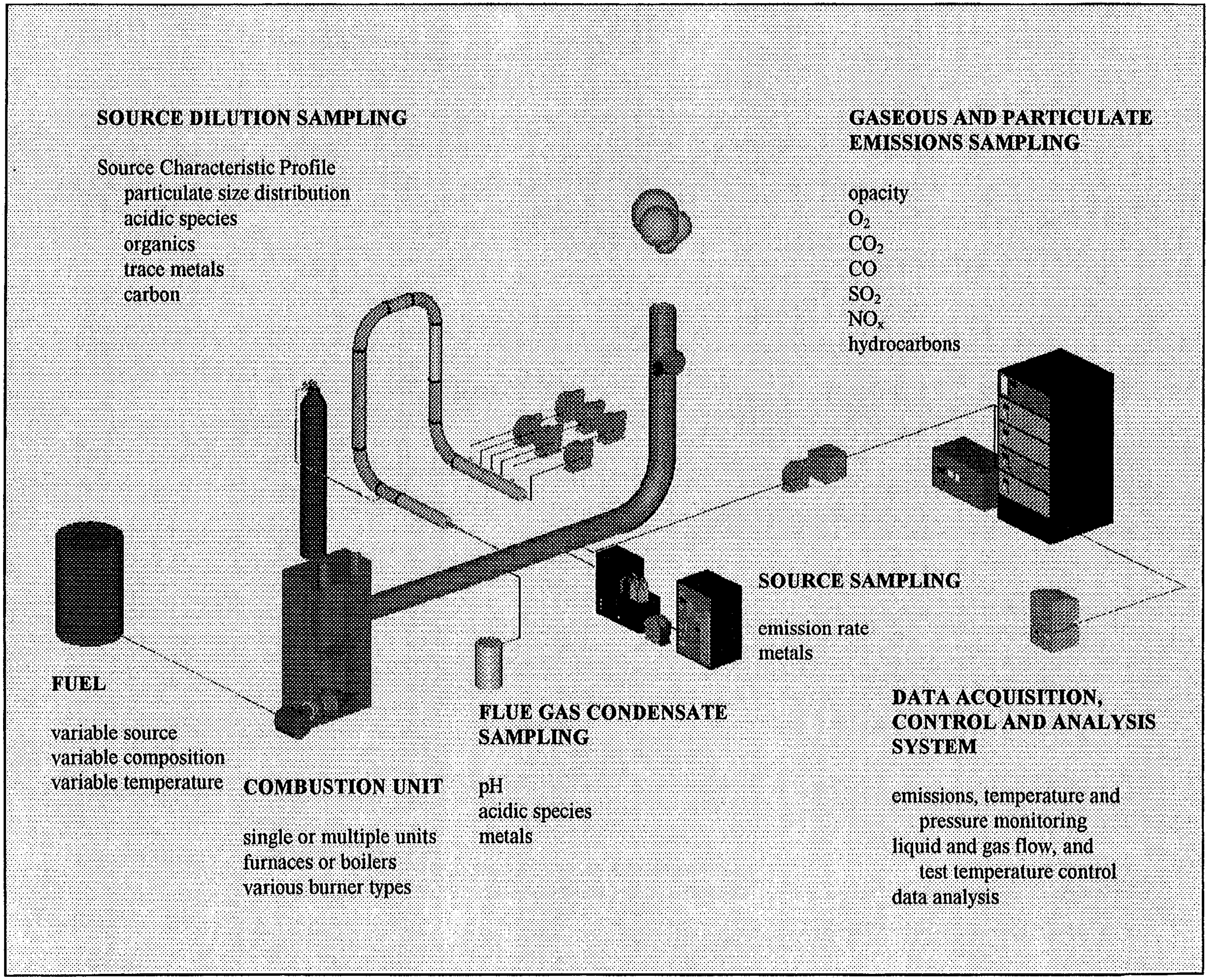

Figure 1 Schematic diagram of liquid fuels combustion research facilities.

Paper No. 97-04

Research, Development, and Testing of a Prototype Two-Stage Low-Input Rate Oil Burner for Variable Output Heating System Applications

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Dr. Thomas A. Butcher, Ph.D., BNL

Research, Development, and Testing of a Prototype Two-Stage Low-Input Rate Oil Burner for Variable Output Heating System Applications

Abstract

The use of a Two-Stage Fan Atomized Oil Burner (TSFAB) in space and water heating applications will have dramatic advantages in terms of it's potential for a high Annual Fuel Utilization Efficiency (AFUE) and/or Energy Factor (EF) rating for the equipment. While demonstrations of a single rate burner in an actual application have already yielded sufficient confidence that space and domestic heating loads can be met at a single low firing rate, this represents only a narrow solution to the diverse nature of building space heating and domestic water loads that the industry must address.[1] The mechanical development, proposed control, and testing of the Two-Stage burner is discussed in terms of near term and long term goals.

Introduction

The Fan Atomized Burner (FAB) was developed at Brookhaven National Laboratory as part of the Oil Heat Combustion Equipment Technology Program to provide a practical low-firing rate technology which could be applied to existing and new appliances for improved efficiency and long term performance.

In the FAB, the fuel oil is atomized with air supplied by the burner's fan. A single fan is used to provide all the combustion air for this burner. The air is delivered at a pressure of about 8 inches of water. Some of this air goes through the nozzle, atomizing the fuel; the remainder passes around the nozzle providing air into the flame zone to complete combustion. The nozzle is designed to establish a small oil film for good atomization and ignition. The burner uses a low pressure oil pump with sufficient lift capability to meet below grade fuel oil storage applications. The combustion air at the required pressure is provided by a plastic blower driven by a brush less DC motor at high speed.

Air Flow Control

The air that goes around the nozzle is split to provide secondary and tertiary combustion air flow into the combustion zone. The tertiary air flow is manually adjustable in the single firing rate design and provides the basis for developing a motor driven version for the two-stage FAB burner. Although the relative position of the tertiary air adjustment has some effect on the secondary air flow, a satisfactory high-fire and a low-fire position have been identified through experimentation. Figure 1 shows the general flow of tertiary air in the TSFAB burner design.

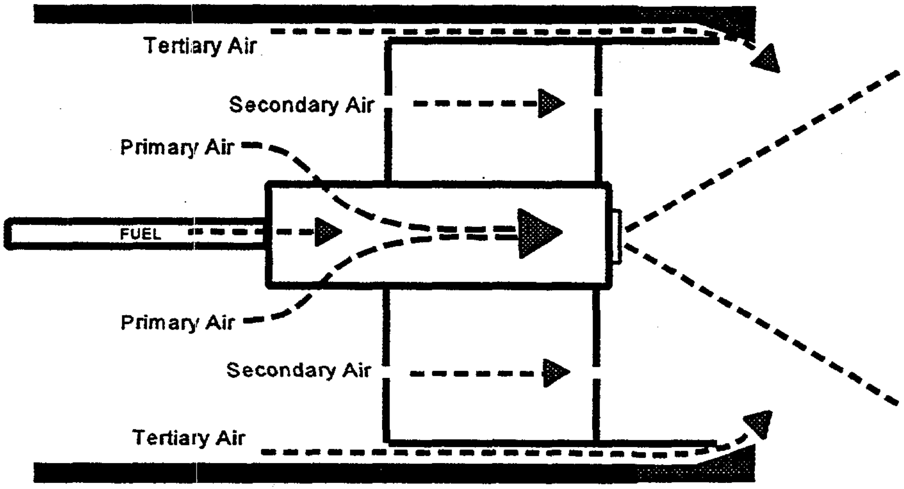

Figure 1 - The tertiary combustion air flow is controlled by the position of the nozzle assembly relative to the taper at the end of the air tube.

Fuel Oil Flow Control

The fuel oil flow control is of a simple design. It is accomplished by using two nearly equal oil flow orifices in parallel. Each orifice is supplied through a solenoid valve. With one valve open, the flow is restricted to the low-fire rate. With both valves open, the combined flow is at the high-fire rate. The control of the solenoid valves is performed in conjunction with the motor positioning of the burner head components controlling the tertiary combustion air. The firing rates actually achieved during experimentation conducted with an early version of the burner in a quartz tube combustion chamber were 0.3 and 0.5 gph respectively resulting in a turndown ratio of about 1.7:1.

Overall Appliance Control

Only two approaches have been considered in the operation of the TSFAB in terms overall appliance control. The first, in a sense a passive approach, is currently offered by a major controls manufacturer. The other, a more active system, requires some development.

In the first approach, the burner starts in low-fire operation through a contact closure in the burner/igniter control. The overall operation after start uses a multi-zone control with domestic water priority through a demand side control signal from a thermostat to signal the burner when to go to high-fire from the base line low-fire state. This control would have a simple fixed logic which requires high-fire, with priority, during domestic hot water system calls from storage and a baseline low-fire operation during space heating calls. Figure 2 provides an overall visualization of this control system applied to the laboratory version of the TSFAB. The figure is a block diagram electro-mechanical schematic of the air and fuel controlling components of the burner and the electrical controls required to link the burner with the appliance operation with the heating loads of the space heating distribution and domestic water system. A suitable reduction in packaging and final size of the control system is an expected outgrowth of the research.

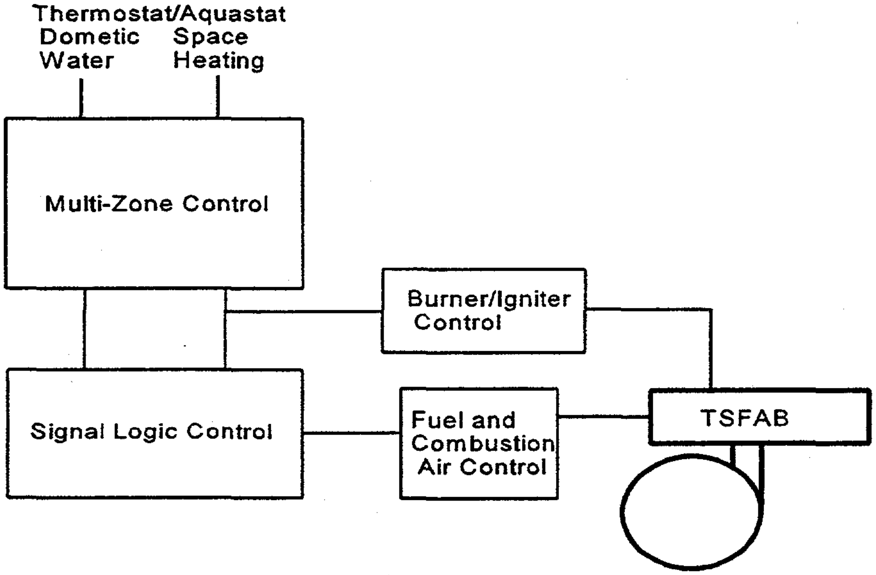

Figure 2 - Block diagram of the control system for the TSFAB

Another approach, more sophisticated in nature, would use a logic system applied to the boiler water delivery side temperature using a single point sensor. The rate-of-rise on the delivery side of the boiler would trigger a switch from low-fire to high-fire. The rate-of-rise set-point would be variable to accommodate the diversity of appliance output to loading found in the field. Thus, under heavy loads the rate-of-rise would be expected to be below some assigned set-point and would require high-fire operation of the burner. Under light to moderate loads the rate-of-rise would be above the assigned set-point and the burner would remain at or revert to low-fire operation. A variation of this scheme would require a second sensor to monitor a common boiler return water temperature. This would provide the control system with information on the boiler water temperature differential. Any effects of the use of a second sensor must be evaluated. In either case, thermally isolated surface mounted thermocouples or thermistors should suffice as sensors.

Measurements taken in field experiments, illustrated in Figures 3, show the fall off of boiler water temperature rate-of-rise as additional heating zones come onto the distribution system during an early morning pull-up from house set-back. Although not actually tested in this experiment, it is anticipated that domestic hot water calls, either from immersion coils or storage tank would precipitate a low rate-of-rise in delivered boiler water temperature and a consequential high-fire operation of the burner.

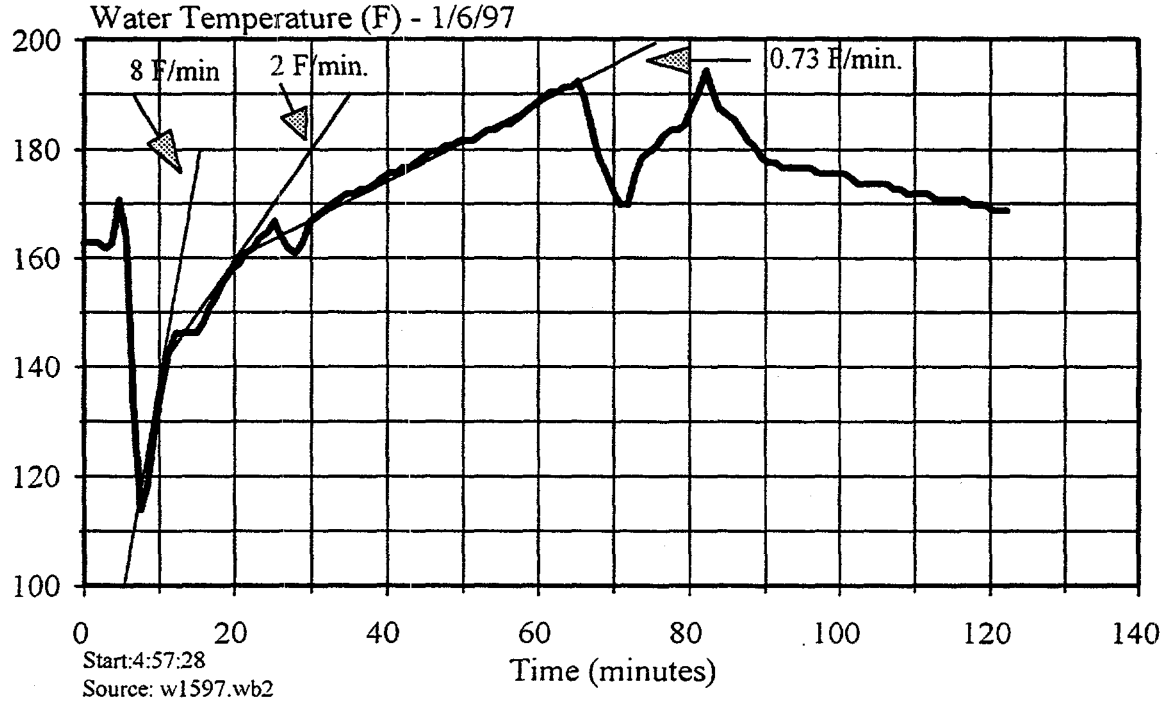

Figure 3 - Rate-of -rise of boiler water temperature during pull-up showing the effect of additional space heating zones coming on-line.

Laboratory Testing

A laboratory version of the TSFAB, with a simple control system has been assembled. This version is an adaptation of the original design and is configured to operate in a two-section cast iron boiler. Preliminary testing of the burner has revealed little change from the original in terms of turn-down ratio. Exploration of the proof-of-concept has identified some issues regarding mechanical alignment and the dimensional control of head components during the wide temperature swings encountered in actual hot firing. These, and other issues, such as head sooting, long term reliability, and the final configuration of the control system remain to be explored during FY 1997.

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Paper No. 97-05

Low Excess Air Operation of Oil Boilers

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Brookhaven National Laboratory

Low Excess Air Operation of Oil Burners

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EFFECTS OF EXCESS AIR

For high efficiency, oil-fired heating appliances should be operated with the lowest excess air achievable without producing smoke. Excess air affects steady state efficiency in two ways. First excess air is unnecessary mass heated from room temperature to flue temperature and discarded. In addition, increasing excess air increases the flue gas temperature, also increasing the rate of energy loss out of the chimney. There is approximately a 1% decrease in steady state efficiency for each 33 degrees of increase of flue gas temperature. Figure 1 shows, for example, the effect of excess air on both flue gas temperature and steady state efficiency. This is the case of a boiler and "efficiency" here is based only on flue losses, boiler jacket losses are not included.

In addition to affecting steady state efficiency, excess air may also affect the rate of fouling of boiler heat exchangers. Prior studies at BNL [1,2,3] have shown that a very important part of fouling is the condensation of sulfuric acid on the heat exchanger surfaces, and the reaction of that acid with the iron in the boiler wall to form an iron sulfate scale. Reduced fuel sulfur has been clearly shown to reduce the rate of fouling [4].

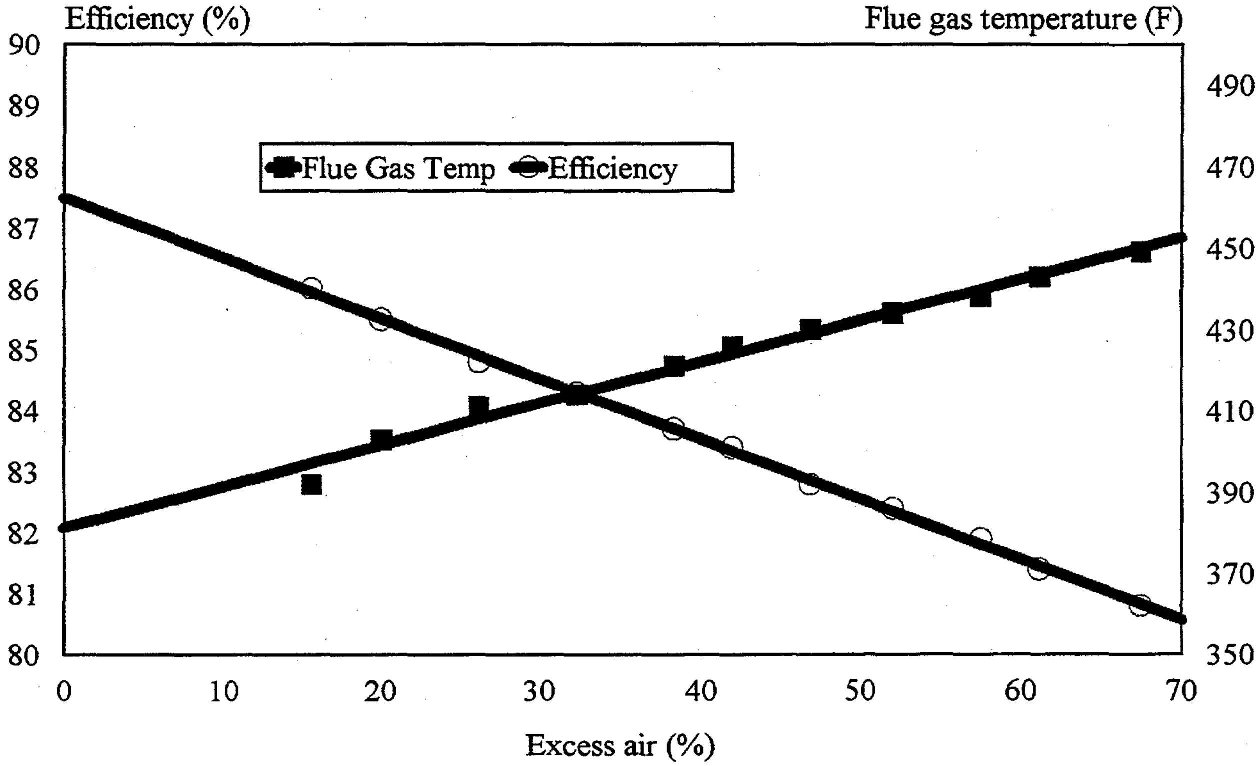

Figure 1. Illustration of the effect of excess air on steady state flue gas temperature and efficiency.

Beyond reducing fuel sulfur it may be possible to reduce sulfuric acid condensation and fouling rates by operating burners at very low excess air levels. In the flame most of the fuel sulfur is converted to SO_2 and simply emitted from the chimney. A small fraction (1-4%) of the fuel sulfur is converted to SO_3 in the flame. This then converts to sulfuric acid and is available to condense on the heat exchanger surfaces, leading to fouling scale. The fraction of the fuel sulfur which is converted to SO_3 depends, in part, on the amount of free oxygen available or excess air. The operation of large electric utility boilers with minimum excess air is a common approach to reducing flue gas acid concentration and minimizing "cold end corrosion" which is very similar to the process of fouling of residential boilers. [5,6] The earlier studies at BNL have also shown that, in a residential heating boiler, flue gas acid content can be reduced by operation at very low excess air levels.

MEASUREMENT OF THE EFFECTS OF EXCESS AIR ON FOULING RATE

To quantify the benefits which operation at very low excess air operation may have on heat exchanger fouling BNL has recently started a test project. The arrangement, which is a modification of the rapid fouling test system used earlier at BNL is illustrated in Figure 2. Essentially, it allows simultaneous measurement of fouling rate, flue gas filterable particulates (soot), flue gas sulfuric acid content, and flue gas SO_2. In this test facility a metered part of the flue gas from a modified steel boiler is passed over small test sections which are cooled with water from the main boiler circuit. Over a period of several days, in either cyclic or steady state operation, fouling deposits accumulate on the surface. After the test period the sections are removed for analysis including total deposit mass, soluble iron,

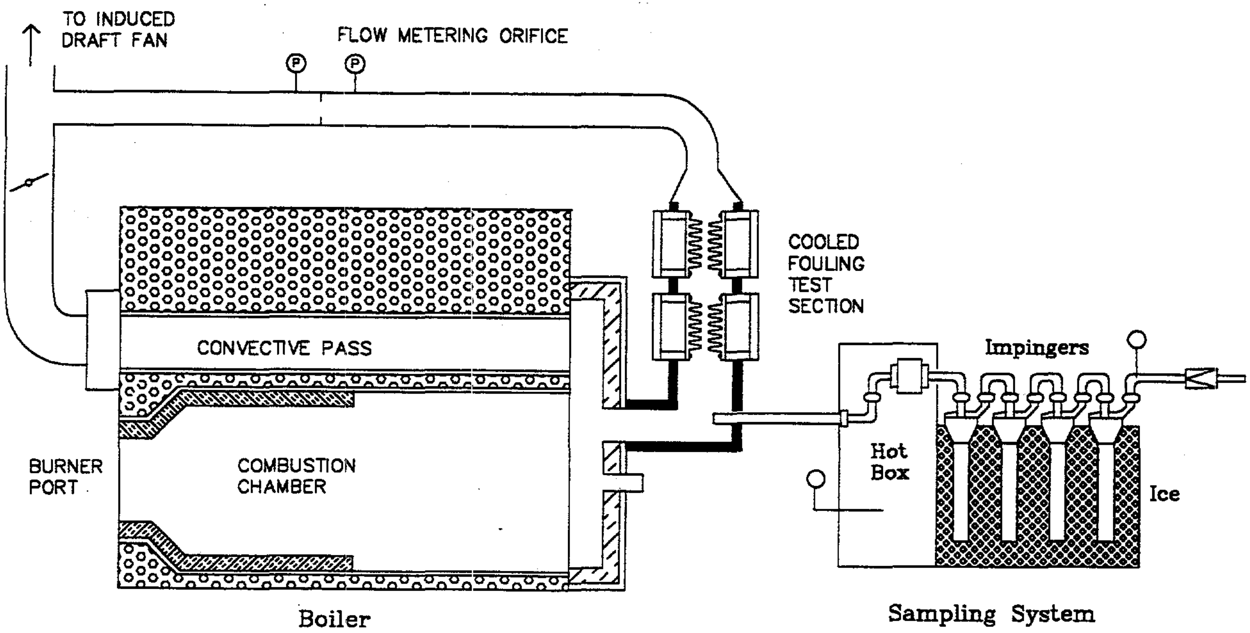

Figure 2. Illustration of test method for evaluation of effects of excess air on fouling and acid production.

and sulfate. The sampling system shown in Figure 2 is operated simultaneously for measurement of the other parameters. The rate of flow of flue gas through the sampling system is carefully controlled and measured. The gas is first drawn through a hot filter for particulates determination. The gas is then bubbled through a set of impingers in a ice bath. The first impinger contains a solution of isopropyl alcohol in water and serves to absorb all of the sulfuric acid. Impingers # 2 and #3 contain a solution of hydrogen peroxide and here SO_2 is absorbed. These impinger solutions are later analyzed to determine flue gas concentrations. This procedure is a modification of a standard test method defined by the U. S. E.P.A. [7]. Tests with this system are now just beginning and it is planned to evaluate a conventional pressure-atomized retention head burner, an air atomized burner, and a European blue flame burner.

CONCEPT OF A SELF-TUNING BURNER

While burners may be able to operate with low excess air in the laboratory, they are not set that way in the field. During routing operation excess air can change as outdoor conditions or indoor pressure changes or as burner air inlets become partially blocked by contaminants. A burner initially setup for very low excess air can move into a critical operating condition, leading to smoking. BNL is currently involved with the development of a sensor/control system capable of adjusting an oil burner automatically to a low excess air setting. This system will eliminate the need for serviceman adjustment of the burner during installation and it will maintain the optimum excess air during the heating season. Currently this system is expected to include a burner with a variable speed fan drive, and a zirconium oxide oxygen sensor. Self-tuning burners which are gas-fired, and which use this type of sensor, are currently available on the market in Europe.

ZIRCONIUM OXIDE OXYGEN SENSORS

The potential for success of the self-tuning burner development effort depends very strongly upon the ability to be able to measure excess air level reliably and inexpensively. Currently, zirconium oxide sensors are widely used for air/fuel ratio measurement in automobile engine exhaust and also for excess air measurement in larger boiler control systems. In its most common form a zirconium oxide oxygen sensor consists of a solid electrolyte (yttrium partially stabilized zirconium oxide ceramic) with porous platinum electrodes on two sides. One side, the reference side, is exposed to ambient air with 21% oxygen. The other side is exposed to the combustion products in which oxygen is being measured. An external voltage is produced across the electrodes which is related to the flue gas oxygen content, the ambient (reference) oxygen content, and the temperature of the sensor by the Nernst equation:

$$V = 0.01197 \cdot T \cdot Ln \frac{[O_2]_R}{[O_2]_F}$$

where:

V = output voltage (millivolts)

T = sensor temperature (°R)
$[O_2]_R$ = oxygen in ambient air (21 %)
$[O_2]_F$ = oxygen in flue gas (%)

This relationship is illustrated in Figure 3. For proper operation a zirconium oxide sensor should ideally be in the temperature range 900 to 1600 F. To use a zirconium oxide sensor for oxygen measurement the strong effect which temperature has on the output signal must be accounted for and two simple methods can be considered. In the first the sensor temperature is measured and used in the equation converting to oxygen content. In the second the sensor is heated to a constant, or nearly constant, temperature. A wide range of alternative approaches are also available but used to a lesser degree. In common automotive practice both heated and unheated sensors are used. For the residential boiler application the objective of this project was to evaluate very low cost options. For this reason, tests to date have involved sensors which are unheated, installed directly in the combustion chamber where they can be heated to the correct temperature by the flame.

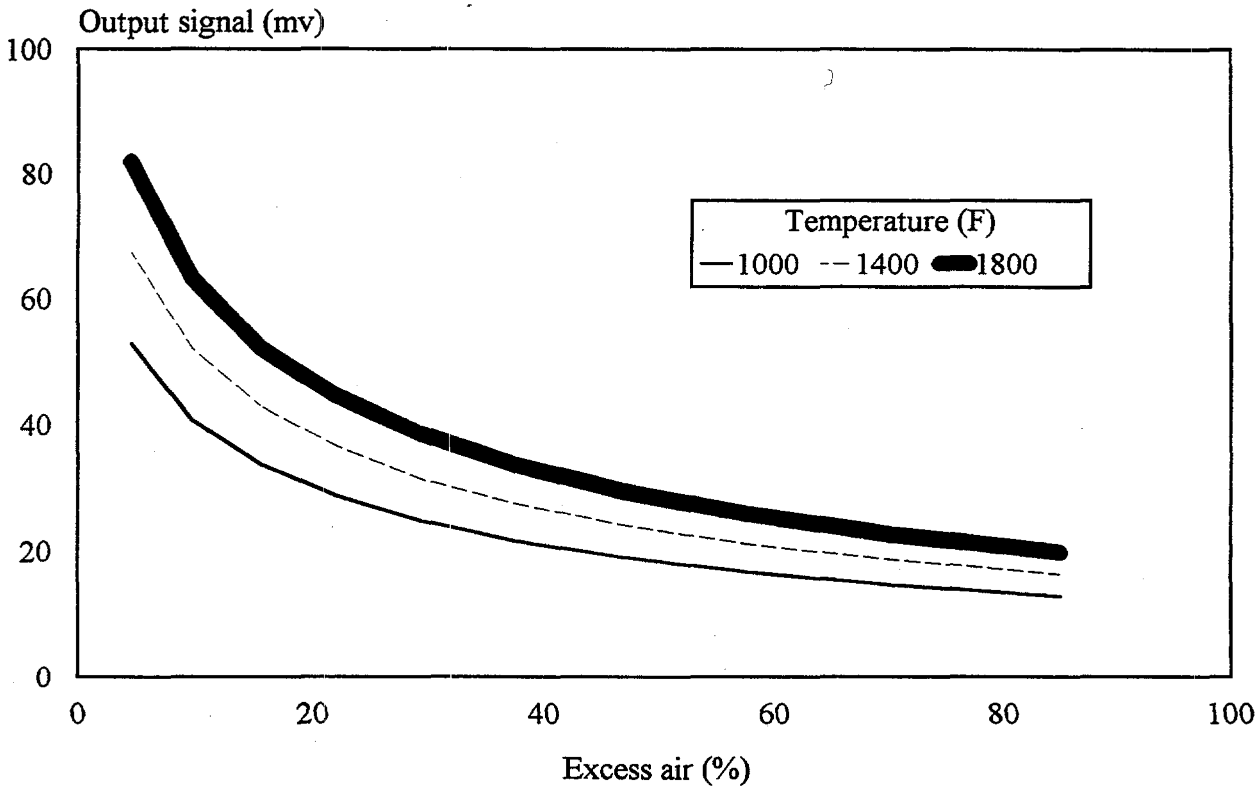

Figure 3. Effect of temperature and flue gas oxygen content on the basic output of a zirconium oxide oxygen sensor

In the BNL lab, an inexpensive, unheated, zirconium oxide sensor was installed in the combustion chamber of a cast iron boiler fired at 0.65 gph. For this test installation the sensor was installed through the view port in a refractory plug. Figure 4 shows the trend in measured temperature in the sensor casing as a function of excess air. Generally at this location the temperature is only marginally

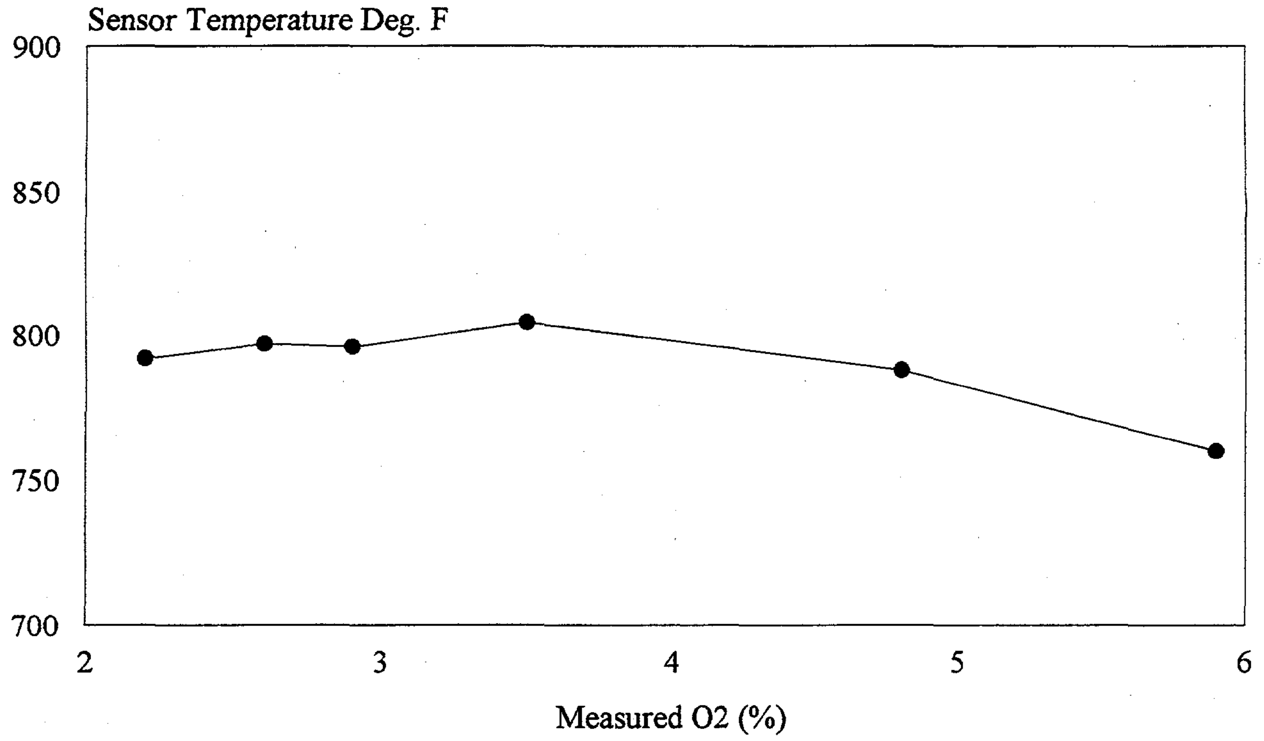

Figure 4. Automotive zirconium oxide oxygen sensor in combustion chamber of cast iron boiler. Measured temperature of sensor casing over range of excess air. 0.65 gph firing rate.

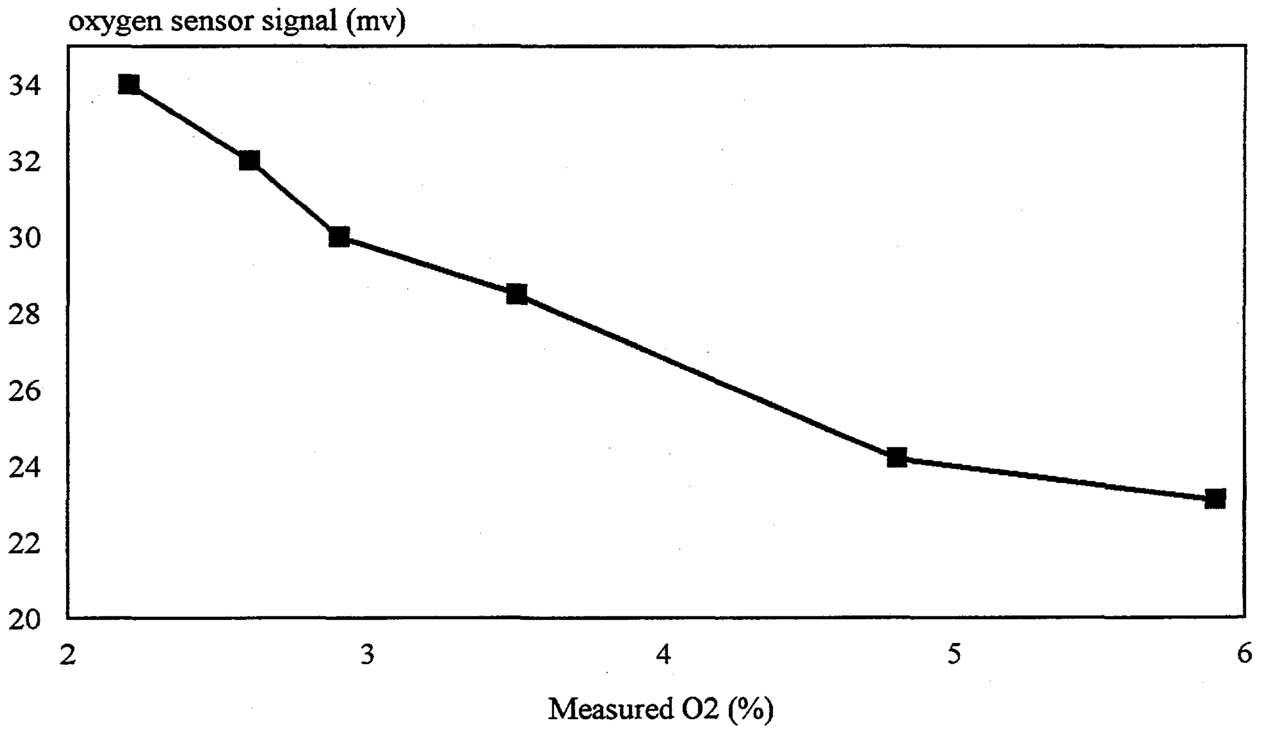

Figure 5. Automotive zirconium oxide oxygen sensor in combustion chamber of cast iron boiler. Measured sensor output signal over range of excess air. 0.65 gph

high enough. At too low a temperature the internal resistance of these sensors becomes high and they may be subject to fouling. Figure 5 shows the measured output voltage over the same excess air range. The output voltage was converted to oxygen content using two methods. In the first, the actual temperature was used in the Nernst equation. In the second, an average temperature was used over the entire range of measurement to evaluate the impacts on accuracy of assuming sensor temperature rather than measuring it. Results are shown in Figure 6. Over this range the agreement with measured O_2 can be considered fairly good relative to the objective of an input for a self-tuning burner. Based on these results it may be possible to use a fixed temperature in a control system. The temperature to be used, would, of course, depend upon the specific boiler or furnace used and the actual firing rate.

In normal cyclic operation, the output of an unheated type oxygen sensor goes through warmup transient after startup. This trend is illustrated in Figure 7 for steel boiler with an unheated oxygen sensor installed through the front door, very close to the burner air tube. Firing rate in this case is 0.55 gph. At this relatively low firing rate the sensor output can only be considered useful for control purposes after about 10 minutes. With higher firing rates, or a heated type sensor the warmup period would be much shorter. The heated type sensors cost about twice as much as unheated sensors and the rapid response benefits must, of course, be weighed against this. At present the focus is on the unheated types although tests with heated sensors are also planned.

FUTURE PLANS

This program is planned for four Phases. The evaluation of candidate oxygen sensors if Phase I, currently in progress. The results of this will feed directly into Phase II, where a complete system for a self-tuning burner will be designed and built. During the second Phase, longer term reliability testing (life testing) of the selected sensor will be done. Preliminary electrical and mechanical system designs and cost estimates for a complete system will also be done. During the rest of Phase II a first complete system prototype will be built. In Phase III the whole system will be reevaluated and an improved prototype will be built. Phase IV involves commercialization.

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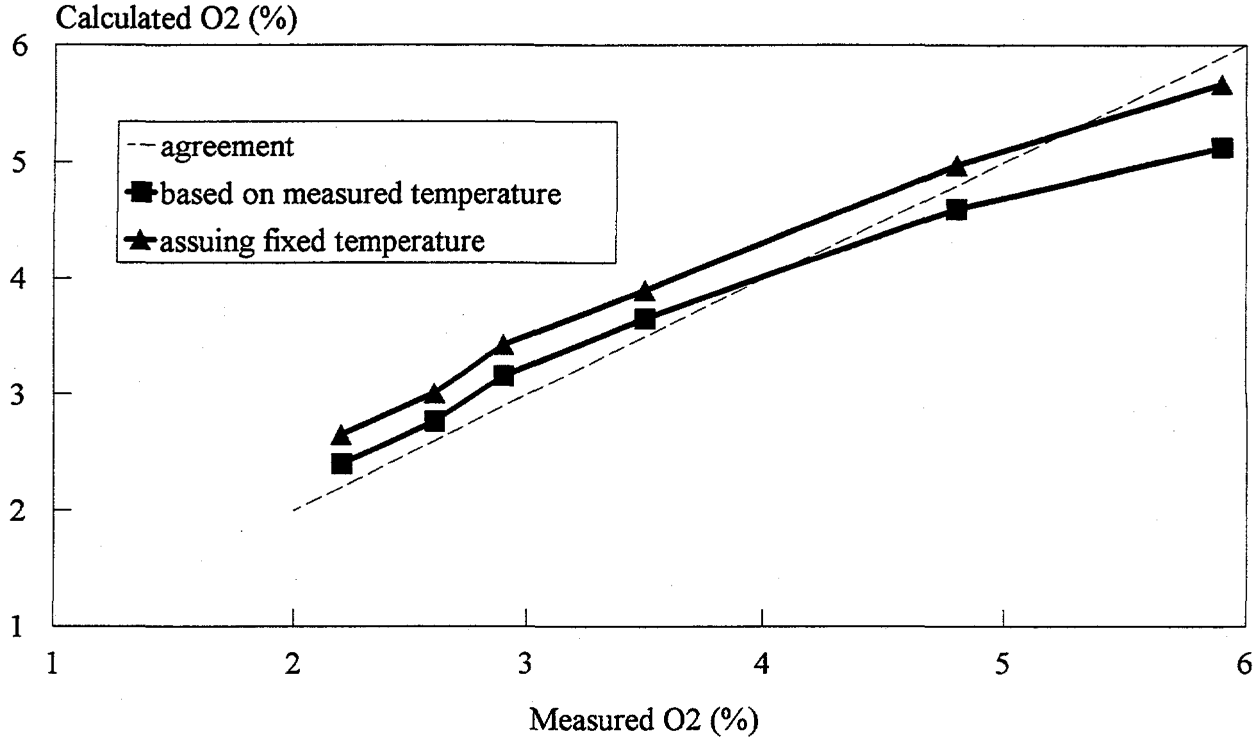

Figure 6. Automotive zirconium oxide oxygen sensor in combustion chamber of cast iron boiler. Calculated flue gas oxygen content at sensor point based on both measured casing temperature and assumed average temperature at sensor.

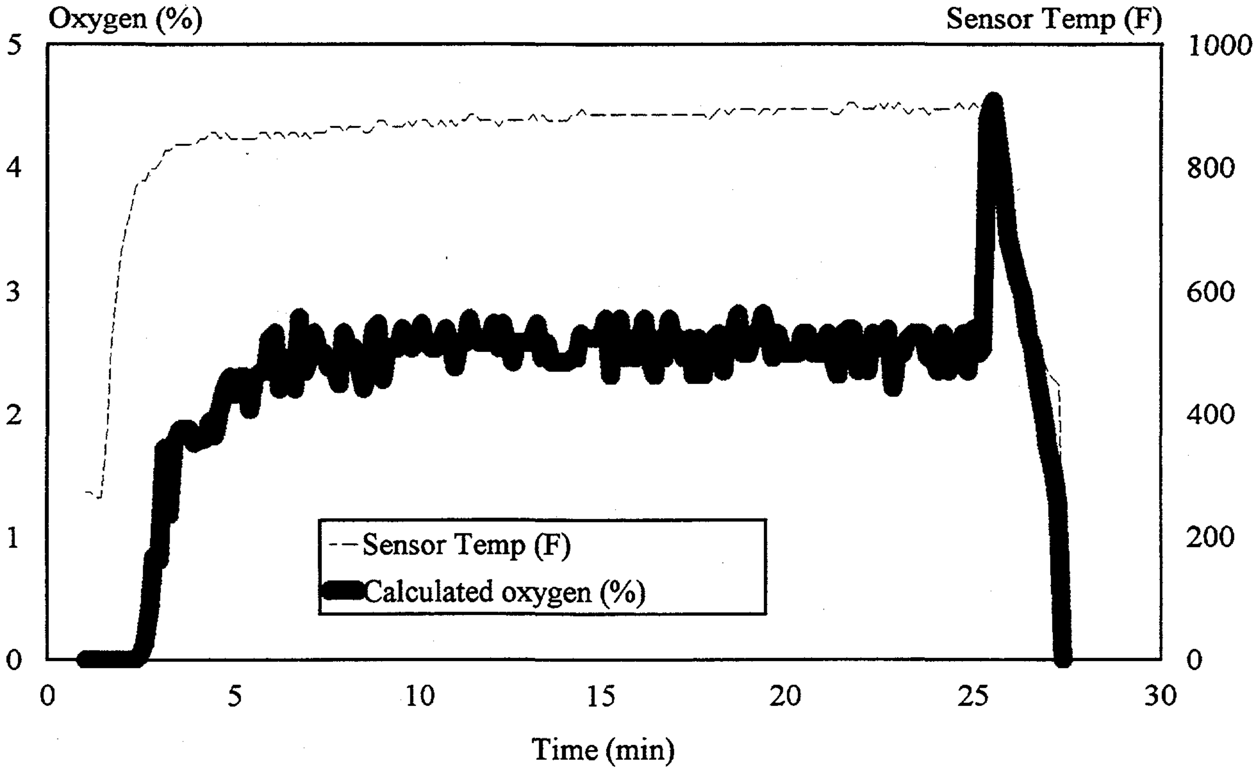

Figure 7. Automotive zirconium oxide oxygen sensor in steel boiler. Transient response during cyclic operation.

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Paper No. 97-06

Development and Certification of the Innovative *Pioneer* Oil Burner for Residential Heating Appliances

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Development and Certification of the Inovative Pioneer Oil Burner for Residential Heating Appliances

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Introduction

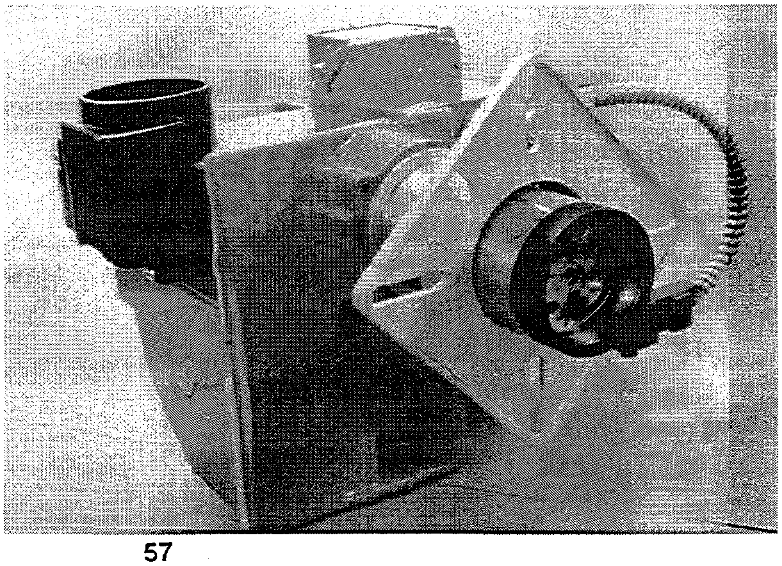
The Pioneer burner represents another important milestone for the oil heat industry. It is the first practical burner design that is designated for use in small capacity heating appliances matching the needs of modern energy efficient home designs. Firing in the range of 0.3 GPH to 0.65 GPH (40,000-90,000 Btu/hr) it allows for new oil heating appliance designs to compete with the other major fuel choices in the small design load residential market. This market includes energy efficient single family houses, town-houses, condominiums, modular units, and mobile homes. The firing range also is wide enough to cover a large percentage of more conventional heating equipment and home designs as well. Having recently passed Underwriters Laboratory certification tests the burner in now being field tested in several homes and samples are being made available to interested boiler and furnace manufacturers for product development and application testing.

Representing the best in true cooperation between government and industry it is the latest in a series of innovative concepts developed by Brookhaven National Laboratory (BNL) and selected for commercialization by the oilheat equipment manufacturing industry. The new burner was developed under a cost shared agreement between the New York State Energy Research and Development Authority (NYSERDA) and Heat Wise Inc. The BNL Oilheat research staff has assisted through technology transfer and engineering support to the project. The engineering support efforts of the BNL staff were provided under the terms of a separate Cooperative Research and Development Agreement (CRADA) between the United States Department of Energy, BNL, and NYSERDA.

The Pioneer burner incorporates the original BNL Fan Atomized Burner (FAB) concept in a product package designed by Heat-Wise Inc. incorporating the extensive use of conventional burner components. The sole exception is unique nozzle assembly, the low pressure combustion air driven fuel atomizer, which has also been redesigned (Patent Pending) by Heat-Wise Inc. to incorporate features for enhanced reliability and service in the field.

Figure 1

Heat Wise Inc.
Pioneer
Fan Atomized Oil Burner



Background

The residential oil burner market is currently dominated by the pressure-atomized, retention head burner. In these burners, oil is delivered to a fuel nozzle at pressures from 100 to 150 psi (690 to 1000 kPa). In addition to atomizing the fuel, the small, carefully controlled size of the nozzle exit orifice serves to control burner firing rate. Burners of this type are currently available at firing rates over 0.5 gph (21 kW). Nozzles have been made for lower firing rates but experience has shown that such nozzles suffer rapid fouling of the small passages required, leading to bad spray patterns and poor combustion performance. Two factors contribute to this fouling. The first is fuel system dirt which might be controlled through better filtration. The second is coke formation on internal passages occurring after normal burner shutdowns when the nozzle is heated by radiation from the combustion chamber. This period after shutdown is more severe than while the burner is actually firing During the on period there is a cooling effect of flowing oil and the combustion air flow over the nozzle. At shutdown, oil remaining in the nozzle line is heated from the still-hot refractory and hard coke can form.

The pressure-atomized, retention head burner has an excellent reputation for reliability and efficiency. While it is only correct to discuss the efficiency of complete heating systems rather than the efficiency of the burner alone, the burner has a very strong influence on system efficiency in several important ways. To achieve high efficiency, the burner should be capable of operating with a minimum of excess air. Smoke production during warm-up and in steady state are the factors which set the lower limit on excess air. Most modern pressure-atomized burners can operate at excess air levels as low as 15% at a firing rate of 1 gph (41 kW), under good conditions (Krajewski et al. 1990). At low firing rates, higher excess air levels are required. A second way in which burners can influence system efficiency relates to fouling of heat exchanger surfaces and degradation of efficiency over time. Burners which are operating very badly, possibly because of a fouled nozzle for example, may produce high smoke levels leading to rapid coating of heat exchanger surfaces with carbonaceous soot. In more normal cases, where the burner continues to operate smoke-free the fouling rates will be lower. One field study concluded that the average efficiency degradation rate is 2% per year (Kelly et al. 1984). Studies at Brookhaven National Laboratory (BNL) have shown that a very important part of the normal fouling deposit is iron sulfate scale resulting from the deposition of sulfuric acid from the flue gas onto the heat exchanger surfaces. The amount of sulfuric acid which is produced in a flame is dependent upon the burner excess air level. Acid production and scaling rate can be controlled by using burners which can operate at very low excess air levels (Celebi et al. 1990; Butcher, Celebi and Wei 1992; Butcher and Celebi; 1993).

Another way in which burners can influence heating system efficiency is through off-cycle losses. After the burner has shut off, the system continues to lose heat up the chimney. This heat loss rate depends upon the rate of air flow through the unit which, in turn, depends upon the burner design. A burner which has high fan pressure also has small open passages that allow lower off cycle air flow rates.

The objective of the effort described in this paper is the development of an advanced, air-atomized burner which can provide new capabilities not currently available with pressure atomized, retention head burners. Specifically this includes:

- ability to operate at firing rates as low as 0.3 GPH;
- ability to operate with very low (5%) excess air levels (14%+ CO_2) for high steady state efficiency and to minimize formation of sulfuric acid and iron sulfate fouling;
- low emissions of smoke, CO and NO_x at these excess air levels;
- future potential for modulation - either stage firing or continuous modulation.

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

Design Development

The Pioneer burner was designed for today's oil heat marketplace and environmental concerns in mind. The widespread need for residential oil burners with large heat input rates has disappeared with the evolution of high efficiency furnace and hydronic heating systems, advanced control options (that manage heat generation, its storage, and priority of use), indirect water heater units, and energy efficient houses that have significantly smaller design loads. All factors that point to the growing need for a combustion technology that can cleanly and efficiently burn oil at rates below the widely recognized practical lower limit of pressure atomizing oil nozzles, 0.5 GPH.

Starting in 1989 BNL has consistently reported to the oil heat industry its research in the Oil Atomization and Combustion Project at the BNL Oil Heat Technology Conference and Workshops now held annually. The Fan Atomized Burner was the result of many years of investigation into atomization options, research, laboratory combustion tests, prototype designs and the development of the concept to the point of demonstrating an advanced prototype system in an employee's home during the winters of 1995 and 1996. The concept was proven to meet the heating load requirements of the home even under single digit temperatures and windy conditions. The BNL prototype FAB featured many advanced and innovative component features including a low electric power consuming fuel pump and a very high efficiency variable speed blower motor package.

There have been several bad instances of new technologies introduced into the oilheat marketplace that have failed to live up to the expectations of benefits promised by manufacturers. In the worst cases these have caused negative feelings on the part of oilheat consumers to the point that oilheat in general was made to appear less desirable in the consumers viewpoint. It is with good reason then, that the nature of the oil heat industry is to often exhibit a general scepticism amd reluctance to accept sweeping change in equipment designs. This has often been commented on in trade journal articles over the years. It suggests that a new oil burner concept embodied by the use of many new components might not be a first choice in the marketplace. However, the level of excitement about the Fan Atomized Burner and the asssociated advances in performance characteristics such as the ability to fire at low firing rates and very low excess air operation certainly mitigates a good deal of the reluctance for change from the status quo.

Heat Wise had already faced many concerns of the industry when designing oil burners for unique heat exchanger applications during the development its own line of flame retention head burners which are currently available in the market. In reviewing the FAB technology Heat Wise considered these issues, along with the industry's general concerns associated with new product developments. It coupled these thoughts with its own experience in oil burner design, manufacture, and marketing. Heat Wise decided that there was a expansive market potential for the technology and that to be successful in manufacturing the FAB it would have to approach the design problem from its own individual and unique perspective.

Heat Wise accomplished this by its extensive efforts to incorporate as many conventional oil burner components in the design as possible. A well designed and engineered blower housing which is commercially available was selected to supply the necessary amount, six inches water, of static pressure required for the low pressure air atomizer to operate in the range of 0.3 GPH to 0.65 GPH. The distinctive design of the blower housing also allows the service technician to open up the burner for maintenance by removing a single screw. The fuel pump is a fairly conventional gear pump modified with a different internal pressure control spring resulting in the much lower fuel pressure requirement (2-20 psi) of the air atomizing nozzle. It is driven off the common shaft and powered by the same motor as the blower as in most other oil burner designs. The burner is UL listed with and uses any of the major brands of primary flame safety controls along with a conventional high voltage transformer and electrodes for spark ignition. The key element, and basically the only unconventional component in the burner, is the fuel nozzle.

The fuel nozzle uses the blowers high static pressure to achieve very fine atomization of the fuel which is pre-mixed with the atomizing air (the primary combustion air) prior to entering the flame zone. This is accomplished through the internal design and operation of the nozzle atomizing and mixing the fuel and primary air. The nozzle coupled with the design of the burner's flame retention-cup-air-tube assembly combines the primary air/fuel mixture from the nozzle with the secondary and tertiary air to accomplish exceptional combustion performance at low excess air levels (2-1/2 % Oxygen).

Test Results

Prior BNL Field Evaluations

Field trials with the BNL Fan-Atomized Burner prototype have been conducted during the 1994/1995 and 1995/1996 heating seasons in one home on Long Island. At this site, the existing boiler is a steel, dry base boiler fired with a conventional retention head burner running at a firing rate of 0.7 GPH. Hot water is provided by a "tankless" coil in the boiler. For the field test, a new boiler was added at the site temporarily and the piping and controls configured such that either boiler could be operated. Instrumentation was installed to monitor system temperatures, fuel use, and heat delivered to both the baseboards and domestic hot water. The new boiler was planned to take full advantage of the capabilities of the Fan-Atomized burner. It is a steel, positive pressure boiler, side wall vented without a draft inducer. The control on the Fan-Atomized Burner was programmed for a 15 second pre-purge and 10 second post-purge. After completion of a heat call, extra heat stored in the boiler is purged into the heated space and the boiler may go fully cold between cycles. A separate, well insulated, 40 gallon indirect hot water heater tank is used with the test system and this is treated as a priority zone.

Testing was done at several different firing rates although the most extensive testing was done at 0.35 GPH. At this input rate, the test system had no difficulty in meeting the heating and domestic hot water demand with outdoor temperatures as low as 7 F. This is the lowest observed outdoor temperature during the test period and is the 99% ASHRAE Handbook design point for the location. At the lowest outdoor temperature conditions for which field testing was done, the burner was on about 90% of the time. Under similar outdoor temperatures, the Fan-Atomized Burner test system has an on/off cycling rate about 83% less than the baseline system. This is due, in part, to the capacity of the hydronic distribution system. At burner firing rates above about 0.45 GPH the energy input exceeds the capacity of the system to deliver heat to the house and the system cycles on the high temperature limit control.

At 0.35 GPH, and 13.5% CO2, the steady state gas temperature leaving the boiler is about 300 F , giving a steady state efficiency (based on stack loss) of 88%. Burner noise was not found to be objectionable in the field. Based on occupant observations the test burner system was quieter than the older, retention head burner system.

Heat Wise Pioneer Burner Test Results

OEM application tests of the Pioneer burner have been conducted for several boiler designs. Others are ongoing at this time. Table 1 summarizes the firing rate, smoke number, and carbon dioxide measurements obtained during these tests including tests conducted as part of the Underwriters Laboratory evaluations. The UL tests were conducted in a modified Peerless boiler as a test bed with a hard firebrick combustion chamber installed per UL certification test procedures. The unit passed all UL tests including those under steady state and long term cyclic combustion conditions and is listed for use with any of the major brands of primary flame safety control. The unit is also being evaluated in three New York state homes. This includes the well instrumented home owned by one of the BNL research staff which will allow for comparison of results with the prior heating season experiments as discusses above. Two other homes were added to the field evaluations once UL listing was confirmed.

Table 1

Boiler Model, Manufacturer	Firing Rate GPH As Tested	Smoke Number	% Carbon Dioxide
L-20, Slant Fin	0.47	0	13
XL-20, Slant Fin	0.65	0	13.2
2-Sect., HB Smith	0.392	0	14
LM,Thermodynamics	0.302	0	13.2
LM,Thermodynamics	0.353	0	13
LM,Thermodynamics	0.409	0	13.2
UL,Modified Peerless	0.303	0	12.02
UL,Modified Peerless LowVolt.Test @ 102	0.308	0	12
UL,Modified Peerless	0.644	0	12.13

Future Plans

Currently Heat Wise is testing six pre-production Pioneer burners. Thse units are built to the final production design which has been tested and listed by Underwriters Laboratory (UL). The units are being used both in evaluation engineering tests by several very interested original equipment manufacturers engaged in developing product lines based of the burners distinctive features and capabilities an d in field trials in three homes in New York state. An initial trial production run of 100 units will be completed by July 1997 and available for oil dealer evaluations during the 1997/98 heating season. There will be a limit of ten units per oil dealer which will allow up to ten dealers to participate. Participating dealers must agree to participate in Heat Wise training programs and be willing to share performance information with Heat Wise. These Pioneer units are intended to be made available both in packaged OEM furnace and or boiler product forms and as separate burners for retrofit investigations. Full production of the Heat Wise, Pioneer burner and marketing introduction on a wider basis is anticipated in time for installation prior to the 1998/99 heating season.

Acknowledgements

The author would like to express his great appreciation all of the members of the BNL research team for their help and assistance in this project. These include Yusuf Celebi and Wei Gang for their direct developmental support in the research laboratory, Dr. Thomas Butcher, Ph.D., Roger McDonald, Richard Krajewski, P.E., and Wai Lin Litzke for their engineering support, and also BNL's leading oil burner design consultant Leonard Fisher, P.E. for his many contributions in the design and development of the unit. Many kind acknowledgments also goes to Raymond Albrecht, Program Manager at NYSERDA for his oversight, support, and technical contributions to the project..

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Paper No. 97-07

Updates on Oilheat Manufacturers Association and the National Oilheat Research Alliance

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Updates on Oilheat Manufacturers Association and the National Oilheat Research Alliance

Oilheat Manufacturers Association (OMA)

Membership Update

As of February 18, 1997 **OMA** is comprised of the following 35 companies: Aero, Allanson, Armstrong, Beckett, Burnham, Cardinal, Carlin, Crown, Danfoss, Delevan, Ducane, EFM/General Machine, Emerson, Energy Kinetics, Field, Gar-Ber, Hago, Heat Transfer Products, Honeywell, Metromatic, Mitco, Mobil, Monarch, Peerless, Riello, Slant Fin, Suntec, Taco, Thermo Products, Thermo Dynamics, Tigerholm, Wayne, Webster, White Rodders, and Z-Flex.

Oilheat Advantages

To date we have distributed 1,000 Oilheat Advantages books, 160,000 Oilheat Advantages brochures, and 43 Oilheat Advantages seminar kits.

Since February 1995 I have presented the Oilheat Advantages seminar 48 times to over 3,500 Oilheat industry people, Realtors, and builders.

Due to strong demand the Oilheat Manufacturers Association has reprinted their popular brochure, **Oilheat** - ***the advantages of the one fuel that warms all*** ! This attractive 11" X 161/2" four color brochure highlights Oilheat's efficiency, cleanliness, reliability, economy, safety, convenience, conservation and low environmental impact. It is ideal for selling, the Oilheat story to realtors, builders, and interested consumers.

Build With Oil

Fueloil & Oil Heat magazine and **OMA** have rejuvenated the successful *Build With Oil* program. OMA has donated $10,000 to get it restarted. If they can secure sufficient funding, the *Build With Oil* group plans to build three *Build With Oil* show booths, advertise in ***Custom Home Builder*** magazine, and have a booth at the *Custom Home Builders National Show*.

PMAA Technician Certification Program

The **OMA** Executive Committee voted to work with NAOHSM and PMAA to rewrite the **PMAA** ***Oilheat Technician' Manual***, and to work with the PMAA Technician Certification Committee on the Continuing Education Program. OMA will help PMAA compile a list of approved seminars for Continuing, Education Unit Credits. In order for a technician to renew his certification he must attend 40 hours of continuing education every 5 years.

PMAA/OMA Advantages Certification

The PMAA Certification Committee, encouraged by their success so far, has agreed to enter into a cooperative project with **OMA**. They are working on a certification program based on **OMA's** Oilheat Advantages program. **OMA** plans to create an Oilheat Advantages workbook, seminar, and test to be used in the program. Anyone in the Oilheat industry is encouraged to take this course, and become a certified Oilheat Advantages expert.

PMAA Oil Tank Task Force

The **OMA** Executive Committee also responded to a request by PMAA's Oil Tank Task Force by pledging $2,000 toward that worthwhile effort.

Oilheat Particulate

One of **OMA's** greatest victories last year was to work with the EPA to get Oilheat's particulate number reported in AP-42 revised downward, to better reflect new clean burning Oilheat equipment. The U.S. EPA has responded to our request to revise the emissions' factors for Oilheat in AP-42. Based upon submittals from John Batey, using information from the Advantages Project and Brookhaven National Laboratory reports, the EPA has reduced reported residential oil burner emissions from 2.5 to 0.4 pounds per thousand gallons of fuel consumed. This is comparable to AP-42's reported gas heating equipment emissions. This lower particulate emission's factor for oil burners is important recognition by the U.S. EPA that modern oil burners are clean burning and produce one of the lowest particulate levels of any home heating source.

Energy Star

Thanks to PMAA and **OMA** the U.S. EPA has agreed to reconsider the exclusion of oil powered equipment from their Energy Star Program. **OMA** sent them an in-depth report on Oilheat efficiencies for their consideration. The EPA has yet to move on furnaces, but at least they have allowed oil powered boilers with AFUE's over 85%.

NEFI Conference

NEFI has invited **OMA** to present a one hour panel discussion at their June convention. The title of our panel discussion is *How To Increase Oilheat Reliability*. It is an opportunity for us to tell dealers about the great new technologies available on the market that improve equipment reliability, and receive their feedback on available reliability strategies.

Fuel Quality Issues

OMA member R.W. Beckett has released an extensive fuel quality study that concluded that fuel quality problems do exist, they appear to be isolated to certain areas of the country and certain refineries, and that an on-going "watch dog" activity is needed. **OMA** is continuing to study these critical issues.

Potential Impacts of EPA Proposed Revisions to Ambient Air Quality Standards for Ozone and Particulate

John Batey has just released an **OMA** study on this vital issue. The new proposed EPA clean air standards could essentially make Oilheat illegal in the majority of areas where it now enjoys its greatest market share! The study examines the nature of the problem and suggests possible courses of action.

Some Other OMA Projects

Venting research and guidelines, IAPMO Building Code & Tankless Coils, NFPA-31 meetings and rewrite, geothermal electric heat pumps versus Oilheat, membership and participation on ASHRAE Technical Committees 106 and 124, AFUE ratings and ratings for combination space and water heating appliances.

National Oilheat Research Alliance

NORA Forms Legislative Action Committee-

The **NORA** Board of Directors has formed a Legislative Action Committee to renew its push of a legislative agenda for 1997. The Board appointed Don Allen and Bob Greenes as co-chairmen of the Legislative Action Committee. According to Allen, the Legislative Action Committee, which was formerly called the **NORA** Steering Committee, is a broad-based committee consisting of marketers, wholesalers, trade association executives and other interested parties. The Committee is responsible for finalizing an Oilheat checkoff legislative proposal and initiating the legislative process in Congress.

“We have spent the last 18 months talking to all segments of the Oilheat industry to gain ideas for structuring an effective check-off program that meets industry needs," said Allen. "We've had input from hundreds of individuals and companies and have developed some excellent ideas for moving forward. We are now ready to finalize our legislative proposal and begin the legislative process. The Legislative Action Committee will have responsibility for moving this effort forward."

Results of Direct Impact Oilheat Industry Survey

The **NORA** Executive Committee surveyed 500 Oilheat dealers in order to gather comments and ideas as well as to build support for the **NORA** concept. To conduct the survey, the committee retained Direct Impact, Inc., a Washington Research and Marketing firm with extensive experience mobilizing association programs to harness grass-roots industry support for legislative initiatives like check-off programs. Preliminary results of the survey indicate: that 96% are in favor of an industry wide program to conduct research, improve education, and advertise the benefits of Oilheat; 86% also felt that the advertising should compare Oilheat benefits with competing fuels; 85% are in favor of a per gallon assessment on all heating oil sold; and 58% were in favor of an assessment of 20 points per gallon (20 cents per 100 gallons) or more. Finally, 38% knew their Congress person and 30% had contributed to their campaign. These numbers are unusually high and indicate that **NORA** should do well launching its Legislative Initiative.

Collection Point

The Committee believes while dealers would prefer the collection point be at the wholesale rack, it appeared that the most workable point is at the retail level provided there are effective audit procedures and stiff penalties for cheating.

Allocation of NORA Funds

Another issue for heated debate is the distribution of **NORA** funds. The original **NORA** budget called for $10 million to be spent on a national pro-Oilheat advertising campaign. The feedback **NORA** has received suggests that 80% to 85% of the funds collected should go back to the states where it came from to be used for local and regional Oilheat promotion. The remaining 20% should be spent on research, education, and administration.

Assessment Level

A third point of contention is the initial assessment level. Some industry leaders feel NORA should start at 10 points and work up to 20 points gradually. Most of members of the committee agreed with the survey results, that 10 points is not enough and **NORA** should start at 20 points.

NORA Time Line

The **NORA** Legislative Action Committee met on March 12, 1997 to begin to draft the proposed legislation. They also plan to meet at the Atlantic Region Energy Expo 97, the 1997 NEFI convention, and the 1997 PMAA Oilheat Conference. The Committee plans to introduce the **NORA** Legislation to the Congress this fall.

Paper No. 97-08

NAOHSM and the Oilheat Industry on the Internet

David Nelson, Service Manager
Kurz Oil Company
Port Washington, NY

NAOHSM and the Oilheat Industry on the Internet

As we head toward the new century the need to exchange information has become more and more important. The advances in combustion technology have created the need to match equipment. The Shell head I serviced when I began my career always took an 80 degree hollow nozzle. Today many different angles and spray types are used with one burner depending on the boiler it is firing into. These close tolerances have lead to better efficiencies and cleaner operation allowing us to compete with other fuels. The use of electronic's in control systems have allowed us to provide better comfort to our customers and reduce their energy costs. An old timer once told me the worse thing they ever did in this industry was to put thermometers on thermostats because if the setting didn't match the thermometer there must be a problem. New heating systems being installed today are comprised of equipment from many different companies. All of these advances have created an information gap. This gap has lead to field service problems. The ability of most service departments and service technicians to obtain and maintain all the necessary manuals has become a job onto it self. This gap will only grow wider as the new equipment developed here at Brookhaven and within the industry enters the market place with the need to maintain and service it properly. To this end NAOHSM has developed it's Internet site.

NAOHSM's mission has always been to educate both the service manager and his technicians. By providing video tapes, sponsoring training seminars and our yearly trade show NAOHSM has been the central information conduit between manufactures and the service trade. In addition local chapter meetings are a forum for exchanging ideas. With the addition of the world wide web site needed information will be available 24 hours a day seven days a week matching the working hours of most service departments.

The Web site is divided into two sections. Member and Non-member. The non-member side contains information related to the Association and also provides a help desk to respond to questions about the oil heat industry. The member area contains information useful to both the service trade and industry. The bulletin board provides members an open forum to exchange information and post questions. Ongoing discussions of industry trends and problems can take place year round instead of just at conventions and meetings. Manufactures can post updates on equipment or to solicit comments. A recent discussion of the viability of changing the industry standard of 100psi to 150psi for fuel pumps has lead to it's inclusion as one of the workshop sessions this afternoon. The calendar is open to all to post up coming events such as meeting, training seminars, and schools. A large area to list contacts and phone numbers of an event can be viewed by clicking on the day of the month the event is listed. To post an event fax the information to NAOHSM's executive director Lou Miningelllo at 201-939-1004.

The Internet began as a Pentagon project to protect the Nations security in the event of a nuclear attack. Set up between major College campuses the Internet soon took on a life of its own. Researchers could exchange information instantly, data could be transferred and e-mail replaced the Post Office. We as an industry have an opportunity to use this medium in a similar way.

My office is filled with books and manuals related to the oil heat industry. Some of the books predate me. I have a file cabinet filled with data sheets and installation guides. Even with all of this information I still spend many hours on the phone with manufactures asking for printed material or technical advice on systems or controls. If this information was stored electronically and accessible to the Internet it would save both my time and that of the technical department of most manufacturing companys. Information on burner-boiler setup, proper nozzle and head settings, circulator pump curves, fan performance on warm-air blowers, trouble-shooting tips, sizing charts and wiring diagrams. To be able to printout a wiring diagram on a multi-stage boiler control or download the sequence of operation for a clock thermostat and pass that information on to the service technician in real time can help to cut costs and provide better service to the customer. Parts ordering would be much simpler if service departments could look up parts break-down sheets. With everybody using the same part numbers and calling each part by the same name, less mistakes would be made. The links section of the Web site continues to grow as we find new companies on the Internet. To make these sites useful they need to contain technical data. As I stated earlier we can work together to provide the best service to the oil heat customer and keep their equipment running as it was designed.

Paper No. 97-09

NCPMA's Efforts to Establish New Oilpak in the Southern United States

John Fuquay, President
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NCPMA's Efforts to Establish New Outdoor OILPAK™ in the Southern United States

John Fuquay and Tim Laughlin

Abstract

For the last twenty years fuel oil marketers in the North Carolina Petroleum Marketers Association (NCPMA) have tried to convince fuel oil equipment manufacturers to develop and market a packaged outdoor oil furnace with electric air conditioning for southern homes and businesses. In order to accomplish this, NCPMA had to identify if indeed there was a market for this type of product, and if so, the size of the market. Market identification was a simple process after NCPMA staff received numerous inquiries each winter about the need for such equipment from fuel oil marketers and HVAC contractors and even homeowners. Marketers share for fuel oil heated homes began to suffer partly because new building codes prevented the replacement of existing oil furnaces without much difficulty and expense. Furthermore, the limited number of basements in the southern US contributed to the problem of the replacement market. Market size was determined by a NCPMA survey to fuel oil marketers, HVAC contractors, other state petroleum associations and other forces in the industry.

After determining the market size and need for the outdoor Oilpak™, as the equipment was later to be called, NCPMA members had to negotiate and convince a fuel oil equipment manufacturer and/or distributor to actually build, test and manufacture one. This was not easy, as proven by the many years and extensive effort that went into this process. NCPMA contacted by phone or letter nearly every manufacturer of fuel oil equipment regarding the production of an outdoor oil furnace. Individual NCPMA members spoke to high ranking company officials about the Oilpak™. Some industry personnel and distributors conducted a meeting with NCPMA members at various locations on the subject. Finally, after getting R.E. Michel Company involved, the distributor for Armstrong Air Conditioning Inc., a breakthrough occurred.

R. E. Michel and Armstrong began to seriously look at this type of equipment, the Oilpak™, after a meeting at NCPMA's office in Raleigh in early 1995. Armstrong and R. E. Michel then flew NCPMA members and HVAC contractors, to the manufacturing facility in Ohio to meet with company engineers to help develop the proto-type Oilpak™. We believe this input from the field and the building and testing of ten proto-type units helped launch what we hope will be a major boost to fuel oil markets in the south and in the entire United States. After successful field testing of the ten proto-type units (four in North Carolina) in the extreme winter of 1995/1996, the Oilpak™ was launched to the public in the late summer of 1996. NCPMA has since then produced a Oilpak™ television comercial and several mailers that focuses on this new HVAC equipment.

NCPMA's Efforts to Establish the New Outdoor Oilpak™
In the Southern United States

By: John Fuquay, Tim Laughlin

From the Start

The heating oil market in North Carolina had been fading according to the 1990 NC census data. This loss had not gone unnoticed by the heating oil membership of the North Carolina Petroleum Marketers Association (NCPMA). Among several problem areas that NCPMA began to address was the total lack of equipment technology that was needed to compete with the packaged outdoor gas furnaces and heat pumps. At first the need for the oil pak was caused by newer building codes that would not allow existing oil furnaces to be replaced. Generally, existing oil furnaces installed in crawl spaces did not meet the minimum clearance requirements as incorporated by the newer building codes. Even when the home owner wanted new oil heat equipment installed, the new building codes would not allow it since no oil heat equipment was made to be installed outdoors. Therefore, the home owner was forced to go with another fuel source that had outdoor technology. We had also noticed on the market a lot of oil fired horizontal furnace outdoor enclosures to meet this market niche. Because none of these enclosures had been Underwriter Laboratories (UL) rated at the time, this was strictly forbidden by the NC Building Code and if found by building inspectors, the enclosure had to be removed. To remain competitive with outdoor packaged gas packs and packaged heat pumps, the heating oil marketer had to do something.

The Survey Says

After doing a thorough search of the heating oil furnace manufacturing industry to be sure that no such fuel oil equipment was made, the decision was made to approach individual manufacturers to obtain their input on the feasibility and cost of the oil pak. NCPMA also wrote to Underwriters Laboratories, GAMA, NC Building Code Engineering Department and of course Brookhaven National Laboratories in February 1994, for further comments. After meeting with three manufacturers of name brand heating oil equipment who promised to research the possibility of successfully building and marketing an oil pak, we received no positive response. The manufacturers just did not see a market potential in the South for trying out new oil heat equipment. We felt that the oil pak would strictly be built for southern markets, because of it being exposed to ambient conditions.

At the Southeast Petro-Food Marketing Exposition in August of 1994, we met with Mr. Charles Deese of the NC Division of R. E. Michel Company, who was exhibiting at the show. Mr. Deese had stopped by NCPMA earlier that summer to see what his company could do for us. We had talked about the need for an outdoor oil furnace, with or without air conditioning. Mr. Deese asked if we had done any type of market surveys to determine if in actuality, there was a need for this type of equipment. Of course the answer was no. Mr. Deese told us to do a survey, get him the results, and he would forward the information to his superiors. In September of 1994, NCPMA staff prepared a survey that was sent to sixty fuel oil marketers, HVAC contractors, industry consultants, PMAA and the Virginia, South Carolina, Tennessee and Georgia Petroleum Marketers Associations.

The survey questions and results are as follows:
NCPMA received thirty-eight replies.

Survey
Question # 1. Is there a need in your area for an outdoor oil pack/furnace?
YES-34, NO-4.
Question # 2. Estimate the number of outdoor oil pack units you would need per year?
1,600 units (averaged).
Question #3. What would you expect to pay for an outdoor oil pack/furnace?
Wholesale $1,650.00 averaged. These numbers varied with the high being $2,500.00 and the low being $800.00 with the bulk of the pricing from $1,500.00 to $2,000.00... MUST be competitive with gas pack.
Question #4. What BTU per hour range should be considered?
Heating 32MBH to 200MBH, Cooling 1.5 tons to 5 tons.
Question # 5. Will the oil pack create a new market for you?
Yes-34, No-4.
Question #6. What technical problems, if any, would there be with an outdoor oil pack?
Corrosion Protection (4 comments)...
Vent/Draft (3 comments)...
Not too big, physical size (2 comments)...
The duct connection should be suitable for low crawl spaces...moisture problems with controls (2 comments)...
Other comments in general, Local inspectors...
Protection from all weather elements...
High static pressure burners and direct vent...
Double wall stainless steel vent pipe...
Price...
Vent gases as not to burn anyone...
Insulate heating oil lines in northern installations...
Unit must add to appearance of the home...
Insulated outdoor ductwork...
Do not see any technical problems that can not be overcome.
Question #7. Your Area?
North Carolina-23, South Carolina-7, Tennessee-0, Virginia-6, Georgia-1, Vermont-1.
Question #8. Any other comments?
We have been in need of an oil pack for some time...
We are losing customers to gas packs...
Build an outdoor oil furnace if you cannot build the oil pack...
Through the years I have had inquiries concerning this type of furnace...
Need this unit for wall/floor/hall replacements...
We would like to know more...
If we are expected to compete with gas packs, then we have to have an oil pack...

We are losing 25-30 customers a year because we do not have an oil pack...
This product will revive oil in the eastern NC and SC areas...
This unit would need a start-up marketing program for both wholesalers and dealers...
I believe an outdoor oil pack is long overdue!...
I know many gas pack customers who would convert, the change over is easy and not expensive...
I strongly believe this would be a large help to oil heat marketers...
We are about 20 years behind the competition...
People want the units out from underneath their home...
We urgently need this for replacements of 25 year old oil furnaces...
Good replacement unit for homes with electric heat and heat pumps...
Please hurry!

As you can see this survey gave us the information we needed to present our case to a manufacturer. The positive tone of the response gave RE Michel Company the marketing information they needed to approach Armstrong Air Conditioning Company to test and build the oil pak.

The Ball Starts Rolling

After RE Michel Co. and Armstrong Air Conditioning Co. met and discussed the prospects of manufacturing and marketing this type of oil heat equipment, a meeting was set up at NCPMA's office in Raleigh in January, 1995. Mr. Jim Pettry, VP sales, Mr. Bruce Maike, VP engineering, with Armstrong and, Mr. Glen Baker and Mr. Charles Deese, NC representatives for RE Michel Co., along with NCPMA staff and several key fuel oil marketers were at this meeting. The purpose of the meeting was to discuss the commitment from NCPMA members to the oil pak if such could be built and to determine what Armstrong's commitment was to build the oil pak. Technical issues were also discussed. These included the oil pak's characteristics such as a minimum AFUE of 80%, 10 SEER air conditioning, cooling range of 2 to 3 tons, and heating range of 50,000 to 90,000 BTUH. Finally, the cost must be as close as possible to the gas packs. It was decided by Armstrong to go back and review the cost associated with the production of the oil pak and do a feasibility study to be completed by spring of 1995. In that same month of January, long time heating oil marketer and HVAC contractor, Don Christian was invited to Armstrong's manufacturing facility in Bellevue, Ohio, to view the proto-type oil pak and discuss technical issues with Armstrong's manufacturing engineers.

In April of 1995, prompted by a letter writing campaign by NCPMA members, Armstrong decided to build 10 proto-type oil paks. The proto-type oil paks were to be field tested in real world conditions in the winter of 1995-1996. In May of 1995, Armstrong and RE Michel companies invited NCPMA staff and several NCPMA members to their Bellevue manufacturing facility to view the first proto-type oil pak. Basically, Armstrong wanted to walk with this new concept before they ran with it. The NCPMA membership was extremely pleased with the outcome thus far and hoped that the outdoor testing would prove successful.

Oil Pak Proto-type Testing

As stated earlier, ten proto-type oil paks were handmade by Armstrong's research and engineering departments with extensive amounts of research dollars. North Carolina, specifically NCPMA and its members, received four of the proto-type's oil paks to be field tested, with others going to dealers in Virginia, Maryland and Ohio. NCPMA had a proto-type oil pak installed at the their Training Building in Raleigh in early October, 1995. Armstrong's testing protocol required a combustion test once a week until the end of February 1996. The data required to be recorded was weekly pump pressure, smoke, carbon dioxide, air shutter setting, draft over fire and stack draft, flue gas and outdoor air temperatures, oil consumption and equipment replacements. This data was forwarded to Armstrong's test engineers on a monthly basis with their input on changes to equipment based on combustion test data, i.e.; new nozzles, changes in air shutter settings and nozzle pin settings. The winter of 95/96 in North Carolina was one for the record books, with snow freezing rain, and 0 degree temperatures over much of the state. No better real world test conditions could have been asked for and this extreme testing ground boosted everyone's confidence that the oil pak was going to be a winner. Armstrong's engineers visited each one of the proto-type oil pak test units in the field in the late winter of 1996. They dismantled all the components to review primary parts for wear and tear. The heat exchanger and Beckett AF-II Burners were all in very good condition.

The design engineers at Armstrong did a wonderful job in implementing our ideas from the pre-design meeting and from the field tests. The installation of a 25 watt oil line heater inside the burner housing helped tremendously with smooth and clean light offs because the fuel oil kept warm on the coldest of nights. The Beckett AF-II burner, providing 140 psi pump pressure, also helped the units operate smoothly and quietly. The redesigns that came from the field testing proved to be very beneficial. Some of the redesigns included triple wall flue vent pipe off the top of the unit was painted the same color as the unit's housing, solid state controls were mounted in a hinged galvanized metal box, increased fan run time with solid state controls, an electrical power plug socket in the unit housing, service access was made easier and various other small changes that were made.

Market Introduction

In July of 1996, the first oil paks began to arrive at RE Michel's distributors in North Carolina. NCPMA had decided earlier to support the oil paks introduction with a fall ad campaign on radio, television, and newsprint. The ad agency came up with a TV commercial that has proved very successful. Rogers Clark, now the president of the Petroleum Marketers of America (PMAA) had one installed in his 100 year old home in Clinton, NC. The home has a southern colonial look and the ad agency used this look to promote the oil pak as something revolutionary in the HVAC industry. The 30 second TV commercial has received a lot of praise for promoting the oil pak.

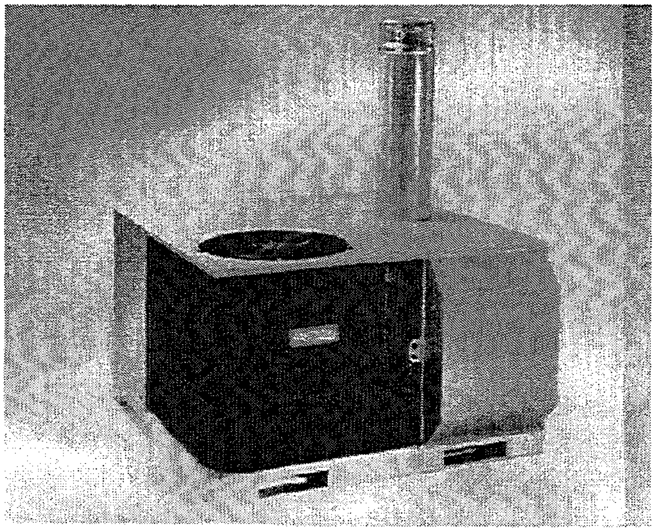
Armstrong and RE Michel also sponsored training sessions throughout the state in the late summer of 1996. HVAC contractors were trained on the proper installation and set up of the oil pak. Over three hundred NC and SC contractors attended these training sessions to become certified by the manufacturer.

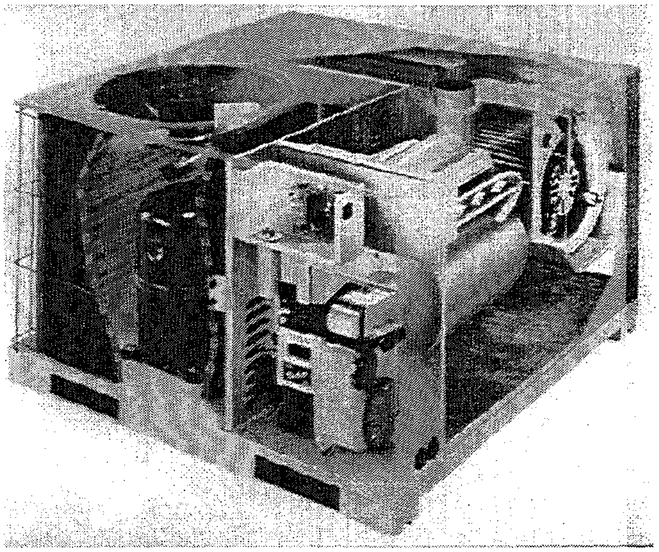
RE Michel also exhibited the oil pak in several HVAC trade shows and Armstrong exhibited in the ASHRAE national shows. One thing that has been a source of pride was the first unveiling of the oil pak at a private party at NCPMA's Southeast Petro-Food Marketing trade show in August 1995. Significant interest was generated by the marketing efforts of RE Michel Company at least a year before the oil pak was in production.

Armstrong stated in the late fall of 1996 that 1,000 production units have been made so far and the planned production schedule for 1997 is 10,000 units. They are receiving inquires about the oil pak from Florida to Alaska. All involved parties seem well pleased with the results thus far.

Conclusion

The heating oil industry from the refineries to the equipment companies must act to ensure the future of heating oil through quick adaptation to changing technology in the market place, quality heating oil products and equipment, sound promotion, energetic marketing and hard work.





Paper No. 97-10

Fuel Oil Quality Task Force

John Laisy, Project Engineer
and
Vic Turk, Director of Engineering

R.W. Beckett Corporation
Elyria, OH

FUEL OIL QUALITY TASK FORCE

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P. O. Box 1289
Elyria, OH 44036-1289

April, 1997

ABSTRACT

In April, 1996, the R. W. Beckett Corporation became aware of a series of apparently unrelated symptoms that made the leadership of the company concerned that there could be a fuel oil quality problem. A task force of company employees and industry consultants was convened to address the topic of current No. 2 heating oil quality and its effect on burner performance.

The task force studied changes in fuel oil specifications and trends in properties that have occurred over the past few years. Experiments were performed at Beckett and Brookhaven National Laboratory to understand the effect of changes in some fuel oil properties. Studies by other groups were reviewed, and field installations were inspected to gain information about the performance of fuel oil that is currently being used in the U. S. and Canada.

There was a special concern about the use of red dye in heating oils and the impact of sulfur levels due to the October, 1993 requirement of low sulfur (<0.05%) for on-highway diesel fuel.

The results of the task force's efforts were published in July, 1996. The primary conclusion of the task force was that there is not a crisis or widespread general problem with fuel oil quality. Localized problems that were seen may have been related to refinery practices and/or non-traditional fuel sources. System cleanliness is very important and the cause of many oil burner system problems. Finally, heating oil quality should get ongoing careful attention by Beckett engineering personnel and heating oil industry groups.

FUEL OIL QUALITY TASK FORCE

R. W. Beckett Corporation

PREAMBLE

In April, 1996 John Beckett, President of the R. W. Beckett Corporation, convened a task force to address the topic of fuel quality and its effect on burner performance. The formation of this task force was prompted by several situations where excessive carbon deposits on burner combustion heads occurred. Specific instances prompting concern were:

- Two residential wet base boilers in Colorado which developed excessive carbon buildup on the burner heads after about 100 hours running time (see Figures 1, 2 and 3)
- A commercial size space heater unit with head carbon buildup both in the field in Pennsylvania and in the R. W. Beckett lab (see Figure 4)
- A small residential furnace with head carbon buildup after a relatively short cycling period with No. 2 heating fuel, with clean performance using diesel fuel
- A medium size wet base residential boiler which exhibited unexpected head and heat exchanger fouling while testing with low sulfur fuel

The need for this task force was supported by service call data related to fuel quality and combustion performance compiled by the R. W. Beckett Technical Services group. Specifically, the percentage of telephone service calls for fuels, combustion problems, and impingement/coke trees on heads, after being relatively stable at about 4% of all calls received from 1990 through 1992, rose to 5.4% in 1995 and nearly 8% in the first quarter of 1996.

INTRODUCTION

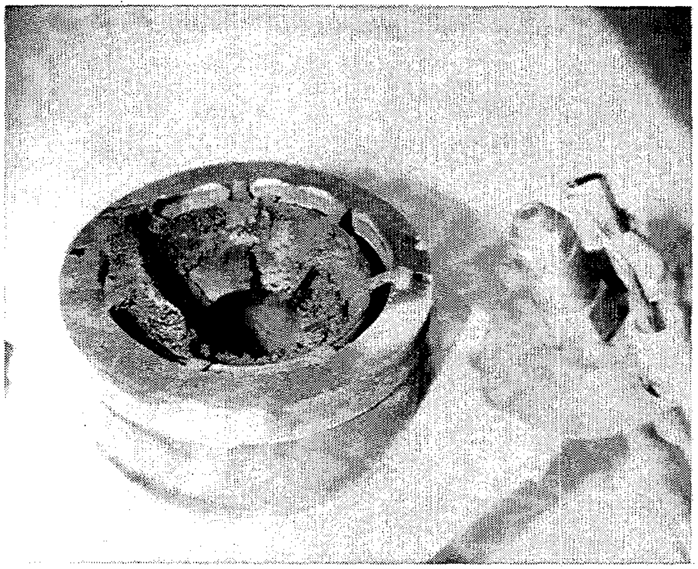
Changes have occurred in the specifications for distillate fuels that went into effect in October 1993. Specifically, low sulfur (<0.05%) was mandated for on-highway diesel fuel, which also resulted in the requirement for red dye marking of regular sulfur (0.5% maximum, commonly 0.2% to 0.3%) off-highway diesel and No. 2 heating fuel oil.

The mission of the Beckett task force was stated as to:

> Understand the impact of fuel oil changes and additive use since January 1995 and take corrective action if required by mid-July (1996).

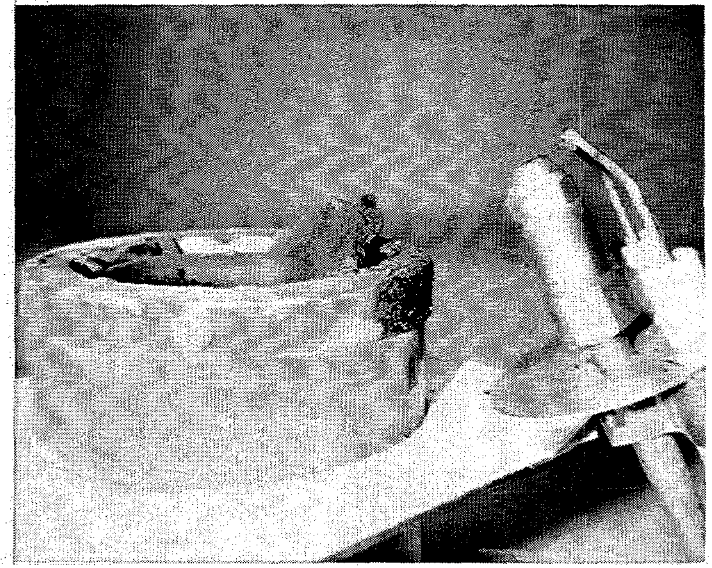
Task force members from R. W. Beckett Corporation were designated as follows:

Robert Cook (Chairman)	Executive Vice President
John Beckett	President
Vic Turk	Director of Engineering



WET-BASE BOILER
1.75 GPH
COLORADO FUEL

Fig. 1

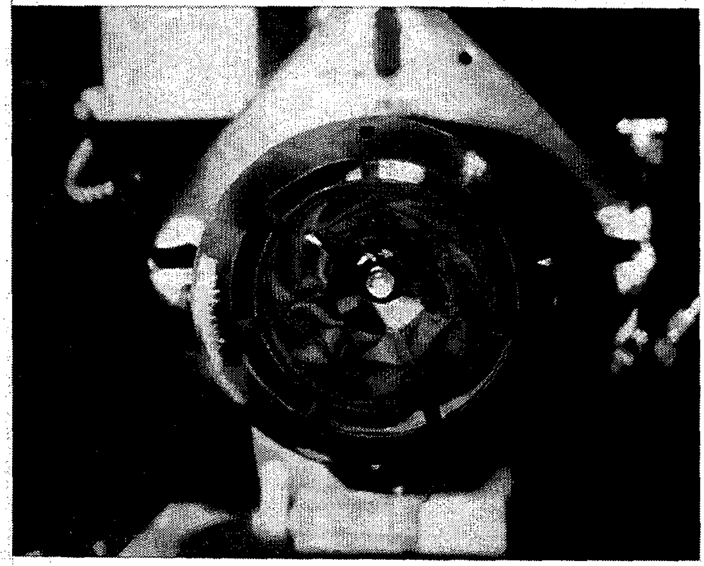


WET-BASE BOILER
1.75 GPH
COLORADO FUEL

Fig. 2

WET-BASE BOILER
1.75 GPH
COLORADO FUEL

Fig. 3



FURNACE
1.65 GPH
STD. NO. 2 FUEL OIL

Fig. 4

John Laisy	Project Engineer
Jerry Herron	Technical Service Manager
Morrison Carter	Controller
Don Faulhaber	Vice President - Sales
Jim Seaman	General Sales Manager
Bill Drennen	Product Manager
Jack Eschweiler	Production Manager

Outside consultants were also asked to participate with the task force, as follows:

John Batey	Energy Research Center, Inc.
Myron Cooperrider	Independent Consultant

Members of the task force met weekly (as available) to identify key issues and to review findings.

OBJECTIVES

It was determined that the team should identify critical issues on which to focus so that the efforts of the task force would ultimately come to a useful conclusion. Critical issues that the team were to be able to answer at the end of the investigation and analysis were listed as:

1. Are units failing excessively in the field? (i.e., has there been a significant increase in failure rates?)
2. What fuel and fuel additive properties have an impact on combustion? (Specifically, what happens to the red dye?)
3. Have refinery fuel processes had an impact on combustion?

INVESTIGATIONS

It was decided that members of the task force would undertake several experiments, investigations, and studies to address the fuel quality/properties/combustion issue. Work in these areas and results are listed below:

1. Experimentation--Beckett and others

   A. Red Dye

      1) Because the addition of red dye is a change from the traditional No. 2 heating oil specification, and because in selected head coking instances a red tinting was seen, it was suspected that red dye could be a root cause. Testing was undertaken at Beckett to compare three fuels in four different appliances in accelerated short term cycle tests. The test fuels included:

- Undyed low sulfur highway diesel fuel,
- Low sulfur highway diesel fuel dyed at 10 times (10x) the normal dosage (to amplify any effect from the dye in our short term test), and
- Standard dyed regular sulfur No. 2 heating fuel (from Beckett's lab supply system)

2) The four appliances used in the test were 1) a large residential wet base cast iron sectional boiler; 2) a commercial size space heater; 3) a small residential furnace; and 4) a medium size residential wet base cast iron sectional boiler, the same "problem" applications noted in the **PREAMBLE** section of this report. Each appliance was operated at a relatively rapid on/off cycle, with 55 gallons of each of the test fuels. (Note: In previous testing, problems of head carbon buildup have been observed after burning as little as 55 gallons of fuel.) The most significant result of these tests was that none of the appliances showed any more head carbon deposits with the 10x dyed fuel than with the undyed diesel fuel (see Figures 5 through 14).

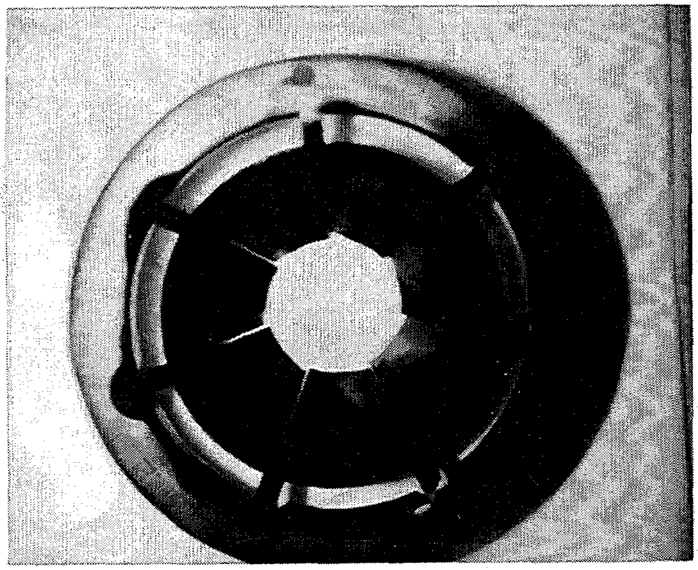
3) At our request, Brookhaven National Laboratory (BNL) performed several limited tests on the effects of dye on atomization and combustion performance. Atomization tests were performed with a conventional, pressure atomized nozzle using undyed low sulfur diesel fuel and then using the same fuel with a 2x dose of red dye. Results indicated no significant difference in the spray droplet size distribution (see Figure 15). Also, a one week combustion test was performed with the same undyed and 2x dyed diesel fuel in a pair of medium size cast iron residential boilers. Some head carbon deposits were noted, although the deposits were not considered to be significant.

4) Also at our request, Delavan performed a series of tests to compare nozzle spray characteristics using dyed standard No. 2 fuel oil from the Beckett lab supply and their standard nozzle test oil (see Figures 16, 17 and 18). The testing performed did not reveal any correlation between the dyed fuel versus Delavan's test oil and excessive soot formation in combustion applications. The testing did demonstrate the expected effects of viscosity and fuel supply pressure on nozzle spray patterns, namely:

   - higher viscosity tends to cause a slight shift in flow pattern inward
   - higher pump pressure tends to cause a slight shift in flow pattern outward

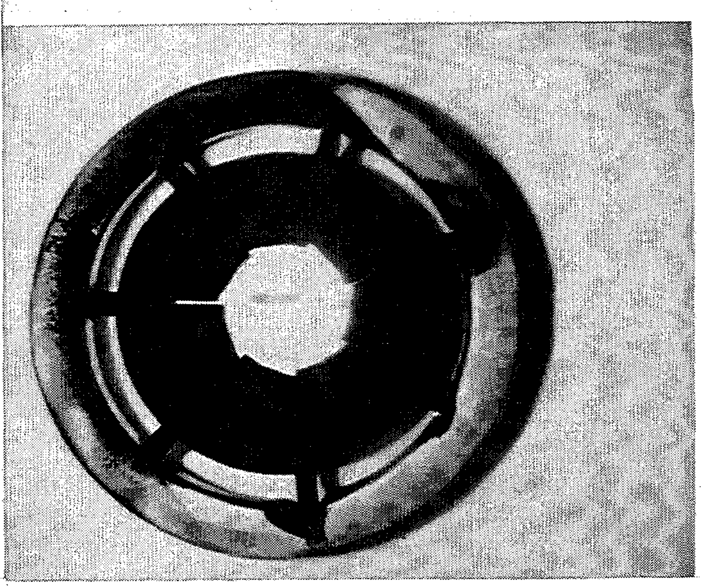
B. Sulfur

1) As mentioned in the **PREAMBLE** section of this report, a previous test at Beckett with a low sulfur fuel in a wet base boiler resulted in unexpected head and carbon buildup (fouling) of the heat exchanger. This experience prompted us to consider the potential effects of mandated low sulfur fuel on burner performance. However, other experimental work in this area at Beckett (namely the 10x test above) and BNL (see



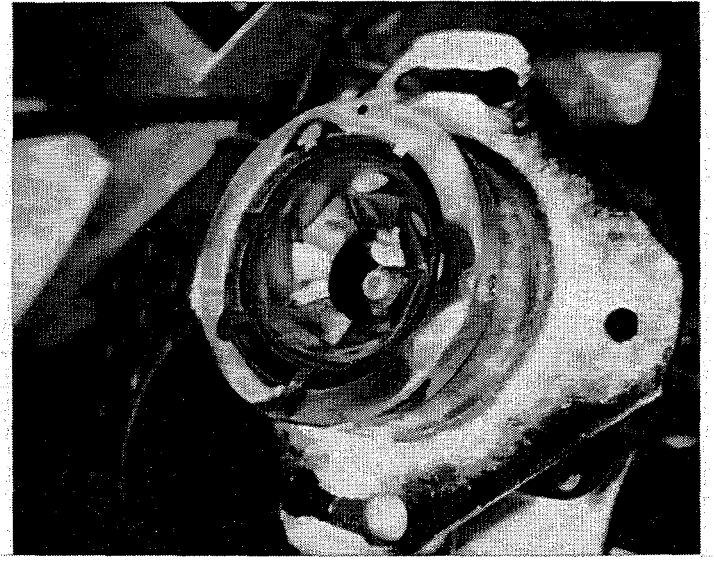
WET-BASE BOILER
1.75 GPH
DIESEL FUEL

Fig. 5



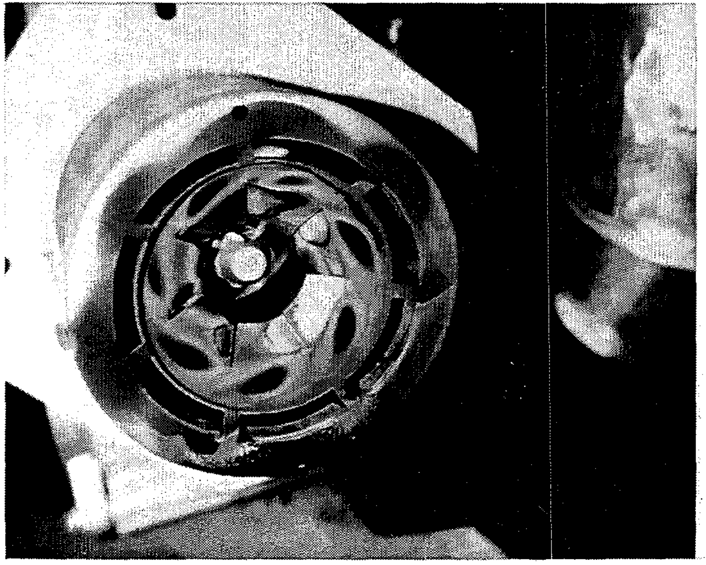
WET-BASE BOILER
1.75 GPH
STD. NO. 2 FUEL OIL

Fig. 6



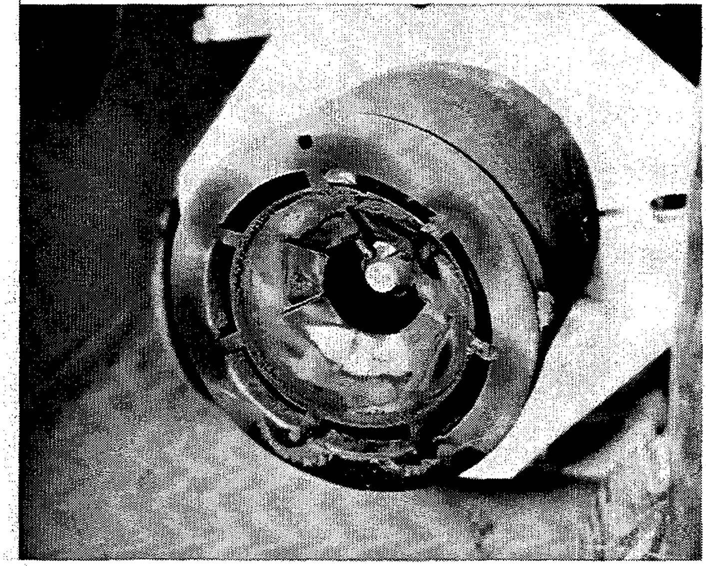
WET-BASE BOILER
1.75 GPH
DIESEL W/10X RED DYE

Fig. 7



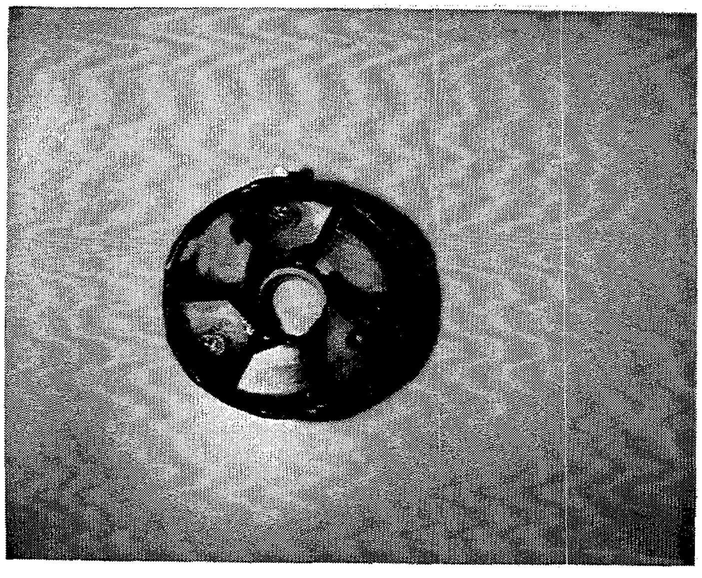
FURNACE
1.65 GPH
DIESEL FUEL

Fig. 8



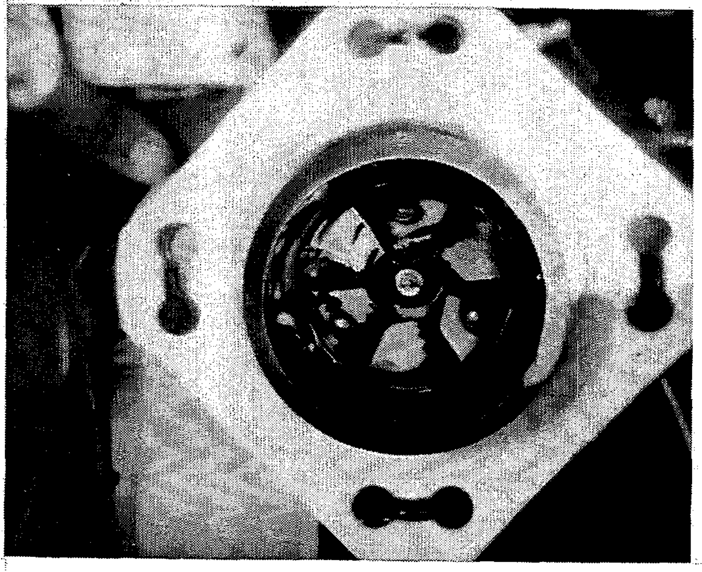
FURNACE
1.65 GPH
DIESEL W/10X RED DYE

Fig. 9



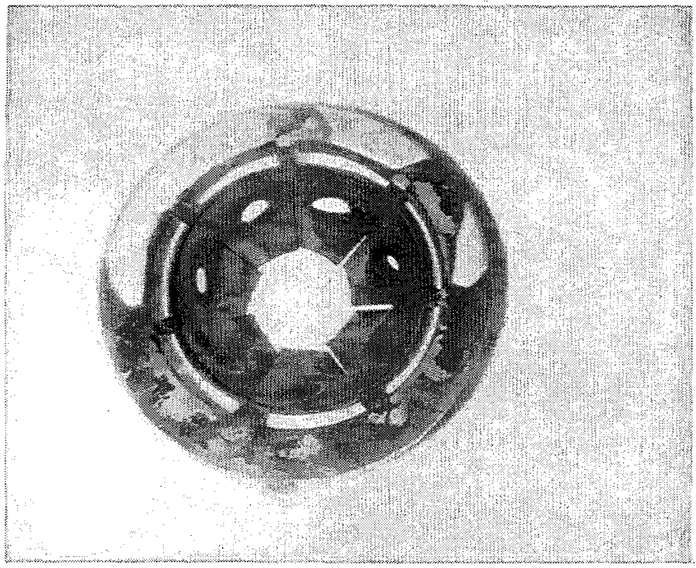
FURNACE
0.65 GPH
DIESEL FUEL

Fig. 10



FURNACE
0.65 GPH
DIESEL FUEL W/10X RED DYE

Fig. 11

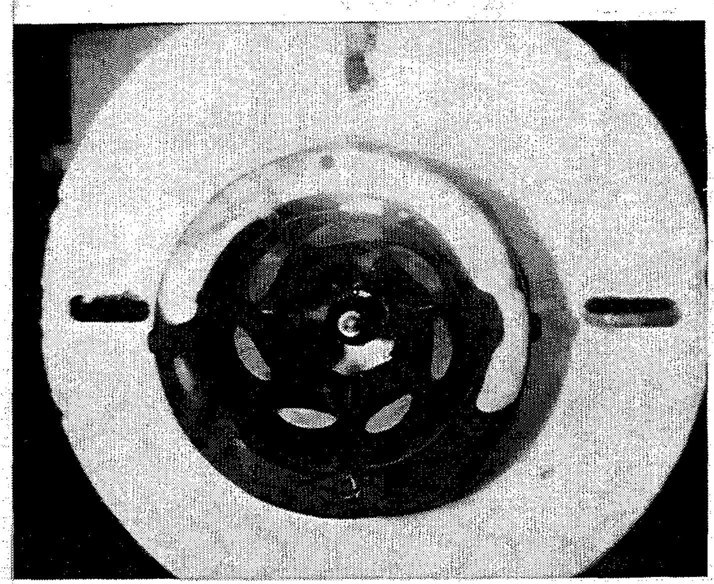


WET-BASE BOILER

1.20 GPH

STD. NO. 2 FUEL OIL

Fig. 12

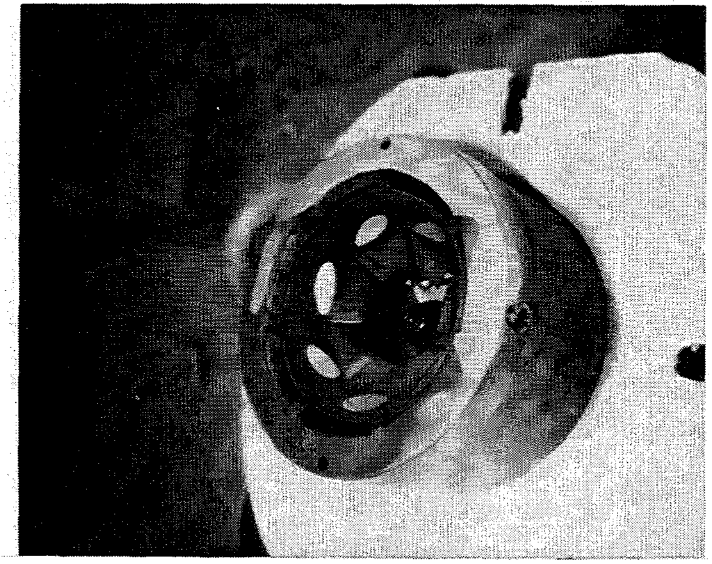


WET-BASE BOILER

1.20 GPH

DIESEL FUEL

Fig. 13



WET-BASE BOILER

1.20 GPH

DIESEL FUEL W/10X RED DYE

Fig. 14

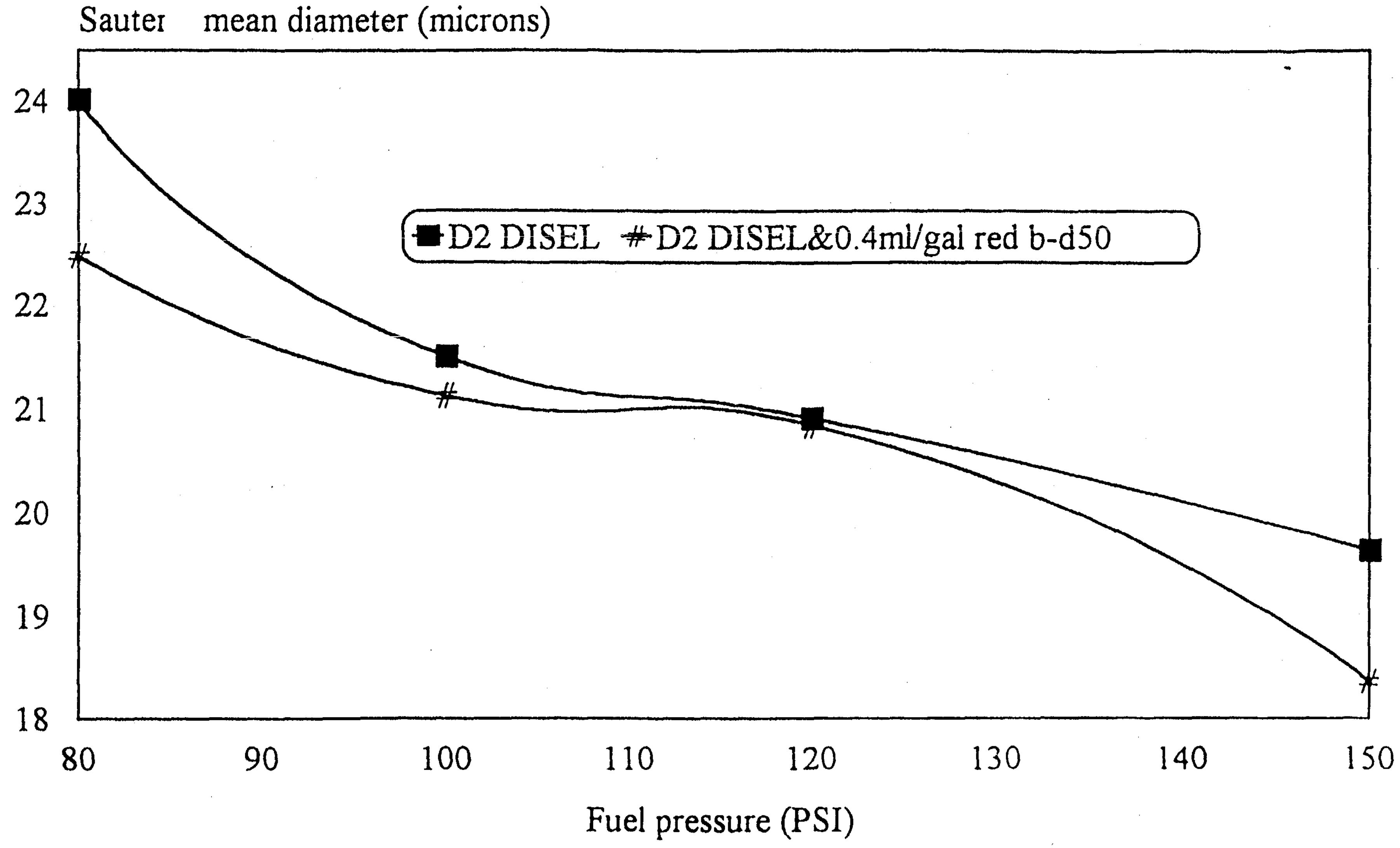
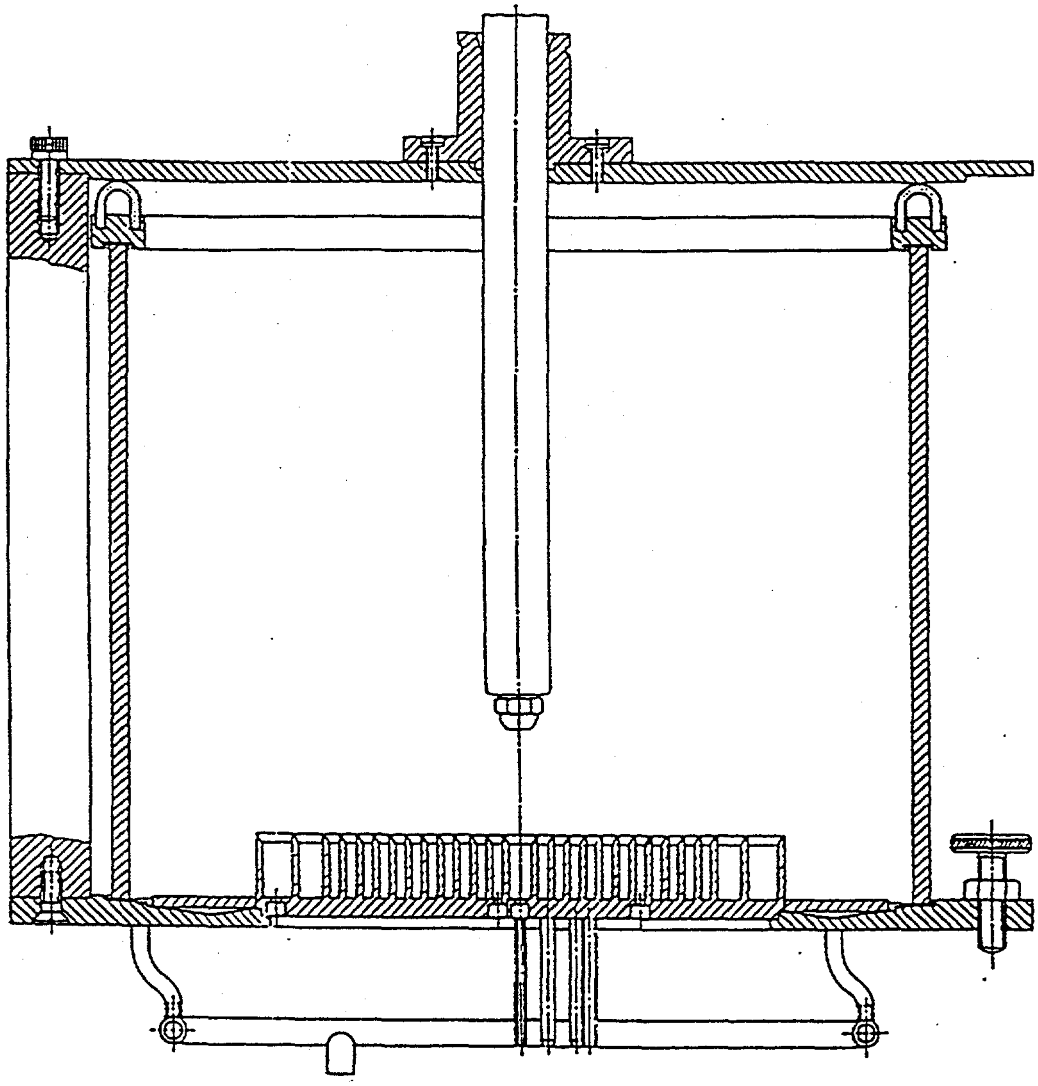


Fig. 15
Courtesy: T. Butcher
BNL



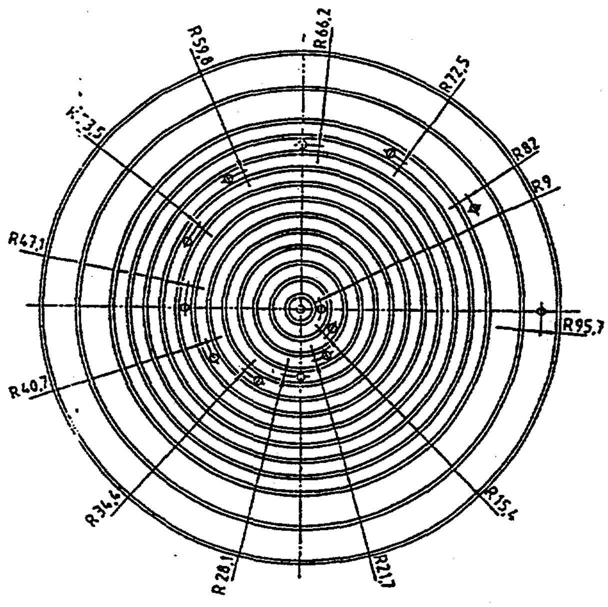
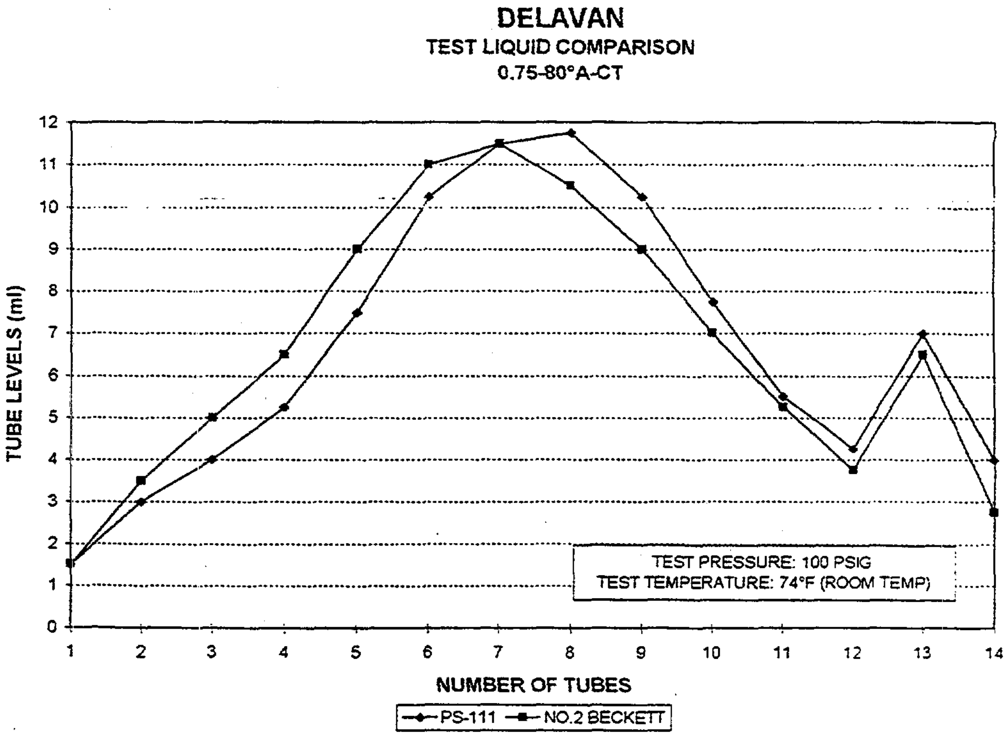


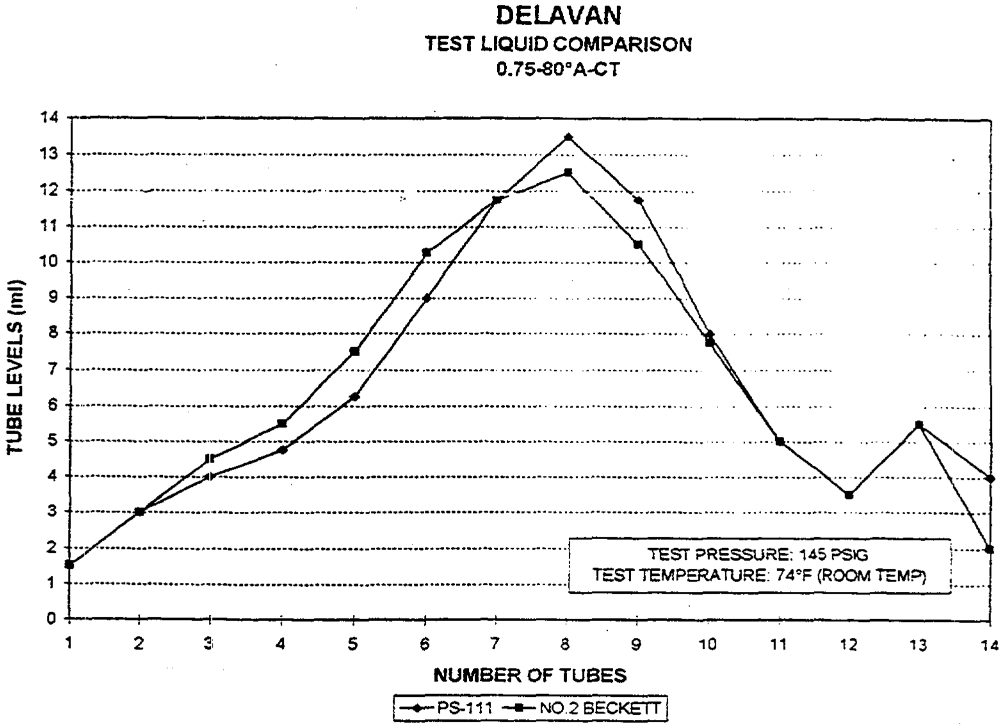
Fig. 16
Patternator
Courtesy: M. Dwight
Delavan

Fig. 17



Viscosity: PS-111 2.9 cSt @ 80 deg. F
No. 2 3.4 cSt @ 80 deg. F

Fig. 18



Viscosity: PS-111 2.9 cSt @ 80 deg. F
No. 2 3.4 cSt @ 80 deg. F

below), and discussions with a major oil dealer who uses low sulfur fuel (see comment under "Industry Comments" below), led us to conclude that low sulfur content is not the cause of head coking.

2) Independent and previous to our team effort, BNL performed a four month side-by-side fouling test in identical wet base boilers to compare regular sulfur fuel (0.5%) and low sulfur fuel (0.04%). Test results showed a greater reduction in efficiency due to heat exchanger fouling with the regular sulfur fuel than with the low sulfur fuel (see Figure 19). Test results also showed dramatically more deposits in the regular sulfur boiler (caked, peeling deposits) than the low sulfur boiler (very light black coating). These results are consistent with general industry understanding and previous results at BNL and at the Canada Centre for Mineral and Energy Technology (CANMET) laboratory.

2. Installation Investigations

It was decided that much knowledge could be gained by surveying some typical oil burner field installations. Because our task force effort occurred concurrently with the heating off-season, these burner installations could be observed during annual burner/appliance cleanup service calls.

Nine in-plant test units in service at Beckett used for space heating and domestic hot water heating were inspected. All units were operated on regular sulfur No. 2 heating oil (same supply as our lab), and all were found to be normal and clean. No excessive head carbon deposits were found.

Six in-home units were inspected by a Beckett factory technician in conjunction with a large oil dealer/service company in Connecticut. No excessive carbon accumulation was found.

Seven units were inspected in Massachusetts by a Beckett factory technician with the assistance of another oil dealer/service company. No evidence of abnormal head coking or fuel problems was discovered.

3. Studies

Government agencies and industry groups in the U.S. and Canada have done studies on heating fuel properties and, in some cases, their effects on burner performance. Properties of most concern are viscosity and percent aromatic content.

The National Institute for Petroleum and Energy Research (NIPER) is an industry group that surveys heating and other fuels to track trends in their properties. No. 2 heating fuel and diesel fuel have been found to be consistently within the ASTM specification requirements

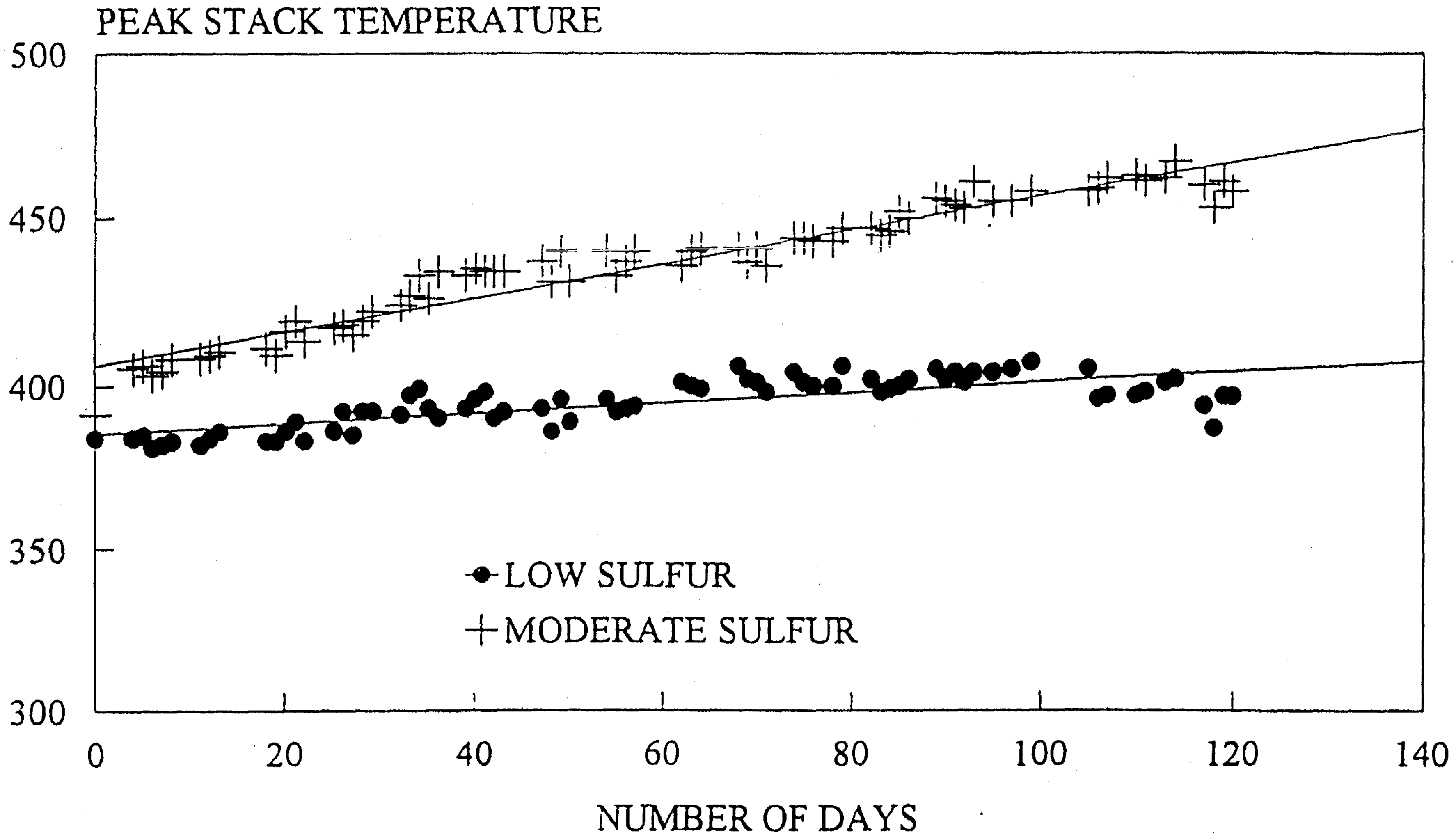


Fig. 19
Courtesy: T. Butcher
BNL

for gravity (an indicator of aromatic content), viscosity, sulfur content, etc. going back to 1982 (see Figures 20 through 23).

Several years ago, BNL performed a research project related to sulfur content, aromatic content and viscosity (see Figures 24 and 25). As compared to the typical moderate sulfur fuel (<0.5% sulfur), BNL found that burner performance did not vary significantly with high sulfur fuel (0.7% sulfur). High aromatic content (tested at up to 55.5% versus the typical 33-34% for No. 2 fuel oil) did not result in degraded burner performance. Viscosity was found to be a key factor, where levels above the ASTM maximum of 3.4 cSt at 40°C will contribute to soot/smoke production, especially during the startup transient period. (It should be noted, however, that NIPER data indicates viscosity levels in the U. S. to be consistently below 3.0 cSt.)

CANMET has performed work to correlate fuel properties with burner performance, finding that sample fuels with high aromatic content, viscosity, and carbon residue showed higher particulate emissions than typical commercially available (on-spec) fuels (see Figures 26 and 27).

4. Industry Comments

Many people in the oil heat industry were contacted to gather information and opinions about fuel oil properties and quality.

A letter was sent to approximately 120 oil heat dealer/trade associations throughout the U.S. to advise them of our task force and its mission. The letter also asked for feedback regarding fuel problems in their respective areas. Some feedback was received, but most of the concern around fuel quality pertained to system cleanliness, not fuel properties.

A meeting was held at the National Association of Oil Heat Service Manager's show in McAfee, NJ in early June, 1996 specifically to discuss the work of our task force. This meeting included service managers, oil company representatives, BNL personnel, and Beckett personnel. Most of the concerns discussed were again related to system cleanliness, not fuel properties.

Another meeting of leading oil heat dealers was held in mid-June, 1996 in Hartford, CT, where John Beckett reviewed the fuel issue and the activities of our task force. Again, attendees mentioned that tank maintenance seemed to be a bigger problem than fuel properties, but concerns about viscosity, gelling, and cold weather performance were discussed. Low sulfur fuel was not considered to be a problem, based on several years experience by one major oil dealer in the Mid-Atlantic area. A major oil company agreed to assist in the investigation of fuel quality issues. Also, plans were made to conduct additional cycle tests comparing low sulfur versus moderate sulfur fuels.

Fig. 20

GRAVITY

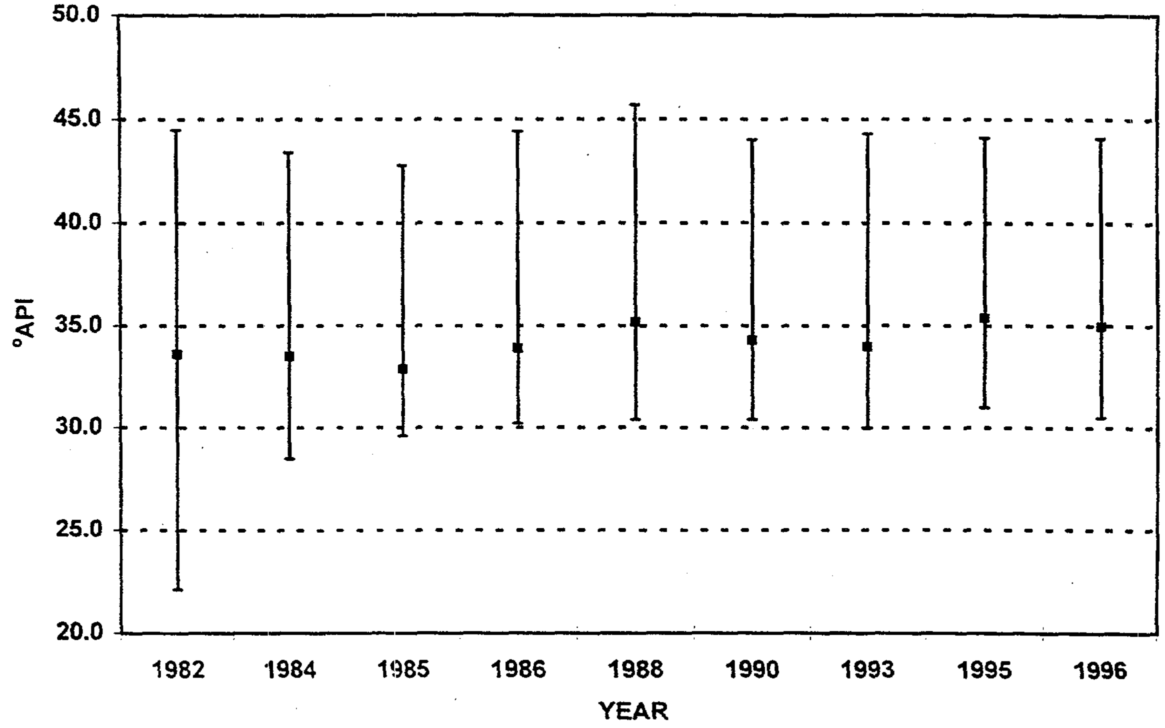


Fig. 21

KINEMATIC VISCOSITY

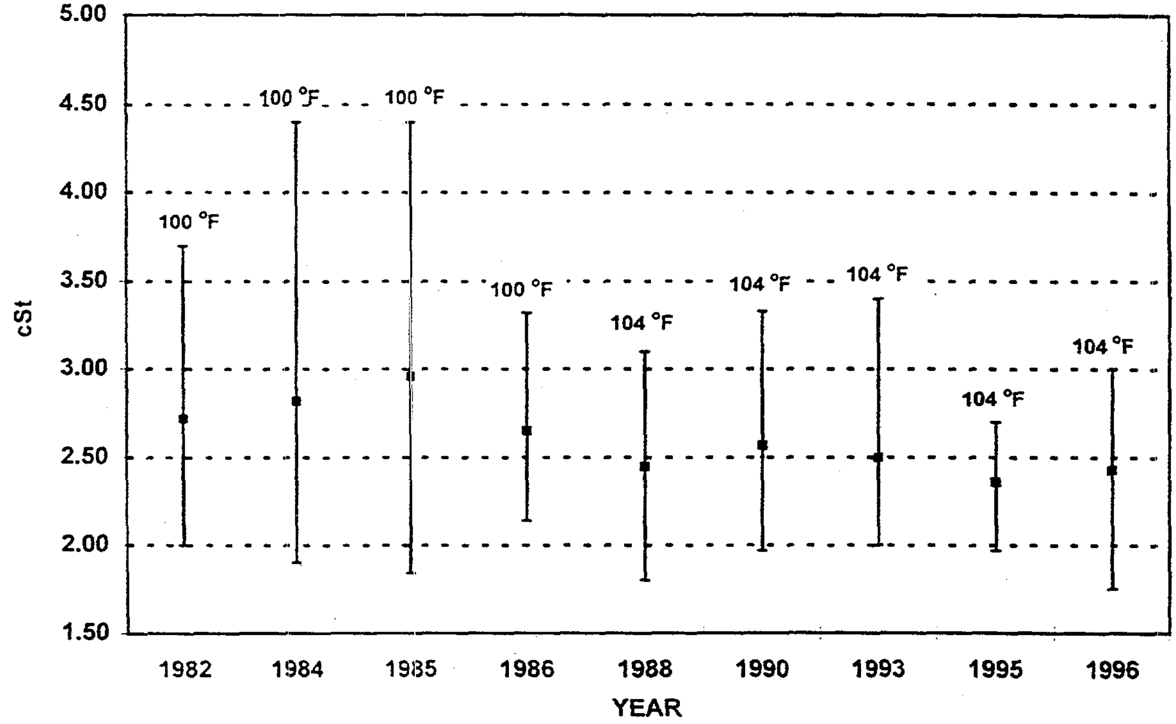


Fig. 22

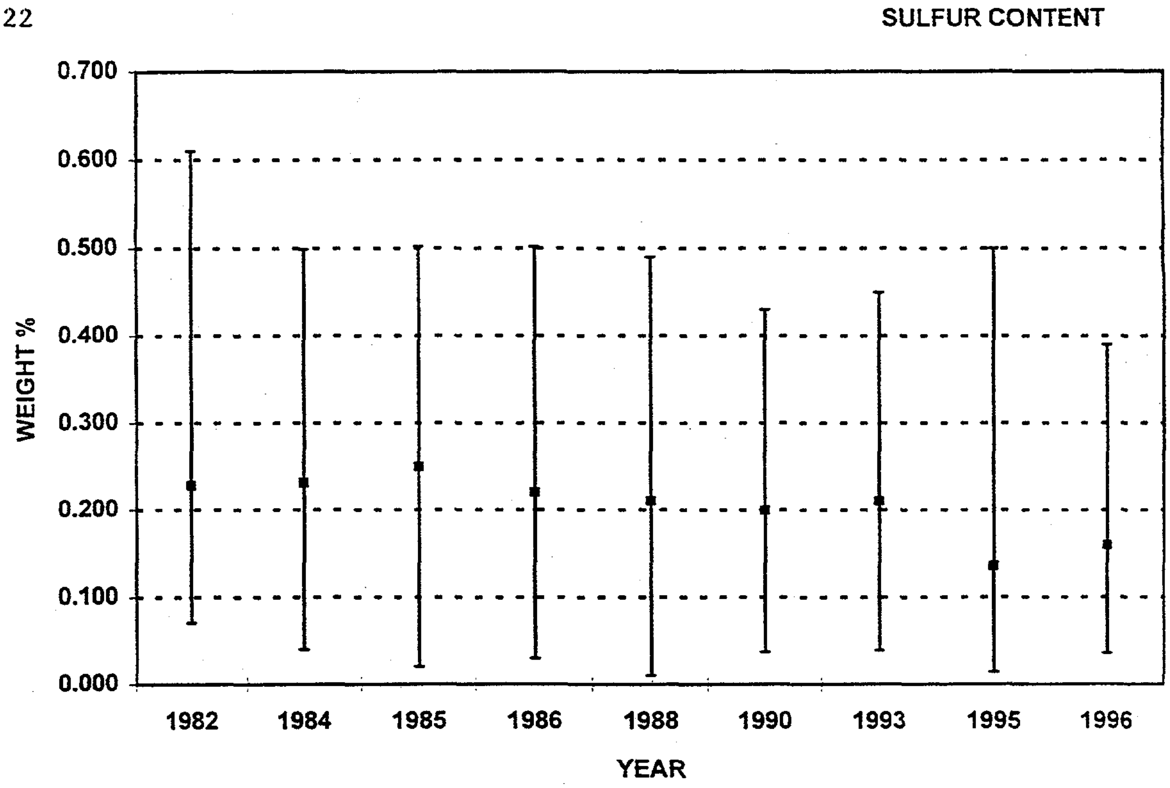

SULFUR CONTENT
WEIGHT %
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
1982
1984
1985
1986
1988
1990
1993
1995
1996
YEAR

Fig. 23

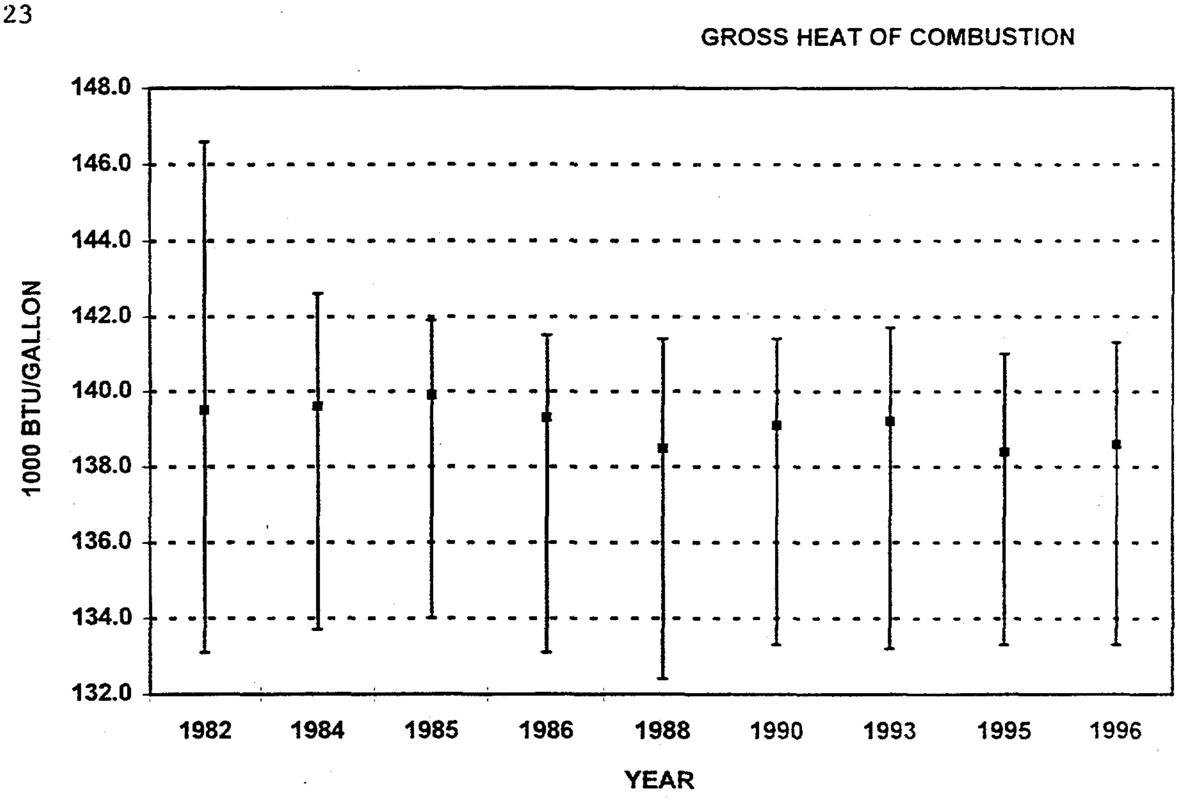

GROSS HEAT OF COMBUSTION
1000 BTU/GALLON
148.0
146.0
144.0
142.0
140.0
138.0
136.0
134.0
132.0
1982
1984
1985
1986
1988
1990
1993
1995
1996
YEAR

Fig. 24
Courtesy: W. Litzke

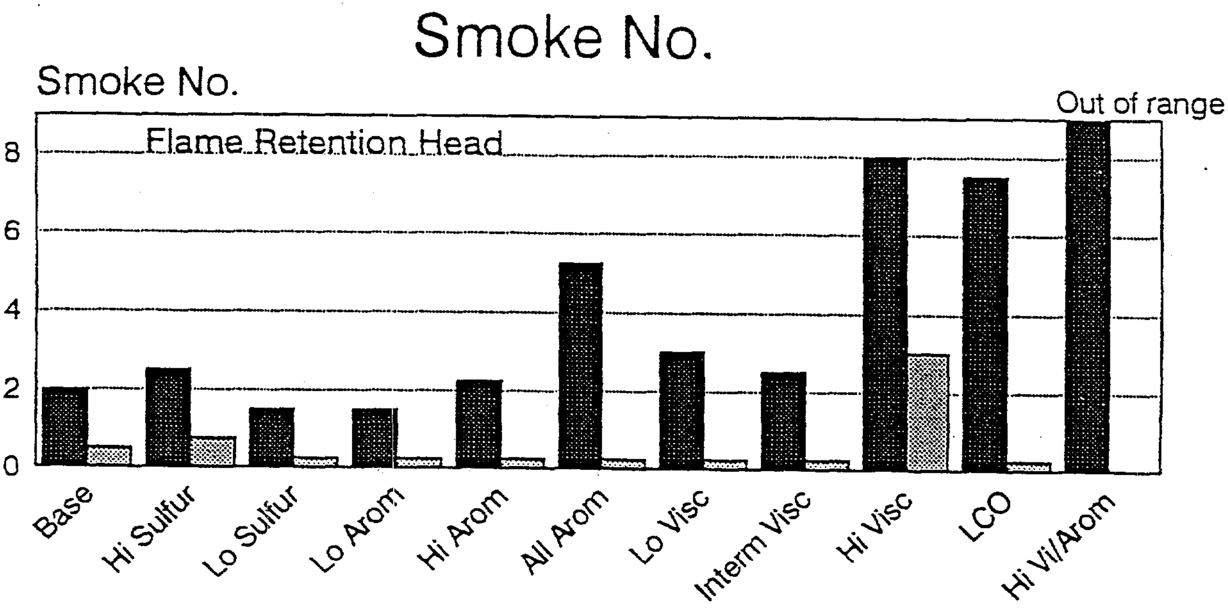
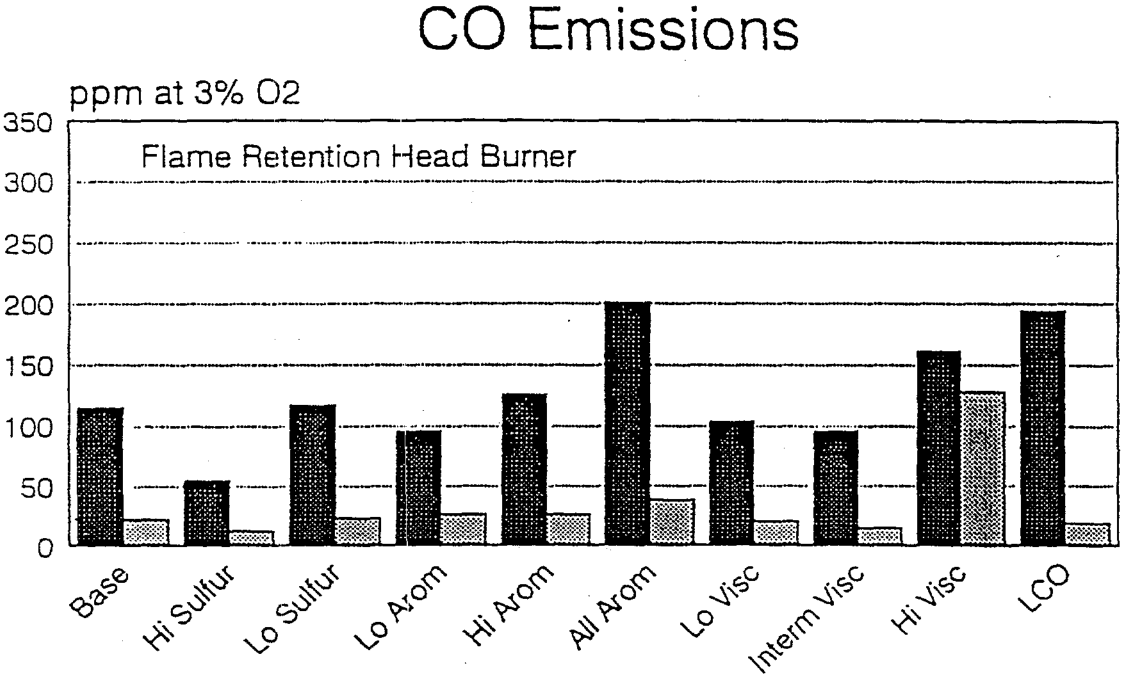
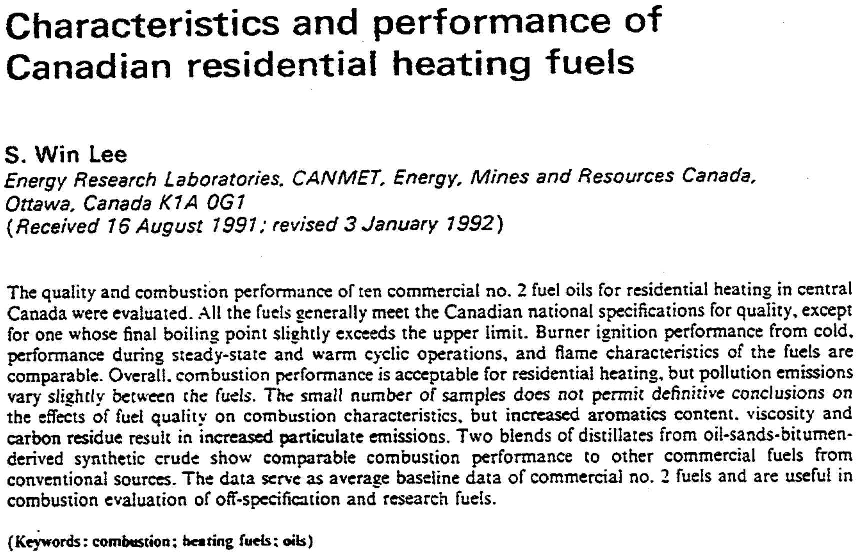


Fig. 25
Courtesy: W. Litzke
BNL





Characteristics and performance of Canadian residential heating fuels

S. Win Lee
Energy Research Laboratories, CANMET, Energy, Mines and Resources Canada, Ottawa, Canada K1A 0G1
(Received 16 August 1991; revised 3 January 1992)

The quality and combustion performance of ten commercial no. 2 fuel oils for residential heating in central Canada were evaluated. All the fuels generally meet the Canadian national specifications for quality, except for one whose final boiling point slightly exceeds the upper limit. Burner ignition performance from cold, performance during steady-state and warm cyclic operations, and flame characteristics of the fuels are comparable. Overall, combustion performance is acceptable for residential heating, but pollution emissions vary slightly between the fuels. The small number of samples does not permit definitive conclusions on the effects of fuel quality on combustion characteristics, but increased aromatics content, viscosity and carbon residue result in increased particulate emissions. Two blends of distillates from oil-sands-bitumen-derived synthetic crude show comparable combustion performance to other commercial fuels from conventional sources. The data serve as average baseline data of commercial no. 2 fuels and are useful in combustion evaluation of off-specification and research fuels.

(Keywords: combustion; heating fuels; oils)

Fig. 26

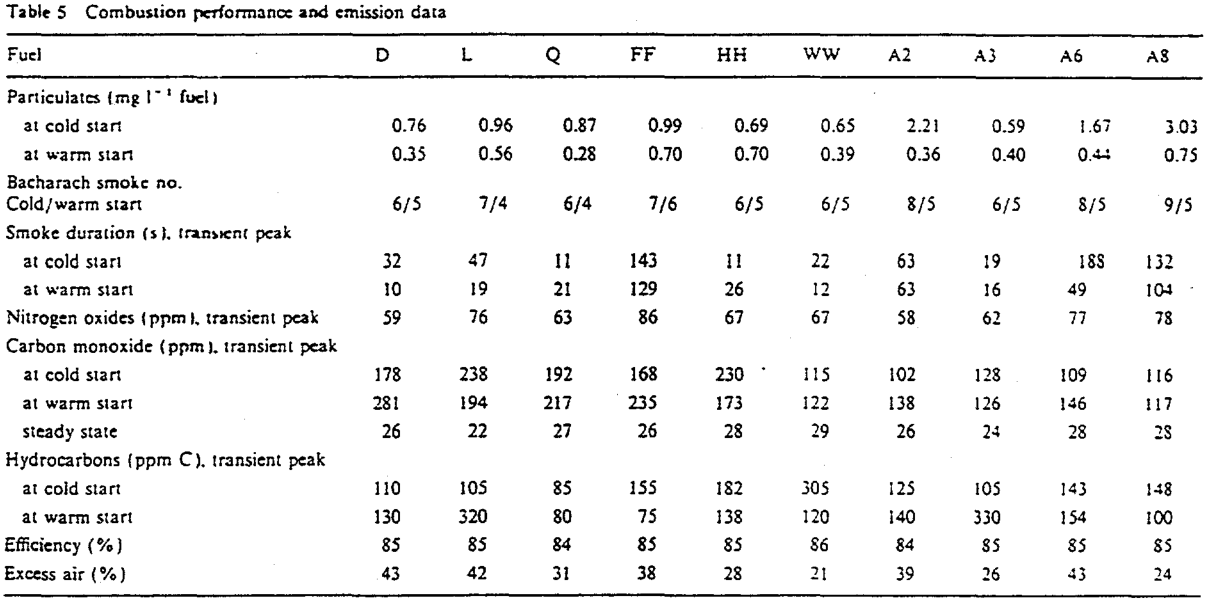


Table 5 Combustion performance and emission data

Fuel	D	L	Q	FF	HH	WW	A2	A3	A6	A8
Particulates (mg l^{-1} fuel)										
at cold start	0.76	0.96	0.87	0.99	0.69	0.65	2.21	0.59	1.67	3.03
at warm start	0.35	0.56	0.28	0.70	0.70	0.39	0.36	0.40	0.44	0.75
Bacharach smoke no. Cold/warm start	6/5	7/4	6/4	7/6	6/5	6/5	8/5	6/5	8/5	9/5
Smoke duration (s), transient peak										
at cold start	32	47	11	143	11	22	63	19	188	132
at warm start	10	19	21	129	26	12	63	16	49	104
Nitrogen oxides (ppm), transient peak	59	76	63	86	67	67	58	62	77	78
Carbon monoxide (ppm), transient peak										
at cold start	178	238	192	168	230	115	102	128	109	116
at warm start	281	194	217	235	173	122	138	126	146	117
steady state	26	22	27	26	28	29	26	24	28	28
Hydrocarbons (ppm C), transient peak										
at cold start	110	105	85	155	182	305	125	105	143	148
at warm start	130	320	80	75	138	120	140	330	154	100
Efficiency (%)	85	85	84	85	85	86	84	85	85	85
Excess air (%)	43	42	31	38	28	21	39	26	43	24

Fig. 27

In late June, 1996 Vic Turk (R. W. Beckett Director of Engineering) attended an ASTM meeting in San Francisco to get involved in the standards setting process and make contact with industry personnel. Information from both users and producers indicated that fuel stability (thermal) is an important property measured independently from others. Fuel stability has been linked by one major user to filter plugging problems, although the mechanisms involved are not known. Fuel processing practice can have an effect on stability, although this is thought to be minimal and processing practices have been consistent for some time now. Red dye has been found experimentally to have no effects on stability at 2x normal dosage. Microbial contamination is acknowledged to have the most pronounced effect on the distribution/use chain (as reflected in comments above) and is influenced by handling practices beyond refinery controls.

CONCLUSIONS

The members of the team felt that our task force effort was worthwhile, and presented the following conclusions in July, 1996:

1. It appears that the oil heating industry does not have a crisis or widespread general problem.
2. In the isolated instances where they have occurred, problems of excessive carbon deposits have not been specific to any one burner or appliance manufacturer's equipment.
3. Neither red dye nor low sulfur appears to be the cause of the isolated problems encountered.
4. Cautions are warranted as related to possible future trends toward higher viscosities, higher aromatic content, reduced thermal stability, or other potential changes to existing fuel characteristics and specifications.
5. Some localized problems that have been seen may be related to refinery practices and/or non-traditional fuel sources. There may also be an increased tendency for low sulfur fuel to gel at colder temperatures, possibly contributing to head carbon formation.
6. System cleanliness (from ship/barge/storage tank to terminal to truck to local tank) is very important and is suspected by many to be a major cause of system problems.

RECOMMENDATIONS

The following recommendations were also made in July, 1996:

1. Heating oil quality should receive ongoing careful attention by heating oil industry groups such as PMAA and/or OMA.
2. Beckett engineering should maintain an active role with ASTM regarding fuel specifications.
3. Beckett engineering should continue to investigate isolated incidents with the assistance offered by one of the major oil companies.
4. Beckett engineering should proceed with an extended low sulfur versus standard No. 2 heating oil sooting/performance test.
5. Additional experimentation to study the effects of viscosity, aromatics, additives, etc. on combustion performance should be encouraged.

6. Study of the effects of refinery practices and fuel processing (catalytic cracking, desulfurization, etc.) on fuel properties and combustion performance is recommended.
7. The findings and results of this task force should be distributed to others in the oil heat industry, including those who participated in the evaluation process.

FINAL NOTES

1. Vic Turk, R. W. Beckett Director of Engineering, and Bob Greenes, Petro-Consult, have joined the ASTM Subcommittee on fuels to monitor and be involved with the standards process.

2. Task force findings were distributed to fuel oil dealers and trade groups in July, 1996 via a mailing, and throughout the oilheat industry through publication in Fueloil & Oil Heat magazine in October, 1996.

3. R. W. Beckett Technical Services telephone service call records for 1996 indicate the following data related to fuels, combustion problems, and impingement/coke trees, as % of the total number of calls:

1st half 1996 (January - June)	7.2%
2nd half 1996 (July - December)	6.6%
Overall 1996	6.9%

   Telephone service calls will continue to be tracked on an ongoing monthly basis.

4. For the 1st quarter of 1997, 6.3% of the telephone service calls handled by R. W. Beckett Technical Services were for fuels, combustion problems, and impingement/coke trees. See Figure 28 for comparison data for October 1995 through March 1996 versus October 1996 through March 1997.

5. R. W. Beckett Corporation wishes to acknowledge and thank the following people for their support and assistance in this effort:

Tom Butcher	Brookhaven National Laboratory
Wai Lin Litzke	Brookhaven National Laboratory
Roger McDonald	Brookhaven National Laboratory
S. Win Lee	CANMET
Marion Dwight	Delavan
John Batey	Energy Research Center

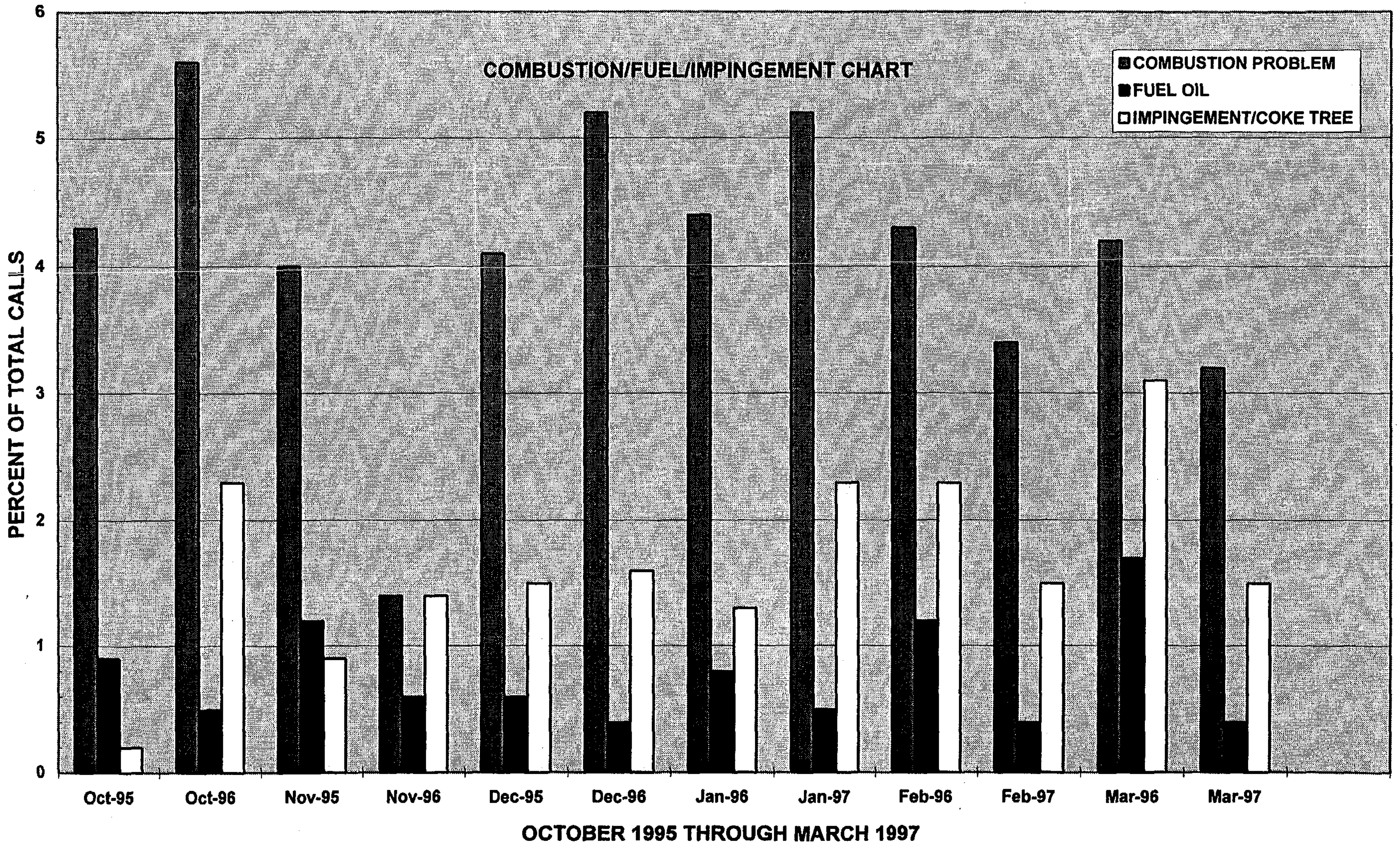

COMBUSTION/FUEL/IMPINGEMENT CHART
▨ COMBUSTION PROBLEM
■ FUEL OIL
☐ IMPINGEMENT/COKE TREE
PERCENT OF TOTAL CALLS
0
1
2
3
4
5
6
Oct-95
Oct-96
Nov-95
Nov-96
Dec-95
Dec-96
Jan-96
Jan-97
Feb-96
Feb-97
Mar-96
Mar-97
OCTOBER 1995 THROUGH MARCH 1997

Fig. 28

Paper No. 97-11

Residential Fuel Quality

Thomas Santa

Santa Fuel, Inc.
154 Admiral Street
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Residential Fuel Quality

Thomas S. Santa, Santa Fuel Inc.

Abstract

This report details progress made in improving the performance of No. 2 heating oil in residential applications. Previous research in this area is documented in papers published in the Brookhaven Oil Heat Technology Conference Proceedings in 1993, 1994 and 1996. By way of review we have investigated a number of variables in the search for improved fuel system performance. These include the effect of various additives designed to address stability, dispersion, biotics, corrosion and reaction with metals. We have also investigated delivery methods, filtration, piping arrangements and the influence of storage tank size and location.

As a result of this work Santa Fuel Inc. in conjunction with Mobil Oil Corporation have identified an additive package which shows strong evidence of dramatically reducing the occurrence of fuel system failures in residential oil burners. In a broad market roll-out of the additized product we have experienced a 29%reduction in fuel related service calls when comparing the 5 months ending January 1997 to the same period ending January 1996.

Introduction

For most retail heating oil distributors and oil burner service contractors the leading cause of oil burner malfunction is the clogged fuel system. This condition results in a significant reduction in the reliability of oil heat as well as contributing to efficiency and safety concerns. The fundamental key to success of this research has been the ability to accurately measure the impact of various measures taken. To date measurement has consisted of taking the number of fuel system failures and dividing it by the number of gallons/100,000 delivered to the study population, (Failures/Gals Delved/100,000). Failures are defined as a fuel filter replaced on a non-routine maintenance call. This yields an index of failures per 100,000 gallons delivered.

We have refined this approach slightly to change the denominator to 100 degree days. This results in an index with units of failures per 100 degree days. We believe this to be more accurate as it eliminates the variance caused by the actual deliveries being made ahead of or behind the degree day schedule. The assumption is that filter fouling is a function of the volume of fuel traveling through the filter. The number of degree days is a more accurate indicator of this than the actual deliveries being made. An adjustment had to be made to the actual degree days to accommodate non heating related use (domestic hot water heating). To accomplish this we added 145 degree days to all twelve months. It should be noted that the Filters/100 Degree Day Index should not be used to compare different sample population results as the larger population will tend to have a higher index number.

Field Trial Actions

Starting in October of 1995 Santa Fuel Inc. began additizing No.2 heating oil being delivered to its customers with a heating oil additive developed by Mobil Oil Corp. The product was designed to reduce sludge related problems. Properties of the additive include anti-oxidation, improved stability, reduced reaction with metals anti-corrosion and dispersion of existing sludge.

The additive has been injected at the truck loading rack prior to delivery. The results were apparently affected by a failure of this injection system between November 1995 and January 1996. Weekly reconciliation of additive and fuel volumes have been conducted since then to insure accurate dosage.

Results

After five years of analysis and experimentation we have finally seen the kind of dramatic results required to justify the expense of a broad additive program. For the five months ending in January 1997 there was a reduction of 29% in filters per 100 degree days. The rate was stable for November, December, and January, the period of maximum volume and a time when the rate normally spikes upward.

The rate per 100,000 gallons delivered also dropped 29% for the five months ending in January 1997. The rate dropped from 18.06 to 12.88 filters/100,000 gal.

Conclusion

Over the years we have tried many different solutions to the sludge problem. This has included several additive packages, filter mediums, tank cleaning methods, delivery methods, oil piping arrangements, and tank replacement. The 29% reduction documented in real service is the first meaningful and sustained improvement experience since the inception of this research.

Future Work

Five months of positive results are not conclusive proof that the additive package is the definitive solution to fuel system problems. Continued monitoring of results will be required for the foreseeable future.

It is important to set performance goals for our product that meet our customers expectations for reliability, safety and efficiency. For the past several years in the sample population used in this study the failure rate has been consistent at roughly 18 fuel system failures per 100,000 gallons. Stated another way, given the average customer has an annual consumption of 1000 gallons, 18% of customers are affected each year. A reasonable goal might be more on the order of 5% or 5 failures per 100,000 gallons delivered.

We should keep in mind that the study population is not necessarily representative of the oil market in general but these numbers provide a critical benchmark against which all companies should be measuring their individual performance.

Table 1: Filter Changes Per 100,000 Gallons Delivered

Santa Fuel Inc.

Month	Year 92/93	93/94	94/95	95/96	96/97	%Change 96 VS 97
SEP	20.8	18.6	16.5	16.4	22.5	37%
OCT	15.8	19.5	18.5	15.2	17.9	18%
NOV	17.9	18.2	23.9	23.6	16.5	-30%
DEC	21.5	20.3	17.7	23.8	12.3	-48%
JAN	21.5	22.9	22.4	17.7	12.7	-28%
FEB	19.3	20.8	21.4	16.1		
MAR	16.3	14.3	16.3	17.0		
APR	11.3	15.0	15.5	14.4		
MAY	23.5	13.6	7.7	17.9		
JUN	11.7	17.4	10.1	18.0		
JUL	17.3	19.9	18.7	17.7		
AUG	14.6	11.2	10.7	15.5		
Average YTD	19.52	19.91	19.78	19.35	16.39	-15.0%
Vol. Weighted Avg. YTD				**18.06**	**12.88**	**-28.7%**

Figure 1

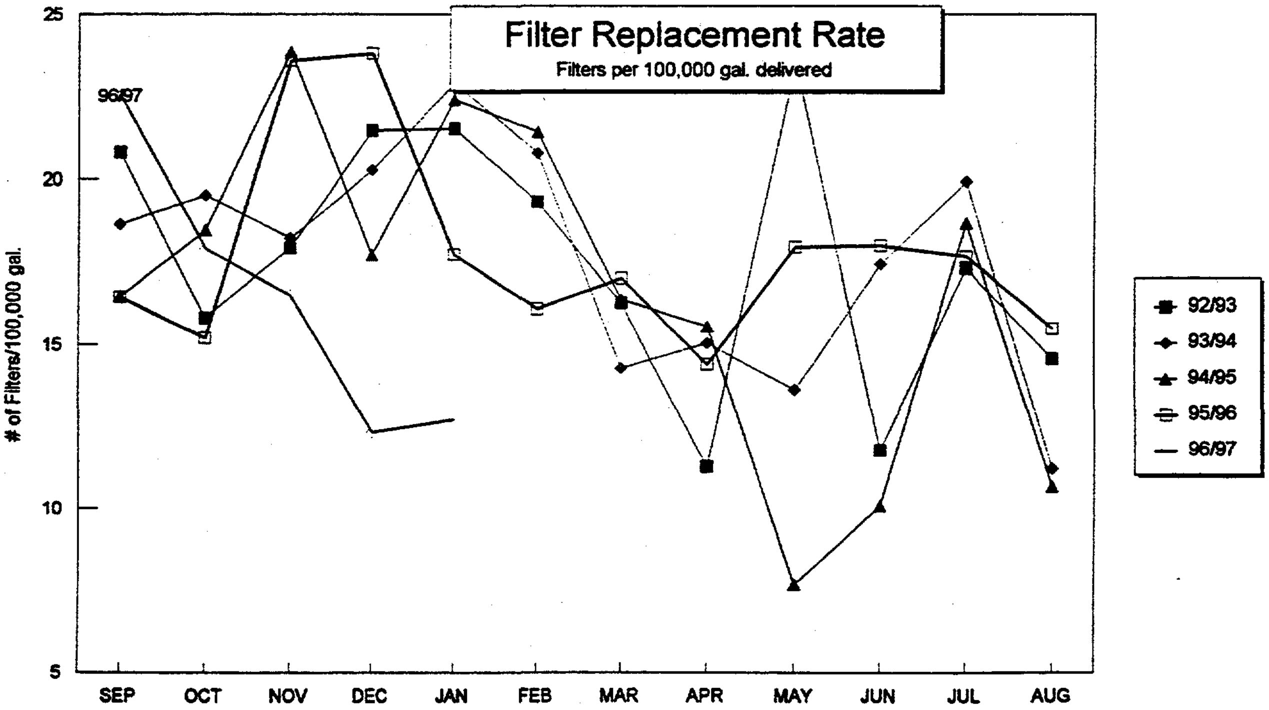
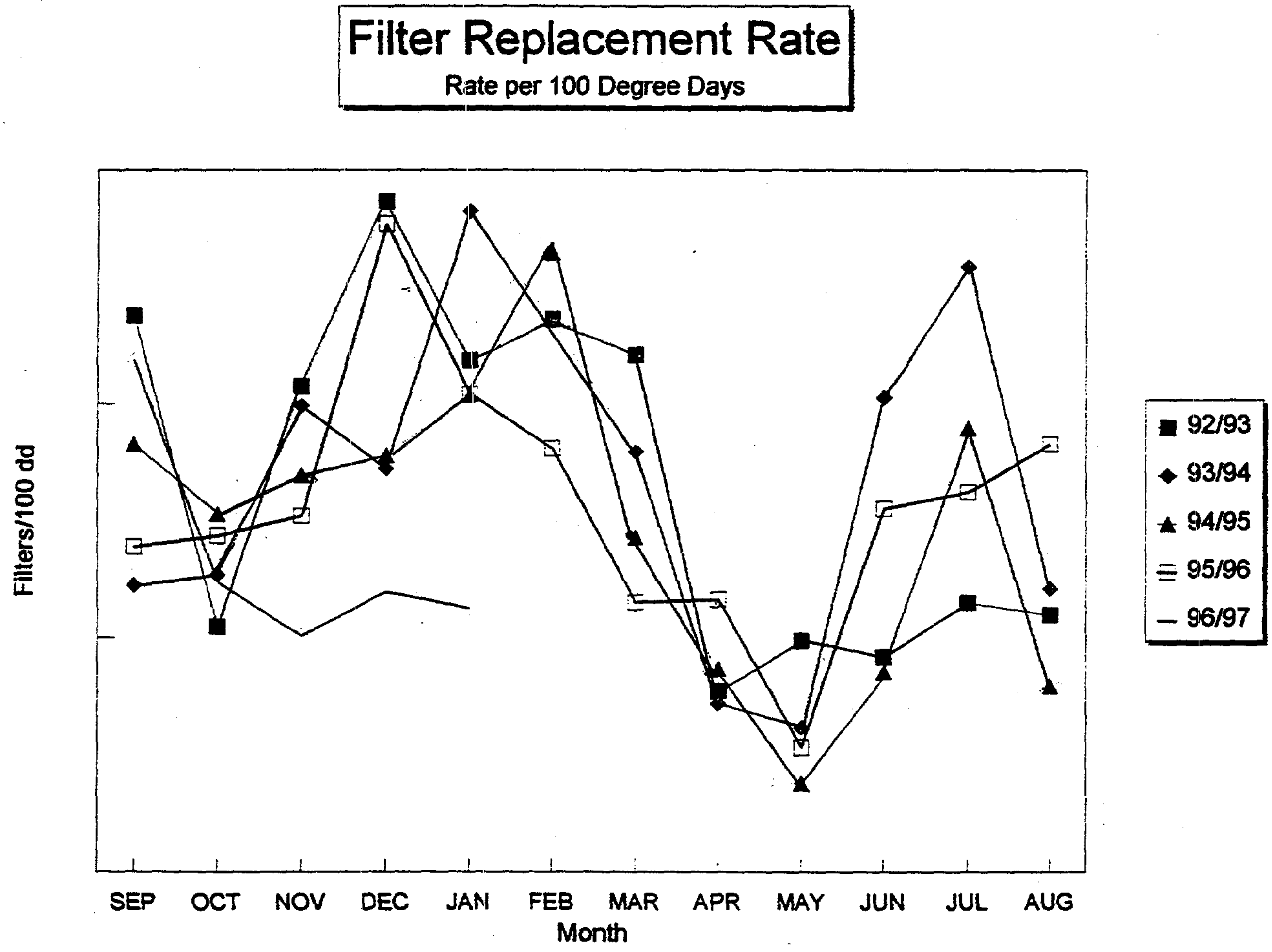


Figure 2


Filter Replacement Rate
Rate per 100 Degree Days
Filters/100 dd
SEP
OCT
NOV
DEC
JAN
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92/93
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95/96
96/97

Paper No. 97-12

Development of a Practical Training Program Based on BNL's Input to New NFPA Lined Masonry Chimney Venting Tables

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ABSTRACT

This paper describes how we developed a practical training program for technicians and sales personnel from the BNL studies that evolved into the Lined Chimney Venting Tables.

One of the topics discussed is our search for solutions to the reoccurring problems associated with flue gas condensation on newly installed oil fired appliances.

The paper will also discuss our own experiences in applying the new venting tables and working through the questions that arise when we encounter installations beyond the scope of the present tables.

BACKGROUND

Not too many years ago, most oil fired heating equipment was operating at less than 70% efficiency. While there were some venting problems associated with condensing flue gases on the older equipment, these problems created few concerns and were, for the most part, ignored. There was very little done to find solutions for these problems until after January 1, 1992 when the new National Appliance Energy Conservation Act went into effect.

The new law required that all boilers and furnaces with inputs of less than 300,000 BTUH meet minimum efficiency standards. The new standards were an AFUE of 80% for boilers and 78% for forced air furnaces. The new law also required that a heat loss calculation be completed on any retrofit or new heating system installation. The higher efficiency standards meant lower flue gas temperatures for most of the equipment now being installed. With these lower flue gas temperatures came a dramatic increase in the number of venting problems with the new installations. Instead of just an occasional instance of having condensate dripping from a chimney clean out, poor draft conditions, or a few bricks missing from the top of the chimney, we were seeing stains on interior walls, odors inside the structures, discoloration on exterior portions of chimneys, tile liners collapsing, and an increase in the number of puff back claims. Not only was it becoming costly because of the claims and call backs, it was also reinforcing in the customers' mind the idea that oil really was a dirty fuel.

Our first attempts at alerting our technicians and sales force to the venting problems we were encountering included several safety and training bulletins. In the bulletins we stressed that before installing any new oil fired equipment, a thorough inspection of the venting system had to be made. We stated that it may be difficult to predict whether a chimney would cause a future problem, but if there were any signs of flue gas condensation with the existing heating system, you could be sure that there would be a problem with the new installation.

We also wanted our people to understand that even though there was a lack of evidence of condensation before the installation, that did not mean that there wouldn't be a future problem and customers had to be alerted to the fact that if a problem did develop, that chimney remediation would have to be done. To avoid the usual finger pointing after the fact, we proposed putting the following statement on our sales agreements:

> *"We have inspected your chimney and although we did not discover any deterioration due to flue gas condensation, we are advising you that should a*

> *condensate problem develop, future chimney remediation will be necessary. Common problems associated with chimney condensation are chimney deterioration, stains on interior or exterior surfaces, sooting, and internal collapse which could increase the dangers of carbon monoxide poisoning.* ***If you notice any signs of chimney condensation, please call your heating contractor.*** *We cannot be held liable for any future claims resulting from damage due to chimney failure."*

This statement was also made available as a sticker to place on the heating appliance in a conspicuous location at the time of the installation.

If one of our technicians or salesmen found evidence of flue gas condensation before a sale was made and the customer refused to install a liner or consider an alternative venting method, we recommended walking away from the sale.

The summer of 1992 found us preparing for a series of technical seminars on using the new Vent II gas venting tables. During preparation for the seminars, we decided we would also put together some guidelines for oil venting. When we began collecting information for the topic, we discovered that there wasn't much available and what did exist was often vague and inconsistent. We found that because of our special interest in the subject and our past experiences, we knew almost as much as anyone else we encountered.

The guidelines we first developed included information on recognizing conditions that cause flue gas condensation, where to look for evidence of condensation, and solutions for correcting the problem.

Some of the solutions we recommended were: relining all exterior chimneys with a metal liner, relining interior chimneys with a metal liner when the chimney showed signs of condensing, and, on some installations, using an insulated connector pipe. We also emphasized the fact that buildings were tighter and better insulated now and fresh air requirements for combustion and ventilation had to be met on all installations.

Even with all of these efforts, we found that we still had problems in some applications. What we suspected (and later confirmed by the work at BNL) was that many of the liners we installed were over-sized and were continuing to condense.

The research and development at BNL was used as a basis for developing our own technical training program for properly venting oil fired appliances.

Training Program for Venting Oil Fired Appliances

A. INTRODUCTION

On January 1, 1992, a new energy efficiency law became effective. The new law required that all residential boilers and forced air furnaces manufactured after that date had to meet minimum efficiency standards of 80% and 78%, respectively. The new law also required that a heat loss calculation be completed for every new heating installation or retrofit application. These higher efficiencies meant lower flue gas temperatures. These lower temperatures resulted in increasing problems with flue gas condensation, poor draft conditions, and chimney deterioration.

Definition of Efficiency Terms

Combustion Efficiency: The effectiveness of the combustion process in converting the chemical energy of the fuel to heat energy. Normally this process is 98-100% efficient.

Steady State Efficiency: The measurement of that portion of a heating fuel that is converted or extracted from the heat exchanger into useful heat energy. This measurement is determined after the heating appliance has been operating long enough to achieve "steady conditions" or maximum flue gas temperature.

Example: Steady State Efficiency of 80% — 80% of each unit of heating fuel is converted to useful heat energy and delivered to the building. 20% is lost in the hot exhaust gases and unburned fuel.

AFUE or Seasonal Efficiency: These two terms mean the same thing. This measurement includes a variable of time which is typically one heating season and takes into consideration the losses that occur when the burner is not firing. AFUE can be used by customers to make efficiency comparisons between different brands of heating equipment.

Review of Combustion Testing Procedures

Since the selection of a chimney liner may depend on conducting a proper efficiency test, it's important to make sure everyone is familiar with the testing procedure.

Placement of the Sampling Holes: We recommend using two sampling holes in the flue pipe. These holes must be located 18" from the breach opening to reduce any chance of reflected heat from the heat exchanger, the equivalent of two flue pipe diameters from an elbow, and the equivalent of one pipe diameter on the heater side of the barometric damper.

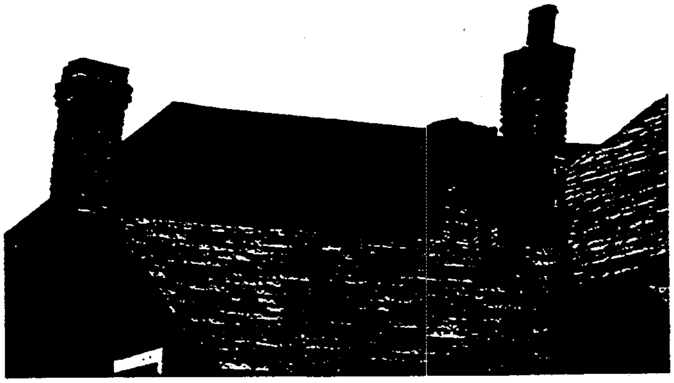
Conducting the Test:

- Place the stack thermometer so the tip is halfway in the flue pipe.
- Start the burner and let run for approximately 10 minutes or until the maximum flue gas temperature is reached.
- Measure the over fire draft.
- Measure the amount of smoke in the flue gas.
- Measure the amount of carbon dioxide in the flue gas.
- Measure the temperature of the flue gas.

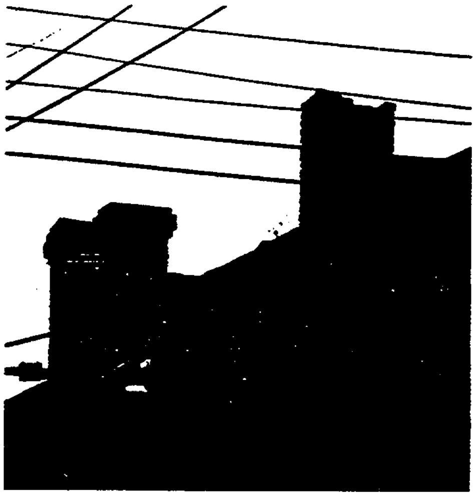
B. RECOGNIZING THE SYMPTOMS OF FLUE GAS CONDENSATION

Although the symptoms of flue gas condensation are fairly easy to identify, they are often overlooked. Masonry erosion such as missing or loose bricks, sand, and flakes of tile liners in the chimney base are easy to spot. Other problems — including stains on wallpaper, paint or surrounding wood; water leaking from chimney clean outs; discoloration of exterior mortar or blocks — can be or are often attributed to other causes. All of these signs point to the possibility of flue gas condensation and associated chimney deterioration.

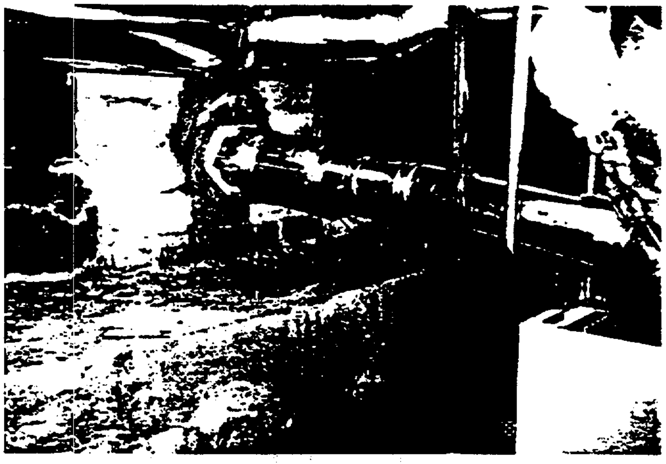
Examples of these symptoms:



Leaning Crown



Damaged Crown



Drainage at Breaching

If a chimney shows evidence of condensation with the older, less efficient heating system, you can be sure you will have future problems with any new system. A lack of evidence does not automatically mean there won't be problems in the future and customers need to be advised that if a problem does arise, chimney remediation will be necessary.

Below is a recommended checklist for determining whether a masonry chimney is suitable for continued use without remediation or lining:

1. Does chimney appear to lean?
2. Does the chimney show signs of deterioration such as loose blocks, bricks, or mortar? Is the crown missing or exterior stucco loose or falling off?
3. Does the chimney have a tile liner?
4. Does the chimney show any signs of leakage along its entire length? From the clean out or the connector pipe?
5. Is there any sand, mortar or flakes of liner in the base?
6. When examining the connector pipe closest to the chimney base, does it show corrosion inconsistent with the rest of the pipe? Is there any evidence of backdrafting?
7. Have there been changes to the structure that give the impression that the new heating system will be smaller and more efficient than the original system?
8. What is the flue gas temperature of the existing furnace or boiler? Is it significantly more than the equipment you will be installing?
9. Measure the flue gas temperature difference between the breech and the disitial end of the connector pipe. Is there a significant drop in temperature?
10. What is the connector pipe length? Are there several 90° elbows?
11. What appliances are or will be connected to the venting system?
12. If the structure is extremely tight or the heating system is in a confined area, have provisions been made for an adequate amount of combustion air supply?

C. CHIMNEY REMEDIATION

When it's been determined that the existing chimney is unsuitable to continue using, alternative venting methods must be considered. These alternatives include metal liners, sidewall venting, direct venting, and factory built non-masonry chimneys. Remember when a new heating appliance is installed, the venting system must be upgraded to meet existing codes.

When determining alternative venting systems, the following information needs to be considered:

1. The heating equipment manufacturer's recommendations must be followed.
2. If the existing masonry chimney is to be used, it must have a liner.
3. Solid fuel burning appliances cannot be vented into the same flue with appliances burning other fuels.
4. Oil and gas fired appliances can be vented into a single flue if there is sufficient draft available for each appliance and each appliance is equipped with a primary safety control.
5. When two or more appliances are connected to a venting system, the one with the smaller connector pipe must enter the vent at a higher level than the larger connector or be joined into a common connector using a suitable joint such as a "Y" or "T" fitting.
6. The base of a factory built non-masonry chimney that extends to the ground must rest on a solid masonry or concrete base at least 2" thick. If the non-masonry chimney does not extend to the ground and is not self-supporting, it will have to rest on a firm metal or masonry support.
7. If the chimney is to be relined, a listed liner for the fuel being burned must be used and a label permanently attached to the connector stating the type of fuel.
8. Chimney connectors cannot pass through combustible walls, floors, or ceilings unless the combustible material is protected. See NFPA #31 — 1-7.2.3. for suitable materials or methods of protection.
9. If the vent connector of a heating appliance is reduced, the maximum firing rate that can be vented into the connector system must be marked on the appliance.
10. A common connector serving two or more appliances must equal the equivalent free area of the individual connectors.
11. If an insulated connector pipe is required, a Type L vent must be used.
12. If more than one oil burning appliance is vented into the same vent, they must be on the same story of a building.
13. If the existing masonry chimney is to be used for a new installation without any remedial work, the condition of the chimney must be re-checked after three months and reinspected after six months of normal operation to verify it is still in good condition and still suitable for continued use.
14. When a customer refuses to follow through with recommendations for remediation or alternative venting systems, we must walk away from the sale.

D. HOW TO USE THE LINED MASONRY OIL VENTING TABLES

If relining an existing masonry chimney is an option, there are three methods for sizing the liner:

Flue Loss Method: Adjust the burner for a trace to a number one smoke reading to achieve a satisfactory level of CO_2 in the flue gas. Measure the temperature of the flue gas at the breech to select the table to use in obtaining the recommended vent size. After selecting the proper table, remember to readjust the burner back to the appropriate smoke and CO_2 levels.

Heating Capacity Method: Divide the BTUH output of the heating appliance by the BTUH input to obtain the approximate steady state efficiency. Use this result for selecting the appropriate table for obtaining the recommended vent size.

AFUE Method: Use the published AFUE efficiency for the model heating appliance. To find the estimated steady state efficiency, add 1% to this valve for hydronic boilers and 2% for forced air furnaces. Use this estimate for proper table selection.

After selecting the appropriate table or tables, determine the vent height above the vent connector and the length of the connector lateral. The liner size is selected by using the firing rate of the appliance, the height of the vent, and the connector lateral length. Using the appropriate table selected by one of the selection methods, find the vent height in the first table column. Next, find the listed lateral length for the vent connector. Read across to find the appliance firing rate. In the column where the information intersects, go to the top of the column for the correct liner size. For length of laterals that fall between the lengths listed on the tables, the user must interpolate between the table entries. Look at the shorter lateral length listed, then look at the longer length listed; compare the two and make a selection based on the table entry that fits.

For burners with fuel pump pressures greater than 100 psig, the chart on the following page can be used for determining firing rates.

If a ***flexible*** liner is to be used, the vent capacity should be reduced by 20%.

Nozzle Capacities

U.S. Gallons Per Hour No. 2 Fuel Oil

Nozzle Rating	Operating Pressure: Pounds per square inch				
GPH 100 psi	GPH 125 psi	GPH 140 psi	GPH 150 psi	GPH 175 psi	GPH 200 psi
.40	.45	.47	.49	.53	.56
.45	.50	.53	.55	.59	.63
.50	.56	.59	.61	.66	.71
.55	.61	.66	.67	.72	.77
.60	.67	.71	.74	.79	.86
.65	.73	.77	.80	.86	.92
.75	.84	.89	.92	.99	1.06
.85	.95	1.01	1.04	1.13	1.20
1.00	1.12	1.18	1.23	1.32	1.41
1.10	1.23	1.30	1.34	1.45	1.55
1.20	1.34	1.42	1.47	1.59	1.70
1.25	1.39	1.49	1.53	1.65	1.76
1.35	1.51	1.60	1.65	1.78	1.91
1.50	1.68	1.77	1.84	1.98	2.12
1.65	1.84	1.95	2.02	2.18	2.33
1.75	1.96	2.07	2.14	2.32	2.48
2.00	2.24	2.37	2.45	2.65	2.83
2.25	2.52	2.66	2.74	2.98	3.18
2.50	2.80	2.96	3.06	3.30	3.54
2.75	3.07	3.25	3.37	3.64	3.89
3.00	3.35	3.55	3.68	3.97	4.25
3.50	3.91	4.14	4.29	4.63	4.95
3.75	4.19	4.45	4.59	4.96	5.30
4.00	4.47	4.73	4.90	5.29	5.66
4.50	5.04	5.32	5.51	5.95	6.36
5.00	5.59	5.92	6.13	6.61	7.07
5.50	6.15	6.51	6.74	7.27	7.78
6.00	6.71	7.10	7.33	7.94	8.48
6.50	7.26	7.69	7.96	8.60	9.20
7.50	8.38	8.87	9.19	9.92	10.60
8.50	9.50	10.06	10.41	11.24	12.02
10.00	11.18	11.83	12.24	13.22	14.14
11.00	12.29	13.02	13.47	14.55	15.55
12.00	13.40	14.20	14.70	15.90	17.00
13.50	15.09	15.97	16.53	17.85	19.09
15.00	16.77	17.75	18.37	19.84	21.21
17.00	19.00	20.11	20.82	22.48	24.04
19.50	21.80	23.07	23.90	25.80	27.60
22.00	24.59	26.03	26.94	29.10	31.11
25.00	27.95	29.58	30.61	33.07	35.35
28.00	31.30	33.13	34.30	37.00	39.59
31.50	35.21	37.27	38.58	41.67	44.54

E. OTHER VENTING ALTERNATIVES

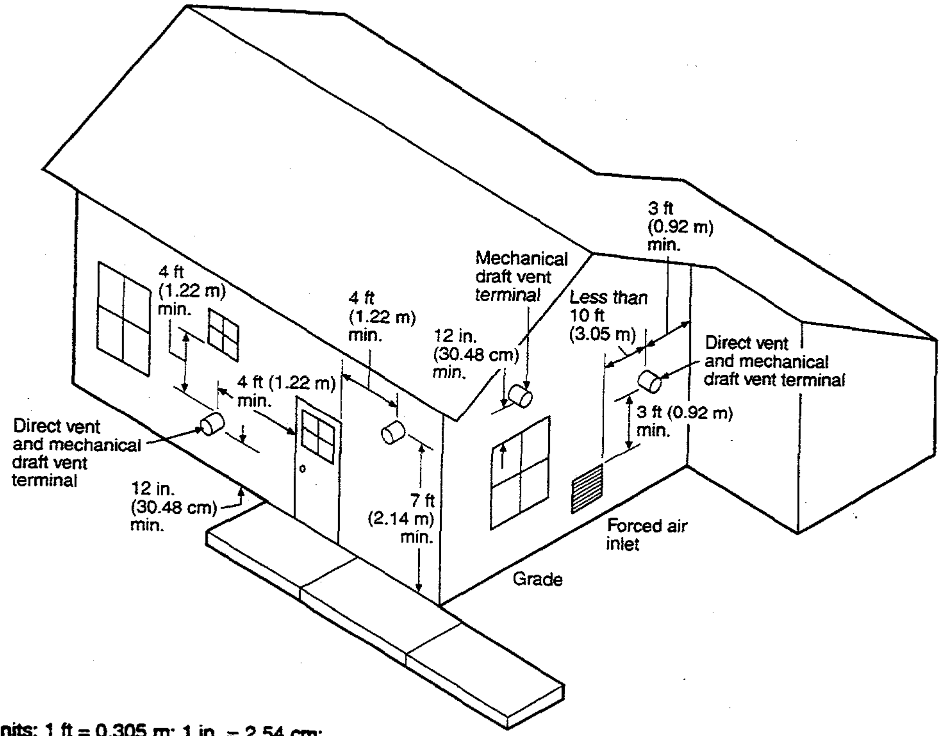
There may be some situations where relining a chimney is not appropriate. When this occurs, alternative vents such as insulated non-masonry metal chimneys or side wall vents may have to be used.

Factory built non-masonry chimneys are a suitable alternative to the masonry chimney, particularly when used in new construction. These chimneys can now be sized using the lined masonry chimney tables. New requirements for supporting these chimneys are now effective.

Sidewall venting is another option, but must be approached with caution. Burner performance and adjustment are critical in any sidewall application. The location of the vent terminal is important not only because of safety concerns, but selection must also be in an area where the fumes will not offend the occupants when they are outdoors.

When using a power vent system, it's recommended that the connector size be the same as the breech size for its entire length and reduced at the power vent unit. It's also recommended that combustion air be piped directly to the burner.

A power or sidewall venter must be equipped with proper safety controls and be installed at the terminal end of the vent system.



**For SI units: 1 ft = 0.305 m; 1 in. = 2.54 cm;
1 Btu/hr = 0.293 watts**

Exit Terminals of Mechanical Draft and Direct-Vent Venting Systems.

F. COMBUSTION AIR REQUIREMENTS

Combustion air requirements are an important part of any new installation. Many times the problems associated with inadequate make up air are not evident until well after the installation has been completed.

If the heating appliance is installed in what is classified as a confined space, outside combustion air is a requirement. A confined space is defined as any area that is less than 50 cubic feet of space for every 1,000 BTUH input of the heating appliances located in that area.

When calculating combustion air requirements, the BTUH input of all the appliances in the area have to be considered. The ventilation requirements for clothes dryers are greater than other appliances. a rule of thumb to use when calculating these requirements is:

- For gas dryers, multiply the input of the burner by 5 to find the equivalent input.
- Electric dryers should be estimated to have input requirements equal to 100,000 BTUH.

If the combustion air supply is to be brought in from outside the building, it should equal one square inch of free area for every 4,000 BTUH input for vertical ducts and one square inch of free area for every 2,000 BTUH input for horizontal ducts. For air supplied from inside the building, the air supply will have to equal one square inch of free area for every 1,000 BTUH input.

Summary

Although the venting tables do not address chimney heights above 25 feet, we have (in certain applications) extended the tables beyond that height. These applications have short straight lateral runs and fairly warm ambient temperatures surrounding the heating unit. With these conditions, we feel fairly confident in extending the tables to 30 feet. We also have some applications where we have gone beyond that height.

I have included two examples of applications beyond the scope of the tables.

Example #1

A member of a church in northern Vermont called to see if we could help in solving a problem they were having with their new heating system. Since we were the oil supplier, we complied with the request. Two new furnaces had been installed the previous year. Toward the end of the heating season, the church members discovered that the chimney was literally falling apart.

Responding to the call, we found two 200,000 BTUH forced air furnaces in the basement of the church. The two furnaces were vented into an unlined brick chimney that was 38' high. One connector pipe was 8' with two 90° elbows. The other connector pipe was 4' with two 45° elbows. A heat loss calculation revealed the furnaces were grossly over sized and the ductwork connected to each furnace was only capable of handling 100,000 BTUH.

Since the furnaces were capable of handling multiple firing rates, the decision was made to fire the units to match the capacity of the ductwork. A firing rate of 1.10 gph was chosen because we were concerned with abnormally low flue gas temperatures. Since sidewall venting was not an option because of the location of the furnaces, we decided to use two 4 inch flexible liners in the existing brick chimney. The liners were the maximum size we could get down the chimney. Connector pipes were sized to match the size of the breech openings, and were installed without barometric dampers.

After test firing the units, we found we were maintaining an over fire draft of -.01 and a breech draft of -.03. We increased the firing rate to 1.25 gph because the flue temperatures were in the low 300°F. range. This change in the firing rate did not affect the over fire draft, but did give us the increase in temperature we were looking for.

Because of our concerns over the long term performance of the furnace with the long lateral run, the church negotiated with the installer to replace the front flue furnace with a properly sized rear flue furnace. The two units fired at 1.25 gph have operated satisfactorily for almost a full heating season.

Example #2

This example involves an installation of a forced air furnace in one of our northern New York locations installed in the early fall of 1996. The furnace was slightly over sized for the medium sized single story ranch home that was the site of the installation. Although there wasn't any evidence of venting problems before the installation, flue gas condensation became a problem right from the beginning. Because the customer was never informed of the possibility of flue gases condensing, her problem became our problem.

The chimney was 17' high and the connector pipe was 12' long. To compound the problem, the basement where the furnace was located was extremely cool. The firing rate of the furnace was .75 gph. Using table F-7, we recommended a 4" ridge liner with a 4" type L vent connector pipe. These corrections were made in late November 1996. When we reinspected the venting system in January 1997, we found the problem had been corrected and the customer was satisfied with the results.

As we continue working with the tables, we are discovering several situations not specifically addressed by them. Through our own initiatives and experimentation, we have found enough tolerance and flexibility to allow for solving some of the more complex venting problems.

The examples in the summary are two of several where we were willing to experiment and assume the liability for the suggestions we made.

Recommended FIRING RATE CAPACITIES and METAL LINER SIZE for retrofitting clay tile-lined masonry chimneys. To be used when field inspection indicates relining is required. Base Case: Exterior residential clay tile-lined masonry chimney complying with NFPA 211, Standard for Chimneys, Fireplaces, Vents, and Solid Fuel-Burning Appliances, subsections 3-2.2 through 3-2.7. Minimum Liner Temperature = 95°F; Minimum Draft = 0.03 inches of water.

NR = Not Recommended

Table F-7(a)
Steady State Efficiency = 88%
(12% CO_2, 275°F. Gross)

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

Table F-7(b)
Steady State Efficiency = 86%
(12% CO_2, 345°F. Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.65-1.5	0.4-1.0	0.4-0.5
	6	0.65-1.5	0.4-1.0	0.4
	8	0.85-1.5	0.4-1.0	0.4
	10	0.85-1.5	0.4-1.0	NR
15	4	0.65-2.25	0.4-1.5	0.4-0.85
	6	0.65-2.25	0.6-1.5	0.4-0.75
	8	0.65-2.25	0.5-1.5	0.4-0.65
	10	0.75-2.25	0.5-1.5	0.4-0.65
20	4	0.75-2.25	0.5-1.75	0.4-1.0
	6	0.85-2.25	0.65-1.75	0.4-0.85
	8	0.85-2.25	0.65-1.75	0.4-0.85
	10	0.85-2.25	0.65-1.75	0.4-0.85
25	4	0.85-2.25	0.65-2.0	0.4-1.0
	6	0.85-2.25	0.65-2.0	0.5-1.0
	8	0.85-2.25	0.65-2.0	0.5-1.0
	10	1.0-2.25	0.55-2.0	0.5-1.0

Table F-7(c)
Steady State Efficiency = 84%
(12% CO_2, 420°F. Gross)

Height Ft.	Lateral Ft.	Liner 6 in.	Liner 5 in.	Liner 4 in.
10	4	0.4-2.0	0.25-1.25	0.25-0.65
	6	0.4-2.0	0.25-1.25	0.25-0.65
	8	0.4-1.75	0.4-1.25	0.25-0.5
	10	0.5-.75	0.5-.0	0.25-0.5
15	4	0.5-.25	0.4-1.75	0.25-0.85
	6	0.5-2.25	0.4-.5	0.25-0.85
	8	0.65-2.25	0.4-1.5	0.25-0.85
	10	0.65-2.25	0.4-1.5	0.4-0.85
20	4	0.65-2.25	0.4-2.0	0.25-1.0
	6	0.65-2.25	0.4-2.0	0.4-1.0
	8	0.65-2.25	0.4-1.75	0.4-1.0
	10	0.65-2.25	0.4-1.75	0.4-1.0
25	4	0.65-2.25	0.4-2.25	0.4-1.0
	6	0.65-2.25	0.5-2.25	0.4-1.0
	8	0.65-2.35	0.5-2.0	0.4-1.0
	10	0.75-2.25	0.5-2.0	0.4-1.0

Table F-7(d)
Steady State Efficiency = 82%
(12% CO_2, 495°F. Gross)

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

Table F-7(e)
Steady State Efficiency = 80%
(12% CO_2, 575°F. Gross)

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

Paper No. 97-13

An Overview of Carbon Monoxide Generation and Release by Home Appliances

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AN OVERVIEW OF CARBON MONOXIDE GENERATION AND RELEASE BY HOME APPLIANCES

John E. Batey, PE

INTRODUCTION

Carbon monoxide (CO) is an odorless, colorless and tasteless gas which is ***highly toxic*** and can be produced by many combustion sources commonly found within homes. Potential sources include boilers and furnaces, water heaters, space heaters, stoves, ovens, clothes dryers, wood stoves, fireplaces, charcoal grilles, automobiles, cigarettes, oil lamps, and candles. Any fuel that contains carbon can form CO including, natural gas, propane, kerosene, fuel oil, wood, and coal. Exposure to elevated CO levels typically requires its production by a combustion source and its release into the home through a venting system malfunction.

The health effects of CO range from headaches and flu-like symptoms to loss of concentration, coma and death depending on the concentration of CO and the exposure time. At levels of only 1%, which is the order of magnitude produced by automobile exhaust, carbon monoxide can cause death in less than 3 minutes. While most combustion equipment operate with low CO levels, many operating factors can contribute to elevated CO levels in the home including: burner adjustment, combustion air supply, house air-tightness, exhaust fan operation, cracked heat exchangers, vent blockages, and flue pipe damage. Test data on CO emissions is presented from a wide range of sources including Brookhaven National Laboratory, Gas Research Institute, American Gas Association, the US Environmental Protection Agency, and the US Consumer Product Safety Commission for many potential CO sources in and near the home.

General information is presented concerning burner adjustment and some other conditions that may contribute to elevated CO release in homes. Also, several case studies of CO hazards are reviewed as well as some ways to reduce the risk of CO exposure in homes.

Two common misconceptions about carbon monoxide include:
1. Oil burners cannot produce Carbon monoxide, and
2. Oil burners automatically shut themselves down before high CO levels are produced.

BOTH OF THESE STATEMENTS ARE FALSE.

However, oil burners usually produce elevated smoke levels **BEFORE** high carbon monoxide levels are reached which serves as a **"warning signal"** not available with most other energy sources. The good news is that the risk of exposure to high Carbon Monoxide levels by operating oil burners is lower than many other combustion sources commonly found in homes including gas appliances.

This paper briefly introduces the subject of Carbon Monoxide exposure in homes and includes the following subjects:

- What is Carbon Monoxide and what are its health effects?
- Case studies of Carbon Monoxide exposure and injury in homes
- How does CO build up in homes?
- What are typical Carbon Monoxide emissions from home appliances?

What is Carbon Monoxide and What are its Health Effects?

Carbon Monoxide is a highly toxic gas that is difficult to detect because it is odorless colorless, and tasteless. It replaces oxygen in our blood and can cause serious injury and death at elevated concentrations and exposure times. The US Environmental Protection Agency has set **35 parts per million** (ppm) in air as the maximum 8-hour exposure level and the ambient CO limit is only **9 parts per million**. This is a very low concentrations of only 0.0009%. CO is dangerous at low concentrations because it has 200 times greater attraction to blood than oxygen. This means that, even at low concentrations (in the part per million range), CO will be absorbed by the blood and displace oxygen which is needed to support life.

The effects of Carbon Monoxide vary with its concentration and the time of exposure. The Table that follows shows that initial symptoms often include *headache, dizziness, tiredness, nausea, vomiting, and diarrhea.* **Unfortunately, these are also symptoms of the flu and CO poisoning is often misdiagnosed as the flu.** In fact in one medical study 23.6% of all emergency room patients with flu-like symptoms actually had elevated CO levels in their blood. As CO levels in the blood increase (and oxygen levels decrease), the symptoms often include *loss of concentration* and *impaired judgment*. This becomes more dangerous because we become unable to recognize the danger that exists. As the CO levels in the blood rise further, symptoms include *convulsions*, *coma*, and *death*. At these elevated CO concentrations, the body is depleted of oxygen and damage can occur to the heart, brain and other organs. It is imperative that the affected person be removed from the high CO area to fresh air (or oxygen) so that the blood can begin to expel the CO and absorb oxygen. Everyone has some CO in their blood: people living in rural areas typically have 1%; people living in cities about 3%; and cigarette smokers typically have between 4% and 10% CO in their blood. CO poisoning occurs when levels increase above about 20%.

HEALTH AFFECTS OF CARBON MONOXIDE EXPOSURE

HEADACHE

DIZZINESS

TIREDNESS

NAUSEA

VOMITING

DIARRHEA

LOSS OF CONCENTRATION

IMPAIRED JUDGMENT

CONVULSIONS

COMA

DEATH

HEALTH AFFECTS OF CARBON MONOXIDE (CO)

CONCENTRATION PPM	%	EXPOSURE TIME AND SYMPTOMS
9	0.0009	MAXIMUM AMBIENT ALLOWED - USEPA
35	0.0035	MAXIMUM FOR 8-HOUR EXPOSURE
200	0.02	HEADACHE IN 2 TO 3 HOURS
400	0.04	LIFE THREATENING AFTER 3 HOUR FLUE GAS LIMIT FOR GAS HEATERS
800	0.08	DIZZINESS, NAUSEA, CONVULSIONS IN 45 MINUTES, DEATH IN 2 TO 3 HOURS
1600	0.16	HEADACHE, DIZZINESS, NAUSEA IN 20 MINUTES, DEATH IN 1 HOUR
3200	0.32	HEADACHE, DIZZINESS, NAUSEA IN 10 MINUTES, DEATH IN 30 MINUTES
6400	0.64	HEADACHE, DIZZINESS, NAUSEA IN 2 MINUTES, DEATH IN 10 TO 15 MINUTES
12800	1.28	DEATH IN 1 TO 3 MINUTES

The table on the left shows how Carbon Monoxide concentration and time of exposure both effect symptoms. The first two values are 9 parts per million (ppm) and 35 ppm which are the ambient air limit and the 8-hour exposure limit. As the CO concentration increases to 200 ppm, headaches occur in about 2 to 3 hours. At 400 ppm, it can become life-threatening after 3 hours of exposure. This is also the maximum flue gas concentration recommended for gas-fired heating equipment.

As the CO levels in the air rise further, more serious symptoms occur. At 1600 ppm headache, nausea and convulsions can occur within 45 minutes and it can cause *death in only one hour.* at 6,400 ppm symptoms can be observed in two minutes and CO can be deadly in *10 to 15 MINUTES.* When the CO levels exceed one percent (10,000 ppm) death can occur in only ***1 to 3 MINUTES***. These levels (or higher) can be produced by automobile engines.

Clearly, Carbon Monoxide is a dangerous gas that can cause serious injury and death when it reaches relatively low concentrations and homeowners must be prepared to protect themselves. Also, heating equipment service technicians must be aware of the causes of CO so that they can properly adjust burners and heating system for low CO levels. Oil burners typically produce very low levels of about 30 ppm in the flue gas when the equipment is properly adjusted. The amount of CO produced can increase rapidly (by factors of 10, 100, 1000 or more) as any burner goes out of adjustment. Therefore, regular heating system inspection and burner tune-up is recommended to assure continued low CO risks in homes.

Case Studies of Carbon Monoxide Exposure

Several case studies are briefly reviewed that demonstrate the very serious nature of elevated Carbon Monoxide levels.

Case 1. Chicago - November 1990 - A family of 10 died from CO poisoning while sleeping in their Chicago home. This included a mother, father, and 8 children ranging in ages from 10 to 25 years. An HVAC trade publication indicated that the suspected causes of the lethal CO levels were an oversized gas valve that had been recently installed and a gap in the sheet metal flue pipe apparently allowed the CO to be released into the home. This tragic incident resulted in a new requirement for CO detectors in Chicago homes.

Case 2. Eight people died from acute Carbon Monoxide poisoning in their apartment including a man, woman, four children, a nephew, and a neighbor. The people had been sick and vomiting but had suspected food poisoning as the source of their illness. A hot water heater was found with a broken vent pipe and a water leak which caused the gas burner to run continuously, contributing to the high CO levels. Air samples taken in the apartment showed CO levels of 2000 parts per million which can be lethal in less than one hour.

Case 3. Los Angeles - November 20, 1994 - A father and his two sons died and his wife and daughter were hospitalized with Carbon Monoxide poisoning. While preparing to go to church, the father went into the attached garage of their house and started the engine of the family's van. The garage door was closed. The Fire Department found the victims one hour later when the heat generated by the engine exhaust set off the fire alarm. Automobile exhaust can contain deadly levels of CO and must never be operated in closed garages or near fresh air intakes into buildings.

A detailed description of what happens during Carbon Monoxide release in a home is presented in the August 1985 issue of Readers Digest in the article "Is There a Killer in Your Basement?" by Laurence Alpert, MD. Everyone should read this article.

How Does Carbon Monoxide Build Up in Homes?

Two events are needed for elevated CO levels to build up in homes:

- **Formation** of Carbon Monoxide by the burner by incomplete combustion of the fuel, AND
- **Release** of the exhaust gases into the home by a venting system malfunction

CO can be **formed** by any fuel that contains carbon if the combustion process is not fully completed. This includes natural gas, propane, kerosene, fuel oil, coal, and wood. When the fuel is completely burned the carbon is converted to Carbon **Di**oxide or **CO2** which is a harmless gas. During incomplete combustion, some of the carbon is released in the exhaust gases as Carbon **MON**oxide or **CO** which is highly toxic.

Some of the common causes of incomplete combustion and elevated CO include:

- Inadequate air supply to the burner
- Burner mal-adjustment - too little or too much combustion air
- Excessive fuel firing rate
- Dirt or debris on burner
- Clogged gas orifice or oil nozzle
- Flame impingement on cold surfaces

CO can be **released** into the house by any event that prevents complete removal of the combustion exhaust gases from the home by the chimney or venting system. Some of these include:

- **Vent blockage** and spillage of gases into the home caused by damage to the chimney liner, broken flue tiles, animal nests, soot build up in the chimney or cleanout that partially blocks the flue , or any other condition that prevents normal chimney venting.

- **Heat Exchanger damage** or cracks that allow exhaust gases (which may contain CO) to enter the warm air flowing to the house.

- **Flue Pipe damage** which permits some of the exhaust gases to escape into the house before reaching the chimney.

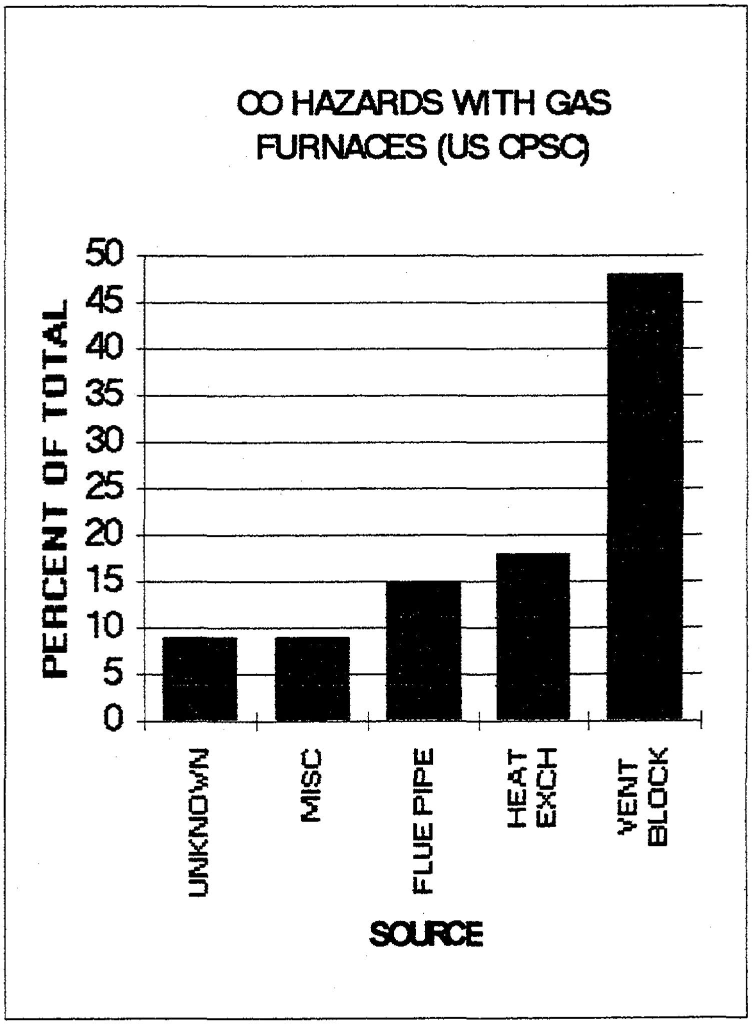
- **House exhaust fans** which can cause house de-pressurization and chimney backdrafting.

- **House Sealing and Caulking** which can reduce the amount of air entering the house by infiltration though cracks and reduce the air supply the burner.

- **Scale and Soot Buildup** in flue passages of heating equipment which can reduce air flow to the burner and prevent normal venting of exhaust gases

- **Any Other Conditions** that prevent normal operation of the chimney or venting system.

The bar chart on the right shows the causes of Carbon Monoxide hazards in homes based on a study of gas furnaces by the US Consumer Product Safety Commission. The most frequent cause of CO release was blocked vents (almost one-half of the cases) followed by heat exchanger damage and flue pipe leakage. These three source accounted for more than 80% of the CO risks in the US CPSC study.



If Carbon Monoxide is produced by a burner, the chimney or vent system normally removes the combustion gases from the house. Dangerous situations occur when CO is produce by the heating equipment ***AND*** the vent system is not working properly. Some of the exhaust gases containing CO can escape into the home. The trend toward "air tight" energy-efficient houses, and expanded use of multiple exhaust fans increases the risk of CO exposure.

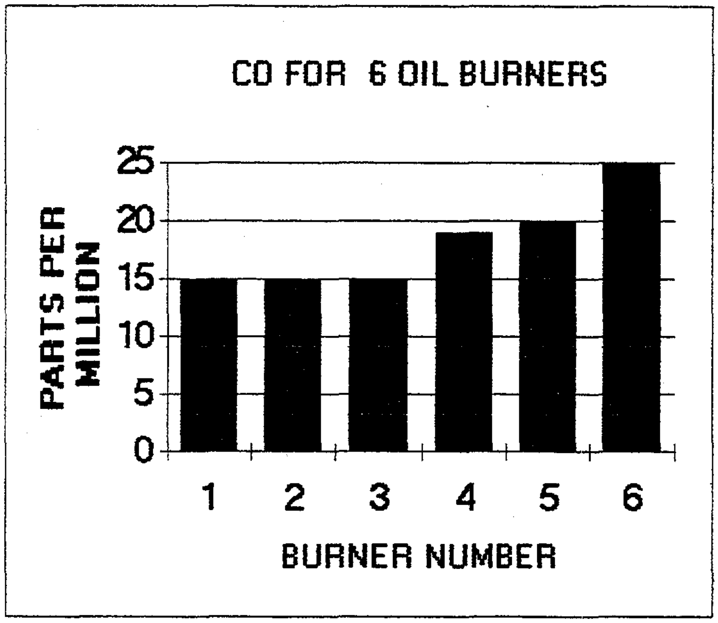
One approach for reducing the risk of CO exposure is to introduce a source of outdoor air to the heating unit to prevent depressurization of the boiler or furnace room. National Fire Protection Standard 31 offers some guidance concerning outdoor air supply for oil burners.

What are Typical CO Emissions from Home Appliances?

Oil Burners

Properly adjusted oil and gas heating equipment produce very low CO levels and these gases are normally removed from the house by the chimney or vent system.

The Bar chart on the right shows the CO emissions from six oil burners that Brookhaven National Laboratory tested in 1990. When *properly-adjusted*, these modern oil burners produce very low CO emissions averaging only **18 parts per million** (ppm) during steady operation, and only **26 ppm** during on-off cycling. These low CO production rates are less than the 8-hour exposure limit of 35 ppm, AND these gases are normally removed from the house by the chimney or vent.



Accurate burner adjustment is important to assure low CO emissions by oil burners and by all combustion equipment. Laboratory and field tests by the USEPA and Brookhaven have shown that the **CO - versus - excess air** curve is "U" shaped, and CO can increase with too little **or** too much combustion air. If the air shutter is closed too much and insufficient air is supplied to the flame, CO levels can increase. Typically, the smoke number rises **before** high CO concentrations are reached, and smoke serves as an important WARNING SIGNAL to help set oil burners for low CO. If too much air is supplied to the flame, CO levels can also increase as the excess air cools the flames and prevents complete burning of the fuel. Lab and field tests suggest that if the excess air increases to a point where the flue gas CO2 falls below 6% or 7% (depending on the burner), Carbon Monoxide levels can increase. Service technicians must be aware that both **insufficient AND excess air supply** can cause elevated CO emissions with oil burners.

Each oil burner has a unique CO - versus- excess air curve. That's why combustion test equipment is recommended for properly adjusting all burners to ensure efficient and safe operation with low CO levels. When an oil burner is adjusted for low smoke (zero to trace) with high CO2 readings (as recommended by the burner manufacturer), Carbon Monoxide is typically near its minimum level.

Other Combustion Equipment in Homes

Other fuel-burning equipment and appliances found in homes can produce elevated and potentially dangerous levels of carbon monoxide if the burner goes out of adjustment or malfunctions. A brief summary of some of the emission rates from home appliance follows.

Gas Boilers

GAS -FIRED HOT WATER BOILERS
CARBON MONOXIDE
PARTS PER MILLION

BOILER NO.	BLUE FLAME	YELLOW FLAME	FACTOR
4	6	967	161
5	8	61	8
6	4	402	101
7	5	929	186
8	7	860	123
9	20	203	10
10	308	1855	6
11	9	1075	119
12	8	9	1
13	89	237	3
14a	51	355	7
14b	90	1277	14
15a	175	281	2
15b	919	1801	2
16	27	39	1
17	19	29	2
AVG	109	649	6

REF: BROOKHAVEN NAT'L LAB 51067
NOTE: BOLD VALUES ABOVE 400 PPM

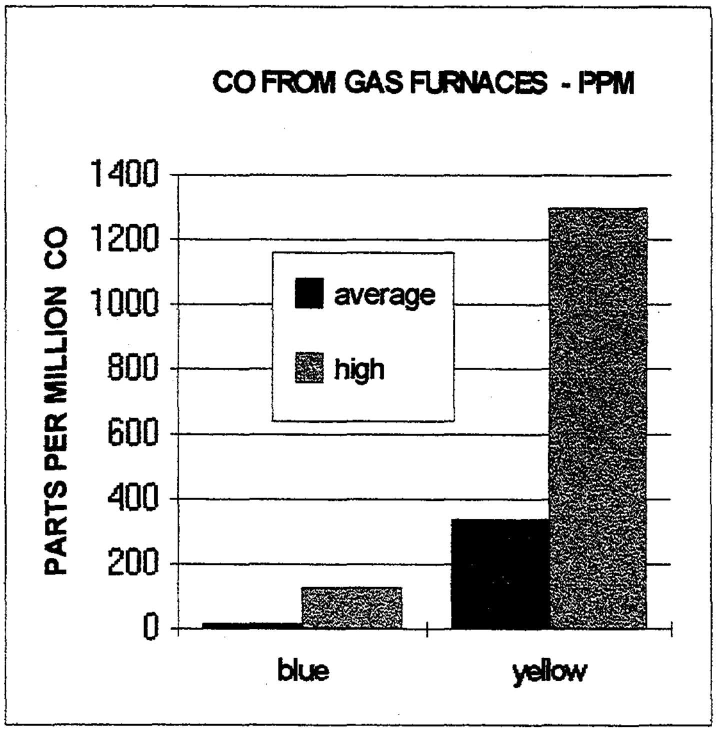
The table on the right summarizes Carbon Monoxide emissions for natural gas boilers presented in a report by Brookhaven. For properly adjusted burners with blue-flames, the CO levels range from 4 ppm to 919 ppm. The average value is **109 ppm** which is well below the accepted upper limit of 400 ppm in the exhaust of gas heating equipment. Only one boiler (number 15b) exceeds this value.

However, when the burners are not properly adjusted, as indicated by yellow-flame operation, the CO levels *increase significantly* for the same boiler. The CO levels with yellow flames range from 9 ppm to 1855 ppm with an average value of **649 ppm** which is above the flue gas limit of 400 ppm. In fact, 8 out of the 16 boilers operated with flue gas CO that exceeds the 400 ppm maximum. This increased by as much as a factor of 186 when the burner flame was yellow instead of blue. For example, Carbon Monoxide emissions from boiler #4 increased from 6 ppm to 967 ppm when the burner flame changed from blue to yellow.

Four of the yellow flame boilers operated with CO concentrations above 1000 ppm (1075, 1277, 1801, and 1855 ppm). The CO health effect chart discussed earlier indicates that if a vent problem developed and CO accumulated at this level within the house, it could be deadly in less than 1 hour. Therefore, proper gas burner adjustment is very important to assure safe operation.

The CO levels for gas boilers vary widely for both blue flame and yellow flame operation. Even when operating with blue flames, the CO levels varied from 6 ppm to 919 ppm which is a wide range. At 6 ppm the health risk is near zero, but at 919 ppm significant risk exists. Laboratory and field studies by Brookhaven and other researchers generally indicates more consistent CO level and less variability with oil burners.

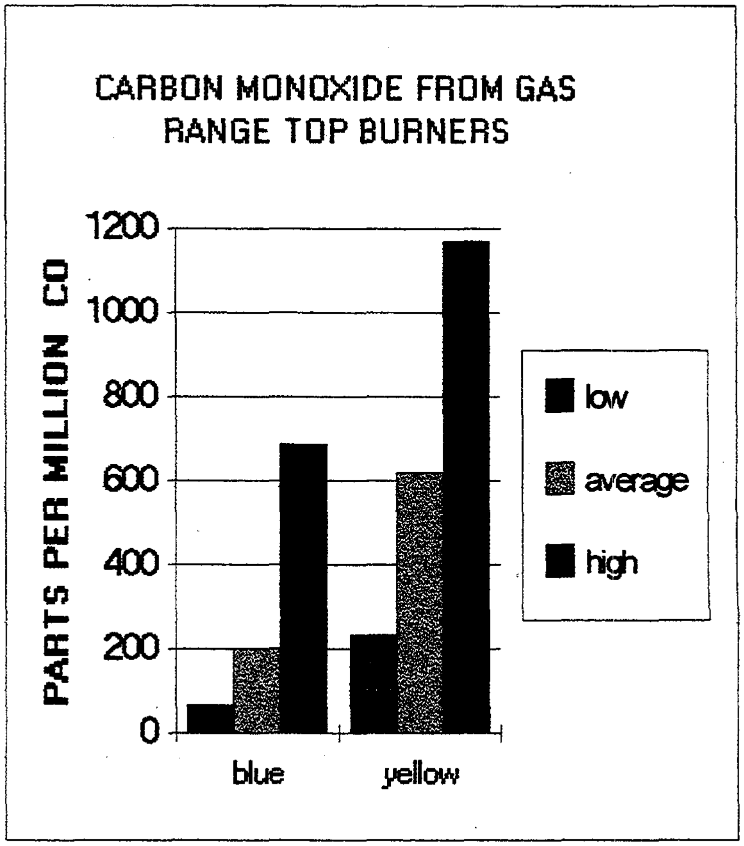
Gas Furnaces



The bar chart on the right shows average and high carbon Monoxide emissions for natural gas furnaces when operating with blue and yellow flames based on information summarized in Brookhaven Report 51067.

With properly adjusted <u>blue flames</u>, the average CO level is **17 ppm**, and the high value is **127 ppm** for the 38 furnaces tested. When the same furnaces were operated with <u>yellow flames</u>, the average CO production increased to **336 ppm** with a high value of **1299 ppm**. One-third of the gas furnaces with yellow flames had CO levels exceeding the limit of 400 ppm. Three furnaces had flue gas CO concentrations <u>exceeding 1000 ppm</u> which could produce health risks if a venting problems developed.

Gas Range Top Burners



The chart on the right summarizes tests on Carbon Monoxide emissions from 12 gas range top burners published by the Gas Research Institute (GRI Report 85/0075). When operate with a <u>blue flame</u>, CO release varies from a low of 68 ppm to a high value of 687 ppm, with an average of 201 ppm, based on the GRI tests. These are high CO levels and ***the exhaust gases are not directly vented outdoors***. The high level of 687 ppm could produce health risks in an air-tight house if the burner were operated for an extended time period with all the windows closed and exhaust fans turned off.

Gas stoves with <u>yellow flames</u> produced even higher CO emissions with a low of **235 ppm**, an average value of **621 ppm**, and a high value of **1170 ppm**. With yellow flames <u>average</u> emissions are similar to high value with blue flame operation. The maximum measured Carbon Monoxide emissions with yellow flames was 1170 ppm which could produce hazardous levels if the burners were operated for long periods of time.

If these high CO levels accumulated within the house, they could present a health risk (see the Health Effects Chart). This is why gas cooking appliances should never be used for space heating.

Gas ovens were found by the same GRI study to produce CO emissions ranging from less than 50 ppm to more than 250 ppm. Ovens typically operate for longer time periods than range top burners, and can also contribute to elevated CO levels in homes. These emissions can increase rapidly as a burner goes out of adjustment, and CO release from ovens have been measured that exceed 1700 ppm. Again, gas cooking appliances must never be used for space heating.

Other Household Sources

The following is brief summary of other equipment and appliances found in homes that can produce elevated Carbon Monoxide levels.

Space Heaters:

Unvented space heater are sometimes used that burn gas or kerosene to produce space heating and the exhaust gases are *vented into the living space*. The Gas Research Institute (GRI 85/0075) presented information on typical CO emissions from properly adjusted heaters as follows:

	CO parts per million
Natural Gas	10 to 260
Kerosene	9 to 310

These rates of CO release can increase significant as burners go out of adjustment, and *these gases are emitted directly into the living space. Careful attention to burner adjustment* is very important and the heater manufacturers' instructions must be carefully followed.

Gas Clothes Dryers:

Limited testing by the Gas Research Institute found a CO emission rate of approximately 220 ppm for a gas dryer. If the burner goes out of adjustment (for example, lint accumulates and affects the combustion air flow), then these CO levels can increase. Gas dryer exhaust vents should be checked to be sure that these gases are removed from the house.

Wood Stoves:

CO emissions data published by the US Environmental Protection Agency (Publication AP-42 - Fourth Edition) indicates that uncontrolled wood stoves produce approximately 260 pounds of Carbon Monoxide per ton of fuel burned. For a heating value of 6,300 BTU per pound, this equals 20.6 pounds of CO per million BTU which is **790 TIMES HIGHER** than residential fuel oil. Therefore, CO emissions from wood stove can be **20,000 parts per million** or higher. This can produce serious adverse health effects if the exhaust gases are not completed vented from the house.

Automobiles:

Gasoline engines used in automobiles can also produce very high Carbon Monoxide emissions. While newer models often produce lower levels older vehicles can emit 1% to 2% CO when properly tuned. This equals **10,000 to 20,000 parts per million**. Carbon Monoxide levels increase as the engine adjustment changes and can reach 7% or 8% CO or higher. Furthermore, if a car engine is operated in an enclosed area (such as a closed garage), the oxygen content of the air can be depleted, and the CO levels can rise far above the 1% or 2% level for normal well-tuned operation. These Carbon Monoxide levels can be deadly in one to three minutes. Therefore, automobiles (or any other engines) must never be operated in enclosed areas, and auto exhaust can be a source of CO build up in homes.

*When a home's CO detector indicates elevated CO levels, it is important to look at **all** combustion sources in and around the house. Many other sources besides oil burners are more likely to produce elevated Carbon Monoxide levels.*

SUMMARY

Carbon Monoxide is a *highly toxic* gas which can be produced by most combustion equipment commonly used in homes including oil burners. Health effects range from headaches and flu-like symptoms at low CO concentrations to convulsions, coma and death when the CO level reaches much less than 1%. Carbon Monoxide can be deadly in 1 to 3 minutes when it reaches a concentration in the air of only 1%.

Carbon monoxide causes serious injury and death as summarized in many published case studies that document the risks from a wide range of sources including boilers, water heaters, and automobile exhaust. Oil heat service technicians and all oil company employees should review these incidents so that they are familiar with the warning signs of CO poisoning and can respond accurately to customers' questions.

CO formation by combustion equipment **and** its release into the house are both required for elevated levels to occur. Many conditions can cause elevated CO production burners, but in most cases the chimney or vent system will safely remove the exhaust gases from the house. Some common causes of exhaust gas (and CO) leakage include: vent blockages, heat exchanger cracks, flue pipe leaks, house exhaust fan operation (which de-pressurizes the house), and scale or soot build-up in boilers and furnaces. The risk of CO exposure increases in "air-tight" houses and houses with many air exhaust devices. Adding a separate supply of outdoor air for the heating equipment can help lower the risk of CO formation caused by house de-pressurization.

Carbon Monoxide emissions from burners used in homes varies widely depending on many factors including equipment adjustment. Properly adjusted oil and gas heating units produce very low CO levels that are not hazardous during normal operation. Tests by Brookhaven shows that well-tuned oil burners produce approximately 18 to 26 ppm of CO in their exhaust, which is lower than the 8-hour exposure limit for ambient air. Furthermore, most oil burners produce higher smoke numbers **BEFORE** CO emissions increase. This serves as a "warning signal" which is not available with other fuels. Careful oil burner adjustment using combustion test equipment is recommended to assure low CO levels. Carbon Monoxide levels can increase if a burner receives ***too much excess* air**, which cools the flame and prevents complete burning of the fuel.

Published CO emissions information for other combustion equipment in homes is reviewed in the table below.

CO PPM FROM HOME APPLIANCES

		Average	High	Comments
GAS BOILER	**Yellow flame**	649	1855	
GAS FURNACE	**Yellow flame**	336	1299	3 of 16 above 1000 ppm
GAS RANGE TOP	**Blue flame**	201	687	
GAS RANGE TOP	**Yellow flame**	621	1170	
SPACE HEATERS	**Nat Gas**	130		10 to 260 ppm
	Kerosene	160		9 to 310 ppm
GAS DRYERS		220		
WOOD STOVES		20,000		Estimated - USEPA data

Some of the elevated Carbon Monoxide levels shown in the table can cause serious health risks if some of the exhaust gases leak into the house. Proper adjustment of gas burners (blue flames) is important to minimize CO emissions. It is clear that many sources of Carbon Monoxide exists in home beside oil burners, and it is important to look at ALL combustion equipment when elevated CO levels are measured.

RECOMMENDED ACTION:

Educate oil heat service technicians and all oil company employees about the dangers of CO exposure, actions to reduce oil burner emissions, common sources of CO in the home, the importance of regular burner service (for all fuels), the safety advantages of oil burners, and how to accurately respond to your customer's questions about carbon monoxide.

Paper No. 97-14

The Advanced Flame Quality Indicator System

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The Advanced Flame Quality Indicator System

Richard A. Oman, Vincent S. Calia, Michael J. Rossi, Douglas F.L. Davis, and Andrew M. Rudin; Insight Technologies, Inc.

Abstract

By combining oil tank monitoring, systems diagnostics and flame quality monitoring in an affordable system that communicates directly with dealers by telephone modem, Insight Technologies offers new revenue opportunities and the capability for a new order of customer relations to oil dealers. With co-sponsorship from New York State Energy Research and Development Authority, we have incorporated several valuable functions to a new product based on the original Flame Quality Indicator concept licensed from the US DoE's Brookhaven National Laboratory. The new system is the Advanced Flame Quality Indicator, or AFQI. As before, the AFQI monitors and reports the intensity of the burner flame relative to a calibration established when the burner is set up at AFQI installation. Repairs or adjustments are summoned by late-night outgoing telephone calls when limits are exceeded in either direction, indicating an impending contamination or other malfunction. A microprocessor-based customer unit incorporates CAD cells for monitoring up to two oil flames independently, a pressure transducer for monitoring oil tank level and filter condition, safety lockout alarms and a temperature monitor; all reporting automatically at instructed intervals via an on-board modem to a central station PC computer (CSC). Firmware on each AFQI unit and Insight-supplied software on the CSC automatically interact to maintain a customer database for an oil dealer, an OEM, or a regional service contractor. In addition to ensuring continuously clean and efficient operation, the AFQI offers the oil industry a new set of immediate payoffs, among which are reduced outages and emergency service calls, shorter service calls from cleaner operation, larger oil delivery drops, the opportunity to stretch service intervals to as along as three years in some cases, new selling features to keep and attract customers, and greatly enhanced customer contact, quality and reliability. Prices for sale or lease are targeted for payback in less than two years, with payback in less than one season for the most troublesome customers in the franchise. Some of the more exciting possibilities for the near future are establishing insurance rebates (from reduced exposure to smoke and puffback damage), adaptation of AFQI's to commercial and industrial installations (including dual fuel) and adding the ability with infrared to tune the burner from AFQI measurements alone; a feature that is one of the objectives of a new NYS ERDA contract that we are just starting.

The presentation will display details and operation of the hardware, outline the modes and magnitudes of payback for customers, dealers and OEM's, and show some sample installations and results.

Acknowledgments

This paper includes accomplishments under a cooperative effort between New York State Energy Research and Development Authority (NYSERDA) and Davis Aircraft Products Co., Inc. of Bohemia, NY (Davis). Insight Technologies, Inc. would like to acknowledge the efforts of many who have assisted in this and related efforts. In particular, the NYSERDA Program Manager Ray Albrecht has been a continuous, effective and enthusiastic enabler of our efforts.

Introduction

This paper presents the results of our work on oil heat flame quality indicator equipment. Descriptions and rationale are presented for a number of value-added features that have been incorporated into the current Insight Advance Flame Quality Indicator (AFQI). Investigations of the potential for inexpensive infrared adjuncts to the original CAD cell-based Flame Quality Indicator technology[1]are also presented.

As has been reported extensively by Butcher and colleagues at previous Oil Heat Technology Conferences, the Flame Quality Indicator (FQI) operates by monitoring the signal levels of a conventional CdS ("CAD") cell detector placed in the air tube of a conventional oil burner. The CAD cell is a detector sensitive to ultraviolet and visible light, and so responds well to the emissions from hot soot particles when observing an oil burner flame. To apply this technology to an operating oil burner, the FQI instrument must be adjusted to recognize the level of brightness in that unit when the flame is adjusted properly, and to establish the levels above and below that "set point" at which the flame can be regarded as still operating within acceptable limits. The balance of this paper describes the products that Insight Technologies, Inc. has developed that employ and build on the technology licensed from the US Department of Energy.

Enhancing The Market Appeal Of The Flame Quality Indicator

Most of the problems that oil heat has in the competitive world are related to the production of soot and other contaminants that in turn result from poorly adjusted or maintained equipment. The FQI offers a major advance in allowing oil service agencies to reduce service costs by being continuously aware of the quality of operation of all of the units for which they are responsible. The original FQI provides information as to the satisfactory operation of the heating appliance, but it provides it in the form of indicator lights at the burner location, where it is may be ignored and difficult to monitor. In order to increase the value added in the FQI concept Insight Technologies, with cooperative funding from NYSERDA, developed the Advanced Flame Quality Indicator. The AFQI incorporates a number of features designed to make flame quality monitoring more attractive to oil dealers and service contractors, and to add value for end user customers.

In addition to developing the above features of the current AFQI product, we have explored possible new sensing opportunities for future FQI-based products. Extensive work was performed to establish the infrared (IR) emissive characteristics from a retention head oil burner, and to establish the potential for exploiting inexpensive IR detectors in conjunction with the CAD cell detectors. The primary motivation for this part of our effort was to reduce the need for the use of exhaust gas testing in initial setup. The expectation for IR in this regard is that radiation from gas molecules in the IR, which is well understood, would peak at maximum flame temperature. This would provide an absolute indication of proper tuning of the burner that would be relatively independent of the particulars of each burner installation. Sample results of the IR measurements are given in this paper.

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[1] US Patent Number 5,126,721 ("Flame Quality Monitor System for Fixed Firing Rate Oil Burners", T. A. Butcher and P. Cerniglia., US Department of Energy Brookhaven National Laboratory)

The Original Flame Quality Indicator Concept

The original Flame Quality Monitoring patent by Butcher and Cerniglia[1] describes a concept that still is employed by the current FQI products. The intensity of the oil flame emission in the visible and ultraviolet spectrum is used to assess the flame operational state relative to its condition when set up by the service technician. A conventional Cadmium Sulfide ("CAD") photocell is mounted in the air tube of an oil burner, viewing a portion of the periphery of the burner flame. This sensor, which is the same type as the flame sensor usually employed in the burner's primary control, is monitored quantitatively (not just "on" or "off" as in the primary control) by a simple resistor bridge circuit. The sensor's resistance when the flame is set up (after a two-minute warmup) is permanently recorded and used as a standard of comparison for the flame emission throughout the forthcoming operational period. When the flame changes significantly (for any reason) the emission (and the resistance of the CAD cell) will change, and if the emission changes are sufficiently large the FQI circuitry records an "out-of-range" condition. Several such readings in subsequent burner cycles will result in a panel indicator light and a relay actuation that can be used to call for service.

Although there are many sources of emission in any flame, the primary source that drives the signal from the cad cells in oil flames is the ensemble of tiny particles ("aerosols") that are the result of droplets being consumed in the flame. These particles, which are mostly carbon in some form with a little ash, glow strongly in the visible and uv regions at the temperatures of flames. As the temperature and mixing properties of flame change, the radiation of these particles changes in complex ways, but the formation of smoke and soot from poorly configured flames generally tends to produce increases in radiation for small changes. Extremely poor tune of the flame will cause temperature to fall off, and that will drive flame intensity down at both rich and lean extremes. The less air supplied to the flame, the higher the concentration of soot that forms, and the brighter the flame appears to the CAD cell. The CAD cell indicates increased light levels by a decrease in its resistance, so a brighter flame results in a smaller resistance of the CAD cell. This (simplified) behavior is exhibited until the flame gets so rich that its temperature drops significantly, causing the resistance to increase sharply as the light falls off, because radiation depends very sharply on temperature. In a practical burner installation, this drop in brightness occurs well into the region where smoke levels are unacceptably high, so for the range of practical operation, the FQI signal depends monotonically on fuel/air ratio. That means that there is no particular region of the curve that is identifiable from the FQI signal alone as the proper set point, so an independent setup using stack gas analysis must be performed.

The Advanced FQI

The Advanced Flame Quality Indicator (AFQI) was developed by Insight under a cooperative agreement with NYSERDA to add sufficient value for oil dealers, customers and service contractors that the resulting product would be a commercial, as well as a technical, success. An on-board modem was added to provide automatic reporting of all heating system data on a regular basis to a modem-equipped personal computer. A pressure transducer was incorporated to report oil tank level by hydrostatic pressure when the burner is off, and to report filter pressure drop when the burner is on. This enables more accurate scheduling of deliveries (larger drops with lower delivery cost per gallon) for oil dealers, and timely filter service. A second CAD cell channel was added for independent monitoring of an oil-fired water heater or a second burner in commercial or institutional installations. Additional analog input ports were incorporated to monitor local temperatures by thermistor, and to monitor safety and/or alarm status. The AFQI has a set of NC/NO relay contacts that can be programmed to control external equipment. These services, which transport the customer's operational status automatically and directly to the agency responsible for service, make the AFQI a cost-effective tool for transforming the relationship between an oil dealership and its customers. In order to provide these services a complete redesign of the FQI system was required. The resulting product is based on an Intel microprocessor with firmware that can be altered to address new requirements for specialized sets of customers. Figure 1 displays the current Advanced Flame Quality Indicator exterior.

The AFQI is available from Insight Technologies, Inc. at a trade price of about $400 each in single quantity, or by a no-initial-cost leaseback plan. This device provides flame quality indications for up to two oil burner flames, measurements of line pressure between the filter and the burner pump, and auxiliary inputs for the monitoring of local temperatures and burner lock-out. In addition to the expanded set of indicator lights on the display panel, this unit issues automatic telephone reports using its integral modem to an appropriately configured remote computer that maintains a customer database. The AFQI reports flame indicator signals and pressures in the oil line when the burner was last on, and also when it was last off. The pressure with burner off measures the hydrostatic pressure in the tank. It reveals the gallons remaining from a lookup table in the central station computer (CSC). The difference between that pressure and the pressure with the burner running reveals the pressure drop across the filter. This allows the dealer or service contractor to assess when filter replacement is necessary, or when tank contamination is a problem.

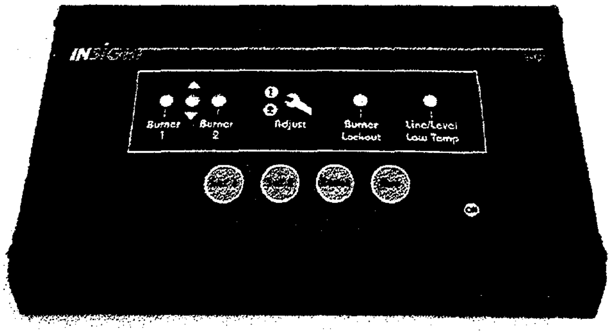

Figure 1 - The Current AFQI Product

Outgoing calls from each AFQI unit using the customer's telephone line are the only calls employed by the system to avoid an inconvenience to the homeowner or commercial building manager. The AFQI firmware retains the burner-off pressures for several pre-determined periods before the calling time, and reports all the pressure data. This set of pressures (tank contents indications) at recent specific times is useful in accurately determining the correlation between oil consumption in each customer's unit and local instantaneous weather conditions despite relatively infrequent calls (typically much less than one per week on average). The firmware in the AFQI unit receives a message back from the central station computer during the call, instructing it when to call again.

The on-board firmware, central station database and communication management software are designed to work together to maximize the size of oil deliveries without significant risk of any customer running out of oil. The algorithms have locally adjusted standard-climate predictions that are continuously updated by the tank level measurements to allow the system to learn the energy-consumption characteristics of each individual customer. The advantage of using this sophisticated learning approach with many tank levels transmitted per call is that it enables accurate and reliable management of the "troublesome" (i.e., previously unpredictable) accounts that are the highest payoff targets for AFQI installations. In addition to offering the dispatcher the current tank contents, it gives a prediction of oil level for any future time, suggests the best delivery date, and selects a good time for the next update. Calibration of the tank level data is affected by pushing a button on the AFQI front panel when the tank is first filled after installation. That initiates a first call that the computer recognizes as providing the filled calibration level.

Econometric Models and Market Analysis

There is a great deal of interest in the FQI equipment and capability of all types throughout the industry, but there are several reasons why it is only now being recognized as a device that can revolutionize the oil heat industry. The core of the value added by the AFQI lies in reduction of service costs, and the real value of specific modes of reducing those costs is difficult to measure in advance. This value added occurs directly by the shift of service calls to non-emergency time periods and the reduction of cleaning time because of reduced heat exchanger fouling. With the AFQI, heat exchangers don't have time to get fouled because the AFQI provides early warning of a contaminating condition and calls for service. Cost is further reduced indirectly by the ability to extend routine service intervals after experience with FQI monitoring verifies that clean-burning equipment runs clean longer. While this is a significant value, it requires that dealers and service contractors accept that the real costs of service are reducible by the introduction of a new type of equipment. Improved system efficiency pays off for customers, but only indirectly for oil dealers. Reduced shut-down risk, and soot contamination and puffback hazards pay off primarily in life-style intangibles to customers, and financially to insurers; but the former is impossible to quantify, and the insurers are not yet aware of the FQI's advantages to their risk position.

In order to ensure the success of any product, it is essential that the market can recognize its features as adding value to their objectives far exceeding the cost of those features. In order to understand that process better, we interviewed a number of oil dealers and service managers, and formulated a market model to estimate the value of each of the current and proposed features of FQI systems. In this model the value added is expressed through the calculation of a payback period assuming different modes of payment, and from the viewpoint of different industry participants (residential consumers, oil dealers, service contractors, and OEM's). These calculations were done on Microsoft Excel™ spreadsheets. Some sample outputs of these models are shown in Figure 2 below.

The payback numbers derived from these econometric studies are of course no better than the quality of the assumptions that drive them, but nevertheless, they are extremely valuable in showing where the perceived values are real and where they are not. They also teach better strategies for developing the market. For example, the calculation of return for a dealer who is considering installing an AFQI system is heavily influenced by the benefit of increasing the average size of oil deliveries. A recent industry-wide study[2] indicates that actual delivery costs average $25.25 per delivery. For an average drop of 187 gallons (a well-managed dealership goal), the annual delivery cost for a 1000-gal customer with a 275 gallon tank is $135.27. When we put AFQI's in that group, we contend that the new communication level can result in dramatically improved average oil drops of around 210 gal. The annual saving potential for AFQI's that increase the average drop to 210 gal is about $15 per customer per year. However, if we restrict consideration to only the 20% or so that have the worst delivery problems, that same well-managed dealership would find the average drops for that group to be typically less than 160 gal without AFQI's. If AFQI's can increase the drop to the same challenging 210 gal, we find the annual saving produced by each AFQI rises to $37.50 from delivery cost reduction alone. When a good reason for the AFQI exists in a particular installation, the returns are much greater.

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[2] Oil Heat Advisor, Fall 1966

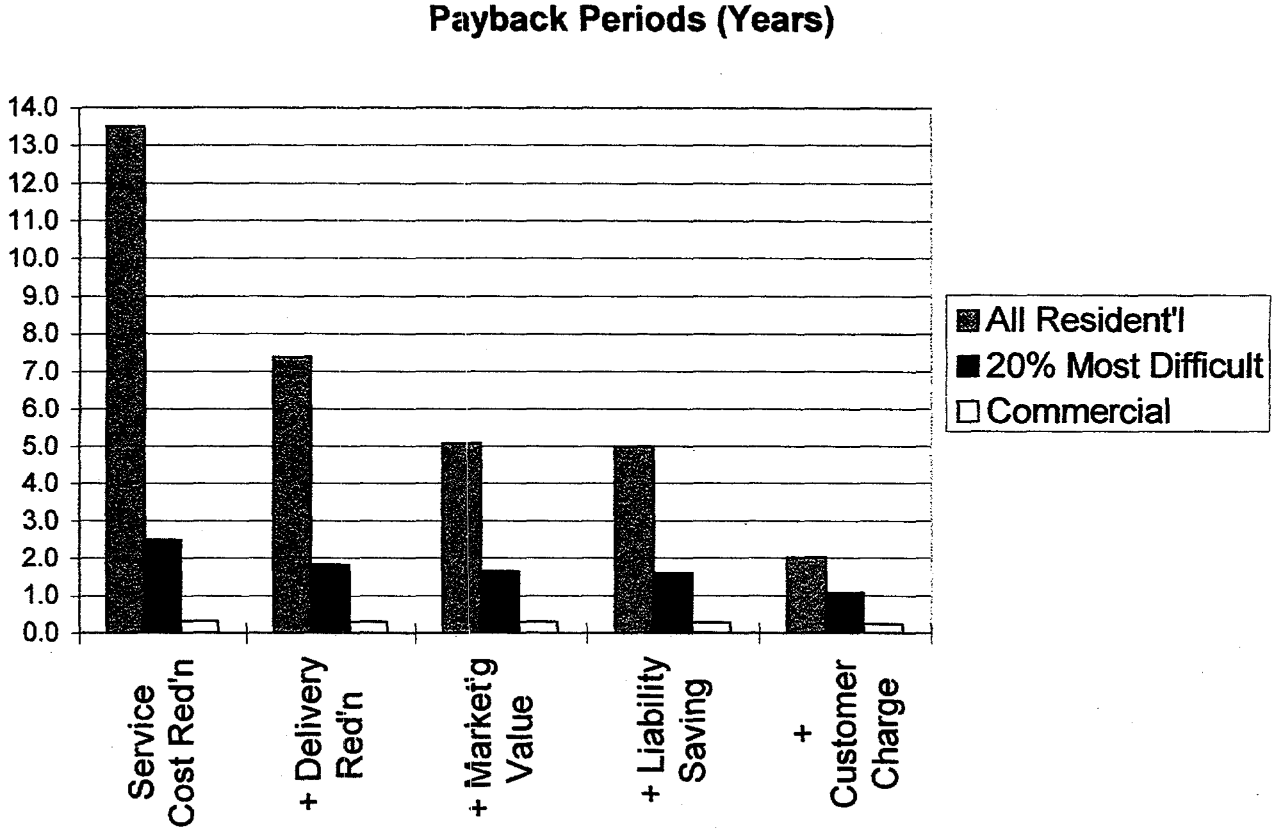

Figure 2 - A Typical Payback Analysis - The estimated payback time in years is shown as an accumulating function, starting only with the reduction in service cost, then adding each mode of value sequentially. An average of typical 1000 gallon per year residential customers is the left column, the 20% of customers most demanding of service is the second, and the commercial example is a 30,000 gal per year installation. In the commercial case, the dominant value added is in the reduction of labor cost required for the on-site custodian to ensure continuity of service.

A similar strategy applies to the reductions in service cost, where choosing the fraction of the customers that generate the most service calls for the first wave of installations greatly accelerates the payback. When estimating marketing value of the AFQI as an attraction to new and current customers, the focused strategy would call for using the AFQI as an incentive for a customer to reverse his decision to change dealers or fuels, or perhaps as a feature of an intense advertising campaign to attract new customers in a particular region. There is another large gain in reduction of exposure to major cleanup liability, for which we need to develop appropriate ways of apportioning costs among homeowners, insurance companies and dealers in relation to how they benefit. After applying these strategies, we estimate that the AFQI payback periods for properly chosen segments of the customer base will drop to about one year.

It is difficult to evaluate commercial installations in a way similar to the residential customers, but the rough assessment shown in Figure 2 makes it clear that the payoff periods for commercial-scale installations are unquestionably attractive. The primary benefit is in reduced custodial monitoring costs, because the AFQI sends out an alarm whenever an impending or actual breakdown condition is detected. Commercial facilities require more development testing than has yet been completed. Our beginnings in this area are described at the end of this paper.

A component of payback that is smaller and less predictable than the service cost savings is the fuel saving that results when burners are maintained within tighter limits than is possible in the industry today. A further complication is that this saving is realized by the owner of the building, not by the dealer who must provide and install the AFQI equipment. To show the effect of this very real benefit, we advocate a program in which the end customer is charged a monthly fee, something less than half of the estimated fuel cost saving, for having the AFQI installed on a 5-year lease basis. While this would certainly reduce the number of customers that participate, it would automatically direct AFQI's to those customers who are most supportive of, and therefore will benefit most from, the AFQI functions. The customer charge used in Figure 2 is $6 per month for residences, and $25 per month for commercial. Many dealers assure us that those charges are smaller than what the market will bear for AFQI services alone. If combined with other monitoring services, this charge could increase greatly, based on current monitoring charges for burglar alarm service. In this mode the dealer continues to profit long after the AFQI is paid off. One segment of the market that is not yet in our model is the customer who is away for long periods of time (snowbirds, vacation homes, etc.) and who is willing to pay simply for continuous surveillance of his/her heating system.

All of this points to a marketing prospect that relies on pilot projects with several large oil dealers who are willing to conduct trials to convince themselves of the long-term benefits of FQI systems in their residential accounts. One of the features most desired by several such customers was the ability to measure the level of oil in the customer's tank. Adding that feature to the AFQI has enabled a concomitant ability to monitor the oil filter's pressure drop, covering another frequent service issue. We hope to be able to report in the near future on the real market's response to these and the other features of the AFQI.

Infrared Measurements

Two series of measurements were conducted on oil burners at the facilities of Heatwise, Inc., Ridge, NY. These measurements had two main purposes. The first was to map typical burner flames spatially and spectrally for a sequence of burner adjustments spanning the practical range of burner operation. The second was to evaluate the utility of prototype infrared (IR) detectors of the types that could be provided in future FQI products at appropriate cost levels. To fulfill the first objective, the Northrop Grumman Corporation was contracted to perform measurements with several types of advanced IR spatial and spectral instruments. For the second objective, photoconductive and thermal IR detectors with a variety of spectral filters were purchased from several vendors, and used to observe the flames from various aspects, and in several installation configurations. Figures 3 through 5 below show the spectra for the Heatwise burner viewed from the front wall for 5 airflow settings, from which we extracted consistent variation of IR intensity viewed from the burner front wall in several bands; and a typical set of band images from one of the fuel/air settings as viewed from the side.

Figure 3 shows the flame spectral intensity, viewed from the front wall of the burner, for each of 5 burner settings. A sixth (richer) setting produced smoke so rapidly that the viewing window was rapidly sooted. The peaks around 2 micrometers (μm) and 2.8 μm are dominated by well-understood radiation from hot H_2O vapor, while the notched peak around 4.4 μm is the radiation from hot CO_2

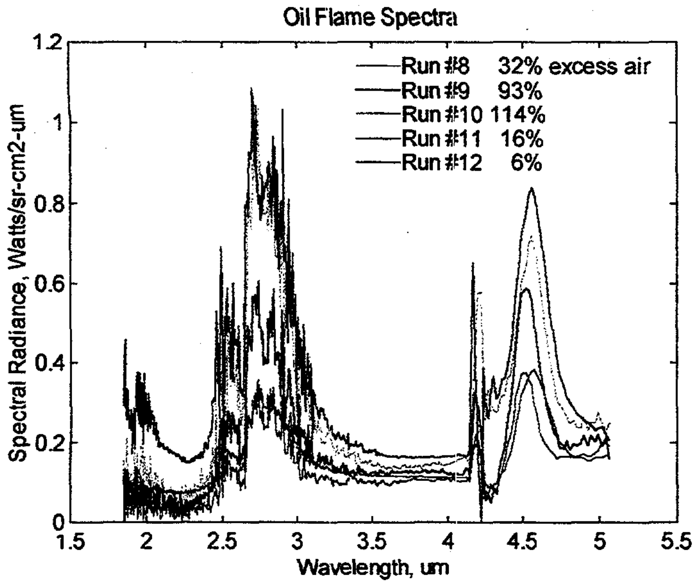

Figure 3 - Infrared Spectra taken from the front wall of the Heatwise Burner for several Airflow Settings - These spectra show the primary radiating systems in the IR from an oil flame; H_2O, CO_2, the underlying continuous emission from solid particles, and CO, which is buried by the radiation from hot CO_2 between 4.5 and 5 μm.

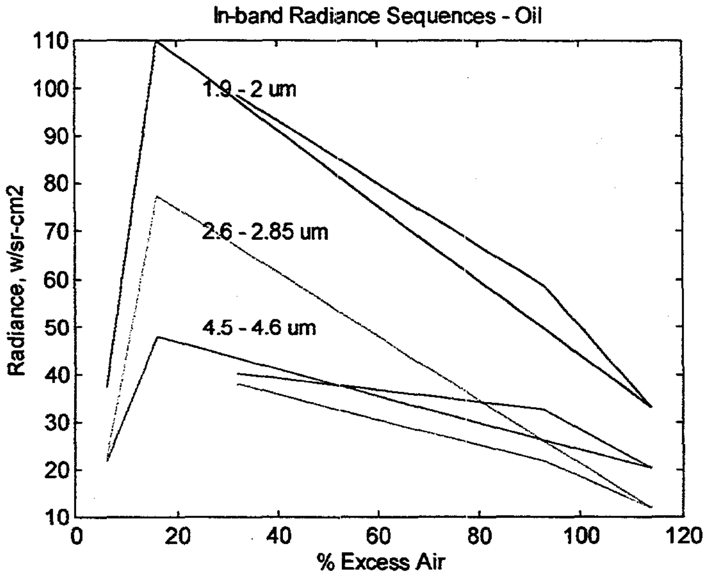

Figure 4 - Variation of Oil Flame Intensities with Fuel/Air Setting - The data in Figure 3 where segregated into the three strongest spectral regions, and each of them was plotted against excess air. The curves follow the test sequence, starting at 30%, going out to 110%, then tracing back to the smoky condition at 8%. Note the universal peaking around the best setting for this burner. Subsequent tests have confirmed this behavior.

that is able to penetrate the strong absorption of the cooler CO_2 in the combustion chamber, which is opaque at 4.3 μm. There is an underlying component of the emission that gradually increases to the right (longer wavelengths). This is due to the emission from incandescent particles (mostly carbon) that are always present in an oil flame that is sustained by evaporating droplets, along with the radiation from the back wall of the boiler that is seen through the flame. Other species that are known to be radiating in this region are CO (buried under the CO_2 between 4.5 and 5 μm), SO_2 (mostly to the longer wavelength side of the figure), and NO_x, which are not large enough to be seen in the presence of the other radiators.

In Figure 4 we show the in-band intensity extracted from the data of Figure 3 for the three spectral regions of maximum IR emission. The IR intensity is shown as it varies with the % excess air in the burner adjustment. In each band the peak IR intensity occurs at or near the setting for maximum combustion efficiency. Each curve is plotted in the sequence that the data were taken, so the "loop-back" of each curve indicates the level of reproducibility in the assessment. If this behavior proved to be universal, and could be captured by an inexpensive IR detection system, it could provide the basis of an "absolute" tuning instrument; namely, an instrument that would give peak signal at the proper tuning condition without prior calibration in a particular burner. This is in contrast to the CAD cell radiation pattern, which continues to increase to the left through the peak performance region.

The images in Figure 5, which are typical of 5 such sets at different burner settings, show how flame shapes and brightness levels vary across each of the 6 IR bands for a particular fuel/air setting. The label "XXX bright" conveys that the image in that frame has been intensified by a factor XXX to enhance viewing; the larger numbers corresponding to less intensity before intensification for equal brightness in the views. These aggregate of all of these views shows how the physical shape of the flame varies with fuel/air settings, and how those shape changes show up differently in each of 6 IR spectral regions ("bands"). Knowing where the radiation is strongest in each band is important to ensuring that instruments are located in regions where they can see the most meaningful changes.

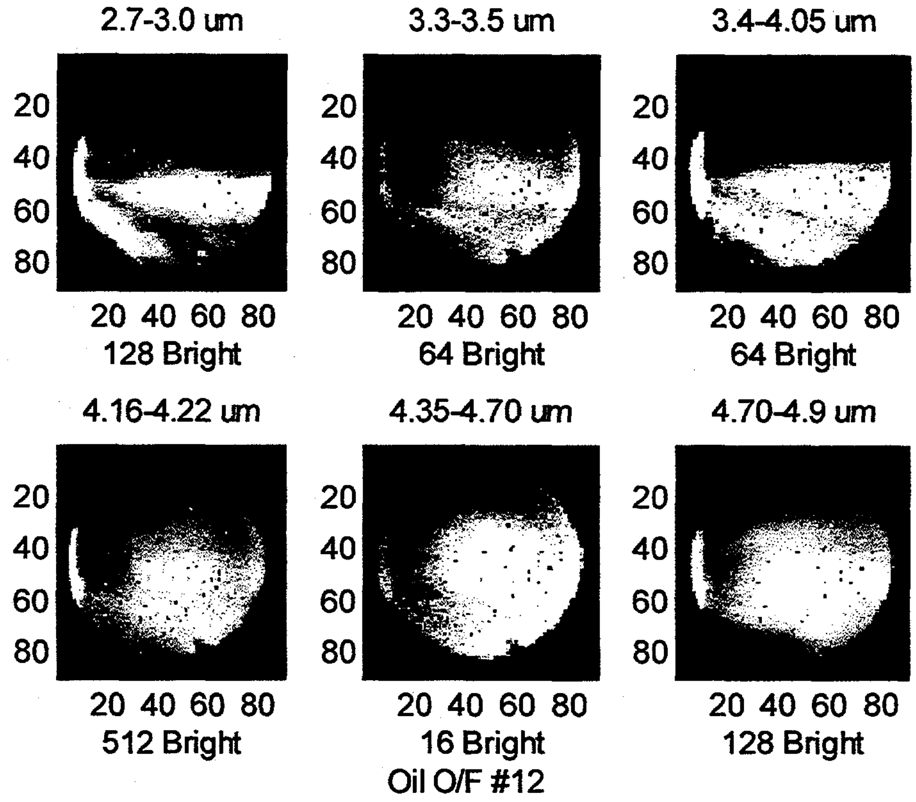

Figure 5 - Six IR Band Images Viewed From Side for Fuel-Rich Setting - These images help us understand how best to view an oil flame so as to monitor its characteristics most definitively.

We also took measurements using candidate prototype detectors that employed PbS and PbSe photoconductive detectors with a variety of filters, viewing through a chopper wheel from the burner front wall and unchopped through the blast tube. The primary lessons learned from those and subsequent tests with other detectors and other viewing aspects are:

- Flame signals in several bands can be seen against the background radiation of the combustion chamber inner wall surfaces, but one must be aware of that background in interpreting the data

- DC drift ("1/f noise") is a serious problem for IR photoconductive detectors of the PbS and PbSe class for systems that do not use mechanical chopping of the flame signals. A chopper would be an undesirable mechanical feature for a practical FQI
- Detector installations must be carefully designed to prevent overheating of the detectors due to excess flame intensity, positive pressure in the combustion chamber, or other problems

Our investigations have pointed the way to superior IR detector technologies, which are immune to the 1/f noise problems, and have better high-temperature endurance capability. These new technologies are being tested for use in the next generations of FQI equipment. The Insight AFQI described in this paper currently has no IR sensing, restricting its application to quality indication relative to a calibration established at installation. The goals of future versions of FQI equipment include reducing the dependence on exhaust gas analysis at setup, and eventually providing sensing that is accurate and reliable enough to drive the control for a self-adjusting burner.

Pilot Installations

There have been several installations of both the FQI and the AFQI. Distributors throughout the US have stocked the original FQI for well over a year. In addition, Insight has supplied test units to several organizations. The incorporation of several of the oil dealer's most desired functions in the AFQI is aimed at increasing the real and perceived value for the FQI's functions in the dealer community. Pilot testing of the AFQI in both residential and institutional applications is still in process, having been started in the Fall of 1994 with early versions of hardware and software.

The first of these installations[3] (Figure 6) is in a residential system, with an AFQI monitoring a Riello 40 F3 burner in a Viallant F100-35 hot water boiler, fed by a 275 gallon tank internal to the basement. After setup, the AFQI has remained within the acceptable range.

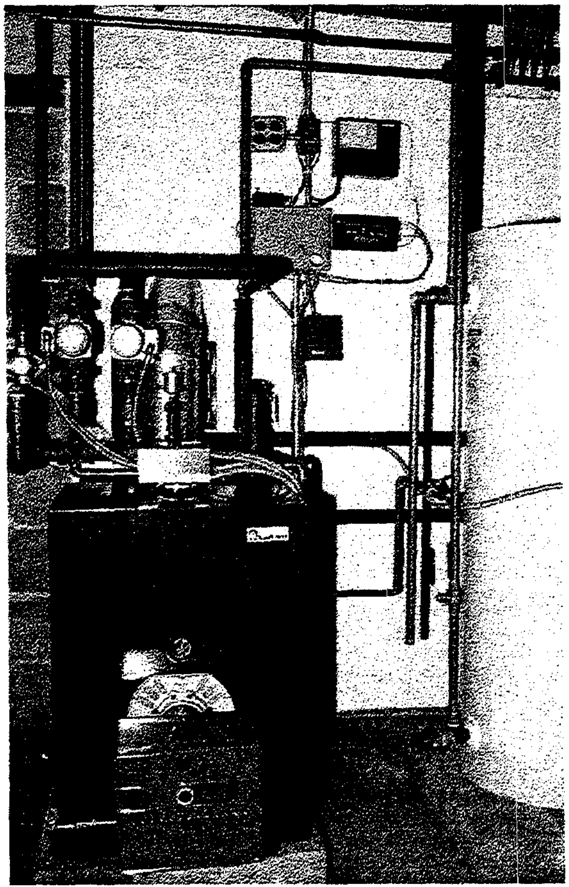

Figure 6 - Pilot Residential Installation of the AFQI - Development units have been tested in this location over the past two years.

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[3] A. Rudin; Fuel Oil & Oil Heat, Jan. 1997, Pg 17-19.

Figure 7 shows results of the pressure transducer monitoring oil tank level for almost a full year in that installation. The comparison in Figure 7 of AFQI readings with the stick levels as oil is consumed and after deliveries through the season show clearly the effective performance of this technique. Installation is simple, and requires only attaching a standard tubing tee to the downstream side of the filter, and removing air bubbles. After the tank is filled, the technician pushes a button on the AFQI face, initiating a call to the CSC that automatically establishes the calibration for that particular facility. The AFQI also records the pressure when the burner is running, and includes that value in the standard report. A simple comparison of burner-on and burner-off values gives the current pressure drop across the filter. As the filter becomes clogged, an alarm is initiated when the filter pressure drop reaches the preset levels for warning of impending burner failure.

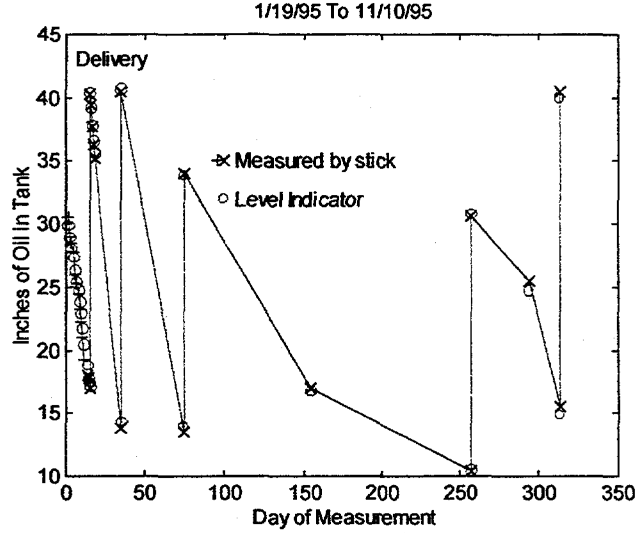

Figure 7 - Record of Pre-AFQI Oil Tank Level Monitoring - The precursor to the AFQI's tank level monitoring unit was tested through a full year. It faithfully and accurately tracked tank levels through burns and fills. The system also works for buried tanks.

Figure 8 shows one of the AFQI's installed in 7 complexes of 330 apartment units at Fillmore Gardens in Brooklyn, NY[4]. These are large Weil-McLain boilers, ranging from 2.5 to 5 million BTU per hr. in capacity, each equipped with Gordon-Piatt combination oil/gas-fired burners. These units burn oil when the outside temperature is below 20° F, and gas the rest of the time. In order to detect both kinds of flames with the AFQI, and IR detector (PbS) is installed in the second CAD channel, and appropriate changes to the input load resistor for that channel are all that is necessary to provide analogous gas FQI signals in the IR. The primary requirement for these units was to ensure continuous operation of all boilers, and to report via pager to the maintenance superintendent upon any burner failure. While fulfilling this mission, the opportunity to acquire operational data

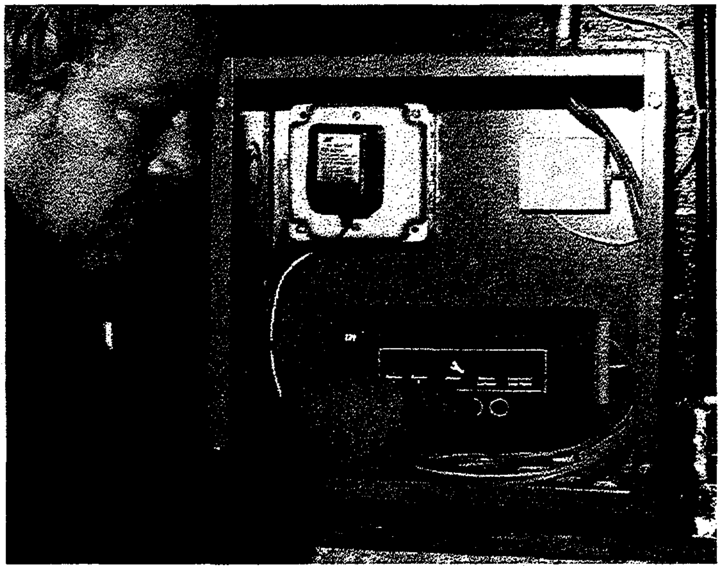

Figure 8 - One of 7 Pilot Commercial Installations; Modified AFQI's are operating in 7 large apartment complexes in Brooklyn, NY in a pilot program with Brooklyn Union. They are modified for dual-fuel sensing.

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[4] A. Rudin, Fuel Oil News, Jan 1997.

from the AFQI's in gas and oil on large commercial units is a rare opportunity.

Conclusions and Prognosis

We are just beginning to develop the potential value of flame quality monitoring in the oil heat industry. The technical success of the Flame Quality Indicator in preserving a clean and properly adjusted burner flame is a potentially powerful contributor to the need of the oil heat industry for improved customer perception as a clean, safe, economical way of heating. It is our judgment that in order to realize that improvement in customer perception, market incentives beyond flame monitoring are needed in the FQI product to ensure that it is recognized by each of the industry decision makers as a productive investment for their particular enterprise. Insight Technologies, Inc. has taken the position that a combination of communication and sensing features that have several different modes of adding value is the right way to ensure marketing success. The resulting AFQI system empowers a contractor to install any number of customer units and maintain any desired level of status reports in a PC database; all at a cost that provides payback in one or two years. These paybacks come in a flexible combination of reduced service costs, greater reliability, cleaner and safer operation of all burners, and monthly revenue from customers for added services. An important strategy for all participants is to set up an initial program of AFQI installations for those accounts that have the most erratic service and delivery history, expanding AFQI usage as experience in the dealership improves and unit costs decrease. Other areas of value assessment that we are working to establish are the effectiveness of a dealer's ability to offer the AFQI in attracting and retaining oil heat accounts, and the potential for insurance rebates from the companies that insure against soot and smoke damage. The ability of the AFQI to report status of analog and digital information makes it an attractive partner in a combined intrusion alarm and heating system sensing system.

We also see an exciting potential for future products that exploit the infrared (IR) radiation from flames. New detector technology is bringing the cost of rugged IR sensors down near that of the CAD cell. Our data have confirmed that the relationship between IR emissions and flame state is fundamentally superior to that in the ultraviolet and visible, where the CAD cell operates, and that the practical problems of using IR in residential and commercial burners are not serious. Insight Technologies is just beginning a new contract with NYSERDA that we expect will pave the way to instruments that can be used to tune a burner from a meter, without the need to test exhaust gases or smoke levels. Other goals of that work are a burner primary control that can distinguish between weak and strong flames, and ultimately a sensor system that can drive a self-adjusting burner.

III. WORKSHOP SESSIONS

Workshop Topics

1997 Oil Heat Technology Conference & Workshop

Brookhaven National Laboratory

April 3-4, 1997

A: Panel Presentation: ISH Show Impressions and Opinions and Should Oilheat Standardize on 150 psi Pump Pressure ?

B: Carbon Monoxide Discussion Forum

C Forum: NFPA Standard 31 Revision Year 2000 Actions ?

D: Fuel Quality, Storage, & Maintenance - Industry Discussions

Workshop Topics
Workshop Group A:

Part I
Panel Presentation - ISH 97 International Sanitation and Heating Expo

Part II
Should the Oilheat Industry Standardize On 150 PSI Oil Pump Pressure ?

Chairmen:	**Ray Albrecht, Part I** **NYSERDA** **David Nelson, Part II** **NAOHSM**	**Rapporteur:**	**Dr. Thomas Butcher, Ph.D.** **BNL**

Part I

Raymond Albrecht, NYSERDA; Robert Boltz, Vincent R. Boltz, Inc.; Alan Levy, OSI; Vic Turk, R.W. Beckett Corp.; John Huber, PMAA; and Thomas Butcher, BNL will share their impressions and slides of the 1997 International Sanitation and Heating Exposition held on March 18-22, 1997 in Frankfort, Germany. This is the world's largest exhibit of heating technology held only once every two years. There will be discussions updating you on how the European heating industry and manufacturers are dealing with new environmental regulations (oxides of nitrogen, etc.) and how oil burners are being designed to meet these new requirements. We hope to also learn about new venting options, heat exchanger designs, and other hardware systems as well.

Part II

Should the industry consider a new standard oil pressure for setting up burners. There is some concern that the many different pump pressure settings being recommended by the Original Equipment Manufacturers (OEMs) for different models of heating equipment will cause future service problems. One scenario is that a steam hydronic unit rated for use with an oil pressure of 150 psi will eventually need a replacement of its primary control on which the OEM has placed a service warning label that indicates that the unit requires a 150 psi oil pressure. The unit is replaced but the label is not transferred by the busy service technician. The next time a service call is required the next service technician doesn't know anything about the higher pump setting and checks the pressure because the unit was not running properly. He finds the pressure at 150 psi and not the standard 100 psi which he decides to set it at now. As a result the unit is not ever going to run right and make steam until someone pulls out ***the book***. Trouble is the book is missing from the truck. Currently this issue is being tossed about on the NAOHSM Internet site. David Nelson would like to gather your opinions and insights about changing to a 150 psi as a standard for all oil fired units. What are the pros and cons on the issue? Will homeowners be left out in the cold? Can you really change a fifty or more year old tradition? We expect some lively discussions!

Discussion:

International Sanitation and Heating (ISH)

ISH is the largest international heating equipment show with over 2000 exhibitors and 250,000 visitors. Based on informal observations, about 80% of the exhibitors are German, another 10-15% are Italian and the remainder from other European countries. There were a few U.S. companies represented.

In the burner hall there are blue flame burners nearly everywhere. Europe has in place a set of both voluntary and mandatory standards for small oil burners which include NOx emission limits. To date the use of blue flame burners has been non-uniform. Some countries (e.g. Switzerland) have now NOx limits for new units equivalent to about 60 ppm (@ 3% O2). On Jan. 1, 1998 Germany will adopt a similar regulation. The effect of this is to force all new installations to use blue flame burners. Currently only about 40% of the new installations in Germany use blue flame. In other countries (France, Spain, Italy) a considerably lower fraction is blue flame.

In the European market, heating systems cost at least twice as much and in the U.S. They are obviously a lot nicer but questions were raised during the workshop about the actual value. How much of the extra cost really results in true functionality and benefits for the homeowner? From a design and aesthetics perspective the appliances, however, are very impressive. Relative to the U.S. market there is much greater effort put into noise control, with covers filled with foam insulation. Controls and boiler face panel displays are very big. Outdoor reset appears to be universal. Constant circulation is common. There is little or no use of tankless coils, with hot water being produced either in an indirect system or in a wall mounted, instantaneous water heater. There was some discussion about cultural differences. Europeans are prepared to spend considerably more for their systems. Part of this is due to the existing regulations on minimum efficiency and inspections. Part may also be related to home ownership patterns. European families keep homes longer, often passing them down through generations, making it easier to justify greater heating system investment.

Fuel Pump Pressure Standard 150 PSI ?

These second topic raised during the workshop was the concept of an industry standard, 150 psi pressure level for all fuel pumps. Such a standard would improve service quality and performance overall. After considerable lively discussion the consensus was that it is really not possible to regulate a base fuel pressure. The industry is now changing at such a rapid rate that the pressure is likely to remain a moving target for some time. In may be better to improve technician education. In addition, we need a better labeling system to make it clear what the pump pressure should be on each installation. Robert Hedden will raise this questions further with the Oil Heat Manufacturer's (OMA) association. The technician in the field should be able to know the pump pressure quickly and easily.

Workshop Topics
Workshop Group B:

Carbon Monoxide Discussion Forum

Chairman:	**John Batey, Energy Research Center, Inc.**	**Rapporteur:**	**Roger McDonald, BNL**

Each topic will be introduced briefly followed by discussions by the workshop group.

1. Carbon Monoxide levels and related health effects - What are safe levels?
   - Ambient Air levels
   - 8 Hour Exposure Limits
   - Range of Ambient Levels In Homes and *Action* Levels

2. Case Studies of CO Exposure/Injury In Homes - From All Appliances
   - Reported Cases of CO Exposure and Injury
   - Discussion of Oil-Related cases

3. Typical CO Emissions From Home Equipment and Appliances
   - Oil Burners
   - Gas Boiler and Furnaces
   - Gas Cooking Appliances - Range Top Burners and Ovens
   - Space Heaters
   - Other Combustion Equipment

4. Factors That Affect CO Emissions
   - Oil Burner - Air Supply
   - Gas Burner Adjustment - Blue and Yellow Flames
   - Excess Fuel Firing Rates
   - Combustion Testing and CO Emissions From Oil Burners
   - Other factors

5. Common *Actions* To Lower The Risk of CO Exposure In Homes
   - Chimney/Vent Blockage
   - Heat Exchanger Damage
   - House De-Pressurization - Exhaust Fans and Air-Tight Houses
   - Scale/Soot Build-Up in Boiler or Furnace
   - Operating Automobiles in Garages
   - Other Causes

6. Some *Actions* to Lower the Risk of CO Exposure
   - CO Detectors, Pros and Cons
   - Regular Burner Service / Checking Vent System Including the Clean Out
   - Use Combustion Test Equipment To Tune Oil burners

- Never Use gas Cooking Equipment for Space heating
- Be Careful with Unvented Space Heaters
- Replace Outdated Oil Burners
- Be Sure Wood burning Appliances are Vented properly
- Warn Homeowners in ***Tight Homes*** About Operating Multiple Exhausts
- Start a **CO Awareness and Education Program** in Your Company

Discussion:

Initial discussions focused on the question of what are acceptable CO levels in homes. Many different levels can be cited included US-EPA recommendations of 9 ppm for ambient levels and 35 ppm for 6-hour exposure; 40 ppm for flue concentration in gas-fired equipment; some fire department policies to evacuate houses when CO levels exceed 10 ppm. One example cited was a Pennsylvania Fire Department which evacuates buildings when CO levels are above 10 ppm. Some standard and accepted CO levels and action levels are needed, and do not now exist. Perhaps the US Consumer Product Safety Commission, BNL, and other groups can work together to formulate acceptable CO levels in homes Some information was presented by John Batey from one reference on estimates of CO blood levels versus common exposure conditions:

CO Blood Levels
(Estimates)

Less than 1%	People living in rural areas
3%	People living in cities
4% -6%	Cigarette smokers
6% -10%	Smokers who work in enclosed area with CO (e.g. parking garages)
10%	Firefighters after a fire(highest CO level considered safe)
up to 20%	Police officers in heavy traffic

CO Poisoning Levels

20% - 25%	Blurred vision, nausea and vomiting, severe headache
30% -35%	Unconsciousness
40% or higher	Death

NOTE: A person's size and general health both effect response to elevated carbon monoxide levels.

The precision and accuracy required for CO test equipment was discussed next. A highly accurate instrument capable of measuring down to as low as 1 ppm with an uncertainty of only several ppm may be needed for ambient air measurements in homes. Regular calibration is also needed to a assure continued measurement accuracy. Measurement accuracy and precision is an important topic to address after action levels are determined.

Some discussions then followed on the impact of positive pressure oil equipment that produces a gas pressure in the combustion chamber that is above atmospheric pressure. It is possible that some combustion gases could escape form the heating unit which could contribute to elevated CO levels if the burner was producing carbon monoxide. The need for standardized test procedures to evaluate this situation was briefly discussed.

The need for CO meters with advanced oil burners was presented by one workshop attendee and a discussion followed. Some newer oil burners can produce elevated CO levels at the same time or before flue gas **smoke** levels increase. Therefore, CO measurement may become an important part of burning servicing and tune-ups in the future. Two problems include equipment drift and house depressurization, which can contribute to increased CO levels in homes. Typically CO levels from oil burners are low when the burners are set up according to manufacturer recommendations which includes near-zero **smoke** levels. One attendee cited a case where a plugged nozzle resulted in CO levels of 3200 ppm due to flame impingement on cold surfaces. Also, interaction of the burner with the house and house depressurization are important factors that must be evaluated. Possible solutions include:

- Relief damper to admit outside air when depressurization occurs.
- Dedicated air supply to the burner
- Use of *smoke pencils* to identify back drafting
- Use of draft gauge to measure the indoor-to-outdoor pressure differential

Homeowner should be advised about the risks associated with operating many exhaust devises at the same time in a tight home. Also, service technicians need to be educated about the problem of house depressurization and burner/house interactions so that problems can be avoided. New training programs are recommended for both gas and oil service technicians.

The advantage offered by a *safety switch* to turn the burner off if a room becomes too negative was discussed. This can be particularly important for tight homes. Also, chimney construction and design was discussed, and it can have an important impact on house depressurization and CO formation. Installing chimneys indoors was discussed as one approach for reducing venting problems.

Specific action recommend by the workshop attendees include:

- Set acceptable ambient CO limits for homes
- Regularly service of oil burners and vent systems
- Educate oil heat service technicians and homeowners about potential risks form CO in homes and how to avoid unhealthy levels
- Use CO detectors in homes to protect occupants - the less sensitive models that alarm at ambient CO levels of 50 to 100 ppm are recommended to avoid false alarms.

Workshop Topics
Group C:

NFPA 31 Standard - Year 2000 Revision ?

Chairman: Gary Potter **Rapporteur: Richard Krajewski**
Agway Energy Products **BNL**

Discussion:

The session was animated and moved about among the several questions posed to the group. This discussion has been edited to address these questions as they were posed in written form.

1. From the Field - What problems have been uncovered using masonry chimney tables in the NFPA 31 Standard ?

In the report presented at the conference (Paper No. 97-12) the figure shown on page 9 is not correct. A correct version of this figure can be found in NFPA 31 1997 Edition. The tables for metal re-lined masonry chimneys are consistent with the latest edition of NFPA 31

In general, the metal re-lined masonry chimney tables in Appendix E of NFPA 31 (1997) offer good, easy to use information but are limited in their present form. The natural gas appliance tables in NFPA 54, generated by use of Vent II, have proven to be complicated and difficult to apply. In terms of interpolation, field applications of the existing NFPA 31 tables have revealed some success in going to higher chimney heights. In addition, the reported successful application of the NFPA 31 tables to size chimney liners for two furnaces into a single non-conforming brick chimney lends some confidence in their (the tables) flexibility.

The tables should be expanded to include 30 to 60 foot chimneys. The text of NFPA 31 needs to be reviewed regarding the permitted connector/liner sizing protocol currently offered to the installer. Common venting of multiple appliances can be pursued through the use of the existing tables but "rule-of-thumb" recommendations should be included for now. Ultimately, the model should be upgraded to handle multiple appliances.

2. The list of industry identified issues discussed earlier includes:
   -Items that can be done using the existing OHVAP model
      Flexible liners
      Masonry chimneys with and without tiles
      Chimney heights greater tan 25 feet
      Larger flue sizes
   -Items that would require significant model revisions
      Ambient temperatures below 0 Deg.F
      Multiple appliance operation

There remains a strong need for multiple appliance recommendations and lower ambient temperatures. Direct recommendations are needed for derating of the appliance when; flexible (rougher) liners are used, offsets are present in the chimney, multiple elbows are used. In addition to the low ambient temperature requirement, some consideration should be given to the issues of ambient pressure (high altitude) as well as whole house depressurization.

3. Suggestion for diagnostic aid/tools for venting system inspection?

Beyond a brief discussion of the newly presented slide-rule which interprets the current NFPA 31 tables, no additional offerings were made. New applications of existing field instrumentation should be written up and included in the text portion of the NFPA 31 tables. Labeling of appliances is an important concern and needs to be addressed. A permanent means of recording the entry of servicing information (especially vent sizing/firing rate) is important for subsequent service personnel to have at their finger tips.

In Summary:

Venting Research Activities for the Remainder of FY1997

1) Prepare revision outline of the OHVAP Final Report
2) Continue special case runs of OHVAP to expose possible limitations
3) Continue chimney survey effort
4) Comparison checks with the ASHRAE analysis for large chimneys; issue guidance

Venting Research Activities for FY1998 and Beyond (No Assigned Priority)

1) Expand the tables to include metal chimneys and power vents and develop new tables
2) Expansion of the tables to 30 to 60 foot chimneys and incorporate into tables
3) Examine the effects larger flue tile sizes and incorporate into tables
4) Examine the effects of additional connector elbows, chimney offsets, altitude and less than ideal chimneys and issue guidance
5) Examine the applicability of the existing tables to furnace operation and issue guidance
6) Examine the effects of proposed new integrated systems and issue guidance.
7) Examine the usefulness of the tables for common venting applications and issue guidance.
8) Examine the effects of dilution air on whole house energy conservation and chimney drying and issue guidance.
9) Examine the application of *weather proofing* existing masonry chimneys
10) Develop the characterization of clay liners and alternative liner materials.

Workshop Topics
Group D:

Fuel Quality, Storage, & Maintenance Industry Discussions

Chairman: John Laisy **R.W. Beckett Corporation**

Rapporteur: Wai Lin Litzke **BNL**

I. Chairman's Questions / Discussion on fuel quality issues:

- What trends are being seen in delivered fuel quality?
- What procedures are being used to clean and maintain cleanliness of tanks and fuel systems?
- Are additives being used? Which ones with what success? How are they used/controlled?
- Do you, the oil dealer, use or recommend low sulfur fuel?.
  How often is kerosene used to solve combustion or low temperature flow problems?
- Are any specific inputs or recommendations to ASTM needed regarding fuel specifications?
- What testing programs should BNL be undertaking related to fuels and fuel quality?
- What work should the major oil companies be doing regarding fuels and fuel quality? Equipment manufacturers? Additive manufacturers?
- Other major fuel-related concerns affecting oil heat industry?

II. Future work at BNL:

- What future research areas will benefit the industry?
  - Is there a need to reevaluate current fuel quality standards, such as ASTM D-396? ASTM D-396 committee will soon be reviewing the option to decrease the maximum allowable sulfur content in fuel oil. Should other changes be discussed?
  - Cooperative field studies between BNL and Industry members.
- Will these areas fit the program goals under NORA?

III. Round Robin Testing of Fuel Additives

- Consequences of sludge build-up and high maintenance/service requirements?
- How can current or future field testing of sludge-control additives benefit the industry as a whole?
  Review & Discuss Robert Tatnall's Proposal for Round Robin Additive Tests
- Identify Oil Industry Interest Level & Companies willing to Volunteer/ Participate

Discussion:

There is generally a strong interest in fuel quality issues both in the U.S. and Canada. Frequently encountered fuel quality related problems in the field include suspended water and high cloud point. ASTM standard D-396 does not specify cloud point; only the pour point is specified. In Canada the petroleum industry is working on developing a standard for evaluating cold flow properties of heating oil.

There is also considerable interest and concern on the effects of fuel sulfur and fuel stability on the performance of residential heating systems. ASTM specifications have broad ranges for the various fuel properties. Even though the national average for fuel sulfur in heating oil is 0.3% by weight or less there are regions where much higher levels are found. It was suggested that lowering the standard requirement from 0.5% to 0.3% would direct the trend to lower average sulfur. Consistency of product is a concern for many fuel marketers. Fuel stability is also not specified in D-396 but maybe it should be. A stability specification like D-2274 for diesel fuel may be desirable for fuel oil. Much research work is being conducted by the petroleum industry to look at methods of evaluating fuel stability with accelerated techniques and correlating it with long-term fuel degradation.

Clearly, the heating oil industry needs to be actively involved in standards generating organizations in order to voice their fuel quality concerns and effect changes to specifications. There may be a desire for a ***premium*** grade ASTM specification for heating fuel. Several participants of this workshop are members of the American Society for Testing and Materials (ASTM) and the International Association for Stability and Handling of Liquid Fuels (IASH). It was noted that ASTM needs data and test results to support recommendations for specification changes. It is suggested that BNL should expand its capabilities to test fuel quality parameters with heating systems and provide the necessary technical data to support measures in changing specifications.

BNL is currently revising a manual, **Maintenance and Storage of Fuel Oil for Residential Heating Systems**, which was first published in 1992. This revised manual will be published and distributed to the heating industry by Petroleum Marketers' Association of America (PMAA) during the summer of 1997. It was suggested that problem tanks be replaced, not just cleaned, like other major home replacements (ie. roofs, etc.). Also, tanks need to be accessible. There is general interest by the workshop participants to have included in this manual test methods for evaluating fuel additives. It appears, however, that because fuel properties vary extensively a specific method to determine acceptability of an additive with one fuel may not necessarily show the same results with another fuel.

A poll of the workshop participants, by show of hands, was done to determine the level of interest on the proposal for round-robin testing of fuel oil additives as proposed by Robert E. Tatnall, P.E. This would require individual fuel marketers to participate in a relatively large-scale field testing program to evaluate the various after-market additives. BNL would have the role of coordinating this effort, collecting and analyzing the data. Almost half of the participants indicated interest.

IV. FINAL ATTENDANCE LIST

1997 OIL HEAT TECHNOLOGY CONFERENCE & WORKSHOP REGISTRANTS

Martin Van Adelsberg	L.J. Dove Associates
Raymond K. Albrecht	NYS Energy Research and Development Authority
Don Allen	E. T. Lawson
John Andrews	Brookhaven National Laboratory
Bob Barnes	Barnes Heating & A/C
John Batey	Energy Research Center, Inc.
Drew Behrens	Dowling Fuel Co.
Bob Bellemore	Bellemore Heating Oil Inc.
Raymond P. Bellemore	Bellemore Heating Oil Inc.
Scott Bellemore	Bellemore Heating Oil Inc.
Elizabeth Bennett	Nalco/Exxon Energy Chemicals
David A. Bessette	Arlex Oil Corp.
David C. Bixby	Gas Appliance Manufacturers Association
Robert V. Boltz	Vincent R. Boltz, Inc.
Lewis Boyce	Carlin Combustion Tech, Inc.
Jim Brewer	National Chimney Sweep Guild
Richard J. Brinkman	Brinkman Oil/ Brinkman Heating
Gail Brown	Brookhaven National Laboratory
Keith D. Buchanan	Sun Co. (Sunoco)
Thomas R. Burns	Protech Systems Inc.
George Burpee	Bellemore Heating Oil Inc.
Thomas Butcher, PhD	Brookhaven National Laboratory
Dennis Cady	Webster Heating & Specialty Products, Inc.
Vince Calia	Insight Technologies, Inc.
Thomas Campbell	Mestek, Inc.
John Carey	New England Fuel Institute
Ken Carr	J. W. Pierson Co.
Marty Castro	Mobil Oil Corp.
Yusuf Celebi	Brookhaven National Laboratory
Richard E. Ceriani	Armstrong Air Conditioning Inc.
Martin J. Chmura	Board of Education City of New York
Charles Cogan	WR Marran's Sons Inc.
Greg Commins	Baerendlau Oil Co.
James M. Connors	Mestek
Daniel Crouse	Wise Oil & Fuel Inc.
Peter Cullen	Carlin Combustion Technology Inc.
James Davenport	Brookhaven National Laboratory
Kenneth Davenport	Heritagenergy

Ed DeJaegher	Triangle Tube/Phasee III
James F. Denham	Peter MacFarlane Inc.
Michael Deutsch	CECOM RDEC C2SID-South
Albert Disoteo	Dowling Fuel Co.
Robert Dolan	Castle Oil Corp.
Dennis Dowd	Meenan Oil Co.
Nelson Driver	Driver Heating Oil, Inc.
F. Marion Dwight	Delavan
Tom Edge	Heritagenergy
Peter Ehinger	Sears
Ashley Eldridge	National Chimney Sweep Guild
Norman Ferland	Cheshire Oil Company, Inc. T-Bird Div.
Leonard Fisher, P.E.	Consultant, BNL
Michael Foglia	Protech Systems Inc.
Don Foreman	Honeywell
Denny Frost	R.S. Leitch Co.
John Fuquay	Berico Fuel Inc.
Michael Furey	Brookhaven National Laboratory
Paul Geiger	Fueloil & Oil Heat
Jeremy Godfree	Product Design
Robert B. Greenes	Petroconsult, Inc.
John Griffin	General Utilities, Inc.
Gary Hainley	Burnham Corporation
Richard Harris	Carpenter & Smith, Inc.
Robert Hedden	Oil-Heat Mgmt Services
Paul F. Heinrichs	Meenan Oil Co.
John A. Hill, Jr.	Consultant
Brian Hills	Nalco/Exxon Energy Chemicals
Marie Hobson	Brookhaven National Laboratory
Dennis Hoskin	Mobil Technology Co.
John Huber	Petroleum Marketers Association
Dale L. Hunsberger	Suntec Industries
Paul Hunter	Danfoss Automatic Controls
J. Ian Hutchinson	Riello Canada Inc.
Everett E. James	Thermo Products, Inc.
Paul Jennings	Santa Fuel, Inc. & Subsidiaries
Bola R. Kamath	Heat Wise, Inc.
E. Karnis, P. Eng.	Newmac Manufacturing Inc.
Michael D. Kaufmann	Energy Kinetics

Edward Kitchen	Int'l. Lubrication & Fuel Consultants
Tom Koehler	J.W. Person Co.
Jack Kracklauer	Econalytic Systems
Richard Krajewski	Brookhaven National Laboratory
George Kusterer	Bock Water Heaters, Inc.
Esher R. Kweller	U.S. Department of Energy
Vito Laera	Petro Oil Co.
John Laisy	R.W. Beckett
George Lanthier	Firedragon Enterprises
Steve Lasser	Energy Kinetics
David Languilli	Brookhaven National Laboratory
Timothy Laughlin	North Carolina Petroleum Marketers Association
Win Lee, PhD	C.C.R.L./E.R.L.
Richard W. Lenzer	J.W. Piccozzi, Inc.
Alan Levi	O.S.I.
Richard Levi	O.S.I.
Walter B. Lingner	Petro
Lindy Lindtveit	Sid Harvey Industries Inc.
Wai Lin Litzke	Brookhaven National Laboratory
Steve Lopes	Octel America
Robert D. Lynch	Energy Matters
Edward MacPhail	Cheshire Oil
Ray Maddock	R.W Beckett Corporation
Bruce Maike	Armstrong Air Conditioning Inc.
Larry Makarewicz	Kirks Fuel
Jim Macaluso	Nalco/Exxon Energy Chemicals
Jack Marran	W.R. Marran's Sons, Inc.
John Marran	Energy Kinetics
Roger Marran	Energy Kinetics
Steven McCarthy	Weatherization Training Center at Penn College
Bud McClintock	Mobil Oil Corp.
Roger McDonald	Brookhaven National Laboratory
Rich McElwee	Weil-McLain
L. Melcher	Honeywell Home and Building Control
Fred Meyer	Index Industries, Inc.
Will Miller	Santa Fuel, Inc. & Subsidiaries
Richard G. Mohrfeld	Mohrfeld, Inc.
Blaize Monostory	Petro Partners
Frank Mondsini	J.W. Pierson Co.

Joseph Monks	Mohonk Oil Co., Inc.
Judy Monks	Mohonk Oil Co., Inc.
John D. Morris	Ethyl Corporation
Jerry Moskowitz	Carpenter & Smith, Inc.
Kenneth R. Moskwa	Weil-McLain
Reza Mossavi	GSW Water Heating Company
James Murray	R.S. Leitch Co.
David Nasner	Main Brothers Oil Company Inc.
David Nelsen	Kurz Oil
Robert E. Nelson	Quantum Group Inc.
Rainer Ober	Baerenklau Oil Co.
Richard A. Oman	Insight Technologies, Inc.
Suhas N. Patil	Refractory Specialties, Inc.
Victor Piano	Dowling Fuel Co.
Angelo Piccozzi	J. W. Piccozzi, Inc.
Joseph Pihanich	Boyestown Furnace Co.
John Pilger	Chief Chimney Services
Tony Polvino	Sun Company
Gary E.Potter	Agway Petroleum Corp.
Steven Rakvica	Dunkurk Radiator Corporation
Eric Rantanen	Mestek, Inc.
Harry Ritz	Story-Winn Fuel Co.
Paul Romanelli	Warm Thoughts Communications
Jim Rosenberg	Webster Heating & Specialty Products, Inc.
Andrew Rudin	Insight Technologies, Inc.
Dave Rumph	J.W. Pierson Co.
Richard Rutigliano	Primedia Services
John Ryan	Heritagenergy
Matthew Ryan	Petroleum Heat and Power Co., Inc.
John Santa	Santa Fuel Inc. & Subsidiaries
Thomas S. Santa	Santa Fuel Inc. & Subsidiaries
Tom Saxton	Meenan Oil Company
Hos Scheibein	Grace Oil Co.
Jim Scheibein	Grace Oil Co.
Daniel A. Schildwachter, III	Fred M. Schildwachter & Sons, Inc.
Kenneth R. Schliphack	B&C Fuel Oil Co., Inc.
Herbert C. Schneider	Carpenter & Smith, Inc.
George Schultz	Fuel Oil News
Karl Schuster	Castle Oil Corporation

Darrel Scribner	Preferred Utilities Mfg. Corp.
Kevin T. Scully	LACO Service
Peter B. Shively	CECOM RDEC C2 SID-South
Joel M. Siegler	Ethyl Corporation
Gregory Singlemann	Tuthill & Young Oil Inc.
Ed Sorensen	LACO Service Inc.
Erik Spek	Riello Canada, Inc.
Robert Springer	Heritagenergy
Ed Squire	Octel America
Gary W. Steer	Fredricks Fuel & Heating Service
Jeff Stembridge	Delavan Inc.
Jack Sullivan	New England Fuel Institute
Robert E. Tatnall	Fairville Products Division
Richard Taylor	Weatherization Training Center at Penn College
Perumal Thamaraichelvan	Carlin Combustion Technology, Inc.
Thomas Thompson	Wise Oil & Fuel
Tom Tjernlund	Tjernlund Products, Inc.
Henry Troost	Honeywell Inc.
Rick Trout	Mobil Oil Corp.
Victor J. Turk	R.W. Beckett Corp.
Andrew D. Vasilakis	Advanced Mechanical Technology, Inc.
Dan Voorhis	Wayne Home Equipment
Raymond Walsh	Riello Canada, Inc.
Joel Watts	Yankee Oilman Magazine
George Wei	Brookhaven National Laboratory
Edward J. Wisniewski	Wayne Power Burners
Jim Wood	Delchester Oil Co.
Douglas Woosnam	Petroleum Heat and Power, Co., Inc.
Ronald Von Ronne	Main Brothers Oil Company Inc.